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Addresses of Authors

Boske, Leigh B., Lyndon B. Johnson School of Public Affairs, University of Texas, Austin, Tex. 78712
Cervenka, Kenneth J., Center for Transportation Research, University of Texas, Austin, Tex. 78712
Doyle, John, Planning, Research and Public Transportation Division, Washington State Department of Transportation, Transportation Building, Olympia, Wash. 98504
Eash, Ronald, Chicago Area Transportation Study, 300 W. Adams Street, Chicago, Ill. 60606
Euritt, Mark A., Lyndon B. Johnson School of Public Affairs, University of Texas, Austin, Tex. 78712
Evers, Kathleen, Public Transportation Division, North Carolina Department of Transportation, P.O. Box 25201, Raleigh, N.C. 27611
Falter, Daniel C., Planning, Research and Public Transportation Division, Washington State Department of Transportation, Transportation Building, Olympia, Wash. 98504
Farkas, Z. Andrew, Center for Transportation Studies, Morgan State University, Baltimore, Md. 21239
Fwa, T. F., Graduate Research Assistant, Purdue University, Civil Engineering Building, W. Lafayette, Ind. 47907
Garcia-Diaz, Alberto, Texas Transportation Institute, Zachry Engineering Center, Texas A&M University, College Station, Tex. 77843
Grubb, Norton W., Lyndon B. Johnson School of Public Affairs, University of Texas, Austin, Tex. 78712
Kidder, Alice E., Office of Sponsored Research, Babson College, Babson Park, Mass. 02157
Newell, Betty L., Central Virginia Community Health Center, Inc., P.O. Box 20, New Canton, Va. 23123
Rock, Steven M., Illinois Institute of Technology, Chicago, Ill. 60616
Schauer, Peter, Peter Schauer Associates, Route 2, Boonville, Mo. 65233
Sharma, Satish C., Faculty of Engineering, University of Regina, Regina, Sasketchewan, Canada S4S A02
Simmons, Patrick B., Public Transportation Division, North Carolina Department of Transportation, P.O. Box 25201, Raleigh, N.C. 27611
Sinha, Kumares C., Purdue University, Civil Engineering Building, W. Lafayette, Ind. 47907
Tayebali, Akhtarhusein, Engineering Department, University of Regina, Regina, Sasketchewan, Canada S4S A02
Villarreal-Cavazos, Arturo, Texas Transportation Institute, USDA Building, Texas A&M University, College Station, Tex. 77843
Walton, C. Michael, Center for Transportation Research, University of Texas, Austin, Tex. 78712
Werner, Al, Transportation Planning Services, Alberta Transportation, Edmonton, Alberta, Canada A3A 10

Thickness Incremental Method for Allocating Pavement Construction Costs in Highway Cost-Allocation Study

T. F. FWA and KUMARES C. SINHA

ABSTRACT

A new incremental approach is proposed for allocation of pavement construction costs to highway users. A description of the concept and a working algorithm for computation of the cost responsibility of each vehicle class are presented. The proposed procedure considers pavement thickness increments rather than traffic volume increments or decrements commonly employed in past cost-allocation studies, thereby eliminating the need for an iterative process to compute the vehicle equivalent single-axle load (ESAL), which is required for cost responsibility calculations. The procedure also eliminates the economy-of-scale problem present in the classical incremental cost-allocation method. A hypothetical numerical example is given for illustration. Cost responsibility results of a full-scale analysis are also presented.

Highway cost-allocation studies seek to distribute highway cost equitably among all classes of users. The results of cost-allocation studies have been used to assist state legislatures as well as the U.S. Congress in making highway user tax decisions.

New pavement cost is one of the major cost items in a highway cost-allocation study. Historically, the most commonly used procedure for allocating pavement construction costs has been the traditional incremental method. In this method, the costs of pavement are allocated on the basis of the incremental costs needed to build a thickness capable of accommodating a particular category of traffic (1). The cost-allocation method employed by a 1965 FHWA study (2) is an example of the incremental technique in which trucks and cars share the costs of the basic pavement depth necessary for carrying cars, and the costs of the extra pavement depth required to carry heavy trucks are charged to heavy trucks (2).

In spite of its wide application in the area of cost-allocation, the traditional incremental approach has been found to be unsatisfactory as a procedure for allocating pavement construction cost. Pavement costs remain one of the most controversial aspects of highway cost allocation. Presented in this paper is a review of the traditional incremental method as well as other methods adopted in recently completed studies, and a proposal for revised incremental approach for allocating pavement construction costs.

REVIEW OF EXISTING COST-ALLOCATION METHODS

In general, the existing pavement cost-allocation methods may be classified into three broad categories: (a) methods that follow the traditional incremental approach, (b) methods that distribute cost directly in proportion to a cost allocator, and (c) decremental or avoidance methods based on a removal technique that hypothetically removes vehicle groups from the traffic stream. Listed in Table 1 are some recent studies classified according to their allocation methods (2-11).

The direct cost-allocator approach is easy to use. However, its theoretical basis is weak, and it is questionable whether an equitable and fair cost allocation is attainable with such an approach.

TABLE 1 Allocation Procedures for New Pavement Cost in Recent Studies

Procedure Type and Study	Description
Traditional incremental approach	
Oregon, 1980 *(4)*	Incrementally by observed axle weight
Wyoming, 1981 *(5)*	Traditional six-step incremental method
Maryland, 1983 *(6)*	Eleven axle load increments, cost allocated on the basis of axle miles
Direct cost-allocator approach	
Kentucky, 1982 *(7)*	Based on total 18-kip ESAL for a 20-year period
Georgia, 1979 *(8)*	First 5-in. concrete or equivalent asphalt concrete thickness distributed to all vehicles according to vehicle miles of travel (VMT); balance allocated on the basis of ESAL and VMT
Virginia, 1982 *(9)*	Minimum pavement method; minimum thickness costs distributed by average daily traffic (ADT); balance allocated by ESAL
Maine, 1982 *(10)*	Passenger car equivalent (PCE), 50 percent of minimum pavement cost; VMT, the other 50 percent; balance allocated by ESAL
Connecticut, 1982 *(11)*	Common costs allocated by VMT, attributable costs by ESAL
'Decremental removal' or avoidance approach	
FHWA, 1982 *(2)*	Uniform removal technique by hypothetically removing vehicle classes and calculating costs saved using AASHO Road Test equations
Wisconsin, 1982 *(3)*	Basic costs distributed in proportion to PCE miles; service costs allocated by avoidance technique; remaining unallocated service costs distributed to all vehicle groups in proportion to ESAL
Virginia, 1982 *(9)*	Similar to Wisconsin basic-avoidance-residual technique, except that the basic costs are allocated to all vehicles on the basis of ADT

The traditional incremental approach, which has enjoyed wide application in the past, has been much criticized for its unfairness in allocating pavement thickness costs by giving the benefits of economy of scale to heavy vehicle classes (2,3,12). Economies of scale in pavement cost allocation arise from the nonlinear relationship between pavement thickness and traffic loadings. A curve of pavement thickness plotted against traffic loading tends to level off as load increases. Figure 1 shows a typical pavement

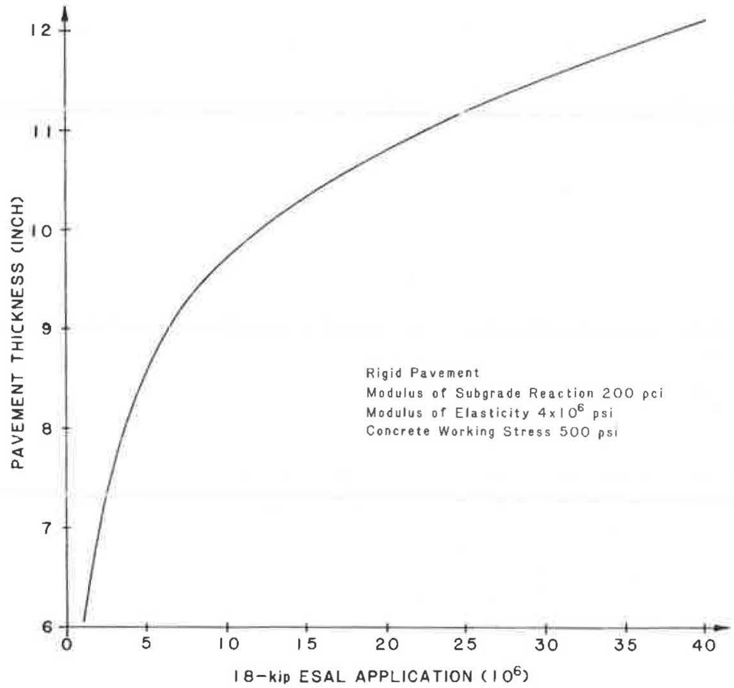

FIGURE 1 Relationship between ESAL application and pavement thickness.

thickness-load relationship for rigid pavements. A similar nonlinear relationship also holds for flexible pavements. This means that the last unit thickness at the top of a pavement could withstand much higher traffic loading than could the first unit thickness at the base of the pavement. Under the traditional incremental approach, vehicle classes are added sequentially to the traffic stream and those vehicle classes added later are assigned lower unit costs than those vehicle classes added earlier. An unfair allocation results as long as the sequential addition of vehicle classes, which is the central idea of the traditional incremental approach, is retained.

In reality, traffic loadings are applied randomly and not in the pattern assumed in the traditional incremental approach. Applying traffic loads sequentially in vehicle classes is also not consistent with most pavement design procedures. Practically all pavement design methods involve consideration of the entire traffic loadings as one entity and the pavement thickness is then designed for these mixed traffic loadings as a whole. No existing design procedure has indicated or implied that a certain thickness is designed explicitly for a particular class of vehicle. In other words, vehicle classes have never been considered individually for thickness design purposes.

The considerations discussed in the preceding paragraph can be used as a yardstick to judge the rationality of any cost-allocation procedure for pavement thickness cost. Several attempts have been made to improve the accuracy and rationality of the traditional incremental method. Studies have been made by using 15 or more increments (2), instead of the traditional six increments that were used to increase the accuracy of cost allocation. Unfortunately, the cost (pavement thickness) increment is not a linear function of the parameter (in this case, the vehicle class) increment. Increasing the number of increments alone does not eliminate the inherent weakness of the method. That is, the economy-of-scale problem remains no matter how many increments are used in the analysis.

In an attempt to overcome the economy-of-scale problem, the Wisconsin study (3) employed a technique called Basic-Avoidance-Residual (BAR) for allocating pavement costs. A vehicle group is randomly removed from the traffic stream and the reduction in pavement thickness is calculated. This vehicle group is then returned to the traffic stream and the procedure is repeated by removing a different vehicle group. The calculated cost reduction for the pavement saved each time is considered to be the responsibility of the vehicle group removed. The main drawback of this procedure is that thickness reduction is computed for each vehicle group at the top end of the thickness design curve shown in Figure 1. This is not consistent with the actual concept used with most pavement thickness design procedures. Another undesirable feature of this method is that the avoidance technique described in the preceding paragraphs cannot fully account for the entire attributable pavement thickness. A residual thickness is left unallocated after all vehicle groups have been considered. This leftover portion is distributed to each vehicle group in proportion to its contribution to the total equivalent single-axle load (ESAL).

A notable contribution toward logical allocation of pavement thickness cost was made in the federal cost-allocation study completed in 1982 (2). A decremental approach was adopted in which traffic was systematically removed and the attendant hypothetical cost savings were assigned to the vehicles under consideration. Because order of removal can drastically affect the costs assigned to a given axle, it was proposed that each vehicle class be divided into an equal number of subgroups, and one subgroup from each vehicle class be removed before the second subgroup was removed from any class. The amount of thickness saved was distributed to vehicle classes on the basis of ESAL. On the basis of the argument that the ratios of thickness saved for one vehicle class relative to other vehicle classes were nearly constant at different points on the removal curve, only an average ESAL value for each vehicle class was computed. Each average ESAL value was obtained iteratively by first assuming a middle-range pavement thickness.

DESCRIPTION OF THE PROPOSED APPROACH--THE THICKNESS INCREMENTAL METHOD

A revised incremental procedure is developed in this paper to (a) overcome the problem of economy-of-scale in pavement thickness cost allocation and (b) be consistent with procedures commonly used in pavement design.

The proposed cost-allocation procedure begins by defining pavement thickness increments, in contrast to the common practice of starting with traffic increments or decrements. There are two advantages to this new approach: (a) by beginning with a known thickness, calculation of ESALs becomes a straightforward noniterative procedure, and (b) pavement thickness is more directly related to cost than is traffic loading.

In the definition of the number and magnitude of pavement thickness increments, a minimum practical pavement thickness must first be determined because it is impractical to construct surface, base, or subbase courses of less than some minimum thickness. This minimum thickness is the basic pavement thickness that is required regardless of the traffic level. For instance, the AASHTO Interim Guide (13) recommends the following minimum practical thicknesses:

Course	Thickness (in.)
Surface	2
Base	4
Subbase	4

Only those costs that correspond to the thickness in excess of the specified minimum will be allocated by the incremental approach described in this section. The costs corresponding to the minimum thicknesses cannot be allocated to any particular vehicle group and will be considered as nonattributable costs or basic costs. These costs are the collective responsibility of all the vehicles that use highways. They are commonly distributed to vehicle classes on the basis of a use-related travel function such as vehicle-miles of travel (VMT) (2) or passenger car equivalent (PCE) (3).

The total thickness in excess of a specified minimum is divided into equal increments, the number and thickness of which depend on the desired accuracy of the final results. Beginning with the specified minimum thickness, a thickness increment is first added. With this thickness, the ESAL of each vehicle type or a representative vehicle type of a vehicle class can be computed directly from equations developed from the AASHO Road Test (14).

The same procedure is repeated for each additional increment until the last increment is added and analyzed. The incremental pavement thickness cost calculated for each thickness increment is assigned to all vehicle classes based on their need for that thickness in accordance with pavement design procedure. When each increment is sufficiently small, the proportional amount of incremental pavement thickness cost attributable to a given vehicle class can be taken as being in direct proportion to its ESAL value at the thickness concerned.

An important feature of the foregoing procedure with respect to input data requirements is worth mentioning. With the exception of direct cost-allocator methods (i.e., the second procedure category in Table 1), virtually all analytical cost-allocation methods use the following general relationships:

$$c = f(T,C,m) \quad (1)$$

$$t = g(Vt,VPx,ESALx,r,s,k) \quad (2)$$

$$ESALx = h(t,Wx) \quad (3)$$

$$CRx = w(ESALx,\sum_x ESALx,t,c,VPx) \quad (4)$$

where

- c = unit pavement thickness cost;
- m = pavement material type;
- T = total thickness of pavement;
- C = total pavement cost;
- V = total traffic volume;
- Vt = traffic volume considered in an intermediate stage of cost-allocation analysis, $0 \leq Vt \leq V$;
- t = pavement thickness corresponding to traffic volume Vt, $0 \leq t \leq T$;
- VPx = volume proportion of vehicle class x, x = 1,2,...,n;
- n = total number in vehicle class;
- ESALx = equivalent 18-kip single axle load of vehicle class x, x = 1,2,...,n;
- r = regional factor to account for regional climatic and environmental effects;
- s = subgrade soil property parameter;
- k = pavement material properties;
- Wx = axle loads of vehicle class x, x = 1, 2,...,n; and
- CRx = cost responsibility of vehicle class x, x = 1,2,...,n.

The FHWA study's Uniform Removal Technique, Wisconsin's BAR method, and the traditional incremental approach all involved consideration of increments or decrements of traffic volume and the resulting pavement thickness was computed iteratively by using the relationships in Equations 2 and 3. This process requires a complete range of input information, as is needed in a design problem. Cost-allocation analysis, though closely related to design, is not a design problem because the total pavement thickness is already known. For a pavement constructed or going to be constructed with a total thickness T and cost C, Equations 1, 3, and 4 indicate that with an appropriate procedure such as the method proposed in this paper, it is not necessary to resort to the iterative thickness design steps in order to calculate cost responsibilities. Consequently, information such as V, r, s, and k need not be known in a pavement cost-allocation problem.

COMPUTATIONAL ALGORITHM OF THICKNESS INCREMENTAL METHOD

The AASHO Road Test equations (13,14) for the ESAL calculation can be expressed as follows:

$$\log ESALx = G\,[(1/b_{18}) - (1/b_x)] + \log\{[(L_x + L)/19]^A \cdot (L)^B\} \quad (5)$$

$$G = \log[(I - P_t)/(I - 1.5)] \quad (6)$$

$$bx = C + [D(L_x + L)^E/(SN + 1)^F \cdot (L)^H] \quad (7)$$

$$SN = T \text{ for rigid pavement} \quad (8a)$$

$$SN = a1 \cdot D1 + a2 \cdot D2 + a3 \cdot d3 \text{ for flexible pavement} \quad (8b)$$

where

L_x = axle load (kips);
L = 1 for single axles, 2 for tandem axles;
P_t = terminal serviceability index;
SN = slab thickness (for rigid pavement), structure number (for flexible pavement);
A,B,C,D,E,F,H,I = constants with values specified in Table 2;
a1,a2,a3 = layer coefficients representative of surface, base, and subbase course, respectively; and
D1,D2,D3 = thickness (in.) of surface, base, and subbase course, respectively.

TABLE 2 Values of Constants in Equations 5-8

Constant	Flexible Pavement	Rigid Pavement
A	4.79	4.62
B	4.33	3.28
C	0.40	1.00
D	0.081	3.63
E	3.23	5.20
F	5.19	8.46
H	3.23	3.52
I	4.20	4.50

Inputs to the problem include (a) cost information, (b) pavement data, and (c) traffic composition, vehicle axle configuration, and axle-weight data. In practically all previous cost-allocation studies, pavement costs were assumed to be directly proportional to thickness. The Thickness Incremental Method presented herein does not have this restriction. The algorithm described in the following can accommodate any nonuniform linear or nonlinear thickness-cost relationship.

The computation algorithm for cost allocation involves the following steps:

1. Divide the pavement thickness in excess of a practical minimum into N equal increments. In the case of flexible pavement, each increment is composed of thickness of surface, base, and subbase materials in the same proportions as are in the total "excess" thickness to be allocated.
2. Calculate the cost for the minimum thickness and distribute to all vehicle classes on the basis of VMT.
3. Calculate the incremental thickness cost.
4. Add an increment to the minimum thickness, and compute ESAL for all vehicle classes (or vehicle types if desired) using Equations 5 through 8.
5. Compute the cost responsibility factor of each vehicle class (or vehicle type) as the following ratio:

$$F(i,j) = P(i) \cdot ESAL(i,j) / \sum_{r=1}^{M} [P(r) \cdot ESAL(r,j)] \quad (9)$$

where

$F(i,j)$ = cost responsibility factor of vehicle class i for thickness increment j,
$P(i)$ = proportion of vehicle class i in traffic stream,
$ESAL(i,j)$ = ESAL of vehicle class i for thickness increment j, and
M = total number of vehicle classes.

6. Allocate incremental thickness cost to each vehicle class as follows:

$$c(i,j) = F(i,j) \cdot Cd(j) \quad (10)$$

where $c(i,j)$ is the cost allocated to vehicle class i for thickness increment j, and $Cd(j)$ is the incremental cost for thickness increment j.

7. Repeat steps 5 and 6 for each new thickness increment until the full pavement thickness is reached.
8. Calculate the total allocated cost for vehicle class j by summing up its cost responsibility for all increments:

$$C(i) = CM(i) + \sum_{j=1}^{N} c(i,j) \quad (11)$$

where

$C(i)$ = total cost responsibility of vehicle class i,
$Cm(i)$ = cost responsibility of vehicle class i for the minimum thickness, and
N = total number of thickness increments.

AN ILLUSTRATIVE EXAMPLE AND FINDINGS

A hypothetical problem, described in Figure 2, is developed herein for illustration purposes. Only two vehicle types are chosen for ease and clarity in presentation. Also, minimum practical thickness is set to 0 to highlight the salient features of the incremental allocation procedure. Cost is assumed to be directly proportional to pavement thickness. From the results shown in Figure 2, the following observations can be made:

1. Incremental cost responsibility varies with pavement thickness. A fair allocation of cost cannot be attained by using a direct cost allocator. Using an ESAL evaluated at full thickness as the cost allocator overestimates cost responsibility of the heavier vehicle whereas using an ESAL at intermediate range tends to underestimate its responsibility.
2. The cost responsibility curve fluctuates because it depends on the relative magnitude of ESALs of different vehicle classes that are themselves nonlinear functions of thickness. It may not be appropriate to use an average ESAL value for each vehicle class to allocate costs.
3. The overall cost responsibility distribution will change when a minimum practical thickness is introduced. The direction of this change depends on the magnitude of the minimum thickness introduced and the vehicle-mile proportion of each vehicle class.
4. For structural numbers greater than 6, further analyses show a small but steady increase of heavy vehicle responsibility.
5. Results from a similar analysis performed on concrete pavement (see Figure 3) show the same pattern of cost responsibility distribution, but the amplitudes of fluctuations of the cost responsibility curves are much smaller.

Figure 4 presents a plot of cumulative cost responsibility versus pavement thickness for the problem described in Figure 2. The total cost responsibility of each vehicle class is given by the responsibility value at T, the total pavement thickness.

In Table 3, cost responsibility factors for the hypothetical problem in Figure 2 are computed by using five different methods. The traditional incremental method always underestimates the cost respon-

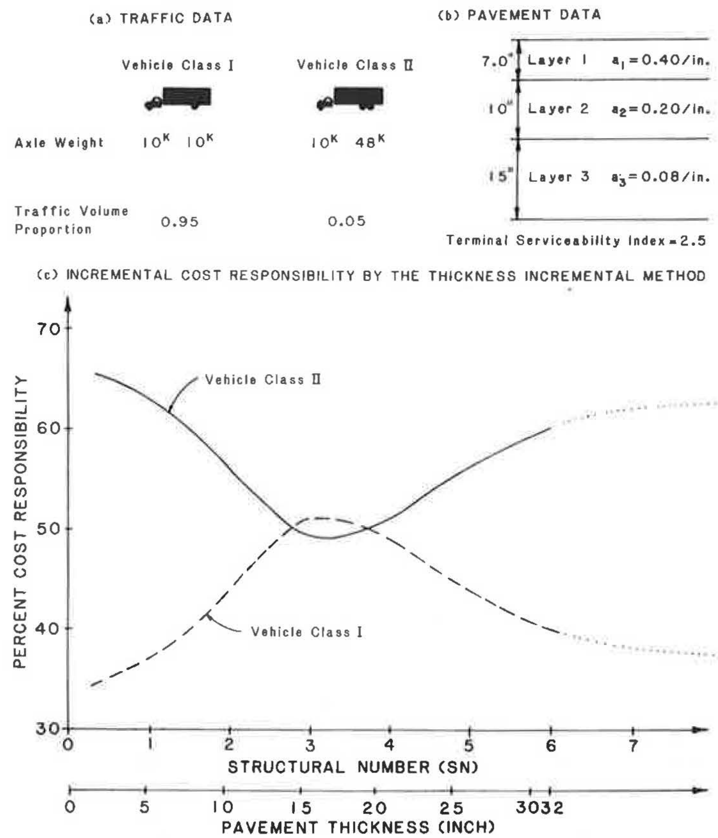

FIGURE 2 A hypothetical cost-allocation problem for flexible pavement.

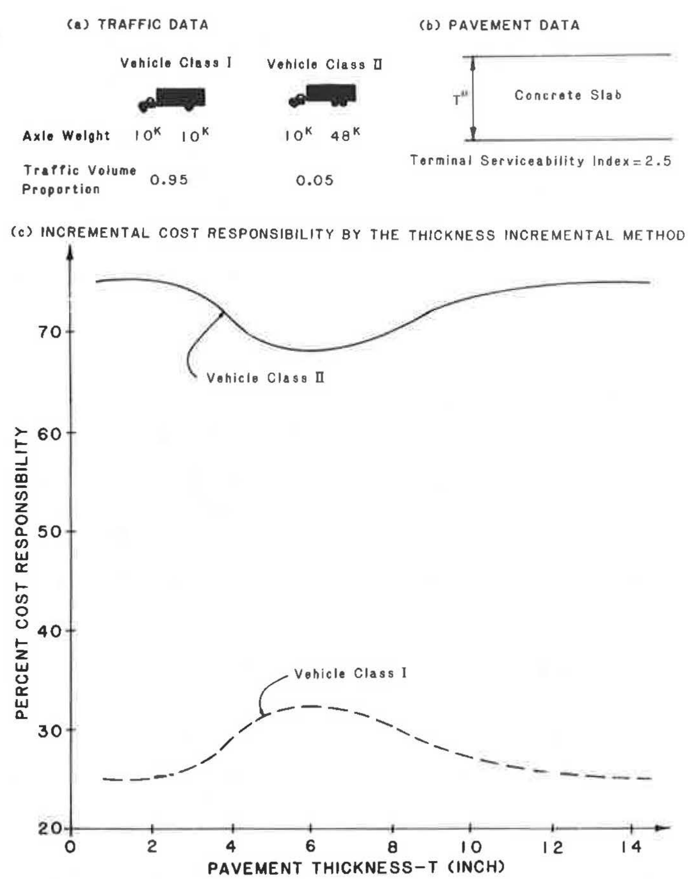

FIGURE 3 A hypothetical cost-allocation problem for rigid pavement.

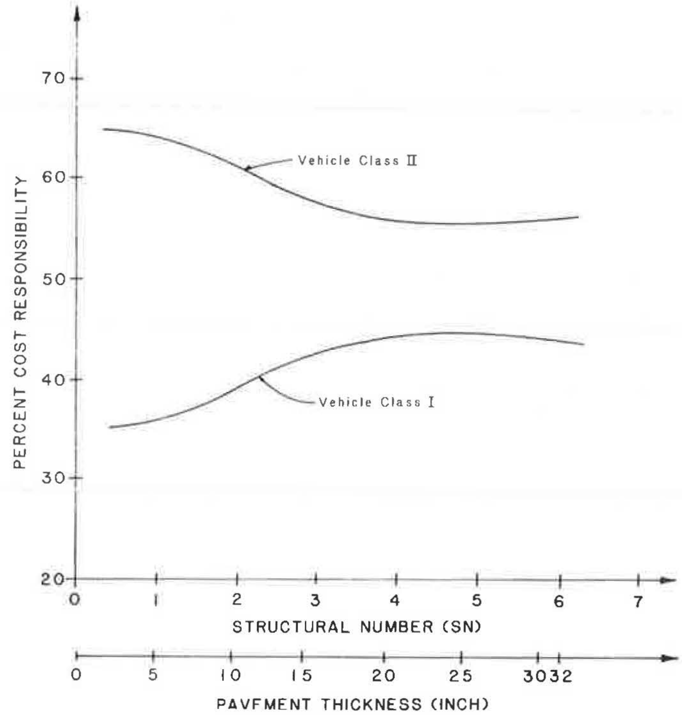

FIGURE 4 Variation of cumulative cost responsibility with pavement thickness—by thickness incremental method for problem in Figure 2.

TABLE 3 Solution to Figure 2 Problem with Different Cost-Allocation Methods

Method	Cost Responsibility (%) Vehicle Class I	Vehicle Class II
Thickness incremental method	43.81	56.19
ESAL cost-allocator method	40.00	60.00
FHWA study's *(2)* Uniform Removal Technique[a]		
Evaluated at SN = 2.5	48.38	51.62
Evaluated at SN = 3.0	50.54	49.46
Evaluated at SN = 3.5	50.45	49.55
Wisconsin study's BAR method[a]	38.79	61.21
Traditional incremental method[a]	81.54	18.46

[a]Additional data: total 18-kip ESAL applications = 10,000,000; region factor = 1.0; soil support value = 2.5.

sibility of heavy vehicles because of the economy-of-scale problem described earlier. The second and third methods may underestimate or overestimate heavy vehicle responsibility. In the former case, this depends on the total thickness of pavement as can be seen from Figure 2 and in the latter, on the thickness at which ESALs are computed. For most practical situations where total heavy truck ESAL is higher than total light vehicle ESAL, Wisconsin's BAR method leads to an overestimation of heavy vehicle responsibility.

RESULTS OF A FULL-SCALE STUDY

The thickness incremental method was used in the 1983-1984 Indiana cost-allocation study to allocate pavement construction costs. Presented in Tables 4 and 5 are data and cost responsibility results for rural Interstate highways in Indiana. Sixteen contracts completed between 1980 and 1983 were included in the analysis.

Table 4 shows the average traffic volume composition of 14 vehicle classes on Indiana rural Interstates. Each of these 14 classes was further subdivided into weight categories in increments of 2,500 lb. Table 4 presents the aggregate cost responsibilities for the 14 vehicle classes. For illustration, the breakdown of class 12 vehicle cost responsibility into weight category responsibilities is shown in Table 5.

CONCLUSIONS

There are two unique features that distinguish the proposed procedure from other existing cost-allocation methods: (a) a more direct approach using the cost-related pavement thickness as the controlling parameter is followed; and (b) the amount of input data required is considerably less. For example, only the proportional distribution of each vehicle class in the traffic stream is needed.

TABLE 4 Average Traffic Volume Composition on Indiana Rural Interstates

	Vehicle Class[a] 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Volume (%)	15.64	48.84	2.36	0.31	1.12	0.42	0.36	0.06	0.17	0.07	2.52	27.20	0.76	0.16
Cost responsibility (%)	8.54	26.85	1.98	0.48	0.65	0.42	0.47	0.03	0.23	0.06	3.73	54.19	2.13	0.24

[a]Definition of vehicle classes: Class 1, small passenger cars; Class 2, standard and compact passenger cars, panels, and pickups; Class 3, two-axle truck (2S and 2D); Class 4, bus; Class 5, car with one-axle trailer; Class 6, three-axle single-unit truck; Class 7, 2S1 tractor-trailer; Class 8, car with two-axle trailer; Class 9, four-axle single-unit truck; Class 10, 3S1 tractor-trailer; Class 11, 2S2 tractor-trailer; Class 12, 3S2 tractor-trailer; Class 13, other five-axle; Class 14, six or more axles.

TABLE 5 Pavement Construction Cost Responsibility Factors for Weight Categories of Class 12 Vehicle on Rural Interstate

Subdivision No.	Weight Category	Cost Responsibility (%)
1	Less than 22,500	0.040
2	22,500-24,999	0.205
3	25,000-27,499	0.736
4	27,500-29,999	2.170
5	30,000-32,499	1.847
6	32,500-34,999	1.192
7	35,000-37,499	1.043
8	37,500-39,999	0.971
9	40,000-42,499	0.938
10	42,500-44,999	0.934
11	45,000-47,499	0.964
12	47,500-49,999	1.009
13	50,000-52,499	0.971
14	52,500-54,999	1.252
15	55,000-57,499	1.490
16	57,500-59,999	2.075
17	60,000-62,499	2.047
18	62,500-64,999	2.159
19	65,000-67,499	2.708
20	67,500-69,999	4.418
21	70,000-72,499	7.609
22	72,500-74,999	9.015
23	75,000-77,499	4.923
24	77,500-79,999	2.296
25	80,000-82,499	0.254
26	82,500 and above	0.624
Total		54.190

By having each vehicle class proportionally represented each time an incremental cost is allocated, the proposed cost-allocation procedure effectively eliminates the economy-of-scale problem associated with the traditional incremental method. Iterative procedure is avoided by taking the thickness increment as the starting parameter. The algorithm is applicable to any nonuniform linear or nonlinear thickness-cost relationship. The procedure is easy to understand because it follows traditional thought in increasing thickness to account for increasing traffic.

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On the Elimination of Gasoline Tax Deductibility and the Distribution of Income

STEVEN M. ROCK

ABSTRACT

In 1979, the deduction for state and local gasoline taxes on income tax returns was eliminated. To determine the resulting impact on income distribution, the change in net gasoline tax incidence must be determined. Conventionally, the incidence of a (gross) gasoline tax has been calculated by noting the relationship between income and purchases of motor fuel. Most studies have not explicitly included consideration of the impact of allowing state and local gasoline taxes to be deducted; however, one study concluded that the impact of deductibility is to make the fuel tax less regressive. Using data available from the Bureau of Labor Statistics (U.S. Department of Labor) and the Internal Revenue Service (U.S. Department of the Treasury), the opposite was found. This resulted from the positive correlation of income with three factors: marginal tax rate, percentage of taxpayers who itemize deductions, and amount of gasoline tax paid. It is concluded in this paper that the elimination of deductibility has made the gasoline tax less regressive.

Effective for taxable years beginning in 1979, the Revenue Act of 1978 repealed the itemized deduction for state and local gasoline taxes on federal individual income tax returns. This was largely in response to the mood of conservation and the concern over dependence on foreign oil spawned by the energy crisis of the 1970s. The purpose of this paper is to examine the impact of this repeal on the net incidence of a motor fuel tax.

In most studies of excise tax incidence it is assumed that the final incidence is similar to the initial distribution of liabilities (statutory incidence) (1-3). This conclusion may be modified in some market structures and under some cost conditions. In general, tax increases will raise costs and the relative price of the taxed product, which will, in turn, cause resources to move out of the industry thus further raising prices. To the extent that labor and capital can receive approximately the same income in other industries, the entire tax may be shifted to buyers in the form of higher prices.

Such complete shifting of an excise tax may be questioned if different geographic regions have different tax rates. This could alter consumer purchasing patterns and the ability of a firm to raise prices for competitive reasons. However, this problem can be avoided empirically if data on actual tax payments by income level are available. If only the repeal of gasoline tax deductibility is examined, however, it can be safely assumed that differential fuel tax rates would not change and therefore would not affect purchasing patterns.

Approximately 35 percent of motor fuel taxes are paid by businesses. The burden of this portion of gasoline taxes will depend on resultant changes in prices, profits, and wages. Because the emphasis in this paper is on individual tax payments, business-based fuel purchases will be ignored. The incidence of a gasoline tax could therefore be calculated by noting how gasoline purchases (and gasoline taxes) vary by income level.

PREVIOUS STUDIES

A few studies have included consideration of a motor fuel tax incidence. In most of these studies, however, this tax has been combined with other goods that are either selectively taxed or combined with all sales and excise taxes (2-4). One study that included separate calculations on gasoline tax incidence was conducted by Freeman (5) using 1972 household data provided by the Brookings Institution. Using an assumed tax of $0.20 per gallon (although the results would, in a relative sense, be representative of any tax that would be proportional to use), an incidence pattern was obtained that was slightly progressive except at the extremes of the income distribution where there was regression. A second study, by Zupnick (6), examined the incidence of a tax-induced $0.10-per-gallon price increase. Average fuel economy by model year was combined with average miles driven by income group and with ownership of each model year by income class. The result was progressive in the lower to middle income brackets, but was regressive in the upper income bracket. Unfortunately, the type of data used by Zupnick are no longer being collected. None of these endeavors included consideration of deductibility impact on incidence.

The only study that has included specific consideration of deductibility was conducted by Due (7). By using Internal Revenue Service (IRS) statistics, the distributional pattern of state and local gasoline tax deductions was explored. For 1973, it was estimated that such deductions fell continuously from 2.3 percent of adjusted gross income (AGI) in the lowest income bracket to negligible amounts (as a percentage of AGI) in the highest income bracket. He reexamined this result by using Brookings Institution data on tax savings from deductions as a percentage of tax paid in the absence of deductions, by income level. The gasoline tax deduction again tended to fall in percentage terms as income levels rose, although the middle income brackets displayed a proportional range. Due concluded that state and local gasoline taxes are a progressive deduction that reflects a declining percentage of taxable expenditures relative to income. A deduction was regarded as progressive if the tax savings from it constituted a lower percentage of income in high income groups than in low income groups; that is, the deduction increased the progressivity of the income tax. The implication is that the removal of deductibility would make the distribution of income less equal.

However, there is a serious limitation in Due's analysis: as noted by the author, the sample was limited to only those taxpayers who itemized deductions on their tax returns. Less than 2 percent of all taxpayers in the lowest income bracket deducted gasoline taxes. Those in this bracket who did itemize would be expected to have substantial individual deductions because most taxpayers at that income level took the standard deduction. On the other hand, almost 80 percent of the highest income bracket taxpayers itemized deductions. Although it is true that for those who itemized deductions, the amount deducted as a percentage of income decreased as income level increased, the percentage of those who itemized deductions increased strongly as income level increased. Considering the population as a whole, the overall benefits of itemizing accrued largely to higher income taxpayers. As shown in the following paragraphs, deductibility made the gasoline tax more regressive; removal of deductibility made the tax system less regressive.

ANALYSIS

To determine the incidence of a state and local fuel tax after deductibility, data on gasoline tax paid by income bracket must be matched with data on gasoline tax itemized by income bracket. This necessitates the merging of two data sources as follows.

Motor fuel tax paid by income level can be calculated from the Bureau of Labor Statistics report, consumer Expenditure Survey (CES) (8,9). However, because the CES does not report on tax deductions, the average itemized gasoline tax deduction per tax return by income level must be obtained from IRS statistics. With knowledge of the marginal tax rate per income level, the reduction in federal income tax due to itemization is available. The net incidence of a gasoline tax can thus be computed and the impact of deductibility repeal examined.

One major problem in merging these two data sets is that they use somewhat different definitions of income. The CES uses a concept called family income, which is broader than the IRS concept of AGI. Because they are not identical, those households in a CES income bracket may not be the same group as those in the same bracket using AGI. Family income includes most of AGI, plus pensions, unemployment and workers' compensation, and cash transfer payments less certain occupational expenses. The compatibility problem will be most evident in the lower income brackets, where transfer payments and unemployment compensation are proportionately larger. A family with a low AGI in this situation would have a somewhat higher family income.

Two options exist. The first would be to manipulate the two data sets by making adjustments to make them more compatible. However, this may result in simply substituting one set of problems for another. The chosen option was to assume that the two data sets are compatible and note that this will introduce some inaccuracy or bias in the analysis. As concluded in the following, this problem will not materially affect the results.

The first step in the analysis is to calculate incidence ignoring the impact of itemizing. This would reflect incidence if deductibility was not allowed and can be determined by noting state and local gasoline tax paid by income level. The CES uses 12 income brackets, ranging from under $3,000 to over $25,000. As documented in Table 1, gross motor fuel expenditures (including taxes paid) rose from an average of $108 for the lowest income bracket to $635 for the highest income bracket from 1972 to 1973.

To determine how much of the gross expenditures represent the gasoline tax, it is noted that from 1972 to 1973, the weighted average of state and local motor fuel taxes was about $0.75 per gallon (10). Coupled with an average gasoline price of $0.40 per gallon, state and local taxes represented about 18.75 percent of gross spending. Multiplying the gross expenditures by 18.75 percent yields tax payments and the results are displayed in row 2 of Table 1. The families in the lowest income bracket paid an average of $20 in state and local gasoline taxes, whereas those in the highest income bracket paid an average of $119.

Using the mean income within each bracket (row 3), the amount of gasoline tax paid as a percentage of income is calculated (row 4). This percentage falls from 1.2 percent of income in the lowest bracket to 0.3 percent in the highest. These numbers can be normalized by using the concept of relative incidence. The highest income groups' fuel tax payments as a percentage of income is assigned an index value of 1.0; the other income brackets are scaled accordingly. On this basis, the lowest income group pays 3.7 times more gasoline tax as a percentage of income than does the highest income group--a regressive result. Most of the regression occurs between the first two and the last two income brackets. The tax is roughly proportional for a wide income range.

There is some discrepancy between the previously cited studies and the results presented in Table 1. This may be partly because of the income brackets chosen for these studies, which do not match the income brackets of Table 1. Nevertheless, the regression at low and high income levels is consistent with both Freeman's (5) and Zupnick's (6) findings. The results of Musgrave et al. (2) agree with the regressive impact at higher income levels.

Actually, relative incidence could have been calculated by simply using data on gross gasoline expenditures without separating out the tax. Because gasoline taxes would be proportional to quantity purchased and hence expenditures (being unit taxes), the relative incidence for either expenditures or taxes on expenditures would be the same. That is, comparing total expenditures on gasoline as a percentage of income for each income bracket relative to that of the highest income bracket would yield

TABLE 1 Gross Gasoline Expenditures and Incidence, 1972-1973 *(8)*

	Family Income ($000s)											
	<3	3-4	4-5	5-6	6-7	7-8	8-10	10-12	12-15	15-20	20-25	>25
1. Gross expenditures ($)	108	153	193	237	270	306	363	418	482	544	614	635
2. State and local gasoline tax ($)	20	29	36	45	51	57	68	78	90	102	115	119
3. Mean income ($)	1,713	3,491	4,494	5,482	6,478	7,486	8,970	10,952	13,404	17,237	22,118	37,661
4. Gasoline tax (% of income)	1.19	0.82	0.80	0.81	0.78	0.77	0.76	0.72	0.67	0.59	0.52	0.32
5. Relative incidence	3.7	2.6	2.5	2.5	2.4	2.4	2.4	2.3	2.1	1.8	1.6	1.0

the same relative pattern as the distribution of gasoline tax burden. However, because the deduction value of motor fuel tax itemization was not uniform by income level, the tax paid needs to be separated out for later adjustments.

An initial concern relating to state and local tax itemization on federal income tax returns is the determination of who receives the most benefit. That is, most taxpayers use the standard deduction, which can be taken in lieu of itemizing. A certain amount of the standard deduction implicitly includes state and local tax payments; however, it is impossible to determine how much. In addition, nonitemizers receive no additional benefit for additional expenditures of taxable goods. in other words, the only beneficiaries at the margin are those who itemize. For this group, the corresponding reduction in income taxes would lower the (net) gasoline tax paid for the purpose of calculating incidence. It is assumed that the full amount of gasoline taxes paid represented a deduction by those who itemized. That is, the sum of all deductions except gasoline tax is assumed to be larger than the standard deduction.

The first row of Table 2 displays the average dollar amount of gasoline tax paid per tax return as calculated by the IRS (11,12). It consisted of the average gasoline tax deducted by those who itemized, weighted by the percentage of all returns from those households that itemized. For example, in the lowest income bracket ($0-$3,000) the average gasoline tax paid by those who itemized was around $60. (This amount is substantially higher than the corresponding figure determined from CES data for all families. As mentioned previously, those families who do itemize would be expected to have substantial individual deductions.) But because less than 2 percent of families in this income bracket itemized, the average per return was only $0.76. Separate calculations were made for 1972 and 1973, and the results averaged out to be identical to the CES data for the corresponding period.

Each dollar of gasoline tax deducted lowered income tax liability. To approximate this amount, the average income level within each tax bracket was calculated from IRS data and the marginal tax rate associated with this amount is noted in row 2 of Table 1. Because the overwhelming majority of tax returns that contained itemizations were filed jointly (84 percent), the joint marginal tax rate was used. In addition, the average taxable income within each AGI bracket was calculated for itemizers only because the tax benefit occurred to them only.

The third row is the average income tax savings per return, obtained by multiplying the average gasoline tax deducted by the marginal tax rate. For example, the highest income bracket taxpayer averaged $36.52 in income tax savings ($93.64 average deduction multiplied by 0.39). As expected, the value of itemizing rose significantly with income. This occurred because the percentage of taxpayers itemizing, the marginal tax rates, and the amount of gasoline taxes paid were all positively related to income. The final row suggests that the impact of a gasoline tax deduction was regressive because the tax savings constituted a higher percentage of income, as income levels rose. This result is exactly the opposite of that found by Due (7).

To calculate net incidence, gasoline taxes paid at each income level (from Table 1, row 2) are reduced by the average income tax savings at each level (from Table 2, row 3); the results are displayed as net taxes paid in the first row of Table 3. The second row displays net taxes paid as a percentage of income; it is seen that they remained the same for the lower income brackets, but declined significantly in the higher income brackets (compared with gross fuel tax incidence). Relative incidence emphasizes this result. Tax payments for families in the lowest income bracket as a percentage of income went from 3.7 times as much as the highest income bracket ignoring deductibility, to 5.4 times as much including deductibility. Thus, motor fuel tax deductibility increases the regressive nature of this tax. Alternatively, the existence of itemized deductions makes the individual income tax less progressive.

QUALIFICATIONS

The CES data reflect expenditure patterns and thus incidence from 1972 to 1973. If the distribution of these patterns has changed, tax incidence could change. However, updated CES results are not now available. In addition, the use of a single year's income in calculating incidence can be criticized as being unrepresentative of a longer-run view of income [e.g., Davies (13)]. Unfortunately, no data are readily available to correct this. As mentioned previously, the data and results are based on a national aggregate sample. Individual state or local incidence could differ because of variations in tax rates and expenditures. Finally, the merging of the two data bases could cause inaccuracy in the results. As mentioned previously, the bias is most likely in the lower income brackets. However, because the impact of deductibility appears minor in these brackets, the problem does not appear serious.

TABLE 2 Gasoline Tax Deductions, Marginal Tax Rates, and Tax Savings, 1972-1973 *(10)*

	Adjusted Gross Income ($000s)											
	<3	3-4	4-5	5-6	6-7	7-8	8-10	10-12	12-15	15-20	20-25	>25
1. Average deduction per return ($)	0.76	4.38	7.87	12.50	17.83	23.89	34.26	44.98	54.67	76.84	96.70	93.64
2. Marginal tax rate (%)	14	14	15	15	16	17	19	19	19	22	25	39
3. Tax savings per return ($)	0.11	0.61	1.27	1.88	2.85	4.06	6.51	8.55	10.39	16.90	24.18	36.52
4. Tax savings (% AGI)	0.006	0.017	0.028	0.034	0.044	0.054	0.073	0.078	0.078	0.077	0.098	0.097

TABLE 3 Incidence of (Net) Gasoline Tax, 1972-1973

	Family Income ($000s)											
	<3	3-4	4-5	5-6	6-7	7-8	8-10	10-12	12-15	15-20	20-25	>25
1. Net state and local gasoline tax ($)	20	28	35	43	48	53	62	70	80	85	93	83
2. Net tax (% of income)	1.18	0.80	0.78	0.78	0.74	0.71	0.69	0.64	0.60	0.49	0.41	0.22
3. Relative incidence	5.4	3.6	3.5	3.5	3.4	3.2	3.1	2.9	2.7	2.2	1.9	1.0

CONCLUSIONS

Given the qualifications, the results should be viewed with some caution. Nevertheless, although the numbers may not be exact, it is clear that by allowing state and local gasoline taxes to be deducted on federal income tax returns, coupled with the positive correlation between income and marginal tax rates, and purchases of gasoline and percentage of taxpayers who itemize, a more regressive tax would result. This is the opposite conclusion to that reached by Due.

The implication of this result is that the 1979 removal of the deductibility of state and local motor fuel taxes made the net incidence of the tax the same as the gross incidence. That is, the tax became less regressive, making the distribution of income somewhat more equal. Although this was not a stated reason for the policy enactment, it is, nevertheless, a significant by-product.

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Abridgment

A Model for Management and Public and Private Finance of Rural Road Systems

Z. ANDREW FARKAS

ABSTRACT

The Forest Service, U.S. Department of Agriculture, directly manages one of the largest and most varied transportation systems in the world and may be an appropriate model for general management and public and private financial management of rural road systems. The Forest Service system includes approximately 321,000 miles of roads, foot trails, airfields, aerial tramways, waterways, and cableways with low-volume roads making up most of the system. Examined in this paper are the policies and requirements of the Forest Service as a possible model for rural road management and planning, and for cooperative public and private financing. Because the economies of rural areas are generally natural resource based, these policies and requirements should be applicable in some form to rural road systems worldwide. National forest management plans contain the public's objectives for private sector development and public use of forest resources. The national forest road systems are planned and managed to support these objectives. The public and private sectors then cooperate in the financing of construction and maintenance of national forest roads. Explicit development objectives require uniquely supportive road systems in order to properly exploit natural resources. The private sector constructs and maintains roads from which the public can also benefit. This model is an appropriate example for coordinating economic development and roads expansion in rural areas with limited public financial resources.

Although it is not a transportation agency, the Forest Service, U.S. Department of Agriculture, directly manages one of the largest and most varied transportation systems in the world and may be an appropriate model for general management and cooperative public and private financial management of rural road systems. The Forest Service system includes approximately 321,000 miles of roads, foot trails, airfields, aerial tramways, waterways, and cableways. Low-volume roads make up the predominant part of the transportation system and most are located in the western United States in national forests. National forest roads often carry less than 100 vehicles per day and traffic volumes vary significantly by season and use. Of the 321,000 miles of roads, 27 percent is currently closed to all traffic, 29 percent is maintained for passenger car use, and 44 percent is maintained for high clearance (including two- and four-wheel drive) vehicles (1,p.37).

The Forest Service is a natural resources management agency that is responsible for managing the national forest road systems for use, protection, development, and management of national forest lands, and for providing access to natural resources extraction for the private sector and to recreational activities for the public. The national forests contain 87 million acres of commercial forests and 41 million acres of rangeland. The forests also contain 2.5 million acres of surface water (2,pp.3-1 - 3-3). These land and water resources support commercial timber harvesting, energy and nonenergy minerals mining, commercial ranching, fishing and trapping, and an assortment of public outdoor recreation activities, including boating, hunting, and skiing. The agency has a tradition of public and private cooperation in resources development and transportation of goods and services.

Users of national forest roads are as varied as the major activities occurring on national forest lands. The transporting of forest products and minerals, recreationists traveling to and from the forest sites, landowners commuting from within or near national forests, and administrative-related travel make up the bulk of traffic on forest roads. In situations where the Forest Service and other public road agencies have mutual jurisdiction, local commercial traffic, busing of school children, and mail delivery may also be involved.

The objective of this research is to examine the policies and requirements of the Forest Service as a potentially more widely applied model for management and cooperative public and private finance of rural roads. Because the economies of rural areas in general are natural resource based, Forest Service policies and requirements may be applicable in some form to the management of other rural road systems in mixed capitalist, developed, and developing countries.

Other rural jurisdictions are faced with similar concerns for providing adequate roads to support economic development. It has been suggested that, if misallocation of resources and economic stagnation are to be avoided (3,4), transportation planning by developed and developing countries should be done in concert with specific economic development and social objectives. Public and private financing of roads could be beneficial to developing rural areas, but the role of such cooperation should be more clearly defined when economic development and social objectives are incorporated into the planning process.

FOREST SERVICE ROADS MANAGEMENT: PLANNING AND ANALYSIS

Each national forest is required to develop an integrated land and resources management plan every 15 years. The management plan is the basis for each national forest's management program, including roads management. The plans and programs are guided by nationally established goals and locally established issues of resources production and protection, environmental quality, and social and economic impact. These plans identify the potential for resource outputs and examine management program alternatives for resources production. One of the primary criteria for evaluation of management program alternatives is to maximize present net value of resource outputs (5,p.F-2).

Each management program alternative must have a road system associated with producing a mix of outputs at minimum costs. These costs include monetary costs as well as physical, biological, social, and economic effects (6,p.7).

National forest resources that are accessed for the first time by road provide most of the calculated benefits to the economic analyses of road investments in management plans. These resources consist of timber, energy and nonenergy minerals, and recreation activities. The "willingness-to-pay" values of these resources are treated as the benefit values of a road providing first-time access. Timber benefit values, for example, consist of the "stumpage value," the value on the stump as determined by the bid price for timber by timber companies. The stumpage value becomes a direct monetary return to the United States Treasury. This stumpage value minus the costs of producing and protecting the resource is the benefit value of access to the resource area (7,pp.F-13 - F-14). For those national forest road projects that are reconstructions of existing roads or are constructions of alternative roads and do not provide first-time access, the benefits consist of reduced user, maintenance, and operating costs.

Selecting the most appropriate road system may require analyses of several options to meet a management program alternative's resource mix. The anticipated quantities of resource outputs for each management program alternative are converted into trips and allocated over the links in the road network. After the estimated traffic has been allocated throughout the network, a roads management alternative is developed, concerning road standards, facility construction, maintenance, and operation. For example, a resource management program emphasizing timber production may require restrictions on recreation traffic and specific standards of construction. Each management program alternative may result in unique trip generations and distributions throughout the road network (8,pp.20-21). A selected management program will then require the implementation of an appropriate road system for the anticipated traffic.

IMPLICATIONS FOR RURAL ROADS MANAGEMENT PLANNING

The implications of the Forest Service experience for other rural road systems are that economic and social objectives can and should be seriously incorporated into a roads management planning process. Although other rural areas may not have the organizational unity and the relatively homogeneous land uses or ownership that national forests have, rural jurisdictions should attempt the integration of economic development with roads management. Development of mineral resources, prime agricultural lands, or industrial areas can place differing requirements on a developing road system.

An entire road system may be evaluated in terms of several economic development scenarios. The scenario most likely to occur with promotion of the public and private sectors may require a road system different from the one in place. The system should then be modified and managed in coordination with development objectives.

The projected traffic in a rural area may not be sufficient to justify road improvements on the basis of reduced user costs. A "value-added" approach can be used for measuring the benefits of increased production of natural resource, agricultural, or manufacturing outputs resulting from a road investment. This approach determines the difference in net income to developers, manufacturers, and transporters of outputs with or without a road investment. The appropriate value-added approach may range from estimates and hand-accounting of benefits to samples of enterprise budgets and linear programming analyses of shadow prices (9,pp.19-46; 10).

MANAGEMENT AND FINANCE OF NATIONAL FOREST ROADS

Appropriated Funds and Purchaser Credit

Once the planning of resources management and of road systems has been accomplished, agency cooperation with other public and private bodies takes place, not only in the development and use of forest resources but in the finance of roads needed to support commercial and public activities. The Forest Service is often involved in cooperative road work and ownership with other jurisdictions, if such work or joint ownership is essential to providing access to national forests or other lands managed by the Forest Service (11). Of even greater significance, however, are the relationships between the Forest Service and private firms in the financing and management of roads.

The Forest Service does build national forest roads from appropriated funds, but purchasers of timber for commercial purposes are authorized to build and maintain roads as well (12). Timber purchasers built 5,733 miles of roads in fiscal year 1983 on national forests, while the Forest Service built 2,016 miles with appropriated funds (13, p.133). The cost of these purchaser-built roads was about $131 million and for appropriated roads the cost was about $252 million; purchaser roads are generally built to lower design standards and consequently cost less to build.

The timber purchaser may receive credit for the cost of road work subject to the terms of a timber sale contract. This purchaser credit may consist of a sum deducted from the timber purchase amount if the road is to be used later for national forest management purposes. The purchaser is required to build only the minimum standard of road needed to harvest and remove timber or other products, subject to environmental regulations (14). If the Forest Service requires a higher standard road for future resource protection or administrative purposes, the Forest Service may enter into a cooperative agreement with the purchaser. In this case, the Forest Service may construct a road with a combination of purchaser credit and government funds or furnish the materials or funds to the purchaser for construction (15).

Management of Cooperatively Financed Roads

The Forest Service must actively manage its road systems because of the variations in use by season, traffic composition, and location. The agency may restrict certain types of traffic at certain times or close roads altogether for land management and safety reasons (16). For example, if public recreation use is high during one season, then timber hauling may be restricted and vice versa. Road closure is the most extreme management step and the agency must coordinate that with other jurisdictions, the general public, and private landowners. When there is no need for a road for a certain period, the road may be closed, which protects natural resources and maintains the investment in the road and public safety. For example, roads constructed for seasonal or intermittent use are closed to minimize road and environmental damage and to maintain public safety. Roads that are not maintainable may be closed until reconstruction or obliteration. Short-term roads (i.e., those used only for a timber harvest), may be closed until obliteration is completed (17).

The agency may not restrict access to property owners within a national forest. Many parcels within a national forest are privately owned and the agency must allow access to them for the owners. Those who may use roads during restricted or closed conditions must adhere to rules of use, to conditions of a special permit, and may even have to pay a bond to repair any possible damage. Existing mining laws allow miners the right of entry into national forests for minerals exploration and development. A special use permit to miners may require them to perform maintenance or make payment for maintenance expenditures caused by mining-related traffic (18). In any case, commercial users are responsible for all traffic-related maintenance commensurate with their uses.

The Forest Service is responsible for maintenance necessitated by national forest administrative and recreation activities. Levels of maintenance for a road are generally determined by the amount of average daily traffic (19) on roads ranging from closed intermittent service roads of any standard to double-lane, paved roads that provide a high degree of user comfort (20).

IMPLICATIONS FOR RURAL ROADS MANAGEMENT AND FINANCE

Other rural jurisdictions could rely on public and private cooperation to build and maintain responsive road systems. Roads would more readily accommodate the changing spatial patterns of economic development if private developers were to directly finance the construction of portions of the public roads system. Rural jurisdictions could share the costs of new roads with developers, based on the expected composition of traffic (e.g., development-induced or general public traffic). A new development may require a higher standard of road than the current one because of increased traffic volumes. Construction of the higher standard road could be financed by the private development. It may be argued that the private sector in the United States already pays for roads through property and fuel taxes. There is often little immediacy or spatial sensitivity in the public sector's allocation of tax revenues to roads in areas of potential or actual development. It is also perceived in many states and localities that the financial burdens of such taxes have become excessive.

The private sector can be motivated to participate in public roads financing when tax benefits or profits exist. Outright private ownership of transportation facilities has been newly researched, discussed, and promoted in the literature (21). It is questionable whether traffic volumes would be high enough, the public's transportation objectives narrow enough, and the institutional constraints small enough for privatization of most rural road systems except in limited areas of private land development.

SUMMARY AND CONCLUSIONS

The Forest Service has developed policies and requirements for integrated resources and roads management and for cooperative public and private financial management of roads. National forest management plans contain the public's program for private sector development and public use of forest resources. The national forest road systems are planned and managed to support those objectives. The public and private sectors cooperate extensively in the financing of construction and maintenance of national forest roads.

The general and financial management of national forest road systems in the United States provides a unique but applicable model for the general and financial management of other rural road systems. Although myriad land uses, ownership patterns, public agencies, and economic priorities in rural areas may complicate the application of such a model, the components of the model are based firmly on the concepts of a mixed capitalist economic system. Yet, it is rare when economic development objectives and roads expansion are formally managed by the public sector in financial cooperation with the private sector. Institutional and legal constraints to extensive public and private cooperation exist in this as well as other countries and would have to be lessened for wider application of this model to take place.

ACKNOWLEDGMENT

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Cost-Effective and User-Oriented Sizing of Rural Roads

SATISH C. SHARMA, AKHTARHUSEIN TAYEBALI, and AL WERNER

ABSTRACT

Analyzed in this paper are two important aspects of road sizing: the common approach to selecting the 30th highest hourly volume for design hourly volume (DHV) for all types of road uses; and the development of a cost-effective annual average daily traffic (AADT) criterion for upgrading two-lane rural highways. The study's most important feature is that the road type variable is used in a more detailed and objective manner than in past studies. The highway system for Alberta, Ontario, Canada is investigated and the roads are classified into six types according to trip characteristics (e.g., trip purpose and trip length distribution). Based on other road design and traffic data, and economic cost statistics from Alberta Transportation, a detailed economic analysis is carried out. The main conclusions of this study are that: (a) the type of road use is a significant variable that must be considered for appropriate sizing of roads from the economist's and user's perspectives; (b) to provide a more uniform service to the users of various road facilities, it is more appropriate to use a range of highest volume hours for the design of different types of roads; (c) the total highway cost is minimized typically at a volume-to-capacity ratio of 0.35 regardless of the type of road use; and (d) the typical AADT values at which two-lane rural roads would need upgrading vary from a range of 1,750 to 2,500 for highly recreational routes to 6,500 to 8,500 for commuter routes.

During the recent years of budgetary constraints, highway authorities have attempted to achieve the greatest use from the dollar spent. There is an increasing concern about many of the past approaches to highway design and improvement programming that have typically been subjective in nature and generally lacking in economic rationalization (1,2). The sizing of roads, for example, has not been definitive under Alberta Transportation policy to date. The major parameters considered in the past have been (a) the traditional 30th highest hourly volume for designing a new facility, (b) the average annual daily traffic (AADT) volume and safety considerations for upgrading an existing facility, and (c) the use of level of service B for all applications including the urban and suburban areas that fall in the Alberta Transportation jurisdiction.

Another point of concern regarding the current practice in Alberta and other Canadian provinces is that, in general, the basis for road-sizing criteria has been dependent mainly on U.S. research during the 1940s and has seldom involved detailed economic analysis of Canadian primary highways. Also, the current practice focuses on facility utilization rather than being roadway-user oriented. The purpose of this paper is to emphasize the need for economic and road-user considerations in designing and upgrading rural highways.

In particular, this study is concerned with two aspects of road sizing: a cost-effective AADT criterion for upgrading two-lane rural roads, and the reexamination of design hourly volume (DHV) from the road user's perspective. The road use type, or road user's perspective, is characterized in this paper by such variables as trip purpose and trip length distribution. More specifically, the objectives of the analysis presented in this paper are to

1. Investigate the effect of road use type on DHV and prioritization of highway improvements;
2. Suggest a range of highest hourly volumes suitable for design purpose from the user's perspective, rather than the commonly used 30th highest hourly volume, which focuses on facility utilization;
3. Investigate a cost-effective volume-to-capacity (V/C) ratio for the design of roads; and
4. Carry out economic analysis for determining the most appropriate levels of AADT values at which roads of given geometric design standard and traffic conditions should be considered for improvements.

However, it should be emphasized that the work in this paper is based on a cost-effectiveness methodology that is not, in any sense, intended to replace a benefit-cost analysis.

Presented first in this paper is a brief description of the variables considered in the analysis. Then methodologies for reexamination of DHV and derivation of highway cost relationships in terms of the V/C ratio and AADT are explained. Next the results and discussion are provided, followed by a summary and conclusions.

STUDY VARIABLES AND ANALYSIS PROCEDURE

On the basis of a review of literature and Alberta Transportation experience, the major critical elements that need to be considered in road sizing are (a) traffic variables such as road use characteristics, AADT, vehicle classification, and speed-volume relationship; (b) geometric design variables such as road standard type, passing sight distance (PSD), and average highway speed (AHS); and (c) economic factors such as cost of highway construction, maintenance, travel time, and accidents; vehicle running costs; and discount rate.

All of the previously mentioned factors are considered in this analysis with Alberta Transportation statistics as the data base. The economic analysis methodology and the DHV evaluation included here are based mainly on concepts previously developed by Haritos (3), Cameron (4), and Winfrey and Zellner (5). The classification of the road system under investigation is based on a recent paper by Sharma (6).

Classification of Alberta Highways According to Road Use Type

From past Alberta experience, it became evident that one of the most important variables affecting the design and upgrading of two-lane highways was the user/driver consideration reflected by the purpose and length of trips that involved use of a given facility. This user/driver variable was included in the present analysis by grouping the roads into different categories by using an improved method of road classification based on temporal volume variations and road use characteristics (e.g., trip purpose and trip length distribution). The improved method, as proposed by Sharma (6), was believed to be more objective, comprehensive, and statistically more credible than the existing methods. It involved the application of such standard computational and statistical techniques as (a) hierarchical grouping and (b) Scheffe's S-method of multiple group comparisons. The road system under investigation was classified into six main types that were found to be significantly different from each other with respect to variables such as monthly, daily, and hourly variations in traffic volume; trip purpose; and trip length distributions. These types are as follows:

1. Suburban commuter, [e.g., the Permanent Traffic Counter (PTC) site C9 located on Highway 3 east of Lethbridge];
2. Regional commuter/recreational (e.g., the PTC site C39 located on Highway 1 west of Secondary Road 791);
3. Rural long distance (e.g., the PTC site C18 located on the Trans-Canada Highway west of Redcliff);
4. Rural nonrecreational (e.g., the PTC site C144 located on Highway 2 north of Nampa);
5. Long distance/recreational (e.g., the PTC site C114 located on Highway 16 east of Jasper National Park); and
6. Highly recreational (e.g., the PTC site C165 located on Highway 11 near Nordegg).

The detailed information on temporal volume variations, trip purpose, and trip length characteristics of these different types of roads are included in the paper by Sharma (6).

Road Type and Highest Hourly Volume Characteristics

The highest hourly volume patterns are conventionally represented by plotting the percent of AADT volume versus highest volume hours of the year. From past experience, it is conceptually known that the road use characteristics of a given route generally affect such highest hourly volume patterns. This generalization was found to be true for the highest hourly volume patterns of various road types observed in the present study. In fact, a statistical analysis indicated that the type of road use has a much more significant effect on the highest hourly volumes compared with other variables such as volume of traffic or AADT value. The high demand for travel on predominantly recreational road sites during only a few periods of the year accounts for a large proportion of the total annual traffic, but on commuter road sites, the total annual volumes are more evenly distributed throughout the hours of the year.

The distribution of hourly volumes associated with a particular type of road is used as one of the main variables in this study. All of the 8,760 hourly volumes in a year are considered in the analysis. The probability that a user will experience a traffic volume exceeding the nth highest hourly volume is defined by the relationship

$$P(CON)_n = [100/365(AADT)] \sum_{i=1}^{n} \cdot V_i \quad (1)$$

where $P(CON)_n$ is the percent probability that a user will experience a traffic volume exceeding the

TABLE 1 Vehicle Classification at Typical Road Sites

Road Site and Type	Vehicle Classification (%) PC	RV	SU[a]	HT	Remark
C9 - Suburban commuter	84.0	5.0	6.0	5.0	Average of 6 samples
C39 - Regional commuter/recreational	75.0	9.0	6.0	10.0	Average of 3 samples
C18 - Rural long distance	72.0	11.0	7.0	10.0	Average of 15 samples
C144 - Rural nonrecreational	80.0	6.0	7.3	6.7	Average of 5 samples
C114 - Long distance/recreational	71.0	20.0	4.0	5.0	Average of 4 samples
C165 - Highly recreational	78.0	20.0	2.0	0.0	Guessed

Note: PC = passenger cars; RV = recreational vehicles; SU = Single-unit trucks; HT = heavy trucks.

[a]Buses are included in SU class.

nth highest hourly volume, and V_i is the volume during the ith highest hour. The probability value calculated from Equation 1 is also referred to in this paper as the probability of user congestion. The hourly volumes, when ranked in decreasing order of their percentages of AADT, are referred to as "highest hourly patterns", or "hourly volume signatures."

Road Type and Vehicle Classification

Another important variable in this study is vehicle classification. Although the proportion of various types of vehicles will vary within the different road classes to a certain extent, there will usually be a significant variation between the classes. For example, the recreational road sites would be expected to have a larger proportion of recreational vehicles, and the rural long distance road sites would generally be expected to have a larger proportion of trucks than would the commuter sites.

The vehicle classification in this study is used as a variable that is associated with a particular type of road. Table 1 shows the vehicle classification at the typical road sites. (These data are based on past Alberta Transportation studies.)

Alberta Highways Cost Data

In any attempt to define the costs attributable to providing a highway link, the costs for right-of-way, construction, maintenance, environmental disruption, motor-vehicle running costs, accidents, and travel time might be included. In the analysis presented here for Alberta, the following cost factors are used: construction, maintenance, motor-vehicle running cost, and travel time.

Quantifiable costs related to environmental disruption (e.g., costs of erosion control, noise attenuation, and other measures to protect the environment) can be included in construction costs. However, unquantifiable costs, (e.g., those for wildlife disruption) are not included. Accident costs have not been included here because no Alberta data were readily available and accident costs can be considered part of the safety analysis that some agencies prefer to handle separately.

The highways cost data and the road design data that follow are based on past Alberta Transportation studies (7,8) and can be updated to 1982 dollars by using appropriate inflation factors. RAU-209, RAU-211, and RAU-213 are road design class codes used in Alberta and refer to rural arterial, undivided, two-lane facilities with total pavement widths of 9, 11, and 13 m, respectively. A right-of-way cost of $4,942/hectare ($2,000/acre) is included in the cost figures. (Also, these costs apply for the region east of Red Deer and may vary considerably from area to area.)

1. Capital costs: $306,180/km for RAU-209, $364,500/km for RAU-211, and $422,820/km for RAU-213;
2. Annual maintenance costs: $1,600/km for RAU-209, $1,900/km for RAU-211, and $2,200/km for RAU-213;
3. Discount rate: 8 percent over a 20-year (design) life of facilities;
4. Vehicle running costs: The 1979 running costs given by Ashtakala (7) were updated to 1982 dollars. The running costs for recreational vehicles (RVs), however, were not given by Ashtakala (7); therefore, an average of costs for passenger cars (PCs) and single-unit trucks (SUs) was estimated to be the running cost for RVs; and
5. Value of travel time: $7.00/hr for passenger cars, $7.00/hr for recreational vehicles, $13.30/hr for single-unit trucks, and $15.30/hr for heavy trucks (HTs). These values are also in 1982 dollars and are based on the Alberta Transportation studies (7,8).

Cost-Volume Relationships

It can be observed from these data that the fixed capital costs for roads are high, and annual maintenance costs are also significant. If the road carries little traffic, the unit agency cost of providing the roadway is very high; as volume increases, however, unit cost decreases.

For road user costs (time plus running costs), lower traffic volumes usually provide the least unit cost, and as volume increases, the cost to the user increases because of congestion. Adding the agency cost (construction cost plus the maintenance cost) curve and the road user cost curve should result in a relationship in which, at some volume of traffic, a minimum total cost of travel will occur.

To compute the total cost relationship as a function of the volume of traffic, it is necessary to relate capital and maintenance costs and road user costs to a common base. Because agency costs are a function of volume and road user costs are a function of travel speed, the speed-volume relationships presented in the 1965 Highway Capacity Manual (HCM) (9) were used to determine the user costs as a function of volume and expressed in term of cents per vehicle kilometer.

Two types of cost-volume relationships were computed for the purpose of this study, unit cost (in cents per vehicle kilometer) versus V/C ratio, and unit cost versus AADT.

The agency cost for a particular volume of hourly traffic was calculated by using the relationship

$$AC = [100(CC \times CRF_{i,n} + MC)]/8{,}760\ Vol \quad (2)$$

where

AC = agency cost (¢/vehicle-km);
CC = capital cost ($/km);
$CRF_{i,n}$ = capital recovery factor for interest rate i and useful facility life of n years;
MC = annual maintenance cost ($/km); and
Vol = volume of traffic (vehicles/hr).

The first step in determining the vehicle running cost was to calculate the V/C ratio for a particular hourly volume of travel and given road traffic and design conditions. The speed of travel was then estimated from the speed-volume curves presented in the HCM (9). Finally, the vehicle running costs were obtained from the empirically derived tables of running costs at various speeds (7).

The denominator of the V/C ratio, [e.g., the capacity (C) of a road facility] was calculated by using the HCM method for two-lane rural highways. The values of adjustment factor (W) for lane width and lateral clearance at capacity were assumed to be 0.90, 0.95, and 1.0 for RAU-209, RAU-211, and RAU-213, respectively. The passenger-car equivalents (10) of 2 and 1.6 were used for trucks and RVs, respectively.

The travel time cost for a given traffic stream was calculated by using the following relationship:

$$TC = \{[(P_{pc}T_{pc} + P_{rv}T_{rv}) + (P_{su}T_{su} + P_{ht}T_{ht})] \div 100\}[(1/S) - (1/AHS)], \text{ or}$$

$$TC = (TW/100)[(1/S) - (1/AHS)] \quad (3)$$

where

TC = travel time cost (¢/vehicle-km);
$P_{pc}, P_{rv}, P_{su}, P_{ht}$ = percentages of PCs, RVs, SUs, and HTs, respectively, in the traffic stream;
$T_{pc}, T_{rv}, T_{su}, T_{ht}$ = time values for PCs, RVs, SUs, and HTs, respectively (¢/hr);
TW = weighted mean travel time cost;
AHS = the average highway speed or the desired speed of travel (km/hr); and
S = space-mean speed of travel possible at a given volume of travel (km/hr).

The cost-volume relationship in terms of AAHC (average annual hourly cost in cents per vehicle kilometer) versus AADT was developed to exhibit a measure of economic efficiency that might be used to minimize the total highway cost as a function of AADT, which undoubtedly is the most common measure of traffic volume used by all those who are involved in highway transportation. At a given value of AADT, the traffic volumes for each of the 8,760 hours of the year were computed from the (highest) hourly volume pattern associated with a particular type of road use. The total highway cost for each of the hourly volumes was then calculated in the manner described earlier. The weighted average annual hourly cost was defined as

$$AAHC = [1/365(AADT)] \sum_{i=1}^{8,760} [V_i(AC_i + RUC_i + TC_i)] \quad (4)$$

where

AAHC = average annual hourly cost (¢/vehicle-km);
AC_i, RUC_i, TC_i = the agency cost, vehicle running cost, and travel time cost, respectively, for the ith hour (¢/vehicle-km); and
V_i = traffic volume for the ith hour.

RESULTS AND DISCUSSION

Reexamination of DHV Concepts from the User's Perspective

The DHV is the volume of traffic during 1 hour that is used as an acceptable operating condition for design purposes. Traditionally, the determination of DHV involves the use of a graph showing the highest hourly volumes of the year according to rank. The 30th highest hourly volume is used by a number of agencies as the DHV for rural highways on the premise that the slope of the curve changes rapidly at that point and it provides the most economical volumes for use in design (1). In a case in which the slope changes rapidly at some point other than the 30th highest hourly volume, the DHV is chosen at the knee of the curve.

Highway designers have raised some serious questions in the past about the validity of the conventional DHV approach (1). One is that the identification of the knee of the curve of the hourly volume distribution can be a difficult matter requiring excessive judgment (4). Another criticism of the traditional approach is that it focuses on facility utilization rather than being roadway-user oriented. The problem of selecting a design hourly volume is addressed in the HCM, which contains the statement, "This frequent reference to the 30th highest hour should not be misconstrued as a recommendation for rigid adoption, but rather as an example of typical highest hour relationship and trends."

Figure 1 shows a plot of the percent probability $[P(CON)_n]$ that a user will experience a heavier traffic congestion than design hourly volume. The plots are calculated by using Equation 1. It should be noted here that detailed analyses were carried out for a total of 25 road sites in Alberta, but for the sake of simplicity, only the results for the

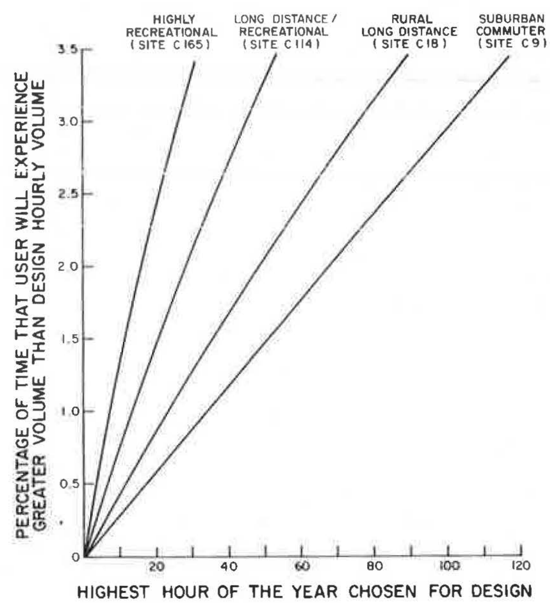

FIGURE 1 Percent user congestion as a function of the highest hour chosen for design.

typical sites of C9, C18, C114, and C165 are included in Figure 1 and the rest of this section. The analysis results for the sample site C144 (rural nonrecreational route) were very similar to the results of site C9, the example of a suburban commuter route. Also for the sake of simplicity, the other sample site, C39 (a regional commuter/recreational route), was excluded from presentations because it appeared to represent conditions between the suburban commuter site, C9, and the rural long distance site, C18.

If the traditional approach of selecting the 30th highest hour as the design hour is taken for all types of road facilities, it can clearly be seen from Figure 1 that even though each facility will experience hours equalling or exceeding the 30th highest hour volume of only 30 hours per year (0.34 percent of all hours), the percent of the time that a typical user will experience a volume exceeding that of the 30th highest hour will vary significantly with respect to the type of road under consideration. For example, of all the travelers using the commuter site, C9, only 0.92 percent will experience user congestion as compared with 1.25 percent for the rural long distance site, C18; 2.2 percent for the long distance recreational site, C114; and 3.35 percent for the highly recreational site, C165. It is therefore obvious that the traditional approach of facility utilization (e.g., 0.34 percent facility congestion at the 30th highest hour) does not provide an equitable transportation service from the user's perspective.

The user congestion plots such as those given in Figure 1 would be helpful to the highway authorities in developing road design policies that consider the user's perspective. One obvious alternative approach is to provide a more uniform service to the user by selecting different design hours for different types of road uses. For example, to provide a service that permits a 1.5 percent user congestion, the highway agency can select a design approximately corresponding to the 50th highest hour for a commuter route, whereas the rural long distance, long distance/recreational, and highly recreational routes could be designed to the 35th, 20th, and 10th highest hours, respectively. (The use of the 10th highest hour in designing a highly recreational route may seem to be an overdesign but the tourism business is so important in some provinces that this has become necessary.)

Cost-Effective Volume-to-Capacity (V/C) Ratio

Figure 2 exhibits cost-volume relationships for the typical road sites. For the highway cost data as used in this study, it is evident that the total (agency plus user) unit cost (CT) for all the sites is at a minimum level corresponding to a V/C value of about 0.35. The magnitude of the minimum cost varies because of the values of travel time and the vehicle mix associated with a particular type of road site. The rural long distance site, C18, operates at a most expensive level because it carries the highest average percentage (17 percent) of trucks for which the value of travel time is considered to be higher than that of passenger cars or recreational vehicles.

Although the location of the minimum cost point shown in Figure 2 lends some credibility to providing level of service B as a design criterion, there are several factors that will affect the analysis and cause a shift of the minimum cost point. These factors include increased construction and maintenance costs in difficult terrain and the perception of travel time value.

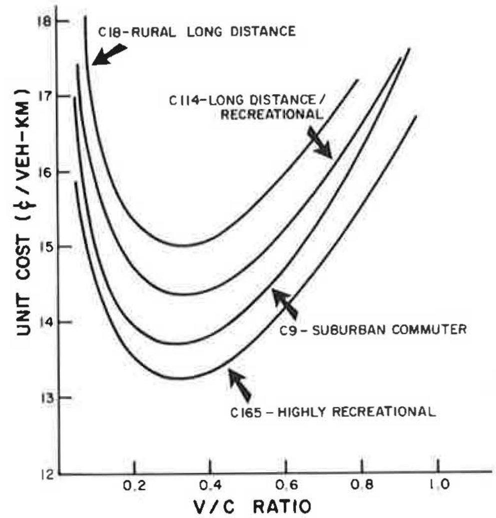

FIGURE 2 Cost versus volume-to-capacity ratio (RAU-211; AHS = 100 km/hr; PSD = 80 percent).

The literature on travel time value (11) suggests that the long distance travellers attach more importance to the amount of travel time saved and its dollar value than do the short distance travellers. Comfort and convenience are also considered to be more important for long distance trips. If these factors were considered in the analysis and different travel time values were assigned to the different road sites depending on the trip length distribution, then the suburban and regional commuter roads would have the cost minimization at the higher V/C ratio than the long distance or provincial and interprovincial roads.

AADT as a Criterion for Upgrading of Roads

Figures 3-6 show certain cost relationships in which the unit costs are plotted against AADT values. Each of these figures is drawn for a different sample site and contains three types of curves: (a) the annual average hourly cost as calculated from Equa-

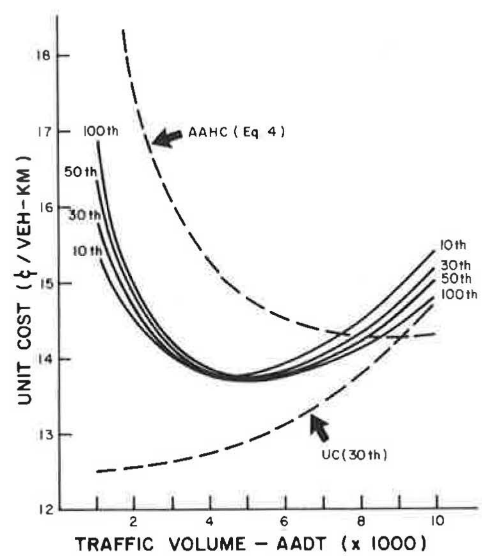

FIGURE 3 Cost versus AADT curves for site C9 (RAU-211; AHS = 100 km/hr; PSD = 80 percent).

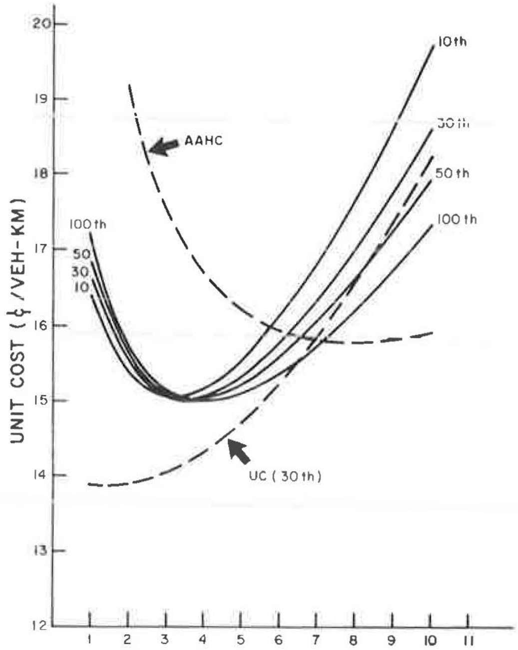

FIGURE 4 Cost versus AADT curves for site C18 (RAU-211; AHS = 100 km/hr; PSD = 80 percent).

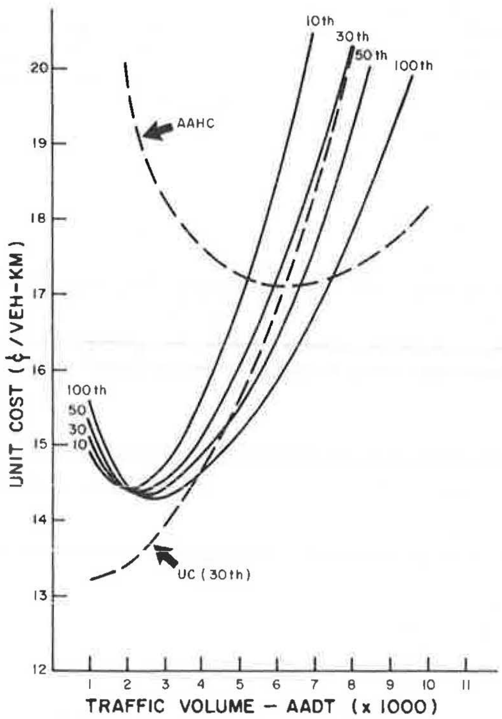

FIGURE 5 Cost versus AADT curves for site C114 (RAU-211; AHS = 100 km/hr; PSD = 80 percent).

tion 4 versus AADT; (b) the total unit cost (CT) curves for the 10th, 30th, 50th, and 100th highest hours; and (c) the road user cost during the 30th highest hour [UC(30th)] as a function of AADT.

The minimization of AAHC cannot be taken as an appropriate criterion for upgrading (or designing) two-lane roads because, before the AAHC reaches a minimum value, hundreds of highest hours would experience user congestion--an unacceptable situation

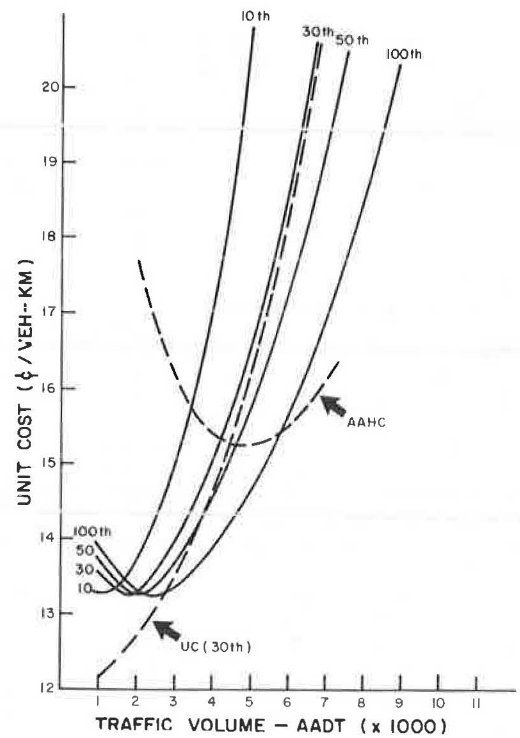

FIGURE 6 Cost versus AADT curves for site C165 (RAU-211; AHS = 100 km/hr; PSD = 80 percent).

from the user's point of view. But the AAHC curves along with the other cost curves in Figures 3-6 appear to help in establishing the appropriate values of AADT at which the roads of different types should be upgraded.

By taking the example of rural long distance site C18 and carefully examining the various cost curves of Figure 4, a number of interesting points can be made. One is that the AAHC, which includes both the agency cost and the user cost, is very high at low AADT values and the rate of increase of AAHC is particularly high for AADT values less than 4,000. Another observation is that, when the total agency and user costs during the 10th, 30th, 50th, or 100th highest hour are considered, the highway cost is minimized at an AADT value between 3,000 and 4,000. Finally, the plot of user cost during the 30th highest hour appears to indicate that the user cost starts increasing rapidly beyond the 3,000-4,000 AADT range. The plots of user costs during other sample hours, (i.e., the 10th, 50th, and 100th) were excluded to avoid overcrowding the figures. Moreover, the results would not be affected by including the user costs during those hours.

The AADT ranges at which the highway costs for other examples are minimized during the selected design hours are 4,500-5,500 for the commuter site, C9; 2,000-3,000 for the long distance/recreational site, C114; and 1,000-2,500 for the highly recreational site, C165. These are also the AADT ranges at which the user costs start increasing rapidly.

Figures 3-6 may also be used to compare the AADT values resulting in the minimum highway cost if a user congestion of 1.5 percent is permitted for all types of roads. As mentioned previously, a 1.5 percent user congestion corresponds to the 50th highest hour for site C9, the 35th highest hour for site C18, the 20th highest hour for site C114, and the 10th highest hour for cite C165. The values of AADT at which minima occur are 4,500, 3,500, 2,300, and

1,250 for sites C9, C18, C114, and C165, respectively.

Another interesting observation that can be made from these figures concerns the user cost increase rate with respect to AADT beyond the range where the total cost minimization occurs. It is evident that this rate is lowest in the case of the commuter site, C9, and highest in the case of the highly recreational site, C165. The user cost increase rate is higher for the long distance/recreational site, C114, as compared with the rural long distance site, C18.

The plots of Figures 3-6 correspond to the road standard RAU-211 with an average highway speed (AHS) of 100 km/hr and a passing sight distance (PSD) of 80 percent. The costs were also computed for other road standards (e.g., RAU-209 and RAU-213) and PSDs (e.g., 0 and 100 percent). Other variables being constant, it was generally found that the higher the road standard, the higher will be the value of AADT at the point of cost minimization. For example, if site C18 is considered with 1.5 percent user congestion, the AADTs for the minimum costs will be approximately (a) 3,250 for RAU-209 with 80 percent PSD and (b) 3,750 for RAU-213 with 80 percent PSD, as compared with a value of 3,500 for RAU-211 with 80 percent PSD.

Importance of the Road Use Variable

The analysis carried out for this study clearly indicates that the consideration of the road use type is one of the most important variables affecting the sizing of rural highways. It may even be stated that for a project such as this the road use variable is more important than the vehicle classification (or percent trucks) variable that is widely used in traffic engineering studies.

Figure 7 shows the importance of the road classification (RC) variable as compared with the vehicle classification (VC) variable. It may be recalled that the RC variable has been characterized in this paper by the highest hourly pattern or hourly volume signature exhibited by the road under consideration. In Figure 7(a), the road classification (RC) is varied while the vehicle classification (VC) is kept constant at a PC of 72 percent, an RV of 11 percent, an SU of 7 percent, and an HT of 10 percent--the same vehicle classification as that of site C18 (i.e., VC18).

However, in Figure 7(b) , all the plots use the same RC or hourly volume signatures as that of site C18 whereas the variable VC is assigned the values VC9, VC18, VC114, and VC165, which are the vehicle classifications for C9, C18, C114, and C165, respectively. (Note that the notations such as RC18, etc. represent the road classes or hourly volume signatures of the various sample sites such as C18, etc.)

It is obvious from these figures that road use type greatly influences cost minimization in relation to AADT. A two-lane recreational route would require upgrading at a much lower AADT value than a two-lane commuter route from the perspectives of total highway cost and user cost. The overall highway cost levels are higher for roads carrying a higher percentage of trucks because of the higher value of time allocated to these vehicles.

Testing of Results and Further Comments

The study results pertaining to the minimization of highway costs as a function of AADT were tested by comparing them with the actual practice by Alberta Transportation of upgrading two-lane roads.

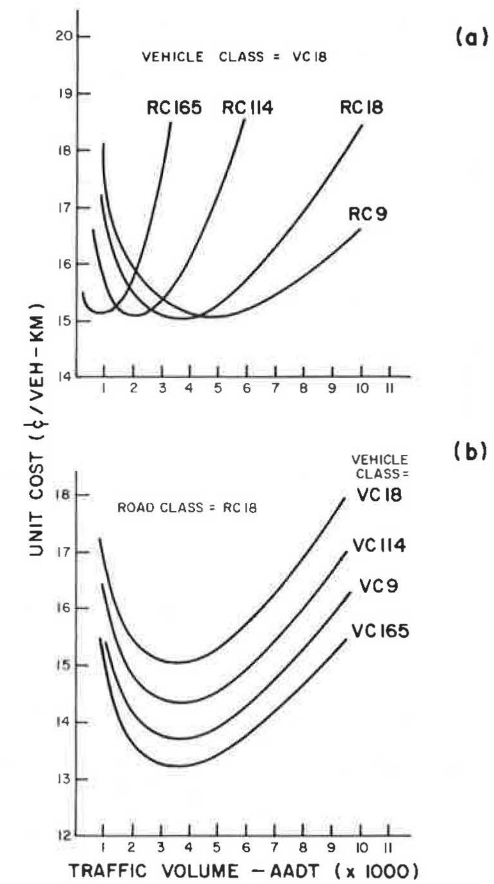

FIGURE 7 Effect of road type and vehicle mix on cost curves at 1.5 percent user congestion (RAU-211; AHS = 100 km/hr; PSD = 80 percent).

As mentioned earlier, upgrading two-lane roads to three- or four-lane facilities has not been definitive under Alberta Transportation policy to date. In the past, facilities have been reconstructed on the basis of need, as dictated by traffic demand and safety. In one of its reports (12), Alberta Transportation indicated that "expansion to four-lanes will not be undertaken until volumes reach the 6,000 to 8,000 AADT range." However, since the time of that report, the province has received a large number of user complaints about the poor level of service provided by some of the two-lane roads carrying volume ranges of 2,000 to 4,000 AADT. In many such cases, requests were made to upgrade these roads to four-lane standard.

Table 2 includes a list of two-lane roads typically of RAU-211 standard with AHS equal to 100 km/hr and PSD equal to 80 percent that were expanded to four-lane standard during the last several years. The upgrading of some sections of Highway 1 (Trans-Canada Highway) at a range of 3,000 to 5,000 AADT might have been perceived by some as political or a result of public pressure at the time. But the results of this study indicate that there is good justification from both the economic and user considerations to upgrade rural long distance roads at AADT values in the range of 3,000 to 5,000.

As shown in Table 2, the recent cases of road upgrading in Alberta have been for three types of roads: (a) suburban commuter, (b) regional commuter/ recreational, and (c) rural long distance. A careful examination of the actual practice and the results of this study, such as those shown in Figures 3 and

TABLE 2 Some Recent Alberta Examples of Two-Lane Roads Upgraded to Four-Lane Standard

Road Section	Year of Upgrading	Estimated AADT Before Upgrading
Rural long distance sites		
Highway 1 west of Highway 36	1981	4,490
Highway 1 east of Secondary Road 550	1982	4,250
Highway 1 east of Secondary Road 873	1983	3,110
Highway 1 east of Redcliff	1981	4,500
Highway 1 west of Highway 41	1983	3,120
Regional commuter/recreational sites		
Highway 1 east of Medicine Hat	1983	5,650
Highway 1 east of Highway 21	1981	5,100
Highway 2 south of Morinville	1984	5,430
Highway 16 east of Highway 22	1983	5,160
Highway 16 east of Elk Island Park	1982	5,500
Suburban commuter sites		
Highway 1 west of Highway 3 in Medicine Hat	1981	8,000
Highway 2 north of St. Albert	1984	9,180

Note: Two-lane roads were typically of RAU-211 standard with AHS = 100 km/hr and PSD = 80 percent.

4, appears to indicate that an appropriate range of AADT for upgrading is past the minimum cost point when the total highway cost starts to increase rapidly.

There is another example regarding the planned upgrading of the Yellowhead Highway (Highway 16) during the next few years. This highway west of Wabamun Lake to Jasper National Park is a two-lane facility with provisions for climbing lanes in some places. It represents a rural long distance/recreational function except in the vicinities of towns (e.g., Edson) where the function changes partly to commuter or regional trips. The estimated AADT on the long distance/recreational portions that now varies between 2,300 to 3,750 is expected to increase to between 2,500 and 4,000 at the time of upgrading. This range of AADT for upgrading a long distance/recreational route is also suggested by the results of this study.

According to these results, a two-lane highly recreational route such as the one represented by site C165 would require upgrading at an AADT value in the range of 1,500 to 2,500. It may be rare, however, to have a route with a high volume such as 2,000 (note that the present AADT at C165 is 700). A similar comment about the nonrecreational rural routes can also be made here. As mentioned earlier, the cost-volume characteristics of nonrecreational routes are similar to those of the local or suburban commuter; therefore, a nonrecreational rural route with a RAU-211 standard classification and a PSD of 80 percent should require upgrading at an AADT above 6,000; however, these roads carry only a low volume of traffic that generally varies between 1,000 and 3,000 in Alberta.

It should be noted that the term "upgrading" does not necessarily refer to a four-lane option only--other options, such as shoulder widening or three-laning, may be appropriate in a number of situations. Also, even though the analysis, such as that presented here, includes many variables (e.g., road type, vehicle classification, AADT, geometric design variables, and various highway costs), other investigations (e.g., the conventional benefit/cost study involving various matters as safety considerations and possible changes in flow patterns because of upgrading) should also be carried out before a final decision is made. In other words, the AADT criterion as proposed in this research should be used to establish a preliminary prioritization of highway improvements.

SUMMARY AND CONCLUSIONS

This paper analyzes two important aspects of road sizing. First, it reexamines the common approach of selecting the 30th highest hour for design hourly volume (DHV) for all types of road uses. Second, it develops a cost-effective AADT criterion for upgrading two-lane rural highways.

The most important feature of this study is that it uses the road type variable in a more detailed and objective manner than in previous studies. Alberta's highway system is investigated and the roads are classified into six types according to trip characteristics such as trip purpose and trip length distribution. These characteristics are

- suburban commuter,
- regional commuter/recreational,
- rural long distance,
- rural nonrecreational,
- long distance/recreational, and
- highly recreational.

Based on other road design and traffic data, and economic cost statistics from Alberta Transportation, a detailed analysis is carried out that attempts to make the DHV approach more user-oriented and minimize the total cost of highway transportation for upgrading two-lane roads. The main conclusions of this study are as follows:

1. Road use type is a significant factor that must be considered for appropriate sizing of roads from the economist's and user's perspectives.

2. If the traditional approach of selecting the 30th highest hour as the design hour is taken for all types of road uses, it is clear that, even though each facility will experience hours equalling or exceeding the 30th highest hourly volume during only 30 hours per year (0.34 percent of all hours), the percent of the time that a typical user will experience a volume exceeding that of the 30th highest hour will vary significantly with respect to the type of road under consideration. For example, of all the travelers using the commuter site, C9, only 0.92 percent will experience user congestion as compared with 3.35 percent for the highly recreational site C165.

3. An obvious alternative DHV approach will be to provide a more uniform service to the users by selecting different design hours for different types of road uses. For example, to provide a service that permits a 1.5-percent user congestion, the highway agency can select a design corresponding to approximately

a. The 50th highest hour for suburban and rural nonrecreational routes;

b. The 40th highest hour for regional commuter/recreational sites;

c. The 30th to 35th highest hour for rural long distance sites;

d. The 20th highest hour for long distance/recreational sites; and

e. The 10th to 15th highest hour for highly recreational routes.

4. The total unit cost versus volume-to-capacity curves indicates that the total highway cost is minimized typically at a V/C ratio of 0.35 regardless of the type of road use. However, there are several other factors that may cause a shift of the minimum cost V/C point (e.g., the perception of the value of travel time).

5. The cost versus AADT curves developed in this study and the actual practice followed by Alberta

Transportation indicate that the AADT can be used as a good criterion for cost-effective and user-oriented upgrading of two-lane roads. The AADT values at which the total highway costs are minimized during certain selected highest hours (i.e., 10th, 30th, 50th, and 100th) vary significantly from one road type to another. The geometric design variables, such as the road (RAU) standard, average highway speed, and PSD also affect the value of AADT at which cost minimization occurs. The analysis also indicates that for the purpose of upgrading two-lane roads, road use type is a more significant variable than vehicle classification.

6. On the basis of results and the experience gained from this study, the suggested typical ranges of AADT for the purpose of prioritizing the upgrading of two-lane roads are

a. 6,500 to 8,500 for suburban commuter and rural nonrecreational routes;
b. 5,000 to 6,500 for regional commuter/recreational routes;
c. 3,750 to 5,000 for rural long distance routes;
d. 2,500 to 3,750 for long distance/recreational routes; and
e. 1,750 to 2,500 for highly recreational routes.

It is believed that the analysis presented in this paper contributes toward the clarification and further understanding of the DHV considerations and cost-effective criteria for upgrading two-lane rural highways. It is hoped that this will lead highway agencies to invest more wisely not only from the economist's viewpoint, but from the user's viewpoint as well.

ACKNOWLEDGMENTS

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The observations and views presented in this paper are the authors' own. The criteria presented are not formal Alberta Transportation policy.

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Abridgment

Texas Highway Finance: The Highway Cost Index

MARK A. EURITT, KENNETH J. CERVENKA, C. MICHAEL WALTON,

LEIGH B. BOSKE, and W. NORTON GRUBB

ABSTRACT

The major era of highway development in Texas, and in the United States in general, began with the creation of the Federal Highway Trust Fund and the 1956 initiation of the Interstate highway program. By the 1970s, dedicated revenues flowing into state and national highway trust funds were lower than expected, which resulted in the recognition of an impending financial shortfall. Reviewed in this paper is Texas' experience with a new funding approach, the Highway Cost Index (HCI). Discussions are presented on the major activities and events that preceded the adoption of House Bill 3, which established the HCI in 1977; the structure of the HCI; and on two of the major problems encountered during its operation that caused it to fail.

In the early 1970s, the Texas State Department of Highways and Public Transportation (SDHPT) experienced a highway planning and funding dilemma. The cost of highway activities, mainly construction and maintenance, was increasing. Financial resources available to the state were lower than had been originally forecast. Dedicated revenues flowing into the state (and national) highway trust funds were lower than expected and this resulted in a financial shortfall.

In response to this funding dilemma, the State Legislature adopted House Bill 3 (H.B. 3) in 1977, which created a new mechanism for highway funding. This mechanism was established, in part, to provide increased funding without increasing taxes by utilizing a part of the state's large budget surplus. A major aspect of H.B. 3 was the measure of increased oversight and budgetary control that was created by the formation of the Highway Cost Index (HCI) Committee. The HCI Committee, which included the governor, the lieutenant governor, and the comptroller of public accounts, would periodically review and certify index numbers that directly affected the annual program activities of the SDHPT. House Bill 3 increased funding by providing for the inclusion of general funds in the State Highway Fund when dedicated highway revenues failed to meet a specified funding level. The traditional "user pay" policy, in the form of dedicated revenues, was linked with nonuser or general fund revenues to ensure a sustained level of state highway activity.

This paper contains a review of Texas' experience with this new funding approach. The first section provides a discussion of the major activities and events that preceded the adoption of H.B. 3. Following this are reviews of the structure and procedures of the HCI, and of two of the major problems encountered during its operation.

THE FUNDING DILEMMA

In June 1975, the management consulting firm of McKinsey and Company was hired by SDHPT to conduct a comprehensive and objective year-long evaluation of the department's highway program. It had become evident before this time that SDHPT was committed to a large backlog of construction projects. (Construction projects include right-of-way, acquisition, rehabilitation, and reconstruction.) Because of the anticipation of a financial shortfall over a 20-year period, there was growing concern that most of these projects would never be completed.

Anticipated Revenues

Because of steady increases in the number of vehicles and the total miles of travel in Texas, motor vehicle registration fees and motor fuel taxes have been increasing consistently over the years. From 1955 to 1975, revenues from state sources grew at an average rate of 6 to 7 percent per year. However, inflation rates have also been rising. Construction costs in Texas increased 3.2 percent per year from 1955 to 1965, 7.0 percent per year from 1965 to 1971, and 19.0 percent per year from 1971 to 1975.

Just as the inflation rate was increasing, there was a growing concern that the rate of increase in revenues would decrease as many Texas drivers purchased smaller, more fuel-efficient automobiles and were forced to drive at lower, more economical speeds. Decreases in fuel consumption were also expected to decrease the amount of construction reimbursement monies available from FHWA (FHWA). Forecasts by the McKinsey/SDHPT study team indicated that only $1.9 billion in constant 1975 dollars would be available from 1976 to 1995 for reduction of the construction backlog. It was concluded that without new revenue sources, virtually all state revenues would be absorbed by nonconstruction expenditures. By 1985, only $20 million (in 1975 dollars) would be available for use toward the reduction of the construction backlog, and only $28 million (in 1975 dollars) would be received from FHWA. From 1976 to 1995, a total of only $120 million (in 1975 dollars) would be available for reduction of the backlog.

The Construction Backlog

When the McKinsey study began, SDHPT estimated that the value of the 20-year backlog of construction projects was $5.2 billion (in 1975 dollars). The McKinsey/SDHPT study team, however, carefully examined the cost figures of these projects and reinterpreted the definition of a project backlog. The revised inventory of committed projects included all projects

1. On which a formal action or commitment had been made by SDHPT (e.g., a minute order of the commission, public speeches, the construction of the first stage of a project);
2. That identified the existence of a "gap"--a short section of unimproved roadway on an otherwise improved highway; and
3. For which there was the expectation that a facility would be maintained at a safe level of service, without recurring periods of intense congestion.

The addition of the newly identified projects and the revision of all construction and right-of-way costs resulted in a backlog increase (in 1975 dollars) from $5.2 billion to $10.9 billion. New estimates for rehabilitation costs were later produced, resulting in a 20-year committed backlog of $11.8 billion.

A major objective of the McKinsey study was the examination of the projects in this $11.8 billion backlog. The central question was, "How did the construction backlog get so large?" Aside from inflation, one possibility was that there may have been major limitations in the traditional project-oriented approach to planning. Four major problem areas were identified:

- Authorization of too many projects;
- Requirement of large-scale, rigid responses;
- Preparation of too many detailed designs; and
- Assumption that adequate funding was available.

Public requests for projects were commonly authorized, with no detailed evaluation of the project in relation to the total highway system or the availability of funds. The McKinsey Report cited, as further examples, large and costly highway designs where (in the study team's opinion) simpler designs might have been adequate.

Confronted with limited funding and rising costs, a new approach to highway planning was recommended: the development of a balanced statewide system that would result in maximum benefits for a given level of funding. This was accomplished by providing for the transfer of general state revenues to the State Highway Fund (SFD) to supplement dedicated-tax revenues so that a guaranteed level of funding could be attained. The amount of general revenue to be transferred each year was determined by the following formula:

General revenue transfer = (base amount x HCI)
 - dedicated revenue.

The implication was that Texas should build a practical highway system for near-term needs rather than an ideal one for the needs of the distant future--system benefits, rather than individual project benefits, should be maximized. Once a funding level was established for the entire state, the projects submitted by the districts would be selected by the SDHPT on the basis of how much they would contribute to the overall statewide system.

THE HCI

The HCI was designed to maintain the 1979 level of highway services ($750 million) by measuring and compensating for the impact of inflation on the costs of construction, maintenance, and operations--the three functional areas of highway activity. This was accomplished by comparing the combined weighted-average costs of construction, maintenance, and operations in the current fiscal year to what they were in the 1979 base year.

The SDHPT established a detailed record-keeping system for identifying relevant costs whereby the major expenditure activities of each functional area could be divided sequentially into increasingly disaggregated classes of expenditure denoted as categories, elements, and control items. For example, the functional area of maintenance contains categories of expenditures for maintenance materials, contracts and lease services, fuels, and highway equipment. These categories would be subdivided into 13 elements and 24 control items. The Texas Highway Cost Index Procedures manual defines the cost index for each step as "the summation of the products obtained by multiplying each of its respective cost indices by their corresponding usage factors or weights."

PROBLEMS WITH THE HCI

In the determination of the total state revenues for the SDHPT, the HCI and state-dedicated revenues must be forecast. Then, at the beginning of the fiscal year, the total dedicated revenues of the SDHPT must be set by multiplying the forecast HCI by $750 million. These dedicated revenues have two components: forecasted dedicated revenues, and a general revenue transfer equal to total dedicated revenues ($750 million times the forecasted HCI) minus forecasted dedicated revenues.

At the end of the fiscal year, when actual values for the HCI and dedicated revenues are known, corrections must be made. Revenues for SDHPT are corrected by determining the difference between what revenues should have been (the true HCI times $750 million) and the dedicated revenues (the forecast HCI times $750 million). Thus an underforecast of the HCI leads to additional revenues at the end of the fiscal year and an overforecast leads to the loss of revenues. (More precisely, any correction is added to or subtracted from the following year's certified revenues.) At the same time, the actual amounts of the dedicated revenues become known, and a correction in general revenue transfers is made. Therefore, errors in forecasting create two distinct problems: (a) a planning problem for the SDHPT, because incorrect forecasts of the HCI generate incorrect revenues that must be corrected later, and (b) the incorrect transfer of general revenue funds, which, under some conditions, may affect other state programs.

The forecasting of the HCI and general revenues became a problem because of serious errors in forecasting in the years following the adoption of the HCI. Table 1 gives information on various forecasts of the HCI, when they were made, and how they compare with the actual HCI for each fiscal year since the HCI forecasting procedure went into effect. (During fiscal years 1978 and 1979, the first years under House Bill 3, the HCI was assumed to equal 100.0.)

The data in Table 1 indicate that the HCI forecasts for 1981, 1982, and 1983 were consistently high and off by large amounts. Adjustments caused by these overestimates resulted in significantly reduced revenues in succeeding fiscal years. The effects of these overforecasts are even more significant considering that $7.5 million is associated with one point of error in the forecasts. In fiscal

TABLE 1 Forecast and Actual Values of the HCI

Fiscal Year	Date of Forecast	Forecast HCI	Actual HCI
1980	–[a]	109.16	122.64
1981	–[a]	118.16	113.80
1982	1980	151.43	120.15
1983	1980	162.97	120.15
1984	1982	143.51	127.85[b]
1985	1982	155.32	138.72[b]

[a] These two "forecasts," made in 1979, were determined by available general funds and not by a forecasting technique. The regular forecasts would have required more general funds than were available.
[b] Represents forecasts made in April 1984.

years 1982 and 1983, the overforecasts amounted to $234.6 million and $319.8 million, respectively, and $117.4 million and $169.5 million for 1984 and 1985, respectively. Because of the correction mechanism in the House Bill 3 formula, any overforecasts of the HCI would lead to revenues being taken back at the end of the fiscal year. Thus, these overestimates make it extremely difficult for financial planning.

When the HCI is broken down into its three major components, it becomes clear that the major error in forecasting the HCI comes from the construction component. The basic reason underlying this is the difficulty in forecasting energy prices. Energy prices are most important to construction costs and least important to operation costs (which are largely personnel costs), and are somewhere in between for maintenance. The large overforecasts of construction expenditures can therefore be explained partly by the fact that, although most forecasters in the early 1980s thought energy prices were going to increase steadily, energy prices actually stabilized in the early 1980s.

Also, beginning in 1981, increased competition from construction apparently drove down bids submitted for construction projects, a phenomenon that was not foreseen and not included in HCI forecasts. Because the construction component of the HCI is based on bids submitted by contractors, it is an important variable in the forecasting procedures.

In addition to forecasting difficulties, the HCI also had a theoretical flaw in its construction. The HCI was designed to measure price inflation associated with the cost of individual inputs for providing highway services rather than price inflation associated with the cost of producing outputs for highway services. The latter should cause significant concern. However, this problem would not be significant if, from one year to another, similar types of projects (e.g., the construction of a new mile of road on the Interstate system or the rehabilitation of a mile of road on the state system) required the same ratio of input to outputs (e.g., the exact same amount and kind of machinery, manhours, cubic yards of earth removal, etc.). When the ratio of inputs to outputs changes, so does the productivity from providing highway services. As productivity increases, the cost per unit of output might well decrease, even in the face of rising prices for inputs. The difficulties of creating reliable measures of outputs of highway services are well known; yet, some effort should have been made to establish one or more output indices, whatever their weaknesses, to determine changes in productivity and to gauge the real impact of price inflation on the provision of highway services.

CONCLUSIONS

After 6 years of operation, the Texas legislature in its first 1984 special session voted to discontinue the use of the HCI procedure. In place of the general revenue transfer, fuel taxes were increased to 10 cents per gallon and motor vehicle registration fees were also increased. The HCI mechanism did not provide the desired stability for highway funding. Unpredictable energy prices as well as a mix of other factors created considerable concern over the basic utility of the index. Although the index itself did not succeed, it served as a catalyst for major discussions on highway finance.

During the past decade, the SDHPT has performed a number of planning studies that have affected their programming operations. These studies are seen to be evolving toward a rational cost-benefit concept of balancing mobility and preservation requirements with financial constraints. Priority or preference assignment predicated upon such a concept can be a means of ensuring goal attainment, effective management, and accountability.

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Highway Bond Financing, 1962-1982: An Examination

JOHN DOYLE and DANIEL C. FALTER

ABSTRACT

The current emphasis on rehabilitation of the nation's public works infrastructure suggests that state and local highway officials will be considering the use of additional debt financing. Coincidentally, there is a growing concern over the magnitude of outstanding public debt. This paper provides an examination of state and local highway debt financing from 1962 through 1982. For state highways, 10 eastern states accounted for nearly two-thirds of new debt assumed during the study period. Toll facility debt remained relatively constant over the period, falling from two-thirds to only one-third of total state highway debt. A significant trend at the state level has been the increased emphasis on issuance of general obligation bonds and the declining use of limited obligation and revenue bonds. The relative importance of bond funds as a source of state highway construction has changed only moderately. The proportion of road-user taxes used for debt service payments doubled during the study period. Municipal highway debt and local debt incurred for highway-related purposes grew at about twice the rate of state highway debt. On a per capita basis, total state and local highway debt increased at a much lower rate than total dollar debt. The study revealed that there was significant variation in the manner in which debt was used by individual states to finance highways. The growth in highway debt has generally been conservative when compared with other major categories of debt.

Financing through debt is a basic tenet of a capitalistic system. Debt financing not only allows industry and business to build and expand, but contributes largely to the development of the public infrastructure. Without debt financing, many major U.S. highways and bridges would not have been built.

The economic advantages of debt are not particularly complex. When practiced with prudence and intelligence, debt acquisition can provide similar benefits to an individual, a private firm, or a public entity. High on the list of justifications for debt financing are

1. The inability to finance projects or acquire goods with current revenues and cash flows;
2. The realization that the present value of money is greater than the future value of money to the borrower; and
3. The greater derived benefits of debt over the cost of debt.

However, there is growing concern among public officials and taxpayers over the magnitude of public debt. There is also an awareness of costly failures in the banking and nuclear plant construction industries that have resulted largely from poor debt management. Coincident with these concerns, there is a growing emphasis on the need to rehabilitate and maintain the highway infrastructure. Consequently, many highway officials will, at some point, have to address the issue of debt financing and their decisions that follow will attract the scrutiny of state legislators and the public. The purpose of this paper is to examine the trends and patterns of highway debt over the past 21 years. Included are an examination of

- State highway obligations,
- Sources of highway construction funds,
- Debt service requirements,
- Local government debt (highway related),
- Per capita highway debt, and
- Highway debt versus other debt.

Previous work in this area was done by Duzan et al. in 1952 (1) and McCallum in 1963 (2). This paper may be viewed as an extension of these previous efforts. [Note that short-term debt and refunding bonds (bonds sold to retire existing bonds) are not included in the study; and the term "highway" is used in this paper to refer to state highways, county roads, and city streets.]

HISTORY OF HIGHWAY BOND FINANCING

Bond financing has been an important factor in financing highway construction throughout this century. The 1920s saw the first significant use of bond proceeds relative to other revenue sources; nearly 40 percent of construction was financed with bond funds. Several states financed major highway programs almost exclusively with bond authorizations. The 1930s saw several major projects funded through bond issues (e.g., San Francisco Bay Bridge, Pennsylvania Turnpike). However, because of large infusions of federal aid, the relative amount of bond financing decreased to about 20 percent of total construction. The 1940s were characterized by two distinct periods of activity: (a) very limited construction levels, and thus bond sales, during the war years; and (b) rapid acceleration of highway building in postwar years with about $2.2 billion in new debt assumed at state and local levels.

Borrowing for highway purposes increased dramatically during the 1950s, with 39 states and the District of Columbia incurring almost $10 billion in new debt. Outstanding debt for all types of obligations increased from $1.5 billion to $9.4 billion. Ten states located in the northeast and north central regions issued more than $400 million in bonds and accounted for almost two-thirds of new highway obligations between 1950 and 1960. The principal use of bond funds in these states was for the construction of major turnpikes.

STATE HIGHWAY OBLIGATIONS

State Bonding Practices

During the 21 years of this study, 41 states and the District of Columbia issued or assumed $24.8 billion in highway obligations. This assumed debt is approximately 50 percent greater than obligations issued during the previous 60 years. New issues for the 1962-1982 period are indicated in Figure 1 (3, Table SB-1), split between toll and free facilities.

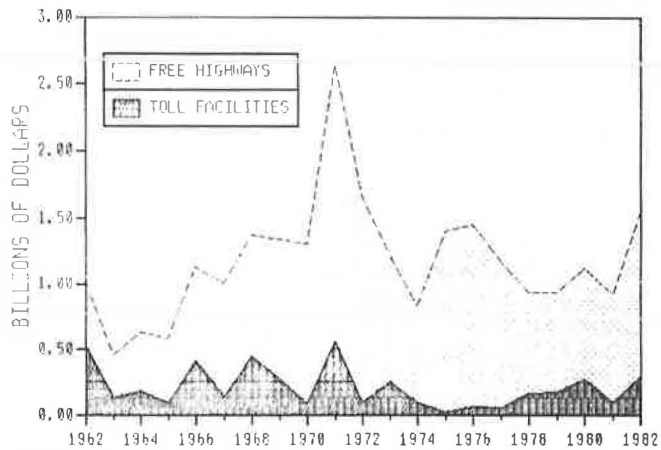

FIGURE 1 Annual state obligations, issued or assumed, for highways during year, 1962-1982.

Great variation exists among the states with respect to bonding practices. Nine states, all lying west of the Mississippi River, assumed no debt for either free highways or toll facilities during the 21-year period. These states were generally rural with relatively small populations. Nine additional states issued bonds during 5 or fewer years over the period; again, these were primarily western states with low population densities (Indiana and Michigan are exceptions). Ten states incurred highway debt exceeding $1.0 billion each during the 21 years; the total for these states ($15.4 billion) amounted to 62 percent of all state highway debt for the period. Two of these states, New Jersey and Pennsylvania, accounted for one-fifth of total obligations. The 10 states all lie east of the Mississippi River and are characterized as urban with relatively high population densities.

The bonding practices followed by these various groups of high- and low-debt states are consistent with trends in existence since World War II. Rural western states have generally managed to meet their lower construction needs with state funds and federal aid, whereas many eastern states with greater population pressures have required additional funds to provide needed facilities.

Toll Facility Bond Issues

During the study period, 23 states issued revenue bonds to finance toll roads, bridges, and ferry capital construction. For six states (California, Indiana, Iowa, Oklahoma, Texas, and Virginia), toll facility financing was the only purpose for which bonds were issued. Toll financing during the study period resulted in the issuance of $4.6 billion in bonds, or about one-fifth of all state highway bonds issued as shown in Figure 1. This is in contrast to the 1950s, when approximately the same absolute level of toll revenue bonds accounted for nearly one-half of new obligations.

The relative decline in the importance of bond financing for toll facilities is due partially to increased availability of federal funds. In many instances, debt service on general obligation bonds issued for toll facilities is actually paid from toll revenues. For the year 1982, general obligation bonds were sold to provide funding for toll roads in Florida and Virginia, but toll revenues from the projects will be used for debt service. In the same year, bonds issued for the San Francisco Bay Bridge, the Maine Turnpike, and the Dallas-North Tollway are supported only by tolls.

Outstanding Debt by Facility Type

Outstanding state government highway debt for all types of facilities increased from $10.5 billion to $19.3 billion between 1962 and 1982 [Figure 2 (3, Table SB-2)]. Total debt peaked in 1979 at $20.3 billion. Figure 2 shows that state debt for toll facilities and for state highways (i.e., toll-free facilities) have reversed positions of dominance during the study period. State highway debt grew from $3.6 billion in 1962, or one-third of the total debt, to $12.2 billion in 1982, nearly two-thirds of the total debt. Toll facility debt was relatively constant over the two decades, standing at $6.7 billion in 1962, peaking at $8.0 billion in 1972, and declining to $6.2 billion at the end of 1982. The relative share of toll facility debt declined from 64 percent to 32 percent during the period. By the end of the study period, 27 states had outstanding debt for toll facilities. Eight states in the East and the South had $300 million or more in outstanding toll facility debt, accounting for two-thirds of total state debt.

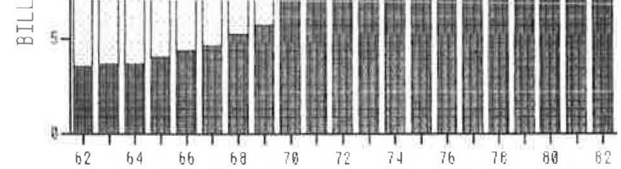

FIGURE 2 Outstanding end-of-year state obligations for highways, 1962-1982.

An interesting trend occurring over the study period was the growth of state government bond issues for local roads. By the end of the period, outstanding debt included only about $1.0 billion of this type of debt (5 percent of total debt), but the absolute amount of state-incurred debt for local roads grew by more than 500 percent ($163 million in

1962). About 75 percent of this type of debt was concentrated in two states and the District of Columbia. Of course, all outstanding debt in the District of Columbia ($178 million) was classified in this manner. Maryland ($351 million outstanding for county roads) and Washington ($200 million outstanding for city and county arterials) had regularly issued bonds in support of local roads. The other states with programs of this type were Alabama, Georgia, Massachusetts, Mississippi, and New Jersey.

State Bond Issues by Type of Security

The various types of bonds available for funding public capital projects are classified according to the security that underlies the debt. Three major types of bonds have historically been utilized to fund highway construction:

1. General obligation bonds--Principal and interest payments on these bonds are guaranteed by the full faith and credit of the governmental unit issuing the bonds. These bonds can generally be sold at a lower interest rate than other bond types because the full taxing power of the issuing authority is available to repay the bonds. For highway facilities, a specific road-user tax is normally pledged to provide principal and interest payments. General obligation bonds have been utilized to finance highway projects during most of this century.
2. Limited obligation bonds--These bonds are secured by a pledge of a specific tax or revenue of a specific fund. Revenues generated by the constructed facility may also be pledged, but such revenues cannot be the sole security. Limited obligation bonds thus have a broader security base than bonds backed only by project revenues, but are not as secure as general obligation bonds. Limited obligation bonds were first issued at the state level in 1929; their use peaked in the 1960s but continues today as an important method of securing highway construction funds.
3. Revenue bonds--Revenue bonds are obligations issued in support of specific projects, and are secured only by pledged earnings of the facility. Bondholders stipulate in some cases that tolls or other earnings of the facility must be adjusted if earnings prove insufficient. Revenue bonds have been in use in the highway field for the last half-century to fund bridges and tunnels, and have been used extensively since World War II to finance major turnpike systems.

Use of the three major types of security arrangements has changed markedly during the 21-year study period. Figure 3 (3, Table SB-2B) shows outstanding debt by security type for state highway facilities in 1962, 1972, and 1982. The most significant trend throughout this period has been the increased use of general obligation bonds. Bonds backed by the full faith and credit of state governments accounted for $11.1 billion in outstanding debt in 1982 compared with $2.8 billion 21 years earlier, an increase of nearly 300 percent. Total outstanding debt increased only 85 percent during this period. Although general obligation bonds accounted for about one-fourth of outstanding debt in 1962, they now account for well over one-half of outstanding debt. For 1982, about 65 percent of the $1.6 billion in new highway obligations was backed by the full taxing power of the states issuing the bonds.

As indicated in Figure 3, issuance of limited obligation bonds increased substantially through the 1960s in terms of absolute dollars. Outstanding debt for these types of bonds grew from $2.8 billion

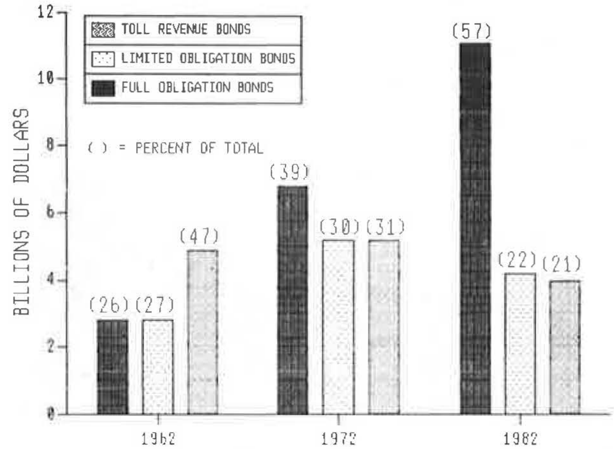

FIGURE 3 Outstanding state highway debt by type of security, 1962, 1972, and 1982.

to $5.2 billion between 1962 and 1982, an increase of 86 percent. Although the chart indicates a 30 percent share of all bond types for limited obligation bonds in 1972, they actually peaked at 32 percent from 1969 to 1970. During 1982, eight states issued $370 million in new limited obligation bonds, or 23 percent of total new highway debt.

Outstanding debt for toll facilities remained fairly constant through the 1960s and 1970s in terms of absolute dollars. However, the trend toward greater use of general obligation bonds for toll facility financing has reduced the relative percentage share of outstanding debt for toll facilities financed by revenue bonds to about one-fifth of the total debt, compared with nearly one-half in the early 1960s. In recent years, toll facility bonds have generally been concentrated in a few large issues. Table 1 (3, Table SB-1) lists 1978-1982 total bond issues for toll facilities including general obligation issues, issues backed only by tolls, and the largest single issue for each year.

TABLE 1 Toll Facility Bond Issues, 1978-1982

	Bond Category ($ millions)		
Year	Total Including General Obligation Bonds	Backed Only by Tolls	Single Largest
1978	174.2	174.2	Texas-Houston Ship Canal Bridge (102.0)
1979	190.9	17.3	Florida-Hillsborough County Expressway (117.5)
1980	283.1	283.1	Indiana-East-West Toll Road (259.5)
1981	99.0	25.0	California-San Francisco Bay Toll Bridge (25)
1982	297.5	200.6	Texas-Dallas-North Tollway (168.1)

Source of Highway Construction Funds

Analysis of the source of funds for state highway construction presents a somewhat different perspective of the role played by bond financing. As noted previously, significant growth has occurred over the last two decades in new bond authorizations for state highways. However, as shown in Figure 4 (3, Tables SF-3, SF-4), the relative importance of bond funds as a source of state highway construction changed only moderately during this period.

During the early 1960s bond sales for construction of state-administered highways averaged about

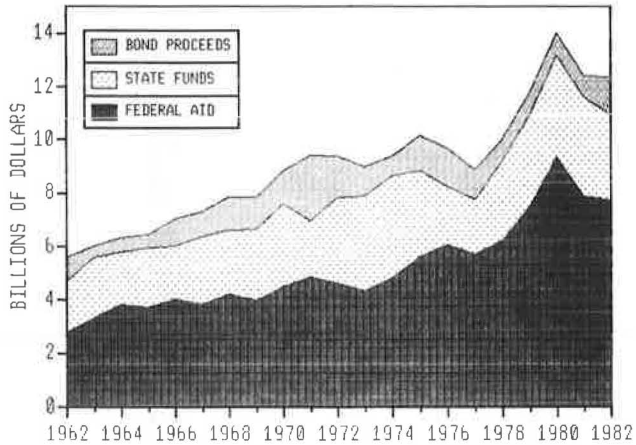

FIGURE 4 State highway construction by source of funds, 1962-1982.

$0.6 billion annually and provided about 8 percent of total construction funds. Beginning in the middle 1960s and continuing through the middle 1970s, bond sales averaged about $1.4 billion annually and 15 percent of funds available for highway construction. The year 1971 was atypical of this period, with 26 percent of construction funds provided by bond proceeds. In that year, six states (Florida, Illinois, Kentucky, New Jersey, New York, and Pennsylvania) had unusually large bond issues totalling $1.5 billion.

During the last 5 years of the study period, use of bond proceeds for highway construction declined, averaging about $1.0 billion and 8 percent of total construction funds (the year 1982 being an exception to this latest trend). Figure 4 shows that the use of state funds other than from bond sales has been consistent over the years, having averaged about 30 percent of construction funds. Federal aid funds accounted for 58 percent of construction dollars in the early 1960s, declined to about 50 percent during the late 1960s to middle 1970s, and increased rather dramatically from 1976 through 1982 to an average of 64 percent of total highway construction.

As an indicator of the variability among states in the use of bond funds, Table 2 (3, Tables SF-3, SF-4C) shows total construction funds, bond proceeds used for construction, and the percentage of the total made up of bond proceeds. The data shown are for the 32 states that issued bonds for use in construction of state-administered highways from 1978 through 1982. Four states utilized bond funds for more than 25 percent of their construction needs during this period, led by Delaware at nearly 50 percent. One of these four states, Arizona, has not historically depended upon bond issues, but had a very large issue in 1982. Six states issued bonds only once during the 5-year period. As noted previously, total bond proceeds over this period provided 8 percent of total construction funds, and this figure increases to only 11 percent when the 18 states with no bond sales are excluded from this calculation.

Debt Service Requirements

Another way of assessing the impact of state highway borrowing is to examine the level of debt service payments over time and among the states that have incurred long-term debt. Of particular interest is the use of road-user tax receipts (primarily motor fuel taxes and motor vehicle fees) to support in-

TABLE 2 Use of Bond Funds for State-Administered Highways, 1978-1982

State	Total State Highway Construction ($ thousands)	Bond Funds Used for Construction ($ thousands)	Bond Fund Percentage
Delaware	323,733	157,315	48.6
Massachusetts	1,012,693	307,300	30.3
Arizona	844,787	218,829	25.9
Connecticut	683,721	172,946	25.3
New Jersey	935,425	191,052	20.4
New Hampshire	304,380	60,500	19.9
Illinois	3,219,675	585,061	18.2
Kentucky	2,032,528	366,797	18.0
Louisiana	2,296,634	414,015	18.0
North Carolina	1,676,589	300,517	17.9
Maine	357,137	63,655	17.8
Hawaii	358,754	59,347	16.5
West Virginia	1,515,884	200,000	13.2
Indiana	857,751	104,020	12.1
New Mexico	603,725	65,825	10.9
Georgia	2,040,335	208,650	10.2
Minnesota	1,339,025	132,100	9.9
Ohio	1,647,725	150,000	9.1
Washington	1,564,693	135,000	8.6
Alaska	627,009	45,600	7.3
Alabama	1,321,751	79,000	6.0
Wisconsin	801,730	47,970	6.0
Vermont	190,401	10,803	5.7
Florida	3,014,334	169,646	5.6
Nevada	450,453	25,041	5.6
Mississippi	991,143	55,000	5.5
Pennsylvania	2,290,586	112,247	4.9
Kansas	851,006	40,000	4.7
Texas	5,164,612	175,951	3.4
Virginia	2,156,206	57,000	2.6
California	2,804,253	55,432	2.0
Oregon	845,774	15,000	1.8
Total, above states	45,124,452	4,781,619	10.6
Total, all states	61,084,771	4,781,619	7.8

debtedness. This is because the amount of such receipts remaining after debt service payments gives an indication of the state's ability to fund current and future construction needs, as well as to match federal aid receipts.

Figure 5 (3, Table DF) shows, for states with debt service payments, the change through the study period in state road-user tax receipts and the amount of these receipts used for debt service. In this chart, the top of each bar indicates the level of total tax receipts, and debt service payments are shown as a portion of tax receipts. The percentage of road-user tax receipts used for debt service is

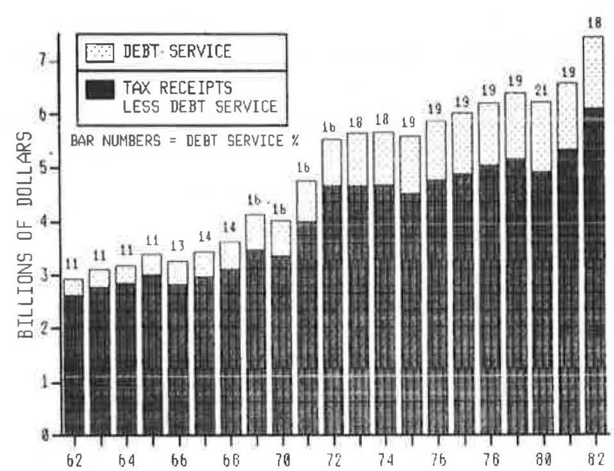

FIGURE 5 Total road-user tax receipts and portion used for bond debt service, 1962-1982.

indicated for each year. Total tax receipts approximately doubled over the 21-year study period, whereas debt service payments quadrupled. Thus, the percentage of tax receipts dedicated to the support of highway debt doubled during the study period, peaking at 21 percent in 1980, but declined during 1981 and 1982. It is clear from the trend shown in Figure 5 that servicing of highway bond debt has claimed a steadily increasing portion of state funds that would otherwise be available for current construction work. It should be noted that when this analysis is performed using total receipts available for highways (including federal aid) and debt service payments made from all sources of revenue, the ratio of debt service versus total receipts drops considerably. Using this computation method for 1982 shows that only 8 percent of total highway receipts was used for debt service payments, whereas (as shown in Figure 5) 18 percent of state road-user taxes was used for this purpose.

Table 3 (3, Table DF) provides further indication of the wide disparity among states in the assumption of highway debt. This information represents a state-by-state analysis of the data shown in Figure 5 for the year 1982. Three states, Connecticut, Delaware, and Hawaii, used more than one-half of their road-user taxes for debt service, and an additional eight states used at least one-fourth of available road-user tax receipts for this purpose. Connecticut and Delaware might be expected to appear near the top of this list because they were previously shown to be leaders in the use of bond funds for construction (Table 2). Hawaii heads the list in Table 3 partially because it is one of the few states that used only road-user taxes to make debt service payments. Arizona appeared high on the list of states using bonds for construction primarily because of a large bond issue in 1982, but it is one of the lowest states in terms of debt service payments. With the exceptions of Hawaii and Kansas, the states with the highest percentage of debt service lie east of the Mississippi River and are concentrated in the Northeast and the South.

TABLE 3 Use of State Road-User Tax Receipts for Bond Debt Service Payments, 1982

State	Road-User Tax Receipts ($ thousands)	Debt Service Payments ($ thousands)	Debt Service Percentage
Hawaii	26,763	16,966	63.4
Delaware	54,467	28,028	51.5
Connecticut	146,426	73,464	50.2
Georgia	156,199	64,471	41.3
West Virginia	199,568	81,592	40.9
Mississippi	114,688	44,858	39.1
Massachusetts	258,186	98,117	38.0
Kansas	138,322	46,479	33.6
Louisiana	250,068	78,959	31.6
New Jersey	163,603	49,860	30.5
Rhode Island	49,901	13,560	27.2
Illinois	369,857	91,100	24.6
Vermont	58,472	12,937	22.1
New York	501,086	113,822	22.7
Pennsylvania	914,901	196,113	21.4
Maine	70,536	10,490	14.9
Ohio	535,582	78,540	14.7
Alabama	132,533	19,374	14.6
Michigan	241,203	26,098	10.8
Tennessee	223,481	22,462	10.1
Wisconsin	218,366	21,045	9.6
Nevada	68,592	5,640	8.2
New Hampshire	79,674	6,147	7.7
Washington	234,563	17,205	7.3
North Carolina	462,858	32,565	7.0
South Carolina	237,544	13,251	5.6
Florida	411,711	22,272	5.4
Maryland	250,580	12,485	5.0
Oregon	136,194	5,802	4.3
Minnesota	243,963	8,724	3.6
Arizona	136,161	3,294	2.4
Nebraska	83,139	1,419	1.7
Kentucky	292,759	3,415	1.2
Total, above states	7,461,946	1,320,554	17.7
Total, all states	11,052,181	1,320,554	11.9

Local Government Bond Financing

From 1962 through 1981, local government agencies issued approximately $20 billion in long-term bonds for streets, roads, and indirect street functions. At the end of 1981, $10.7 billion in combined debt was outstanding for all local government entities. Growth of outstanding debt over the study period for the rural, municipal, and "other local" categories, is shown in Figure 6 (3, Tables UB-2, LB-2, UF-11, UF-12).

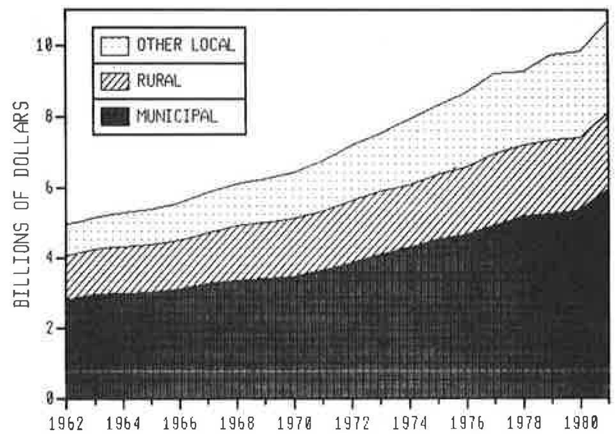

FIGURE 6 Local government outstanding highway debt: municipal, rural, and other local, 1962-1981.

Continuing a trend established in the 1950s, municipal highway debt grew between 1962 and 1981 at a significantly higher rate than highway debt in the counties, townships, and other rural governments. With total new issues of $10.6 billion during the period, municipal debt stood at $6.0 billion at the end of 1981, or 113 percent higher than in 1962. In the rural units, $4.1 billion in debt was assumed during the 20 years; outstanding debt grew 68 percent and stood at $2.2 billion in 1981. It may be assumed that the relatively large growth of municipal debt is a direct result of growth in urban areas as compared with rural areas during the 1960s and 1970s. Pressures to reduce traffic congestion and develop new services, as well as shortages of necessary construction funds, have resulted in a widespread requirement to obtain needed funds through bond issues.

The highest growth rate in local government debt has occurred in the "other local" category in Figure 6. This category includes bond debt for parking facilities and indirect street functions (street lighting and cleaning, sidewalks, and storm sewers) for both municipal and rural government agencies at the beginning of the study period; this type of debt accounted for less than one-fifth of total rural and municipal highway-related debt. Through 1981, outstanding debt for parking and indirect street functions nearly tripled, and at the end of that year constituted one-fourth of total local government debt. Again, the increase is largely due to growth of cities and the resultant need for streets and related facilities.

As was found to be the case with state highway debt, considerable variation exists among the states with respect to local government bonding practices. Rural authorities in 17 states had no outstanding debt at the end of 1981; for municipalities and the "other local" categories, the comparable numbers are 9 and 14 states, respectively. Only four states (Alaska, Nevada, Oklahoma, and Utah) had no outstanding local debt of any kind, whereas minimal local debt (less than one-half of 1 percent of the total) existed in 14 other states. These 18 states with little or no local highway debt are primarily western and northeastern states.

Local agencies in 17 states had assumed greater debt for highway and related purposes than had their counterpart agencies at the state level. For example, Texas possessed one-fourth of total municipal debt, one-fifth of total rural debt, and slightly less than one-fifth of total local outstanding debt. New York also had significant local debt with 12 percent of the total. The top 10 states in terms of total local debt are listed in Table 4 (3, Tables UB-2, LB-2, UF-11, UF-12).

TABLE 4 Outstanding Local Highway Debt, 1981

	Debt Category ($ millions)			
State	Rural	Municipal	Other Local	Total Local
Texas	446	1,499	67	2,012
New York	245	634	396	1,275
California	34	225	619	878
Minnesota	27	491	51	569
Pennsylvania	52	166	235	453
Ohio	9	262	170	441
Louisiana	179	184	23	386
Florida	277	98	0	375
Wisconsin	84	243	34	361
Maryland	184	54	109	347
Total, 10 states	1,537	3,856	1,704	7,097
All other states	627	2,107	857	3,591
Total, all states	2,164	5,963	2,561	10,688

COMBINED STATE AND LOCAL DEBT

Outstanding

Combined outstanding debt for state, municipal, and rural highway facilities is shown in Table 5 and Figure 7 (3, Tables SB-2, UB-2, LB-2, UF-11, UF-12). Total outstanding debt grew consistently at about 4 percent annually through 1978, but has since leveled off. State highway debt has generally accounted for at least two-thirds of total debt through the study period, although with the drop in the states' outstanding debt in 1981, this share was reduced to 62 percent of the total. A major factor in the 1981 decline in state highway debt was redemption of nearly $1.5 billion in bonds by Kentucky.

Only Utah had no state or local highway debt outstanding in 1981, although several other states (primarily north central and mountain states) have incurred limited highway debt. Illinois, New Jersey, New York, Pennsylvania, and Texas accounted for nearly one-third of the combined state and local highway debt. The most prominent states in terms of total amounts of state and local highway debt were generally southern and northeastern.

Per Capita Highway Debt

The absolute level of highway debt in the state does not necessarily give a true measure of the impact of

TABLE 5 Annual Outstanding Highway Debt for State and Local Authorities, 1962-1982

	Debt Category ($ millions)				
Year	State	Municipal	Rural	Other Local	Total
1962	10,454	2,803	1,285	875	15,417
1963	10,579	2,967	1,281	920	15,747
1964	10,913	3,019	1,317	983	16,232
1965	11,059	3,048	1,363	1,005	16,475
1966	11,814	3,144	1,394	1,056	17,408
1967	12,177	3,285	1,450	1,129	18,041
1968	12,903	3,384	1,555	1,178	19,020
1969	13,514	3,430	1,579	1,242	19,765
1970	14,020	3,501	1,632	1,313	20,466
1971	15,851	3,653	1,678	1,425	22,607
1972	17,171	3,868	1,770	1,552	24,361
1973	17,462	4,103	1,810	1,614	24,989
1974	17,631	4,323	1,775	1,855	25,584
1975	18,136	4,556	1,820	1,947	26,459
1976	18,657	4,686	1,875	2,131	27,349
1977	19,128	4,917	2,036	2,277	28,358
1978	20,282	5,190	2,003	2,123	29,598
1979	19,761	5,247	2,106	2,398	29,512
1980	20,091	5,383	2,023	2,465	29,962
1981	18,095	5,963	2,164	2,561	28,783
1982	19,312	-[a]	-[a]	-[a]	-[a]

[a]Data not available.

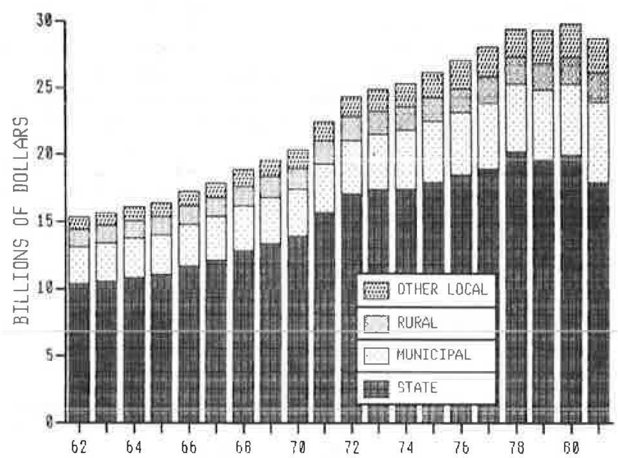

FIGURE 7 Annual outstanding highway debt by jurisdiction, 1962-1981.

the debt on the state's residents. Examination of the states with the largest outstanding highway debt shows that these are primarily the states with the greatest population. For example, of the top 10 states in terms of total highway debt, 7 are also among the nation's 10 most populous states. These 10 states accounted for 55 percent of state and local highway debt and 48 percent of the total U.S. population in 1981.

One method of giving perspective to the level of highway debt in the various states is to compute the debt on a per capita basis. Per capita state and local highway debt stood at $127 in 1981 compared with $84 in 1962. The 20-year growth rate of 51 percent in per capita debt is significantly lower than the growth rate of total debt (87 percent). Per capita debt peaked in 1978 at $134.

Individual state per capita debt varied in 1981 from $0 (in Utah) to $671 (in Delaware). Many of the states with relatively high per capita debt were also found to rank relatively high in terms of using road-user taxes for debt service and bond funds for state highway construction. About one-half of the states with greater than average per capita debt are

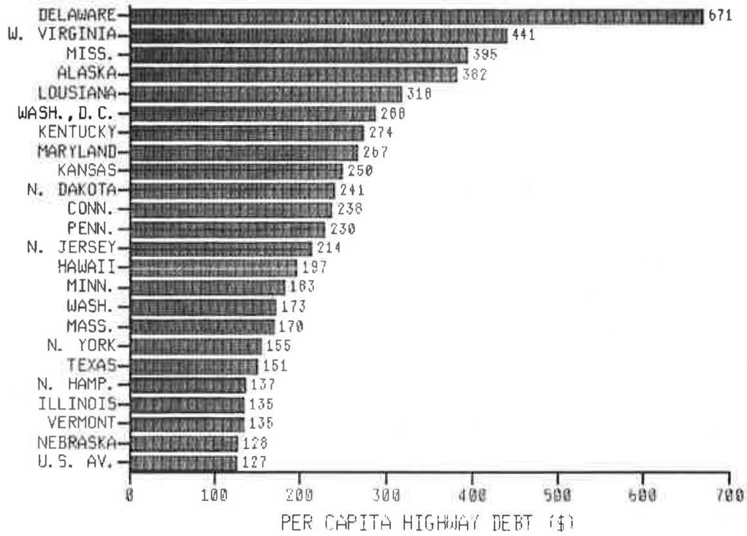

FIGURE 8 Per capita highway debt, state and local authorities, 1981.

located in the East, with the South, the Midwest, and the Pacific states also represented. Figure 8 (3, Tables SB-2, UB-2, LB-2, UF-11, UF-12; 4) shows 1981 per capita highway debt for the 23 states with values higher than the national average of $127.

Highway Debt Versus Other Debt

Assumption of debt for highway purposes is not a unique situation in our society. Public agencies issue bonds for many purposes in addition to highways. At the local level, schools and utilities are major recipients of bond proceeds. State governments incur debt for school and other public buildings, and a wide variety of facilities used for waste disposal, water supply, pollution control, recreational purposes, and so on. Federal government debt is not assumed for specific capital facilities, but it funds a broad spectrum of programs dealing with national defense, social services, and resource development. Of course, many other sectors in our economy assume debt as well, including corporations and consumers.

It has been noted that combined state and local highway debt has grown steadily, approximately doubling during the study period. Table 6 (5, Tables 448, 511, 857, 928, 1159; 6, Table 18), shows the 20-year growth of various categories of public and private debt and demonstrates that the increase in highway debt has been relatively conservative. It is particularly notable that state highway debt has increased less than 100 percent whereas total state government debt has increased more than 550 percent. Local government debt in total has grown at more than twice the rate of local highway debt. In 1962, state and local highway debt included 19 percent of total state and local government debt. By 1982, this share had dropped to only 8 percent.

TABLE 6 Comparison of Highway Debt with Other Public and Private Debt, 1962-1982

Debt Category	1962 ($ billions)	1982 ($ billions)	Percent Increase
Public			
Federal	298.2	1,142.0	283.0
State	22.0	143.7	553.2
Local	59.3	236.6	299.0
Private			
Mortgage	236.0	1,545.0	554.7
Farm	30.2	201.7	567.9
Consumer	46.0	370.6	705.7
Highway			
State	10.5	19.3	83.8
Local	5.0	10.7[a]	114.0

[a]1981 data.

CONCLUSION

Perhaps the most important finding of the study is that from a national perspective, state and local highway debt has not become an unmanageable burden. Although indebtedness for highways has shown steady growth through the past two decades, this growth has been extremely conservative when compared with other major categories of debt. The comparison to state and local nonhighway debt is especially relevant and shows that the other major governmental programs have utilized bond financing to a much greater degree than has the highway program. This is partially due to the widely accepted philosophy of dedicated funding for highways, resulting in assured sources of revenues and a reduction in the need to incur debt. The favorable indebtedness situation for highways is also a tribute to the major commitment at the federal level to provide an adequate national transportation system on a pay-as-you-go basis.

At the state level, a significant trend has been increased emphasis on issuance of general obligation bonds and the concurrent reduction in use of limited obligation and revenue bonds. This phenomenon has coincided with a general increase in interest rates, and reflects a prudent approach to debt management that minimizes total debt service costs. It should be noted, however, that even with the current prevalence of general obligation bond funding, highway user taxes and toll receipts continue to be the principal sources of revenue used for debt service purposes.

Use of highway bond financing by local rural authorities has not shown significant growth during the period of study. However, municipal highway debt and local debt incurred for highway-related purposes have grown at nearly twice the rate of state highway debt. This trend is one indicator of the exceptional infrastructure needs that have developed in the nation's urban areas and the inability of local authorities to generate sufficient funds to finance capital programs from current revenues. These problems will inevitably affect both state and local government as the municipalities seek greater distributions of state highway user taxes as well as additional sources of local funds.

Analysis of highway debt at all jurisdictional levels has shown a remarkable variability among the states with respect to bonding practices. Several states (primarily western) have followed a pay-as-you-go philosophy and have avoided highway indebtedness completely, or nearly so. The philosophy has been adopted at the state level in a few states but not by the local government agencies. Many states (primarily eastern) appear to have transcended the acceleration principle of bond financing, that is, incurring debt only during short periods of relatively great construction needs and retiring debt as construction needs are reduced. These states tend to utilize bond funds on a regular basis and as a result must use a relatively high proportion of current revenues to retire debt. It must be noted in this discussion that although philosophical differences may account for some of the variation in state bonding practices, it is certainly easier to remain with a pay-as-you-go policy in a rural, low population state than in an urbanized, high population state. It is recognized in many cases that the immediate and long-term benefits of reduced traffic congestion and improved safety derived from a new highway facility will outweigh the costs of incurring new debt to build the facility.

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Development and Application of New Highway Cost-Allocation Procedures

ARTURO VILLARREAL-CAVAZOS and ALBERTO GARCIA-DIAZ

ABSTRACT

Previous attempts at resolving the highway cost-allocation problem of determining equitable changes for each vehicle class that shares transportation facilities such as highways and bridges can be reduced to two approaches: proportional allocation methods that determine costs in proportion to one or more measures of highway usage, and incremental methods that allocate costs on the basis of highway design differences necessary to accommodate heavier vehicle classes. Developed in this paper are two new highway cost-allocation methodologies that actually extend the basic concepts of the incremental and proportional allocation procedures. The new methods are referred to as the "modified incremental approach" and the "generalized method". Both methods fulfill the following conditions: (a) highway costs are completely financed by users (completeness condition); (b) vehicle classes reduce their cost responsibilities by sharing the facilities with other vehicle classes (rationality principle); and (c) vehicle classes are charged at least enough to cover their corresponding marginal costs (marginality principle). An example using Texas Pavement data illustrates the application of the proposed methods.

The issue of highway financing has received a great deal of attention from state legislators in recent years because a significant portion of U.S. highway pavements is deteriorating to unacceptable levels of user serviceability. To combat this problem, a highway cost-allocation procedure must be implemented that includes the cost of keeping a highway (or other transportation) facility operational during a specific planning horizon. A primary objective of this procedure would be to determine the fraction of the total cost to be charged to each vehicle class served by that facility.

The results of recent cost-allocation studies are summarized in this paper. Two alternative cost-allocation methods are developed in particular: modified incremental and optimization. The optimization method will be referred to as a generalized procedure as it is based on an extension of the concepts used in the incremental (1-3) and proportional allocation (2,4,5) methods.

Proportional allocation methods determine cost responsibilities based on the extent to which each vehicle class uses a highway facility. This is determined by such measures as gross vehicle weight, vehicle miles travelled, and equivalent single axle loads (ESALs). These methods, however, may yield results that conflict with the perception of fairness by individual vehicle classes--this hinders the acceptability of the results by all the users of the facility and questions the overall applicability of the proportional methods.

Incremental allocation methods identify cost responsibilities on the basis of the cost differences associated with the sequential introduction of vehicle classes into the traffic stream. Different results are obtained when vehicle classes are introduced in different sequences, however. This inconsistency constitutes a serious flaw in any cost-allocation method in terms of equitability.

The two procedures discussed in this paper exhibit properties that make them superior to those previously used in the context of highway facility planning. In particular, they fulfill three fundamental requirements:

1. Completeness: the provision of highway facilities must be entirely financed by the various vehicle classes that utilize them;
2. Rationality: the common facility is the most economically attractive alternative for all vehicle classes to meet their transportation needs; that is, any other alternative to satisfy this need, such as using an exclusive facility, would be more expensive for any vehicle class; and
3. Marginality: the allocated costs associated with any vehicle class must be sufficient to at least cover its corresponding marginal costs.

The completeness requirement ensures that only funds provided by highway users are considered for financing the common highway facility. (This condition conforms to the directives established in Section 506 of the Surface Transportation Assistance Act of 1978.) The rationality requirement is a well-established concept in the economics literature (6) that deals with a fundamental characteristic of economic behavior. Therefore, any procedure that violates this condition would be strongly objected to as it would be uneconomical for a vehicle class to contribute toward a common facility when there are more economical alternatives available. The marginality requirement is another widely accepted economic principle (7). Assuming that the completeness requirement is met, the violation of this principle implies the existence of cross-subsidization among the vehicle classes involved. The rationality and marginality requirements established an essential element of fairness or equity in the cost-allocation procedure.

In conclusion, having an equitable cost-allocation methodology (that satisfies the rationality and marginality principles) to analyze the aspects related to highway financing enhances the acceptability of the results among the various vehicle classes that ultimately must cover the total cost of the facility. This important issue is briefly discussed in the following sections on the proportional and incremental methodologies.

BACKGROUND

Current solution procedures for the highway cost-allocation problem yield results that are not totally acceptable from an economic point of view because they deviate from the ideal concept of charging each user class based on the cost it causes. Although a noncontroversial solution methodology to the problem may not exist, cost must be allocated in some rational way. Traditionally, it has been an accepted practice to define cost responsibilities on the basis of some criterion that represents the use of the facility by the various vehicle classes.

The most widely used highway cost-allocation method is the incremental approach, which was adopted for use in the earlier cost-allocation studies conducted in the United States. This approach was adequate while new construction was the principal element of highway cost. However, now that a larger portion of the budget must be assigned to the maintenance and rehabilitation of existing facilities, the incremental approach has been reviewed and questioned, and some important problems, which will be discussed later, have been discovered.

The incremental method has been used in a number of cost-allocation studies such as the first Federal Highway Cost Allocation Study (1), and studies conducted in several states including Kentucky, Montana, North Dakota, Rhode Island, Virginia, and Washington (2,3,8-11).

According to the incremental method, the cost of a highway facility designed for the lightest vehicle class is initially calculated; then, vehicle classes are added in order of increasing axle weight, and corresponding highway design or rehabilitation costs are calculated for the resulting traffic streams and a specified design period. The cost difference in each step between one design and the next is allocated to the vehicle class incorporated in that step. Some minor variations of the basic incremental method have also been considered (4).

Although it meets the aforementioned completeness, rationality, and marginality requirements, there is one important problem with the incremental method: it is inconsistent. The method produces different results when vehicle classes are introduced in different orders. This is due to the presence of overlapping facility requirements demanded by the various vehicle classes. Figure 1 shows this inconsistency. The shaded areas in parts a-c represent costs allocated to vehicle classes 1, 2, and 3 when they are sequentially introduced. However, the shaded areas in parts d-f represent the same costs when class 3 is included first, followed by classes 1 and 2.

Another accepted approach to the problem under consideration is to allocate costs in proportion to a numerical criterion which, in the context of transportation systems, represents a measure of use or damage caused by the vehicle classes using a common highway facility. This method is known as the

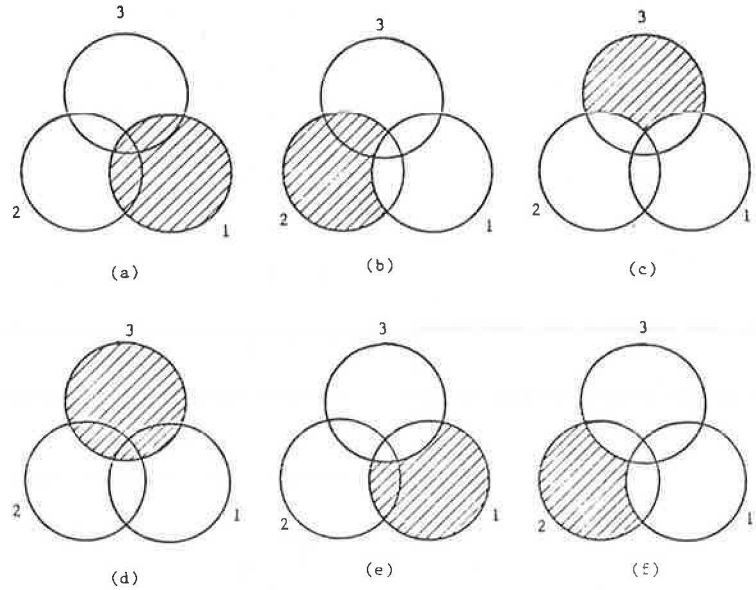

FIGURE 1 Basic approach of the incremental method.

proportional method or the consumption approach (4,5). The appeal of this method lies in its simplicity and that, when the appropriate basis is selected, the fairness of its results is less controversial.

A major issue with the proportional allocation method, however, is that it may yield cost allocations that conflict with the interests of the individual vehicle classes. This problem arises because the strategic alternatives (coalitions) available to the vehicle classes for meeting their transportation needs are ignored in this method. Such strategic alternatives include sharing a common facility with all vehicle classes, sharing a facility with some of the other vehicle classes, and having an exclusive facility. In other words, under the proportional allocation method, it is possible for a particular vehicle class to pay more for sharing a common facility than for having an exclusive one.

In a pioneering and enlightening article, Young et al. (12) analyze several cost allocation methods used in water resources management. Among the methods discussed, those that stem from the theory of cooperative games (6,13) are of particular interest. These methods provide the means for approaching the cost allocation problem by accounting for all the possible strategic alternatives available to each vehicle class in providing needed highway facilities. These various strategic possibilities actually establish constraints that define a set of feasible solutions that satisfy the completeness, rationality, and marginality requirements. The cost allocations resulting from these methods are more likely to be accepted because they are formulated on the basis of fundamental economic principles.

THE MODIFIED INCREMENTAL APPROACH

A modified version of the incremental approach is proposed as a suitable methodology for allocating construction, reconstruction, or rehabilitation costs. The proposed modification to the incremental approach attempts to overcome the consistency problem previously mentioned; however, an indirect result of this modification is that the computational complexity of the new procedure is increased.

In the modified incremental approach, cost estimates are prepared for every vehicle class, as well as for every combination of two or more vehicle classes. As an illustration, if a highway is designed to accommodate vehicle classes 1, 2, and 3, the final cost allocation for each class is determined only after considering hypothetical designs for the following vehicle class combinations and computing the corresponding design costs: (a) class 1, (b) class 2, (c) class 3, (d) classes 1 and 2, (e) classes 1 and 3, (f) classes 2 and 3, and (g) classes 1, 2, and 3.

Using the cost estimates obtained for these class combinations and a few fundamental operations, the total cost (corresponding to the combination including classes 1, 2, and 3) is partitioned into as many cost components as vehicle combinations; moreover, each cost component can be considered as the estimate of the cost effect of a vehicle class combination. To simplify the description of the method, the following notation is used:

C_1 = cost of a highway designed for vehicle class 1 alone,
C_2 = cost of a highway designed for vehicle class 2 alone,
C_3 = cost of a highway designed for vehicle class 3 alone,
$C_{1,2}$ = cost of a highway designed for vehicle classes 1 and 2,
$C_{1,3}$ = cost of a highway designed for vehicle classes 1 and 3,
$C_{2,3}$ = cost of a highway designed for vehicle classes 2 and 3,
$C_{1,2,3}$ = total cost of a highway designed (for vehicle classes 1, 2, and 3).

The shaded areas in Figure 2 illustrate the notation described above. In this figure, each individual vehicle class is represented by a circle. When two or more vehicle classes are simultaneously considered, the corresponding circles exhibit a certain degree of overlapping. This overlapping represents the portion of the total cost that is due to a combined effect of two or more vehicle classes.

As can be shown in Figure 2, the portion of the total cost that can be attributed only to individual

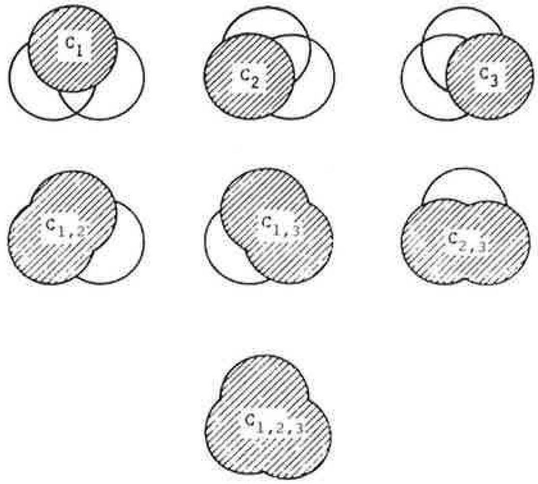

FIGURE 2 Input cost estimates.

classes is given by Equations 1, 2, and 3, respectively:

$$P_1 = C_{1,2,3} - C_{2,3} \quad (1)$$

$$P_2 = C_{1,2,3} - C_{1,3} \quad (2)$$

$$P_3 = C_{1,2,3} - C_{1,2} \quad (3)$$

The portions of the total cost attributed to the interaction of any two vehicle classes, (1 and 2, 1 and 3, and 2 and 3) can be calculated similarly by using Equations 1-3 and the initial cost estimates C_1, C_2, C_3, and $C_{1,2,3}$ as follows:

$$P_{1,2} = C_{1,2,3} - C_3 - P_1 - P_2 \quad (4)$$

$$P_{1,3} = C_{1,2,3} - C_2 - P_1 - P_3 \quad (5)$$

$$P_{2,3} = C_{1,2,3} - C_1 - P_2 - P_3 \quad (6)$$

The results from Equations 4-6 are used to obtain $P_{1,2,3}$, the total portion of the cost attributed to the interaction of all vehicle classes, as follows:

$$P_{1,2,3} = C_{1,2,3} - P_1 - P_2 - P_3 - P_{1,2} - P_{1,3} - P_{2,3} \quad (7)$$

Figure 3 depicts the partitioning of the total cost $C_{1,2,3}$ into the portions defined in Equations 1-7. As shown in this figure, the allocated cost for vehicle class 1, for example, is equal to P_1 plus appropriate fractions of the portions $P_{1,2}$, $P_{1,3}$, and $P_{1,2,3}$. These fractions can be defined in terms of relative facility usage, as measured in vehicle miles of travel (VMT). If V_1, V_2, and V_3 represent the amount of VMT associated with classes 1, 2, and 3, respectively, the final allocated cost R_1, is given by Equation 8:

$$R_1 = P_1 + [P_{1,2}V_1/(V_1 + V_2)] + [P_{1,3}V_1/(V_1 + V_3)] + [P_{1,2,3}V_1/(V_1 + V_2 + V_3)] \quad (8)$$

Similar results can be obtained for the cost allocations corresponding to classes 2 and 3.

$$R_2 = P_2 + [P_{1,2}V_2/(V_1 + V_2)] + [P_{2,3}V_2/(V_2 + V_3)] + [P_{1,2,3}V_2/(V_1 + V_2 + V_3)] \quad (9)$$

$$R_3 = P_3 + [P_{1,3}V_3/(V_1 + V_3)] + [P_{2,3}V_3/(V_2 + V_3)] + [P_{1,2,3}V_3/(V_1 + V_2 + V_3)] \quad (10)$$

Figure 4 represents the final cost allocations given in Equations 8-10. In Figure 4a, it can be concluded that the modified incremental method meets the completeness condition because the sum of the areas representing R_1, R_2, and R_3 is equal to the area representing the total cost $C_{1,2,3}$ of Figure 2. The shaded area shown in Figure 4b represents the marginal cost of vehicle class 1. As can be seen by comparing Figure 4b with Figure 3, this marginal cost is exactly equal to P_1. By comparing Figures 4a and 4b it is also clear that $P_1 \leq R_1$; therefore, the cost allocated to vehicle class 1 is at least equal to its marginal cost. This shows that the marginality requirement is satisfied. Similarly, the fact that $R_1 \leq C_1$ indicates that the cost allocation corresponding to class 1 in a joint design is less than it would be in a design intended only for class 1. This also shows that the rationality requirement is satisfied.

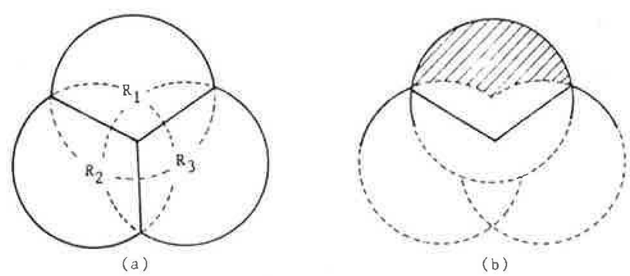

FIGURE 4 Cost allocation using the modified incremental approach.

The modified incremental approach does not have the inconsistency limitation of the standard incremental method because all possible vehicle class combinations are considered in it and the vehicle classes are not required to be included in any sequence. The development presented in this section can be used for any number of vehicle classes.

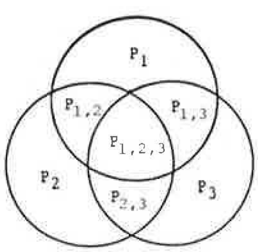

FIGURE 3 Partitioning of the total cost.

THE GENERALIZED METHOD

This procedure is based on concepts from the theory of cooperative games (6,13). A linear programming model that includes a set of meaningful economic constraints is formulated and solved to determine the appropriate cost allocation among the vehicle classes that share a transportation facility. Although the procedure developed in this section is valid for any number of vehicle classes, it will be demonstrated by using three classes. The notation given in the previous section will be used here, also.

The generalized method expresses the completeness, rationality, and marginality principles in terms of a mathematical model. The completeness requirement, which establishes that the vehicle classes must entirely finance a highway facility, is stated below:

$$R_1 + R_2 + R_3 = C_{1,2,3} \quad (11)$$

The rationality principle, which imposes the condition that the common facility must be the best alternative for each individual vehicle and for all subgroups of vehicle classes 1 and 2, 1 and 3, and 2 and 3, is represented as follows:

$$R_1 \leq C_1 \quad (12)$$

$$R_2 \leq C_2 \quad (13)$$

$$R_3 \leq C_3 \quad (14)$$

$$R_1 + R_2 \leq C_{1,2} \quad (15)$$

$$R_1 + R_3 \leq C_{1,3} \quad (16)$$

$$R_2 + R_3 \leq C_{2,3} \quad (17)$$

The marginality principle establishes that the cost allocations for vehicle classes 1-3 and the sum of allocations for subgroups 1 and 2, 1 and 3, and 2 and 3, must at least equal the corresponding marginal costs; this requirement is expressed by:

$$R_1 \geq C_{1,2,3} - C_{2,3} \quad (18)$$

$$R_2 \geq C_{1,2,3} - C_{1,3} \quad (19)$$

$$R_3 \geq C_{1,2,3} - C_{1,2} \quad (20)$$

$$R_1 + R_2 \geq C_{1,2,3} - C_3 \quad (21)$$

$$R_1 + R_3 \geq C_{1,2,3} - C_2 \quad (22)$$

$$R_2 + R_3 \geq C_{1,2,3} - C_1 \quad (23)$$

As indicated by Young et al. (12), if Constraint 11 holds, then Constraints 12-17 are equivalent to Constraints 18-23. This means that Constraints 18-23 are redundant and need not be considered in the analysis.

Constraints 11-17 define the set of feasible solutions for the cost allocation problem. This set is called the "core" (13) of the problem and is represented in Figure 5a. In this Figure the core is the shaded segment on the plane representing Constraint 11. The boundaries or sides of the core are indicated by Constraints 12-17.

The core may contain several solutions of which only one must be selected. One way to accomplish this is to systematically reduce the set of feasible solutions until it contains exactly one solution. The core reduction procedure is illustrated in Figure 5b. The core is reduced by "moving" its sides (constraints) in the directions of the corresponding arrows while keeping them parallel to the original positions. Mathematically, the size of the core is reduced if an amount t is subtracted from each right-hand side of Constraints 12-17. Because only one point is desired, the amount t should be as large as possible without violating any of the constraints. In conclusion, the core reduction procedure can be formulated in terms of the following linear programming model:

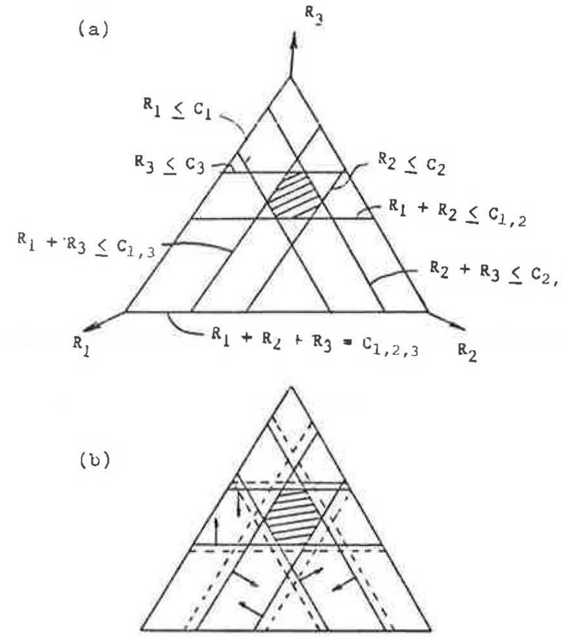

FIGURE 5 The core in the generalized method.

maximize t (24)

subject to:

$$R_1 \leq C_1 - t \quad (25)$$

$$R_2 \leq C_2 - t \quad (26)$$

$$R_3 \leq C_3 - t \quad (27)$$

$$R_1 + R_2 \leq C_{1,2} - t \quad (28)$$

$$R_1 + R_3 \leq C_{1,3} - t \quad (29)$$

$$R_2 + R_3 \leq C_{2,3} - t \quad (30)$$

$$R_1 + R_2 + R_3 = C_{1,2,3} \quad (31)$$

$$R_1, R_2, R_3, t \geq 0 \quad (32)$$

ENVIRONMENTAL FACTORS

An attractive feature of the generalized method is that it lends itself to a meaningful analysis of environmental costs. Environmental costs are those caused by factors other than traffic loads and, therefore, cannot be directly attributed to the individual vehicle classes.

The procedure described in this section can be easily extended to more than three vehicle classes. For convenience in this presentation, it is assumed that only three classes are involved. The total number of vehicle combinations in this case is eight. Each of these eight combinations can be represented in terms of a sequence of plus and minus signs, as indicated in Table 1. In this table, a negative sign indicates that a vehicle is not included in a combination, and a positive sign indicates that it is included. As an illustration, combination 2 corresponds to a design for class 1 only with cost C_1, while combination 4 corresponds to a design for classes 1 and 2, with cost $C_{1,2}$. In particular,

TABLE 1 Vehicle Combinations

Combination No.	Vehicle Class 1	2	3	Cost[a]
1	−	−	−	C_0
2	+	−	−	C_1
3	−	+	−	C_2
4	+	+	−	$C_{1,2}$
5	−	−	+	C_3
6	+	−	+	$C_{1,3}$
7	−	+	+	$C_{2,3}$
8	+	+	+	$C_{1,2,3}$

[a]"Cost" refers to the cost of a highway designed for a particular vehicle class or classes (i.e., C_0 = highway cost for 0 vehicle classes; C_1 = highway cost for vehicle class 1; and $C_{1,2,3}$ = highway cost for vehicle classes 1, 2, and 3).

combination 8 corresponds to a design for vehicle classes 1, 2, and 3; this is the design whose cost $C_{1,2,3}$ is to be allocated to the three vehicle classes. Combination 1 corresponds to a scenario with no vehicle classes. Because the cost C_0 associated with this scenario is not traffic-load-related, it is assumed that it estimates the cost effect due to environmental factors.

It is always possible to express C_0 as a fraction of the total cost; that is,

$$C_0 = eC_{1,2,3} \quad (33)$$

where e is an unknown number between 0 and 1. The methodology described in this section can be used to find a maximum value for e for given C_1, C_2, ..., $C_{1,2,3}$.

The proposed method is based on the concept of effects associated with a two-level factorial experiment (14). This concept is illustrated here using Table 1. As can be seen in this table, four combinations include vehicle class 1 and four combinations do not include it. The average cost associated with the combinations not including class 1 is given by

$$E_1^- = (C_0 + C_2 + C_3 + C_{2,3})/4 \quad (34)$$

Similarly, the average cost associated with the vehicle combinations including class 1 is equal to

$$E_1^+ = (C_1 + C_{1,2} + C_{1,3} + C_{1,2,3})/4 \quad (35)$$

The statistical effect of class 1 is defined as $E_1^+ - E_1^-$ because this difference measures the average increase in cost due to vehicle class 1. Letting E_1 equal $E_1^+ - E_1^-$, and using Equations 34 and 35, E_1 can be written as

$$E_1 = [(C_1 - C_2 + C_{1,2} - C_3 + C_{1,3} - C_{2,3} + C_{1,2,3})/4] - eC_{1,2,3}/4 \quad (36)$$

By setting $A_1 = [(C_1 - C_2 + C_{1,2} - C_3 + C_{1,3} - C_{2,3} + C_{1,2,3})/4]$ and $B = C_{1,2,3}/4$, it is possible to rewrite Equation 36 as

$$E_1 = A_1 - Be \quad (37)$$

The relationship given in Equation 37 is linear and indicates that the effect due to vehicle class 1 decreases as the impact of the environmental factors is increased. This behavior is shown in Figure 6a.

A similar procedure is followed to find the relationships for vehicle classes 2 and 3. Figure 6b shows three hypothetical linear relationships for the three vehicle classes under consideration. Since E_1, E_2, and E_3 must be positive, the range for e is

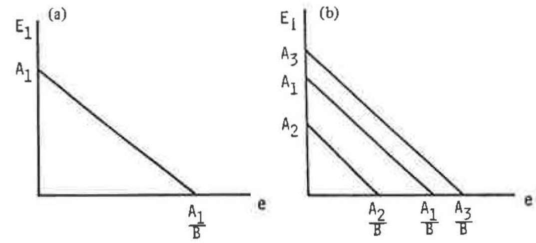

FIGURE 6 Effects of the vehicle classes on cost as functions of e.

between zero and the minimal A_i/B value. In the case of the illustration given in Figure 6b, this value is A_2/B. In general, $0 \leq e \leq e'$ where

$$e' = \min[(A_1/B), (A_2/B), (A_3/B)] \quad (38)$$

In summation, the cost effect due to the environmental factors can, at most, be a fraction e' of the total cost. Values of e exceeding e' are not valid because they would yield a negative value for the effect associated with at least one vehicle class.

APPLICATION

An application of the modified incremental approach and the generalized method using a small sample from Texas pavement data is presented in this section. Although realistic, these data are by no means comprehensive and are used here only for illustrative purposes. Results from these methods are compared to those from existing procedures.

It is intended to allocate the estimated rehabilitation costs incurred in an 18-year analysis period among four vehicle classes for a highway system consisting of two kinds of pavements. Table 2 describes the vehicle classes considered in this example, accumulated ESALs throughout the analysis period for each vehicle class, and percentages of VMTs corresponding to each vehicle class. Table 3 displays highway classification, pavement type, and pavement mileage for each of the two kinds of pavement.

TABLE 2 Vehicle Class Data

Vehicle Class	Truck Type	ESALs (millions)	VMT (%)
1	2D	3.590	96.43
2	3A	0.647	1.18
3	3-S2	15.317	2.06
4	2-S1-S2	5.172	0.33

TABLE 3 Illustrative Pavement System

Pavement	Highway Classification	Pavement Type	Mileage (lane miles)
1	Interstate	Flexible overlaid	57
2	U.S.	Hot mix	135

A modification of the RENU program (15) was performed to obtain rehabilitation costs for the variation vehicle combinations. Using these figures and ESAL data, rehabilitation costs were estimated for all vehicle combinations. Table 4 gives the rehabilitation cost estimates associated with each vehicle class combination. Figure 7a shows the behavior of

TABLE 4 Rehabilitation Cost Estimates

Combination	Cost ($ millions)
1	1.06
2	0.76
1,2	1.11
3	1.87
1,3	2.04
2,3	1.90
1,2,3	2.06
4	1.18
1,4	1.46
2,4	1.24
1,2,4	1.51
3,4	2.105
1,3,4	2.22
2,3,4	2.13
1,2,3,4	2.24

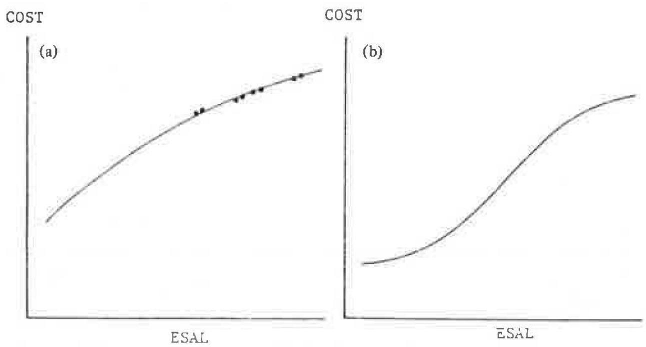

FIGURE 7 Rehabilitation cost as a function of ESALs.

these costs as a function of the number of ESALs applied during the analysis period.

Table 5 displays allocated rehabilitation costs for five cost allocation methods. The first column (INCR1) corresponds to the standard incremental method as described previously. The second column (INCR2) gives results from a variation of the standard incremental method where a cost increment is assigned not only to the vehicle class introduced at a given step but also to heavier vehicle classes, and is further divided among them on the basis of vehicle miles travelled (VMT). The column labeled "PROPR" shows costs allocated using a proportional method where the total cost is divided into nonload-related cost (33 percent) and load-related cost (67 percent). Nonload-related costs are allocated on the basis of VMTs whereas load-related costs are assigned in proportion to ESALs. The last two columns (MIA and GM) correspond to the application of the modified incremental approach and the generalized method, respectively.

TABLE 5 Comparison of Cost-Allocation Methods

Vehicle Class	Cost by Method ($ millions)				
	INCR1	INCR2	PROPR	MIA	GM
1	0.349	1.075	0.883	0.947	0.410
2	0.759	0.009	0.049	0.033	0.320
3	0.731	1.098	0.979	1.047	1.030
4	0.401	0.058	0.329	0.213	0.480

Note: INCR1 and INCR2 = incremental methods 1 and 2, PROPR = proportional method, MIA = modified incremental approach, and GM = generalized method.

A considerable difference in the results can be observed among the different methods. When there is a small increment in cost as a result of introducing a new vehicle class, the standard incremental method gives an unfair advantage to the newly introduced vehicle class, as can be seen in the first column (INCR1). The difference between the modified incremental approach and the generalized method is explained by the influence of the measure of (nonload-related) highway usage (VMT) on the allocation of common costs in the modified incremental approach. In these examples, the modified incremental approach attributes a significant portion of the total cost to the interaction of all vehicle classes. A large percentage of this interaction cost is absorbed by vehicle class 1 due to the high number of VMTs associated with it. On the other hand, the generalized method is insensitive to VMTs and allocates costs solely on the basis of costs occasioned by the vehicle classes. The maximum percentage of the total cost e' that can be attributed to the environment is equal to 45 percent, as indicated by Equation 38.

EXTENSIONS

The generalized methodology developed in this paper can always be used when the design costs correspond to the relationship shown in Figure 7a; however, if this relationship is changed to that shown in Figure 7b, the core may not exist. The reason for this is that the straight lines that are used to reduce the core, as shown in Figure 5b, will be actually displaced in the opposite directions. As indicated by Young et al. (12), it is necessary in this case to generate a core by introducing a procedure that will force the straight lines to be moved toward the center of the feasible region.

The core generation procedure is mathematically equivalent to changing the objective function (Equation 24) to minimization and changing the sign of t from negative to positive in Constraints 25-31. It should be noted that when the core generation procedure is needed, the marginality and/or rationality principles may not apply to some vehicle combinations.

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Funding Sources for Transit System Operations

RONALD EASH

ABSTRACT

This paper contains an analysis of transit system operating fund sources in the United States. Data were compiled from individual operators' reports to the Urban Mass Transportation Administration, U.S. Department of Transportation, as required by Section 15 of the Urban Mass Transportation Act of 1964, as amended. Funding sources are tabulated into five categories: earned income, locally provided support, federal support, state support, and other income. The average shares of a transit operator's income from these five sources are computed by the number of vehicles operated and by geographic region. The statistical correlations between the share of an operator's funding from a particular source and simple system performance measures are computed. Conclusions are drawn on the importance of federal operating support to different categories of transit operators.

The process of funding transit systems in the United States has changed substantially over the past 40 years. Until the end of the 1940s, transit systems were predominantly privately owned companies that depended on farebox revenues. Shortly after World War II, transit ridership started to decline because of increased automobile ownership and the shift of population and employment from central cities to lower density suburban areas. From 1945 to 1955 transit ridership declined by more than 50 percent in the United States (1,p.156). Private transit operators found it increasingly difficult to stay in business, and either curtailed service temporarily or abandoned operations altogether.

The 1950s marked a major conversion of the transit industry from private to public ownership, usually in the form of municipal and regional transit operating authorities. These operating authorities were able to obtain funds to buy needed transit equipment because they normally had the authority to issue bonds backed by the newly purchased equipment or future farebox revenues. Operating expenses were, however, still largely covered by passenger fares.

By the early 1960s, most transit agencies were at the point where additional public subsidies were needed to cover operating expenses as well as new equipment purchases. The Urban Mass Transportation Act of 1964 established federal support for the purchase of new transit vehicles and the construction of facilities. This federal capital assistance freed some local and state funds for operating subsidies. But the need for additional transit operating subsidies led to the National Mass Transportation Assistance Act of 1974, which provided for Section 5 federal operating assistance for transit systems.

Reviewed in this paper is the 1982 funding of transit operating costs through farebox receipts and revenues from different levels of government. Several analyses are presented that include:

1. Calculations of operating expenses recovered from the farebox for different-sized transit properties;
2. Examples of regional differences between local and state government responsibility for operating assistance; and
3. Measurements of the correlations between operating fund sources and transit system performances.

DATA SOURCES

The data for these analyses were obtained from the operating statistics that each transit operator reports under Section 15 of the Urban Mass Transportation Act of 1964, as amended. An annual report is compiled from these operator-supplied figures by the Urban Mass Transportation Administration, which includes individual operator and industry summary figures on transit revenues, transit expenses, nonfinancial operating data, and performance measures. The most recent report for 1982 is used in this paper (2).

Data are reported for 336 transit operators ranging in size from owners of a single vehicle to the New York Transit Authority/Metropolitan Transit Authority (TA/MTA), which operates nearly 11,000 transit vehicles. The data items used for statistical analysis are:

1. Total income received by an operator for operating expenses.
2. A breakdown of this income according to whether it is earned or comes from federal, local, or state sources.
3. Number of vehicles owned and annual passengers carried.
4. Population of the urbanized area where the operator is located.
5. UMTA local administrative region in which the operator is located.

For all practical purposes, reported income in the Section 15 report equals an operator's operating expenses.

There are several limitations to this data set, however. The most serious defect is that it does not include information on several transit modes, including commuter rail. As a result, revenue data for cities with extensive commuter rail services are incomplete. Reporting problems also occur when: (a) an operator purchases transportation services from another party; (b) when the service an operator provides covers more than one urbanized area; and (c) when there is more than one operator in an urbanized area.

AVERAGE REVENUE SOURCE CALCULATIONS

Revenue sources have been divided into five categories for the calculations:

1. Earned income, which comes primarily from fares but also includes other transportation revenue, such as school bus service, and some nontransportation revenue, such as advertising;
2. Local revenue, which includes taxes levied by the transit operator, local government special fare assistance, and local government grants;
3. Federal revenue, which comes primarily from Section 5 federal operating assistance;
4. State revenue, which includes state special fare assistance and state grants; and
5. Other revenue, such as interest income, which the operator receives from outside sources.

Total income for the 336 transit operators in 1982 was approximately $7.5 billion.

There are two ways to compute an industry average for the contribution from each of the aforementioned sources. First, all the funds can be summed by category for the 336 operators and then the average income source shares can be computed. This calculation provides true averages; but, it may not provide the best example of revenue sources for an average company because the characteristics of a few large transit systems may dominate the calculations. The New York TA/MTA alone accounts for more than one-fourth of all transit revenue in the United States. An alternate approach is to compute the average of the individual funding shares for each of the 336 operators.

Table 1 gives the average contribution by funding source calculated by using both methods. The difference between the two averages can be illustrated as follows. For the first average, the total earned income for all 336 operators accounts for 43.7 percent of all operators' revenue. However, the average contribution that earned income makes to total income for the typical operator is only 32.3 percent. This means that the first average is not a good descriptive statistic for earned income. The earned income of individual operators is not uniformly distributed around the mean, but is skewed because a few large operators have a disproportionate share of all earned income. The 27 largest transit systems account for more than three-fourths of all transit revenue, and generally also have the highest earned income levels.

TABLE 1 Operator Income by Funding Source

	Income Source (percent)				
	Earned Income	Local Support	Federal Support	State Support	Other
Average Computed by Total Income	43.7	29.1	12.3	13.3	1.6
Average Computed by Operator Sources	32.3	26.1	27.0	14.2	0.4

Regardless of the method of computation, earned income is the most important revenue source. The relative importance of local, state, and federal subsidies is, however, not entirely clear because they would be ordered differently depending on the average used for ranking. In terms of total dollars, the federal subsidy is less than either the state or local subsidy levels. Yet for the majority of operators in the data set, it contributes more to revenue than the other two government subsidies.

Table 2 gives data on these apparent contradictions. In this table, dollar contributions to transit revenue are computed for four different-sized transit properties: (a) very large transit companies with more than 500 transit vehicles; (b) medium-sized operators with between 100 and 500 transit vehicles; (c) operators with between 50 and 100 transit vehicles; and (d) small transit operators with less than 50 vehicles. Note first that the majority of transit operators in the data set are quite small, and second, the dominance of the larger operators. The average operator allocation of reve-

TABLE 2 Income Sources by Operator Size

Operator Size (Vehicles)	Number of Operators	Percent of Total Income	Funding Source (percent)				
			Earned Income	Local Support	Federal Support	State Support	Other
500+	27	77.7	45.3	29.1	10.1	13.7	1.8
100 to 500	61	14.9	41.3	30.1	17.4	10.0	1.1
50 to 100	62	3.9	32.8	25.2	24.4	17.5	0.1
0 to 50	186	3.5	30.9	29.0	25.7	14.4	0.1
Total	336	100.0	43.7	29.1	12.3	13.3	1.6

nue closely matches the allocation of the largest operators.

The data in Table 2 indicate that the importance of earned income generally declines for smaller transit operators, and that federal operating subsidies compensate for this decline in earned income among smaller properties. Local, state, and other revenue sources are hardly affected by operator size. The sum of these three revenue sources is a fairly uniform 40 to 45 percent of all revenue, regardless of the size of transit systems.

REGIONAL DIFFERENCES IN FUNDING TRANSIT SYSTEMS

Sources of revenue for transit systems were then tabulated by UMTA administrative region to determine whether there were regional differences in their funding. The states that make up the UMTA regions are shown in Figure 1.

Table 3 gives data on income sources by UMTA administrative region. These data indicate that there are some regional differences in transit funding that are correlated to some extent with the average transit system size in each region. Region II, which includes the New York metropolitan area plus New Jersey and several upstate New York transit systems, is unique for its high level of earned income and its relatively low percentage level of federal support. Both are also characteristic of large transit systems in general. With regard to the low level of federal support, this region accounts for one-third of all national transit revenue, and it is probably politically unacceptable for one region to receive one-third of all federal operating funds.

Some analysts have argued that federal support for transit has generally favored the new systems in the sunbelt states at the expense of the older and larger transit systems in the northeast. This appears to be only partially the case for federal operating subsidies. Although the southeast (Region IV) shows a high level of federal support, it is not significantly greater than the adjacent east coast (Region III) and midwest (Region V) UMTA regions. Surprisingly enough, the highest level of federal support occurs among the small number of transit systems in the plains states in Region VII. Federal operating subsidies for the remaining regions in the sunbelt, the southwest (Region VI), and west coast (Region IX), are only average.

The characteristics of local and state support can be summarized by examining the two extreme cases, the mountain states in Region VIII and New England (Region I). New England has the lowest level of local subsidy and the highest level of state subsidy, whereas the mountain states' region shows no state subsidies at all but the highest local support. In those UMTA regions that are not particularly urbanized, supporting transit is predominantly a local responsibility. States are more active in

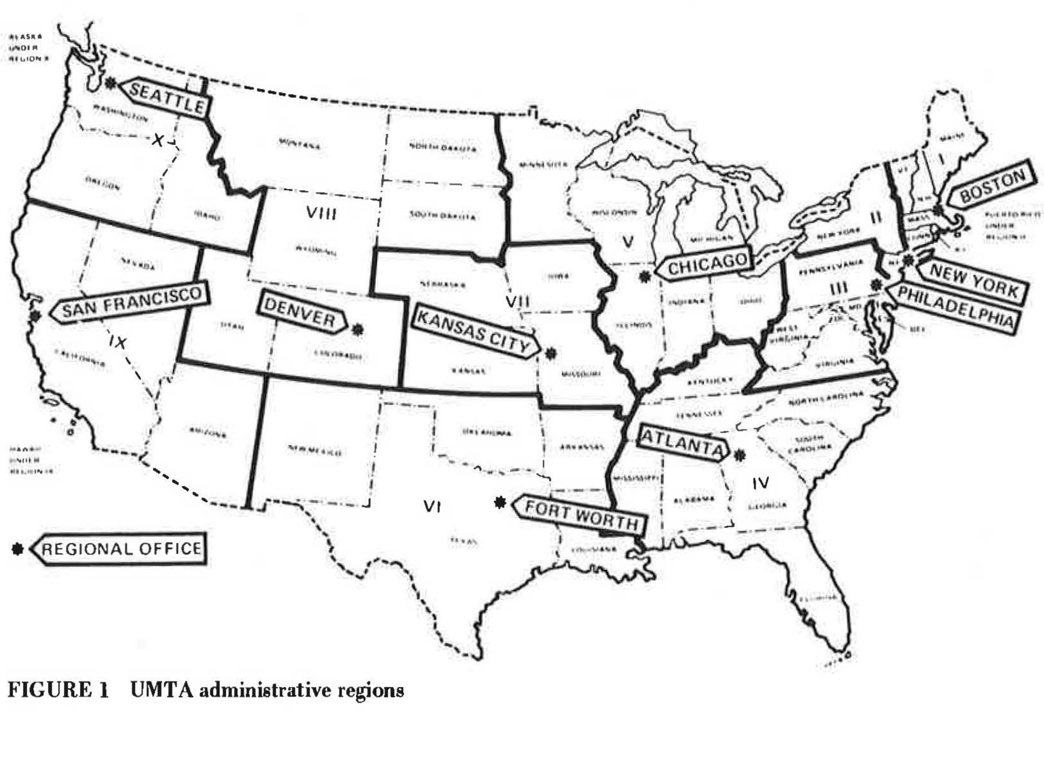

FIGURE 1 UMTA administrative regions

TABLE 3 Income Sources by UMTA Administrative Region

UMTA Region	Number of Operators	Percent of Total Income	Funding Source (percent) Earned Income	Local Support	Federal Support	State Support	Other
I	32	5.0	37.1	17.9	12.8	32.2	0.0
II	40	33.0	53.8	18.8	7.3	15.9	4.2
III	33	13.1	44.2	18.3	16.8	20.7	0.0
IV	46	4.7	43.4	36.6	19.6	0.5	0.0
V	75	16.3	39.8	33.6	14.3	12.3	0.0
VI	35	5.1	31.4	53.3	12.1	3.1	0.1
VII	15	2.0	30.8	40.3	23.2	5.6	0.1
VIII	6	1.6	23.9	62.3	13.8	0.0	0.0
IX	44	16.2	39.2	39.5	13.7	6.5	1.0
X	10	3.1	28.8	48.3	10.1	12.8	0.0
Total	336	100.0	43.7	29.1	12.3	13.3	1.6

subsidizing transit when their populations are largely urban. The relatively low level of combined local and state subsidies in the New York-New Jersey Region II is explained by the high level of earned income that transit systems in this region generate.

TRANSIT SYSTEM PERFORMANCE AND FUNDING SOURCES

A correlation analysis was carried out to describe the relationships between funding for transit systems and their performance. The different funding shares for the individual operators were correlated with six variables that characterized the metropolitan area where the transit service was provided and the efficiency of the transit system. These variables are total revenue, urban area population, transit vehicles operated, annual passengers carried, vehicles per population, and passengers per population.

Table 4 summarizes the results of this correlation analysis and lists the correlation coefficients along with their significance at the 95 percent level.

The data in Table 4 indicate the trend for earned income noted earlier--that the proportion of an operator's total revenue from earned income increases with the size of the transit system. Earned income also appears to depend on operator efficiency as measured by per capita urban area passengers. Local and state sources of revenue show less correlation with the selected variables. However, local support appears to be at least slightly positively correlated with the size of the operator and with transit system performance.

Federal operating support for transit shows the most interesting correlation characteristics. Federal operating support is significantly negatively correlated with size of the transit systems, thus corroborating the previous discussion. However, federal support is also negatively correlated with the three system performance variables: passengers carried, vehicles per population, and passengers per population. Transit systems that are poor performers in terms of these measures depend to a greater extent on federal operating subsidies than on better performing systems.

The data in Table 5 indicate how funding sources correlate with annual passengers and passengers per population for the four different-sized transit operations used previously. Note that the funding sources are interrelated because the funding source variables are expressed as percents and must sum to 100 percent. A positive correlation for one funding source implies that at least one other funding source must be negatively correlated for a given transit system size category. Because the data are divided into more categories than in Table 4, the significance of the correlation coefficients is generally less, and a lower value of 90 percent is used as a threshold significance.

There are some general differences in the correlation coefficients depending on the size of the transit system. By examining the signs on the correlation coefficients, it is possible to ascertain some of the reasons for these differences. For very large transit systems, high per capita ridership tends to make a transit system more self-supporting because of increased earned income. For medium-sized

TABLE 4 Correlation Between Funding Sources and System Performance Variables

Funding Source	Total Income	Urban Area Population	Transit Vehicles	Annual Passengers	Vehicles/ Population	Passengers/ Population
Earned Income	0.12*	0.28*	0.16*	0.13*	0.02	0.16*
Local Support	0.03	0.02	0.02	0.01	0.11*	0.09
Federal Support	-0.20*	-0.37*	-0.23*	-0.17*	-0.14*	-0.26*
State Support	-0.01	0.01	-0.01	-0.01	-0.01	-0.03
Other	0.07	-0.01	0.06	0.07	-0.07	-0.04

*Probability that the correlation is nonzero is greater than 95 percent.

TABLE 5 Correlation Between Funding Sources and Ridership Variables by Vehicles Operated

	500+ Vehicles		100 to 500 Vehicles		50 to 100 Vehicles		1 to 50 Vehicles	
Funding Source	Pass.	Pass./Pop.	Pass.	Pass./Pop.	Pass.	Pass./Pop.	Pass.	Pass./Pop.
Earned Income	0.37*	0.29	-0.00	-0.27*	0.29*	-0.08	0.22*	0.16*
Local Support	-0.15	-0.20	0.18	0.24*	-0.04	0.24*	0.04	-0.10
Federal Support	-0.33*	-0.26	-0.31*	0.01	-0.30*	0.12	-0.22*	0.03
State Support	0.01	0.15	0.00	0.02	-0.05	-0.06	-0.07	-0.07
Other	0.95*	0.54*	-0.05	-0.11	0.03	-0.05	-0.09	-0.11

*Probability that the correlation is nonzero is greater than 90 percent.

transit systems, however, the situation is reversed--high per capita ridership is associated with lower levels of earned income and higher levels of local subsidy. The positive correlation with local subsidies for these medium-sized systems means that the high per capita ridership has been achieved through high local subsidies and low fares.

Earned income is positively correlated with total riders for three of the four sizes of transit systems, as would be expected. Although there is some evidence that local support is correlated with per capita passengers for medium-sized transit systems in particular, state support is uncorrelated with this system performance measure regardless of system size. Federal operating support is generally negatively correlated with both the total passengers and per capita passenger variables. In fact, federal operating support is significantly negatively correlated with total ridership for all four size categories of transit systems.

SUMMARY AND CONCLUSIONS

Existing patterns of funding for transit can be summarized in the following manner. Earned income, largely from passenger fares, accounts for approximately one-third of smaller operators' revenue and increases up to nearly one-half of revenue for the very largest transit systems. State and local subsidies consistently account for 40 to 45 percent of a transit operator's income. Federal operating support is used to close the gap between earned income from the farebox and the operating costs remaining after state and local subsidies.

The division of subsidies for operating costs between state and local sources depends on: (a) the degree of urbanization in the state; (b) traditional divisions between state and local government responsibility within regions of the U.S.; and (c) the apparent desire of some medium-sized cities to promote transit use through high local subsidies and low fares. Local support of operating costs also appears to be somewhat related to performance of the system as measured by ridership.

Existing federal operating subsidies tend to favor smaller transit systems, but federal operating subsidies are less regionally biased toward the sunbelt regions than many have argued. The method by which federal subsidies are distributed does appear to reward inefficient transit systems. Moreover, this tendency cannot be completely explained by different regional characteristics or by the inefficiency of smaller transit operators.

Depending on one's point of view, federal operating subsidies either support inefficient operations or are a safety net to keep marginal transit systems operating until ridership builds. Current policies for distributing federal operating support do not appear to offer incentives to transit operators to improve system efficiency or to local and state governments to increase their support. It is also clear that the smaller transit systems will be hurt the most if federal operating subsidies are reduced without changing the way federal operating support is allocated because a larger percentage of their income is obtained from federal subsidies.

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Practical Implementation of Innovative Financing in Rural Mobility Programs

ALICE E. KIDDER

ABSTRACT

The majority of rural areas in the United States have no available public transportation. Fear on the part of local elected officials that such a mobility program may overstrain local budgets, and the failure of state and federal funding to provide an infrastructure for developing, planning, and implementing such programs on behalf of rural areas may account for the vast imbalance in per capita expenditures for transit between urban and rural areas. This paper contains data on exceptional cases: examples in which local initiative has succeeded in installing at least a modest level of stable long-term mobility for rural residents. The following questions are considered: (a) What level of service is financially viable in low density areas in the long run?; (b) What are the sources of support, and how stable are they?; (c) Are the "success" stories replicable, or are they the result of unique situations of state support, unusual rural economic conditions, or other nonreproducible conditions?; and (c) What are the roles of state and federal government in financing and regulating the promotion of innovative financing arrangements for rural public transportation?

It is a truism that rural mobility programs cannot exist on a long-term basis unless the total revenues from fares, sales, and subsidies exceeds the sum of operating and capital costs. Because the accounting for financial inflows and outflows is done annually, deferred costs or temporary deficits (delayed payments to suppliers) can obscure the basic formula:

$$C(X)_t \leq R(X_t) + S_t \quad (1)$$

where

- $C(X)_t$ = dollar value of costs (both capital and operating) of producing transportation service X during time period t, including the implicit dollar value equivalent of in-kind contributions;
- $R(X)_t$ = revenues other than subsidies, that are generally a function of the service given (e.g., fares, sales of advertising space, payments for contract or charter service, payments for subscription service, etc.); and
- S_t = subsidies or funds received from public sources, private donations, or implicit support from creditors in a deficit; also, the dollar value of in-kind contributions.

For simplicity, the relationship may be summarized as revenues plus subsidies must be greater than or equal to the costs of operating and replacement of used equipment.

The average rural community has no public transportation because: (a) the costs of setting up and implementing such a program are prohibitive--the organizational, administrative, and operating costs are approximately $0.30-0.50 per vehicle mile and average trip lengths are 10 miles round-trip from origin to destination; (b) revenues are insufficient to cover start-up costs--in many cases, long-term ridership would be so low that the farebox revenue would cover only a small portion of the operating costs; and (c) subsidies are not available--many states have no program to provide operating assistance to rural areas, and federal Section 18 funds only average about $2 million per state; consequently, they cannot be expected to serve the majority of rural communities.

FINANCIAL APPROACHES

It is interesting to note that some exceptions to these generalizations do exist. A growing number of rural systems has achieved a long-term balance between inflow and outflow by using the following approaches.

Type 1. Reduction of Cash Costs by Use of Volunteers and Other In-Kind Donations

In this approach, subsidies come from private, in-kind donations, such as service providers who offer their time, vehicles, and gasoline to operate a program of rural mobility. In this case, cash costs are very low. Revenues, however, are also likely to be low or nonexistent.

An excellent example of this type of funding is ELDERBUS. In 1973, a surgeon in Southbridge, Massachusetts, secured $2,500 from the Lions Club to lease a station wagon. He used his office's answering service to collect requests for service and recruited volunteer drivers from among the town residents. In time, the program became well-enough established to derive support from state and federal funding sources (1,p.17).

Type 2. Private Sector Solutions where the Level of Service is Determined by the User's Willingness to Pay Full Cost

In a 1976 survey of 1,000 randomly selected small communities, North Carolina Agricultural and Technical State University's Transportation Institute found that approximately one-third of the rural communities interviewed had some (low) level of service provided by taxi companies on a pay-as-you-go basis. In these cases, rural residents had to pay very high per-mile rates that compensated for the high cost of providing service to low-population areas. For the most part, subsidies did not exist here, and the revenues equalled the operating costs. The system's long-term viability depended on the taxi company's ability to generate sufficient revenues from rural or urban service to facilitate needed capital replacement when necessary.

Type 3. Social Service Agency Provides Outreach to Rural Areas as Part of General Operating Budget

In this approach, a single social service agency, which is independent of transit or other social service agencies, provides some kind of service to rural areas such that revenues plus external and internal subsidies from the operating budget cover the full value of the costs of service operation. This is expressed as

$$C(X)_t \leq R(X)_t + [S_{agency}]_t + S_t \quad (2)$$

The key to long-term stability is the continuation of subsidy for the agency's basic purpose; when changes occur in the operating budget of the agency, the transportation activities may fall an early victim to budget cuts.

Type 4. Coordination of Service Delivery and Financing Among Several Social Service Agencies

In this case,

$$R(X)_t + [S_i]_t \geq C(X)_t \quad (3)$$

where R represents revenues including payments from one agency to another for clients from a coordinated or integrated transportation program offered by one or more members of the social service agencies group serving a rural area; and S represents a subsidy that may include the combination of in-kind services (i) from a variety of agencies.

The social service agencies may also derive subsidy from programs such as the Urban Mass Transportation Administration (U.S. Department of Transportation) 16(b)2 program that covers much of the cost of buying new vehicles, or from state support for regional transportation program operating costs.

Type 5. Joint Urban/Rural Transportation Authority Operation of Programs

In these cases, the distinction between urban and rural systems is blurred. Rural transportation authorities operate in a fashion similar to urban ones, offering long-term service built around high levels of point-to-point demand (such as commuter service to an industrial park from a limited number of communities), or are service extensions of high-demand urban systems.

Here, subsidies from the state frequently result in the long-term survival of the system independent of its revenue generation. Subsidies support the whole system, in the urban/rural context, and the cross-subsidy from the high-density service to the low-density service may be quite high, but hidden in the total budget of the whole organization.

Type 6. Rural Public Transportation Programs Operating under Authority of Local Political Jurisdictions

Some rural areas (a remarkably small number) have been able to achieve positive votes for long-term local subsidies of transportation service that operate within a designated political jurisdiction or combination of such jurisdictions. In this case, the rural area(s) have an agency that acts as a counterpart to the urban transit agency in providing service to the general public. The long-term financing for this project comes from the assurance of local support, and from the ability to attract state and federal funding on the same terms as urban transportation authorities.

APPROACHES TO FINANCING

The preceding typology does not exhaust the list of ways in which long-term rural mobility programs are supported, but reflects the most generalizable examples. Other examples are indeed unique such as Native American programs of community transportation that draw funds from the Bureau of Indian Affairs; experiments with statewide rural systems, such as the Delaware Authority for Special Transportation; and programs sponsored by individual employers, such as the Pilot Life bus program in High Point, North Carolina.

Volunteer Systems

In a number of rural towns in Central Massachusetts (e.g., Bolton, Boylston, and Harvard) local volunteer groups called "Friends of Elders" have formed. These volunteers work with programs for the elderly (e.g., councils on aging, senior citizen groups) by providing transport by private automobile on request. One volunteer takes charge of telephone contact work using a residential phone; other volunteers work on a schedule to provide service as needed. The financial burden is borne by the individual volunteers, without compensation. Tax deductions are available for these expenses, however, because the in-kind services are provided through a charitable organization.

This type of program has two advantages: (a) it is flexible enough to meet changing needs without the cumbersome task of obtaining altered external funding or doing long-range planning; and (b) the system places no burden on the taxpayers, who have shown by their support of legislated tax ceilings that they will not tolerate additional social service programs.

The drawbacks of such a system are equally obvious: (a) The program is not visible to the general public--therefore, it cannot be relied on as a source of mobility for nonresidents; (b) The program is self-limiting--the availability of volunteers limits the time, distance, and other dimensions of the service offered. The program is most useful in support of organizational activities (bringing people to nutrition programs or medical facilities), rather than as a source of personal mobility for the average rural resident; and (c) The program serves only a subset of the transportation-disadvantaged individuals in rural areas: the elderly whose travel demands match the service levels offered by the volunteers.

For-Profit, Private Sector Solutions

Both taxi and privately operated bus services have decreased in rural areas. Deregulation has enabled major carriers to withdraw intercity service from a significant number of rural communities; what is not known is how many smaller, local operators have assumed responsibility for short-line service. In a June 1984 conversation with Edward Ramsdell of the Transportation Systems Center, the author was informed that recent research by the Center suggested that the abandoned service was not important in terms of lost mobility because the stops that were dropped were not heavily used.

Many rural communities have taxi service only as an occasional run from a more urban community some distance away. There may be a delay of several hours on calls for service where pickup is required. The service is costly to the users, as the per mile rates must cover the costs of both front haul and (empty) backhaul.

This service could be subsidized and coordinated with social service transportation needs, but this rarely occurs. The network of contacts of the private operators appears not to overlap with that of the social service agencies. Federal regulations require that UMTA Section 16(b)(2) recipients who request funding must notify taxi companies of their intent to offer service. It would be interesting to study whether such a procedure results in more use of private sector solutions for rural social service mobility programs.

One innovative method that has been found to link the rural transportation-dependent individual with private transportation operators is the use of a brokerage agency. The Central Vermont Transportation Association, for example, takes calls from would-be riders and refers them to existing trip-makers (taxis, school buses, commuters, etc.) But where do the funds come from for even this basic overhead? The answer is a series of special demonstration grants supported by the U.S. Department of Transportation. Under Section 4(i) of UMTA funding, and, previously, a Federal Highway Administration Transportation Systems Management (TSM) grant, the program initiators derived financial support to initiate the brokerage program. But what happens after the termination of federal funding? It is hoped that the program will be converted into a regional transit district under the statutes of the state of Vermont. Under those circumstances, it would become a "type 6" system, fully eligible for state and federal operating and capital assistance. Time will determine whether this strategy is successful. The system currently derives funds from social service budgets, following the "type 4" model description that follows.

> The City of Chico (California) was the first community in Butte County to establish [a transportation service for the elderly and handicapped.] Chico, the largest city in Butte County with a population of about 50,000, is an agribusiness center...Financing the Chico elderly and handicapped system was no problem, as abundant TDA (state sales tax) funds were available. However, ... staff who were responsible for designing the elderly and handicapped system were under pressure to develop the most cost-effective service possible...The El Cajon shared ride taxi service appeared to be a noteworthy success, and it was decided to emulate its features as much as feasible. The two most important aspects of system organization which were copied from El Cajon were shared ride operations and compensation of the DRT provider on a consumed service basis. The latter was accomplished by paying the provider a fixed fee per ticket collected from the riders, the fee being determined by competetive bidding...These features of the system's organization were most compatible with operation by a local taxi company. Not surprisingly, the Chico taxi and ambulance company was the winning bidder with a bid of $1.95 per ticket collected (up to three can ride on one ticket.) (2,pp.8-9).

Social Service, Single Agency Approach

An excellent example of this kind of rural outreach transportation program is provided in New York State by the Associations for Retarded Children (ARCs). By using state funds, the ARCs pick up the participating children in rural counties and transport them, usually by car, to their respective special schools. This type of service is very expensive, with the per capita cost frequently more than $4,000 per year. However, the service is deemed necessary, because there are not alternative transportation providers.

Stability of funding rests with the continuation of state support for the entire activity. Fluctuations in social service agency funding can lead to changes in the mobility components of such programs. An example of this variation may be found in the demise of the human resource development programs. Transportation expenses were frequently subsidized by CETA funding; with its termination, however, the transportation to training programs ceased.

Many rural areas currently have service on a limited basis from these types of programs. Following is a list previously researched by the author, which gives the variety of funding sources used in rural systems and includes the social service agencies likely to offer service to rural areas:

- Associations for Retarded Children
- Councils on Aging
- Community Block Grant programs to former OEO programs, now typically a social support, local agency
- Community Mental Health Programs
- Community Mental Retardation Programs
- Easter Seal Programs
- Private Industry Councils (inheritors of the employment and training programs)
- Visiting Nurse Associations
- Vocational Rehabilitation Programs (frequently state-operated)

The typical pattern is to use overhead funds to design, plan, and implement the program (staff time of management, typically), and later to use portions of the general operating budget of the agency to cover the costs of gas, oil, and so forth. Volunteer drivers are frequently used or agency personnel are called in to provide driver services. Thus, the costs of the transportation program are hidden in the general budget, which becomes a source of substantial subsidy funding for the mobility program.

The advantage of this funding base is that it does not depend on political decision making over the level of transit support (frequently a political football in state legislatures), but is derived principally from decisions at the federal level to fund broad-based social service programs or from private donations to local charitable organizations that are likely to continue over time.

The difficulty is that these mobility programs are not community-wide, but focus on a subset of the mobility needs of only the client population. This type of program does not serve the personal transportation needs of transit-dependent individuals for shopping, recreational, or social purposes, because the trips are typically limited to bringing clients to participate in the agency's programs.

Multiagency, Coordinated Transportation for Rural Areas

Madison County in New York State has designed a plan for a multiagency transportation program that is coordinated by the county government. It links the following transportation resources: (a) UMTA Section 16(b)(2) vehicles from social service agencies, (b) vehicle maintenance from the vocational education program, and (c) operating support from the Council on Aging.

The program has demonstrated that single agency programs operating independently within the county frequently have vehicles going empty in one direction. Matching up route patterns can have the effect of eliminating empty backhauls. Sharing of operating costs reduces the burden on any one agency.

A serious handicap to the growth of this program into a regional transportation service is the decision on the part of the New York State Department of Transportation to interpret UMTA guidelines as precluding the use of Section 18 funds for programs built out of UMTA Section 16(b)2 vehicles with a social service thrust. This dilemma has been skirted in other states that have permitted such pooling of resources.

Perhaps the most well-known of the coordinated systems is OATS (formerly the Older Americans Transportation System) operating in 88 counties of rural Missouri (3,pp.14-15). The agency, originally set up with a $30,000 grant from the Office on Aging, now enjoys purchase of service contracts with eight area agencies on aging, and receives funds from social service block grants and the Older Americans Act. Other revenues come from the state Department of Mental Health. Rider donations and outright gifts from local groups make up about 15 percent of the budget.

Another example of successful merging of funding from different sources is the previously described Central Vermont Transportation Association (CVTA). The CVTA also serves as an intermediary between funding sources and transportation providers, and has drawn funds simultaneously from the United Way, Medicaid, UMTA Section 16(b)2, vocational rehabilitation, and funding for programs on aging. They expect to be eligible to receive UMTA Section 18 funding after they have achieved transit authority status.

Rural Systems as Extension of Urban Systems

In the Delaware Valley, the LANTA transit agency not only serves the major cities of Easton, Allentown, and Bethlehem, Pennsylvania, but also runs service to outlying areas such as Forks Township. In Albany, New York, the Central District Transit Authority (CDTA) uses state and federal funds given to the agency as a whole to provide rural service into Rensselaer and other low density areas. In Massachusetts, the Worcester Regional Transit program includes twice-a-day runs through rural communities to Clinton, Massachusetts. These cases are examples in which the cost of operating a fixed-route service to rural areas is cross-subsidized by the general subsidies going to the entire urban-based transportation system. Section 18 federal funds for rural areas are frequently used to cover the marginal costs of these low-density area programs. This is true in the case of Worcester, Massachusetts, for example. Start-up costs are reduced because planning and vehicle acquisition can be performed by an urban system that has considerable local-service experience.

Unfortunately, these fixed-route links between rural and urban areas are likely to be set up to facilitate the needs for vehicles in the cities, and do not reflect the origin and destination needs or the trip time requirements of rural residents. A person in Clinton taking the bus to Worcester for a doctor's appointment will have to wait in Worcester until the end of the day to return on the second bus trip.

These programs have the advantages of visibility. They are open to the general public. They do serve some of the needs of the general population of transportation-disadvantaged individuals. For instance, they facilitate the movement of transients between urban and rural areas and are occasionally used by the rural poor and elderly for shopping and medical trips.

These programs do not come close to meeting the mobility needs of rural populations, however. For example, (a) they do not provide service between neighboring communities, (b) they do not deliver clients to social service agency programs, and (c) the routes do not necessarily match the needs of the poor to get to welfare offices, employment offices, or food stamp programs.

The federal Section 18 program funds are more likely to go to this kind of program, because the urban transit authorities have close negotiational links with the state departments of transportation through which the federal rural funding must pass. Also, the urban agencies have the professional capacity to participate in the planning process, and through the metropolitan planning organizations are set up to conceive their mission on a regional basis. What these groups lack is familiarity with the trip-making patterns of local, rural residents. They frequently have no information on the location of the transit-dependent individuals in these areas, nor of their travel demand patterns. The urban planners are likely to assume that the principal demand is for service to the adjacent large metropolitan area. As services redeploy to more attractive, near-rural areas, the trip patterns of rural residents are reoriented more toward nearby rural towns and suburbs, than to the core of the urban center.

One of the most innovative responses to this dilemma can be found in Kingston, New York, where the local transit authority receives Section 18 funding through the state. The transit authority provides an extensive network of trips on a route-deviation basis with advance reservation for rural residents throughout a wide rural area. Through careful planning, trip generators such as the local community college, medical centers, rural shopping centers, and other likely destinations are linked with outlying rural residents. Trips are planned to serve one quadrant of the area one day and another quadrant the next. The county planner provides an in-kind donation of professional services in planning and managing the system. Use of agency vehicles acquired from former programs spreads the resources. Some adjustments of basic routes have been required by funding cutbacks, but other users (such as students) help to generate new revenues.

Rural Community Government-Sponsored Transportation Programs

The type of agency most likely to design service to meet the needs of the rural transportation-dependent individual is a locally supported, public trasportation program operated or contracted for by a local government. The most prevalent example of this is the rural school busing programs, organized and paid for by local school boards.

Why do we not find many examples of rural transportation authorities? Because rural elected officials fear the specter of high transit deficits that follow the fate of some urban transit programs. Nevertheless, where state or federal funding has assisted with pioneering demonstration projects, some examples of rurally voted transportation subsidies can be found. A number of rural Michigan communities dedicated portions of the local property tax to support dial-a-ride programs initiated in the 1970s.

Residents who have voted for state revenues to be specifically allocated to support rural transportation programs (New York and California are the most notable examples) are most likely to see the rise of rural transportation programs. For example, California uses an earmarking of sales tax revenue to support nonurban transit. Such a state-level initiative provides an opportunity for long-range planning and implementation of a regional, rural-oriented transit. It would be useful to have a survey of a random sample of California rural communities to determine what difference such funding availability makes to the level of service delivered in the "average" community. Clearly, the availability of Transportation Development Act (TDA) funds was an element in the success of the Chico taxi-based system described earlier.

LONG-RUN VIABILITY OF SERVICE LEVELS IN RURAL COMMUNITIES

There is no one "optimal" service level that is cost-effective for rural areas. The existing systems show a wide array of service levels. The matter is up to the local communities. Heavy investment in service, such as in Kingston, New York, pays off with increased accessibility ot colleges, hospitals, and shopping centers to the rural transit-dependent individual. Alternatively, low levels of service are provided very cost-effectively by all-volunteer systems.

It is clear that where resources are marshalled to provide a high level of service, it is possible that resources can be wasted. In Plattsburgh, New York, for example, a fairly high level of state support to that rural system permitted it to run an experimental bus route to an outlying area for 3 months without a single rider! Such examples demonstrate the futility of applying urban-oriented, fixed route, large bus solutions to low density areas. Much more likely to generate ridership is the demand-responsive, or at a minimum, the route-deviation approach, such as is used in Kingston, New York.

STABILITY OF FUNDING IN NONURBANIZED AREAS

Fear of the long-range uncertainty of the continuation of Section 18 funding reduces the utility of federal sources in stimulating new programs. Other funding sources (medicaid, community block grants, mental health, for example) appear to be a steadier source of financial support to mobility programs reaching low density areas. Even these programs are subject to political overhauls, however, and are not immune to budget pairing. How this affects the transportation components depends on how the bureaucracy views the role of mobility in service delivery.

Volunteer systems also experience ups and downs in resource availability. Because they are less visible to the general public and the press, their inability to provide a continuing service may not be as blatant as when a social service program closes or when an intercity bus route is abandoned.

Instability is rooted in the current financing system which takes decisions outside the hands of local decision makers. Whether or not a given rural community has a particular level of service is the result of financing decisions made by social service agencies, state legislators, UMTA officials, and many others not resident in the rural community. Because there is no dedicated funding automatically open to a rural community that elects to match funds on an equal basis, for example, local elected officials do not usually debate the value of adding a public transportation program to local social service initiatives. They fear that they may soon be left with 100 percent of the financial responsibility for operating and renewing the service.

CAN CURRENT RURAL SYSTEMS SERVE AS ROLE MODELS FOR LONG-RUN ECONOMICALLY VIABLE PROGRAMS?

Unfortunately, the existing examples of rural mobility systems that have lasted more than 5 years frequently appear to have special circumstances surrounding their birth, growth, and current financial success. Short-term federal initiation grants (such as the Section 147 program) got some programs off to an unusually high level of initial funding. In many cases, ridership was neither large nor wealthy enough to sustain that level of funding, and the proximity of rural areas to the planning expertise of an urban system (as in the case of Rensselaer County and Albany) has resulted in a level of service that cannot be duplicated in a more isolated rural county, such as Madison County, New York.

"Type 4" systems appear to be easier to replicate elsewhere. The overhead costs of setting up a coordinated system can be met by the determination of a social service agency manager to devote staff time to the purpose. A recent Massachusetts conference on rural transportation demonstrated that such initiatives could come from a variety of sources: community action organizations, health care providers, councils on aging, church groups, employers, and many other groups with flexibility in work assignments to paid managers (4).

Other funds can occasionally be found for start-up of coordinated, interagency systems. For instance, demonstration project funding from the U.S. Department of Transportation is offered on a competitive and recurring basis; state funds are available through Offices of Aging (where the state decides this is a priority); and in one case, seed money came from the U.S. Department of Agriculture as a feasibility experiment on rural transportation cooperatives. Alert local staffers can keep abreast of these external funding opportunities by reviewing the Federal Register and other publications listing available grant opportunities.

Type 4 systems appear to have a good success rate in maintaining funding. Where funds from several social service agencies are pooled, as was the case in OATS, cutbacks in one source can be made up by applications to newer opportunities. Skill in grantsmanship and perseverance are obvious requirements.

Nevertheless, administrative entanglements can cause financial difficulties in coordinated systems. A recent Department of Health and Human Services study noted (5,pp.28-29):

> ...financing difficulties were encountered across the (HDS coordination experiment)

projects. The major problems tended to fall into one of four categories: cash-flow problems with service purchasers, the nature of the coordination savings, finding stable sources of operating assistance, and capital replacement...

The report goes on to note that although there are cost savings from coordination, these tend to be expended in increased service levels and higher costs of management and administration rather than in a total cost reduction for the combined system.

ROLE OF STATE AND FEDERAL FINANCING AND REGULATIONS

State financing opportunities are currently much more important than federal initiatives in determining which rural programs can be started. For the most part, UMTA Section 18 funds have already been deployed to sustain existing rural programs, and frequently serve to add a rural link to existing urban programs. Few states have uncommitted funds that could be used to underwrite the initiation of new rural service. The case of the Chico, California, taxi-based system shows the advantage of a dependable, state-based transportation funding source that gives a private supplier of service a rationale for long-term private investment of funds in vehicles and service delivery.

State regulations, or interpretations of UMTA guidelines, are very important in creating conditions that encourage or discourage the development of innovative local rural financing. A recent statement by a New York legislative commission on rural resources cites an example where state DOT regulations have impeded development of locally initiated coordination programs (6,p.8):

> ...state administrative oversight (of Section 18 programs) has attempted to fit local planning efforts into an urban criterion. New York State implementation of Section 18 serves to frustrate coordinated usage of 16(b)(2) vehicles and Section 18 funds as intended by Congress and consistent with local needs. We have found that some New York State localities have been in the 'planning' stages since 1979, in their efforts to set up a rural transportation system under Section 18 guidelines.

This criticism suggests that there is a double-barreled impact of having both federal and state regulations governing the allocation of transit subsidies; each program's rules have an impact, but the interpretation of each other's rules may have a secondary, confusing impact.

CONCLUSIONS

This paper contains a number of illustrations of how the costs of offering rural mobility programs have been met on a continuing basis through a combination of revenue and subsidy sources. The illustrations show that there are many variations in service levels and cost that have evolved from local experimentation with means for improving the mobility of transportation-disadvantaged individuals--some of whom are almost cashless. Others require very high levels of state funding. What these illustrations have in common is the documentation that needs for passenger service exist and can be met with a variety of innovative financing approaches. The menu is large--it should offer an attractive array to elected officials from the majority of rural communities, which have no mobility programs whatsoever.

The suggestion is made in this paper that state, rather than federal, funding and regulations are becoming the key element in creating the opportunity for local agencies to initiate and develop a coordinated transportation funding mechanism. Change agents are most likely to be found among social service agency managers, who see mobility programs as a means to a wider goal of service delivery. UMTA and state DOTs should investigate means for improving the utilization of these local management resources, especially in localities where urban planning expertise is not readily available.

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A Virginia Model for Financial and Community Support of Rural and Specialized Transportation Systems

BETTY L. NEWELL and PETER SCHAUER

ABSTRACT

The information in this paper is based on documented field experience in Central Virginia where two human service agencies, a community health center and a community action agency, are using current transportation funding to provide the local match required to fund a regional public transportation system in four very rural counties. Virginia has several unique elements that affect the local share required for a community to institute public transportation. For capital expenditures, UMTA Section 18 will provide 80 percent. If requested by a local governing body, the Virginia Department of Highways and Transportation will also contribute an additional 19 percent, leaving only a 1 percent local share remaining to be funded. Further, this 1 percent local match can be raised through local business donations because Virginia has a Neighborhood Assistance Act program that will provide a 50 percent tax credit for donations to approved community projects. Because of the strict nature of Virginia statutes, not only is a thorough financial plan required, but strong local community development is required to assure local government support for a system. Virginia's experience in funding is important to share with other states in fostering rural and specialized transportation systems and the positive aspects and some of the drawbacks of this model are shown in this paper. Virginia statutes tend to create a favorable environment for rural and small urban transportation in contrast to the hostile or benign environments typical in most states.

As do most states, the Virginia Department of Transportation (VDH&T) places heavy emphasis on highways and spends a relatively minor portion of transportation funding on public transportation. There are, however, several statutes that create a favorable environment for public transportation and have helped a new rural provider, the Central Virginia Transportation system (CVT) to be established in the Central Virginia counties of Amelia, Buckingham, Cumberland, and Fluvanna.

These four counties are in the Piedmont area of Virginia west of Richmond, north of Farmville, and east of Charlottesville. This area contains approximately 1,500 mi^2, has a population of 38,000, and a population density of 26.7 persons per mi^2 including 6.6 percent transportation-disadvantaged (1), 13 percent 65 years or older, and 18.9 percent below poverty level. This area has a significant need for public transportation when compared to areas where public transportation is already provided. The district's rural character is reflected in the large percentage of land devoted to agriculture and forest. Although agricultural uses still dominate the district land use pattern, agriculture employment has declined continually over the past 30 years. Jobs in retailing, service, and government sectors have increased steadily and manufacturing employment has shown increases over the past 20 years.

The lead agencies for planning services in the area were the Central Virginia Community Health Center, Inc. (CVCHC) and the Central Piedmont Action Council, Inc. (CPAC). These private, nonprofit corporations had provided transportation services to their own clients for more than 14 years, but there was no local public transportation. Both agencies were spending large amounts of money, serving a limited population, and duplicating services by covering many of the same routes at the same time. During calendar year 1983, more than $200,000 was used for CVCHC and CPAC transportation services.

Several factors were considered in deciding to establish a public transportation system in Central Virginia: the poor utilization of CVCHC and CPAC vehicles, the duplication of services, the lack of public transportation in the area, the high level of poverty and transportation-disadvantaged persons in the community, continuing requests from other human service agencies, repeated requests from the general public, and a need to secure an alternative funding source.

A major consideration of the CVCHC was the increasing concern by state and federal health officials over the low utilization and high cost of transportation for CVCHC patients. This criticism was focused on resource utilization, however; not on management. It was believed that services were being provided at the lowest cost possible, but due to the nature of the services, it was underutilized. The service had available seats, but did not have extra available time, so a creative method of opening up the services was needed. It was realized by the CVCHC Board of Directors and by the U.S. Department of Health and Human Services project officer assigned to monitor the CVCHC program that by modification of Center policy, a general public system could be created from the nucleus of services available from CVCHC. It was recommended that technical assistance be sought to determine the cost and feasibility of opening up the service.

Establishment of public transportation in Central Virginia required several levels of effort and persuasion. The CVCHC and CPAC management and boards had to modify internal policies to begin the process. The CVCHC Board approved this modification in October 1982. The VDH&T had to be convinced that there was sufficient need and demand to justify use of public funds for the project. Regional planning agencies had to be shown that the proposed service design was feasible and county governments had to be convinced that public transportation would be in the best interest of the public.

Historically, studies conducted by regional planning district commissions and the VDH&T several years earlier (1,2) had recommended that CVCHC and CPAC combine their transportation resources and form the basis of a new, expanded system, but the studies provided neither a specific need or demand statement nor a step-by-step blueprint for development of the new system.

Despite the lack of a blueprint for providing services, a major formal step in the cooperative public transportation venture was taken in May 1983 when CVCHC and CPAC each filed Section 18 applications with the VDH&T. The VDH&T indicated that the applications had merit, but that they were incomplete with regard to specific operating detail. A suggestion by the Public Transportation Division of VDH&T that technical assistance was advisable resulted in a CVCHC application for a Section 18 Technical Assistance grant request for a two-stage Transportation Development Plan (TDP). Work on the TDP was initiated in August 1983 and was completed in January 1984 (3). The first phase of the TDP updated and expanded earlier data on the need of residents and concluded that public transportation was both needed and feasible in the proposed service area. Phase II provided a service plan to meet the need and demand identified in Phase I. Revised fiscal year (FY) 84 Section 18 applications were filed in February 1984 along with FY 1985 requests. At the suggestion of the VDH&T, there was a single, combined application filed by CVCHC for CVCHC to operate the system in Buckingham and Fluvanna and to subcontract with CPAC to operate the system in Amelia and Cumberland. The proposed budget for the system's first full year of operation totaled \$825,000: \$185,000 for administration, \$290,000 for operating deficit, and approximately \$350,000 for capital equipment. Authorization from the VDH&T to proceed was received in July 1984 and the system is expected to begin service to the general public in mid-1985.

The application projected the use of a combination of federal, state, and local dollars with existing agency contributions to establish and operate a public transportation system that would continue to meet the needs of CVCHC and CPAC clients and also meet the needs identified for the general public. A combination of fixed route, feeder service and a demand-response component was recommended and found to be necessary based on the demand identified in the TDP. This entire process was fostered by the favorable environment of several statutes from the U.S. Government and the State of Virginia. Each of these statutes is described in the remainder of this paper.

Section 18 funding provides for public transportation cost reimbursement at the following rates: 80 percent for administrative costs, 50 percent for operating deficit, and 80 percent for capital expenses. In Virginia, the remaining costs may be supplemented by state funding assistance (1984 Acts of the General Assembly, Chapter 744, Item 640) and by a new law, the Neighborhood Assistance Act, that encourages private businesses to become involved in community projects (Code of Virginia, Chapter 19, Section 63.1-320).

Capital assistance of 95 percent of the nonfederal share (19 percent of the total cost) is available from the state if, and only if, it is requested by the local governing bodies. In the CVT system, local governing bodies in each of the four counties requested the capital assistance on behalf of the system. The federal and state combination of funding left a 1-percent share of the total capital costs that must be made available by local sources. This 1-percent local match for capital will be raised through community donations and should be enhanced by the Virginia General Assembly's passage of the Neighborhood Assistance Act that became effective in 1982.

The Neighborhood Assistance Act is a unique state program that encourages businesses to invest in community improvements by allowing state tax credits as incentives for business firms to invest directly in community services designed to benefit low income individuals. Improved community relations, enhanced public image, increased visibility, and tax credits are all potential advantages of participation in the program by community businesses. Applications for approval of projects is handled by the Virginia Department of Social Services. This program emphasizes partnerships between the private and public sectors. The Neighborhood Assistance Act calls for defining local problems, designing local solutions, and using all available resources to improve the environment for both business and the community. The Act lists such areas as education, job training, crime prevention, and community services as types of projects to be sponsored under the new program. Flexible guidelines allow local groups and businesses to design specific community programs. Examples include child care centers; job training centers; cultural centers for art, music, dance, and drama; winterization of homes for the elderly and handicapped; renovation of older neighborhoods; and, in Central Virginia, public transportation. The CVT public transportation system has been approved as a Neighborhood Assistance Act program, and businesses that invest in the program may take a 50 percent state tax credit for any contribution greater than \$100. The Virginia General Assembly designed the Act so that virtually all Virginia businesses, regardless of type or size, can take advantage of this incentive for community involvement. In addition to credits for monetary support, tax credits may also be taken for materials, employees' paid time and services, and other resources, with appropriate verification. Although many businesses are familiar with federal government programs that require elaborate record-keeping and reporting, the Neighborhood Assistance Act program is state-operated with simple, streamlined application and record requirements. The paperwork can be developed by either the business or the neighborhood organization involved in the effort.

Another exceptionally attractive feature in Virginia, for systems operated by public bodies, is a 95 percent reimbursement for nonlabor operating costs not reimbursed by Section 18. This means that expenses such as fuel, tires, and maintenance can be reimbursed to a system by the state. The CVT will not be eligible for these funds because it will not be operated by local governments or any other public body. The CVT operating costs not funded by Section 18 will be funded by CVCHC and CPAC dollars presently used to operate the nonpublic system. These funds are part of the CVCHC and CPAC maintenance of effort. Both agencies have made a commitment to continue transportation funding at the same level as before Section 18 funds were requested. The TDP addressed the issue of possible incorporation by the

CVT as a separate public service corporation, but this was not considered the most desirable entity for several reasons: recognition and relative acceptance of the CVCHC and CPAC organizations by the community, initial time and expense to develop a new organization, long-term funding issues with regard to current funding levels, strong indications that county governments did not wish to be anymore involved than absolutely necessary, and an associated reluctance to develop a new legal entity. Once public operation experience is gained and the service is well established in the community, a separate corporate status may be more feasible.

Eighty percent of the administrative costs of the CVT system will be reimbursed by Section 18 with the remaining 20 percent coming from both the CVCHC and CPAC budgets to help fulfill their maintenance of effort requirements. If a public body were operating this system, 10 percent of the administrative costs would be covered by state dollars also, leaving only a 10 percent local requirement.

Establishment of the CVT system has required close cooperation and coordination at many levels. CVCHC needed permission from both its community board of directors and the U.S. Department of Health and Human Services (DHHS) because approximately 70 percent of CVCHC funds comes from a Public Health Service Section 330 grant. The remaining 30 percent comes from locally generated patient fees and is available as local dollars for UMTA match purposes. CPAC also needed permission from its board of directors. CPAC receives most of its funding through the Community Services Block Grant program. The most difficult cooperation to obtain was that from the County Board of Supervisors. The county governments were concerned about possible liability and future obligation for funding if federal and state funds were decreased or discontinued. It required more than 20 meetings with local Boards of Supervisors and community pressure to obtain necessary agreements from the 4 counties. The liability issue was addressed by specific contracts between the four counties and the operators that passed on the liability the counties incurred through the state-county agreements. A special provision of the county-operator contracts was that the operators would secure a bond that would guarantee that any costs incurred by the counties would be fully reimbursed by either the operator or the bonding company.

A major problem in securing agreements from the counties was the philosophy of local officials who considered transportation a low priority public service. Local governments, contrary to what would be expected, appear to be less sensitive to such local needs than are state and federal governments. A gradual, yet undocumented, change appears to be occurring in the rural areas as younger, better-educated persons are seeking the improved quality of life available in rural areas. Also, an increasing number of elderly are moving back to the rural area and these persons historically have a much higher need for public transportation because of limited income and physical restrictions. Both of these factors are likely to increase pressure on local government for essential services, such as public transportation.

Strong encouragement for the public system has come from human service agencies such as the health departments; and social service, vocational rehabilitation, mental health, and senior citizen services in the four counties. Local churches have expressed strong support and a local Chamber of Commerce has expressed an interest in some joint ventures with the system. After the public system has established credibility in the community, it is anticipated that local governments may agree to become more involved.

It is believed that several factors are present that will ensure success for this project. The CVCHC has always considered transportation a cost center and is aware of the high cost of providing transportation services. Transportation is considered a separate line item on the detailed semiannual cost report filed by CVCHC to DHHS (4). This is in contrast to many human service agencies who have difficulty establishing actual transportation costs because these costs are so interwoven with other program costs. This has led to an underestimation by some agencies of the actual cost of transportation.

Another factor to help assure success of this project is that CPAC has an excellent community network in place that can assist in securing public support. Also, an extensive marketing campaign, specifically tailored to the area, will assure that all rural residents know about the system and how to use its services. The VDH&T required an extensive TDP to assure that there was sufficient demand for public transportation in the area and that it was feasible to provide public transportation by enhancing existing providers. A large TDP steering committee, which included representatives from each county government, planning district commissions, school boards, and various human service agencies, has assured that these community groups are aware of what level of services are planned for the region. A CVT Advisory Committee will assure that there is continuing community input into service delivery. These factors, along with the favorable Virginia statutes described earlier and the increasing awareness at the federal level of the issue of rural transportation funding equity, should give the new CVT system an opportunity to show that public transportation is a legitimate public service in the rural area, and that community cooperation can allow scarce resources to have maximum impact on the lives of all the community.

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Developing Sources of Local Funding: The Experiences of Two North Carolina Communities

PATRICK SIMMONS and KATHLEEN EVERS

ABSTRACT

Most Section 18 transportation systems can be classified as either countywide or small urban systems depending on their service area and passenger profile. Because countywide systems tend to originate from coordinated human service transportation systems, they cater primarily to human service agency clients. However, small urban systems tend to provide service to the general public using fixed routes, reflecting their origins as privately owned transit systems. Both systems are faced with the difficult issue of obtaining local financing to match Section 18 funds. At least three alternatives are available: (a) developing revenue sources that count as local cash matching funds, such as subscription and charter service; (b) collecting more farebox revenues, which decreases the net operating deficit; and (c) increasing the amount of unrestricted federal funds by contracting with human service agencies. Tapping these revenue sources requires building a system that serves both the general public and local human service agency clients. One such system, known as AppalCART, operates in Watauga County, North Carolina. Its success in expanding local revenues to include previously untapped sources of funds has resulted in a very small request for local government funds. Opportunities to build a comprehensive system similar to AppalCART exist in other parts of North Carolina. In Pitt County, three separate transportation systems provide service to the general public, human service agency clients, and university students. The existing need for substantial local cash contributions to two of these systems could be significantly reduced by establishing a comprehensive countywide/small, urban Section 18 system. Combining the resources of the public and private sectors under current federal Section 18 program guidelines can reduce the need for direct local government subsidies.

The Section 18 program in North Carolina currently includes approximately 24 separate subrecipients. As a rule, these systems can be categorized as follows:

1. Countywide--those that cater primarily to human service agency needs;
2. Small urban--those that serve cities with fixed-route transit service and a population between 10,000-50,000;
3. User-side subsidy programs that provide low-cost taxicab service for low-income residents in two small urban areas; and
4. Intercity bus subsidy programs that provide service to areas of the state where bus service has been abandoned or severely cut back by private operators.

Of these four systems, local financing is more often an issue for the countywide and small urban systems. This is due to their comparatively large budgets; for example, the average fiscal year (FY) 1985 budget for countywide systems is more than $300,000. For small urban systems, the average is about $250,000. The user-side and intercity bus subsidy programs have smaller budgets and, as a result, fewer problems obtaining local financing to match Section 18 funds.

Countywide and small urban systems differ in the ways in which they meet their local financing needs. Countywide systems tend to originate from coordinated human service transportation efforts, and thus make extensive use of unrestricted federal funds from human service agency contracts to reduce the cash match needed from the local government. In turn, this reliance on human service agency contracts translates into minimal emphasis on general public ridership. Farebox and subscription service revenues are usually insignificant. Small urban systems, on the other hand, tend to replace unprofitable private carriers and carry general public passengers almost exclusively. Few unrestricted federal dollars are collected; instead, farebox revenues reduce the system's net operating deficit. Both systems usually require significant local government contributions to match Section 18 funds, although the small urban systems tend to require a larger portion than the countywide systems.

For these two systems, the problem of local financing is not easily resolved. Revenue sources that count as local cash match, such as subscription service and charter and advertising profits, can substitute for local government contributions. Farebox revenues from general public ridership can reduce the net operating deficit and lower the amount needed from local and federal sources. To a point, human service agency contracts can lessen the need for local dollars. Tapping all of these revenue sources, however, requires a system that builds on both human service agency and general public ridership, rather than focusing on one or the other as is common.

Discussed in this paper are: the efforts of two North Carolina community Section-18 transportation providers to develop local revenue sources; the success of the Watauga County Transportation Authority (WCTA) in expanding the available local revenues to previously untapped sources; the current situation in Pitt County, North Carolina, where three separate transportation providers are considering ways to combine their services and make more effective use of available local revenues; and the effect of federal financial policies on local funding decisions and, subsequently, other Section 18 subrecipients across North Carolina.

THE WATAUGA COUNTY TRANSPORTATION AUTHORITY

Located in the northwestern part of North Carolina, Watauga County is well-known for its scenic mountain views and cool climate. These factors make the county a desirable tourist destination and resort location although they limit the development of transportation networks. Today, less than 40 percent of the 38,000 county residents live in the town of Boone, located in the center of the county. The rest have settled across the county, separated from each other by terrain and sometimes by climate. Although the area is served by several highways, including the Blue Ridge Parkway, many residents are isolated from even this network. Commercial interests in the area actively promote a year-round tourist industry.

Using the Planning Process to Build a Foundation

Innovative ways to provide transportation have been a part of Watauga County since at least 1968, when Watauga, Avery, Mitchell, and Yancey Counties Community Action, Inc. (W.A.M.Y.) applied for and received transportation funds from the United States Office of Economic Opportunity (OEO). Designed to serve low-income, rural residents, the resulting Green Eagle Transportation Cooperative was one of the first federally subsidized rural transportation projects. The Green Eagle operated for slightly more than 3 years and is considered a "successful failure." Its services were subsidized primarily by W.A.M.Y. through its local initiative funds from OEO. The cooperative form of management created bookkeeping problems, and the largely inexperienced board of directors could not mobilize resources effectively. In 1973 OEO instructed W.A.M.Y. to discontinue its subsidies to the cooperative. After the service ended, W.A.M.Y. and other human service agencies continued to provide transportation for their clients. Comprehensive Education and Training Act (CETA) funds typically were used to pay driver wages, with county funds used when federal and state aid was insufficient.

In the late 1970s, the state of North Carolina began putting more emphasis on transportation development planning at the county level. In particular, the state agencies involved in transportation funding wanted more coordination of existing transportation resources, and in 1979, the governor signed an executive order requiring coordination. Meanwhile, planners from the regional council of governments and representatives from Watauga County human service agencies met in 1977 to discuss goals and specific recommendations for the county transportation development plan (TDP). The consensus was to: (a) develop a consolidated transportation system, focusing on existing transportation resources; (b) devise a mechanism for referring clients to the system; and (c) form an independent transportation authority under the guidance of county government.

Forming a transportation authority proved more difficult than originally envisioned by the TDP committee. Although a TDP was completed in 1977. the county commissioners rejected a plan to create an authority. Concerns about the limited amount of public input, and what they saw as minimal justification for the proposed budget, formed the core of their dissatisfaction. The commissioners created another committee, this one representing a broader constituency, to reexamine the concept of a transportation authority. Although the committee recommended that an authority be formed, the commissioners wanted further evidence of public support and access to this new entity.

By 1980 a third TDP committee had been formed by the commissioners. A revised TDP was developed that included some limited general public service, and an authority was formed that year. Even at this early date, the plan envisioned a joint maintenance facility and a central dispatching center. It also incorporated the newly created Appalachian State University (ASU) bus service, known as AppalCART, into the countywide system. Because the county recently had been designated by the U.S. Department of Energy as the nation's first Model Energy Conservation and Development Area, the revised TDP included energy conservation and alternative fuel use for the system's vehicles. In fact, the 5-year implementation plan stipulated that during the first year, work would be coordinated with the ASU faculty and staff to build a still for the conversion of produce into fuel-grade alcohol. It was anticipated that several of the transportation system's vehicles would initially be converted to run on this fuel, with others converted later as the still produced more fuel over time.

The commissioners supported the TDP because it represented commitment by the town of Boone, ASU, and human service agencies. The commissioners also required agency directors to sign written pledges turning vehicles and other resources over to the authority. A central element in obtaining county support for the system was the emphasis on general public ridership.

The final version of this TDP was adopted in 1980, and it has guided the development of transportation services in Watauga County ever since. The county recently applied for the received planning funds from federal and state sources to update the TDP and prepare a management audit that will assess the organizational structure and service delivery of the system.

The Watauga County Transportation Authority: Its System and Operations

It is no surprise that county residents and out-of-state tourists have different transportation needs: the elderly and handicapped want access to nutrition sites, shopping, social activities, and workshops; low-income residents want dependable, low-cost transportation so they can find jobs; students at ASU, which is located in Boone, want to leave their cars and the ever-present campus parking problems behind; and skiers want to be able to get to the slopes in southern Watauga county safely and conveniently, even though they may be staying in Boone.

When each group has different demands and financial resources, how can one operator meet all their needs? In Watauga County, the key has been to pool all available resources, both public and private, so that all groups can be served. Starting with the foundation laid by the Green Eagle Cooperative, which primarily served human service agency clients, the Watauga County system has incorporated the resources available from ASU, other human service agencies, the public, and the private sector. The result is a comprehensive, countywide service with 30 separate routes, most of which are open to the public. More specifically, the services are provided to

1. Human service agencies, which use seven reserved routes for a variety of programs, Monday through Friday;
2. Mobility-impaired citizens, who can ride a door-to-door, demand-responsive service that puts first priority on work and education-related trips;
3. ASU students, who can ride campus routes that also serve Boone. Service is available Monday through Sunday;
4. Winter tourists, who can take advantage of guaranteed route service from Boone to the Beech Mountain ski resort. Shuttle service within the Beech Mountain area also is provided; and
5. Local civic groups and schools, which can reserve vehicles for local charter service. Vehicles are available with or without operators, after regular operating hours on weekends.

As of this year, the AppalCART system, as it is now known in Watauga County, operates from a new maintenance and office facility located in Boone and funded primarily through the Section 18 program. Thirty-three vehicles are available for service, ranging in size from 7 to 15 passenger vans to 30-ft transit buses. Ridership for all groups served reached 180,000 trips in FY 1984, and this figure is expected to increase by about 50 percent in FY 1985. The full-time staff of 23 is supplemented with 11 part-time drivers.

The alcohol-producing still mentioned earlier currently produces fuel to run one vehicle, and additional vehicle conversions to alcohol operation are anticipated this year. Corn is used to produce the alcohol, although the system's director expects to use discarded, imperfect sweet potatoes later this year. Because the stillage that is left after processing the vegetable matter provides a high-quality animal feed, the cost of producing the alcohol will be reduced by selling this by-product to local farmers.

The FY 1985 AppalCART Budget

Operating a system the size of AppalCART is not an inexpensive proposition. Total costs for FY 1985 are estimated at more than $800,000, and even after Section 18 funds are applied to the net operating deficit, there will remain a sizable local match that must be collected from various government agencies. As shown in Table 1, this local match is estimated at about $230,000. Of this total, the Watauga County Board of Commissioners is directly contributing only $1,500, which represents less than 1 percent of the local funds needed to match federal and state funds.

TABLE 1 Fiscal Year 1985 Budget: Watauga County Transportation Authority

	Dollars				
	Total	Section 18	State	Local	Farebox
Administration	170,628	136,502	16,678	17,448	
Operating	432,876	189,438		189,438	54,000
Capital	233,408	186,726	23,341	23,341	
Total	836,912	512,666	40,019	230,277	54,000

So how does Watauga County collect more than $500,000 in federal and state funding with a cash commitment of $1,500? How does this project meet the federal and state requirements for local cash match? For operating assistance, the local match ($189,438) is made up of local revenues and unrestricted federal funds, as indicated in Table 2.

TABLE 2 Local Match for Operating Assistance

Source	Local Revenues (dollars)	Unrestricted Federal Funds (dollars)	Total Operating Match (percent)
Watauga County general funds	1,500		(less than one)
Aging Program (county funds)	32,600		17
Parks and Recreation (county funds)	11,000		6
Special route guarantees (Beech Mountain resort and Patterson School)	36,952		20
Contributed goods (TVA still and donated buses from Beech Mtn.)	32,566		17
Sheltered Workshop		30,000	16
Mental Health		17,500	9
Community Action Program		18,720	10
Head Start		2,520	1
Job Training Partnership Act		6,080	3
Total	114,618	74,820	100

Several issues merit further discussion. The private sector, represented by Beech Mountain resort and Patterson School, accounts for about 28 percent of the local operating match through special route guarantees and in-kind contributions. Because federal policy allows in-kind contributions, such as contributed capital to count toward local cash revenues, only a portion of the private sector involvement is in the form of actual cash payments to the authority. Watauga County indirectly contributes about 23 percent of the local revenues through its funding programs for the aging, and parks and recreation which both purchase service from AppalCART. In essence, these funds provide two services for the county: (a) they pay for transportation services for these programs; and (b) they count as local cash revenues for Section 18 purposes, thus allowing the authority to maximize the amount of federal and state funding it receives.

The Watauga County system has also been particularly effective in working with human service agencies, and provides virtually all human service transportation in the county. Unrestricted federal funds from these agencies account for slightly less than 40 percent of the total operating match. Because other system-generated revenues such as farebox receipts and special route contracts have increased significantly, the vehicle mileage charge to the human service agencies has dropped from $.70 to $.58 this year. As a result, the amount of unrestricted federal funds collected from these agencies is also likely to decline.

Other system-generated revenue on the operating side comes from two sources. General public passengers who are not associated with ASU or human service agencies pay fares based on the number of zones they travel through. Travel through one zone costs $.25, and the maximum fare is $1.00. In FY 1985, approximately $8,000 in farebox revenue will be collected from these passengers. A much larger source of revenue is the authority's contract with Watauga County to provide maintenance service for county vehicles, which is estimated at $46,000 this year.

The ASU is a full partner in the WCTA and contributes one-half of the required local cash match

TABLE 3 Local Match for Administrative and Capital Assistance

Source	Amount (dollars)	Required Local Match (percent)
Appalachian State University and Institute for Transportation Research and Education	32,710	80
Charter profits	2,465	6
Advertising profits	1,000	3
Grant from Appalachian Regional Commission for energy project	4,614	11
Total	40,789	100

for capital, administration, and operations. (See Tables 2 and 3.) Faculty, students, and staff of the university ride AppalCART for free through the town of Boone or the campus.

AppalCART takes maximum advantage of federal fiscal policies for the Section 18 program. The system's FY 1985 Section 18 budget includes:

1. Sufficient unrestricted federal funds from human service agencies to cover 25 percent of the net operating deficit;
2. Sufficient revenues from other local sources to meet almost 99 percent of the remaining local cash match needed for the entire system; and
3. Significant revenues from the private sector, including charter and advertising profits, contributed capital, and special route guarantees.

AppalCART combines the financial resources available from both the public and private sectors more effectively than any other Section 18 system in North Carolina. It has developed into a countywide public transportation provider that can meet the needs of all residents. In doing so, all available sources of local revenue are being used.

PITT COUNTY, NORTH CAROLINA

Other North Carolina small urban systems are currently working to combine existing transportation resources more effectively and reduce the amount of local matching funds needed to run the system. Planning efforts underway in Pitt County, North Carolina, are exploring the potential for greater coordination among three different transportation providers, including:

1. Greenville Area Transit (GREAT): This fixed-route, small urban transit system provides service primarily within the city of Greenville (1980 population was approximately 35,740). More than 20,000 passengers are carried each month, the majority of which are low-to-moderate income residents who do not have alternate transportation available. Three routes operate Monday through Saturday.
2. East Carolina University Student Government Transit (SGT): This fixed-route system serves students and faculty of East Carolina University. It is financed through student fees, so no fare is charged to ride any of the four routes. These routes do not overlap with the routes provided by GREAT, although SGT riders can transfer to GREAT routes downtown.
3. East Carolina Vocational Center (ECVC): This private, nonprofit human service agency provides fixed-route and demand-responsive service for its clients and other agency clients in Pitt County. The ECVC currently has contracts with the County Council on Aging and the Mental Health agency to provide their transportation needs.

All of these providers have recognized the potential for coordination, and a TDP developed in 1982 for GREAT contained several coordination goals, including (a) the ECU transportation system and GREAT should be merged, subject to mutual agreement between the city of Greenville and the ECU Student Government Association, and (b) GREAT should coordinate to the maximum extent feasible with human service agencies.

The Pitt County TDP, also developed in the early 1980s, further explored the options for additional human service coordination with GREAT. Similar to the situation in Watauga County, those involved in this planning effort recognized the increase in operational efficiency that would result from consolidation of services. However, GREAT has a policy of providing only limited service outside the city of Greenville, a fact that would restrain the amount of service to human service agencies. Ultimately, this TDP put responsibility for Pitt County human service transportation in the hands of ECVC, mostly because of the agency's ability to provide service as demonstrated by its proven track record.

This separation of service areas by GREAT, ECU, and ECVC results in higher local cash payments for transportation than would be necessary with a consolidated, countywide service similar to that found in Watauga County. For FY 1985, the city of Greenville will pay more than $70,000 to match Section 18 operating assistance. This represents about 40 percent of the net operating deficit, with other local revenue ($9,000) coming from charter and advertising profits and a special route guarantee. Because GREAT receives no unrestricted federal funds, the city's financial commitment to the system remains quite large.

Recently, the city of Greenville and ECU have discussed consolidation of their systems, as originally called for in the 1982 GREAT TDP. One of the advantages listed for GREAT includes help with local match required under Section 18. If ECU purchases service from GREAT, these revenues could be treated as local matching funds, possibly reducing the amount of city funds needed to support the system. In return, ECU students and faculty could continue to ride the system for free and by taking advantage of federal and state assistance, reduce the SGT costs.

Further consolidation may eventually result from the efforts underway. Consolidation of human service transportation under GREAT would allow that system to take advantage of unrestricted federal funds as part of the Section 18 local match. This is a sensitive political issue; ECVC, the existing human service transportation provider, has built a strong constituency in the counties it serves. In addition, the city of Greenville prohibits GREAT from operating outside the city limits. Although the two systems have agreed to exchange passengers at designated transfer points when travel is required in the city and the county, more formal arrangements will be needed for the city to take advantage of the available unrestricted federal funds.

CONCLUSION

As indicated earlier, federal financial policies influence countywide and small urban Section 18 systems differently. Because farebox revenues are used to reduce the net operating deficit rather than the local cash match, countywide systems have less incentive to attract public riders. Instead, local politics dictate that system directors look first to human service agencies because funds from these agencies will reduce the local cash match more effectively than will farebox revenues. Special attention is paid to agencies that can pay their transportation bills with local and state funds because these payments will also decrease the amount of local cash match needed from the county commissioners. Efforts to generate farebox revenue through increased public ridership tend to take a back seat as a result.

Small urban systems, on the other hand, are accustomed to collecting fares and providing fixed-route service. Before the Section 18 program went into effect, most of these systems had been operated by private transit companies, so any move to provide human service transportation may be a significant change. For local officials, however, this move offers a chance to reduce the amount of local tax dollars needed to support transit operations by collecting unrestricted federal funds from these agencies.

How can these two types of Section 18 properties build, support, and develop a system that effectively combines resources from both the public and private sector, as found in Watauga County? County systems need to devote more effort to general public service. Not every county has a major university or ski resort, or both, but other possibilities outside of the typical 8 a.m. to 5 p.m. coordinated human service agency client transportation exist. Community colleges and large employment sites such as industrial parks and shopping centers can offer similar potential for special route guarantees as well as fare-paying riders. In particular, contracts that can count as local revenue should be actively sought.

For small urban systems, the challenge is just as great. To tap the supply of unrestricted federal funds, human service agencies must be convinced that the transit system will be able to meet the needs of their clients. County leaders must recognize that county tax dollars used to pay transportation costs for these agencies may be spent more effectively by contracting with an established transit system--assets such as maintenance facilities could be better utilized as a result. Salaried administrative personnel may be able to take on additional duties, thus further reducing the cost of providing additional service.

Building support and maximizing the use of available resources requires careful planning. Much of the success of AppalCART can be traced back to the extensive--and sometimes frustrating--planning efforts of the late 1970s. Those efforts used information from the Green Eagle service as a starting point for understanding the community's transportation needs. All of the agencies participated because they knew clients who needed transportation that was not being provided. Some of those representatives also recognized that other groups, such as students and the public, could be a part of a countywide system as well.

North Carolina DOT makes planning funds available to counties on an 80-percent federal, 10-percent state, and 10-percent local basis. Counties and small urban areas can use these funds to explore and document ways to improve the level of service provided while maximizing the use of available resources. Any proposed changes would generally constitute an updated TDP, an approved version of which is required by the Public Transportation Division of the North Carolina Department of Transportation before awarding any federal or state transportation funds to a county or small urban area.

In addition to the Greenville/Pitt County example, other small urban areas in North Carolina have explicitly recognized the potential for expanded, countywide service in addition to traditional fixed-route city service. This year, the city of Salisbury will use planning funds to hire a consultant who will be charged with the task of preparing a joint TDP with Rowan County. The city is currently paying more than $100,000 a year to support transit operations with very little human service agency coordination being realized, a situation that is unacceptable to local decision makers. With an established system already in place and a new maintenance facility on the way, city and county administrators realize that both jurisdictions would benefit if Salisbury Transit began providing service to human service agency clients located throughout the county. Not only would county transportation funds be spent more effectively, but the city could take advantage of unrestricted federal funds to reduce its cash match on the operating side.

Similar city-county planning efforts are underway in other parts of the state, and they are fortunate indeed to have the WCTA as a role model. It takes time to build support and implement service changes, but the Watauga example shows how much can be accomplished when existing resources are fully coordinated and utilized.

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