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Foreword

Ten papers and one abridgment are contained in this RECORD covering the broad topics of the economics of the diesel fuel tax, economics of urban transportation, transit cost allocation formula, influence of the highway network structure on economic development, and concepts of engineering-economic systems analysis for transportation planning.

Swartz discusses the proposed three cent per gallon tax differential for diesel tax that is designed to eliminate the apparent tax advantage granted diesel vehicles created by the greater fuel economy of the diesel engine. The author notes that the application of the incremental-cost analysis method of determining the three cent differential has resulted in a serious misinterpretation of the basic cost-occasioned principle. Several questions are raised by the author that he states must be considered before the advisability of a diesel fuel tax differential is proved.

Ferreri, in using the operating costs of the Metropolitan Dade County Transit Authority, develops a cost allocation formula that could be applied to any bus operation. Cost items were allocated among four major elements affecting expense: vehicle costs, vehicle-miles, peak vehicle needs, and passenger revenue. Various formulas were devised and tested and evaluated using combinations of the allocations. He concludes that for long-range planning projections, a simplified operating cost formula using only vehicle-miles and vehicle-hours is more than adequate and desirable. For short-range service improvements and fiscal planning, however, a more accurate allocation formula such as the four-variable method is more appropriate.

Kraft in his paper discusses the current urban transportation problem and suggests three basic tools that might be appropriate for solving the urban transportation problem: (a) changes in the physical transportation system, e.g., in vehicles or roadways; (b) changes in organization of existing technologies to improve the service qualities offered; and (c) changes in the location and organization of economic activity. Various research needs are suggested by the author that need full investigation before economic principles can be applied to our urban transportation problems.

Shafran and Wegmann propose a procedure to consider additional information in the evaluation of alternative transportation systems when the main objective of the improvements is to increase the economic growth of a depressed or stranded area. The effect of transportation improvements on the economic development of Appalachia is discussed. The authors conclude that the objective of the Appalachian Regional Development Act is to increase the economic growth of Appalachia by concentrating public investments in growth points and attracting industry and that transportation improvements can help achieve these goals by increasing the locational advantage of growth points relative to major metropolitan centers.

Kuhn and Lea in their paper present the engineering-system analysis work conducted as a part of the Dahomey Land Transportation Study in West Africa. The authors state that the central logic of the Dahomey Study is the accomplishment of desirable future transport tasks at minimum true costs to society. According to the authors there is complete integration between transport planning per se, and socioeconomic developments, especially in the crucial agricultural sector, to the target year 1990.

The paper by Cassel et al describes a methodology used in the development of an interim master plan for transportation in Pennsylvania to 1975. A computerized resource allocation model for evaluation and selecting projects on the basis of multiple criteria in terms of their anticipated costs and benefits was the most important feature of their methodology.

Wendt and Goldberg in their paper describe the Bay Area Simulation Study or BASS model that was developed for forecasting future growth of the San Francisco Bay Area. The BASS model is composed of three distinct submodels: an employment and population projection submodel the output of which is fed into two other submodels that allocate projected population, employment, housing, and land development among various subareas of the region. The key determinant of estimated future land use and development in the BASS model is the time required to travel from place of employment to alternate places of residence.

Griswold in his paper discusses the development of "Infosites" (octagonal buildings erected adjacent to rest areas to house permanent advertising displays for firms catering to Interstate motorists) on opposite sides of Interstate 80 near Iowa City, Iowa. They were built in the belief that an information gap would result from federal and state laws controlling billboards along the Interstates. The author concludes in his paper that motorists can get information they need to travel across the state without relying on Infosites, and advertisers can get their message to motorists without Infosites. The sites should be used at the gateway points to the state according to Griswold.

Bottiny discusses the need for quick, inexpensive tools with which to determine future transportation requirements in urbanized areas by determining and measuring relations between a prime indicator or transport need, automobile availability, and certain socioeconomic variables. Theoretical relationships between change in automobile availability and change in certain population, employment, and income factors were formulated.

The abridgment of the Sauerlender paper discusses his work on a Leontief input-output model whose technological coefficients are sensitive to change in transportation costs and factory prices of commodities.

Davidson et al, in a study of economic benefits accruing from the scenic enhancement of highways, concluded that there is a significant relationship between scenic highways and a reduction in injuries. A present value figure was derived that can provide a guideline for policy decisions on the need for scenic highways in New Jersey.

Contents

Development of a Transit Cost Allocation Formula

MICHAEL G. FERRERI, Simpson and Curtin, Transportation Engineers, Philadelphia

The operating cost accounts of the Metropolitan Dade County Transit Authority are analyzed to develop a cost allocation formula of general application to any bus operating company. Standard cost account items were allocated among four major elements that affect expenses: vehicle costs, vehicle-miles, peak vehicle needs, and passenger revenue. Further study determined the relative loss in accuracy flowing from the elimination of two of these variables. In total, three formulas are devised and evaluated. The first uses all four allocators, the second eliminates peak vehicle needs, and the third uses only vehicle-miles and vehicle-hours.

The "four-variable" analysis resulted in the following cost allocation formula: $C = 0.1459\ M + 3.0017\ H + 0.0578\ R + 2521.69\ V$. C is average daily cost of route operation, M is average daily vehicle-hours of service on route, H is average daily vehicle-miles of service on route, R is average daily passenger revenue on route, and V is peak vehicle needs on route. Comparison of operating costs by routes as calculated by the formula with route costs resulting from two- and three-variable formulas showed a maximum route mean square error of 10.8 percent for crosstown routes. The maximum deviation for the entire MTA system was only 6.3 percent. The conclusion to be drawn from this analysis is that for long-range planning projections, a simplified operating cost formula using only vehicle-miles and vehicle-hours is more than adequate and probably desirable because of the need to estimate only miles and hours of service on each route. On the other hand, for short-range service improvements and fiscal planning, a more accurate allocation formula such as the four-variable method is more appropriate.

•TO allocate community financial resources among transportation facility improvements, it is necessary to estimate the use of the elements of a proposed transportation network related to the expenditures required to achieve that use. The development of area-wide transportation plans with specific new facilities requires estimates of the number of trips that will use each facility—transit and highways—for the design year.

Transportation studies have developed data that provide an understanding of present transit use, travel patterns, characteristics of riders, and the related socioeconomic characteristics that affect transit use. These data are being employed in modal split-traffic assignment processes to develop future estimates of transit facility use for any set of system circumstances.

The other side of the revenue and traffic analyses for area transportation studies, the cost of travel, has been very carefully tabulated in terms of capital improvements recommended for the transportation facilities master plan. When considering improved transit service and possible rapid transit developments, previous studies have

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made meticulous estimates of the cost of capital facilities while completely overlooking the expense involved in operating the surface transit system.

Transit systems currently spend only 5 to 10 cents of their revenue dollar on capital costs. The other 90 to 95 percent of annual costs go toward the day-to-day operation of the system. Transit companies that operate fixed rapid transit facilities sometimes devote as much as one-third of their operating expenses to the amortization of these capital facilities; the great bulk of expense still goes to operating the system.

The mass transit analysis conducted for the Miami Urban Area Transportation Study (MUATS) devoted planning attention and prepared cost estimates for the 10 percent item, capital costs. This paper, however, fully develops the companion analysis necessary for the proper calculation of the 90 percent item, the cost of operating any of the transit system alternatives to be tested. Revenues and operating costs of the Metropolitan Dade County Transit Authority (MTA) are analyzed by subaccounts to develop a cost allocation model for application to routes of test transit networks.

MTA PATRONAGE AND SERVICE

MTA operated more than 11.7 million miles and carried almost 50 million passengers in the fiscal year ending September 30, 1965 (the "study year"). The system provides four types of service including seven Miami-to-Miami Beach routes, an additional 24 routes that serve downtown Miami, six crosstown routes that do not enter downtown Miami, and special and chartered services. Where possible, it will be useful to examine the system in terms of these four service categories.

As shown in Table 1, the Miami-Miami Beach routes accounted for about 24 percent of total miles and about 23 percent of total hours in fiscal year 1965, but produced more than 29 percent of the system's passenger revenue. The downtown Miami routes were responsible for about 68 percent of total miles and 69 percent of total hours, generating a somewhat less-than-proportional 65 percent of passenger revenue. The crosstown category is clearly the weakest among the regularly scheduled routes, accounting for about 7 percent of both miles and total hours, but only 4 percent of passenger revenue.

Using passenger revenue per mile as a measure of productivity, the superior performance of the Miami-Miami Beach routes over the downtown and crosstown routes is more evident. The 79.83 cents per mile generated by the Beach routes is about 26 percent higher than the 63.24 cents per mile generated by the downtown routes, and is almost 92 percent higher than the 41.64 cents per mile produced by the crosstown routes.

The advantage of the Beach routes is even more pronounced in terms of a second measure of productivity, average revenue per hour. Again, as shown in Table 1, the Beach routes generated $8.8501 per hour, which was about 33 percent higher than the $6.6597 per hour recorded for the downtown routes and almost double the $4.5020 per

TABLE 1

TRANSIT PATRONAGE AND SERVICE
PROVIDED MTA SYSTEM BY TYPE OF SERVICE
(Fiscal year ended September 30, 1965)

Routes	Passenger Revenue	Miles Operated	Hours Operated	Revenue Per Mile (dollars)	Revenue Per Hour (dollars)
Miami-Miami Beach (7 routes)	$2,269,660 (29.17%)	2,843,257 (24.25%)	256,455 (23.17%)	0.7983	8.8501
Crosstown (6 routes)	$ 320,620 (4.12%)	769,985 (6.57%)	71,216 (6.43%)	0.4164	4.5020
Downtown Miami (24 routes)	$5,065,917 (65.13%)	8,010,643 (68.33%)	760,678 (68.73%)	0.6324	6.6597
Special and Miscellaneous	$ 122,750 (1.58%)	98,620 (0.85%)	18,408 (1.67%)	1.2447	6.6683
System	$7,778,947 (100%)	11,722,505 (100%)	1,106,757 (100%)	0.6636	7.0286

hour produced by the crosstown routes. These results are a reflection of higher average speeds on the Beach routes and relatively slow operation on the crosstown routes.

It is interesting to note that although the special and miscellaneous bus services are very productive in terms of revenue per mile ($1.2447), they are no more productive than the downtown routes in terms of revenue per hour ($6.6683). This results from the fact that long layovers at chartered outings, the Orange Bowl, Hialeah, etc., inflate the hours in this category.

The trend of patronage and service in the three full fiscal years of MTA operation is shown in Table 2. The picture that emerges from these data is one of impressive gains in passengers and revenue, coupled with relatively stable levels of service.

In the years since MTA operation, there has been a marked divergence in the trend of transit riding in the Miami area as compared with the national trend. Table 2 illustrates comparative statistics for MTA trends and all United States motor bus passengers.

In the 1963-1965 period, total passengers on MTA rose by more than 6 percent while the U. S. total remained stable. Similar conclusions may be drawn for revenue passengers—MTA up 3.01 percent, U. S. down 0.05 percent. The number of miles operated in the United States has increased only slightly in this period (0.34 percent), while MTA has actually added 141,586 miles in their first full year of operation.

In the 1963-1965 period, total MTA passengers rose by more than 6 percent and revenue passengers by more than 3 percent. In the same period, total miles declined by about 1.5 percent and total hours by slightly more than 2 percent. It is interesting to note that the declines in both miles and hours occurred in the 1964-1965 fiscal period, while both total passengers and revenue passengers rose sharply in that same period. As the result of these developments, the three most important measures of productivity—passengers per mile, revenue per mile, and revenue per hour—each improved significantly as shown in Table 2. Passengers per mile increased by almost 8 percent, revenue per mile by almost 6 percent, and revenue per hour by more than 6 percent in the 1963-1965 span.

Figure 1 graphically illustrates the divergence in trends between the MTA system and the national average. More dramatic increases in transit use are evident in the 1966 figures which show a 7.4 percent gain over 1965, bringing the level of annual revenue passengers to within 2.5 percent of the 1954-1958 reference period. This type of growth picture is extraordinary and is a significant mirror of the vigorous growth in Dade County.

TABLE 2

TREND OF TRANSIT PATRONAGE AND SERVICE PROVIDED
MTA SYSTEM AND TOTAL U.S. SURFACE TRANSIT
(1963 to 1965)

Patronage	Service	Fiscal Year Ending			Percent Change		
		1963	1964	1965	1963-1964	1964-1965	1963-1965
Total passengers	MTA	46,919,688	48,050,775	49,837,488	+2.41	+3.72	+6.22
	U.S.	5,822[a]	5,813	5,814	-0.02	0.0	-0.01
Revenue passengers	MTA	41,416,986	41,258,948	42,664,085	-0.38	+3.41	+3.01
	U.S.	4,752[a]	4,729	4,730	-0.05	0.0	-0.05
Revenue	MTA	7,475,017	7,519,046	7,778,947	+0.59	+3.46	+4.07
	U.S.	985.8[a]	1010.3	1036.3	+2.48	+2.57	+5.12
Miles	MTA	11,906,796	12,048,382	11,722,505	+1.19	-2.70	-1.55
	U.S.	1523.1[a]	1527.9	1528.3	+0.32	+0.03	+0.34
Hours	MTA	1,131,050	1,134,535	1,106,757	+0.31	-2.45	-2.15
Total passengers per mile	MTA	3.94	3.99	4.25	+1.27	+6.52	+7.87
Revenue per mile	MTA	$0.6278	$0.6241	$0.6636	-0.59	+6.33	+5.70
Revenue per hour	MTA	$6.61	$6.63	$7.03	+0.30	+6.05	+6.35

[a]United States totals by calendar year, motor bus passengers in millions. MTA totals by fiscal year ending September 30th.

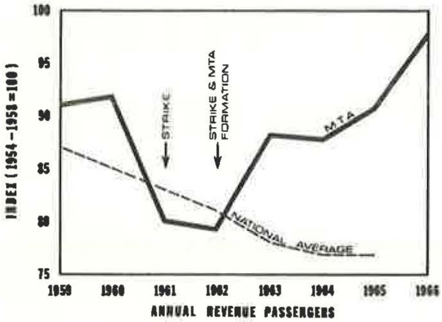

Figure 1. Trend of transit traffic, Metropolitan Dade County Transit Authority (MTA).

OPERATING COST ACCOUNTS

The details of MTA operating expenses in fiscal year 1965 are shown in Table 3. The analysis shows the cost for each item of expense in cents per mile, and relates each item to total cost in percentage terms.

Aggregate operating costs in the 1964-1965 fiscal period amounted to 50.05 cents per mile. Transportation expenses dominated overall costs at 27.48 cents per mile, or about 55 percent of the total. Maintenance cost averaged 7.56 cents per mile, accounting for 15 percent of the total. Cost in the general and miscellaneous category totaled 5.48 cents per mile, or about 11 percent of the total, while garage expenses aggregated 4.93 cents per mile, or about 10 percent of the total. Finally, cost resulting from injuries and damages totaled 3.63 cents per mile for the system as a whole, or about 7 percent of overall per-mile costs.

The largest single item of cost in the 1964-1965 fiscal period was transportation personnel salaries (superintendents and drivers), at 26.96 cents per mile. The other outstanding items were coach maintenance (4.92 cents), injuries and damages (3.63 cents), and fuel and other garage expenses (2.16 cents and 2.62 cents, respectively).

FORMULA FOR ALLOCATION OF COSTS TO INDIVIDUAL ROUTES

The point of departure from which to assess the impact of changes in the existing network of transit routes serving the Miami area is the present pattern of revenues and expenses on the routes of the MTA system. Route revenues are readily obtainable from the records compiled by MTA on the present system and may be developed from traffic estimates being prepared for several future systems. Determination of route operating costs, however, requires additional analysis.

TABLE 3

OPERATING COST PER VEHICLE-MILE, MTA SYSTEM, ANALYSIS BY MAJOR CATEGORIES AND ITEMS OF COST

Category or Item	Fiscal Year Ended September 30, 1965		Category or Item	Fiscal Year Ended September 30, 1965	
	Cost per Mile (cents)	Percent of Total Cost		Cost per Mile (cents)	Percent of Total Cost
Transit authority	0.14	0.28	General and miscellaneous (cont'd)		
Engineering	0.12	0.24	Employees' welfare	0.86	1.72
Garage			Insurance	0.16	0.32
Fuel	2.16	4.32	Storeroom labor	0.11	0.22
Lubricants	0.15	0.30	Miscellaneous	0.27	0.54
Other	2.62	5.23	Audit	0.07	0.14
			Information and promotion	0.14	0.28
Total	4.93	9.85	Salaries of management	–	–
Transportation			Total	5.48	10.94
Superintendence and drivers	26.96	53.87	Maintenance		
Other	0.52	1.04	Superintendence	1.16	2.32
			Buildings, etc.	0.20	0.40
Total	27.48	54.91	Coaches	4.92	9.83
			Tires and tubes	0.78	1.56
Bus card advertising	0.71	1.42	Shop and garage	0.03	0.06
Advertising	–	–	Service car equipment	0.02	0.04
Injuries and damages	3.63	7.25	Miscellaneous shop	0.25	0.50
General and miscellaneous			General and miscellaneous	0.20	0.40
Management fee	1.71	3.42			
Salaries of clerks	1.59	3.18	Total	7.56	15.11
General office	0.18	0.36			
General law	0.07	0.14			
Rent—office	0.32	0.64	System	50.05	100.00

This study analyzes the detailed operating expense accounts of MTA leading to a classification of each expense item within one of several categories as the basis for allocation to individual lines. A consideration of the nature of various operating costs has resulted in the identification of four major elements that have been used to allocate particular expense items. These four elements are vehicle-hours, vehicle-miles, peak vehicle needs, and passenger revenue.

This four-variable formula is calibrated in this paper and compared to the MTA formula that has been developed by the transit authority using three of these four elements: vehicle-hours, vehicle-miles, and passenger revenue. One additional two-variable formula is developed using only vehicle-hours and vehicle-miles. The premise behind this comparative investigation is that for planning purposes, the simpler the formula, the easier the application, if a sufficient degree of accuracy can be maintained.

Vehicle-Hours

The wages of drivers and transportation superintendents represent by far the largest single element of cost in the MTA system, having accounted for about 54 percent of the total cost per mile in fiscal 1965. Employees engaged in operating vehicles are paid on an hourly basis. Allocation of this wage expense would be most properly made on the basis of hours of service on each of the lines. This is best estimated by the aggregate vehicle-hours operated on each line, and this is the basis that has been used to allocate the wages of transportation personnel.

Another important classification has been allocated on a vehicle-hour basis; that is, employees' welfare expense. Whereas costs in this category are attributable to all classes of employees, the bulk of the amount is directly assignable to the largest group of workers; namely, the operating force. Thus, these nonpayroll labor costs have been allocated in the same fashion as the main portion of direct wages and are assigned to individual routes on the basis of vehicle-hours.

Data were obtained from several bus systems throughout the United States to statistically test the relationship between transportation expenses and vehicle-hours of service. A linear relationship exists between these two variables (see Fig. 2) with a significant degree of correlation. The coefficient of correlation indicates that more than 96 percent of the variation of transportation expenses is attributable to vehicle-hours operated.

Vehicle-Miles

Many costs are related directly to the miles of operation on each route. Garage expenses such as fuel, lubricants, and other costs are direct functions of the number

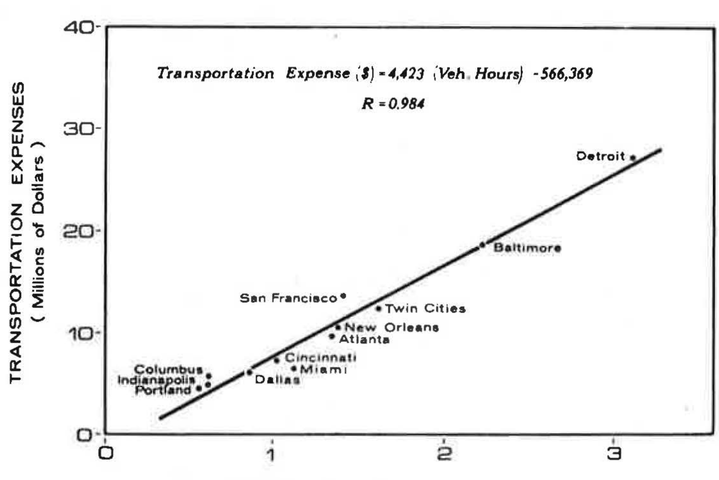

Figure 2. Relationship between transportation expenses and vehicle-hours operated (typical bus operations, 1965).

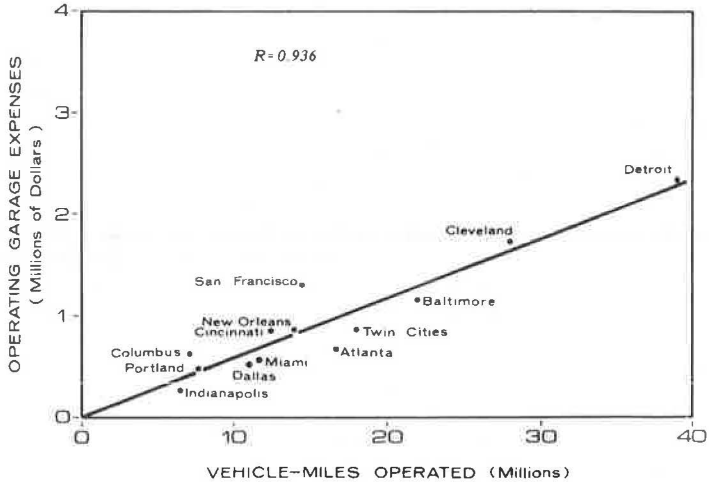

Figure 3. Relationship between operating garage expenses and vehicle-miles operated (typical bus operations, 1965).

of miles operated. Figure 3 illustrates this relationship for several transit properties—a straight line is developed with a significant degree of correlation. Maintenance of revenue equipment is also directly related to the vehicle-miles operated (Fig. 4); this includes costs such as tires and tubes, maintenance of coaches, and maintenance superintendence. Engineering expense has also been assigned to individual routes on the basis of vehicle-miles operated.

Passenger Revenue

Operating costs resulting from injuries and damage have been assigned to individual routes on the basis of the percentage relationship of passenger revenue to the total of all routes in the system. Essentially, accident costs are a function of exposure and could therefore be allocated on vehicle-miles or perhaps vehicle-hours of service. It is believed, however, that either of these bases could introduce some distortion and that passenger revenue is a better means of measure. If vehicle-miles were used as

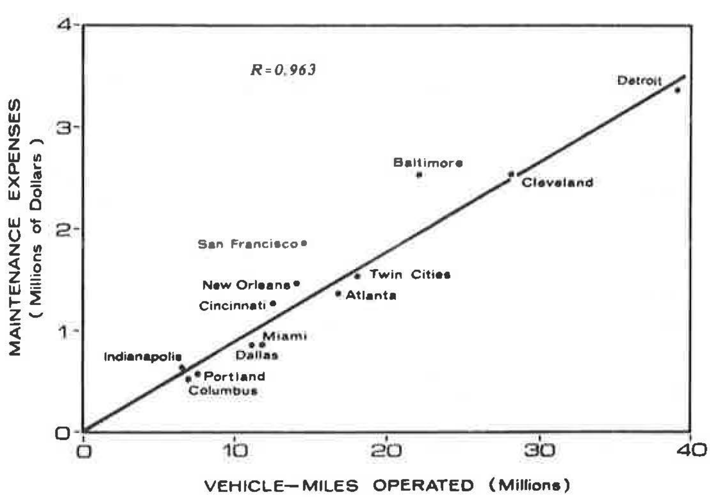

Figure 4. Relationship between maintenance expenses and vehicle-miles operated (typical bus operations, 1965).

the foundation of allocating accident costs, it would mean that relatively fast lines (such as the Miami-Miami Beach lines) operating outside the most heavily congested areas would bear a disproportionate share of accident expense. Whereas vehicle-hours would overcome this problem to some degree, passenger revenue is believed to be a more appropriate basis because it tends to reflect the extent of operation of the line in more heavily congested areas. In addition, passenger revenue is a direct measure of exposure to claims for injury to passengers on the transit vehicles.

Peak Vehicle Needs

Many individual expense items do not vary as functions of any of the foregoing allocators. Thus, for example, the cost resulting from providing storage facilities for vehicles is a function of the number of vehicles required to operate the line rather than the numer of miles or hours of service provided. Therefore, various maintenance expenses have been allocated on the basis of the percentage relationship of the peak-hour vehicle needs on each line to the system-wide, peak-hour vehicle needs; these expenses include maintenance of buildings, fixtures, grounds, shop and garage, and service car equipment, miscellaneous shop expense, and general and miscellaneous maintenance.

A number of broad, overhead expense items have also been assigned to the individual routes on the basis of peak-hour vehicle needs. These include general office costs, the salaries of general office clerks and officials, and all general and miscellaneous expenses with the exception of employees' welfare expense. Advertising and transit authority expense have also been assigned on the basis of peak-hour vehicle needs on each line because these are not items that will vary significantly with changes in volume of service provided on the individual routes.

Application of Allocation Formulas to MTA System

The classification of each operating expense item in one of the four allocation variables is reflected in Table 4. This table aggregates each operating expense account to its appropriate cost allocator.

Taking all classes of service together, including special and miscellaneous, the four-variable formula resulted in the apportionment of 54.3 percent of aggregate cost on the basis of vehicle-hours, 27.9 percent on the basis of vehicle-miles, 10.5 percent allocated on the basis of peak vehicle needs, and the remaining 7.3 percent as a function of passenger revenue.

Table 4 also indicates the relative weight of each variable on a unit basis. The route costs attributable to vehicle-miles result in an aggregate cost of 14.59 cents per mile. Route costs attributable to vehicle-hours of operation yield a unit cost of $3.0017 per hour.

The four-variable analysis results in the following cost allocation formula:

$$C = 0.1459M + 3.0017H + 0.0578R + 2521.69V$$

where

C = average daily cost of route operation;
M = average daily vehicle-miles of service on route;

TABLE 4

FOUR-VARIABLE COST ALLOCATION

Basis of Allocation	Total Cost Allocated (dollars)	Percent of Total Cost	Unit Cost
Vehicle-miles	1, 710, 783.92	27.9	14.59 (cents per mile)
Vehicle-hours	3, 322, 110.60	54.3	3.0017 (dollars per hour)
Passenger revenue	449, 727.98	7.3	5.781 (percent of passenger revenue)
Peak vehicles	640, 509.20	10.5	2, 521.69 (dollars per vehicle)
Total	6, 123, 131.70	100.0	

H = average daily vehicle-hours of service on route;
R = average daily passenger revenue on route; and
V = peak vehicle needs on route.

The results of the application of each of the three formulas to MTA route-operating statistics are illustrated in Table 5. Route-operating costs range from a low of 35.47 cents on Route 2, which is a relatively high-speed (22.6 mph) peak-hour operation serving Richmond Heights, to a high of 65.11 cents on Route C, one of the major Miami-Miami Beach routes.

TABLE 5

ROUTE COST PER MILE COMPARISON
THREE FORMULAS

Route	Annual Vehicle-Miles	Annual Vehicle-Hours	Two Variable Cost Per Mile	Four Variable Cost Per Mile	MTA Cost Per Mile	Percent Difference: Two Variable Compared to MTA	Percent Difference: Four Variable Compared to MTA	Percent Difference: Two Variable Compared to Four Variable
1-South Miami	336, 044	24, 757	$0.4600	$0.4527	$0.4521	+ 1.75	+ 0.13	+ 1.61
2-Richmond Heights	54, 810	3, 028	0.4047	0.3776	0.3547	+14.10	+ 6.46	+ 7.18
3-Grapeland Heights	209, 837	21, 629	0.5483	0.5410	0.5419	+ 1.19	- 0.16	+ 1.35
4-Coral Way-N.W. 12th Avenue	342, 834	34, 195	0.5383	0.5374	0.5242	+ 0.78	+ 2.52	+ 0.17
5-N.W. 2nd Avenue-Westchester	735, 006	74, 140	0.5413	0.5616	0.5485	- 1.31	+ 2.42	- 3.65
6-Hialeah Limited	629, 488	56, 587	0.5087	0.4938	0.5018	+ 1.38	- 1.59	+ 2.93
11-Miami Shores, W. Flagler	669, 202	62, 717	0.5202	0.5459	0.5226	- 0.46	+ 4.46	- 4.71
12-Miami Shores, N.E. 2nd Avenue	299, 150	29, 150	0.5314	0.5351	0.5379	- 1.21	- 0.52	- 0.69
14-Coconut Grove—Hialeah	630, 311	61, 929	0.5338	0.5542	0.5339	- 0.00	+ 3.80	- 0.07
15-N.W. 27th Avenue	392, 700	38, 098	0.5301	0.5261	0.5231	+ 1.34	+ 0.57	+ 0.76
16-South Dixie Express	64, 388	4, 232	0.4362	0.4826	0.4059	+ 7.46	+18.90	- 9.61
17-Dinner Key	145, 689	13, 944	0.5262	0.4936	0.4973	+ 5.81	- 0.74	+ 6.60
18-Civic Center-Mercy Hospital	286, 388	28, 540	0.5380	0.5252	0.5132	+ 4.83	+ 2.28	+ 2.44
19-N.W. 7th Street	174, 487	17, 284	0.5362	0.5341	0.5349	+ 0.24	- 0.15	+ 0.39
21-Liberty City	424, 780	50, 063	0.5927	0.6062	0.6298	- 5.89	- 3.75	- 2.23
23-N.W. 22nd Avenue	342, 781	32, 641	0.5247	0.5170	0.5103	+ 2.82	+ 1.31	+ 1.49
24-N.W. 46th Street	169, 265	18, 380	0.5648	0.5589	0.5693	- 0.79	- 1.83	+ 1.06
25-Miami Shores	311, 135	29, 185	0.5205	0.5065	0.4996	+ 4.02	+ 1.38	+ 2.76
26-N.W. 7th Avenue	335, 365	34, 054	0.5437	0.5267	0.5662	- 3.97	- 6.68	+ 3.22
27-Civic Center Crosstown	90, 911	11, 187	0.6083	0.5991	0.5912	+ 2.89	- 1.34	+ 1.54
28-Coconut Grove	264, 166	24, 181	0.5137	0.4968	0.4884	+ 5.18	+ 1.72	+ 3.40
29E-East Hialeah	201, 437	16, 987	0.4920	0.4771	0.4644	+ 5.94	+ 2.73	+ 3.12
29W-Palm Springs	241, 027	20, 955	0.4999	0.4728	0.4657	+ 7.34	+ 1.52	+ 5.73
30-Miami Springs	425, 524	40, 192	0.5224	0.5266	0.5045	+ 3.55	+ 4.38	- 0.80
34-Le Jeune Road	210, 227	16, 831	0.4792	0.4545	0.4364	+ 9.81	+ 4.15	+ 5.43
37-17th Avenue Crosstown	92, 561	9, 253	0.5390	0.6345	0.5102	+ 7.60	+24.36	-15.05
100-Park Ride-Airport	247, 431	18, 323	0.4612	0.4212	0.4343	+ 6.19	- 3.02	+ 9.50
A(XX)-S.W. 3rd Avenue and 13th Street	106, 862	10, 323	0.5288	0.6469	0.5584	- 5.44	+15.85	-18.26
B-Key Biscayne	131, 318	8, 515	0.4335	0.4075	0.4549	- 4.70	-10.42	+ 6.38
C-Mt. Sinai Hospital	336, 825	32, 760	0.5308	0.5469	0.6511	-18.48	-10.00	- 2.94
K-Surfside	539, 686	45, 850	0.4939	0.4873	0.4957	- 0.36	- 1.70	+ 1.35
L-Venetian Causeway-Little River	580, 705	51, 584	0.5055	0.4910	0.4894	+ 3.29	+ 0.51	+ 2.95
M-MacArthur Causeway Limited	315, 354	29, 576	0.5204	0.5156	0.5451	- 4.51	- 5.41	+ 0.93
O-Meridian Avenue	62, 377	6, 604	0.5567	0.5245	0.5205	+ 6.95	+ 0.77	+ 6.14
R-Biscayne Point-Normandy Shore	259, 099	24, 313	0.5206	0.5033	0.4933	+ 5.53	+ 2.03	+ 3.44
S-Bay Harbor	466, 005	44, 531	0.5257	0.5268	0.5571	- 5.64	- 5.44	- 0.21
T-Tuttle Causeway Limited-Surfside	497, 720	41, 831	0.4912	0.4769	0.4859	+ 1.09	- 1.85	+ 3.00
X-	5, 459	663	0.6034	0.5814	0.6595	- 8.51	-11.84	+ 3.78
Total	11, 629, 344	1, 089, 012						
Percent root mean square error						5.93	7.26	5.48

TABLE 6
FORMULA RESULTS COMPARED BY SERVICE CLASS

Service Class	Percent Root Mean Square Error		
	Two Variable Compared to MTA	Four Variable Compared to MTA	Two Variable Compared to Four Variable
Miami-Miami Beach	8.82	10.42	7.88
Crosstown	7.36	10.82	8.63
Downtown	3.65	4.20	3.98
System Total	6.00	6.29	5.98

Comparison of operating cost by routes indicates close agreement between all of the calculation methods. Generally, the smallest routes (in terms of vehicle-miles operated) have the largest percent differences. Table 6 summarizes the differences between these formulas through the use of the percent route mean square error for each class of service. In total, none of the formulas exceeds an 11 percent difference with any of the others. The largest percent difference by category occurs in the crosstown routes, which have been previously shown to be at the low end of the revenue-producing scale, This close agreement between formulas is to be expected because, as Table 4 illustrates, more than 80 percent of the operating costs are attributable to vehicle-miles and vehicle-hours under any of the calculation methods.

The four-variable analysis should result in present day operating costs that may be considered more accurate measures than the two-variable formula that uses only vehicle-hours and vehicle-miles. However, when applied to a future set of circumstances, the four-variable formula requires that peak vehicle needs be estimated for each route. The estimating process required to obtain this variable on a route basis introduces estimating problems that may produce peak vehicles at a lower level of accuracy than the final formula itself.

To obtain peak vehicle needs on a route basis, the analyst must estimate at least the round-trip running time on the route, the maximum load point volume on the route, the peak-hour, peak-direction volume past the maximum load point, and the vehicle-load factor (percent occupancy of the bus). The many assumptions necessary for an estimate of peak vehicle needs, therefore, increase the desirability of using a route cost estimating method that relies on as few variables as possible, yet still maintains a suitable level of accuracy.

The conclusion to be drawn from the analysis in Tables 5 and 6 is that for long-term planning projections, a simplified operating cost formula such as the two-variable allocation is more than adequate and is probably more desirable because of the need to estimate only miles and hours of service on each route. For short-range service improvements and detailed fiscal planning, a more accurate allocation formula such as the four-variable method or the MTA formula is more appropriate.

Planning Application

The cost allocation methodology developed in this report is being utilized to determine the future cost of modifications in surface bus routes. This operating cost in combination with capital and operating expenses for grade-separated rapid transit facilities to be analyzed in the transportation study testing process will yield the total community cost resulting from a number of transit alternatives. Projected system costs will be measured against anticipated revenues, derived in other study phases, to measure financial feasibility of alternative solutions to the public transit problem.

Economic Aspects of Urban Passenger Transportation

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•FOR several years the public has expressed concern over the problem of urban transportation (1). Although it is not clear what the problem is, or whether, indeed, there is one, some symptoms can be identified: public transit is losing riders and farebox revenue fails to cover system costs; businesses in the central business districts are losing customers; in some places traffic congestion at the least appears to be growing worse, particularly at peak hours (2); parking appears to be inadequate; population and employment in the central city decline as people and jobs move to the suburbs; and the poor and unemployed left behind in the central cities need costly social and economic support, but those who can pay for these programs have moved out. These symptoms reflect a host of problems and no doubt some of them are conditioned by the nature of the transportation system. Although it is reasonable to seek improvement in the system, it is misleading to postulate an "urban crisis" that can be defined simply in terms of transportation.

Under the pressure of public concern, major planning programs have often taken too narrow a view. They have treated transportation as if it were an isolated problem unrelated to the broader question of how members of the community are to provide themselves with the goods and services that improve the quality of their lives. The demand for transportation is a derived demand. People seldom make a trip for its own sake, but rather to satisfy some want or to earn an income. Although nearly all responsible planners, researchers, and community leaders are aware of this fact, its importance for planning requires detailed attention.

Residential locations have become more decentralized with the movement of households to the suburbs. Similar changes in work, shopping, service, and recreation have occurred. Some would argue that the automobile has caused this decentralization, but it is more likely that in the absence of a highly developed, ubiquitous public transportation system, the automobile has allowed, rather than caused, the migration. It makes living and working in remote locations possible.

The automobile, however, is a relatively expensive means of travel. In planning and evaluating transportation systems it is important to recognize that the outward movement to the suburbs has taken place in spite of a very high money cost, at least for transportation. To an economist, this implies that the consumer finds compensation elsewhere. Where public transit is an alternative, use of the automobile may be compensated by the better service afforded and, where transit is not available, by the open space, privacy, clean air, quiet, better schools, or safety of suburban life.

The dispersion of homes and employers has made the collection and distribution tasks of public transportation systems particularly difficult to accomplish with existing technologies and organization. It would appear that the very substantial decline in public transit usage may be attributed, at least in part, to the failure of transit systems to adapt to decentralization. In effect, this failure can be regarded as an implicit reduction in the average quality of service available to potential trip-makers. The result has often been financial difficulty for public transit leading, in many cases, to further explicit reductions in service. Thus the problem is compounded by making automobile travel even more attractive.

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There is evidence that these trends will become even more pronounced in the future as populations grow, incomes rise, and more leisure time expands (3). The resulting diminution in transit service will make it more difficult to provide for groups with special public transportation requirements. But unfortunately, there is evidence that along with this growth we will still have substantial numbers of poor, handicapped, young and aged, each with their special needs. These groups will not be able to participate fully in our modern society unless some provision is made for their transportation. Careful attention to their specific needs will make it possible to design transportation systems offering appropriate levels of service at prices they are willing to pay.

In the past, nearly all wants could be satisfied in a relatively small area centrally located in the city. Public mass transportation could move large numbers of people efficiently because residential areas were dense and activities were centralized. With the new, lower densities of our metropolitan areas, the transportation technologies developed in the past have become obsolete.

It is important to consider the tools available for solving the urban transportation problem, i. e., the problem of making it possible for people living in modern urban society to gratify their desires. Three basic tools appear appropriate: (a) changes in the physical transportation system (e. g., in vehicles or roadways), (b) changes in the organization of existing technologies to improve the service qualities offered and, perhaps most important, (c) changes in the location and organization of economic activity. The evaluation of the usefulness of these tools requires that we first understand the transportation system available today and observe the reactions of trip-makers to its characteristics.

THE TECHNOLOGICAL TOOLS

Automobiles

The automobile is in many respects ideal. For most door-to-door travel, it is more convenient than any other form of transportation as well as being small, comfortable, and private. Furthermore, the automobile can carry freight—a particularly important feature for shopping trips. Under favorable conditions, the driver is not constrained by schedules and can operate independently of others. For all intents and purposes, the service is totally responsive to the driver's individual demand. Under conditions of severe congestion he may not be so free to act.

Although the driver must (or should) be almost totally occupied with the tasks of driving, he may listen to the radio, smoke without disturbing others, or talk privately with other passengers. Auto passengers, of course, are free to occupy themselves more productively although probably not as easily as on a high-quality commuter railroad.

The automobile requires an extensive roadway system; but the system is also required for truck freight, public bus movements, and utilities; the roadway is multipurpose. Nevertheless, the roadway systems in our major urban areas are often inadequate to provide relatively unimpeded service. This inadequacy is frequently compounded by their use for parking and unloading freight.

Car ownership has become general throughout the United States with the steady rise in personal incomes. Since the decline in residential and employment densities, two-car households have become commonplace. Often one automobile is almost exclusively devoted to commuting trips.

Along with the benefits of good service, the automobile has contributed to the problems of air pollution, land consumption, and the preservation of the aesthetic qualities of urban areas, particularly in the older sections of our cities. Congestion delays are frequent and parking is often inadequate. Where the road is shared with buses, the increased congestion has had an impact on the quality of public transportation service.

Railroad and Rail Rapid Transit

Those who live and work close to rapid transit or commuter railroads can obtain excellent service downtown for very low fares (but perhaps not so low costs). The vehicle is large making standing, entry, and exit easy for the passenger; and wide, comfortable seating can be provided. There are disadvantages, too, because the exclusive right-of-way is totally unadaptable to changes in the geographic distribution of residential and economic activity, or to changing distributions of trips. This inflexibility makes it necessary for trip-makers who wish to use the facility, and who live or work in new areas distant from the transit line, to ride or walk to the station. Often, where jobs or residences have moved, the existing transit system may no longer provide a desired service.

Urban rail transit is expensive as well as inflexible. Low passenger fares cannot be maintained unless the system is employed at or near full capacity. This means that urban rail transit is economically viable chiefly in areas of high residential and employment density. And only where customers are plentiful can it come close to providing reasonable door-to-door service. In most systems, however, service is generally poor. Passengers are obliged to walk, climb stairs, transfer, and wait until the public transit schedule happens to coincide with their own.

Bus and Other Public Highway Systems

Public transportation systems using only public streets and highways have the flexibility of the automobile but suffer the same impediments to travel. The nature of the roadway and the size of the vehicle provide the essential ingredients for a close approximation to door-to-door service (although few systems attempt to provide it). The smaller size of the bus, however, makes seating less comfortable than in railroad cars. Although in comparison with rail systems the costs of bus service are relatively high per available seat mile, buses may be more efficient for travel in areas of moderate or low density. Under the present organization, bus travel often requires transfers and significant waiting time. Bus system reliability is highly sensitive to weather conditions, particularly ice and snow. (Although it is potentially possible to provide rail service that overcomes some of the sensitivity to weather, as a practical matter it has not been achieved with the principal commuter services in our major cities.)

Taxi service, like the automobile, provides door-to-door service anywhere but without the burden of driving; the disadvantage of having to wait for a taxi compared with private auto travel is compensated for, in part, by the elimination of delays and walking required in parking. The passenger must, however, pay handsomely for this level of service.

Jitney service is not now provided in most urban areas, but is worthy of consideration since it can be operated much like a taxi but at a somewhat lower cost. Even then its costs are higher than those for bus operations, but the improved service may make it worth much more to the passenger. Either door-to-door or near door-to-door service can be achieved and because the vehicle can accommodate only a few passengers, significant delays to the trip-maker owing to picking up other passengers are reduced.

POSSIBLE NEW TECHNOLOGIES AS TOOLS FOR TRANSPORTATION SYSTEM IMPROVEMENT

Many new technologies have been suggested for mass transportation, but these often focus on line-haul trip characteristics and ignore the problems of collecting and distributing passengers. These systems are intended to provide increased comfort, speed, and greater aesthetic quality to our urban environment. If analyzed in terms of the service characteristics of door-to-door travel, most of the systems that provide these other qualities appear to be very much like existing rail rapid transit. One concept, however, appears to be a notable exception.

Perhaps the most interesting technological concept is the dual-mode vehicle—i. e., a vehicle capable of operating as a private automobile in fulfilling the collection and distribution functions in low-density areas, and operating as part of a high-speed train for the arterial links of the trip. One suggestion is to have a self-powered vehicle that can operate normally on city streets and would be used to take a trip-maker from his door to an exclusive, grade-separated guideway where the vehicle would be automatically controlled to become part of a high-speed train. Although the system requires a separate roadway that cannot be shared with other vehicles, it meets the door-to-door service requirement and the need for high-speed mass movement over the major network links.

The system would be much improved, however, if the mass movement mode could be accomplished on existing roadways. Perhaps median strips or separate lanes could be converted for this use. Maximum exploitation of the facilities already available would obviate the need for new rights-of-way and thus limit the investment required. Of course, in addition to the technical problems that remain to be solved, the economics and regulation of the system must be thoroughly explored before such an innovation is adopted.

Past emphasis on public mass transportation has been on costs per capacity unit. It is not at all clear that low-cost transportation per se is the answer. As indicated earlier, current mass transportation travelers, automobile riders, pay a very high price to obtain a high level of service. Although costs cannot be ignored, solutions must give consideration to the characteristics of service provided; it may well be necessary to charge much higher fares, but these might be gladly paid if the service warranted them. Here a significant problem arises: we have little or no information on the values trip-makers place on service characteristics. Without this information the design of new solutions is virtually impossible.

We do not know how travelers value their time. We do not know if, for example, they find the time getting to and from transit terminals, or waiting and transferring, more or less onerous than equivalent amounts of time spent in the vehicle. There is some evidence that reductions in these excess times evoke greater traveler response than do similar reductions in the in-vehicle time (4). If it should become the aim of public policy to design systems that lure trip-makers away from the automobile, then we must look carefully at the travel qualities of the automobile and attempt to provide competitive qualities in our public systems.

ORGANIZATIONAL CHANGE AS TOOL FOR IMPROVING TRANSPORTATION

Progress toward improved service may not require technological change. A significant step forward may be possible if we take an entirely new look at our existing systems. Routes and schedules are largely an outgrowth of patterns developed during a different era of urban living. Perhaps if we consider abandoning them and starting over again, we can design a system without any additional cost, but one that will provide greatly improved service. It is often difficult or impossible with today's systems to get people from their homes to present locations of jobs. The transportation problem of the ghetto resident is probably not so much high transit fares as the near impossibility of traveling to distant jobs without extreme discomfort and sacrifice of time. The present growth in job opportunities for workers from the ghetto is in the suburban and fringe area rather than in the CBD. Public transit to these outer areas is often nonexistent; where service is provided from the ghetto areas, it is generally poor, requiring multiple transfers, long waits at stops unprotected from inclement weather, and long walks to the place of work from the transit stop.

It is often argued that public transportation must be provided to take care of the aged, the handicapped, or those who either have no car or are too young to drive. There is no particular reason to require it to do so. A system requiring the passenger to step up to board a bus, or to climb stairs to reach a subway platform, will be of little or no use to the feeble or handicapped. Separate, special systems might be provided for these groups, at relatively low cost, without seriously compromising mass transportation needs. Low-fare taxi or jitney service may be the most appropriate mode for accommodating this rather small fraction of our population.

Another pressing problem in most central cities is the reduction of taxable property through land takings for transportation roadways. (The mere reduction in the total land available for building may not destroy taxable property value. Depending on the elasticity of demand for land, the value of remaining land may increase by an amount that more than compensates for the lost land.) To avoid congestion while maintaining a suitable tax base there has even been talk of keeping the automobile out of the CBD. Such action, in failing to recognize urban society's transportation demands realistically, might very well restrict the use of the city to those few having access to good public transit and might well be the death knell of the city. It is surprising that other solutions have not been more extensively explored and implemented. In particular, much more attention should be given to the use of air rights over the major roads of the CBD; air rights can be used for buildings or for pedestrian malls that would separate people from vehicular traffic, and so improve the flows through the CBD. Other advantages would also accrue such as keeping the often expensive results of inclement weather from interfering with the flow of traffic in these highly congested areas. It would seem that the use of air rights could make large areas available for transportation without significantly adding either to the cost of building or to any deterioration of an already troublesome tax base.

Simple methods of increasing roadway capacity should not be neglected. Substitution of off-street for curbside parking would seem to be an essential consideration before engaging in major new roadway construction. Elimination of curbside parking may cost less than the construction of a new road, even when land acquisition and construction costs seem reasonable. For in addition to these costs, a new road disrupts traffic during construction and does little to relieve the congestion and hazards caused by curbside parking.

Other low-cost improvements that should be considered are more elaborate signalization systems, effective use of one-way streets, and better control of pedestrian traffic. Rather than use major new road construction as a panacea for increasing roadway capacity, all other techniques at our disposal should be thoroughly explored. Often, external incentives distort these analyses. Federal or state funds may be available for road building but not for other, simpler solutions, thus making a comparative analysis favor socially expensive alternatives. In other cases a division of responsibility between agencies prevents consideration of a comprehensive set of alternatives.

CHANGES IN THE LOCATION AND ORGANIZATION OF ECONOMIC ACTIVITY AS TOOLS FOR IMPROVING TRANSPORTATION

When it is fully recognized that travel demand is derived from the demands for other goods and services, other areas for improvement in transportation become apparent. Functions once served by the CBD, when the city was more concentrated, may no longer be economic. As a prime example, the CBD served as a major shopping center for the metropolitan area. As the area grew and densities declined, automobile usage became more common, causing congestion and parking problems that disadvantaged retailers in the CBD. Soon the large suburban shopping center began to compete by providing a wide variety of goods and services, easy access, and convenient parking. There the automobile could be used as it should be both for passengers and freight. Needless to say, suburban shopping centers often prospered at the expense of downtown merchants who consequently complained. In this case, one could argue that natural market forces are playing a role in the adjustment process making the use of land for general retailing, such as food and everyday clothing, relatively more attractive in the suburbs than in the CBD. By focusing attention on the location economics of various activities, the planner may hasten the functional development of the CBD. Activities that draw on very large segments of the population may require a central location; those that can achieve sufficiently large markets in suburban areas might best avoid the CBD. Thus, the CBD may be appropriate to highly specialized retailing, art galleries, theaters, exhibition halls and museums, financial activities, and government offices. The suburbs may yield production economies to industries that require large tracts of land or single-story structures. Suburban industry can usually provide better facilities for rail and highway freight movements, and better access and parking for personnel.

By considering the sources of input for each activity, its market, and the behavior of the consumer, planning can achieve better functional use of land in the urban area. In fact, failure to give appropriate attention to the services that should be provided by the city will only compound the city's problem. Although attention should be given to aesthetic design, its emphasis at the expense of function may only result in a modern beautified city serving few if any needs of society.

In addition to changing land uses to conform to the functional needs of society, perhaps other approaches might improve the quality of transportation in our cities. A large part of the transportation problem is the peak hour. Often our highway systems are more than adequate during off-peak periods, but are badly congested during peaks. New facilities are "demanded" to accommodate growing peak traffic. The problem of peak periods is even more pronounced for public systems where large investments remain idle for most of the day. The accommodation of peak travel makes our urban transportation systems very expensive and leads to poor utilization. Rush hours, however, reflect our social habits and practices. Business hours are generally uniform in the city. It is possible that some small changes in business hours could result in substantial improvement in transportation service with no corresponding increase in investment. Retail activities might, for example, open later in the morning and remain open in the evenings; school hours might be rearranged so that the traffic schools generate would not impede the journey to work. There are, of course, important reasons for all businesses to maintain similar hours, for communication and coordination, but incentives could perhaps be created that would induce some to change. Before embarking on a program to encourage staggered hours, more detailed analysis is required, however. They may produce serious undesirable effects such as reduction in car-pooling opportunities and disruption of family schedules. Even marginal changes may bring major relief from peak-hour congestion. For example, substantial improvement in downtown highway circulation might be brought about if deliveries were made at night.

A goal of some planning activities is the promotion of the central city as a place to live and work, so that higher densities might be achieved. It is difficult to know whether people can be induced to return to the city. If they live in the suburbs for the sake of suburban life, it may not be possible to induce them to return. The experiment has not been performed and furthermore, because such an experiment would require renovation of very large tracts of land, it may not even be feasible—failure would mean substantial waste of resources.

PROVISION FOR UNCERTAINTY

Plans for new transportation facilities should recognize the uncertainties of our forecasts. The problems created by uncertainty are no less severe for the automobile highway system than for urban public transportation systems. There is much we do not know about consumer behavior with respect to transportation. Although it is relatively easy to describe the trips made today with today's systems, trips must be related to the characteristics of the traveler and to the geographic distribution of activity. It is difficult to gage these relationships, let alone to predict the future, even if we assume an unchanging transportation system instead of a new one. Proper planning and implementation of new systems require detailed knowledge of future origin and destination patterns. Errors in these forecasts can lead to wasteful land taking, unnecessary relocation of people and utilities, and useless construction. The costs of such errors can be substantially reduced if the uncertainty in forecasting is explicitly acknowledged in the planning process.

Flexible systems provide some insurance against uncertain forecasts. The placement of steel rails or the pouring of asphalt or concrete is very costly and the result is long-lived. New public systems that make use of existing roads are highly flexible; in fact, the provision of new bus routes on existing streets is relatively risk-free. Rail rapid transit construction, however, is very inflexible and, hence, risky. Proper allowance for these considerations in planning decisions may require overwhelming evidence of large volumes of traffic to come before rail systems are introduced, but much less evidence is needed for new bus routes. Where new highways appear to be justified, and construction is begun, rights-of-way can be reserved for future increases in lanes, and underpasses or bridges can be built to accommodate future expansion. Where forecasts indicate that future highway expansion will be desirable, land reserved now might lower the costs of future acquisitions and eliminate some of the social dislocations that so often occur. Land reservation for future contingencies might preclude new building construction or placement of utilities that would have to be relocated in any future land taking if their expected useful life over which their costs must be recovered is severely shortened. Although there is no way to avoid errors completely, precautions should be taken to insure that they are not too costly.

FINANCING URBAN PUBLIC TRANSPORTATION

A major issue of transportation today is the question of subsidy. With the decline of transit usage many transit operations, particularly in our larger urban areas, may not be able to continue operating without some form of subsidy. In some cases, it is thought that subsidy is more desirable than a fare increase, even though the latter might provide adequate revenue. Commuter railroads have had constant financial problems. Before dealing with the question of whether to subsidize, the question of need should be resolved. Perhaps with new approaches to public transportation systems, no subsidy would be required or it could at least be reduced. This does not mean reducing service to a bare minimum; indeed, the application of this solution in the past may well be the root of the problem. Instead, improved service may produce added revenue without increasing costs (5).

Furthermore, if a service were offered that competed in quality with that provided by the automobile, it is very possible that much higher fares could be exacted. Limited evidence indicates as much: large amounts of money are spent for automobile travel; and recent studies made of the value of time indicate travelers place a value of between two and four dollars per man-hour on their travel time, including the entire package of service qualities (6, 7). This would indicate that public transit improvements in door-to-door travel time could be priced fairly high. Significant improvements in these times probably will not be achieved from higher line-haul speeds, but rather from stops closer to homes and places of work and from elimination of long waits and transfers.

There is little if any evidence that free parking at suburban terminals or lower fares will attract many to the public system. The transit industry sometimes uses a rule of thumb that each one percent increase in fare will result in a 0.3 percent loss in riders. If the rule has any validity, the reverse should also be approximately true. Recent empirical work of a more detailed nature indicates that travel demand is insensitive to fares, but relatively much more responsive to improvements in service. In the study by Domencich and others it was found, for example, that the elasticity of demand with respect to line-haul cost was -0.09 for work trips, but the elasticity with respect to the non-line-haul portions of travel time was -0.71, a relative response seven times greater (4).

It is often argued that raising fares will hurt poor people. Certainly it will, but the poor service offered them may hurt much more. In fact, it is reasonable to assume that where no service is provided it is equivalent to charging an infinite fare. Improved service may afford the poor a wider choice of job opportunities that could lead to higher incomes. Since transit subsidies are generally financed by regressive local taxes, the burden of low fare systems often falls on these same poor people. These methods of financing subsidies usually transfer income from the poor to the rich. This is partly owing to the nature of the route systems; i. e., there is a cross subsidy between heavily used segments in the downtown areas and the lightly used suburban segments. The heavily used segments often pay their way, while the lightly used routes are deficit operations providing public transportation for wealthier groups in society. Certainly this aspect of subsidy is undesirable.

Indirect subsidies are inefficient; from an efficiency point of view, direct payments to the poor coupled with fares that can meet costs will lower the total costs of both activities and, in part, will eliminate the income transfers from the have nots to the haves. The subsidy problem may not be simple; from a political point of view, it may be more expedient to subsidize transit from general funds than to make direct welfare payments. Arguments that welfare payments destroy the pride of the recipient should perhaps carry some weight. There are administrative procedures that could be used to alleviate some of the psychological effects of the dole, such as the negative income tax or impersonal methods of distributing welfare checks. In any event, it would be unwise to confuse these considerations peculiar to welfare with the already over-complicated problems of public transit.

Those persons requesting subsidies for transit often justify their demand by arguing that the private automobile system is subsidized but the public system is not. The facts are not clear; it appears that the urban automobile traveler may in fact pay more money in the form of user charges than is spent on urban highway facilities (2). In any event, even if there is a subsidy, two wrongs certainly do not make a right, and it is not at all obvious that if the subsidy (if any exists) were removed from the automobile system by increased user charges (or by some other means) any benefit would accrue to transit.

The most vociferous proponents of subsidized transit are often the merchants of the CBD who have undoubtedly suffered from the new development patterns of our cities. Subsidies may bring temporary relief but eventually the pain will become unbearable. Because the demand for transportation is derived, any subsidy to transportation is ultimately a subsidy to other activities. One must question the merit of using public moneys to subsidize moribund private activities. This is not to argue that subsidies are never appropriate, but to suggest that thorough consideration must be given the question before resorting to this solution. Subsidies are often useful for overcoming short-run phenomena. The most efficient allocation of our resources may require a geographic reshuffling of activities that will be governed by the incentives of the marketplace. The subsidy may serve only to distort the natural incentives or to delay needed adjustments. Yet they may be useful supplements in the interim while the needed adjustments are taking place. Some insurance should be provided, however, that such adjustments will be made.

RESEARCH NEEDS

Before economic principles can be applied to our urban transportation problems, several areas of research must be more fully investigated. We must learn a great deal more about consumer responses to changes in the transportation system. The models generally used for urban transportation planning have many serious deficiencies that must be overcome. These models have grown erratically; they fail to recognize many fundamental economic principles explicitly, making it impossible for the planner or systems designer to investigate the sensitivity of travel to system changes.

The usual approach to urban transportation modeling divides the trip-making process into several separate and distinct submodels: trip generation, trip attraction, trip distribution, route assignment, and modal split. The models treat these operations largely as separate decisions. For example, models that describe selection of mode and trip generation are constructed independently of each other, as if the factors used to explain modal choice had no effect on trip generation. Economic theory tells us, however, that if travel is costly, or otherwise onerous, fewer trips will be made. Thus, one of the very relationships we must explore, the effect of modal characteristics on the number of trips made, is explicitly denied.

Some progress has been made toward incorporating all the elements of the trip-maker's decision in a single model that describes the effect on travel of changes in travel times, travel costs, socioeconomic characteristics, and the characteristics of all the alternative transportation choices available (4, 8, 9). Although these models are still at a very primitive stage of development, their further exploration may well lead to improved forecasting and design.

A second area requiring intensive research is land use modeling. We must learn how people facing a particular geographic distribution of activities locate their places of residence, employment, shopping, recreation, etc. The decisions people make must be related to the characteristics of the areas considered, their personal socioeconomic situation, and the characteristics of the transportation system available. Study of this aspect of consumer choice points to the necessity of introducing some dynamics into the entire urban modeling process, because changes made in the transportation system and in land use are likely to influence each other.

The development and application of such large-scale models is not at all simple; a great deal of research is required. But this is not impossible with the research tools at our disposal. Ultimately, the present separation of land use and transportation modeling must be eliminated if good planning is to result.

These models must explicitly incorporate variables to describe the characteristics of the policy tools available to the system designer. The transportation system designer should be able to evaluate the effects on travel behavior of changes in public transit fares, line-haul travel times, parking charges, transfers, walking time, zoning regulations, etc. Without explicit understanding of how such characteristics affect travel, the designer must operate on assumptions, either implicit or explicit, and the chances for error may be greatly increased.

Once the effect of policy changes on travel behavior is understood, analysis of the benefits derived from various system improvements can begin. While it appears that the models required to describe and to forecast transportation and land use can be based on sound existing theory, the same may not be true for benefit/cost evaluation—the basic process for the determination of priorities and the allocations of limited capital budgets. Conceptually, the problem is similar to that of capital budgeting for private industry, but in that case, benefits can be measured as profit. No comparable single measure has found universal acceptance for application to public investments. If user charges are imposed through use taxes, tolls, transit fares, or parking charges, this revenue could be used to offset costs and we may attempt to apply the private standard of profit, or the excess of willingness to pay over cost, to these investments. It is often argued, however, that these systems frequently create external effects that are not directly reflected either in the measured costs or in the money revenues. To the extent that any net external additions to or subtractions from benefit are created by the system, they should be incorporated in the benefit/cost calculus. Changes in the transportation system often create income transfers. Although such transfers may be desirable, it seems best to exclude the value of such transfers from the benefit/cost analysis in determining whether a change is worthwhile. If the change is not worthwhile when the value of desirable transfers is included, it may be possible to effect the transfer at lower total social cost through other, more direct means.

Beyond the problem of measuring benefit, the specific analysis of the relative values of different systems has also been the subject of controversy on several levels. The major problem is that transportation improvements are long-lived and create streams of future benefits and costs. A means must be devised to account for this time dimension. Several measurements have been used or proposed for comparing individual projects: the annual cost method, the benefit/cost ratio, the rate of return, and the net present value. It appears that net present value is generally the best measure for taking account of the time dimension while remaining consistent with capital budgeting theory, particularly when priorities are to be established. The measurement makes it relatively easy to compare initiation of a project now with delay to a later time when some degree of uncertainty may have been eliminated. In practice, however, the other techniques are often used in the evaluation of transportation improvements (10).

Two further problems must be resolved for any formula selected for measurement: (a) the appropriate discount rate, and (b) the life of the investment. There is a strong tendency on the part of engineers and planners to apply low discount rates and long lives to transportation investments, thereby tending to justify nearly any investment. Some attention should be given to these issues so that realistic values are insured.

These research problems are primarily of a fundamental nature. It is unlikely that their solution will be found in a practical day-to-day planning environment. Although it is important that research in these areas should recognize the practical problems of application, we should not expect their solution to be the result of any specific planning study. Instead, some purely developmental effort in a research environment seems warranted.

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The Influence of the Highway Network Structure on the Economic Development of West Virginia

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A procedure is proposed to consider additional information in the evaluation of alternative transportation systems when the main objective of the improvements is to increase the economic growth of a stranded area. The effect of transportation improvements on the economic development of Appalachia is discussed within the context of the Appalachian Regional Development Act. It is concluded that the objective of the Act is to increase the economic growth of Appalachia by concentrating public investments in growth points and attracting new industry. Transportation improvements can help achieve these goals by increasing the locational advantage of growth points relative to major metropolitan centers. West Virginia is presented as a case study.

•OVER the past decades, Appalachia has become synonymous with underdevelopment and has been a problem area within the national economy. The Appalachian Region includes West Virginia and parts of 12 other states. (The Appalachian Region was so defined in the Appalachian Regional Development Act of 1965 and amendments. The definition includes those counties in the states that share the same social and economic problems.) The region can be described as an area of gently rolling to mountainous terrain with a large nonurban and nonfarm population, a population growth below the national average, high unemployment rates, and a low level of public expenditures and services.

Appalachia has continually been used as an example of a stranded area within a highly developed economy. The Region has lagged behind the remainder of the United States in terms of economic growth and ability to adjust to economic changes. In 1965, Congress passed the Appalachian Regional Development Act (ARDA) to provide federal assistance in meeting the Region's special problems and in promoting its economic development.

Transportation improvements play a key role in the federal program for Appalachia. In 1964 the President's Appalachian Regional Commission recognized the importance of increased accessibility to foster economic growth by recommending adequate provision of access by highway and air, both to and within the Region, as one of four priority areas of investments. As a result, ARDA authorized the construction of an Appalachian Development Highway System supplemented by local access roads. ARDA emphasized transportation improvements as a means of stimulating development and further specified that "public investments...shall be concentrated in areas where there is a potential for further growth" (1). The planners and administrators in charge of carrying out the provisions of ARDA were then given a clear and explicit statement of goals and means to attain them. The goal of promoting the economic growth of the Region

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was to be accomplished by public investments, especially transportation investments, in those areas with the greatest potential for growth.

Immediately, questions arose as to the relationship between transportation and economic development. Through ARDA, Congress directed planners to use transportation to achieve specified development objectives. Yet, the tools were not available to the planners. Most decisions to improve transportation facilities have been predicated on the forecast of transportation demand based on existing trends. Construction priorities have usually been based on the greatest benefits to users or on the greatest needs. A new approach was needed to make decisions on transportation improvements according to the ARDA requirements. However, the actual selection of the Appalachian Development Highway corridors was based on satisfying the forecast demand predicated on existing trends. The concept of a changing demand as a consequence of providing new linkages between Appalachia and the surrounding regions was not considered.

The measurement of changes in the locational advantage of places is presented in this paper as one technique presently available to the transportation planner that can be of assistance in evaluating the effects of alternative transportation improvements. Adequate consideration of this type of information is especially critical when the main objective of transportation investments is to stimulate economic development.

APPALACHIAN DEVELOPMENT CONCEPTS

The concept that transportation improvements result in immediate economic development is erroneous. In most cases where a transportation improvement did stimulate rapid development, a combination of other factors was also present. For example, railroad construction stimulated the development of the West, but the same type of development could not have taken place if rich mines, dense forests, and vast resources had not been present (2, 3).

In the Appalachian Region, most natural resources are already being exploited. Zwick has posed questions concerning the magnitude of the impact from transportation improvements in an advanced economy like the United States. He stated that "there is now a relatively ubiquitous supply of transportation in all areas of the United States; and as a result, most future economic growth can be expected to be rooted in forces exogenous to the transportation industry" (4). The problem facing transportation planners in charge of selecting transportation improvements according to the requirements of ARDA can be summarized in the form of a question: How can transportation improvements stimulate development in a stranded area such as the Appalachian Region in which natural resources are being exploited? This question can be dealt with by analyzing the specific development problems of the Appalachian Region within the context of ARDA.

ARDA was based on the concept of stimulating development of a stranded area by public investments. However, Congress was aware that the problems of the Appalachian Region are too large to be solved entirely by a governmental program. Therefore, ARDA specified where investments should be made and how they were to stimulate development, so that in the future the Region could support itself:

> The public investment made in the Region under this Act shall be concentrated in areas where there is a significant potential for future growth, and where the expected return on public dollars invested will be the greatest . . . Congress expects that the Region will generate a diversified industry, and that the Region will then be able to support itself, through the workings of a strengthened free enterprise economy (1).

In effect, ARDA applied the growth point theory of economic development to the problems of the Appalachian Region and specified the type of development that the Region should attract.

The growth point theory of economic development is based on the realization that the problems of development are too large to be solved by a "balanced growth doctrine" of equal aid to all regions and political subdivisions. This regional development strategy aims at integrating more developed areas with less developed areas through the location of economic activity. The objective is then to select a few high-potential growth points where investments can be concentrated in an attempt to bring neighboring areas within the orbit of development (5).

Congress also specified the type of development that should be attracted by stating that the Region should generate a diversified industrial base. The importance of this statement is obvious from a close look at the economic problems of the Appalachian Region. The high unemployment rates prevalent in Appalachia have been a result of an economy based on extractive industries. A shift to a diversified economic base is essential for economic growth to take place. The Region can diversify and prosper only by attracting new industries (6, 7).

Friedmann has noted that "accessibility to product markets has become the most significant single issue in location decisions within the United States" (8). He also points out that most new industrial locations are in or near metropolitan regions, whereas the locational potential of other areas has been declining. An increased accessibility to markets is then a prerequisite for the economic growth of the Appalachian Region. Furthermore, those areas with a greater locational advantage relative to regional markets have a greater potential for growth.

The transportation network of a stranded region such as Appalachia can be of assistance in achieving regional development goals in two ways: (a) an analysis of the existing transportation network can help identify the growth points with the greatest development potential; and (b) the existing transportation system can be improved in order to increase the accessibility to markets of the growth points previously selected. The selection of growth points should be based on human resources and available infrastructure, in addition to the accessibility factors.

Not all transportation improvements will increase to the same extent the accessibility to markets of the Appalachian Region. The objective, as expressed in ARDA, is to select those transportation improvements that will result in the greatest increase of the locational advantage of areas of high growth potential relative to regional markets. It is expected that the remaining areas within the Appalachian Region will become integrated with the more developed areas so that, in the end, the investments made will benefit the entire Region. Furthermore, the aim is to diversify the economy of the Region by attracting new industries. Transportation improvements can help attract new industry by increasing the accessibility of the Region to major markets and, therefore, this type of investment is emphasized.

ARDA has directed planners to develop an Appalachian Development Highway System supplemented with local access roads that would best serve the objective of promoting the economic development of Appalachia. The aim of the Appalachian Development Highway System is to increase the locational advantage of Appalachia by providing better direct connections between high-growth potential areas in Appalachia and major metropolitan centers outside Appalachia. The local access roads would then connect the major centers in Appalachia to the remainder of the Region.

Based on these regional goals, a procedure will be developed to assist in the evaluation of alternative transportation systems. The objective is to make use of analytical techniques that reflect the strong regional goals expressed in the Appalachian Regional Development Act.

WEST VIRGINIA: A CASE STUDY

West Virginia is the only state defined by the Appalachian Regional Development Act as being totally within Appalachia. Prior to World War II, West Virginia's economy was mainly dependent on coal mining and agriculture. Since that time, a major readjustment in the economy has been taking place while the state has been losing population owing to inadequate employment opportunities. Mining was the single largest industry in 1948 when employment reached a high of almost 125,000. By 1963, this figure dropped to 44,500, both because of a reduction in the demand for coal and an increased automation in the mines. At the same time, manufacturing and trade have become the most important of West Virginia's economic activities. However, the level of manufacturing and trade activity in West Virginia still remains less than the national average (9).

Assumptions

Certain assumptions are made in order to calculate indices that reflect the manner in which transportation improvements can influence future development. First, it is assumed that the future economic development of West Virginia is dependent on attracting new industry. Within a highly developed economy such as the United States, industries become market oriented, and West Virginia must increase its accessibility to regional markets in order to compete with other areas.

Second, it is assumed that the future economic development of West Virginia depends on the provision of better services to the population, because West Virginia must compete with major metropolitan centers in attracting new industry. A need exists within the state to expand urban centers in order to provide more and better public services.

Third, it is assumed that areas outside Appalachia already have good access to markets, whereas the accessibility to markets of West Virginia will be substantially increased by improvements in the transportation system of the Appalachian Region. The existing transportation system of West Virginia does not provide a high level of service in linking the major centers of the state with surrounding areas. The transportation improvements now under construction will greatly change the accessibility patterns of the Region.

Finally, only the highway portion of the transportation system is considered in this paper. Taking into account the magnitude of investments in the highway system relative to the other modes, it can be concluded that the effect of other modes on the future development of the state will be minor.

Growth Points and Regional Markets

A growth point has been defined as an area where growth has been occurring over a period of time and where this growth could be reinforced to stimulate the economy of the surrounding region (5). The Economic Development Division of Litton Industries conducted a study in 1965 to identify areas of growth potential in the Appalachian Region. This study concluded that urban areas "are consistently associated with higher levels of activity," and, therefore, synonymous with a higher growth potential (10). Based on

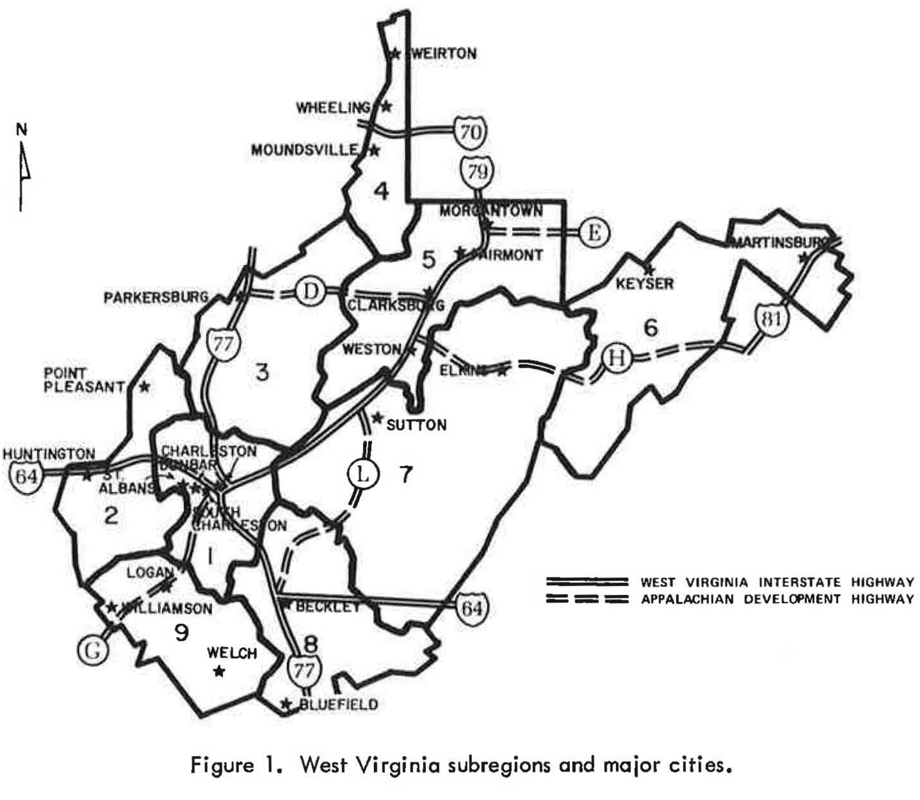

Figure 1. West Virginia subregions and major cities.

these results, all major cities in the nine subregions of West Virginia were selected as growth points. The nine West Virginia subregions are shown in Figure 1 as delineated by the Office of Research and Development at West Virginia University based on the boundaries of administrative districts, watersheds, economic characteristics, population characteristics, housing, and transportation facilities. Twenty-three urban areas or potential growth points were identified for the nine subregions of West Virginia (11).

Major and minor regional markets outside of West Virginia were defined on the basis of the size of the Standard Metropolitan Statistical Area (SMSA) and the distance from Charleston, West Virginia, the government center of the state. Those SMSA's with a population over one million and located within 250 miles of Charleston, or with a population of over 500,000 and located within 150 miles of Charleston were defined as major markets. Only six metropolitan areas, all located near the northern and western portion of the state, were identified as major markets. SMSA's with a population greater than 300,000 and located less than 150 miles from Charleston, and those metropolitan areas with an SMSA population greater than 15, 000 and located within 100 miles from Charleston were added as additional minor markets. The following analysis first considered only major regional markets, and then both major and minor regional markets together. Figure 2 shows the major and minor regional markets, the West Virginia growth points selected for this study.

◉ Major Regional Market — SMSA with a population in excess of 1 million and located less than 250 miles from Charleston, or an SMSA with a population in excess of 500,000 and located less than 150 miles from Charleston.

★ Minor Regional Market — SMSA with a population in excess of 300,000 and located less than 150 miles from Charleston, or an SMSA with a population in excess of 150,000 and located less than 100 miles from Charleston.

Figure 2. West Virginia cities and major and minor markets.

West Virginia Highway Network

The West Virginia highway network has lagged behind the rest of the nation, mainly because of the problems encountered in attempting to finance public services within a depressed economy and because of the high cost of road construction in mountainous terrain (12). As shown in Figure 1, two new highway systems are presently being constructed in West Virginia: the National System of Interstate and Defense Highways (517 miles to be constructed at a cost of $900 million), and the Appalachian Development Highway System (426 miles to be constructed at a cost of $618 million). In effect, the Appalachian Development Highway System supplements the Interstate System by providing access to those areas that are not well served by the Interstate System.

By analyzing the highway network at three points in time and by analyzing two alternative future systems, three separate effects of highway improvements are discussed:

1. The change in locational advantage of West Virginia growth points during the construction period of the Interstate System was measured by comparing the 1965 System, including only some completed Interstate sections, with the 1950 base highway network.
2. The impact on the locational advantage of West Virginia growth points resulting from completion of the Interstate System was measured by comparing the 1975 network, assuming only the completion of the Interstate System (1975A network), to the 1950 base and the incomplete 1965 network.
3. The effect on the locational advantage of West Virginia growth points resulting from completion of both the Interstate and Appalachian Highway Systems was measured by comparing the 1975 network, assuming the completion of the Interstate and Appalachian Systems (1975B network), to the 1950 base, the 1965 incomplete, and the 1975A network.

The Structure of the Highway Network—Indices of Locational Advantage

Graph theoretic measures describing network structure have been applied to transportation networks by other authors in recent years (13, 14, 15, 16). One of these indices was considered appropriate to characterize the structure of the West Virginia highway network in order to measure the locational advantage of growth points in the state. An additional index similar to a gravity formula was also included.

Accessibility—The accessibility index, with minor modifications, is a measure of the locational advantage of growth points in West Virginia with respect to regional markets. The accessibility index is defined as:

$$A(i,M) = \sum_{j=1}^{M} t_{ij}$$

where

$A(i,M)$ = accessibility of growth point i to M regional markets,
t_{ij} = minimum path travel time from growth point i to jth regional market,

i = 1, 2, 3, . . . n (growth point in West Virginia), and
j = 1, 2, 3, . . . M (regional markets outside West Virginia).

This index is similar to the traditional graph theoretic accessibility index, except for two modifications. First, travel time in minutes is used rather than distance. In West Virginia, the level of service provided by the highway network can best be reflected by driving speeds, mainly because of the wide divergence in driving speeds found on the state's highways. Freeway travel averages 60 mph, but travel on the predominant two-lane winding roads ranges from 25 to 45 mph. Second, accessibility is defined to only M regional markets rather than all other places in the network, because only the locational advantage relative to markets outside West Virginia is hypothesized to influence development.

Interaction Potential—It is apparent that the above index has the inherent shortcoming of giving an equal weight to each market and growth point. In reality, some markets are larger than others and, although a farther distance away, may be more important because of their size. To account for the different size of markets and growth points, an index of interaction potential is included and defined as:

$$I.P.\ (i,M) = \sum_{j=1}^{M} \frac{P_i \cdot P_j}{t_{ij}}$$

where

I.P. (i,M) = interaction potential between growth point i and M regional markets,

P_i = population of growth point i,

P_j = population of regional market j,

t_{ij} = minimum path travel time from growth point i to regional market j,

i = 1, 2, 3, . . . n (growth point in West Virginia), and

j = 1, 2, 3, . . . M (regional market outside West Virginia).

The index of interaction potential is thus based on the structure of the transportation network and the population of the growth points and markets.

The two indices were computed for the 1950 base network, the 1965 network with part of the Interstate System completed, and two 1975 networks. The 1975A network assumed the completion of only the Interstate Highway System, whereas the 1975B network assumed the completion of both the Interstate and Appalachian Development Systems. Minimum time paths were computed between each growth point and each regional market. The travel times were then available for the two indices describing the locational advantage of places resulting from implementing a particular highway network structure.

Analysis of the Structure of the West Virginia Highway Network

The two indices computed for the four networks will be used to analyze the three effects stated previously.

Accessibility to Markets—Accessibility measures the locational advantage of a growth point in relation to surrounding regional markets. It is, therefore, a good measure of the effect of transportation improvements on the development of a stranded area such as West Virginia. The importance of accessibility to markets in industrial location decisions has been stated previously. Furthermore, most consequences resulting from highway improvements in a developed economy can be traced directly to the locational advantage of a given place relative to other places. Figure 3 traces the patterns of accessibility to major markets for the four highway networks considered.

Comparison of the 1950 and 1965 accessibility patterns reflect the impact resulting from the construction of the West Virginia Turnpike and the first sections of the Interstate Highway System. During this time period, the average travel time to markets from most areas of the state decreased by at least one hour. Some sections in the southern part of the state located near the Turnpike indicate an average travel time decrease of more than two hours. The pattern of accessibility did not change radically during the 1950 to 1965 period; the northern panhandle (region four) remained the most accessible area to major markets, and the most southern part of the state (region nine) remained the least accessible area.

Patterns of accessibility produced by the 1975A network decreased average travel time to markets by 2 hours in most areas of the state when compared to the 1950 pattern. The average travel time to markets was more than 3 hours lower in some sections of region nine. However, the relative locational advantage of most places remained unchanged. The difference between the most accessible and the least accessible growth point remained about four hours.

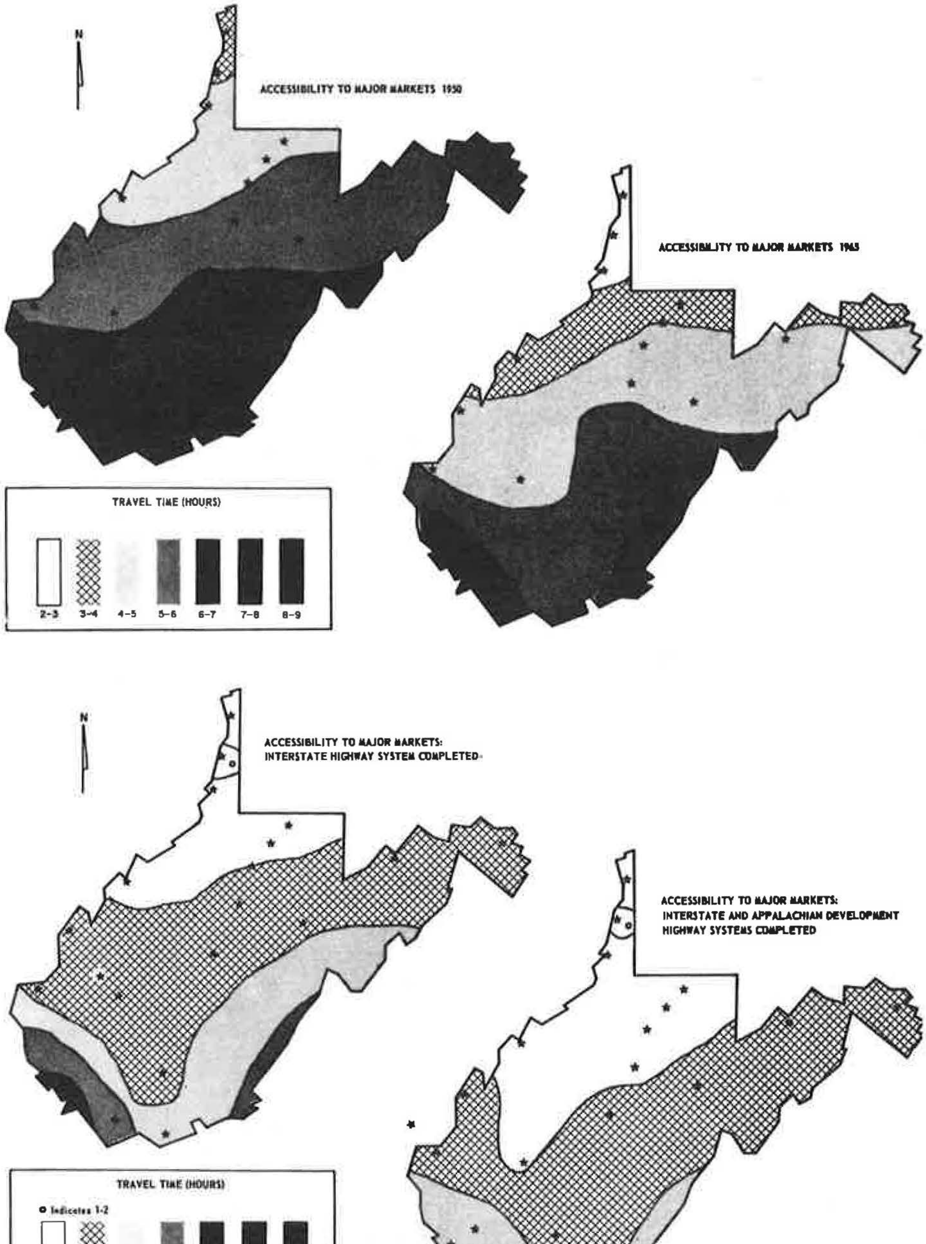

Figure 3. Accessibility to major markets.

Completion of the Appalachian Development Highway System (1975B network) reduced the difference between the most accessible and the least accessible growth points to just over three hours. Thus, construction of the Appalachian Development Highway System tends to equalize accessibility differences between regions of the state. However, even with the completion of the Appalachian Development Highway System, the relative position of each growth point remains similar to 1950, only the differences are smaller.

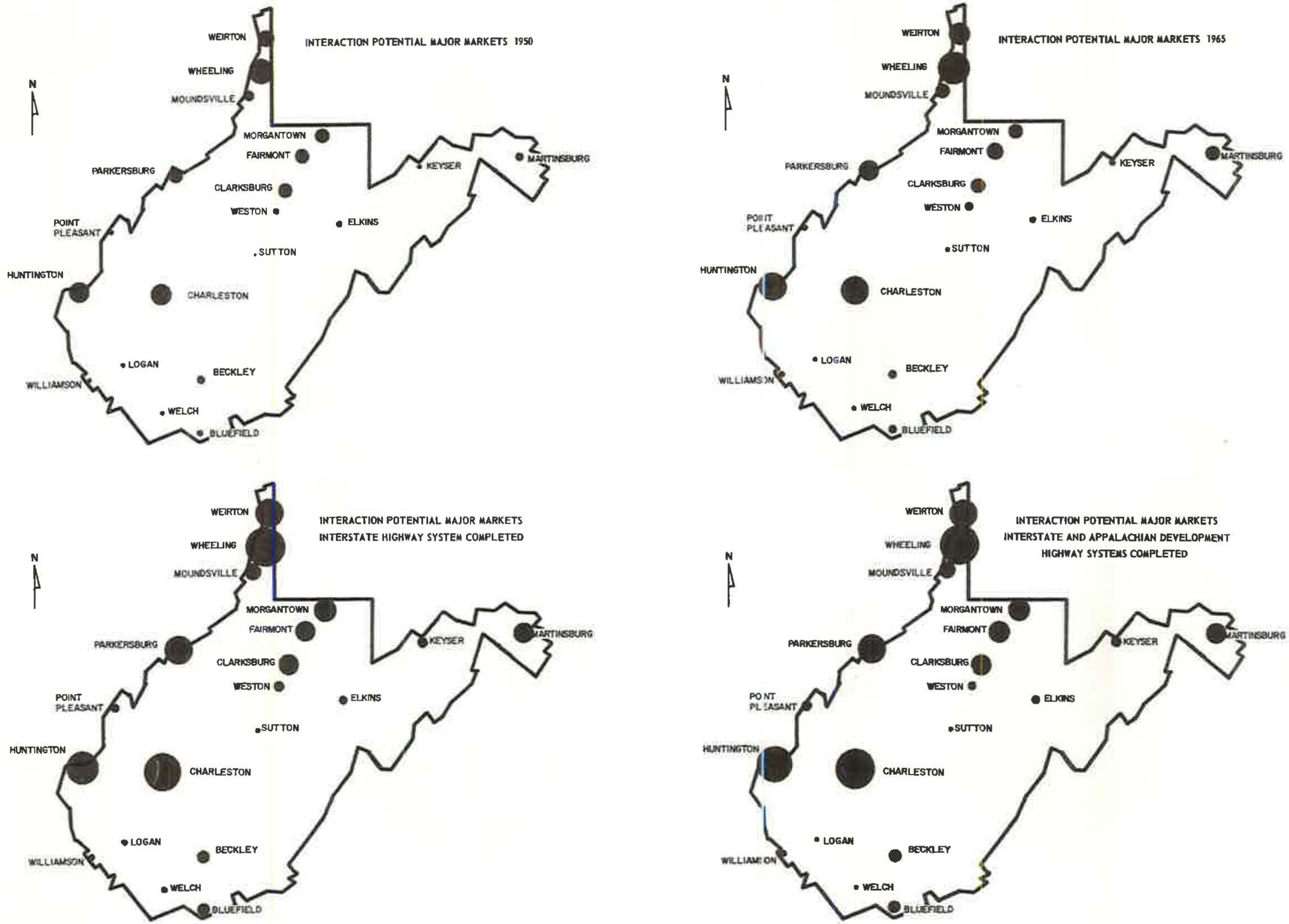

Figure 4. Interaction potential major markets.

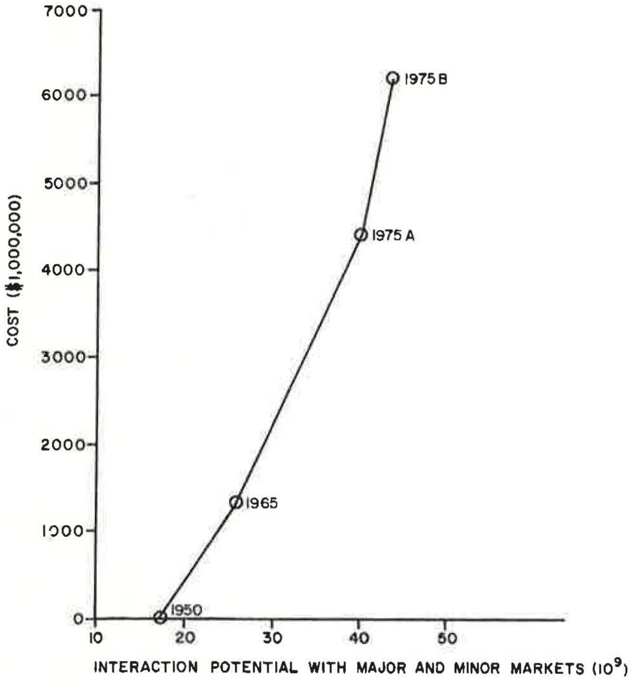

Figure 5. Change in interaction potential with major and minor markets of 23 West Virginia cities vs highway construction cost.

Interestingly, analogous results were achieved when analyzing the changes in accessibility of West Virginia growth points to both major and minor regional markets.

Interaction Potential—Interaction potential is a measure of the potential flow of people and goods between West Virginia growth points and regional markets. Figure 4 displays the interaction potential between major markets and each West Virginia growth point for the four networks considered.

Between 1950 and 1965, the interaction potential remained approximately identical for regions five, seven, and nine. However, substantial increases in interaction potential were noticed for Charleston, Huntington, Parkersburg, and the northern and eastern panhandles. As a result of completing the Interstate Highway System (1975A network) and the anticipated population growth of West Virginia cities and surrounding regional markets, all growth points showed a substantial increase in interaction potential with the exception of Sutton, Welch, Williamson, and Logan. Construction of the Appalachian Development Highway System had almost no effect on the interaction potential of West Virginia growth points. Williamson, Charleston, Huntington, Morgantown, Fairmont, and Clarksburg only indicated a slight increase in interaction potential. Otherwise, no noticeable change was apparent.

The interaction potential considering both major and minor markets was always larger than the interaction potential with only major markets because of the greater number of markets. Although the absolute value of the interaction potential was altered, the relative position of growth points remained the same regardless of whether or not minor markets were considered.

Locational Advantage of Growth Points—In summary, the locational advantage indices show that significant changes are taking place. The locational advantage of all growth points increase with the construction of the two new highway systems. However, the relative locational advantage of growth points in the state do not change significantly from 1950 to 1975. The more accessible growth points in 1950 should remain more accessible in 1975, and the least accessible growth points in 1950 should remain least accessible in 1975. It is becoming more and more difficult to radically alter accessibility and interaction patterns between cities. However, changes are possible and alternative systems can be tested to measure the effects of each alternative on the locational advantage of growth points.

The Relationship Between Network Structure and Construction Costs

An analysis was made of the relationship between the construction costs for transportation improvements and the indices of locational advantage. The cost of constructing the Interstate System was assumed to be $1,500,000 per mile, and the cost of constructing the Appalachian Development Highway System was assumed to be $1,250,000 per mile.

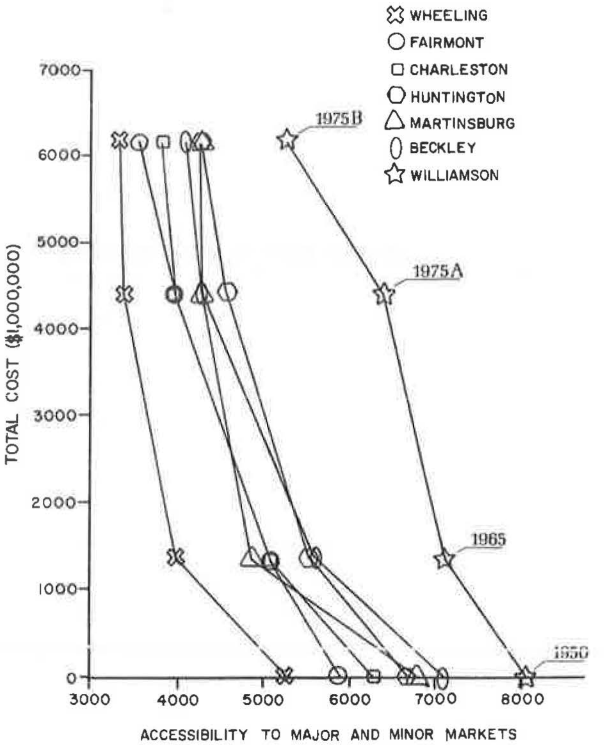

Figure 6. Change in accessibility to major and minor markets vs highway construction cost.

Figure 5 shows a plot of the estimated construction cost required to increase the interaction potential with major and minor markets for the 23 West Virginia growth points considered in this study. The results indicate that the rate of increase in interaction potential diminishes as the number of miles of high-type facilities increases. Construction of the first sections of the Interstate Highway System, as reflected in the incomplete 1965 network, increases interaction potential at a much higher rate per dollar of construction funds than the final additions to the Interstate System or the supplemental Appalachian Development Highway System. An analysis of this nature should assist the transportation planner in evaluating the impact of alternative systems. It might also be possible to determine how many miles of freeway should be provided for the Region. If additional funds are available, they might be used in upgrading feeder roads or improving the air network with greater returns.

Figure 6 shows the changes in accessibility for a sample of West Virginia growth points. The plot indicates that certain highway improvements will tend to aid some growth points more than others. In 1965, with only some sections of the Interstate System completed, Martinsburg became more accessible than either Fairmont, Charleston, Beckley, or Huntington. After the Interstate Highway System is completed, the situation will change as Charleston and Fairmont become more accessible. Beckley and Martinsburg will then be equally accessible and Huntington will remain less accessible. Finally, completion of the Appalachian Development Highway System will change the relative locational advantages of these five cities. As in 1950, Fairmont and Charleston are the two most accessible cities, but they are now followed by Beckley, Martinsburg, and Huntington, in that order. The net effect, then, has been to increase the locational advantage of Beckley over Martinsburg and Huntington.

A comparison of the relative accessibility of West Virginia growth points in 1950 and 1975 indicated that, although changes have occurred, Wheeling remained the most accessible growth point and Williamson the least accessible. The added cost of the Appalachian Development Highway System does not provide any further accessibility to cities such as Martinsburg and Wheeling. However, the Appalachian System was of particular importance to Williamson, because this city was lagging far behind in relative accessibility even after completion of the Interstate Highway System.

The above analysis indicates how the locational advantage of West Virginia cities will shift through programming of significant West Virginia highway construction projects. In the case of West Virginia and other stranded areas, information of this nature can assist in selecting the highway alternatives that provide the greatest increase in accessibility to those cities demonstrating the highest growth potential when measured by available infrastructure, human resources, etc. A trace of accessibility patterns might significantly alter highway investment policies under the selected strategies of (a) maximizing aid to growth points demonstrating greatest potential, or (b) equalizing the regional growth prospects for all urban areas considered.

This type of analysis can and should be considered along with the traditional economic and social consequences generally enumerated in evaluating alternative transportation investments. This information is not a replacement for the traditional economic analysis. Rather, it is additional information that should be included with traditional consequence measures in order to provide a package of information to the decision-maker that will assist him in reflecting on all data that might be relevant to his decision. Where strong statements of regional goals have been previously specified, as in West Virginia, the transportation alternatives must be evaluated within the context of those regional goals. The importance of the indices developed in evaluating alternative systems lies in the care that was exercised to select indices reflecting regional goals.

CONCLUSIONS

This paper suggests that, insofar as possible, the evaluation of alternative transportation systems should be based on analytical techniques reflecting regional goals. The indices of the locational advantage of growth points in West Virginia indicate that the proposed highway improvements in West Virginia will have an impact on regional accessibility patterns. The importance of considering this kind of information when a transportation investment is to serve specified development objectives (as in the case of the Appalachian Development Highway System) is obvious.

The value of the procedure used is based on the relationship between the indices presented and the effect of transportation improvements in a stranded area such as Appalachia. The possibilities for utilizing a similar procedure in other areas are many. However, the indices developed must be based on a study of the role of transportation in achieving specified goals. For example, the economic growth of depressed areas and central cities in urban regions might become an important national goal in the future. The evaluation of urban transportation systems could then consider the increase in accessibility of depressed areas to industrial centers as one important criteria in the selection of a system. The proposed procedure presented in this paper can then supplement the traditional economic analysis and other consequences of transportation improvements whenever strong regional goals are specified.

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Engineering-Economic Systems Analysis for Transport Planning in Dahomey, West Africa

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This paper reports on methodological advances achieved by the Dahomey Land Transport Study, recently carried out by a Canadian group under the auspices of the United Nations Development Program and the World Bank. The study employed an engineering-economic systems analysis aimed at the accomplishment of desirable future transport tasks at minimum true costs to society.

There was full integration between transport planning per se, and socioeconomic developments, especially in the crucial agricultural sector, to the target year 1990. Given population estimates, production and consumption quantities, both present and future, for each node, the "TRANS" Model calculated individual commodity surpluses and deficiencies throughout the country. It then simulated freight and passenger movements through the land transport network by applying a "minimum cost path" criterion. These calculated traffic flows for the current year were then compared with actual movements, obtained through O-D studies and counts, and the TRANS Model calibrated.

The TRANS Model output, link inventory information, and new proposal costs were all fed into the "OPT" Model. Its chief purpose was to confront various traffic loads generated by the TRANS Model with different technical network designs. It selected from those the one combination that promised to handle the total logistics task <u>at minimum total costs</u>, the cost streams being discounted at relevant trial interest rates over the planning period 1969 to 1990. Inherent in the OPT Model were economic-technical interactions between vehicle and road, as analyzed by Robley Winfrey and Jan de Weille; tax content and foreign exchange adjustments; and convergent iterative traffic assignment versus network design calculations.

•DAHOMEY shares boundaries with Togo, Upper Volta, Niger, and Nigeria. It extends 700 km (kilometers) north-south, but has a width of only 325 km in the north, and 125 km along the Atlantic Coast in the south. Dahomey has 700 km of paved and 5,400 km of unpaved roads, ranging from good national highways to quite miserable tracks. The well-run OCDN Railway, operated jointly by Dahomey and Niger, connects the capital and port city of Cotonou with the important inland center of Parakou. There are also short money-losing east-west railway lines in the south. Cotonou has a jet airport with good international services.

Independence in 1960 brought severe economic and political problems. For the last decade there has been stagnation in the production of three important export crops—

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palm oil, shelled groundnuts, and coffee. Only cotton fiber and tobacco have shown solid growth. Simultaneously, Dahomey has experienced growing demands for consumption goods, especially those imported goods that benefit the urban population and higher income classes. Thus, although 78 percent of imports were covered by exports in 1958, this proportion deteriorated to 40 percent by 1965. One must conclude that Dahomey has a weak, vulnerable economy burdened by severe, chronic, balance-of-trade deficits.

Demographic trends lend urgency to the economic problems. The Dahomey birthrate of 5.4 percent per annum is one of the highest in Africa. Although the country as a whole is certainly not too heavily settled, with a population of 2.3 million and an average density of 19.9 inhabitants per sq km, the biggest increases take place in the overpopulated southern regions. It is estimated that Dahomey will have 4.6 million people by 1993.

Troubled by a faltering economy, trade deficits, rapid population growth, political and social unrest, Dahomey needs assistance. In order to discover possible solutions in the transport sector of the economy, the Dahomey Land Transport Study was commissioned by the World Bank (IBRD), the executive agent of Dahomey, and the United Nations. The study called for rigorous economic analyses of the several possible highway and railway development programs in order "to assess the future role of the railroad in Dahomey and to develop a program for maintenance, rehabilitation, and improvement of the existing road network of Dahomey to meet the needs of national as well as international traffic." A Canadian consortium composed of N. D. Lea and Associates Ltd. as sponsors and Lamarre, Valois International Limitée were commissioned in 1967 on the project.

DATA GATHERING

The field work concentrated on collection of data for the analysis system.

Geocoding

A multipurpose network coding system, involving area and point numbering, was used for both broad socioeconomic and precise engineering analyses. All significant "nodes" and "links," including modal transfers and international connections, were numbered with allowance for new nodes and links.

Supply and Demand

Present and future supply-demand interactions of up to 40 commodities were estimated from available data by geonodes, applying an eclectic combination of interregional input-output (1, 2) and industrial complex analysis techniques (1) to Dahomey's goods exchange patterns with considerable geographic precision. From physical resource surveys, public-private development plans, market studies, and economic trend analyses, the 1975 and 1990 supply and demand interactions among the geonodes were estimated for each important commodity (Table 1).

Two categories of person trips—"public" and "private"—were analyzed by node as a function of socioeconomic attraction factors. Trip-making characteristics of people were obtained through roadside interviews at cordon lines placed around several representative zones. These characteristics were then related to demographic information.

Inventory of Facilities

Exact stock of the highway network was taken through an efficient photo inventory technique, used for the first time outside North America. It utilized a van equipped with an odometer, a survey speedometer, a ball bank indicator, an altimeter, a clock, a board showing the date and the two link nodes, and a motion picture camera. The camera was mounted in order to photograph both the driver's view of the road and the instrument readings and was set to expose one frame every 25 meters. The vehicle was then driven over all accessible roads in the network at maximum practical speed.

With the aid of a special analytical projector, the resulting color films could be shown at simulated driving speeds of 0 to 1500 kph (kilometers per hour). The highway

TABLE 1

SAMPLE SUPPLY-DEMAND FLOWS AMONG ECONOMIC NODES

Supply						Demand		
Analysis Node Number	Economic Node Number	Tons	Price (CFA Francs)	Percent in Season 1	Percent in Season 2	Analysis Node Number	Economic Node Number	Tons
Raw Cotton—North—1967								
65	52001	487	25	20	80	61	51001	3510
67	52003	161	25	20	80	75	54001	2740
71	53001	1485	25	20	80	83	62001	1030
72	53002	161	25	20	80			
74	53009	1218	25	20	80		Total	7280
75	54001	326	25	20	80			
76	54004	220	25	20	80			
77	56001	2082	25	20	80			
78	57001	110	25	20	80			
81	61001	7	25	20	80			
83	62001	515	25	20	80			
85	62004	386	25	20	80			
87	63001	6	25	20	80			
88	64001	77	25	20	80			
92	65001	39	25	20	80			
	Total	7280						
Raw Cotton—South—1967								
10	14001	92	30	15	85	39	41002	3520
20	22001	465	30	15	85	57	45001	1500
32	33002	372	30	15	85			
37	34007	372	30	15	85		Total	5020
38	41001	373	30	15	85			
44	41011	368	30	15	85			
49	42002	239	30	15	85			
50	43001	686	30	15	85			
54	44001	184	30	15	85			
55	44003	262	30	15	85			
57	45001	710	30	15	85			
58	45002	212	30	15	85			
59	45009	322	30	15	85			
60	45010	363	30	15	85			
	Total	5020						
Cotton Fiber—1967								
39	41002	1230	90	25	75	13	21001	215
57	45001	525	90	25	75	113	75000	3240
61	51001	350	90	25	75			
75	54001	1000	90	25	75		Total	3455
83	62001	350	90	25	75			
	Total	3455						

TABLE 2

TECHNICAL CLASSIFICATION OF ROADS

Name	Symbol	No. Lanes	Width Meters Base	Width Meters Surface	Surface Type	Design Speed (kph)	Remarks
Track	P	1	3	0	Dirt	60	Built by one pass of bulldozer, with temporary structures (culverts and drainage pipes) and a bare minimum of earthwork. No imported materials.
One-lane "terre de barre" road	TB1	1	4.0	3.5	Loose	80	Built on a minimum embankment using either in-place or imported "terre de barre" which is a natural red sandy clay. At least two provisions for passing per kilometer. Existing rain gate regulations still apply.
Two-lane "terre de barre" road	TB2	2	7.0	6.0	Loose	80	Use either in-place or imported "terre de barre". Existing rain gate regulations still apply.
One-lane laterite road	T1	1	4.0	3.5	Loose	80	Imported laterite surface on minimum embankment. Rain gate regulations remain.
Two-lane laterite road	T2	2	7.0	6.0	Loose	80	Imported laterite surface. Rain gate regulations remain.
One-lane paved road	B1	1	9.0	3.5	Hard	100	Asphalt surfacing by double seal coat or 50 kg/m^2 of sand asphalt. Imported base (7m) of sufficient strength to permit all-weather use.
Two-lane paved road	B2	2	9.0	6.0	Hard	100	Asphalt surfacing by double seal coat or 50 kg/m^2 of sand asphalt. Imported base (7m) of sufficient strength to permit all-weather use.

TABLE 3

CHARACTERISTICS OF SELECTED STANDARD MOTOR VEHICLES

Characteristics	Class 1 Niger	Class 2 General	Class 3 Special	Class 4 Common	Class 5 Private
Weight (kg)	10, 500	4, 450	12, 000	1, 450	850
Horsepower SAE	210	120	240	75	53
Payload (kg)	16, 700	4, 900	14, 500	1, 100	460
Vehicle cost (000 CFA franc)	4, 320	1, 650	6, 130	612	462
Life[a] (000 km)	500	400	500	250	150
Annual travel[a] (000 km)	75	60	75	50	30
Average speed[a] (km/hr)	55	60	55	65	65
Crew wages (CFA franc/hr)	90	80	120	90	—
Crew size	3	2	2	2	1
Maintenance cost:					
Parts (CFA franc/km)[a]	5.18	4.13	7.36	.73	.46
Labor (CFA franc/km)[a]	1.50	1.10	1.55	.38	.30
Insurance cost (000 CFA franc)	1, 180	350	1, 220	120	50
Oil cost (CFA franc/km)	1.54	1.08	1.85	0.23	0.15
Average fuel cost[a] (CFA franc/km)	6.70	4.40	5.90	2.20	1.40
Number of tires	10	8	10	4	4
Tire cost (000 CFA franc)	36.50	26.10	38.00	9.50	4.40
Tire wear factor[b]	.00067	.00033	.00067	.00021	.00025

[a]For paved roads.

[b]This factor is applied to a tire-life constant related to surface type to give the tire wear in a formula which also includes speed.

inventory specialist viewed these films in the field office and coded the pertinent inventory data for each of the 220 road links in the Dahomey network. A rating panel assigned each link to one of the seven technical road classes shown in Table 2. Throughout the project, the easily stored inventory films were found very useful for refreshing memories, for checking field conditions, and for briefing staff members and decision-makers.

Physical inventory data for the railway system, both fixed installations and rolling stock, were readily obtained from OCDN sources.

Traffic Flow and Vehicle Data

Traffic counts and origin-destination roadside interview surveys generated information on the flows of goods, people, and vehicles over the existing highway network. Corresponding railway traffic data were obtained from OCDN records.

Vehicle registration records yielded data on the number, type, and characteristics of vehicles using Dahomey's highways. Further information was obtained through interviews with truck operators, oil companies, vehicle dealers, and truck drivers at roadside stations. For the analysis, five composite vehicle types were developed, as shown in Table 3.

Capital and Maintenance Costs

Capital costs required to raise each highway link to successively higher standards, as well as costs of constructing railway links, were estimated on the basis of unit prices, quantities, and construction techniques appropriate for the specific location.

Railway and road maintenance costs were derived from Dahomey records, and were adjusted as required for indicated changes in methods and productivity. Three highway maintenance conditions were analyzed throughout: (a) normal maintenance, which permits vehicle operations over the road for most of the year under best conditions expected for the surface type; (b) minimum maintenance, which insures pavement preservation, but involves rather poor operating conditions, at least during certain periods; and (c) zero maintenance, a frequently encountered condition that results in deterioration to a lower classification for the road link within a given time span.

For each technical class of road and for both normal and minimum maintenance, the annual cost was expressed in an equation of the form

$$C = A + Bn$$

where

C = total annual maintenance cost in CFA francs per km,
A = constant maintenance cost in CFA francs per km,
B = variable maintenance cost in CFA francs per km per vehicle per year, and
n = traffic flow in equivalent vehicles per year.

For example, in southern Dahomey the maintenance costs (excluding taxes) for 2-lane roads were as follows:

Laterite	— Normal	C	=	22,000	+	870n
	— Minimum	C	=	14,000	+	470n
Terre de Barre	— Normal	C	=	22,000	+	530n
	— Minimum	C	=	14,000	+	320n
Paved	— Normal	C	=	176,000	+	34n
	— Minimum	C	=	14,000	+	400n

ROAD INVENTORY RESULTS

In 1967, the highway network in Dahomey comprised about 4,200 km, excluding urban streets. The network was subdivided as follows:

P	Track	1,340 km
TB1 and T1	One-lane earth	1,150 km
TB2 and T2	Two-lane earth	1,010 km
B1	One-lane paved	330 km
B2	Two-lane paved	370 km

Lack of maintenance and inadequate drainage structures are, with few exceptions, outstanding characteristics of all Dahomey roads.

Table 4 shows a portion of the road inventory data. Each link is identified by two node numbers. Village names are given where applicable. Link lengths, accurate to ±10 meters, are followed by the operating speed, defined as the average speed of the inventory vehicle excluding the influence of traffic. Roughness speed, determined by the inventory specialist, is the speed at which the driver can operate the vehicle when road surface roughness is the only limitation. It indicates the vehicle operating cost coefficient for the particular surface condition, and, when compared with the operating speed, it also indicates alignment. The maintenance level is shown as "A" for adequate, "M" for minimum, or "0" for zero. Each road is marked as "corrugation prone," a common Dahomey condition, or not. The seasonal delay factor is expressed as the reciprocal of the percentage of time the road is open during the rainy season.

VEHICLE COSTS

Vehicle costs had a very heavy influence in highway economy studies. They were determined by using the highway operating cost program that is part of the TRANS Model. When given the commodity and people flows, as well as the highway link's physical condition, this program calculated the number, types and operating costs of the required vehicles. Unit cost information, determined in Dahomey for the five standard classes of vehicles (see Table 3), was used as input.

TABLE 4

PORTION OF ROAD INVENTORY

Link				Length (km)	Speed		Administrative Class	Inventory Class	Maintenance Level	Rise and Fall (m)	Corrugation Proneness	Seasonal Delay Factor	Culverts	Structures
Code		Name			Operating (kph)	Roughness (kh)								
From	To	From	To											
64003	64701	Birni	x	39.22	44	50	PR	P	M	701	No	1.07	14	0
64004	64005	Kerou	Briniaro	10.16	44	50	RN8	P	M	85	No	1.07	2	0
64005	64502	Briniaro	—	34.59	46	50	RN8	P	M	354	No	1.07	4	0
65001	65002	Tanguiéta	Tayakou	10.71	83	90	RN9	T1	M	79	Yes	1.08	4	0
65001	65007	Tanguiéta	Batia	40.44	42	50	PR	P	M	360	Yes	9.99	5	0
65001	65702	Tanguiéta	x	13.98	86	90	PNIE	T2	M	116	Yes	1.08	7	1
65002	65502	Tayakou	—	16.52	68	80	RN9	T1	M	119	Yes	1.08	4	1
65003	65502	Datori	—	35.00	40	45	RN9	P	O	463	No	1.08	5	0
65006	65702	Porga	x	46.25	80	90	RNIE	T2	M	281	Yes	1.08	4	2

Cost and Performance Equations

The fuel cost equation considered vehicle type, the load being carried, the road link length, the rate of rise and fall, the surface type, and the unit cost for gasoline or diesel fuel. Free speed for each link was calculated by vehicle type using an equation that related it to curb weight, horsepower, load carried, rate of rise and fall, surface type, and design speed of the link. Average running speed was derived from free speed of the vehicle, equivalent daily traffic volume (with a truck counting as 2.5 automobiles), and daily road capacity (maximum traffic volume that can maintain a speed of 40 kph in the peak hour). The tire wear equation related the cost of this item to average running speed; surface type and length of link; and the unit costs of tires. Travel time over each link was calculated from average running speed and a seasonal delay coefficient. This factor was estimated from rainfall records and allowed in a simplified form for temporary and full-time road closures during the wet season. Depreciation and interest costs were calculated from total annual and lifetime vehicle-kilometers, the average year-round operating speed and the average running speed (adjusted for seasonal delays), the capital cost of the vehicle, and length and surface type of the road link. A 12 percent interest rate was assumed. Oil costs were derived from average oil consumption for each vehicle type, link length and surface type, and the unit cost of oil. Crew costs were calculated for each vehicle class from the number of crew members, the average hourly wage paid to each, and the travel time on the link. Vehicle maintenance costs were based on the cost of spare parts, the hours of maintenance labor required for each km traveled; the wage rate for maintenance labor, and the link length and surface type. Fixed costs considered the annual costs of insurance, licensing and overhead, link length, average annual km traveled, and average operating and running speeds of the vehicle.

Congestion Adjustments

Congestion causes costs to rise not only by reducing travel speed, but also by the necessity for frequent speed changes. Allowance was made for this effect by applying the standard operating costs only to the zero traffic condition with double these values at capacity and with these two points describing a linear function. This assumption was considered acceptable for this study where selection is between one-lane and two-lane roads. It would not be suitable for choices among two-, four-, and six-lane roads. Assumed capacities in equivalent vehicles were

Two-lane roads	10,000	vpd	one way
One-lane paved	2,000	vpd	one way
One-lane laterite	500	vpd	one way

Road Surface Coefficients

These were related to the de Weille performance coefficients for "paved," "gravel," and "earth" (3). For adequately maintained hardtop roads, the de Weille coefficient for paved was used. For loose top adequately maintained, the gravel cost index was interpolated one-third toward paved. For hard or loose top with minimum maintenance, the gravel coefficient was moved halfway toward earth. For a maintained track the earth index was used, and for an unmaintained track the earth coefficient was doubled. This important cost interval scale was set by a panel of international experts after much research and discussion.

Operating Cost Comparisons

The highway operating cost program was run to calculate costs for each vehicle class on typical links at various standards. For control purposes, these were compared with vehicle costs obtained by the British Road Research Laboratory (4) for Rhodesia and Zambia (Table 5). Except for different splits among maintenance, labor, and parts, the agreement is quite good. Table 6 compares Dahomey model operating costs on two-lane paved highways with various international results. It appears that these other studies may not have given enough attention to the influence of road maintenance. In any event, the comparisons suggests that the Dahomey model generates reliable vehicle operating costs.

TABLE 5

INTERNATIONAL TRUCK COST COMPARISONS
($1.00 = 250 CFA francs)

Item	Truck Operating Costs[a] (CFA francs per vehicle-km, tax excluded)							
	Rhodesia[b]		Dahomey Model[c]		Zambia[d]		Dahomey Model[e]	
Crew	2.4[f]		3.9[f]		4.9		3.7	
Fuel	4.1		4.4		6.1		6.0	
Oil	0.5		1.5		—		—	
Tires	7.3		5.8		0.8		1.5	
Maintenance[g]								
Parts	3.2	6.2	5.2	6.7	3.8	7.4	6.5	8.3
Labor	3.0		1.5		3.6		1.8	
Depreciation	2.9		7.3		4.7		6.9	
Total	23.4		29.6		22.9		25.4	

[a]Excluding interest, insurance, license, and overhead.
[b]17.6 ton truck, 50 percent load factor on paved surface (from 5).
[c]18.5 ton truck, 40 percent load factor on adequately maintained pavement.
[d]10.7 ton truck on "good gravel" (from 5).
[e]Average between Class 1 (16.7 ton effective payload) and 2 (4.9 ton) trucks on laterite with adequate maintenance.
[f]More crew in Dahomey.
[g]Different emphases on parts and labor.
[h]Probably better maintenance in Rhodesia.

SIMULATION AND ANALYSIS

The analytical work involved two computer programs, "TRANS" and "OPT." TRANS is an adaptation of the transport sector of a model developed by Harvard University (5, 6, 7). OPT was written for this project. Both programs were run on an IBM 360-65 computer in Toronto.

Transport Program

TRANS receives as input the people and commodity supply and demand data by location for a particular year, a description of the transport system, highway vehicle operating cost relationships, and tables containing costs on railway and transfer links. It calculates internally an origin-destination matrix for the commodities, and assigns the flows to the transport system links on the basis of minimum costs as perceived by the shipper or user. The output consists of flows and costs by vehicle type for each link in the system and overall systems performance measures.

TABLE 6

INTERNATIONAL COMPARISON OF TRUCK COSTS ON TWO-LANE PAVED ROADS

Source	CFA Franc per Ton-Km (including taxes)
Ministère de la Coopération, Niger	6.8
SEDES Study, Niger	6.3
BCEOM data for Cameroon	7.0
National Transportation Study, Greece	5.6
Quote from international trucking company for Dahomey	4.0
Dahomey Highway operating cost model	
Adequate maintenance	5.0
Minimum maintenance	8.0

TRANS was calibrated for Dahomey in 1967, using the existing physical transport system characteristics and a cost-based rate structure. Adjustments were made to insure that the model simulated reality as indicated by 1967 traffic counts, roadside interviews, and other traffic records for that year.

Link Optimization Program

OPT requires as input the traffic flows for the present (in this project 1967) on each link of the existing system, and the future traffic flows on each link of the system to be optimized. These data are usually obtained from three TRANS runs. In addition, the capital costs of upgrading each link to successively higher standards, the vehicle and road maintenance cost formulas and the traffic growth formulas to be used for each link, must all be specified.

OPT then calculates the vehicle flows and the total transportation costs, including vehicle operating costs, road maintenance costs, and the road upgrading costs on each link for each year of the period being considered. The results are printed for each link of each year, with the present worth for up to nine selected discount rates. For each discount rate on each link, the maintenance level and construction class are selected that correspond to the minimum present worth of all transportation costs on that link. Total transport costs for the entire system are printed out for three assumptions: first, when no changes are made in the system; second, when only maintenance improvements are made; and third, when all cost-minimizing improvements are made. These "option displays," automatically generated by OPT, are of direct value in policy discussions and decisions.

The link optimization program thus selects the optimum construction and maintenance levels for each link of a given network, with given traffic volumes and a given opportunity cost of capital.

The selection criterion is minimum total cost where cost includes vehicle operating costs (without tax); road construction costs (without tax); road maintenance costs (without tax); government subsidies; other costs and benefits, if any (either positive or negative); and exchange and shadow price adjustments, if any. Under flexible resource adjustment assumptions, this is equivalent, in the long run, to the maximization of the net present value of benefits.

Network Optimization

Cost minimization or net benefit maximization in present value terms is achieved for a transport network by using the TRANS and OPT models iteratively as follows:

1. TRANS is run for the future year with the existing network plus all proposed new links, with all road links at an assumed uniform standard.
2. The resulting flows are fed into OPT, which gives as output the optimum standard to which each link should be upgraded and the optimum maintenance level.
3. The standards and projects determined in step 2 are applied to the road system to form an improved system. Because improvements result in changes in traffic volumes on the various links in the system, the TRANS Model is run again to obtain new future year traffic assignments for the improved system.
4. OPT is then re-run to determine the optimum configuration of each link with the revised traffic volumes, thus taking account of the interdependencies among the various links. The improvement possibilities that were rejected in step 2 have an opportunity of being selected in step 4, if the changes in traffic volumes make them relatively more attractive.
5. Steps 3 and 4 are repeated as an iterative procedure until there are no further improvements to the system.

It should be noted that the procedure does not simply test complete exogenous packages. New packages are formulated by the procedure itself, when it optimizes each link while taking account of the interdependencies among the various links. The only improvements that must be introduced exogenously by judgment are completely new links.

Several possibilities for improving the network by the addition of new links may be compared by optimizing each network by the use of the five steps and then comparing the resulting network efficiency measurements.

The procedure for evaluating network packages in Dahomey was as follows:

1. Two separate test networks consisting of the existing network with some new links added and some existing links removed were chosen by judgment. This judgment was based on the input data and preliminary runs of the programs.
2. Each of the test networks was optimized using the iterative procedure described above.
3. A series of subanalyses was performed using the link optimization program to determine if new links were justified.
4. The two networks in their optimized condition were compared and the better one selected.

SAMPLE RESULTS

Table 7 shows part of the OPT printed output for the highway (node 20) link between Bimbereke and Berouboue. This is presently a two-lane laterite road (construction class 5).

TABLE 7

OPTIMIZATION OF LINK BETWEEN 65 (BIMBE) AND 66 (BEROU) - MODE 20

PRESENT CONDITIONS - CONSTRUCTION CLASS 5

(a)

LINK CHARACTERISTICS DISTANCE KM	DESIGN SPEED KPH	RISE -FALL FT	REGION	DELAY SEASON	DELAY FACTOR	INTERPOLATIONS VOL.PRES. SYSTEM	VOL.IMPR. SYSTEM	CST.PRES. SYSTEM	CST.IMPR SYSTEM
37.20	100.00	1200.00	NORTH	1	1.00	5	5	5	5

	OPERATING COST			MAINTENANCE COST		CAPITAL	OTH. COSTS	TOTAL COST			DAILY
YR	M/L 1	M/L 2	M/L 3	M/L 1	M/L 2	COST	+ BENEFITS	M/L 1	M/L 2	M/L 3	VOLUME
67	0.	66.891	0.	0.	1.866	0.	0.	0.	68.757	0.	113
68	0.	80.732	0.	0.	2.114	0.	0.	0.	82.846	0.	133
69	0.	94.911	0.	0.	2.368	0.	0.	0.	97.280	0.	155
70	0.	108.753	0.	0.	2.617	0.	0.	0.	111.369	0.	176
71	0.	115.842	0.	0.	2.744	0.	0.	0.	118.586	0.	186
72	0.	120.906	0.	0.	2.834	0.	0.	0.	123.740	0.	194
73	0.	125.970	0.	0.	2.925	0.	0.	0.	128.895	0.	201
74	0.	134.410	0.	0.	3.076	0.	0.	0.	137.486	0.	214
75	0.	138.461	0.	0.	3.149	0.	0.	0.	141.610	0.	220
76	0.	131.372	0.	0.	3.022	0.	0.	0.	134.394	0.	210
77	0.	123.269	0.	0.	2.877	0.	0.	0.	126.146	0.	197
78	0.	114.829	0.	0.	2.725	0.	0.	0.	117.555	0.	185
79	0.	106.389	0.	0.	2.574	0.	0.	0.	108.964	0.	172
80	0.	97.950	0.	0.	2.423	0.	0.	0.	100.372	0.	159
81	0.	103.013	0.	0.	2.514	0.	0.	0.	105.527	0.	167
82	0.	108.753	0.	0.	2.617	0.	0.	0.	111.369	0.	176
83	0.	114.154	0.	0.	2.713	0.	0.	0.	116.860	0.	184
84	0.	120.568	0.	0.	2.828	0.	0.	0.	123.397	0.	193
85	0.	126.645	0.	0.	2.937	0.	0.	0.	129.582	0.	202
86	0.	133.397	0.	0.	3.058	0.	0.	0.	136.455	0.	213
87	0.	141.162	0.	0.	3.197	0.	0.	0.	144.359	0.	224
88	0.	148.589	0.	0.	3.331	0.	0.	0.	151.920	0.	236
89	0.	156.691	0.	0.	3.476	0.	0.	0.	160.167	0.	248
90	0.	165.131	0.	0.	3.627	0.	0.	0.	168.758	0.	260

(b) PRESENT VALUES

DISC RATE										
5.0	0.	1585.04	0.	0.	37.62	0.	0.	0.	1622.65	0.
8.0	0.	1179.94	0.	0.	28.17	0.	0.	0.	1208.12	0.
10.0	0.	991.14	0.	0.	23.76	0.	0.	0.	1014.90	0.
12.0	0.	845.76	0.	0.	20.35	0.	0.	0.	866.11	0.
15.0	0.	683.99	0.	0.	16.55	0.	0.	0.	700.54	0.
20.0	0.	507.62	0.	0.	12.39	0.	0.	0.	520.01	0.
30.0	0.	323.02	0.	0.	8.01	0.	0.	0.	331.03	0.
40.0	0.	231.58	0.	0.	5.82	0.	0.	0.	237.39	0.
50.0	0.	178.40	0.	0.	4.53	0.	0.	0.	182.94	0.

ALTERNATIVE NO. 0 - CONSTRUCTION CLASS 5

(c) PRESENT VALUES

DISC RATE										
5.0	1265.38	1579.46	1941.29	61.92	37.17	0.	0.	1327.31	1616.63	1949.19
8.0	956.21	1176.01	1429.26	45.20	27.86	0.	0.	1001.41	1203.88	1436.61
10.0	811.34	987.97	1191.49	37.45	23.51	0.	0.	848.79	1011.49	1198.50
12.0	699.26	843.17	1008.98	31.51	20.15	0.	0.	730.77	863.32	1015.68
15.0	573.76	682.04	806.81	24.95	16.40	0.	0.	598.71	698.44	813.08
20.0	435.39	506.34	588.10	17.90	12.29	0.	0.	453.29	518.63	593.75
30.0	287.33	322.38	362.78	10.73	7.96	0.	0.	298.06	330.34	367.46
40.0	211.61	231.22	253.81	7.34	5.79	0.	0.	218.95	237.01	257.77
50.0	166.30	178.19	191.89	5.46	4.52	0.	0.	171.76	182.70	195.29

(d)

ALTERNATIVE NO. 1 - CONSTRUCTION CLASS 6

YR	OPERATING COST M/L 1	OPERATING COST M/L 2	OPERATING COST M/L 3	MAINTENANCE COST M/L 1	MAINTENANCE COST M/L 2	CAPITAL COST	OTH. COSTS + BENEFITS	TOTAL COST M/L 1	TOTAL COST M/L 2	TOTAL COST M/L 3	DAILY VOLUME
67	66.891	66.891	66.891	1.866	1.866	0.	0.	68.757	68.757	68.757	113
68	80.732	80.732	80.732	2.114	2.114	0.	0.	82.846	82.846	82.846	133
69	94.911	94.911	94.911	2.368	2.368	50.600	0.	147.880	147.880	147.880	155
70	108.753	108.753	108.753	2.617	2.617	50.600	0.	161.969	161.969	161.969	176
71	77.166	126.652	162.883	6.463	3.174	0.	0.	83.629	129.826	162.883	183
72	80.741	132.526	170.430	6.493	3.285	0.	0.	87.234	135.811	170.430	190
73	84.317	138.400	177.977	6.522	3.397	0.	0.	90.839	141.797	177.977	198
74	90.276	148.190	190.556	6.571	3.584	0.	0.	96.847	151.774	190.556	210
75	93.136	152.889	196.593	6.595	3.673	0.	0.	99.731	156.563	196.593	216
76	88.131	144.666	186.027	6.553	3.517	0.	0.	94.684	148.183	186.027	206
77	82.410	135.267	173.952	6.506	3.338	0.	0.	88.916	138.605	173.952	194
78	76.451	125.477	161.374	6.457	3.151	0.	0.	82.908	128.628	161.374	181
79	70.491	115.687	148.796	6.408	2.965	0.	0.	76.900	118.652	148.796	169
80	64.532	105.897	136.217	6.359	2.778	0.	0.	70.892	108.675	136.217	156
81	68.108	111.771	143.764	6.389	2.890	0.	0.	74.497	114.661	143.764	164
82	72.160	118.428	152.318	6.422	3.017	0.	0.	78.582	121.445	152.318	172
83	75.974	124.694	160.368	6.453	3.136	0.	0.	82.427	127.830	160.368	180
84	80.503	132.134	169.927	6.491	3.278	0.	0.	86.994	135.412	169.927	190
85	84.794	139.183	178.984	6.526	3.412	0.	0.	91.319	142.596	178.984	199
86	89.561	147.015	189.046	6.565	3.562	0.	0.	96.126	150.577	189.046	209
87	95.043	156.022	200.618	6.610	3.733	0.	0.	101.653	159.755	200.618	220
88	100.287	164.638	211.687	6.653	3.897	0.	0.	106.941	168.535	211.687	231
89	106.008	174.036	223.762	6.700	4.076	0.	0.	112.708	178.113	223.762	243
90	111.967	183.826	236.340	6.749	4.263	0.	0.	118.717	188.089	236.340	256

(e) PRESENT VALUES

DISC RATE										
5.0	1162.35	1710.10	2110.95	74.68	42.40	85.34	0.	1322.37	1837.83	2204.18
8.0	883.92	1267.16	1547.63	54.32	31.52	77.36	0.	1015.60	1376.03	1632.33
10.0	753.19	1061.11	1286.46	44.85	26.45	72.58	0.	870.62	1160.13	1366.05
12.0	651.84	902.69	1086.27	37.59	22.54	68.17	0.	757.60	993.40	1161.15
15.0	538.05	726.78	864.91	29.55	18.20	62.20	0.	629.80	807.18	933.38
20.0	411.97	535.63	626.13	20.93	13.47	53.68	0.	486.59	602.79	685.47
30.0	275.76	336.85	381.57	12.23	8.54	40.75	0.	328.74	386.14	427.00
40.0	205.14	239.31	264.32	8.18	6.12	31.61	0.	244.93	277.04	299.88
50.0	162.37	183.09	198.25	5.97	4.71	24.99	0.	193.33	212.79	226.64

ALTERNATIVE NO. 2 - CONSTRUCTION CLASS 7

(f) PRESENT VALUES

DISC RATE										
5.0	1081.27	1579.46	1941.29	77.56	43.16	148.50	0.	1307.34	1771.12	2097.69
8.0	827.36	1176.01	1429.26	56.37	32.05	134.62	0.	1018.35	1342.68	1571.22
10.0	707.80	987.97	1191.49	46.51	26.88	126.29	0.	880.61	1141.15	1324.79
12.0	614.90	843.17	1008.98	38.95	22.09	118.63	0.	772.48	984.69	1134.31
15.0	510.28	682.04	806.81	30.58	18.46	108.24	0.	649.10	808.74	921.32
20.0	393.80	506.34	588.10	21.61	13.65	93.42	0.	508.82	613.40	687.17
30.0	266.78	322.38	362.78	12.57	8.63	70.91	0.	350.25	401.92	438.37
40.0	200.12	231.22	253.81	8.37	6.16	55.01	0.	263.50	292.39	312.78
50.0	159.33	178.19	191.89	6.08	4.74	43.48	0.	208.90	226.41	238.77

(g)

MINIMUM P.V. TOTAL COST ALTERNATIVES FOR LINK 65 - 66

DISC RATE	ALT NO.	CONST CLASS	MAINT LEVEL	TOTAL COST
5.0	2	7	1	1307.34
8.0	0	5	1	1001.41
10.0	0	5	1	848.79
12.0	0	5	1	730.77
15.0	0	5	1	598.71
20.0	0	5	1	453.29
30.0	0	5	1	298.06
40.0	0	5	1	218.95
50.0	0	5	1	171.76

Part (a) and (b) of the table assume that the present conditions of minimum maintenance (M/L 2) of a two-lane laterite road (class 5) will remain unchanged. The vehicle operating cost and road maintenance cost (shown in millions of CFA francs) have been calculated for vehicle volumes predicted on the assumption that the whole transportation system is maintained in its present condition. The "total cost" entries are the sum of the operating and maintenance costs in each year. The vehicle operating costs are seen to be overwhelmingly larger than the road maintenance costs. The last column lists the predicted average daily two-way vehicle volume in each year.

Part (c), "Alternative No. 0," shows the effects of changing the maintenance level only on this link, while at the same time introducing a package of new links and improvements elsewhere in the network. In this particular case, the volumes are almost the same as in the "do nothing" case, because there is no suitable alternative route, either existing or proposed, to which traffic might divert.

From the present value costs, at 10 percent discount, it is seen that for an increase in maintenance expenditure from 23.51 to 37.45 million CFA francs, a decrease in operating cost from 987.97 to 811.34 million CFA francs is obtained. This gives a ratio of vehicle operating "benefits" to increased maintenance costs of about 12.7 at this discount rate. In almost every case in the Dahomey Study, a very favorable return was shown by maintenance programs, a theory long put forward by transportation engineers and economists.

Parts (d) and (e) show costs obtained by upgrading the link to "Construction Class 6," which is a one-lane paved road. The cost of the improvement—101.2 million CFA francs—is spread over the two years 1969 and 1970, and changes in operating and maintenance costs begin in 1971. There is also provision for inserting other benefits and/or costs resulting from the capital improvement, e.g., the value of extra production as a result of improved transportation.

Part (f) shows similar results for upgrading to "Construction Class 7," which is a two-lane paved road at a cost of 176.1 million CFA francs, spread over two years.

Summary Part (g) shows that at 5 percent discount rate, the total present value cost of two lanes paved at M/L 1 is less than for any of the other standards considered whereas at higher discount rates the two-lane gravel road remains the least cost solution. On this particular link, the highest present values for total costs are obtained by improvement of the road to a one-lane or two-lane paved standard (depending on the discount rate) and abandoning maintenance (M/L 3). Building the road to high standards and then letting it go to ruin through deficient maintenance is a very wasteful practice. Unfortunately, this is precisely what often happens in less developed countries. The reason appears to be that money can be obtained more easily through foreign aid for prestigious road construction than local budget resources can be mobilized for the more productive maintenance costs.

EVALUATION

This section contains an evaluation of the merit of the systems analysis approach used in Dahomey and of the direction that future developments might take.

Advantages of Systems Analysis

With the Dahomey-type systems analysis it becomes practical to carry out much more significant sensitivity tests. For example, the effect of a 20 percent rate change on the railway brought about major changes in the optimum highway network. In the absence of systems analysis, sensitivity tests are usually selected for the ease of calculation rather than for their true significance.

After working with the systems analysis methodology for one project, the staff became aware of some of the substantial built-in errors of the presystems methodology. The network effects were found to be quite significant. When a change was made in one link the evaluation of the effects on all other links, which is not done without systems analysis, was found to be meaningful. The concept of relating specific generated and diverted traffic to each facility change is seen to be meaningless for most links in a system.

The system requires a more rigorous analysis and permits much more significant cross-checking of various data sources. For example, the vehicle-kilometers, vehicle-hours, and vehicle operating costs may be checked against fuel consumption, vehicle registration, vehicle utilization, and user tax revenues.

Maintenance now shows up in its proper perspective and is evaluated against capital intensive projects in an equitable and rigorous fashion.

Need for Permanent Data System

The effort that is being expended throughout the world on "one shot" data gathering for transportation planning is very large. Quite possibly it is as great as would be required to operate permanent data systems. The systems analysis has given a broad overview of the requirements for precision for the various data. Some information types are kept with unnecessary and expensive detail whereas others are sadly and unnecessarily lacking. It would be most helpful, and much less difficult than first appears, to establish an international data system for transportation planning, which could be adopted and carried on at moderate cost by each country.

Systems Analysis as a Permanent Planning Tool

It is quite practical to establish an analysis system, such as the one used in Dahomey, on a continuing basis as a permanently useful planning tool. The system would be maintained operational so that, at any time, any proposed change from the adopted program could be evaluated quickly by a rerun of the programs. Basic input data would be revised periodically, forecasts checked against realized results, and the system continuously refined. It might be given a thorough overhaul once in five years.

Such a planning system would be action-oriented with short lines of communication to the decision-makers. Long, tiresome, action-delaying studies would become a thing of the past. Any proposed budget or program change could be evaluated and reported in a few days within the context of the ongoing analysis system.

The achievement of short lines of communication between decision-makers and the analysts is expected to be much more productive than seeking a completely rigorous analysis of all theoretical possibilities.

The total number of policy choices is staggeringly large: several modes with many physical standards within each mode; selection of links; selection of networks; resource scarcities; cost of money; budgeting and programming options over time; and pricing, administrative, and operational policies. The theoretical combinations are many millions for a simple system. The analyst must exercise judgment in seeking the optimum system. Would there not be a great advantage in getting the decision-maker involved in exercising these judgments? It is practical now for underdeveloped countries that are willing to give dominant importance to economic evaluation criteria. It will soon be possible, also, for more developed countries that are willing to invest substantially for social reasons.

Overestimating Stimulated Production

It was found difficult in Dahomey to verify empirically the dynamic interactions that, according to economic doctrine, should exist between transport costs and commodity supply and demand. It is commonly reasoned in the literature that if transport costs go down, this will stimulate production. But in many instances, agricultural producers in Dahomey did not seem significantly motivated by changes in transport services. They were more concerned with labor, production techniques, credit, markets, and other factors of more immediate interest to them. Analytical tests revealed that the final impact of transport improvements is often slight anyway. Given a unitary elasticity of supply of a product, and a 30 percent transport cost component in final market price, and a 10 percent truck rate reduction passed on to the shipper, the result would be a mere 3 percent growth in production. Few producers occupy themselves with such minute adjustments. This meant that in the Dahomey Study not as much use could be made of the dynamic capabilities of the computer programs as one would have liked.

Selecting Transport Policy Tools

The results indicate that the use of road improvements as the dominant policy instrument may be highly overrated. Using the link analyzed in Table 7 as an example, with 10 percent discounting and adequate maintenance, the vehicle operating cost varies from 80 percent to 96 percent of the total cost for the several schemes. For the minimum total cost scheme, vehicle operating costs are 96 percent of the total costs. Preoccupation with the road part of the costs thus appears very restrictive. It is quite possible that the entire vehicle part including management, driver training, vehicle maintenance and operations, vehicle design, and fleet upgrading, offers much richer opportunities for overall road transport economies.

Better Motor Vehicle Cost Data Needed

The coefficients relating vehicle operating costs to the road surface condition are of crucial importance to any such analysis. Yet the international data base from which such coefficients are derived is very limited indeed. This is one of the most urgent subjects for intensive research.

CONCLUSION

To conclude, the Dahomey Study was an interesting and productive experience. There is great scope for applications elsewhere and for further improvements in systems planning techniques.

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Discussion

GERALD F. RISELEY, Systems Engineer, Texas Instruments Incorporated—The transportation system planning evaluation model put forth in this paper is one of considerable comprehensiveness. The design of the model around the minimum cost path gets to the true problem—getting item A from point C at the lowest cost considering all influencing factors.

On the premise of minimum cost path, the two main criteria for evaluating such a model are (a) the completeness of accounting for all cost factors, and presenting them accurately; and (b) the actual design of the model itself, and how well it "fits" the real life situation.

Because of the nature of the limitations of presenting design data in a research paper, one cannot assay the model design per se, but can only make general comments. A major item of concern is taking into consideration factors other than that of basic cost. One factor is the availability of a given system with respect to strikes, war, and natural disasters. Consideration must also be given to a public or private operation basis. These factors must be considered, quantified, and made available as "plug in" variables.

Another consideration is the actual subsystem definition. No mention was given of two important modes—air transportation and water transportation. These would naturally have to include the developing costs, future growth data, etc., But nevertheless, they are viable alternatives, and should be considered.

The paper does not identify such items as how the railroad terminal costs were factored into the model and how possible hybrid systems might be handled. For example, by using the piggyback system of truck/rail, could the model make predictions of the minimum cost route by outputting an answer such as 200 miles by train, then 20 miles by road, etc.?

Once such a transportation model is broadened, optimized, and made scalable, it will be an important tool for aiding transportation planners. The authors and their team members deserve considerable credit for selecting such an ambitious approach and doing a commendable job.

TILLO E. KUHN, Closure—Mr. Riseley's discussion points are important ones. The capacity for sensitivity tests is an integral part of the model used for the Dahomey Study. The "fail-safe" reactions of any given transport system to strikes, war, and natural disasters could be examined, if desired, although this was not actually done in this particular case. However, other variations in parameters (for example, changes in production patterns or world market conditions for export crops) were explored. Many other options, such as public or private operation of the transport systems components, organizational reform, or even fiscal, monetary, and foreign exchange policies, were considered and can be played through with the aid of computer simulation techniques.

In the Dahomey study both air and water transportation were excluded from the terms of reference set by the clients. However, terminal, transfer, and possible hybird transport systems aspects formed, in fact, part of the Dahomey analysis. The important north-south route through Dahomey between the Atlantic port of Cotonou and the land-locked Republic of Niger provides a perfect example. The simulation model moved petroleum and manufactured goods from ship to rail terminal, by train to the end of the line in Parakou, then through unloading, storage, and loading processes to tractor-trailer combinations or tank trucks, and finally by road to their destinations in Niger. Groundnuts, uranium, and other southbound exports from Niger were handled in the reverse sequence in the analyses.

In short, any operation that can be quantified can also be accommodated within the model. As Mr. Riseley suggests, the Dahomey prototype in the meantime has been considerably broadened and improved for other international applications. Norman D. Lea and I feel that we are just beginning to exploit the immense potential of systems simulations based on high-powered field research and preferably also permanent data banks.

The Economics of the Diesel Fuel Tax Differential

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A 3 cents per gallon tax differential was consistently proposed by the Kennedy and Johnson Administrations. Because the diesel engine consumes less fuel per mile than the gasoline engine does, the differential was designed to eliminate the apparent tax advantage granted to the economic diesel engine.

The determination of the 3-cent differential is based on the estimations of highway use tax responsibility made by the Bureau of Public Roads. Incremental-cost analysis, one technique used by the Bureau, is used as a means to allocate tax responsibility on a "cost-occasioned" basis, but application of this technique has caused serious misinterpretation of the cost-occasioned principle.

Highway user costs are allocated usually on a use basis—either axle-mile or vehicle-mile traveled. But before a diesel fuel tax differential is definitely adopted, any possible opportunities for discrimination against diesel vehicles must be eliminated. The possible encouragement of taxpayers to evade the fuel impost if established and the new developments in engine technology are some reasons for the necessity of detailed analysis of the applications of a diesel fuel tax differential.

•STATE and federal tax authorities for many years have questioned the propriety of taxing diesel fuel at the same rate as gasoline. Their anxiety is based on the greater efficiency of the diesel vehicle compared to similar gasoline vehicles (this is evidenced by a generally greater number of miles traveled per gallon of fuel consumed). If both diesel fuel and gasoline are taxed at the same rate, those vehicles burning the former propellant pay less per mile traveled than their gasoline counterpart. [The fiscal importance of this apparent discrimination is often exaggerated. Although fuel taxes in 1965 accounted for 64.1 percent of state highway revenue and 69.5 percent of net revenues of the federal Highway Trust Fund, diesel fuel represented only 5.8 percent of the total fuel consumed for highway purposes (1).]

The development of the "ton-mile" thesis provided a pseudoscientific justification for the differential tax treatment of diesel fuel. This highway-cost allocation device, which enjoyed immense popularity during the 1950's, assigns highway user tax responsibility on the basis of ton-miles traveled (the simple product of the gross vehicle weight, in tons, times the number of miles traveled).

The greater efficiency of the diesel vehicle generates a larger number of ton-miles per gallon of fuel than its gasoline counterpart. Thus, if the ton-mile thesis is accepted, equity appears to demand a larger tax per gallon of diesel fuel than is imposed on gasoline.

Many years before the formalization of the ton-mile thesis, a few states began to differentiate the taxation of diesel fuel. This was a curious occurrence, because there

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are indications that these taxing jurisdictions lacked substantial proof to justify this procedure. Perhaps the best evidence of the premature imposition of diesel fuel differentials is found in the remarks of tax administrators. Mr. J. D. Hadley, representing the Gasoline Tax Department of Michigan at the 1938 North American Gasoline Tax Conference, remarked that (2, p. 17):

> The question arises as to the rate of taxation upon diesel fuel, as compared with the rate of taxation upon ordinary motor fuel, and we recommend strongly to you that the tax on diesel fuel will remain the same as the tax on ordinary motor fuel for several reasons.
>
> ...while it is advocated that the use of diesel fuel will mean more miles per gallon, yet, it has not been definitely determined with any degree of certainty that such is the case.

Kimberlin, then the Director of the Motor Fuel Tax division of the Texas State Comptroller Department, made this observation (3, p. 57, parentheses added):

> Unfortunately...there was an amendment put on it (tax bill) raising the tax on diesel fuel to eight cents a gallon. We have expected to be attacked as a discriminatory measure....I think they get a little more mileage out of diesel engines than they do the ordinary motor used by the gasoline-operated vehicle. I doubt very seriously there is that much difference in it, however.

This vague notion of the relative efficiency of the diesel motor is common in the early attempts to impose tax differentials. Even in later years, many legislatures did not act on well-developed studies; but, instead, employed either hurriedly compiled investigations based on limited surveys, or worse, used the conclusions found in the studies of other states.

The question arises: Why did states attempt to employ a differential before adequate evidence was available? The answer to this question is found in the nature of the initial taxation of diesel fuel. There has always been special or separate taxation of diesel fuel. Unlike gasoline, a significant percentage of diesel fuel was consumed in non-highway activities. The uniform gasoline tax could not be extended to diesel because of the administrative costs of refunding. Thus, special or separate treatment of diesel fuel developed, which made it prone to differential treatment.

CURRENT DIESEL FUEL TAX TREATMENT

New Mexico was the first state to adopt a diesel fuel tax differential. Their 1938 tax bill established a 7½-cent per gallon tax on diesel fuel and a 5-cent levy on gasoline. This 50 percent differential proved less rewarding than had been anticipated. The large percentage of diesel fuel consumed in non-highway activities lead to widespread evasion of the tax. This administration problem became so severe that the state soon abandoned its attempt to tax diesel fuel differentially.

New Mexico's failure helped to forestall other experiments in diesel differentials. It was not until 1947 that a new interest was generated. In that year, three states (Michigan, Nevada, and Texas) imposed higher gallonage taxes on diesel fuel than on gasoline. As Table 1 indicates, the early 1950's were marked by a number of states moving to this form of taxation. Note that several states have employed this form of taxation but have given it up. Those who have terminated the use of this tax are normally matched with new states attempting this form of taxation, so that since the early 1950's approximately eight to ten states concurrently employed a diesel fuel differential.

In addition to the use of rate differentials, other forms of differentiation have been developed in four states (Oregon, Texas, Vermont, and Washington) and in the District of Columbia. These taxing jurisdictions have imposed special taxes—generally in the form of registration fees—on diesel equipment in an attempt to rectify the alleged inequities existing between diesel and gasoline trucks. The types of differentiation used by these four states and the District of Columbia are listed in Table 2.

TABLE 1

STATE DIESEL FUEL TAX DIFFERENTIALS
(Selected Years 1949-1965[a])

States	1965		1961		1957		1953		1949	
	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel
Arkansas[b]	6.5-7.5	8.5								
California			6	7	6	7	4.5-6	6-7		
Iowa	6-7	7-8	6	7	6	7	4.5	6		
Kansas	5	7	5	7	5	7	5	7		
Michigan							4.5	6	3	5
Mississippi	7	8	7	8	7	8	7	8	6	7
Montana	6	9	6	9	7	9				
Nebraska							5-6	0	5	0
Nevada							4.5	5.5	4-4.5	5
New York	6	9	6	9	4	6	4	4-6		
South Dakota	6	7	6	7	5-6	7				
Tennessee	7	8								
Texas	5	6.5	5	6.5	5	6.5	4	5-6	4	4.6
Vermont	6.5	0	6.5	0	6.5	0	5	0	4.5-5	0
Wyoming	5	7	5	7	5	7				

[a]This table gives the tax rates at the beginning of each year, the changes during the year, and the rates in effect at the end of the year, in cents per gallon.
[b]If no figure is given, the rates for gasoline and diesel fuel are the same.

Federal taxation of diesel fuel has developed quite differently from that of the various state governments. Most states began the taxation of diesel fuel long before the federal government moved into this field.

Prior to 1951, there was no federal tax imposed on diesel fuel; however, the Revenue Act of that year placed a 2-cent per gallon tax on diesel fuel. The tax was structured in the same manner as the gasoline tax, 1½ cents of the tax was made permanent with ½ cent due to expire on April 1, 1954. The temporary part of the tax was extended until 1956, when it was increased to 1½ cents per gallon, making the total tax on diesel fuel that year 3 cents. Parallel to the gasoline tax, the temporary portion of the diesel

TABLE 2

THE SPECIAL TAXATION OF DIESEL USER OTHER THAN DIFFERENTIAL FUEL TAXES

States	1963 Fuel Tax Rates (cents per gallon)		Method of Special Taxation
	Gasoline	Diesel	
Oregon	6	6	A mileage tax is employed on the declared combined weight of vehicles, the weights are set in 2,000 lb increments with a 6,000 lb minimum. The rates range from 1.5 to 48 mills per mile for gasoline (above 76,000 lb the rate is 2.5 mills per ton). For diesel the rates vary from 5.5 mills to 68 mills per mile at 76,000 lb, and 3 mills for each additional ton above that rate.
Texas	5	6.5	Vehicles using diesel fuel pay a registration fee which is 11 percent higher than registration fees for similar vehicles using gasoline.
Vermont	6.5	No tax	Note there is no gallonage tax on special fuels; however, in lieu of the fuel tax, the registration fee on vehicles using special fuels is 1¾ higher than the amount on comparable gasoline vehicles.
Washington	7.5	7.5	Trucks using special fuels pay 25 percent higher registration fees than similar gasoline trucks, plus a flat $2.00 fee compared to a fee which ranges between $0.25 and $1.00 for gasoline vehicles. Buses employing special fuels are taxed $0.20 per hundred miles traveled, whereas gasoline-propelled buses are charged only $0.15 per mile. In addition there is a higher motor vehicle excise tax imposed on diesel vehicles.
District of Columbia	6	6	Vehicles using special fuel are subject to a registration fee double that of gasoline-fueled vehicles.

fuel impost was again increased 1 cent, so that by 1961 the diesel fuel tax was 4 cents per gallon (1½ cents per gallon was permanent and the remaining 2½ cents was a temporary impost).

One cent of the temporary portion of the diesel tax was scheduled to expire on July 1, 1961. However, because of unanticipated cost increases associated with the National System of Interstate and Defense Highways, the Bureau of Public Roads strongly recommended to the President that in place of the scheduled reduction in the diesel tax, an increase in user charges should be instituted. Thus in late February 1961 President Kennedy issued a special message which stated (4, p. 365),

> Our Federal pay-as-you-go Highway Program is in peril. It is a peril that justified a special message because of the vital contribution this program makes to our security, our safety and our economic growth.

Clearly the peril to which President Kennedy referred was this scheduled reduction in the gasoline, diesel and related fuels tax from 4 cents a gallon to 3 cents a gallon. This reduction would not allow a pay-as-you-go method of financing the Interstate Highway Program as intended by the 1956 Federal-Aid Highway Act.

The problems encountered by the Kennedy Administration in financing this massive highway program were not unique to his administration. President Eisenhower had anticipated this difficulty and had recommended that the 4-cent tax on motor fuels be increased to 4.5 cents a gallon. This would raise taxes on the general public. Based on the preliminary results of the Highway Cost Allocation Study (5), President Kennedy believed there was a "fairer" allocation of these taxes, and recommended that as a substitute means of obtaining the same revenue, this present gas tax of 4 cents a gallon should be retained, the following taxes should be increased (4, p. 336, parentheses added):

Tax	Present	Proposed
Diesel fuel	\$0.04 a gallon	\$0.07
Trucks over 26,000 lbs	\$1.50 per 1000 lbs	\$5.00
Highway tires	\$0.08 (per lb)	\$0.10 (per lb)
Inner tubes	\$0.09 (per lb)	\$0.10 (per lb)
Tread rubber	\$0.03 (per lb)	\$0.10 (per lb)

It is clearly seen that the additional revenue necessary to keep the Highway Program on a pay-as-you-go basis would largely have been obtained from trucks using diesel fuel and weighing in excess of 26,000 pounds. It was this aspect in President Kennedy's proposal that he felt made the tax allocation "fairer" than a general ½-cent increase in the fuel tax. To emphasize this point the President indicated that, "Indeed, technical experts in the Bureau of Public Roads advise me that even this increase would not charge heavy trucks their fair share of the cost of this program" (4, p. 336).

After extensive congressional hearings in 1961, the recommendation for a diesel fuel tax differential was rejected. This did not, however, end the pressure for a diesel fuel differential. On May 17, 1965, and again on January 26, 1967, President Johnson asked Congress for increases in highway user charges that are identical to the 1961 recommendations (6). Thus the existence of differential tax treatment of diesel fuel in thirteen states and the continued pressure for a federal tax differential, demands that the appropriateness of this tax clearly be determined.

JUSTIFICATION FOR A FEDERAL DIESEL DIFFERENTIAL

The primary reason for attempting to allocate tax responsibility among highway users is to insure that a competitive advantage is not granted to one vehicle group at the expense of another class of vehicles. An additional factor that is often overlooked is the effect of motor vehicle taxation on other media of transportation. Motor vehicles as a group may be charged the full cost that they occasion; but if the allocation between users is not properly assigned, one class of motor vehicles may be given a competitive advantage over another form of transportation. It is sometimes claimed that heavy trucks, especially those powered by diesel engines, are given this preferential treatment, and thus these trucks are given a competitive advantage over other forms of transportation.

The mode of transportation that is most directly affected by changes in the competitive position of heavy vehicles engaged in line-haul operations is the railroad industry. It has not been until relatively recent years that trucking has been able to compete effectively with the railroads for freight traffic. A significant factor causing this increased competition has been the development of an efficient diesel engine.

The advantages of fuel economy and increased weight-power ratios have been great enough to offset the larger initial cost of the diesel vehicles. This increased efficiency has also made the diesel engine the most popular means of propulsion for large over-the-road trucks. It is this long-distance freight traffic that has been increasing in magnitude in recent years at the expense of rail transportation. This is particularly true in the western states where the railroad network is not as nearly complete as it is in the mid-west and eastern states.

These factors set the stage for a curious paradox. The diesel vehicle is accused of operating with an "unfair" competitive advantage. However, it is not the gasoline-powered trucks that appear to compete directly with the diesel-powered units that claim foul play, but it is the railroads. The reason for this paradox is that the diesel and gasoline vehicles are not truly competitive. That is, while the diesel vehicles can haul heavy loads over mountainous terrain because of their greater torque or sustained pulling power, the gasoline-powered vehicles cannot effectively operate under these conditions. Even on relatively flat terrain where the diesel advantage is greatly reduced, few gasoline-powered tractors are employed in long-haul operations. There are thus two primary reasons why diesel vehicles operate primarily in the mountainous western states. First, the railroad network is not sufficient to service the area. Second, the many hills and grades can be maneuvered efficiently only by diesel vehicles.

A major cause for examining the tax liability of heavy trucks is to guarantee that they are not being granted a competitive advantage over the railroad industry. The determination of a proper allocation of tax responsibility will also insure that no single class of motor vehicles will have an advantage at the expense of another class.

The Diesel Vehicle Tax Liability

Although the Bureau of Public Roads has conducted various studies in the determination of highway user cost responsibility, the most promising is their incremental-cost analysis. This analysis attempts to assign highway user charges on a cost-occasioned basis. For example, consider the treatment of pavement design costs. A basic road or first increment is constructed to carry light vehicles. However, if a somewhat heavier vehicle is to use the highway, a thicker pavement is required. And if a still heavier vehicle is to use the road, another thickness must be added to the basic road. This process is repeated until the road is strong enough to carry the heaviest vehicle. The costs incurred in providing the various construction standards are then assigned to the vehicle class which required them. Thus, the light vehicle would only share the cost of the basic road, the next heaviest class of vehicles would share the cost of the basic road and the next increment of highway pavement, while the heaviest vehicle would bear the full cost of the last increment and share the cost of the other increments of highway pavement.

The results of the incremental-cost analysis conducted by the Bureau of Public Roads can be found in their Supplementary Report (7). To arrive at the appropriate diesel fuel differential, the Bureau of Public Roads separated vehicle groups according to gross weight and visual characteristics, and then subdivided these classifications in regard to the type of fuel used by the vehicles. It is interesting to note that the incremental-cost analysis conducted by the Bureau of Public Roads assigns a substantially larger tax charge to diesel vehicles than it does to identical gasoline vehicles. For example, in the truck semitrailer classifications (private and for hire), three axle gasoline combinations are charged $441.28 per year, whereas diesel vehicles are charged $810.88 per year; four-axle gasoline combinations are charged $783.51 annually and diesels are charged $1,276.57; and five-axle gasoline rigs are charged $819.61 and similar diesels $1,354.08. The primary cause for this larger tax charge on diesel vehicles is their greater annual travel as compared to gasoline vehicles.

In a few cases the annual tax responsibility charged to diesels is not significantly greater than the charge assessed to gasoline vehicles. In the case of the two-axle, four-tire pick-up truck, gasoline vehicles are assessed an annual charge higher than diesel vehicles. The gasoline version of this truck is charged $24.14 annually whereas a similar diesel vehicle is liable for only $16.93 a year. Again the basic cause for the difference in the tax charge for the two vehicles is the larger number of miles traveled annually.

The significance of this factor cannot be overstated. The use of the incremental-cost analysis, as it is applied by the Bureau of Public Roads, assumes in one manner or another that all motor vehicle costs are distributed on a vehicle-mile or axle-mile basis. Those vehicles that are frequent highway users are therefore liable for considerably greater tax liability than the infrequent user.

However, the implicit assumption made by the Bureau of Public Roads that all highway user costs are associated with use is open to serious question. The incremental-cost analysis attempts to assign highway costs on the basis of the costs occasioned by the various vehicle classes. There are a large number of highway costs that cannot be assigned on a use basis. Consider the costs associated with the purchase of rights-of-way, grading, drainage and related work items. These costs account for 49.0 percent of all 1964 federal-aid authorizations (7, p. 118). It is doubtful that there is an additional cost associated with additional use. Once the right-of-way is purchased or the grading is completed, one cannot allocate these costs on a vehicle-mile or axle-mile basis, because that would assume that each vehicle-mile or axle-mile driven has caused an additional cost. In fact, right-of-way costs or the costs of grading are the same regardless of whether there has been an annual use of one million, ten million, or a billion vehicle-miles.

Thus a close examination of the incremental-cost analysis indicates that there is an excellent possibility that not all highway costs can be distributed on a use basis. Those costs that are not associated with use should be distributed on a per vehicle basis. Alterations of the Bureau of Public Roads analysis so that it corresponds with the strict cost-occasioned criterion has the immediate effect of reducing the frequent road users' responsibility and increasing the charge assessed to the infrequent user. In the case of similar diesel and gasoline vehicles, the tax charge of the former would in most cases fall and the liability of the latter would increase. The magnitudes of these charges would greatly depend on the number and the importance of the costs that are not related to use.

Considering the assumptions employed by the Bureau of Public Roads, there is little surprise in their results. Heavy vehicles, and diesel vehicles in particular, travel more miles annually than light vehicles. Consequently the charges imposed on these high-frequency road users are relatively large.

The Diesel Vehicle Tax Payment

There is also little surprise in the fact that a comparison of vehicle tax liability under the Bureau's incremental-cost method and the tax payments made by the various vehicle groups results in an overpayment for lighter vehicles and an underpayment for heavier vehicles. Again, this is particularly true for diesel powered vehicles. Not only does the diesel vehicle travel more miles annually and in so doing create a sizeable tax liability, but in addition, because of its fuel economy, the diesel vehicle consumes relatively less fuel than its gasoline counterpart. Therefore, if the diesel unit travels 50 percent more miles a year than a similar gasoline vehicle, the tax liability that it creates is approximately 50 percent greater than the gasoline vehicle, whereas its tax payments are far less than 50 percent greater than the gasoline vehicle.

The recommendation for a 3-cent increase in diesel fuel while the tax on gasoline is held constant creates a substantial differential in the taxation of motor vehicle fuel. This recommendation proposed by the Bureau of Public Roads is based on a number of factors currently open to question. Table 3 outlines in a very crude manner the justification for this tax proposal.

Table 3 represents the procedure necessary to determine the proper fuel tax for individual vehicles. Because this is simply an illustrative example of the procedure, only arbitrarily selected "for-hire" vehicles were employed. To evaluate fully the potential need for increases in fuel tax rates, this analysis would have to be conducted for each vehicle weight, in each vehicle classification, for both private and for-hire categories.

To establish the relative tax responsibility per gallon for diesel and gasoline fuel, it is first necessary to determine the number of gallons of fuel each vehicle type consumes in a year. This is required because fuel taxes are imposed on a gallonage basis. The

TABLE 3

DETERMINATION OF THE APPROPRIATE DIESEL DIFFERENTIAL FOR SELECTED "FOR HIRE" VEHICLE TYPES BY CLASS OF OPERATION AND TYPE OF FUEL
(Total Fuel Tax Liability)

Class	Vehicle Weight (1000 lb)	Annual Mileage	Gallons per Mile	Gallons Consumed	Total Vehicle Liability (dollars)	Adjusted Vehicle Liability (dollars)	Fuel Tax Rate (cents)	Diesel Differential
Automobiles		9,747	0.070	682.3	31.4	23.55	3.45	–
Buses								
Transit	16-19							
Gasoline		30,717	0.251	7,710.0	183.85	137.89	1.78	0.65
Diesel		32,102	0.179	5,746.3	186.64	139.98	2.43	
Intercity	20-26							
Gasoline		34,872	0.184	6,416.4	388.22	291.16	4.53	1.24
Diesel		57,317	0.159	9,113.4	701.87	526.40	5.77	
School and miscellaneous	12-16							
Gasoline		10,572	0.132	1,395.5	47.41	35.55	2.54	1.97
Diesel		17,032	0.127	2,163.1	130.33	97.74	4.51	
Trucks and combinations								
Single-unit trucks								
2 axles, 4 tires	4-8							
Gasoline		11,252	0.080	900.2	34.51	25.88	2.87	-0.67
Diesel		924	0.094	86.9	2.56	1.92	2.22	
2 axles, 6 tires	12-16							
Gasoline		10,890	0.117	1,274.1	62.22	46.67	3.66	0.25
Diesel		11,940	0.118	1,408.9	73.42	55.06	3.90	
3 axles	32-40							
Gasoline		24,745	0.187	4,627.3	214.37	160.78	3.47	0.03
Diesel		49,740	0.156	7,759.4	362.14	271.60	3.50	
Combinations with semitrailers								
3 axles (2-S1)	40-50							
Gasoline		37,847	0.194	7,342.3	562.95	422.41	5.75	2.04
Diesel		55,544	0.165	9,164.8	952.47	714.35	7.79	
4 axles (2-S2, 3-S1)	50-60							
Gasoline		47,999	0.234	11,231.8	869.75	652.31	5.81	1.25
Diesel		68,305	0.186	12,704.7	1,196.26	897.19	7.06	
5 axles (3-S2)	60+							
Gasoline		43,847	0.264	11,575.06	997.74	748.30	6.46	2.58
Diesel		63,476	0.201	12,756.9	1,338.25	1,153.69	9.04	
With full trailers								
3 axles (2-1)	26+							
Gasoline		20,456	0.178	3,641.2	304.40	228.30	6.27	3.14
Diesel		37,654	0.148	5,572.8	699.90	524.92	9.41	
4 axles (2-2, 3-1)	26-50							
Gasoline		31,768	0.240	7,624.3	479.68	359.76	4.72	1.25
Diesel		51,149	0.195	9,974.0	794.65	595.99	5.97	
5 axles (2-3, 3-2)	Under 60							
Gasoline		24,581	0.231	5,678.2	543.86	407.89	7.18	4.17
Diesel		45,688	0.197	9,000.5	1,362.14	1,021.60	11.35	
6 or more axles	60+							
Gasoline		22.691	0.294	6,671.1	474.12	355.59	5.33	2.03
Diesel		27,834	0.210	5,845.1	575.50	430.12	7.36	
With semitrailers and full trailers	60+							
Gasoline		44,355	0.271	12,020.2	1,278.46	958.84	7.98	1.53
Diesel		53,591	0.200	10,718.2	1,358.93	1,019.20	9.51	

data necessary to arrive at this figure are the annual vehicular travel and the gallons of fuel consumed per mile.

The determination of annual travel is relatively easy to obtain, because this information must be kept by vehicle owners for state taxation purposes. Unfortunately the data concerning fuel consumption are much less reliable. To obtain an estimate of fuel consumption for gasoline and diesel vehicles of various classifications, the Bureau selected five studies independently conducted between 1952 and 1961 (7). The results of these studies were averaged and form the basis for their estimate. (There is no clear indication that the studies included in the Bureau's estimate truly represent the differential performance of gasoline and diesel engines. The studies are based on severely limited samples and are thus subject to criticism.)

The estimate of gallons per mile employed in Table 3 does not conform accurately to the actual consumption rate for diesel and gasoline vehicles. The problem that arises is that diesel vehicles of a particular gross weight generally operate at heavier weights than similar gasoline units. To properly compare the fuel consumption of the two vehicle types, the percentage of travel and the fuel consumption rate at various operating gross weights have to be considered. The Bureau of Public Roads has recognized this problem, but their computations have not been published. The conclusion they draw is that the differential fuel consumption rate (i.e., the ratio of diesel fuel consumption per mile to gasoline consumption per mile) is larger when this factor is considered (7, pp. 306-309). This does not seem to be the proper interpretation. If it is found that a particular vehicle type, for example the 2-S2 tractor-semitrailer combination of 50,000 to 59,999 pounds operates at a registered gross weight of 43,700 pounds in the diesel group and 39,900 pounds in the gasoline group, then it would appear that the fuel consumption differential between these vehicles is smaller rather than larger compared to the consumption ratio for registered gross weight. Certainly a lighter vehicle will consume relatively less fuel per mile traveled than a heavier vehicle. (Note that this does not concern the tax liability of the two vehicles. The fact that diesels generally operate at heavier weights has already been taken into consideration in computing their tax liability.) The computations employed in Table 3 avoid this difference in interpretation by using the estimated fuel consumption rate for the registered gross weight of the vehicles.

Once the number of gallons consumed per mile has been determined for each vehicle type it is a relatively easy task to estimate the number of gallons of fuel consumed annually. This is accomplished by multiplying the annual vehicular mileage times the gallons consumed per mile.

The next problem in determining the tax responsibility per gallon of fuel for both diesel and gasoline units is to establish the fuel tax liability per vehicle. The method employed in Table 3 to arrive at this estimate is very crude; but, given the available data, it is probably a close approximation. One problem is that the total vehicle tax liability estimated by the incremental-cost analysis is not obtained entirely through fuel taxes. Therefore, it would be incorrect to assume that the difference between vehicle tax liability and vehicle tax payments could be corrected entirely through fuel taxes. The other federal taxes must be considered. Fuel taxes accounted for only 70.1 percent of Trust Fund revenues in fiscal 1967. Coupling this fact with the possibility of an increase in nonfuel taxes, along the lines of President Johnson's recommendations, leads to the conclusion that at best no more than 75 percent of the estimated deficiency in diesel vehicle tax will be obtained through fuel taxes. Therefore, total vehicle tax liability has been adjusted to take this fact into consideration.

The end result of these computations is the establishment of fuel tax rates for both gasoline and diesel vehicles. This was obtained by dividing the fuel tax liability by the estimated number of gallons of fuel consumed annually. The per gallon tax liability was consistently higher for diesel than it was for gasoline. However, the magnitude of this difference varied considerably among the various classifications. The greatest diesel differential was found for the tractor full-trailer classification of 2-3 or 3-2. For these vehicle groups gasoline combinations were liable for $7.18, whereas diesel units were responsible for $11.35; the tax differential on diesel fuel necessary to insure its full payment of costs would be $4.17 per gallon. In the lighter weight groups the necessary diesel differential is much smaller. This is particularly true for the single unit trucks.

For example, the 2-axle, 4-tire truck would require a gasoline tax differential of $10.65, whereas the per gallon tax on fuel used by 3-axle vehicles is almost identical for both vehicle types.

It would appear that the imposition of a uniform diesel differential of significant proportions would have both desirable and undesirable effects. If the estimates submitted by the Bureau of Public Roads were accurate and a diesel tax differential of 3 cents per gallon were enacted, the effect would be to discriminate against the lighter diesels and, in all probability, to eliminate them from the market. The effect of the 3-cent diesel differential on heavier vehicles is also in question. There are only two cases in the small sample selected that warrant a tax differential equal to or greater than 3 cents per gallon.

It would appear that the tax responsibility for diesel vehicles is greater than similar gasoline vehicles. This is caused by the heavier observed gross operating weight of the diesel vehicles and the greater number of miles traveled annually. However, if a purely cost-occasioned analysis were employed, the differential between the gasoline and diesel vehicles would be considerably below that indicated by the Bureau of Public Roads data. It is quite likely that in many of the vehicle classifications where the annual travel of gasoline and diesel vehicles are similar, there would be no need for a differential. In the other cases, the required differential clearly would be much smaller than that indicated in the Supplementary Report (7), and consequently would be recommended to the Congress.

It would appear that this 3-cent differential is at best an upper limit for a limited number of vehicle classifications. Two factors are of extreme importance. First, the incremental-cost analysis as conducted by the Bureau of Public Roads has not remained within the confines of a cost-occasioned approach. In so doing, a significant percentage of costs has been allocated on a use basis when costs are not affected by use. Second, the estimate of the ratio of gasoline fuel consumption to diesel fuel consumption is in very crude form.

CONCLUSIONS

It is unlikely that diesel and gasoline vehicles will be found to have the same tax liability even under a strictly cost-occasioned analysis. This is true because the non-use costs will be identical essentially for both vehicles, whereas the total charges for use will be greater on the diesel units because they travel annually a greater distance. But if it were assumed that similar gasoline and diesel vehicles occasioned the same annual costs, problems still would exist in establishing an efficient tax structure. Two basic methods could be employed. Tax charges could be imposed on fuel or directly on the vehicle.

Fuel Taxes

The use of fuel taxes has become the primary method used to raise highway revenue on both the federal and state level. Other taxes are used, but their fiscal importance is greatly outweighed by the tax on fuel. The original purpose for imposing this tax varied from state to state and from states to the federal government. In general it can be asserted that the tax was justified on some benefits basis. Because benefits are closely correlated with use, the employment of this form of taxation could hardly be questioned.

If highway taxes are no longer justified on a basis of benefits received, but instead are tied to costs occasioned, then the use of fuel taxes becomes doubtful. It is unlikely that unadulterated fuel taxes can fully reflect the increase in highway costs for heavier vehicles, take account of costs that are not subject to use, or adequately handle similar vehicles that vary in fuel economy.

To offset the shortcomings of the fuel tax, a variety of additional taxes have been imposed upon highway users. These taxes are normally designed to capture the extra costs occasioned by heavier vehicles. Little constructive work has been done to solve the latter two weakenesses of the fuel tax.

The particular problem posed by the diesel vehicle is its greater fuel economy relative to the gasoline vehicle. The solution to this issue retaining the fuel tax structure is the differentiation of diesel fuel taxes. That is, placing a larger tax on diesel fuel than on gasoline so that the same amount of tax will be charged per mile of travel.

If fuel taxes remain the primary source of highway revenue, then it would appear that some type of differential taxes are necessary for diesel fuel. Unfortunately it is not patently obvious what this differential should be. A modified incremental-cost analysis would indicate a need for larger taxes on diesel vehicles than on similar gasoline vehicles. A thorough study of the relative fuel consumption of diesel and gasoline vehicles would indicate that the former consumes less fuel per mile traveled. But definitive work has not been completed on either of these two questions. Only estimates can be made.

The issue of differentiation cannot legitimately stop with the diesel fuel question. The requirement of an efficient allocation of resources would demand that a whole array of differential taxes be imposed. The relative efficiency of automobiles with approximately the same annual tax liability varies far more than that of gasoline and diesel trucks. If the Volkswagen and Chevy II are charged the same amount yearly, the former should pay more per gallon of fuel than the latter. If this same situation existed for the Chevy II and the Chevrolet Impala, the former is again liable for greater fuel taxes than the latter. Obviously this claim of differentials can be extended to the largest passenger vehicles.

The administration problems of this procedure would be insurmountable. But simply because diesel fuel can be more easily segregated does not appear to be a sufficient cause to impose taxes here and neglect the other over- and under-tax payments.

Thus, the fuel tax is not the ideal taxing instrument to extract the full cost occasioned by highway users. The fundamental problem with this device is its inability to treat differentially the numerous classes of highway users. Even in the case of diesel fuel, where differential fuel taxes are administratively feasible, there are serious limitations. The fuel tax rate is dependent on two factors: annual vehicular travel, and fuel consumption per mile. No definitive study has been made of the latter variable. When a reliable study is made of the fuel consumption rates of various vehicles, it is apparent that the results will reveal widely varying fuel consumption patterns between different geographical areas and under different weather conditions. If fuel taxes are employed as a means to collect the cost that highway users occasion, this should be done only on a regional basis. The logical method to solve the inadequacies of fuel taxes is to turn to another form of taxation.

Per Vehicle Taxes

An excellent substitute or at least a complement for the fuel imposts is a type of per vehicle taxes. These taxes could take various forms from registration fees to excise taxes. The advantage of this type of tax is its ability to treat differentially the various vehicle classes. Thus, if the Volkswagen and the Chevy II each occasion $30.00 a year in highway costs, a registration fee could be imposed to collect this amount. The problems of estimating the relative fuel consumption of the two vehicles and thus a tax differential is not necessary. The same would be true for diesel and gasoline vehicles. Under this sytem, if the former were charged $300.00 more in taxes per year than the latter, the annual registration fee for diesel vehicles would be correspondingly higher than that of the gasoline vehicle.

Per vehicle taxes could achieve an efficient distribution of tax responsibility at a reasonable administrative cost. Unfortunately, to achieve this efficiency some taxpayer convenience must be sacrificed. The primary advantage of fuel taxes is the ease of compliance; that is, a small charge is levied on numerous occasions that makes it relatively painless to pay the annual charge. Per vehicle taxes, on the other hand, are normally paid in lump sums. A large tax every year would work a hardship on some taxpayers. The imposition of this type of taxation would require a reshaping of taxpayers' attitudes toward highway imposts.

This shortcoming could be rectified by combining fuel taxes with per vehicle taxes. The basic tax responsibility could be obtained through fuel taxes with any necessary adjustments being made through per vehicle taxes. That is, the fuel tax rate could be set at a level that would recoup the tax responsibility for the majority of vehicles. Those vehicles that are inefficient and thus consume proportionally more fuel could be charged a negative registration fee, whereas the efficient vehicles could be charged a positive registration fee.

This solution brings us back in a full circle to where we began. That is, to compute the necessary adjustment for the basic fuel tax, estimates must be made concerning the annual vehicular travel and fuel consumption. It has been indicated above that the latter estimate is difficult to obtain. This is particularly true on a national scale where numerous factors must be considered. However, a scientifically administered analysis could obtain reasonable estimates of the comparative fuel consumption of various vehicles. By its very nature this would be an average; thus, the deficiencies of the approach must be recognized.

The advantage of combining the fuel tax with the per vehicle tax is to insure that all under-payments are accounted for. Differential diesel fuel taxes can only be applied to a small segment of the total vehicle population—approximately 1 percent. There is doubtlessly a far greater percentage of vehicles that should also be treated differentially, but because they all consume gasoline fuel this is administratively impossible under the fuel tax option. The use of classified per vehicle taxes provides the means by which these underpayments can be rectified.

The major question concerning the differential taxation of diesel vehicles is thus whether or not the loss of efficiency is great enough to warrant special treatment of diesel vehicles. Few would disagree with the statement that diesel vehicles generally should be charged a greater tax liability compared to similar gasoline vehicles. But this difference varies considerably from one vehicle group to another. Upon reexamination of the incremental-cost analysis it may well be found that for the vast majority of vehicle classifications the tax advantage granted diesel vehicles is not large enough to warrant differential treatment. This is especially true when the potential inaccuracies of the analysis are considered. Even if the tax advantage is of significant magnitude, there is some question as to the propriety of rectifying the condition. Several factors must be considered. First, the correction of the diesel vehicle under-payment, without corresponding corrections for other vehicles, must be considered an explicit policy to insure a proper resource allocation for heavy vehicles only. The implications for resource allocation are as large, if not larger, in the case of the economy car as that of the standard automobile. If the latter situation is not corrected at the same time as the diesel question, then there is some question as to the implicit goals of the policy-makers.

Second, even if all tax payments were to be adjusted to meet their corresponding tax responsibility, there would be some question of the desirability of this course of action. By necessity, this procedure involves the special treatment of small numbers. This type of remedy could be worse than the disease. Beside the administration complications, the introduction of differential taxes opens the door to special concessions for various highway taxpayers. The economic criterion would have to be diligently followed for this approach to yield desirable results.

Third, differential taxation encourages taxpayers to find ways to evade the imposts. Differential taxes imposed on fuel are particularly vulnerable on this point. The extent of potential evasion is the primary reason why the differential taxation of gasoline is unlikely. Those vehicle classes that are charged higher rates per gallon would undoubtedly attempt to buy fuel at the lower rates and use it in the vehicle subject to higher tax charges. The differential treatment of diesel fuel is to a lesser extent subject to evasion. The small diesel operator, like the gasoline operator, can buy fuel for farm equipment and operate his highway equipment with it. In addition, the diesel user can use heating fuel in his vehicle. The question of diesel fuel taxation presents additional administrative problems that are not present in the gasoline tax area. These administrative problems primarily arise because diesel fuel can not be taxed at the distributor. Unlike gasoline, a large percentage of diesel fuel is used for nonhighway purposes, thus, the tax must be levied at the retail level. This vastly increases the number of accounts that must be audited.

Fourth, the whole question of fuel taxation in general and differential fuel taxes in particular may be short-lived. Recent years have witnessed many motor vehicle engine improvements. The most revolutionary is the development of the gas turbine engine. Although this engine is still in the embryonic stages, the implications of its refinements must be considered. When fully developed this engine will be capable of running on any fuel from kerosine to high octane gasoline. The administration problem inherent in taxing numerous fuels that are largely used for nonhighway purposes is overwhelming. It is also inconceivable that it will be possible to establish differential fuel rates for vehicles employing this variety of fuels.

Last, the effects of federal diesel vehicle taxation must be considered. Currently, thirteen states impose additional taxes on diesel vehicles. A majority of the differential taxes are imposed on diesel fuel. These taxes range from a low of 1 cent per gallon in a number of states to a high of 3 cents per gallon in Montana and New York. If the federal government imposes an additional 2- or 3-cent per gallon tax on the diesel's fuel, these vehicles will be subject to a differential of 5 or 6 cents per gallon in some states. It is extremely difficult to find justification for a differential of 3 cents per gallon; 5- or 6-cent differential would discriminate greatly against diesel vehicles.

The federal differential taxation of diesel vehicles in essence would be a preemption of the diesel vehicle tax source. Certainly, no state could justifiably retain its differential once the federal government moves into this taxing area. The immediate question is, therefore, which level of government should differentially tax diesel vehicles? The inherent problems of establishing a gasoline-diesel fuel consumption ratio on a national basis has been discussed previously. To this must be added the regional effects of diesel vehicles; that is, the importance of diesel vehicles to the economy of a particular region. In total it appears that if diesel vehicles are subject to additional taxes, the establishment of the rates and the collection of these imposts should be left with the states, not the federal government.

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Discussion

W. E. MEYER, Pennsylvania State University—Having been associated with the development of automotive diesel engines since their infancy, I have had a close view of the never-ceasing struggle to find a solution to the fuel tax problem. In consequence, I believe there is no solution that will satisfy and pacify all parties to the dispute.

The only way a truce can ever be approached is to abandon the concept, if not the term, of a fuel tax. As far as highway use and providing and maintaining highway facilities are concerned, it does not make one difference how or with what fuels vehicles are propelled. We are at the threshold of major changes in powerplants. It seems absurd that the success or failure of propulsion systems might be influenced, perhaps decisively, by taxing methods that never were defensible by logic.

It has happened that diesel engines proved themselves to be acceptable only in heavy trucks and buses. Would we not have had a fuel tax differential long ago if the diesel had, as many engineers hoped it would have, been used in passenger automobiles? Of course we would have; otherwise the entire highway tax structure would have collapsed. Similarly, it is inconceivable that electric automobiles should go free, as far as fuel tax is concerned, if they ever make the grade.

Any fuel tax is basically nothing but a convenient way of collecting a highway use tax. It is a perfectly acceptable substitute as long as all vehicles use the same fuel with equal efficiency and provided there is proportionality between fuel consumption and the demands that vehicles of different classes make on the highway facilities. When these conditions are not met, straight fuel taxes are not equitable.

I believe that a tax that justly allocates highway use cost is, however, a phantom. All taxes are political tools, whatever method of cost accounting is used. For instance, if federal diesel fuel taxes were increased today, many trucking operations would become unprofitable and the freight they have been moving would be carried by railroads and airplanes. Perhaps such a change should be encouraged to relieve highway congestion, increase pavement life, improve traffic safety, and make driving one's car a little less harrowing.

Some people think the steam car is just around the corner. It is very likely going to use what we now call diesel fuel. Should its development and acceptance be promoted or inhibited by the magnitude of the tax on the fuel it is going to use? The steam car's only claim to acceptability is its lower air pollution potential. Do we want to promote cleaner air via a fuel tax? Whether we do or do not, any fuel tax will operate as a deterrent or a stimulus to the introduction of new types of powerplants. Historically, this is what happened with the diesel engine. I doubt that the diesel engine would have made the progress it did if fuel taxes had been prorated on the basis of fuel consumption to begin with.

Because we are rapidly approaching a possible revolution in propulsion systems, I would plead that any consideration of changes in highway use taxes should take into account the probable effects on novel propulsion system developments and on the factors that make them desirable or practical.

JESSE L. BUFFINGTON, WILLIAM G. ADKINS, and DALE L. SCHAFER, Texas Transportation Institute, Texas A&M University—This response to Mr. Swartz's paper is offered as a substitute for an informal review to have been given at the time of Mr. Swartz's presentation at the 1969 Annual Meeting of the Highway Research Board. The reviewers were unable to make this appointment but became interested in Mr. Swartz's remarks. It is hoped that the present rejoinder will be of some value to those who may be concerned with the subject.

Mr. Swartz has taken issue with researchers and government officials on federal and state levels as to differential taxes applied to diesel vehicles used on public highways. He discusses the current diesel fuel and vehicle registration tax differentials and compares them with differentials justified by use of the incremental-cost method developed by the U. S. Bureau of Public Roads, and published in a Supplementary Report to the Highway Cost Allocation Study in 1965 (7).

After casting some doubt on the validity of research findings used to justify taxing diesel vehicles differentially from gasoline vehicels, he predicts that reliable research findings would justify differential taxation, but with a smaller differential than presently suggested by the incremental-cost method (as applied in the Highway Cost Allocation Study). He suggests the use of both fuel and per vehicle tax differentials as the best method of obtaining the "justified" differential taxes.

Some of the problems related to the subject have been dealt with recently under a Texas Transportation Institute (TTI) cooperative research contract with the Texas Highway Department and the Bureau. A report of findings was published in May 1968 (8). This research effort was made to generate fuel tax differentials for cargo vehicles using Texas highways. The technique used and some of the findings are discussed later.

Use of Diesel Tax Differentials

Mr. Swartz questions the early use of diesel tax differentials on the grounds that selected state tax officials indicated that an actual differential had not been established by "reliable" research efforts. Yet, the two officials he quotes made their statements after the Oregon study was published in 1937, which was a formal research effort designed to determine the actual differential between gasoline and diesel fuel consumption of trucks on rural highways (9). Although the study occurred some 20 years prior to the last of the major studies of this type, the findings are amazingly similar for the same axle types.

Even after 10 research studies have been conducted (two of them on a national basis) to establish the actual fuel consumption differentials for similar vehicles operated in the same uses at various gross weights, Mr. Swartz still questions the appropriateness of diesel tax differentials based on the findings of these studies. He says that "definitive" research of this kind is yet to be done. He further indicates that the reason why only 13 states presently have some type of diesel tax differential is because of the lack of confidence other states have had in the findings of these studies. But actually four of the five states that conducted fuel consumption studies have enacted some form of diesel tax differential. It is our opinion as well as the opinion of those who conducted some of the studies that these findings are reasonably reliable and can be generally applied over the nation regardless of region. Granted, more definitive studies should be forthcoming for fuller coverage, verification, and updating purposes. Presently, at least three other states (Illinois, North Dakota, Arizona) are considering the passage of such a tax law. It is suspected that reasons other than doubting the validity of research findings have played a part in determining whether a state has imposed a diesel fuel tax differential. None of the five states that repealed diesel tax differentials has conducted formal fuel consumption studies. Also, three of these states are traversed by the Rocky Mountains where Mr. Swartz says diesel vehicles enjoy the greatest fuel efficiency over their gasoline counterpart, therefore clearly justifying a significant tax differential.

Determination of Diesel Vehicle Tax Liability

There are a number of accepted methods used for determining the magnitude of a diesel tax liability that might exist between owners of similar gasoline and diesel vehicles used on public roads in various states or the nation as a whole. Some of these are the ton-mile, cost function, differential benefit, incremental-cost, and prorated fuel equivalent methods (PFEM). The latter was used in the Texas study (8). (The method was given a name for identification in this commentary.) Each of the above methods has advantages and disadvantages.

Mr. Swartz devoted much of his paper to criticizing the way that the Bureau used the incremental-cost method in the Highway Cost Allocation Study to determine the highway cost responsibility between gasoline and diesel vehicles. Specifically, he says that the implicit assumption that all highway user costs are associated with use is open to serious question as is the distribution on a vehicle-mile basis. He thinks it is doubtful that right-of-way, grading, drainage and related costs are associated with additional use, and consequently concludes that these costs should be distributed only on a per vehicle basis instead of a per vehicle-mile basis. Accordingly, alterations of the incremental-cost analysis to conform with a strict cost-occasioned criterion would reduce the more frequest road user's (diesel vehicles) total tax responsibility and increase the less frequent user's (gasoline vehicles) total tax responsibility. In other words, this alteration would require diesel vehicles (which are usually heavier and log more annual miles than similar gasoline vehicles) to pay less overall user taxes than that shown in the Supplementary Report of the Highway Cost Allocation Study (5).

In answer to Mr. Swartz's argument, it seems that the Bureau's increment cost responsibility analysis is justifiable. The Bureau states that all expenditures made from the Highway Trust Fund are for the highway construction, engineering, and administration required to meet the demands of anticipated traffic. It states further that highway expenditures are geared to the anticipated use of all vehicles and are not intended to provide standby capacity for added traffic of a particular type. Therefore, expenditures for right-of-way, utility adjustments, roadside development, traffic and pedestrian services, and administration may be properly distributed on a fully accounted basis, since they obviously are in the nature of joint costs.

At this point, the prorated fuel equivalent method will be explained and offered as an alternative to the other above-mentioned approaches used to determine diesel vehicle tax liabilities by axle type or by combined axle types. The method can be applied on a state, regional or national basis. The magnitude of the resulting diesel tax liability generated by this method is close to that generated by the incremental-cost method for the majority of diesel vehicles of about the same gross operating weight (8). (Of course, the Texas study used only Texas loadometer data. The Bureau used loadometer data from 48 states.)

The prorated fuel equivalent method simply develops fuel consumption rate differentials for diesel vehicles equal in gross operating weight to their gasoline counterparts by means of weighting the appropriate fuel consumption rates of each fuel type and gross operating weight class with the current diesel vehicle frequency distribution. Because the central problem is to determine what kind of fuel consumption advantage, if any, diesel vehicles have over gasoline vehicles (identical in other respects to the diesel), it seems imperative to use the diesel frequency for weighting purposes. This method assumes that the fuel consumption rates found in other studies are proper for Texas and that the loadometer distributions represent a cross section of traffic on Texas roads. The loadometer frequency distributions were chosen in preference to registration distributions because the registered gross weights fail to adequately reflect operating gross weights.

Table 4 shows the fuel consumption differentials from frequency distributions of combined axle groups using the composite (compromise) fuel consumption curves presented in the Supplementary Report (7). The footnotes under the table explain the weight ranges, weight classes, assumptions, and formulas used. The differentials developed were generally a reflection of the weight ranges covered by the fuel consumption studies.

Diesel fuel consumption rate differentials presented in Table 4 were the same for both weight ranges used when weighted by diesel numbers (which assumes that diesel vehicles are gasoline powered). Thus, the average Texas diesel cargo vehicle has a fuel consumption rate differential of 1.34 that can be applied to the gasoline tax rate (5 cents per gallon in Texas) to generate the corresponding diesel tax rate (6.7 cents per gallon) at an average operating gross weight of 46,013 pounds. Actually, this method assumes that the diesel vehicle should pay the same fuel tax per mile as the gasoline vehicle of the same gross weight regardless of total distance traveled.

According to this analysis, slightly higher fuel consumption differentials for the major individual axle groups seem to be in order. Table 5 summarizes the findings and shows differentials of 1.45 for 2-S1's, 1.47 for 2-S2's and 1.52 for 3-S2's. These differentials were developed from fuel consumption curves for each axle group as given in two of the five studies used to determine the composite curves, specifically the "Line-Haul Trucking Costs" study (10) and the "Fuel and Time Consumption" study (11). If the composite curves had been used, the corresponding fuel consumption differentials would be 1.31, 1.32, and 1.36. As can be seen, these differentials are more conservative than those developed by use of individual axle group fuel consumption curves.

In summary, the prorated fuel equivalent method does not rely on a highway allocation cost basis. It is an approach to equalizing the use tax responsibility between gasoline and diesel vehicles of the same operating gross weight. This is not to say that a

TABLE 4

FUEL CONSUMPTION DIFFERENTIALS OF COMBINED AXLE GROUPS OF TEXAS VEHICLES AS REFLECTED BY THE COMPOSITE FUEL CONSUMPTION RATES[a]

Characteristics	Loaded and Empty Vehicles in	
	10,100-80,000 lb Weight Range	23,100-73,000 lb Weight Range
Total number of vehicles in weight range		
Gasoline	6,369	2,832
Diesel	10,706	9,854
Percent of all gasoline vehicles weighed	56	25
Percent of all diesel vehicles weighed	99	91
Average vehicle weight in pounds[b]		
Gasoline	26,452	38,344
Diesel	44,813	46,013
Average fuel consumption in gallons per mile[b]		
Gasoline	0.187	0.230
Diesel	0.186	0.188
Gasoline to diesel fuel consumption ratio		
Weighted by gasoline numbers[c]	1.22	1.30
Weighted by diesel numbers[d]	1.34	1.34

[a]The 10,000 to 80,000 pound weight range represents an extrapolation beyond the range of the fuel consumption studies, whereas the 23,100 to 73,000 weight range keeps within the range of the fuel consumption studies.
[b]Weighted by the numbers of vehicles in each 2,000 pound weight class.
[c]Assumes that the gasoline vehicles used diesel fuel for a weighting factor. The formula: Σ (GPM of gasoline x number of gasoline vehicles) ÷ Σ (GPM of diesel x number of gasoline vehicles) where GPM = gallons per mile.
[d]Assumes that the diesel vehicle used gasoline fuel for a weighting factor. The formula: Σ (GPM of gasoline x number of diesel vehicles) ÷ Σ (GPM of diesel x number of diesel vehicles).

TABLE 5

SELECTED FUEL CONSUMPTION DIFFERENTIALS FOR EACH AXLE GROUP OF TEXAS DIESEL VEHICLES WEIGHED IN 1967

Axle Group	Weight Range (pounds)	Average Gross Weight (pounds)	Fuel Consumption Differential
2-S1	37,100-55,000	39,902	1.45
2-S2	27,100-69,000	47,348	1.47
3-S2	27,100-71,000	50,266	1.52

fuel tax differential per gallon can be applied to collect all the highway cost responsibility of the heavy and frequently used gasoline or diesel cargo vehicle necessary to equalize its tax burden with the light and infrequently used single unit cargo vehicle. The incremental-cost analysis proves this point and is useful for this very purpose.

Determination of the Diesel Vehicle Tax Payment

Mr. Swartz is quite critical of the Bureau's method of estimating a vehicle's highway user tax payments for comparison with that vehicle's allocated cost responsibility derived from the incremental-cost analysis. His criticisms stem principally from the Bureau's use of the fuel consumption curves developed for this purpose. The Bureau's method also requires a determination of annual travel for the gasoline and diesel vehicles of various types. Mr. Swartz says accurate travel data are available, but he thinks that the available fuel consumption data are much less reliable. Yet data (presented later) indicate that the composite curves are quite reasonable, being based on five independent studies. Data for the individual axle types, that account for the vast majority of gasoline and diesel vehicles of the same operating gross weight and use (especially tractor-semitrailer combinations), yield very similar gasoline to diesel fuel consumption differentials that are somewhat higher than those yielded by the composite curve. The use of such data seems justified for the present time until more definitive studies can be completed. Failure to equalize the tax burden per mile between comparable gasoline and diesel cargo vehicles seems to be a greater "evil" than use of presently available fuel consumption data.

Mr. Swartz also questions the Bureau's conclusion concerning the effect of using percentage of travel adjustments on operating gross weights of a certain vehicle type, say the 2-S2 gasoline and diesel vehicles registered for 50,000 to 59,999 pounds of gross vehicle weight. He said the conclusion was that a larger differential fuel consumption rate results if the percentage of travel adjustment is considered. Actually, the Bureau implies the opposite conclusion and uses the smaller adjusted differential. What the Bureau actually says is that the fuel consumption differential for the above 2-S2 gasoline and diesel vehicles of equal operating gross weights is even greater than the adjusted or unadjusted differential. The differential based on equal operating gross weights seems to be the more appropriate one to use in estimating the fuel tax payments per gallon of fuel consumed by equivalent gasoline and diesel vehicles.

Another problem discussed in connection with the establishment of the tax responsibility per gallon of fuel for both gasoline and diesel vehicles is that of establishing the fuel tax liability per vehicle. Not all the total vehicle liability estimated by the incremental-cost analysis is obtained entirely through fuel taxes. Mr. Swartz indicates that only 70 percent of the 1967 Trust Fund revenues were collected by fuel taxes and thus concludes that, at best, no more than 75 percent of the estimated deficiency in diesel vehicle tax will be obtained through fuel taxes. So he adjusts the Bureau's total vehicle tax liability on selected vehicle types to obtain a vehicle fuel tax liability that is 25 percent smaller. Then he computes the fuel tax rates by dividing the vehicle fuel tax liability by the annual gallons consumed by a vehicle.

Although agreeing that the per gallon tax liability is consistently higher for diesel than for gasoline, Mr. Swartz believes that the magnitude of this difference varies considerably among the various classifications of vehicles. He thinks that the effect of a 3-cent diesel tax differential would probably eliminate the small diesel from the market. This has not happened in the states where such a tax differential has been imposed for years.

Again, attention is directed to the prorated fuel equivalent method used to determine the diesel vehicle tax liability in the Texas study. The supported diesel differential tax rate per gallon was established directly by multiplying the gasoline tax rate times the single fuel consumption differential discussed in the last section. The present diesel differential tax payment was determined by the diesel differential tax per gallon and the special diesel vehicle registration fee differential distributed on a per gallon basis.

Texas' special diesel vehicle registration fee differential amounts to 11 percent of the registration fee for gasoline vehicles registered at the same gross weight of the power unit. Each registered gross weight was assumed to correspond with a probable operating gross weight that includes trailers or semitrailers attached to the power unit. Also, to spread out the cost of such a diesel vehicle tax over miles of operation, certain annual mileages were assumed. Then by using the diesel fuel consumption rate per gallon at the respective operating gross weights, the tax per gallon was established.

A comparison was made between the supported diesel tax liability per gallon and the present diesel tax payment per gallon to determine the extent of an over- or under-payment. Such an analysis is shown in Table 6. If the goal is to equalize the fuel tax per mile for the average diesel vehicle, then only one diesel tax differential will be needed. For tax purposes, this is a reasonable goal. It is less complicated and easier to be administered than to have a separate differential rate for each axle type. Furthermore, differences are relatively small compared to the difference between gasoline and diesel fuel consumption rates.

Use of a special diesel vehicle registration tax causes the diesel tax payments to be more sensitive to vehicle weight differences, given a single fuel tax differential. But within a given mileage, the registration tax must make up a substantial percentage of the overall diesel tax differential for equalization between axle types. Yet within axle types, the registration tax causes considerable differences in the diesel tax differentials for vehicles with widely differing annual mileages. However, the registration tax schedule, if properly graduated according to the operating gross weight, could cause the present diesel tax differentials to conform closely with the supported diesel tax dif-

TABLE 6

PRESENT AND SUPPORTED DIESEL TAX DIFFERENTIALS FOR VARIOUS GROSS OPERATING WEIGHTS ASSUMING CERTAIN REGISTERED GROSS WEIGHTS AND MILES OF TRAVEL

Gross Operating Weight in Pounds	Assumed Registered Gross Weight in Pounds[a]	Diesel Tax Differential in Cents per Gallon by Miles of Travel					
		50,000		75,000		100,000	
		Present[b]	Supported[c]	Present[b]	Supported[c]	Present[b]	Supported[c]
20,000	20,000	1.74	0.85	1.66	0.85	1.62	0.85
30,000	27,000	1.82	1.25	1.71	1.25	1.66	1.25
40,000	39,000	1.97	1.55	1.81	1.55	1.73	1.55
50,000	39,000	1.93	1.85	1.79	1.85	1.72	1.85
60,000	39,000	1.91	2.05	1.77	2.05	1.70	2.05
70,000	39,000	1.88	2.25	1.76	2.25	1.69	2.25
46,013[d]	39,000	1.95	1.70	1.80	1.70	1.73	1.70

[a]Based on a study of the registered gross weight frequencies. In Texas, the registered gross weight is that of only the power unit and does not include the gross weight of the trailer or semitrailer pulled by the power unit.

[b]Includes the actual 1.5 cents per gallon fuel tax differential and the 11 percent diesel engine tax differential in cents per gallon based on the assumed registered weight and miles of travel and using the composite curve diesel fuel consumption rates.

[c]The total diesel tax justified as indicated by the gasoline and diesel fuel consumption rates from the composite curves.

[d]The average weight of diesel vehicles in the 23,100 to 73,000 weight range. At this weight, the gasoline to diesel fuel consumption ratio is 1.34 that represents 91 percent of all diesels weighed.

ferentials. Such a registration fee would help to equalize the diesel fuel tax payments between the lightweight single unit vehicles and the heavyweight combination vehicles. This essentially means that the owner of a diesel vehicle with an operating gross weight of less than the average diesel vehicle (used to determine the single diesel fuel tax differential of, say, 1.5 cents per gallon) would pay a negative diesel registration fee, and those with an operating gross weight of more than the average diesel vehicle would pay a positive diesel registration fee. Swartz essentially recommends this sort of per vehicle tax to adjust for the inequities created by using a single diesel fuel tax differential for all classes of cargo vehicles.

Conclusions

Mr. Swartz seems to conclude that diesel vehicles should not be taxed differentially for the present due to lack of reliable fuel consumption data, and due to probable wide variability in fuel consumption rates of various vehicles operating in different geographical areas and under different weather conditions. He takes issue with the Bureau and various states for using such data in the determination of a diesel tax differential. He disagrees with the Bureau's incremental-cost analysis and estimates of fuel tax payments by diesel and gasoline vehicles.

Mr. Swartz's paper covers a wide range of points not strictly relevant to the subject he has chosen to discuss. A few of these are attacks on the early application of the diesel tax differential; competition between the trucks and railroads; the small number of states with diesel tax differentials, and the doubts of state tax officials concerning the findings of fuel consumption studies; whether a diesel tax differential could and should be imposed on both federal and state levels; the potential demise of fuel taxes due to the development of the gas turbine engine; and the tendency for differential taxation to encourage taxpayers to find ways to evade payment.

There are more relevant pursuits such as consideration of all the available fuel consumption data and other pertinent data, selection of methods that would allocate costs equitably between vehicles of each fuel type, and determination of more equitable and administratively feasible methods of taxing diesel vehicles to obtain any diesel tax liability that might exist. One challenging inequity regarding federal fuel taxes is the different levels of service furnished from state to state. Similarly those vehicles that seldom are able to have the advantage of the high level of service on the Interstate System do not get tax relief.

This rejoinder is highly critical but it is hoped to be also contributory. Highway taxation is not especially unassailable. Quite to the contrary, it is grossly undernourished in the way of base data on which to decide and administer. The intent and purpose of Mr. Swartz's paper is a subject for continuous questioning.

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THOMAS R. SWARTZ, and JAMES J. RAKOWSKI, Closure—The comments of Meyer are both interesting and useful. Fuel taxes are indeed "basically nothing but a convenient way of collecting a highway use tax." Our reluctance to change this basic method of taxation has in the past interfered with the operation of the market mechanism. Meyer's concern for the future distortions of research and development funds is quite legitimate. This provides an additional justification to reduce the dependency on fuel taxation, with an eventual view of abandoning this tax device.

The urgency associated with finding a solution to this problem should not be understated. Research for a substitute to the internal combustion engine has reached a high pitch. Tax authorities must insure that new innovations—whether they are steam, electricity, or a workable turbine—are not inadvertently favored or discriminated against simply because of an antiquated tax system.

The comments of Buffington, Adkins, and Schafer demand a more comprehensive reply. At first blush their comments appear to be quite critical of the paper. However, closer examination reveals that the discussants do not criticize the major issue found in the paper; but, instead, they have concentrated on a secondary issue that happens to touch on their own research.

The major thrust of the paper is directed toward the Bureau's interpretation of the incremental-cost analysis. Although the analysis is the most appropriate method to allocate highway user cost responsibility, its application has not adhered to a strict cost-occasioned criterion. A substantial portion of total highway costs are fixed costs, such as right-of-way, drainage, roadside development, etc. Incremental-costs analyses have traditionally allocated these costs on a use basis. Once the right-of-way has been purchased or the drainage and roadside development has been provided, there are no additional costs for an additional axle-mile or vehicle-mile traveled. It is true that the frequent highway user receives more benefits, but his use of the right-of-way drainage or roadside development does not result in additional costs.

Those costs that cannot be allocated on a use basis should then be assigned on a per vehicle basis. Naturally, this would substantially alter the cost responsibility of all vehicle classifications. The most obvious adjustment would be a marked increase in the cost allocation to the passenger car relative to the commercial vehicle. Among the commercial classifications the cost responsibility would not only fall, but, in addition, the relative responsibilities of the diesel and gasoline vehicles would be substantially changed. Because the diesel vehicle travels up to twice as many miles as a similar gasoline vehicle, its greater use of the highway facility would not be penalized by charging a cost that does not vary with use.

A second concern of the discussion was the value of per vehicle taxes as opposed to fuel taxes. If it is assumed that the Bureau's current incremental-cost analysis has properly allocated cost responsibility among vehicle classifications, the use of fuel tax differentials to offset variations in mechanical efficiency of similar vehicles is quite awkward and thus a poor choice. Because the differential between similar vehicles varies from one vehicle classification to another, the most equitable tax device would be a flat fuel impost coupled with a per vehicle tax that would recoup the additional tax responsibility. This combination of fuel and per vehicle taxes should be extended over the full range of vehicle classes—from the passenger vehicle to the largest commercial vehicle.

In discussing the relative value of fuel taxes compared to per vehicle taxes, the paper made several references to the existing data on the efficiency of the diesel and gasoline engine. One reference stated that the data on "fuel consumption are much less reliable" then the data on annual vehicular travel, whereas another stated that "definitive work has not been completed on either" a modified incremental-cost analysis or the relative fuel consumption of diesel and gasoline engines. On another page, it is stated that the Bureau's estimate of the ratio of gasoline fuel consumption to diesel fuel consumption is in a "very crude form." These statements may strike Buffington, Adkins, and Schafter as being somewhat strong, but even they qualify the reliability of existing studies by inserting "reasonably" before reliable and by granting that "more definitive studies should be forthcoming." It does not seem profitable to engage in a barren dispute over adjectives because no essential point in the paper depends on the degree of reliability of these estimates.

Buffington, Adkins, and Schafer's sensitivity to fuel consumption differentials is curious on one hand and most distressing on the other. Their sensitivity has caused them to gloss over the essence of the paper. This is best exemplified when they state that "failure to equalize the tax burden per mile between comparable gasoline and diesel cargo vehicles seems to be greater 'evil' than use of presently available fuel consumption data." (This statement seems to imply that the paper asserted that no steps should be taken to correct inequities in fuel taxes because of the "presently available fuel consumption data." We can find no statement or implication in the original paper that indicates that tax assessment consistent with a properly computed tax liability should not be instituted, even if this computation is based on imperfect data.) The thrust of the paper was indeed to challenge the assertion of an equal tax burden per mile. Obviously the discussants noted this fact, but their sensitivity in regard to the reliability fuel consumption ratios compelled them to devote the vast majority ot their long "comment" to that minor topic and only six lines in answer to the major issue.

The criticisms of the incremental-cost analysis found in the paper do not "stem principally from the Bureau's use of the fuel consumption curves developed for this purpose." The key issue in the paper was the fact that the incremental-cost analysis strayed from a purely cost-occasioned analysis. Buffington, Adkins, and Schafer have apparently missed the significance of that point.

Their response to this criticism of the Bureau's incremental-cost analysis is limited to six lines concluding with a non sequitur. Their argument is that highway expenditures are made to meet "the demands of anticipated traffic" and that these expenditures "are not intended to provide standby capacity for added traffic of a particular type." They go on to state that "therefore, expenditures for right-of-way, utility adjustments, roadside development, traffic and pedestrian services, and administration may be properly distributed on a fully accounted basis, since they obviously are in the nature of joint cost."

The reader is somewhat mystified by this rebuttal. What is a distribution "on a fully accounted basis," and what is meant by "since they obviously are in the nature of joint cost?" The authors would have been better advised to take the full quotation from the Supplementary Report (7) rather than taking a sentence here, a phrase or two there, and adding a few of their own comments. The full quotation is as follows (7, p. 107):

> All of the expenditures made from the highway trust fund are for the highway construction, engineering, and administration required to meet the demands of anticipated traffic. At first glance the effect of travel on expenditures for such work items as utility adjustment and roadside development appears remote. It must be remembered however that the highway improvements on which expenditures for utility adjustments and roadside development are made become necessary because vehicles travel and would not be required if all vehicles remained stationary. The idea that

> vehicles occasion so-called standby expenditures simply because of their existence as stationary objects is without merit. The fact of the matter is that highway expenditures are geared to the anticipated use of vehicles and are not intended to provide standby capacity. Expenditures for right-of-way, utility adjustments, roadside development, traffic and pedestrian services, and administration were therefore distributed on the basis of vehicle miles.

It is clear that if a strict cost-occasioned formula is to be employed, this type of argument begs the question. It is indeed true that expenditures are necessary because "vehicles travel" and that the same expenditures would not be necessary if all "vehicles remained stationary." The issue is that certain of these expenditures are what economists refer to as overhead costs or fixed costs. These costs do not vary with output as measured by vehicle-miles or axle-miles traveled. There is no additional cost for additional use, anticipated or not. [For a more complete discussion of the incremental-cost analysis, see Swartz (12).]

After dismissing the major issue of the paper in a half dozen lines, the discussants proceed to enlighten the reader of their own research, which is at best tangentially related to the topic. The most unfortunate implication of this rather extended section is that one begins to question whether the discussants are aware of what their research is intended to accomplish.

The discussants indicate that there are a "number of accepted methods used for determining the magnitude of a diesel tax liability, some of these are the ton-mile, cost function, differential benefits, incremental-cost, and prorated fuel equivalent methods (PFEM)." The discussants seem to imply that the PFEM analysis performs the same role in determining the tax liability for various vehicle classifications as does the ton-mile, the cost function, the differential benefits, or the incremental-cost analyses. Unfortunately the PFEM does not seem to determine vehicle tax liability. At least it does not appear to determine vehicle tax liability in the same sense that other "accepted methods" determine tax liability. In the words of the discussants, the PFEM "is an approach to equalizing the use tax responsibility between gasoline and diesel vehicles of the same operating gross weight." The relevance of the PFEM is restricted further by the assumption that "the diesel vehicle should pay the same fuel tax per mile as the gasoline vehicle of the same gross weight regardless of total distance traveled." In essence, the discussants have assumed away the cost allocation problem. The device simply takes the cost responsibility by combined gasoline and diesel class and assigns a fuel tax rate that provides an equal tax per mile traveled regardless of the fuel consumed. It does not tell us what the annual cost responsibility of a 2-S2 gasoline or diesel rig is; but, instead, it takes the information from one of the "accepted" cost allocation "methods" and establishes a fuel tax rate.

One minor issue raised in the paper does seem to incorporate a misinterpretation. This involves the discussion surrounding the actual consumption rate for diesel and gasoline vehicles when adjustment is made for greater average operating weights of diesel vehicles. On reexamination of the Bureau's work, it would appear that they have been unjustly criticized on this point. This topic is dealt with on pages 306-307 in the Supplementary Report (7). In this section, the authors of the Bureau report were not particularly lucid, a fault that they share not only with us but also with our critics.

There are numerous issues that are quite misleading in the discussants' "comments." For example, they indicate in the first line of their conclusion that "Mr. Swartz seems to conclude that diesel vehicles should not be taxed differentially for the present due to lack of reliable fuel consumption data, and due to probable wide variability in fuel consumption rates of various vehicles operating in different geographical areas and under different weather conditions." This observation seriously distorts the original presentation. In the first line of the conclusions in my paper it was indicated that "it is unlikely that diesel and gasoline vehicles will be found to have the same tax liability even under a strictly cost-occasioned analysis. This is true because the nonuse costs will be identical essentially for both vehicles, whereas the total charges for use will be greater for the diesel units because they travel annually a greater distance." Thus, the basis for the conclusions drawn by Buffington, Adkins, and Schafer is dubious.

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A Resource Allocation Model for Transportation Planning

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This paper describes the methodology used in development of the Interim Master Plan for Transportation in Pennsylvania in the period through 1975. The rationale for development of this plan is based on a three-step approach: (a) determination of goals for transportation development in the Commonwealth; (b) identification of alternative projects and programs to meet these goals, and evaluation of alternative projects and programs under different assumptions about goal values and budget levels; and (c) selection of those projects and programs for the Interim Master Plan that were most beneficial in terms of goal satisfaction and that could be purchased within a specified budget level.

The most important feature of this methodology is a computerized resource allocation model for evaluating and selecting projects on the basis of multiple criteria in terms of their anticipated costs and benefits to meet a set of weighted goals subject to overall cost constraints. The evaluation technique requires an estimation for each proposed project of the out-of-pocket investment cost to the state, and the anticipated benefits in each of nine categories. Those projects selected under all assumptions about goal values and budget levels were included as the "highest priority projects" in the Interim Master Plan; those selected under some goal-value and budget combinations, but not under others, were defined as "second-highest priority projects"; and those projects rarely or never selected under any assumptions about goal values or budget levels were considered as "lowest priority projects."

•THE Franklin Institute Research Laboratories (FIRL) has recently completed the development of the Interim Master Plan for Transportation in Pennsylvania (1) sponsored by the Governor's Committee for Transportation, Commonwealth of Pennsylvania. The Interim Master Plan sought to identify the projects and programs that would best serve Pennsylvania's transportation planning goals in the period through 1975.

Renewed industrial vigor, effective use of natural resources, and success in promoting statewide development all depend significantly on how well Pennsylvania's transportation system anticipates and performs its supporting functions. The proper planning, development, and utilization of Pennsylvania's transport resources and services can stimulate the future growth of the Commonwealth and promote the economic prosperity and social welfare of all Pennsylvanians. This is the challenge addressed by the Interim Master Plan for Transportation: to direct and encourage, through planning, the modifications and adjustments in Pennsylvania's transportation system that will further the economic, social, and strategic objectives of the Commonwealth.

Paper sponsored by Committee on Transportation System Evaluation and presented at the 48th Annual Meeting.

The Interim Master Plan represents the Commonwealth's first attempt to meet this challenge. As a first attempt it suffers from several deficiencies. It is obvious that a realization of the goals of the future must be founded on a clear understanding of the present. But our ability to analyze, measure, and project socioeconomic data, demands for transportation services, and the performance of present and postulated transportation systems and their interactions—so essential to a constructive solution of a wide range of questions and decisions related to transportation—is presently inadequate. Development of a truly comprehensive and definitive plan must await the collection of vital data and the implementation of more sophisticated methodology for long-range transportation planning (2, 3). However, the forces of change cannot be halted while data are gathered and techniques are refined. Planning must proceed with limited data and simple methodologies in the interim. The approach employed in development of the Interim Master Plan provides a methodology that can be used now by the Commonwealth for evaluating and selecting projects on the basis of multiple criteria in terms of their anticipated costs and benefits. The main feature of this methodology is a computerized resource allocation model developed by The Franklin Institute Research Laboratories specifically for evaluating subjectively determined multiple project benefits on the basis of a set of weighted goals subject to overall cost constraints. The model provides for the selection of those projects that would serve best the transportation planning goals of the Commonwealth and that could be purchased within a specified budget level. Although this technique has limitations associated with the subjective ranking of benefits and estimating of costs under conditions of less than adequate knowledge, it does provide a systematic framework for evaluating and selecting projects as compared with using intuitive judgments for allocating resources. In the following sections, the methodology used for development of the Interim Master Plan will be discussed in more detail.

RATIONALE OF THE INTERIM MASTER PLAN

The rationale used for the development of the Interim Master Plan is shown in Figure 1. A similar framework for transportation planning has been previously described by Davidoff and Reiner (4). As shown in the figure, the planning process starts with consideration of the overall goals for transportation development in the Commonwealth. Even though no formal list of goals for Pennsylvania currently exists, we have, nevertheless, started our development of this plan with a specification of some of the goals expressed or implied by executives of the state government.

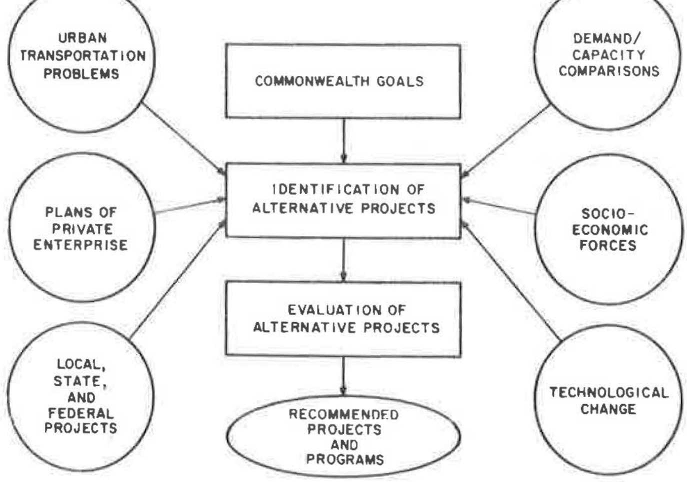

Figure 1. Rationale of Interim Master Plan.

As shown in Figure 1, the second step in the development of the plan involved those projects and programs that would serve to meet the transportation planning goals. Originally, it was intended that a comparison of the projected demands for intercity transport with the capacity of existing systems would suffice to define the elements for the Master Plan (5, 6). However, it became clear that matching of forecast demand with capacity of the existing infrastructure was not sufficient for development of a comprehensive plan. Consideration must also be given to the serious urban transportation problems facing the Commonwealth. Further, it was recognized that socioeconomic forces also dictate transportation needs that must be incorporated in the projects for the Master Plan. Additionally, the plans of local, state, and federal government agencies and private enterprise that require state approval or support must also be considered in the formulation of the master plan. Because new technology will make possible new solutions to transport problems and also raise new problems for the Commonwealth to solve, the recommended Master Plan must also consider the impact of new technology on the Commonwealth. Finally, the plan must allow for the complex interactions between the various transportation modes and between transportation and economic and social development.

The third step in the planning process shown in Figure 1 is the evaluation of the alternative projects and programs to select those that will best serve the Commonwealth's transportation planning goals, given a limited budget for initiating new projects. This evaluation required an estimation for each proposed project of the anticipated benefits in terms of goal achievement and the out-of-pocket investment costs to the state. These estimated benefits and costs were then used to rank and select projects, using a computerized resource allocation model, under different assumptions about the budget for new projects available. Since the relative "value" attached to various goals is a principal factor in determining which projects are selected, several alternative policies were given major priority: (1) Improvements in Transportation Service; (2) Economic Development of the Commonwealth; and (3) Social Development—"Making Pennsylvania a Better Place to Live." The results of these benefit-cost evaluations were used in selecting those projects included in the Interim Master Plan. Those projects that were selected under all assumptions about goal values and all budget levels were clearly preferred and hence are included as "highest priority projects" in the recommended plan. Those projects that were selected under some goal-value and budget combinations, but not under others, were defined as "second-highest priority"; their execution depends on the relative goal values which the Commonwealth wishes to emphasize and the funds that it wishes to make available. Those projects that were rarely or never selected under any assumption about goal values or budget levels are listed under "lowest priority projects."

In the following sections each of the steps in developing the Interim Master Plan will be discussed in more detail.

STATEWIDE GOALS FOR TRANSPORTATION PLANNING

The first step in developing the Interim Master Plan requires defining the objectives and goals that transportation development should serve. Because a formal list of goals and priorities to guide Pennsylvania's future development does not currently exist, it has been necessary to develop one for the study. Unfortunately, very little guidance is available from other transportation planning efforts. In most transportation planning efforts to date, goals have not been defined at all or have been defined in the limited terms of minimizing total transportation dollar costs.

Fundamentally, Pennsylvania's transportation system, like other public improvements, exists for the purpose of serving the citizens and industries of the Commonwealth. To get at the relative worth of a particular transportation project, it is therefore necessary to ask Mr. Citizen how he would evaluate the project himself. Doubtless he would ask at least some of these questions: Will it serve me? My family? For which trips? How much time will it save me and my family? Will it allow me a greater range of places to live while still holding the same job? Allow me to take another job without moving my home? How convenient will it be? How safe? How comfortable? How much will it cost me to use it or not to use it? How will it affect my property visually, physically, and socially, both now and in the future? From similar standpoints, what about the effect on my neighborhood, my city, my state (7)?

Of course, each individual and family in the Commonwealth will weigh these points in different ways, in accordance with the hierarchy of their own personal value systems. Although a complete list of these personal values would be long and doubtless diverse, there are some goals that are probably shared in common among most of Pennsylvania's citizens: personal security, freedom to choose values and pursue goals, social opportunity, physical and mental development, accumulation of knowledge, physical comfort, serenity, happiness, physical pleasure, meaningful human relationships, acquisition of material goods, and sense of personal worth (7).

If Pennsylvania is to provide an environment that encourages the maximum fulfillment of such personal goals, consistent with necessary constraints on socially undesirable acts, then the collective goals of public agencies in the Commonwealth must reflect these personal values. Clearly then, monetary or economic concerns are but one area whose values must be reflected in planning goals.

Given the complexities of dealing with all modes of transportation and the wide range of social impacts that transportation changes can bring about, it is clear that the goals used to evaluate projects for this plan must be based on the broadest possible aims for the Commonwealth and rooted in the basic values of its citizens.

We have therefore abstracted a list of goals for transportation planning, most of which were stated or implied by executives of the state government. Because goals are the ends to which planned courses of action are directed, it has been necessary to define them in operational terms so that either the existence or nonexistence of a desired state or degree of achievement can be established. Based on these considerations, we have defined the following general goals that seem most appropriate for transportation planning in the Commonwealth:

1. Transportation service—Provide capacity to meet transportation requirements when private capital or equipment cannot; increase freight and passenger transport speed; improve comfort and convenience of transport for passengers, and convenience of freight movement to shippers.
2. Fiscal—Reduce cost and increase efficiency of transport.
3. Safety—Identify safety hazards related to transportation and take steps to reduce or eliminate them.
4. Economic—Provide more employment in Pennsylvania; upgrade skills and education of Pennsylvanians and increase their annual incomes; stabilize state's economy by diversifying industrial base, and encourage development of service industries; renew competitive free-enterprise spirit that sparked Pennsylvania's economic growth in 19th century.
5. Land use—Add transportation facilities to provide access to open space and increase use of recreational facilities; increase industrial land use in chronically depressed areas of the Commonwealth.
6. Social—Make the state a more pleasant and stimulating place to live in; reduce pollution and dispose of wastes in a socially and ecologically acceptable manner as well as control noise and beautify the state.
7. Balance competing interests—Help each transportation mode to find its comparative advantages in Pennsylvania and develop them fully for the benefit of all Pennsylvanians; help balance economic development among the state's 13 geographical planning regions.

These goals for economic and social development of the state can be further refined into more specific objectives (8):

1. Attract to our cities small industry fleeing from the high-cost areas of neighboring states.
2. Help Pennsylvania manufacturers in competing with manufacturers in other states and other countries.
3. Fully utilize opportunities afforded by federally funded programs for advances in technology, education, transportation, urban renewal, and economic revitalization; pro-

vide the locational characteristics desired by industry that responds to the needs and programs of the federal government.

4. Capitalize fully on Pennsylvania's proximity to the world's richest markets; facilitate the marketing of Pennsylvania's products and services in "megalopolis."

5. Encourage the pioneering of new technological developments and growth in the life sciences, urban engineering, coal and nuclear energy, and the forest products industries.

6. Promote and encourage materials research and production in Pennsylvania.

7. Make Pennsylvania the "Transportation Research and Development State" to insure full participation in growth industries.

8. Keep more young people in the state, particularly those who are dynamic and have potential for making great contributions to industry, services, or the arts.

9. Attract to Pennsylvania more of the nation's influential decision-makers from the business, education, and science.

One could argue with the goals and objectives just mentioned, or perhaps add to the list the goals and objectives that seem equally worthy of pursuit. However, the goals and objectives, as presented, do give direction for the purposes of planning. They provide the first step toward development of the Interim Master Plan for Transportation. The next step is concerned with the identification of alternative projects that will serve the foregoing enumerated goals.

IDENTIFICATION OF ALTERNATIVE PROJECTS AND PROGRAMS

The second step in the planning process was to generate ideas for alternative transportation improvement programs and projects that could be directed toward meeting the goals and objectives. In most instances this meant finding suitable ideas for adding to the existing transportation and socioeconomic infrastructure in Pennsylvania and for connecting with developments in contiguous states. Also it is often possible for the Commonwealth to add support to ongoing plans of existing organizations or favorably alter their plans by initiation of appropriate projects. Even the administrative and regulative aspects of transportation-related improvements can provide the genesis for possible programs and projects.

It was necessary to conduct a systematic search through several sources for candidate activities to include in a master plan. The sources that most often give rise to ideas for transportation-related projects and programs worthy of consideration are shown as follows: advances in technology; programs of federal government agencies; programs and activities of state and local agencies; transportation-related plans and activities of private enterprise; extrinsic and intrinsic social, economic, and geographic forces; and existing rules and regulations that apply to transportation-related construction, financing, and operations. A preliminary effort was made to generate ideas by exploring these sources. In all a total of 93 projects and programs were identified. However, these 93 projects and programs represent only a selection of principal projects and programs from a universe of possibilities, and some elements of federal, state, and local plans were purposely omitted. Other transportation developments, such as improved locks on navigable rivers, the SST, new facilities for unloading oil from supertankers, etc., are largely the responsibility of the federal government or private industry. These projects have been purposely excluded since they require little if any state funding or guidance.

TABLE 1

SAMPLE PROJECTS FOR EVALUATION

PROJECT			ESTIMATED COST RANGE	PERCENT STATE-FUNDED
NO.	TITLE	DESCRIPTION		
U. URBAN COMMUTING AND METROPOLITAN TRANSPORTATION				
U-4	DEMONSTRATE ELECTRIC CARS	DEMONSTRATE USE OF ELECTRIC CARS IN PHILA. FOR 1976 BICENTENNIAL	$1,000,000 TO $5,000,000	17%
U-5	RAILBUS DEMONSTRATION	FINANCE RAILBUS DEMONSTRATION PROJECTS AT PHILA., HARRISBURG, AND PITTSBURGH	$700,000 TO $1,000,000	17%
U-6	STUDY AERIAL TRAMWAY AT PITTSBURGH	STUDY COSTS, BENEFITS, AND SOCIAL IMPACTS OF AN AERIAL TRAMWAY FROM GOLDEN TRIANGLE TO DUQUESNE HEIGHTS	$5,000,000 TO $20,000,000	17%

The 93 projects and programs were grouped according to their nine principal characteristics, e.g., (R) Intercity Railway Improvements, (H) Intercity Highway Construction, (U) Urban Commuting and Metropolitan Transportation, etc. In some cases, such as that of "Keystone Corridor" construction, the complexity of alternatives associated with the program dictated subdivision into several numbered project components. For some projects and programs the study and implementation also were considered separately. The numbers attached to the projects are for purposes of identification and in no way reflect any assigned priorities of importance. A sample of the identified projects and programs is shown in Table 1. It will be noted that many of the projects are in the nature of "feasibility studies." Such studies are not to be confused with "engineering studies" made after the decision to implement has been made; e.g., a decision to build an Interstate Highway through a corridor across the state implies a subsequent engineering study to determine the best specific route within the corridor.

Costs were assigned to projects and programs by placing them in one of 16 cost range categories to reflect the uncertainties involved in cost estimation. In many cases these costs were very far from precise because of lack of available cost information.

Finally, Table 1 shows in the right-hand column estimated percentages of the total project investment costs that the state government would incur in carrying out the projects and programs listed. The costs to the state were used in the next step of the planning process to evaluate the relative merits of the alternative projects and programs in order to select the ones for inclusion in the recommended Interim Master Plan.

EVALUATION OF ALTERNATIVES

The third step in the development of the Interim Master Plan was the selection of those projects that would best serve the transportation planning goals of the Commonwealth. Almost any project to modify Pennsylvania's transportation system outlined in the preceding section will seem desirable to some citizens and undesirable to others. For example, construction of an urban freeway will immediately satisfy the goals of reduced travel time and increased travel opportunities, but may also be contrary to the social goals of reduced noise, enhanced visual aesthetics, and reduced air pollution. Furthermore, many proposed projects will involve localized benefits with the costs spread statewide. How then can decisions be made about what transportation improvements to make for whose benefit? It is clear that there is no "right" answer to this question and that there never will be. A resolution of this problem requires a definitive statement of the relative importance of all possible planning goals, and the difficulty, previously illustrated, is that pursuing one objective will typically deny another. Thus, the only theoretically valid procedure for ranking projects would be by a vote of all citizens of the Commonwealth, and even that ranking would doubtless be of ephemeral interest, since what people value highly today may be of little concern tomorrow.

In the absence of any empirical data about the relative values Pennsylvanians attach to transportation planning goals, one approach for initiating project evaluation is to set forth a number of "reasonable" divergent goal sets and examine the sensitivity of project selection to the alternative weightings. This is the approach that has been followed in the development of this plan.

The recommended Interim Master Plan was based on selecting from all the alternative projects and programs those that were most beneficial in terms of multiple goal satisfaction and that could also be purchased within a specified budget level. The following steps were involved in this evaluation process:

1. Defining benefit categories;
2. Rating each proposed project in terms of anticipated relative benefits in each benefit category;
3. Normalizing benefits assigned in step 2;
4. Estimating anticipated project costs to state;
5. Ranking transportation goals and benefit categories;
6. Determining probable project budgets; and
7. Calculating benefit/cost to select projects.

Definition of Transportation Benefits

In order to evaluate the extent to which the goals will be achieved by the alternative projects proposed, it was necessary to define benefit categories that could be used to measure goal achievement. The benefit categories used in the development of this plan are defined in the following.

The benefit of increased capacity pertained to improvements in the throughput capability of a given transportation facility that did not necessarily make increased travel speeds possible. It could be measured as the expected volume of additional freight or passenger traffic to be moved per unit time.

The benefit of increased travel speed given was considered to result from improvements that decreased travel time. It could be measured by the expected amount or percentage of total trip time to be saved on a given journey.

The benefit of improved safety was included to reflect the decreased hazards achieved by transportation improvements. It could be measured by the expected reduction in accident rates and the decreased rates of death, injury, and property damage attributable to such accidents.

The benefit of improved comfort and convenience pertained to the comparative comfort and convenience of the alternatives. In the case of public transport projects it can be measured in terms of the anticipated headway between conveyances.

The benefit of cost savings and efficiency pertained to the dollars per year of savings anticipated from a given project and/or to the expected increased amount of utilization of currently idle capacity.

The enhanced economic development benefit pertained to the amount of anticipated increase in the employment base of the state for each given industry group. It was intended to encompass all the economic development goals.

The increased tourism and enhanced recreational opportunities benefit pertained to increasing tourism and recreation by improving access to Commonwealth facilities. It could be measured by the estimated increase in visitor-days per year, for example.

The improved land use benefit was included to reflect the altered land uses expected to result from modifications in the transportation network. It could be measured by the number of acres shifted from one category of use, such as residential land use, to another category, such as industrial and commercial land-use.

The benefit of enhanced social values was intended to encompass all the social goals and was considered to involve both subjectively judged factors, such as the amount of aesthetic enhancement achieved by a particular project, and objectively measurable factors such as changes in air pollution and noise levels.

Obviously, some of the benefits could be expressed in quantitative terms (if data were available) such as the amount of increased capacity, the amount of decreased travel time, the amount of cost savings and/or the amount of available excess capacity utilized, the amount of additional employment generated per industry group, the type and amount of anticipated land-use change, and the number of additional tourist days anticipated. However, other benefits that embody definitely nonquantifiable values, such as comfort and convenience, are clearly only subjective judgments.

Project Benefit Ranking

The relative ranking of the nine benefits anticipated from each project was accomplished by a committee of technical experts. The mechanics of the procedure involved assigning a number to each benefit for each project; an arbitrary numerical scale from -5 to +5 was used in which +5 was defined to represent 100 percent or greater improvement, +4 represented a 50 to 99 percent improvement, +3 represented a 25 to 49 percent improvement, +2 represented a 10 to 24 percent improvement, +1 represented a 5 to 9 percent improvement, and 0 represented insignificant improvement (less than 4 percent), with the negatives representing similar amounts of dysbenefit. However, the choice of the scale used was immaterial so long as the degree of achievement of each benefit for each project relative to all the other benefits of that project could be conveniently represented.

TABLE 2
ALTERNATIVE GOAL RANKINGS USED IN PROJECT EVALUATION

BENEFIT	BENEFIT RANKING		
	TRANSPORTATION-SERVICE IMPROVEMENT	ECONOMIC DEVELOPMENT	SOCIAL DEVELOPMENT
INCREASED CAPACITY	100	10	20
INCREASED TRAVEL SPEED	100	20	10
IMPROVED SAFETY	20	10	20
IMPROVED COMFORT AND CONVENIENCE	100	20	50
COST SAVINGS AND EFFICIENCY	20	50	10

Normalization of Benefit Ratings

The benefit ratings assigned in the preceding step were normalized in terms of the percentage of the state population anticipated to receive them. This was necessary so that two projects with equal benefit ratings were not weighed equally when one was of statewide impact and the other of local interest only. Clearly, other normalizations reflecting the number of different interest groups affected by a given project and scaled to reflect their relative importance are also of interest, but such refinement attach more precision to the benefit estimates than is meaningful.

Estimation of the Anticipated Project Costs

If infinite amounts of money were available to the Commonwealth to spend on transportation projects, then all the transportation planning goals could be satisfied and discrimination among projects would be unnecessary. However, as the Commonwealth has to operate within a limited budget, project costs had to be included as an element in the evaluation. The costs employed were the out-of-pocket investment costs to the Commonwealth, because it is these costs that are charged against the state budget for new programs (admittedly this approach is less than justified from a "national" standpoint). The cost estimates and probable share of the costs to be funded by the Commonwealth for each project were given in Table 1. Use of these estimates in the evaluation involved taking the midpoint where a cost range was shown or the probable cost where it was known, and then multiplying the appropriate cost by the percentage to be funded by the state.

Ranking of Transportation Goals

As mentioned previously, the most crucial aspects of the evaluation of alternative projects involved ranking, relatively, the goals of transportation planning. To circumvent the difficulties involved in basing a master plan on such completely subjective and arbitrary choices, the approach followed was to develop a number of different sets of goal weightings (termed overall development goals) and examine the sensitivity of the project selection to the alternative weightings. Three overall alternative transportation development goals were, therefore, emphasized in the evaluation as follows: improve transportation service; develop state economy; and make Pennsylvania a better place in which to live (social development).

A partial listing of the individual benefit rankings used for each overall goal is given in Table 2. Although a ranking scale of 0 to 100 was used, the choice of scale is immaterial so long as the value attached to each goal relative to all other goals can be conveniently represented. Alternative goal weightings could, of course, be employed. Indeed, the development of a means for establishing a consensus of goals is a political task of the first magnitude for the state government. Several methods and techniques have been proposed for ranking or weighting goals (4, 9, 10, 11, 12, 13, 14).

Determination of Probable Budgets for New Projects

Because the determination of the budget that the Commonwealth should spend for new projects will be very much related to the projects for which expenditures are proposed, it was necessary to examine the sensitivity of project selection to the assumed budget. Two somewhat arbitrary budgets were assumed. The first budget for new projects was simply the existing state-funded new project budget for the Pennsylvania Department of

Highways, estimated to be approximately $300 million per year or $2.0 billion in the period through 1975 covered by this plan. The other budget was defined as the amount required for all of the separately numbered projects that were mutually exclusive; this budget amounted to $4.9 billion.

Benefit-Cost Calculations

The usual procedure in the benefit-cost approach to project evaluation is to place the benefits and costs on some commensurate scale. The most popular approach to this scaling problem has been to use the dollar as the scaling unit. For example, in transportation planning, values are often assigned to travel times and accident rates so that these benefits can be combined algebraically with costs. Then projects are ranked on the basis of some measure of total minimum transportation cost. Although this approach is very convenient, it is clearly inadequate for assessing the many important qualitative benefits of transportation programs. Thus, it was necessary to adopt some other evaluation technique. We have employed for this purpose a computerized resource allocation model developed by The Franklin Institute Research Laboratories specifically for evaluating subjectively determined program benefits in the light of a set of weighted goals subject to overall cost constraints. This model was originally developed to assess cultural exchange programs for the U. S. Department of State (15) and has been adapted for use in developing the Interim Master Plan. Similar concepts for plan evaluation have been proposed by Alexander (16) and Manheim (17). Basically, this model selects the combination of projects that will maximize the procurement of benefits, given specified project costs and a budget level that is to be spent but not exceeded.

The model can be exercised in either of two modes. One mode assumes that the procurement of additional amounts of a given benefit is of decreasing marginal utility [see Jessiman et al (11)]; the other mode assumes that procurement of additional amounts of a given benefit is equally as valuable as the original procurement of that benefit. Both modes were used in this evaluation as another test of the sensitivity of project selection.

The inputs to the model are the elements of information derived in the previously described steps of the evaluation. Forms similar to that shown in Table 3 were completed for each project. This information was next transferred to punch cards along with descriptions of the relative goal rankings and the budget levels to be tested. The resource allocation model was then exercised using a computer to select projects for inclusion in the Interim Master Plan.

The resource allocation model utilizes a technique related to linear programming, but very much simplified to reflect the approximations used as inputs. Basically, a project-by-benefits matrix is formed from Table 3; this is multiplied into a vector of benefit rankings (from Table 2), and divided by a project costs vector (from Table 1). The result is a vector containing a cost-effectiveness number for each activity. The model then "buys" the project with the highest cost-effectiveness number.

TABLE 3

COST/BENEFIT DATA FOR PROJECT EVALUATION (ILLUSTRATIVE)

PROJECT	EVALUATION ELEMENT							
	COST TO STATE ($ X 1000)	CAPACITY INCREASE (THROUGH-OUT)	SPEED INCREASE (TIME SAVING)	COST SAVING AND EFFIC-IENCY	ECONOMIC DEVELOP-MENT	IMPROVED SAFETY		NORMAL-IZING FACTOR
RENOVATE HARRIS-BURG RAIL TERM.	360	0	0	0	1	0		0.03
ESTABLISH FOREIGN TRADE ZONES IN PA.	75	0	0	5	5	0		0.60

At this point, if the model is being exercised in the "marginal utility" mode, the benefit ranking numbers are reduced to reflect partial satisfaction of the benefits; the amount of this reduction is in proportion to the relative amount of each goal provided by the "purchased" project.

The model then recomputes the cost-effectiveness numbers of the remaining projects, and "purchases" a second project. This iterative process continues until the budget is exhausted.

TABLE 4

PRELIMINARY RESULTS OF PROJECT EVALUATION

PROJECT		BUDGET = $ 2 MILLION			BUDGET= $
NO	TITLE	IMPROVE TRANSPORTATION SERVICE	ECONOMIC DEVELOPMENT	SOCIAL DEVELOPMENT	IMPROVE TRANSPORTATION SERVICE
U-4	DEMONSTRATE ELECTRIC CARS	√	√	√	√
U-5	RAILBUS DEMONSTRATION	√			√
U-6	STUDY AERIAL TRAMWAY AT PITTSBURGH		√	√	

RECOMMENDED INTERIM MASTER PLAN FOR TRANSPORTATION

The resource allocation technique described in the preceding section was used to evaluate the 93 projects and programs previously delineated. As indicated previously the technique was based on estimating the project investment cost to the state and the extent of benefits to be provided in each of nine categories. These estimates were manipulated using three goal-ranking assumptions to allocate benefits in combination with two assumptions about the budget for new projects. A portion of the results are shown in Table 4. Those projects and programs chosen under each of the combinations of assumptions are indicated by "√'s." Those projects and programs that received a √ under all combinations of assumptions were assigned the highest priority in the Interim Master Plan for Transportation. Those projects and programs that did not receive any √ were assigned the lowest priority; also projects with two √'s or less were assigned the lowest priority. The remaining projects and programs were assigned to the second highest priority, their execution depending on the relative goal values the Commonwealth wishes to emphasize and the funds that it wishes to make available.

The results of the benefit-cost evaluations were then used to prepare the recommended Interim Master Plan, a portion of which is shown in Table 5. The table shows the projects, project cost to state, and total project cost for each priority group. The order of projects within each priority group is arbitrary and has no significance.

Assuming that the Commonwealth will be able to continue spending at the current level of the Pennsylvania Department of Highways, approximately $2.0 billion in state funds will be available for new projects in the period to 1975. This will be sufficient for all projects in the highest priority and the second-highest priority categories. (It will be recalled that many of the projects are in the nature of feasibility studies.) Hence, the projects in these two categories comprise the recommended Interim Master Plan for Transportation in Pennsylvania to 1975. This Plan is estimated to cost approximately $1.9 billion to the state and $4.1 billion on an overall basis. This does not include the estimated costs for implementing those projects requiring prior feasibility studies. Assuming that each of the projects studied will be found worthy of implementation, it is estimated that an additional $5.0 billion in state funds and $7.2 billion in total (state plus federal and local) funds will be required to imple-

TABLE 5

RECOMMENDED PROJECT PRIORITIES FOR INTERIM MASTER PLAN

PROJECT		PROJECT COST	
NO.	TITLE	TO STATE	TOTAL
1. HIGHEST PRIORITY			
U-4	DEMONSTRATE ELECTRIC CARS	$510,000	$3,000,000
H-2	COMPLETE MAJOR HIGHWAY IMPROVEMENTS	$750,000,000	$1,500,000,000
T-1	CONSTRUCT TOCKS ISLAND ROAD	$22,300,000	$44,600,000
2. NEXT-TO-HIGHEST PRIORITY			
R-17	IMPROVE SELECTED RAIL STATIONS	$32,000	$190,000

ment these projects. Thus the total out-of-pocket investment cost for studying and implementing all projects included in the Interim Master Plan is estimated to be $11.3 billion of which the Commonwealth's share amounts to $6.9 billion.

LIMITATIONS OF METHODOLOGY

On this first effort at developing a master plan, it is, of course, unlikely that all of the goals and objectives that might be served by transportation development have been treated in sufficient depth. Nevertheless, a first attempt has been made at providing goals with projects appropriate to their achievement. Although the analysis and ranking of the projects will provide some guidance for initial actions by the Commonwealth, the important point is that this approach illustrates a methodology for evaluation that can be used until the more sophisticated methodology is available. Goals must be specified, in the interim, and the contributions of various projects to their achievement must be evaluated. Although this technique has merit for the initial efforts at shaping a Master Plan for Transportation, it clearly has the disadvantages associated with the arbitrary ranking of benefits and estimating of costs under conditions of less than adequate knowledge. Nevertheless, it is still a refinement on using intuitive judgments to allocate resources when benefits are difficult to quantify in terms of dollar values.

Because so large an element of subjective judgment is now, and always will be, involved in assessing transportation benefits, it is important that participation by legislators, governmental executives, officials of private enterprises, and public interest groups be solicited in the evaluation process. In this context there are two distinct problems: weighting benefits and ranking goals. Although many benefits are quantifiable and thus can be evaluated with precision by technical experts, the evaluation of qualitative social benefits is clearly a political problem. As such, it cannot be resolved solely by technicians or even by deference to the opinions of decision-makers. The determination of transportation goals, involving as it does the basic values of our society, and the ranking of these goals, are likewise a political problem, solvable only through the political process. No one group is competent to decide which goals should dominate Pennsylvania's development or to assess the benefits of implementing alternative programs. These matters must be resolved through the political process of free, democratic debate.

It must be recognized that the development of the Interim Master Plan is based only on the evaluations of a few selected experts using arbitrary sets of goal weightings; it must also be evaluated in the forum of public opinion by the citizens of the Commonwealth. The real utility of any transportation system to the Commonwealth lies not in the demonstrable benefits calculated by a systems analytic framework, but in the perceived benefits measured by individual citizens whose economic, social, and cultural activities will be served through improved transportation.

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Discussion

ROBERT H. MURRAY, Texas Instruments Incorporated—The authors maintained a commendable consistency in the level of detail employed throughout this evaluation. For example, they avoided the pitfall of plunging into the depths of cost analysis while leaving the overall goals undefined, or vice-versa. Instead, they cut through the problem using the "committee of experts" approach. This enabled them to immediately estimate (a) the relevance of benefits to very general goals, and (b) the effectiveness and relative impact of each project-benefit combination. This level of detail seems quite appropriate for the type of first-cut evaluation and the time frame (1975) specified.

In view of this, it is not surprising that the authors have also produced a very lucid description of their work and the supporting rationale. Since cost-effectiveness evaluations are ineffective until communicated, this is no idle compliment.

It is surprising, however, that a computerized model is cited as the most important feature of the methodology. The innovative mechanisms, the key assumptions and their impact, and the application of such an approach to transportation planning are more interesting, and far more important, than the utilization of one tool or another.

In evolving a formal cost-effectiveness approach to social systems engineering, in which transportation planning occupies an important role, several additional suggestions might be useful, using the work described in this paper as a point of departure.

First, goals should be carefully defined and should address the basic desire for an improved quality of life. These goals should be projected ahead in time to be valid in the time frame of goal achievement. Value forecasting is integral to this task, and work is only recently under way in this area. Value forecasting is also central to normative technological forecasting, another argument in favor of increased emphasis on this discipline.

Second, quantitative evaluation parameters should be defined and mapped into the previously defined goals. Intermediate levels, such as objective and mission definition, can be employed if the problem requires such detail and/or visibility.

The traditional reluctance to quantify subjective factors is inappropriate in view of the fact that all decisions are made quantitatively. An example can be seen in any city's annual budget: the park department, the traffic control department, and the police department are each allocated a different amount of money. This demonstrates a collective decision that somehow quantitatively balances the desires for recreation, transportation convenience and safety, and protection. It would be better to admit this and face the problem directly so that explicit assumptions, definitions, and relative weights can be developed, discussed, revised, and voted on.

Also, expert assistance in quantifying subjective parameters might be obtained more readily if these people realized the normal inaccuracies in our forecasts of objective parameters such as dollar costs.

Third, when identifying and formulating alternative choices, all projects that produce a significant benefit should be considered, especially when the cost is largely borne by another agency. This not only permits consideration of extremely cost-effective projects, but also encourages coordination with other governmental and industrial elements having mutual interests. This was precluded in the authors' evaluation, since projects that were largely the responsibility of industry or the federal government were not considered.

Fourth, when a committee of experts approach is used to evaluate candidate projects, attempts should be made at achieving a consensus. One possibility would be to qualify two or three panels and correlate their findings.

The DELPHI technique, combining quantitative expert opinion, iteration, and consensus-without-confrontation, would seem to be an appropriate vehicle for this type of evaluation, but requires significant commitments from many key people over a period of time to be effective.

One final comment is that the authors' commitment to maximize the received benefit-cost ratio is commendable. This underscores the need for innovative mechanisms that can utilize some evaluation technique to present alternatives to the public, and for collecting and compiling their choices. The people will be heard, and this approach may be a means for an interested public to get directly involved in running their own affairs.

The Use of Land Development Simulation Models in Transportation Planning

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The Bay Area Simulation Study or BASS Model is a large complex of computer models that has as its goal forecasting future growth within the San Francisco Bay Area. The BASS model is composed of three distinct submodels. The first of these is the employment and population projection submodel that forecasts employment by 21 categories and population totals for the Bay Area over the period from 1970 to the year 2020. The results or the output of this submodel are fed into the two other submodels that allocate projected employment, population, housing, and land development in 777 subareas of the region.

The time required to travel from one place of employment to alternate places of residence is a key determinant of estimated future land use and development in the BASS model. These estimates are made through the use of a time-distance matrix assumedly portraying the time required to travel from the center of any one of the 777 tracts to each of the other tracts in the 13-county Bay Area.

The influence of public policy variables is reflected primarily in the assumptions concerning the usable supply of land and the transportation facilities that will be made available. It has been assumed that current freeway plans approved by the State Division of Highways will be completed on schedule and that the first stage of BART will be completed by 1970 and the second stage by 1980.

•URBAN transportation planning is concerned with one phase of the urban environment, namely the moving of goods and people within and among urban areas. Given the systemic nature of cities, it is impossible to completely divorce the transportation aspects of urban living from the economic, social, and political forces that affect and in turn are affected by the transportation subsystem of the metropolitan region. In their review of the transportation planning process, Memmott, Martin, and Bone make the following observation (1):

> In the planning process, consideration is given to all forms of transportation and to the expected future economic and social development of the area. Because urban transportation studies themselves encompass many varied aspects of the urban environment, they require cooperation, consideration, and support of all organizations and individuals engaged in shaping the future of the urban area. . . .Although many phases of a comprehensive urban transportation study are not the direct responsibility of the transportation planner, still he must be continually aware of the effects his plans will have on other aspects of the urban environment.

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Thus, the goal of transportation planning is much broader than simply planning freeway and/or rapid transit networks. Rather, it is concerned with the greater problem of planning for the general economic and social well-being of the urban area. As such, it constitutes an integral and vital thread in the whole fabric of planning for and within the urban system.

These more inclusive goals of transportation planning have also been stressed by F. Stuart Chapin, Jr., in his Urban Land Use Planning (2). Chapin notes that the land use planning process is not separable from that of transportation planning. "The (transportation) plan which emerges from this process (of integrating land use and transportation planning) represents a choice made from a range of alternatives, each tested for its sufficiency against the goals established at the outset. This plan, together with the land use plan, are the principal components of the general plans" (2, p. 345).

Present techniques of transportation planning consist, in their simplest form, of first analyzing the present transportation system. This is done by such devices as origin-destination studies, measuring traffic flows along major arteries, and measuring passenger volume on transit lines. Next, an estimate of the future growth of the region and its subareas must be derived. Finally, the forecast spatial distribution of economic activity is translated into trips within and among the region and its subareas, disaggregated by mode of travel. This provides a forecast of the demand for different kinds of transportation services. The goal of transportation planning process is to satisfy these demands in a way that is consistent with economic, political, and social plans for the region. The end result of this process is, therefore, a detailed plan of the road and transit systems of the future needed to accommodate projected needs (1).

There were usually one or more weaknesses apparent in previous transportation planning studies. First, many were based on the judgment of local experts who were well versed in the economic, social, and political aspects of the region's past and present. The forecasts deriving from these judgmental studies suffer from a lack of reproducibility by other research teams. Different researchers would probably come up with different conclusions. In any event, judgmental studies are severely handicapped in that they cannot easily take into account the multitude of possible combinations of land use and transportation plans. Thus, each transportation plan must be predicated on a limited number of possible land use plans and behavioral assumptions. In addition, it is extremely difficult in this sort of study to have much feedback between the transportation plan and the land use plan. Judgmental efforts are limited to test a small number of alternatives and are essentially partial equilibrium solutions to the transportation planning problem.

Some of the more recent computerized models (for example, the Bay Area Transportation Study in Berkeley, the Penn-Jersey Transportation Study in Philadelphia, and the Hartford Area Transportation Study in Hartford, Conn.) overcome the lack of reproducibility but are usually deficient in two other ways. First, many of the elaborate computer simulation models of the urban region have not been operational in any meaningful sense (the Penn-Jersey Study for example). In a strict sense these models run on the computer, but the output they produce is often lacking in realism or accuracy. The San Francisco Community Renewal Program (CRP Model) is a good illustration.

Second, those models that have run successfully lack flexibility to test a wide range of alternate assumptions about regional growth in employment and population, about behavioral assumptions such as the actual impediment to interaction posed by time-distance, and about the locational criteria for different types of employment and housing. Finally, the relationship between the transportation system and the economic forecasting model is usually a one-directional relationship. Thus, different transportation plans can be derived from different forecasts of the economic and demographic models, but in general it is more difficult to test the effect of different transportation configurations on the intraregional distribution of employment and population.

The preceding strikes at the need for a more comprehensive transportation planning framework where there is a more explicit interaction between the transportation and land use systems of the region. Support for this statement can be drawn from others who are vastly more experienced in the transportation planning field.

In this vein, Levinson and Wynn remark (3, p. 26),

> The vast impact of transportation facilities on community growth and development requires a total "systems" approach involving all modes of transportation and all interested organizations and governmental agencies. In the past, too many transportation plans, studies, and improvements were developed in relative isolation, concentrating almost entirely on one specific mode, and often overlooking the basic intereffects of "feedback" between transportation and land use.

Similarly, Chinitz observes that "the models are typically designed to forecast the economy and work out the implications for transportation investment, but the reverse relationship in which investments in transportation affect the shape of economic development is not readily taken into account" (4).

Finally, Wilfred Owen draws a similar conclusion and observes that "in a nation that is both motorized and urbanized, there will have to be a closer relation between transportation and urban development. We will have to use transportation resources to achieve better communities and community planning techniques to achieve better transportation. The combination could launch a revolutionary attack on urban congestion that is long overdue" (5).

The need for a more comprehensive approach to transportation problem solving is clear. We present in this paper some background information on a land use forecasting model of the San Francisco Bay Area that meets many of the foregoing criteria. The model called the Bay Area Simulation Study, or BASS (6), is a flexible system comprised of several location and forecasting submodels that yield forecasts for 777 subareas of the San Francisco Bay region disaggregated to 21 industry groups, 6 kinds of housing, and population by 3 income classes. (The 13 counties in the region under consideration are Alameda, Contra Costa, Marin, Napa, Sacramento, San Francisco, San Joaquin, San Mateo, Santa Clara, Santa Cruz, Solano, Sonoma, and Yolo.)

This paper describes the BASS model and its component submodels and emphasizes its flexibility and adaptability to comprehensive transportation planning. Stress is placed on delineating areas, to which the BASS model might be successfully applied, that have heretofore been weak points in the transportation planning process.

THE BASS MODEL

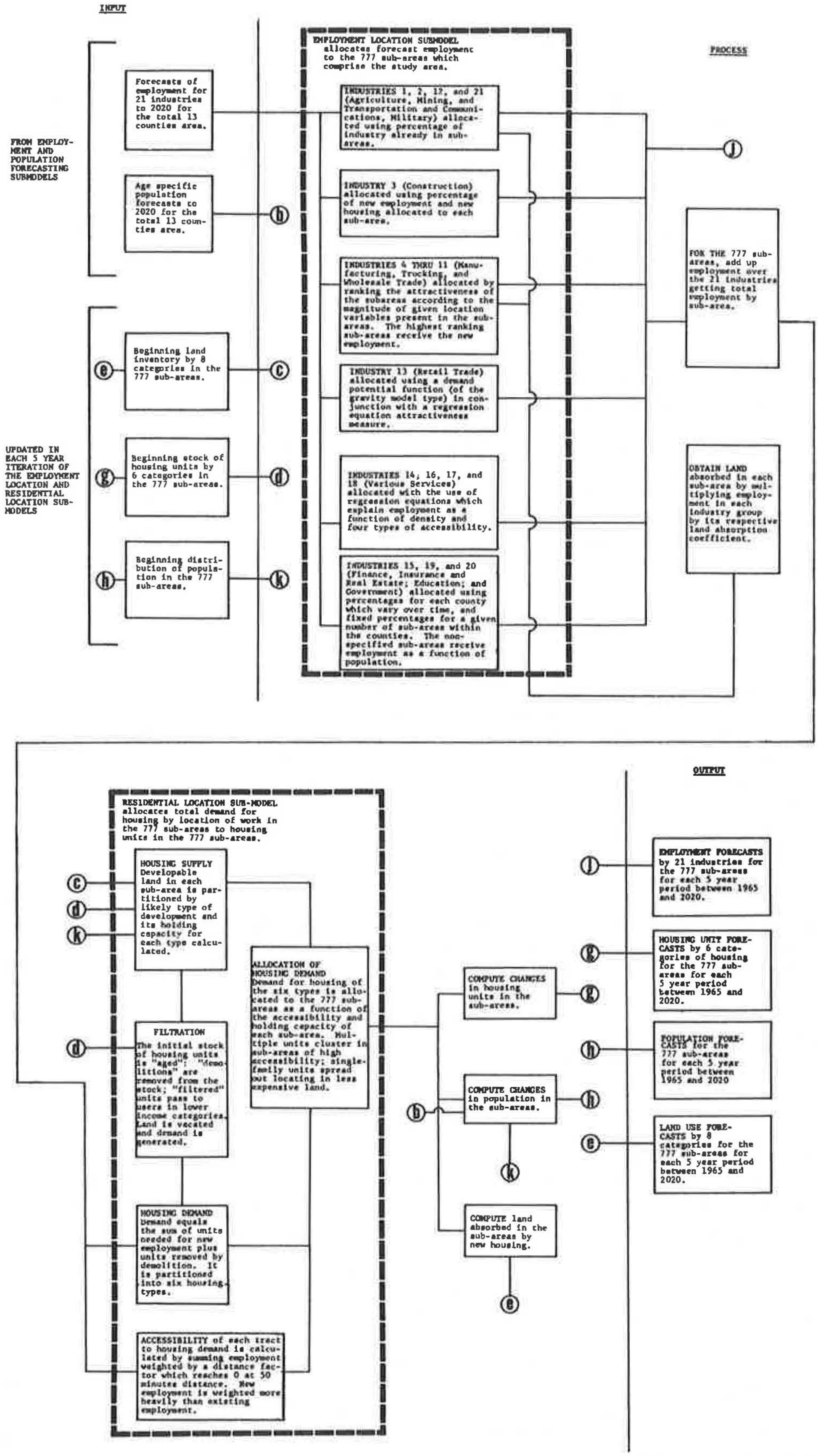
In its simplest terms the BASS model is seen to consist of three distinct submodels:

1. An aggregate forecasting model that projects 21 kinds of employment, and total Bay Area population.
2. A series of employment location submodels that distribute the forecast totals in each of the 21 employment groups to subareas (777 of them) within the Bay Area.
3. A residential location model that distributes population to the subareas. The population is separated according to three income classes, and two structure types for housing (single-family and multiple-family dwellings).

The accompanying two flow charts (Figs. 1 and 2) give a better idea of the flow of information through the model. No attempt is made here to describe the BASS model or its submodels in detail. Rather, a brief overview of each follows so that the general approach can be understood.

The Employment and Population Forecasting Model

Population and employment (by 21 industry types) were forecast using different models that took into account the interaction between migration and employment opportunities. The population model is related to, but strictly separate from, the employment forecasting models. The employment forecast is the result of three employment forecasting frameworks: (a) a structural model based on multiple regression results; (b) a shift model based on differences between national and regional growth rates; and (c) a reconciliation model that combines the structural and shift model forecasts to yield the final employment forecasts.



e 1. Bay Area Simulation Model (BASS): employment and residential location submodels.

The structural submodel builds on forecasts of 22 state and national economic and financial variables to forecast future employment in each of 21 industries annually for the period 1965 to 2020. The forecasts are for the larger 13-county San Francisco Bay Area, and are aggregated into 5-year periods to coincide with the 5-year iteration cycle of the model. (The iteration period need not be fixed at 5 years. Any suitable length of time is acceptable to the model.)

The shift submodel uses differences between the national and regional growth rates to forecast employment in the same 21 industries. This is a type of trend analysis, and is recommended because of its simplicity.

Finally, the population submodel forecasts future population by applying a range of assumptions concerning birth rates, death rates, and migration to the Bay Area, also on an annual basis. These assumptions appear in the population submodel as parameters, and as better information becomes available, these parameters can be adjusted to reflect these improvements in data.

These three models are all used to obtain the final employment forecast. Future employment, then, is forecast by applying age-specific labor force participation rates to the resulting population estimates. The final output of the employment and population submodels is a judgmental reconciliation of the separate forecasts of the structural, shift, and population submodels. The output of the models provides a medium forecast used as the basic input to the location submodels in Figure 2. Alternatively, an upper and lower range varying by one standard deviation is available for testing the sensitivity of the final output of the location submodels to changes in the long-range employment and population projections.

Employment Location Submodels

The employment location submodels (that appear in the first heavily dotted black box in Fig. 2) employ a variety of different techniques to distribute employment among the 777 subareas of the region. One group of industries, including agriculture, mining, transportation and communications, and military, is allocated in proportion to the magnitudes of existing employment in these groups in each of the subareas. Construction employment is allocated with respect to the amount of new housing and employment in each subarea.

One of the most important employment location submodels is that concerned with the location of manufacturing, trucking and warehousing, and wholesale trade. This can be thought of as the industrial location submodel of BASS. The industrial location submodel deals with eight groups of industries. For each group important locational factors were identified using regression analysis and data gathered from extensive interviews with and a survey of industrial realtors in the San Francisco Bay Area. Having identified these factors, weights were assigned to each factor by industry group. These same factors were then measured for each subarea, and in this way eight attractiveness indices were derived for each subarea (i.e., one index for each industry group). Employment was allocated on the basis of these attractiveness measures.

Retail employment, another important employment group, was allocated using a demand potential function of the gravity model type, suitably modified by the use of a regression equation-derived attractiveness index and by existing retail employment.

Service industries were disaggregated into four large groups. For each group a regression equation was used to explain the location of employment. These equations were adjusted to include existing service employment and new population. Because the regression equation fits were quite high, this procedure has worked quite satisfactorily.

Finally, the forecast employment in finance, insurance, real estate, education, and government is allocated by application of percentages, estimated to change over time, to subareas for each class of employment (for finance, insurance, real estate, and government), and by assuming employment will be a function of population for education.

New employment is allocated for each iterative period among the 777 subareas of the 13 Bay Area counties. These estimates are then converted to estimates of land use by the application of land absorption coefficients, and have been projected to change over time. In the employment location submodels, as in the forecasting models, a wide variety of assumptions has been embodied in the form of parameters with which the mo-

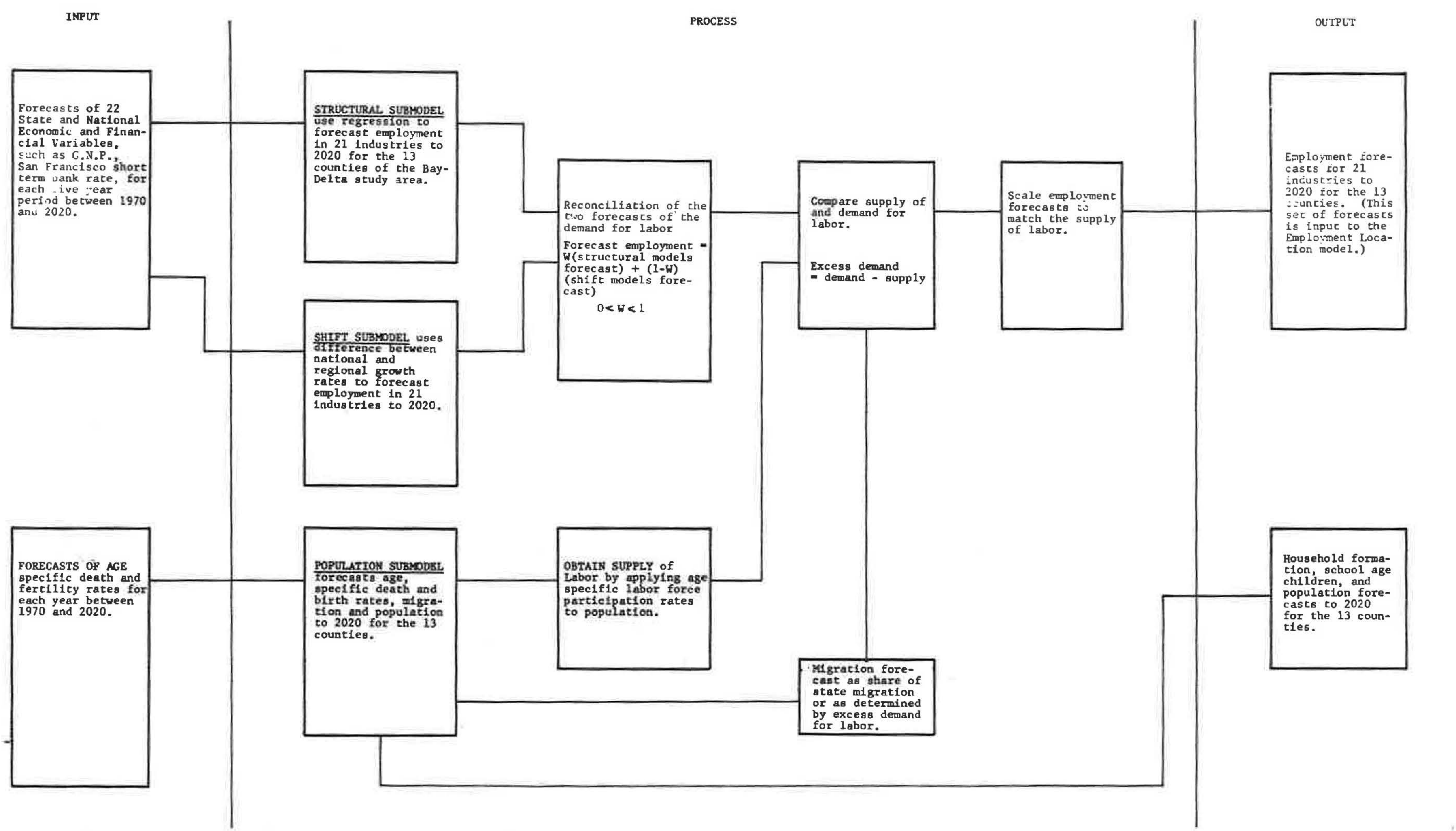


Figure 2. Bay Area Simulation Model (BASS): employment and population submodels.

carries out its calculations. Thus, the weights attached to individual factors in the allocation of manufacturing and service employment are exogenously derived and are supplied parameters that can be varied as better information becomes available. Similarly, the land absorption coefficient can be easily altered with each running of the model. The parameters that can be changed are numerous, and it is sufficient to note here that future findings concerning the location of various kinds of employment can be directly incorporated in the employment location submodels.

The Residential Submodel

The residential location submodel matches the supply of housing and usable land with the estimated housing demand arising from the forecasts of employment and population in the previously described submodels. The inputs to the residential location submodel are identified in Figure 2 by letter designations b, c, d, e, g, h, j, and k, showing the source of each class of input data and the resultant outputs. The model assumes six categories of housing units; i. e., three income classes (high, middle, and low), and two structure types (single-family and multiple-family).

The submodel begins each iteration period with a filtration stage. A set of equations based on the income level of the subarea, the percentage of multiple-family housing units, and the density of development (an analog of density using both employment and population in the numerator) in the area, are used to estimate the shifts in the housing inventory from high to middle income and from middle to low income and from in-stock to out-of-stock.

The supply of usable land for the size categories of housing is then calculated for the 777 subareas. Land available for residential development is considered to include vacant land zoned as residential and agricultural land. The percentage of single-family units to be assigned to a given subarea during an iteration period is determined in the submodel by averaging two ratios. The first ratio is the existing single-family ratio, and the second, weighted twice as heavily as the first, is a function of density of development. The density of development, used as a surrogate for land value, is defined as the sum of population and employment in the subarea, divided by the total usable acres in the subarea.

The total demand for new housing is estimated as the sum of housing removed from the stock by filtration, plus the demand of the new families estimated from the employment and population submodels. This demand is then divided into demand for single-family and for multiple-family units judgmentally with a gradual decrease over time in the percent of single-family.

The partitioning of the forecast housing demand into high-, middle-, and low-income groups for each subarea is made by averaging three estimates using equal weights: the existing division of housing by income classes, an estimate that increases the percentage of high-income housing as a function of density of development, and a third estimate that increases the percentage of high-income housing as the slope of the land increases. The land absorption coefficients used in each subarea are based on the existing density of development.

The allocation of the estimated demand for the size categories of housing to the individual subareas, is made on the basis of the relative accessibility of each area to existing employment, calculated anew for each iterative period. In the 1965 to 1970 iteration, the residential location submodel allocates 30 percent of new housing construction according to accessibility to the location of existing employment to replace stock removed and the remaining 70 percent with regard to its accessibility to new employment. The percentage of the allocation based on accessibility is then increased 3 percent for each 5-year iterative period.

The estimates of population and housing units in the individual subareas are converted into estimates of land use by the use of land absorption coefficients that vary over time with the density of the individual subarea.

Here again note should be made of the flexibility of the residential location submodel. Assumptions regarding the role of accessibility in the location of the six different kinds of housing can be altered in a direct manner. Similarly, the method of partitioning the housing demand into three income classes depends on the relative weights given the three estimates. These weights can also be easily varied. Finally, the split between single- and multiple-family dwelling units can be changed at will as different assumptions seem justified.

THE APPLICABILITY OF BASS TO COMPREHENSIVE TRANSPORTATION PLANNING

The BASS model is immediately applicable to the planning process as it is presently conceived. BASS has been run successfully under a variety of assumptions and the results have been reasonably credible and operationally useful. The model has yielded output that is consistent with the locational trends under way in the Bay Area for the past two decades or more, and the results have been generally similar to county and city projections done by state and local agencies (6, Chap. 6).

The reasonableness of the results is encouraging for those who might desire to use the model for specific applications. The employment and housing forecasts by subarea provide the transportation planner with an alternative basis for generating trips and predicting loadings on the transportation system in the future. This integrated approach to land use and transportation planning fills a long-recognized need.

BASS has additional advantages for the transportation planning process derived from its flexibility. Thus, where traditional transportation studies were concerned with predicting future trip patterns and planning for them, BASS can provide the planner with the ability to test the distribution consequences of a variety of economic forecasts and transportation plans. Such a feedback procedure would certainly go part of the way to eliminating the unidirectional planning process and the criticisms of Chinitz (4), and Memmott, Martin, and Bone (1) noted above. Most important, the cost and time involved in this feedback procedure would be less than that ordinarily expended in the course of the planning process.

The role of the transportation network in the BASS model and its interaction in the forecasts has been ignored so far in this exposition. Transportation plays a key, deterministic role in the model through the matrix of time-distances (6). This matrix (T-D matrix) gives the estimated travel time in minutes at various times among each and every one of the 777 tracts. Thus, there are 777^2 or 603,729 entries (assuming a nonsymmetric pattern of travel times between points). These time distances are the basis for the accessibility calculations used in the employment location and residential submodels for allocating several types of employment (most notably retail trade), population, and housing.

The time-distance matrix can and is modified to reflect the average time-distance between subareas when account is taken of all possible modes. In this way, the entire output from the transportation plan could be used to generate a series of time-distance matrices depending on the relative importance of each mode under each possible plan. The resulting time-distance matrix would embody technological aspects of the plan, such as travel times by each mode, as well as various behavioral assumptions regarding the relative use of each mode.

Thus, the simplest test of the impact of a given transportation plan would be carried out by simply substituting the appropriate time-distance matrix into the model and rerunning it. The cost involved in this kind of change is minimal, and represents a parametric change since the time-distances are really exogenously supplied parameters.

The BASS model has thus been designed to provide the user with the greatest possible flexibility. Some of this flexibility was derived from the parametric nature of the time-distance nature that acted as a focus for all behavioral and technological assumptions about the transportation network (both present and future) and its use. However, as noted previously, there is additional flexibility built into each of the major submodels.

For example, given better estimates of migration, the age distribution of population, labor force participation rates, and so on, new forecasts of employment and population can be generated with virtually no additional effort or cost because provision for employing this information has been built into the employment and population forecasting submodels. In addition, with better information on land absorption coefficients, the industry-specific intrametropolitan location factors, plans for large plants, and the intrametropolitan migration behavior of firms (location forecasts that reflect this information) is obtainable by simply varying about a dozen IBM cards that supply the model with these parameters.

Probably the most important interactions with transportation planning are with the residential location submodel. Here again great flexibility has been provided to reflect changing information on the location of residences. Better behavioral data on the role of accessibility in the demand for different types of housing have direct consequences for the model and can be included simply. Obviously, more accurate time-distance data would improve the accessibility measure and its usefulness in the residential submodel.

Many of the improvements in the BASS model inputs cited above are the outputs of conventional metropolitan transportation studies. Much of this new information can be integrated into the BASS model framework, and technique is not limited to the San Francisco Bay Area. Any area for which the necessary data are available can utilize the BASS model. The number of subareas used can vary from 1 to 900. The time span of each iteration is completely variable, as is the information in the time-distance matrix. This transferability of the technique to any region is perhaps the model's greatest strength and source of usefulness.

A further possibility worth exploring concerns the inclusion within the model of a trip distribution scheme. This would have the immediate advantage of integrating the land use and transportation forecasts because employment, population, housing, land use, and the related distribution of trips would be presented in one output package. The resultant trip distributions might be more reliable as they would be generated simultaneously with the locational decisions. Similarly, shopping and commuting trips would be generated at the time each household is put in place.

Inclusion of the trip distribution algorithm directly within the BASS model represents a major modification of the BASS model. However, previous experience with the model has shown that the relative independence of the submodels allows great flexibility in programming. Thus, in the past we have been able to include substantial subroutines, not unlike the trip distribution algorithms, with relatively little effort, because such additions can take place largely independently of the existing program. Therefore, the entire model need not be reprogrammed with each modification, even if such modifications are quite extensive and intricate.

SUMMARY AND CONCLUSIONS

This paper has focused on the need for a comprehensive approach to transportation planning that takes account of the interaction between economic, social, and political factors and the transportation system. It has emphasized the effect of transportation on other aspects of the urban environment. This constitutes a feedback or complete interaction between the transportation system and the other system of the metropolitan region.

It is the purpose of this paper to present the reader with the basics of the BASS model and how it can be applied to the transportation planning. To this end, the model, really a series of independent but connected submodels, is sketched out briefly, emphasizing the flexibility that has been incorporated into the model's structure. Having provided the reader with the rudiments of the BASS framework, several suggested uses of the BASS model were presented. The thrust of these suggestions is that the model has sufficient flexibility to supply the much needed feedback from the transportation plan to spatial arrangement of employment and residences in the region. Finally, it is suggested that with suitable modification, the model could be extended to generate trip distributions internally, thus bypassing the use of separate trip distribution algorithms.

After several years of working with the BASS model as an operational tool, the authors are satisfied that the suggestions presented in the preceding are feasible. The model has already been applied to forecasting situations involving open-space planning, and water-resource planning. (Water-resource application was done in conjunction with a larger study undertaken by California State Quality Control Board (7). The use of the

BASS model in open-space planning was completed in the summer of 1968, and the results of this application are forthcoming from the Citizens Committee for Open Space, a nonprofit Bay Area organization.) Its extension to the transportation planning field is a natural one that could only help to serve the best interests of both model builders and the entire community of planners. As we have noted many times in the past (6), the BASS model must be used to be useful. With use comes better data, particularly in the critical areas of time-distances and land uses, and experience of the model's performance. The data and the experience interact to make the model much better and more useful.

The application of computerized simulation models is only in the gestation phase. Only through repeated trials can this body of knowledge hope to mature and make a meaningful contribution to human knowledge and the betterment of the urban environment.

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Information Needs of Interstate Highway Motorists in Iowa

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Iowa's "Infosites" bridged an information gap that did not exist, according to this report on the information needs of travelers on Iowa's Interstate Highways. It is reported that motorists can get the information they need to travel across Iowa by Interstate without relying on Infosites, and advertisers can get their message to motorists without Infosites. The Infosites were built by the Iowa State Highway Commission and leased for operation to Stoner System, Inc., an outdoor advertising agency. The Infosites are octagonal buildings erected adjacent to rest areas to house permanent advertising displays for firms catering to Interstate motorists. Two Infosites were placed on opposite sides of Interstate 80 near Iowa City. They were built in the belief that an "information gap" would result from federal and state laws controlling billboards along the Interstates. In fact, this information gap did not appear to exist. In more than 3,000 interviews with travelers on I-80, over 90 percent stated that they had no difficulty in obtaining information.

Advertisers also showed little interest in Infosites. Only 20 percent of the available advertising space was sold. Direct and indirect operating costs of the Infosites were almost three times advertising revenues. Instead of the expense of an Infosite building, the report recommends that simple bulletin boards protected by a small roof be erected at each rest area. The bulletin boards could fill motorists' need for information about gas, food, lodging, and tourist attractions and would be much cheaper for businesses than Infosites, where advertising rates ranged from $95 to $720 per month. Infosite-type centers should be used at gateway points into Iowa, such as Davenport and Council Bluffs, but they should be operated by the Iowa Development Commission as a part of state tourist promotion activities, with only limited participation by advertisers.

•IN JULY 1967, the Bureau of Public Roads, the Iowa State Highway Commission, and Stoner System, Inc., an outdoor advertising company, in a cooperative effort inaugurated a new concept in highway information services. Two information centers were opened at rest areas along Interstate 80 near Iowa City in an experimental program designed to provide travel information of interest to the motoring public.

The Infosite (a registered trademark of Stoner System, Inc.), as the information center is called, is housed in an octagonal building about 30 feet in diameter and provides essentially an indoor form of outdoor advertising. Inside, five of the walls are divided into panels of varying sizes to accommodate the advertising messages of establishments offering lodging or other services to the Interstate Highway motorist. The remaining

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three walls are glass and, by offering an inviting view of the interior, serve to attract the visitor into the Infosite. Attractively designed, well-lighted, and air conditioned, the information center is in sharp contrast to the traditional billboard as an advertising medium. Infosites were erected adjacent to existing rest area buildings that house rest room facilities, a telephone, bulletin board, drinking fountain, and other conveniences.

To evaluate the concept, the Iowa State Highway Commission sought answers to the following questions:

1. What types of information are needed or desired by travelers using the Interstate Highway System in Iowa?
2. What alternative media, either existing or new, are available for use in providing the Interstate motorist with the information he desires?
3. How does the motorist presently obtain information, and how effective are media currently used in supplying the desired information?
4. Does the motoring public accept Infosite as a convenient and effective means of obtaining information?
5. Have business enterprises found Infosite effective in communicating with the traveling public?
6. What guidelines should be used with regard to the future development of the Infosite concept?

"Information" was defined for this study as that needed or desired by the visiting motorist, as opposed to the well-informed local motorist. (As a practical means of separating local drivers from visitors, the interview phase of this study was limited to drivers of cars bearing out-of-state license plates. It was assumed that the information needs of Iowa drivers from a distant corner of the state are the same as the needs of drivers from a neighboring state.)

FINDINGS

Motorists' Information Needs

To identify motorists' information needs, we had to ascertain some characteristics of these people. More than 3,000 drivers of cars bearing out-of-state license plates were interviewed at rest areas and off-ramps on I-80 in Iowa. The majority of the respondents were found to be traveling in family groups on extended summer vacation trips. These travelers came either from states contiguous to Iowa or from states with major urbanized areas, such as New York, Ohio, Pennsylvania, and California. They were passing through Iowa on their way to a destination outside of the state and were planning to spend little, if any, time in Iowa. Many respondents were using I-80 in Iowa for the first time; most of the others had made only one previous trip on I-80 in Iowa in an earlier year. Thus, most of the out-of-state motorists interviewed were persons unfamiliar with Iowa, who intended to rely completely on the information system provided on the highway to meet their need for information. Even though 10 percent of those interviewed were businessmen and others familiar with services available along the Interstate, an information system designed to meet the needs of family groups visiting the area for the first time will also successfully inform drivers who are more familiar with the area.

On the basis of our interviews with these out-of-state motorists, we found that their information needs fall into three principal categories: routine, specialized, and emergency.

Routine Needs—The routine needs of the Interstate Highway motorist are those that he can anticipate and that are of interest to a majority of motorists, making it practical for businessmen to locate facilities to serve these needs at intervals along the highway. There are six such needs:

1. Fuel—Where can I buy my brand of gasoline?
2. Food—Where can we eat?
3. Lodging—Where can we stay overnight?
4. Rest—How far to the next rest area, and the next after that?

5. Highway—What is the best way to get there?
6. Tourist—What can we do, and what is there to see?

The first three of these needs are generally served through private enterprise at service stations, restaurants, and motels that locate at points adjacent to Interstate Highway interchanges, generally to be visible to the approaching motorist. In Iowa, attractively designed rest areas are provided at 25- to 30-mile intervals as a part of the Interstate Highway design. Facilities include parking, rest rooms, drinking water, picnic tables, telephone, and an official bulletin board. Highway information is available to a limited extent from the state highway map and official detour map that is posted on the bulletin board. A limited amount of tourist information is obtainable from a display rack on the rest area building that contains brochures furnished by the Iowa Development Commission.

In our interviews with out-of-state motorists on I-80 in Iowa, we obtained a fairly detailed description of what the motorist is seeking in each of the six routine information areas. The standard "Food, Fuel, Lodging—Next Exit" sign leaves many questions unanswered. In the case of fuel, 60 percent of the motorists interviewed indicated that they preferred a particular brand; 71 percent carry an oil company credit card. Information on the availability of a brand is obtained largely from on-premises pylon signs and from jumbo billboards that are set back the required 660 feet from the Interstate right-of-way. On perceiving that he should begin to look for gas, the typical motorist generally begins by passing up competitive brand stations as he looks for a station offering his preferred brand. As the fuel supply dwindles, if he is unsuccessful in locating the brand he is looking for, loyalty bows to necessity, and the motorist turns off at the next station that comes into view. Chief reasons cited as the advantages of using a credit card are the convenience of receiving one monthly billing and the deferment of the requirement for payment to a future month, which leaves more cash available to the motorist for other current expenses.

For most Interstate Highway motorists, meal requirements are less exacting. In the case of family groups on extended vacation trips, which comprised a significant proportion of the total travelers on I-80, the noon meal was generally a very informal affair. About 30 percent of those interviewed planned to eat a picnic lunch, often at the rest area where they were being interviewed. The remainder intended to look for a facility such as a snack bar or cafeteria where a light lunch could be obtained. For supper, a more formal meal was desired, but information requests generally focused on moderately priced restaurants such as those operated in connection with a motel.

For the 10 percent of motorists who were on camping trips, information on the location of campgrounds near I-80 proved especially difficult to obtain unless they happened to have the official Iowa state highway map. For families not camping, information about motels located at points convenient to the Interstate Highway was most often in demand. From a given point, morning requests for motel information centered on cities several hundred miles away. The focus of requests moved gradually closer until midafternoon, when information on motels in nearby communities was requested. Drivers generally planned to reach a specific destination each evening, and proved receptive to an offer to set up a confirmed motel reservation in their destination city.

The rest areas located along I-80 in Iowa are extremely well designed and offer many amenities not generally available at rest areas in other states. Although expressing enthusiasm for these thoughtful details, many motorists were not aware that the rest areas are spaced at 25- to 30-mile intervals along I-80. A commonly voiced complaint was that the standard sign "Rest Area—1 Mile" only partially fulfills the motorist's information need; he also wants to know how far it is to the next rest area so that he can decide whether to stop at the area just ahead.

In the case of highway information, most motorists would like to be able to obtain a road map of Iowa. In most cases, however, they are unwilling to detour very far off the Interstate Highway to obtain one, because of their uncertainty about how much time will be required and whether a map can be obtained at a given exit. Once a map is in hand, motorists are most often interested in confirmation of the fastest and most direct route to their destination, together with suggestions on alternate routes that may be somewhat slower but much more scenic.

When a tourist information service is available, inquiries center on what there is to see and do along the way. Even though some motorists are traveling on itineraries planned in advance, others have only a general destination in mind and are especially interested to know of points of historical significance, educational interest, or natural beauty that they could visit along their route.

Specialized Needs—The specialized needs of the Interstate Highway motorist are those that he can anticipate, but that are of interest only to a minority of motorists. It is thus less practical to provide for them as frequently as for routine needs. Examples include specialized information about pets (Where can we walk our dog?); camping (Where can we find a campsite?); supplies (Where can we purchase groceries?); mail (Where can we post a letter?); and hobbies (Where can we hunt for minerals?).

The motorist desiring specialized information may or may not be motivated to make a special stop in an effort to obtain it. Although specialized information requests are of genuine importance to the persons making them, their variety is such that it is almost impossible to anticipate them, making it especially difficult to provide for these requests in advance.

Emergency Needs—The emergency needs of the Interstate Highway motorist are those that he cannot anticipate, but that may result in great inconvenience if information on how to obtain help is not readily available. Examples of emergency needs include car service (Where can we obtain a qualified mechanic?); accident assistance (How do we call the police?); fire protection (Where can I report a fire?); and medical treatment (How can I send for a doctor?)

Emergency needs usually must be met under circumstances different from those applicable to routine or specialized needs. First, the motorist in an emergency is often faced with the loss of the use of his car and is thus unable to travel very far for help. Second, he nearly always is unable to wait very long. Emergency services, if they are to aid the Interstate motorist, ideally must be available anywhere along the highway and with a minimum of delay. Finally, because emergency service facilities are almost never located directly on the Interstate Highway, the motorist requiring such service—unless a state police car stops to investigate—must almost invariably walk to a telephone, or send someone else to a telephone to summon help.

Available Channels of Communication

Four basic channels are available for use in communicating with the Interstate Highway motorist depending on (a) whether he is moving or standing still, and (b) whether the communication is visual or aural. Each of these channels is commonly used to convey certain types of information, as Table 1 illustrates. Table 2 supplies definitions of sign terms used in Table 1.

One of the subsidiary questions investigated was whether or not it would be necessary or desirable to develop new methods or systems of communication to better meet the information needs of the Interstate Highway motorist. Mention was made of electronic systems that would make it possible to communicate highway information directly to the drivers of cars appropriately equipped. From a technical standpoint, direct radio communication could easily be developed with existing communications equipment. That such means have not been adopted for more general use is due both to their cost and to the relatively effective coverage possible with the communication channels listed previously. Rather than developing new

TABLE 1

AVAILABLE CHANNELS OF COMMUNICATION

Type of Channel	Motorist	Devices Used	Information Conveyed
Visible	In motion	Official highway sign	Highway
		Standard billboard Jumbo billboard On-premises pylon	Food, fuel, lodging
Visible	Standing still	Highway map	Highway
		Poster Bulletin board	Tourist
		Advertising panels	Food, fuel, lodging
Audible	In motion	Car radio	News, weather, time
Audible	Standing still	Telephone	Emergency
		Information agent	All information needs

TABLE 2

GLOSSARY OF SIGN TERMS

Type of Sign	Description
Official highway sign	Standard information sign erected in conformity with AASHO standards. Highway direction signs have white reflectorized letters on green background. Supplementary information (e. g., "Food, Fuel, Lodging") is presented in white letters on blue field and reflectorized only if available at night.
Standard billboard	Commercial advertising sign measuring 10 by 20 ft and located adjacent to right-of-way.
Trailer sign	Commercial advertising message lettered on standard 40-ft highway trailer parked along right-of-way. (Since trailer is not a "billboard," some advertisers feel it does not violate ban on advertising signs.)
On-premises pylon	Outdoor advertising sign mounted on tall tower visible for a mile or more in each direction. (Advertising signs are permitted less than 660 ft from Interstate right-of-way when they are on premises of business establishments doing the advertising.)
Jumbo billboard	Oversized 20 by 40-ft billboard designed to be legible from distances greater than 660 ft.

communication devices, we believe that efforts should be directed toward making more effective use of the basic devices already employed.

To date, it has been the practice to place greatest reliance on signs as a means of communicating with motorists. Car radios, rest area bulletin boards, and wayside telephones have not been widely relied upon as means of communication. Each of the communication devices discussed is simple and effective. Signs, however, have the advantage of providing nearly complete "coverage" of the motoring public. In addition to being easily created and installed, a message on a well-placed sign will be read by nearly all motorists driving past that point. Radio is a potentially effective means of communicating with the motorist and should be further explored, but it cannot be used to reach the occupants of the one car in ten that has no receiver. Posters, bulletin boards, and advertising panels located at rest areas provide an excellent means of communicating with all motorists who stop there, but not all motorists do. Because most specialized information requests call for an individual response, the telephone is a potentially effective means of answering requests from a number of rest areas at a central facility. That this has not been done is due not only to the problem of cost but also to the fact that existing signs answer most of the motorists' questions. Signs are simple, comparatively inexpensive, and very effective.

Means Presently Used for Communication

One of the premises that led to the development of the Infosite concept was the belief that, because outdoor advertising signs within 660 feet of the right-of-way are banned on I-80 in Iowa, an "information gap" would result. Federal and state laws, it was asserted, have virtually eliminated advertising signs from the Interstate System. Infosite was designed to fill this "information gap" by providing an aesthetically acceptable channel for communication of commercial messages at convenient points along the highway.

In fact, we found that this "information gap" does not exist. One of the principal problems of I-80 in Iowa is not the lack of information signs suited to the motorists' needs, but rather the trend toward an ever-increasing proliferation of legal and illegal billboards.

On the 165-mile segment of I-80 between Des Moines and Davenport, we counted a total of 509 highway signs (363 official, 146 commercial). In either direction there is one sign every $^2/_3$ mile on the average (254 signs in 165 miles). The motorist driving at the posted Iowa Interstate speed limit is faced with a new sign on an average of about every 30 seconds.

The channel of communication that the majority of motorists stated was their sole source of information while traveling on I-80 was the highway sign, both official and commercial. A minority of motorists stated that they made use of service station maps and/or guidebooks for supplementary information; this practice will presumably continue regardless of any changes made in the information provided through official channels. Thus, there is no shortage of information available to motorists traveling on I-80.

In fact, over 90 percent of some 4,000 motorists interviewed stated that they had no difficulty obtaining the information they felt they required.

The problem we find with the information system on I-80 is not a lack of information, but a lack of controlled information. Specifically, current information controls hinge on whether a sign is commercial or noncommercial. The ban on commercial signs within 660 feet of the right-of-way has not resulted in a reduction of the number of commercial billboards. Convinced that signs are an effective means of communicating with their customers, businessmen have simply placed their billboards beyond the 660-foot limit and, of necessity, made these jumbo billboards several times larger than the former roadside billboards.

Instead of judging signs by whether or not they are commercial in content, we conclude that a more effective kind of control would be to permit, for a fee, advertising that meets rigid aesthetic standards and to enforce removal of uncontrolled advertising. The alternative is acceptance of the continued proliferation of jumbo billboards. Only by offering legitimate channels for communication of commercial messages can the use of less desirable communication techniques be controlled or reduced.

In this context, the Infosite, rather than offering a means of providing information where none was thought to be available, should be considered as one acceptable means of offering an alternative and controlled means of communication for advertisers who will otherwise present their message on a jumbo billboard. Evaluated in this light, a somewhat restructured information center is a potentially effective means of communicating needed information to the motoring public.

Motorists' Acceptance of Infosite

From the point of view of aesthetics and safety, the Infosite represents a dramatic improvement over conventional forms of outdoor advertising. The center is well designed and offers an attractive addition to the rest area complex. Whereas the billboard message must be read in a brief glance away from driving duties, and therefore may contain only a brief message, the Infosite advertising panels permit the motorist to read a much more complete message in safety and comfort and at his own pace. To ensure that Infosite would be a complete success from the motorist's point of view, Stoner System, Inc., has gone out of its way to provide, at its own expense, additional information services that it felt would be of interest to Infosite visitors. Advertising space that is currently unsold, rather than being left blank, has been filled with special information panels depicting tourist attractions throughout Iowa. Since tourist information is one of the needs currently not well fulfilled by the present information system, the limited amount of tourist information provided received especially favorable comments. Rarely, in our opinion, has an outdoor advertiser carried out a project with more taste or professionalism.

Interviews with Infosite visitors reveal that the concept has gained a high degree of initial acceptance as a convenient and effective means of obtaining the limited spectrum of information that is currently available there. Of those interviewed, 99 percent indicated that they had found the information they originally sought, and 96 percent indicated that this information was helpful. But 6 percent indicated that they were disappointed by some aspects of Infosite, and 5 percent said there was information they wanted but could not find. The Infosite was classed as a "good idea" by 99 percent of the persons interviewed.

The chief problem cited by Infosite visitors was the lack of breadth and scope in the information available. The motorists' reaction might be summarized as, "It's nice, as far as it goes." Thus far, Infosite has attracted advertisements only from firms within a limited geographic area. Of the six routine information needs of Interstate Highway motorists, only lodging is covered effectively by Infosite. For each of the information needs covered, too few business enterprises are participating, with the result that the motorists' choices are severely limited.

When the concept was being developed, it was thought of in terms of its attractiveness to persons seeking accommodations in neighboring communities along the Interstate. Experience has shown that because the Interstate Highway System makes extended automobile trips practical, most morning inquires concern out-of-state communities 300 or 400 miles away, where the traveler plans to be that evening. Only in the afternoon do visitors begin to request information about nearby accommodations and restaurants. Thus, as presently conceived, one limitation on the effectiveness of the Infosite is the restriction of its scope to a local rather than a statewide area.

Current Infosite clients number less than 20. Advertising space has been purchased by 12 hotels or motels, 2 service stations, 2 chambers of commerce, and 1 tourist attraction. Of the 6 information needs, only lodging is adequately represented, and then only if the motorist is seeking accommodations in the Des Moines-Iowa City area.

From the motorist's point of view, the Infosite is of limited usefulness in providing fuel, food, lodging, highway, and tourist information. The Infosite experiment does, however, provide four important insights that suggest ways of restructuring the present information system.

1. Small advertising panels at rest areas are effective substitutes for roadside billboards and offer advantages of safety and completeness in addition to being aesthetically superior.
2. Motorists' acceptance of direct-line reservation telephones from a rest area to a lodging establishment is high, and sales generated by such a telephone will more than offset the cost of its installation.
3. Successful operation of a public building located in a rest area along an Interstate Highway requires that a full-time attendant be on duty to safeguard the property whenever the building is open.
4. The choice of location of an Information Center should take into account the fact that motorists' inquiries will cover all communities within a one-day drive beyond the center, not just the area in which the center is located.

Business Acceptance of Infosite

The effectiveness of the Infosite as an advertising medium from the point of view of business enterprises appears to be limited to those establishments whose location and product meet rather narrowly defined criteria. It is no surprise that two-thirds of the advertisers currently under contract at the Infosites are lodging establishments; lodging is the largest single purchase the motorist is likely to make each day and, therefore, the one to which he devotes the most advance planning.

In addition to being effective largely for motel advertising, the utility of the Infosite appears to be even further restricted in scope. Motels of well-known national chains that either have a large percentage of referral business from units in other cities or are clearly visible from I-80 have shown little interest in becoming Infosite advertisers. Their explanation is simply that they enjoy such a high rate of occupancy through advance reservations and from motorists who stop after seeing their motel from the highway that additional advertising is unnecessary. Similarly, hotels located in cities some distance from the Interstate find that Infosite advertising is of limited effectiveness, since most through travelers cannot be induced to detour very far from their intended line of travel for accommodations. However, for a motel located adjacent to an interchange but not visible to the approaching motorist, Infosite advertising can be very effective; the monthly cost of an advertising panel in the Infosite is offset by new business in a few days.

For establishments offering fuel or food, the benefits of Infosite advertising are much less apparent. Purchase of meals and fuel are largely made on an impulse basis when a service station or restaurant is seen ahead on the road. Two service stations have placed advertisements; their message, however, is directed primarily to the motorist requiring road service. The odds of a motorist breaking down within easy walking distance of an Infosite being fairly remote, only one or two calls to the service station have been recorded to date. For retail gasoline sales, service stations rely heavily on on-premises pylon signs that put their brand symbol in a position to be seen by the approaching motorist a mile or more down the road. In addition, the principal oil companies have long used the practice of indicating on their free highway maps the locations of their retail service stations at points convenient to Interstate Highway interchanges.

Except as an incidental part of hotel or motel advertising, restaurant advertising was not attracted by the Infosite format. Restaurants located along I-80 in Iowa are chiefly of the snack bar or luncheonette type, and are often operated as an adjunct to service stations to provide an added attraction to motorists. Visibility of the restaurant from the highway appears to be a prime factor in generating sales, and extensive use is therefore made of on-premises pylon signs by these establishments. Although the evening meal may represent something more of a planned purchase, it is often eaten at the hotel or motel selected, thus making lodging advertising the principal generator of evening meals sales.

One tourist attraction, Amana Colonies, has purchased space at Infosite and apparently has found the results to be quite effective. Founded in 1854 as one of the early experiments in communal living, the Amana Colonies today consist of six farm villages where visitors may observe handicrafts and trades being practiced in the traditional manner and can sample home-cooked recipes served family style in one of several restaurants. Because of the prominence of Iowa as a farming state and the growing interest of tourists in American history, the glimpse of 19th century rural America provided at the Amana Colonies has been popular with tourists. Prior to the opening of the Infosites, the state erected "historic markers" at rest areas on I-80 explaining the historical significance of the Amana Colonies. Official highway signs marked "Amana Colonies" also guide the prospective visitor to the correct exit. Thus, the advertising panel at the Infosite serves primarily to heighten interest already created by official signs. Visitors inquiring about the Amana Colonies at the Infosite were shown an advertising panel displaying a map of the best route from the Infosite to the Amana Colonies and were assured by the Infosite attendant that the Amana Colonies represented a worthwhile tourist stopover. Because there are few attractions worthy of tourists' attention along I-80, it is not surprising that the Infosite advertisement produced a measurable increase in the number of Amana Colonies visitors during the latter part of the summer. However, the success of the advertisement was based in part on the fortunate location of the Infosites a few miles on either side of the Amana Colonies exit, and on the semiofficial aura surrounding the Amana Colonies name, which serves to add legitimacy to the advertising message. In our judgment, Lake McBride State Park and the Herbert Hoover Memorial in West Branch are the only other Iowa tourist attractions along I-80 that could be expected to achieve similar results through Infosite advertising.

From the point of view of the businessman, one of the difficulties with Infosite is a lack of differentiation in the product price range. This occurs in part because Infosite was conceived as an advertising medium that would substitute for the outdoor billboard. Infosite display panels are priced from a minimum of $95 a month for a 2- by 2-foot panel to $720 per month for a 4- by 12-foot panel. To date, the largest single purchase has been the 4- by 4-foot panel at $324 per month. By way of comparison, the monthly rental costs for a jumbo billboard range from $230 to $350 per month. Thus, while the basic Infosite panel costs about one-third as much as a jumbo billboard, it reaches only that segment of the total audience that stops at the rest area, or about 10 percent of the total traffic. While the Infosite panels appear to be priced competitively with billboards, there is a gap in the product price range between $5 and $95 per month. For $5 per month, an advertiser may obtain a simple listing of his name and telephone number in a directory positioned next to the telephone. However, unless a vistor's attention is called to the directory by the Infosite attendant, most visitors would overlook it in favor of the attractive back-lighted advertising panels. Lack of a panel priced at, say, $25 per month has prevented Infosite from attracting advertising by family-run or single-unit business that cannot afford either a billboard or one of the present Infosite panels.

No discussion of the business acceptance of Infosite would be complete without considering its success from the point of view of the advertising agency that has undertaken to operate the center. In the planning stages of Infosite, a chief question was whether or not its advertising concept would prove acceptable to potential advertisers. The experience to date has shown that acceptance is high for businesses falling within the criteria discussed previously. Little initial consideration was given to the question of whether or not Infosite would prove successful from the point of view of Stoner System, which is responsible for its day-to-day operation under contract with the Iowa State

Highway Commission. Because Infosite does not return a profit to the advertising agency, further implementation of the concept is out of the question, and even the continuation of the two experimental units is in doubt.

Because the "information gap" on which Infosite was based was found in fact not to exist, sale of advertising space at the Infosites has fallen far below initial expectations. Furthermore, costs have been substantially higher than anticipated because the original plans failed to consider that an attendant would be needed whenever the building was open.

Each Infosite would provide a gross annual income to Stoner System of $83,500 if all of its panels were rented. Direct operating costs, including the cost of the lease, wages, utilities, maintenance, taxes, etc., amount to $24,500 or 30 percent of the gross income. Indirect operating costs (central office personnel, field sales representatives, travel expenses, supplies, etc.) about equal direct operating costs, as in comparable industries.

Current sales of advertising at each Infosite total about 20 percent of the space available. Thus, despite the fact that sales calls have been made on nearly all of the businesses located adjacent to I-80 in Iowa and offering services to motorists, a 50 percent improvement in sales is required to raise income from 20 to 30 percent of potential gross sales, at which point direct operating costs would just be covered. To cover both the direct and indirect operating costs, current sales would have to be tripled, since fully allocated costs amount to 60 percent of the potential gross income. Only if more than 60 percent of the space were sold would any net income accrue to Stoner System, Inc.

The lack of interest on the part of major fuel companies and certain chain motels (already committed to pylon signs and jumbo billboards) suggests that while the current level of sales may be improved upon somewhat, there is no reasonable prospect of tripling the level of sales, as would be required to meet costs. Based on present trends it is unlikely that Stoner System would be interested in continuing to support the Infosite project beyond expiration of its current contract.

CONCLUSIONS

Initially, when the goals of this study were defined by the Iowa State Highway Commission, one of the six steps to be accomplished was the development of a set of guidelines governing the future development and expansion of the Infosite concept. Based on the results obtained to date at the two experimental Infosites, it has become apparent that, although they have made a worthwhile contribution to understanding how the information needs of the Interstate Highway motorist may best be served, they are not self-supporting, and therefore expansion or even continuation of the Infosite concept appears unlikely.

Among the many reasons that made the Infosite approach appear attractive was the fact that it was set up in such a way as to offer the potential of furnishing information to the Interstate Highway motorist at virtually no cost to the Iowa State Highway Commission. The building was constructed by the Highway Commission and leased to Stoner System, Inc., on a basis that recovers the entire cost of the building over the life of the lease. In addition, Stoner System, Inc., pays the cost of maintenance services and utilities, so the only costs to the Highway Commission are administrative costs. If the demand for a medium of communication with the Interstate Highway motorist had been such that two-thirds or more of the advertising space offered for sale at the Infosite was subscribed, the Highway Commission would have succeeded in providing a cost-free information service, and Stoner System would have developed a communications medium uniquely suited to meeting the information needs of the Interstate Highway motorist. This objective is not currently being met, primarily because, despite "antibillboard" regulations, ample opportunity exists for businessmen to reach Interstate motorists by means of outdoor advertising.

It was the intent of the antibillboard legislation to eliminate, or at least severely restrict, the use of outdoor advertising signs along the Interstate Highway system. When the present law against erecting outdoor advertising within 660 feet of the right-of-way was put into effect, it was presumed that no advertiser would be interested in erecting a sign located over 200 yards from its intended readership. The ban has not been effective, because it ignores the fact that certain businesses, principally motels and service stations, depend for their survival on patronage from travelers using the Interstate Highway; to attract this patronage, they must make their presence known to the potential customer. Because the law provides for no alternative means of communication, they must either violate it or erect a jumbo billboard beyond the 660-foot limit.

Three factors make possible the continuing reliance on outdoor advertising:

1. Loopholes in the present law permit some signs to be erected legally within 660 feet of the right-of-way. The principal exceptions permit signs within 10 miles of a commercial zone and signs on the premises of a business offering services to the Interstate motorist.
2. Enforcement of the ban on signs less than 660 feet from the right-of-way has been haphazard. Effective procedures for determining which signs are illegal and bringing about their removal are only now being developed.
3. The development of the jumbo billboard permits the outdoor advertising industry to continue to offer space to advertisers while conforming with the 660-foot limit.

Even supposing that enforcement procedures bring about eventual removal of most signs less than 660 feet from the right-of-way, under the present information structure the long-term trend is clear: Rather than eliminating billboards, the ban will encourage the use of jumbo billboards, which, from an aesthetic point of view, are even more objectionable than the conventional kind. If this trend is to be counteracted, the total information system should be restructured so as to utilize the best aspects of each of the four available communication channels to communicate to motorists each of their six principal information needs.

Currently, only official highway signs are permitted along the roadside. However, the Infosite experiment has demonstrated not only that commercial signs provide information a motorist wants to obtain, but also that such signs can be aesthetically attractive.

A restructured information system should not attempt to ban all commercial messages; rather, it should establish standards for approved commercial messages and insure the removal of all signs that violate these standards. Probably, the only really effective way of halting the trend toward jumbo billboards would be to amend the current legislation to prohibit all outdoor advertising legible from the right-of-way on the Interstate Highway. Short of this, the jumbo billboard can be expected to remain a permanent part of the landscape. However, its rate of growth can be slowed down if the information system on the Interstate Highway provides the businessman with an effective alternative at reasonable cost.

RECOMMENDATIONS

The following steps are recommended as a means of providing a more effective and aesthetically pleasing information system for Interstate Highway motorists in Iowa:

1. As a first step, whatever action is necessary should be taken to eliminate all illegal outdoor advertising within 660 feet of the right-of-way of the Interstate Highway. On the segment between Des Moines and Davenport, two advertisers account for a majority of all such signs.
2. Standards governing official Interstate Highway signs should be reviewed to identify opportunities where either more complete information can be provided without increasing the present number of signs, or the information presently provided can be displayed with a reduced number of signs. For example, the current practice is to list the distance to an exit on one sign: "Newton—1 Mile," and "Food, Fuel, Lodging—Next Exit" on a second sign. By placing symbols of a knife and fork, a gas pump, and a bed along the bottom of the first sign, the information that now requires two signs could be displayed on one. Moreover, because symbols can be recognized much more rapidly than words, the length of time when each driver's attention is distracted would be reduced.

Similarly, altering the rest area signs to show the distance not only to the next rest area but also to the subsequent one would meet an often-voiced request for more definite information about the choice being presented. The sign "Rest Area—1 Mile" gives the driver no clue of how far he may have to go before reaching another rest area, unless he happens to know that they are spaced 25 to 30 miles apart along I-80 in Iowa. By abbreviating the word "mile," the same sign area could be modified to read, for example, "Rest Areas—1 mi. & 28 mi.," thus providing better information at very little added cost.

3. Pressure on businessmen to use the visible-in-motion channel of communication for food, fuel, and lodging information cannot be expected to lessen unless use of the remaining channels of communication for advertising is permitted. The Infosite experiment has demonstrated that effective use can be made of the visible-standing-still channel for commercial messages, which are not only accepted by the motorist but prove effective for certain types of businesses.

The chief obstacle to continued use of the Infosite approach is that costs exceed revenues, largely because the efforts of Stoner System, Inc., to provide a full-service information center had to be carried out before the market support for such a center could be determined. We recommend that the Iowa State Highway Commission experiment further with the use of the visible-standing-still channel for displaying commercial messages at rest areas, by erecting a display of advertising panels on an outdoor bulletin board. The latter could be either an expansion of the existing foyer bulletin board at the rest area building or a separate board mounted on posts and protected by a simple pitched roof. Signs of this latter type are now in use in Colorado.

One approach to such a display would be to mount an official state highway map in the center of the bulletin board and to sell small panels around the edge to motels and other businesses. Because the outdoor bulletin board could be operated on a much more modest budget than the Infosite, the cost of individual panels would be lower; greater representation from service stations and restaurants would then be more likely than is presently the case. Advertisers' panels could be tied into the state highway map to show the location of each business on the map.

Because the outdoor bulletin board requires no attendant and consumes no utilities, it offers both the highway commission and the advertising agency operating it a more economical alternative to the Infosite. The Infosite experiment showed that businessmen would buy advertising space at an Interstate Highway rest area; the Highway Commission should capitalize on this knowledge to provide for a more balanced information format.

4. An official state highway map offers a potentially effective means of communicating a great variety of supplemental information to the Interstate Highway motorist. We recommend that the policy of the Highway Commission regarding the official map be altered to permit its use for display of a wider variety of information which, although not strictly highway information, is of demonstrated interest to the Interstate Highway motorist. In its 1967 version, the Iowa highway map fulfills most adequately its principal mission of showing the current state of highway facilities, but it largely overlooks the opportunity for communicating supplementary information.

We recommend that the map be redesigned and enlarged to fulfill a broader role. Color should be used more imaginatively to emphasize important features, as is done by South Dakota. Iowa's map unaccountably shows the state in yellow and surrounding states in white, which is opposite of the customary practice on nearly all state highway maps.

In addition to the map's central function as a guide to the location of roads and communities, it can also answer most tourists' questions regarding historic sites and recreation areas in the space available on the reverse side of the map. An example of effective utilization for this purpose is Vermont's official highway map. The reverse side of this map provides a comprehensive listing of state parks and forests, historic places, museums, fish and game information, public golf courses, privately owned camp grounds, community swimming areas, and radio and television stations in Vermont. The advantage of this approach is that it answers most tourists' questions by means of a single information device. The listing of Iowa radio stations and their frequencies, both on the highway map and on rest area bulletin boards, would be a desirable step toward greater utilization of the audible-in-motion channel for communication to motorists.

For the map to serve as a basic guide to motorists desiring information, a means must be provided for getting it into their hands. Because only a small proportion of motorists will plan sufficiently well in advance to send for a copy by mail, it seems essential that additional outlets be provided. One approach would be to offer the map for sale in vending machines at rest areas for a nominal fee. Although the state highway map has traditionally been issued free of charge, experience has shown that leaving them in a rack unattended leads to abuses in their use. Because the maps are costly to produce, it would seem reasonable to regulate their distribution through vending machines, while still making the state highway map available free of charge at Highway Commission offices.

5. While the foregoing steps are being carried out, we recommend that a continuing evaluation be made of the demand for approved commercial advertising space and the trend in the development of additional jumbo billboards. Should the policy of eliminating illegal billboards produce sufficient demand, we recommend that serious consideration be given to the establishment of state-sponsored information centers at gateway points in Iowa (initially Council Bluffs and Davenport). These should be staffed by competent travel advisers from the appropriate state agencies. All that would be needed to attract large numbers of visitors to such centers would be an official sign reading "Iowa Information Center—State Highway Map." Information centers would most likely serve primarily in the promotion of tourism in Iowa, a function currently the responsibility of the Iowa Development Commission.

At the center, Interstate motorists could obtain assistance in planning their trip across Iowa and suggestions on points of interest where they might want to stop. Because most tourists want information about overnight accommodations, it would be appropriate for the information center to operate a referral service by which motorists could be directed to specific lodging establishments. Because hotels and motels would be the greatest beneficiaries of such a service, they should be allowed to defray the cost of the service through purchase of controlled advertising panels of the Infosite type.

Whereas an information service of this kind is probably best regarded as the responsibility of the Iowa Development Commission, it can only be placed into effect as a part of an overall information system conceived and directed by the Iowa State Highway Commission.

6. Meeting the demand for information on emergency services requires separate consideration, since the motorist does not know that he will need such information until the emergency occurs. At present, motorists in need of emergency services cannot rely on police patrols for prompt assistance, and the cost of increasing the frequency of patrols to cover every point along the highway several times an hour would be prohibitive.

The emergency information problem is, in essence, one of reaching a telephone from which the motorist can communicate his difficulty to the competent agency. The solution lies in making telephones more readily available along the Interstate Highway. The Highway Commission's policy has been not to list "telephone" as a service alongside food, fuel, and lodging, since it is assumed that wherever the latter is available, a telephone can be found; however, because in many emergencies the motorist is deprived of the use of his car, the availability of a telephone at a service station or motel does not meet his particular need. An interim solution would be to include a telephone symbol on the current rest area signs to call motorists' attention to the fact that a pay telephone is available in the foyer of rest area buildings.

In the long run, a more effective solution would be the installation of emergency telephones at half-mile intervals along the right-of-way, as has been done on the Northway between Albany, New York, and the Canadian border. If a telephone system permits less frequent police patrols, the cost of the installation might be more than offset by the reduced cost of highway patrolling.

A Transportation and Price-Sensitive Interregional Input-Output Model

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ABRIDGMENT

•THIS paper presents a modified form of a Leontief-type input-output model whose technological coefficients are sensitive to changes in transportation costs and factory prices of commodities. A theoretical framework is developed to derive a set of relationships that may be estimated statistically and used to compute revised technological coefficients whenever there are changes in delivered prices of commodities. The model developed is proposed as a device for forecasting interregional commodity flows as a first step in forecasting transportation demands throughout a region.

The implementation of the Leontief-type model requires that economic data for a base year be collected and arranged in an input-output table to reveal the interregional flow of commodities among the various industries situated in the study area. The table is thus a kind of "still" picture of the interrelationships among regions and industries.

If technology and relative prices remain unchanged but, for any reason, there is some change in the pattern of final demand for goods and services, there will be commensurate shifts in the flows of commodities among industries and regions. The interrelationships revealed by the base year input-output table can be used to predict the shift that might be expected to occur as a result of a given change in demand.

The flows of commodities described by the input-output table must be accomplished by the transportation system. Hence, any changes in these flows represent changes in the demands for transportation. Input-output analysis can therefore be used as a tool in the prediction of changes in the demand for transportation when these are a consequence of changes in final demand.

An important deficiency of the input-output analysis has been the absence of a methodology by which the technological coefficients might be made sensitive to changes in delivered prices of commodities. The need for some sensitivity is demonstrated by empirical findings that technological coefficients do change over time. Economics theory also suggests that such sensitivity should be built into the model.

When the delivered price of some commodity from one region changes while the delivered prices of similar commodities from other regions remain the same, there will be shifts in demands in favor of the relatively cheaper sources and hence in the pattern of commodity flows throughout the area. In this fashion, changes in relative prices lead to changes in the location and growth of industries, and in the distribution of the labor force and of the population. All these changes give rise to a new set of interrelationships among regions and industries. The model developed presents a methodology by which the technological coefficients can be modified from time to time whenever significant changes occur in the delivered prices of commodities.

Because changes in transportation costs may be an important source of variations in delivered prices, the model is designed to be sensitive to such changes. It can therefore be used to predict the changes in demand for transportation that may be expected from a given change in the transportation system itself.

The technique by which the relationships between delivered costs and commodity flows are accomplished is an analytical methodology that assumes industries behave like firms that minimize costs and have linear homogeneous production functions belonging to a specific family of such functions.

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Projecting Automobile Availability by Urbanized Area

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This paper is made up of extractions from an unpublished technical report on research conducted in one task under the Bureau of Public Roads national research project, "Underlying Factors in Urban Transportation Analysis." The task is concerned with improving the techniques of estimating future potential demand for highways. The most important single indicator of demand for highway transportation is automobile availability (measured by the ratio of automobiles available to employed residents). Multiple regression analyses were made of the relationships between the 1950 and 1960 ratios of percent shares of automobiles available and nine related population, employment, and income variables for 198 urbanized areas.

Tests were made of the accuracy of the equations in predicting 1960 automobiles available using 1950 as the base year. The equation for urbanized areas in the Type A category, although not as accurate as most of the other equations, predicted values that are within ± 15 percent of the actual values in approximately two-thirds of the cases. Projections of the number of automobiles available in 1975 and 1990 were made for the 28 urbanized areas classified as Type A.

•THIS paper presents part of the research procedure, data development, and statistical analyses and testing that went into the development of quantitative measures of the relationships between change in an urban area's level of automobile availability and changes in a few key related variables. Such measurements might provide better understanding of the different trends among urban areas in the extent to which certain transportation facilities are used and might also serve as guidelines in forecasting future levels of automobile availability, and the implied transportation requirements for an urban area. (The term "urban area" is commonly thought of as being composed of a city and its surrounding "built-up" suburbs; however, delineations of any one urban area may vary from study to study. In this study "urban area" conforms to the definition of "urbanized area" as defined by the U. S. Bureau of the Census in 1960 and given under the section on data development that follows later.)

The aim was to devise a simplifed, rapid, inexpensive, and adequate method of estimating future potential demand for highways by urban area. This was to be accomplished with the use of available data from usual government sources. Another purpose was to tie urban area forecasts to those at the national and state levels.

AUTOMOBILE AVAILABILITY—A KEY PLANNING FACTOR

The most important single indicator of demand for highways is automobile availability. Estimates of the number of automobiles currently available and likely to be available in the future indicate the trend in travel that parallels the change in automobiles available and, consequently, the future requirements of highway and parking facilities implied in these trends.

Future automobile availability may be considered not only as a basis for judging the future demand for highway and parking facilities, but also as an indicator of their

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potential impact on the environmental quality of an urban area. In some cases, problems of traffic congestion, noise and fumes, and the proliferation of highway-oriented businesses may be implied in forecasts of higher levels of automobile availability.

PROCEDURE

Decision Variables—Demographic, Social, and Economic

Hypothetically, change in the aggregate number of automobiles available is associated with change in the area's demographic, social, and economic characteristics. The demographic characteristics are the number of inhabitants in the total area and their distribution between the central city and urban fringe. The total number of families and their distribution among low-, medium-, and high-income brackets are considered to be key social factors. Critical economic factors are aggregate family income and the total number of employed area residents. These factors, selected to be the variables in multiple regression analyses, are listed below:

X_1 = Automobiles available	Dependent or criterion variable
X_2 = Total population X_3 = Central city population X_4 = Urban fringe population X_5 = Low-income families X_6 = High-income families X_7 = Middle-income families X_8 = Number of families X_9 = Aggregate family income X_{10} = Employed residents	Independent or decision variables

Selection of these variables is based on a general theory of growth in urban automobile availability. According to this theory, the number of automobiles available will increase with an increase in an area's total population and/or population shifts from the central city to the suburbs. These population changes reflect change in the distribution of income among the families in the area and/or change in the level of aggregate income. Change in the level of employment is a prime factor underlying change in income. While this deductive logic seems reasonable in general, hypothetically, the relative importance of the associated factors would vary from one area type to another. One or more of the independent variables would be significant in one type of area but not in others. It is also recognized that there is the element of time in the relationships between these factors so that some changes will lead, be concurrent with, or lag other changes. Lead-lag analyses, however, are beyond the scope of this report.

Growth Relationships Vary With Rate of Automobile Availability

Theoretically, the relationship between increasing rates of automobile availability and economic growth is largely determined by the rate of automobile availability already attained. An area with a high ratio of automobiles available to persons employed can be expected to raise that rate only gradually, whereas the opposite would be true of an area with a relatively low existing rate of automobile availability. This would be true even though both areas experienced similar rates of general economic growth. In areas with relatively moderate rates of automobile availability, the increases in these rates would be similar to the economic growth rates.

An Urban Typology Based on an Automobile Availability Index

An urban typology based on the automobile availability rate as a transportation criterion was devised to facilitate urban area comparisons and thereby help to isolate the factors associated with urban area variations in transportation utilization. In a previous study, the authors classified the 213 urbanized areas that existed in 1960, using an index of automobile availablility as the classification criterion (1). The ratio of the number of automobiles available per 100 employed residents was used as the index of automobile availability. The automobile availability types, the automobile availability index ranges for each type, and the number of urbanized areas that fall into each category are as follows:

Type	Number of Autos per 100 Employed Residents	Number of Urbanized Areas
A	100 or more	28
B	90 to 100	31
C	80 to 90	62
D	70 to 80	61
E	60 to 70	15
F	Under 60	1

Because the automobile is the predominant mode of person transportation in almost all urban areas, the ratio of automobiles available to the number of residents employed serves to differentiate between urban areas having varying degrees of automobile preponderance. As noted in the previous study, this measure also helps to indicate the degree of reliance placed on the automobile by workers in their work trips (1). This classification satisfied the need to overcome, to some extent, the variation in rates of automobile availability among urban areas. It was anticipated that analyses of the areas by automobile availability class would help isolate the key variables related to change in automobile availability in each type of area. Prior study (1) indicated the existence of some correlation between an urban area's transportation characteristics and the region of the country in which it is located. Figure 1 shows the national distribution of urbanized area types with populations in excess of 150,000. A southwest to northeast

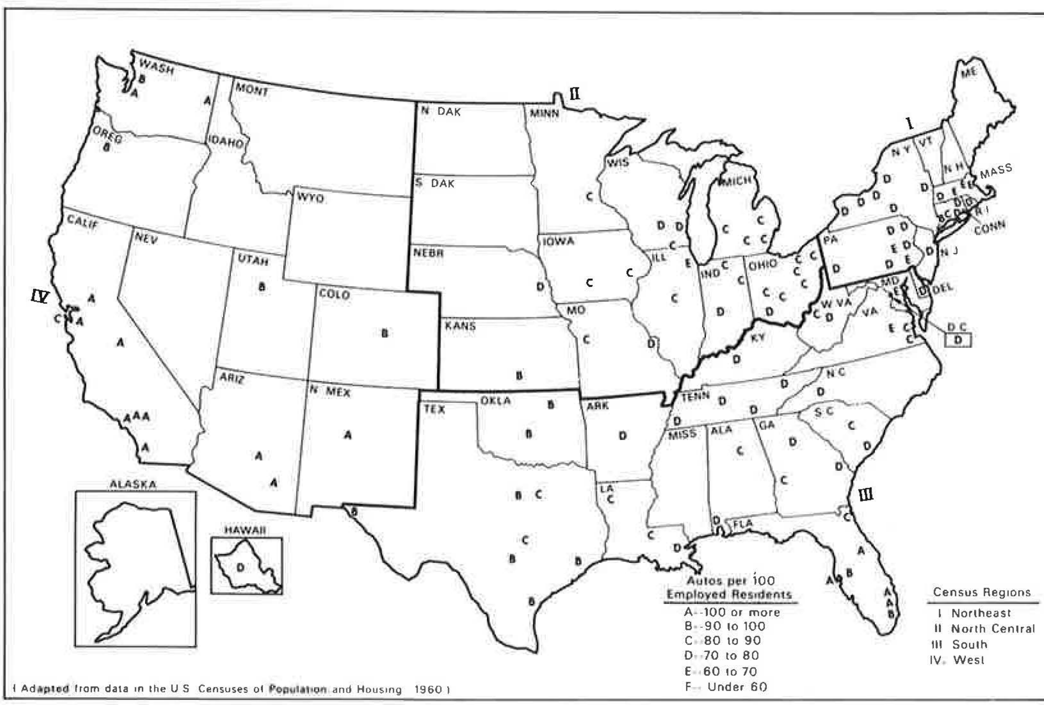

Figure 1. Geographic distribution of urbanized area types with over 150,000 population.

pattern of high (A) to low (E) types is fairly distinguishable. The areas were therefore grouped according to census region for analysis. This general approach seems to be in keeping with Coleman Woodbury's suggestion (2, p. 12) that ". . . comparative studies of many areas or groups of areas may be the road to some explanations that no consideration of the aggregates alone or of individual areas could reveal. . . ."

In his study of intracity traffic movements, F. Houston Wynn (3) observed, "Much serious work has been done by persons seeking solutions to specific problems or making intensive study of a particular urban community. Few researchers have attempted to discover the characteristics of urban travel that are common to all communities."

DATA DEVELOPMENT

Area Definition

Urbanized or urban area is the geographic unit with which this study is concerned. It is defined by the U. S. Bureau of the Census and contains one or more central cities with a population of 50,000 and an urban fringe. In developing data for some variables and certain areas, however, it was necessary to base estimates on data for other geographic units, such as standard metropolitan statistical area (SMSA), state economic area (SEA), and county. Instances in which this was done are explained in the "Data Sources" section discussed later.

Urbanized Area Classifications

Data were compiled for the areas in each of five automobile availability classes developed in an earlier study, ranked as of 1960. The urbanized areas were also separated into four groups according to the census regions in which they were located. When an area is located in more than one region, it is classified in the region in which the largest proportion of the area's population is located.

Data Sources

Most of the data used in the empirical phase of this study comes from Census Bureau publications. However, for a considerable number of the 213 urbanized areas in 1960, there were no readily available comparable data for 1950. In such cases estimates were made using 1950 county data. For the New England region, data for state economic areas containing standard metropolitan statistical areas were used as surrogates for urbanized area data.

Not only were there serious problems of comparability in area of definitions, but there were also problems of comparability between 1950 and 1960 in definitions of some of the variables used. The following is a list of data sources for the variables used in this study. Where appropriate, notes have been inserted to explain means used to overcome in part some of these problems of definition and data comparability:

X_1 = Automobiles available

1960—Estimates based on the number of occupied housing units with one, two, and three or more automobiles available as reported in the U. S. Census of Housing: 1960, Vol. 1, State and Small Areas, HC (1), Tables 16 and 30.

1950—Automobile registrations as of July 1, 1947, as reported in the County and City Data Book, 1949, Table 2 (for Standard Metropolitan Statistical Areas) and Table 3 (for counties), column 32 (Records of R. L. Polk and Company, compiled from state motor-vehicle registrations).

Assumptions: Because the absolute data would be converted to percentage distribution, it was assumed that the distribution of SMSA shares would not be significantly different from the distribution of urbanized area shares. It was also assumed that between 1947 and 1950 there was no change in urbanized area shares of automobile registrations. Another assumption is that there is no significant difference between percentage distributions of automobiles available and automobile registrations.

X_2 = Total population
X_3 = Central city population
X_4 = Urban fringe population

1960 and 1950—U. S. Census of Population: 1960, "Number of Inhabitants, United States Summary," PC (1) 1A, U. S. Bureau of the Census, Table 22, p. 40, and Table 30.

Note: 1950 population data were not available for some areas. In these cases the county urban population was used for the total urbanized area population and urban place population was used for central city population.

X_5 = Low-income families
X_6 = High-income families
X_7 = Middle-income families
X_8 = Number of families
X_9 = Aggregate family income
X_{10} = Employed residents

1960—U. S. Census of Population: 1960, "General Social and Economic Characteristics," PC (1), state series, Tables 75, 76, 85, and 86. Compiled from County and City Data Book, 1962, Table 4, columns 217, 219, and 220.

1950—U. S. Census of Population: 1950, Vol. 2, "Characteristics of the Population," part for each state, Tables 35, 37, 43, and 45, and County and City Data Book, 1952.

Note: Low-income families are those with incomes under $2,000 in 1950 and under $3,000 in 1960. High-income families had incomes of $5,000 or more in 1950 and $10,000 or more in 1960.

For a considerable number of areas, 1950 data are not available. In such cases, estimates for the urbanized area were based on the central city percent distribution of families by income class (County and City Data Book, 1952, Tables 3 and 4).

Aggregate family income was obtained by multiply the number of families by the median family income.

Shift-Share Approach

Many of the problems of data comparability were largely overcome through use of a shift-share approach to the empirical analysis. Data for 1950 and 1960 were compiled in absolute terms for the urbanized areas in each of five transportation classes and four census regions.

The amount attributable to each urbanized area was then expressed as a percent share of the class or regional total in which it was classified. The ratios of the 1960 shares to those of 1950 became the basic measures used in this analysis. This, then, became an analysis of relatives, with the ratios of the 1960 to 1950 shares providing a cross section of change in the 10 variables for each urbanized area, relative to the cross section of change for the other urbanized areas of the same type or region.

Use of percent shares made it possible to compare the values of certain variables in 1960 to their 1950 values, although the definitions of the variables differ somewhat between the two years. The number of automobiles registered in 1950, for example, is not comparable to the number of automobiles available in 1960. By assuming uniformity among the urbanized areas in the difference between the two, the percent shares in 1950 and 1960 became comparable.

Use of percent shares also made it possible to use data for standard metropolitan statistical areas as surrogates for urbanized area data. It was assumed that the percent distributions would not differ significantly.

Estimated percent shares for a group of urbanized areas are applied to a total amount for the entire group to get estimates in absolute amounts for each urbanized area. Estimates of the future total number of automobiles available for the groups of urbanized areas are made on the basis of growth rates implied in forecasts of statewide automobile registrations prepared by state highway departments, as will be shown later.

Multiple Regression Analyses

The multiple regression method was used to analyze relationships between the 1960 to 1950 change in automobile availability (the dependent variable) and change in income, employment, and population (the independent variables as listed previously). Regression analyses were also made using population, employment, and income variables alternately as dependent variables. Due to problems of comparability for the two years, several areas were combined. The New York-Northeastern New Jersey area was excluded because it was the only one in Type F. Output from these regression analyses included equations for predicting the ratio of change in shares of automobiles available in urbanized areas of each transportation type and census region; measures of predictability and reliability such as the standard error of estimate, the multiple regression coefficient, and the coefficient of multiple determination; and forecasts to 1975 and 1990 of the number of automobiles available in 28 Type A urbanized areas.

RESULTS

Nine Regression Models

Multiple regression analyses of the growth data for one dependent variable and nine independent variables produced nine model equations; one for the urbanized areas in each of five transportation classes, and one for the areas in each of four census regions. Table 1 lists these equations along with measures of their accuracy in estimating future growth rates for typical urbanized areas, and for those in a certain section of the country. Differences in the construction of these equations are readily apparent.

Although nine independent variables were used, not more than two emerged from any one analysis as being significantly related to change in automobile availability. This result is due partly to the requirement of a 5 percent minimum F level in order for the independent variable to enter. If, after entry, the F value fell below the 5 percent level of significance, that independent variable was removed from the equation. This procedure is in keeping with the objective of developing simple equations with a minimum of critical variables. In the cases of equations for Type A and E areas, this minimum is one independent variable.

Of the nine independent variables analyzed, only two—low-income families (X_5) and middle-income families (X_7)—do not appear in any of the nine equations. High-income families—the other indicator of income distribution—appears once as the determining factor in Type E areas.

Type A Areas Analyzed

Regression analysis of the 1960 to 1950 ratios of the percent-share distribution of the variables among urbanized areas classified as Type A resulted in the following equation

$$X_1 - 0.2884 + 0.83404X_2$$

TABLE 1

REGRESSION MODELS FOR USE IN FORECASTING AUTOMOBILES AVAILABLE BY URBANIZED AREAS IN FIVE TRANSPORTATION TYPES AND FOUR REGIONS

Urbanized Area	No. of Areas	Constant	First Independent Variable	Second Independent Variable	Standard Error	Correlation Coefficients	
						R	R^2
Type A	28	0.28840	$0.83404X_2$	—	0.2253	0.863	0.7442
Type B	31	-0.19019	$0.65567X_3$	$0.56771X_9$	0.1346	0.901	0.8124
Type C	62	0.22008	$0.52842X_8$	$0.26688X_3$	0.1442	0.905	0.8185
Type D	61	0.55390	$0.81037X_3$	$0.77624X_8$	0.3490	0.993	0.9852
Type E	15	0.41353	$0.65262X_6$	—	0.1153	0.728	0.5297
Region I (Northeast)	34	0.53545	$0.53379X_{10}$	$-0.08414X_4$	0.0718	0.483	0.2333
Region II (North Central)	58	0.42003	$0.39640X_9$	$0.16364X_3$	0.0755	0.592	0.3508
Region III (South)	77	0.32562	$0.48945X_2$	$0.19741X_3$	0.2482	0.756	0.5724
Region IV (West)	28	0.47987	$0.78820X_9$	$-0.13670X_4$	0.2407	0.779	0.6062

in which X_1 equals the predicted ratio of the percent share of automobiles available and X_2 equals the ratio of the percent share of total population. This equation is shown as Part A at the top of Table 2. Part B of the same table gives the standard error of estimate ($S_{1.2}$), the multiple correlation coefficient ($R_{1.2}$), the coefficient of multiple determination ($R^2_{1.2}$), and other measures.

It is significant that, of the nine independent variables analyzed, only total population, in passing the F test at the 95 percent confidence level, emerged as an explanatory variable. One reason for this outcome may be that intercorrelations among the independent variables are high enough, in this case, so that none of the eight remaining variables could significantly add to the explanatory power of the total population variable.

It is likely, however, that the similarity of urbanized areas of this type, in their dependence on the automobile for transportation, is chiefly responsible for the close association between automobile and population growth rates. Persons migrating into these areas and residents of these areas who come of driving age have great need for automobiles because of the distances between locations of residence, occupation, recreation, and other centers of activity and, therefore, these persons are likely to buy automobiles with a minimum of regard for income and/or employment.

Stated differently, the characteristic spread-city, low-density structure of the urbanized areas in the highest automobile availability class is conducive to automobile

TABLE 2

TYPE A—PREDICTED AUTOMOBILES AVAILABLE

A. Estimating equation: $X_1 = 0.28640 + 0.83404(X_2)$. $S_{b_{1.2}} = 0.09352$.

B. $R^2_{1.2} = 0.7442$; $R_{1.2} = 0.863$; $S_{1.2} = 0.2253$; $\overline{X}_1 = 1.2377$. $S_{1.2} \div \overline{X}_1 = 18$ percent. $N = 28$.

C. Automobiles available in 1960—predicted vs actual.

Urbanized Area	1950 Percent of Total	Predicted Ratio[a]	1960 Automobiles Available			Difference from Actual	
			Percent of Total[b]	Predicted[c]	Actual	Number	Percent
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Los Angeles-Long Beach, Calif.	61.6734	1.04179	56.9830	2,754,815	2,572,209	182,606	7.1
San Diego, Calif.	5.1438	1.18475	5.4048	261,293	295,916	-34,623	-11.7
San Jose, Calif.	3.5689	1.87425	5.9324	286,800	232,188	54,612	23.5
Phoenix, Ariz.	2.8496	1.47441	3.7263	180,147	203,742	-23,595	-11.6
Sacramento, Calif.	2.9483	1.27900	3.3444	161,684	174,733	-13,049	- 7.5
San Bernardino-Riverside, Calif.	2.6923	1.03804	2.4786	119,827	143,182	-23,355	-16.3
St. Petersburg, Fla.	1.8455	1.27800	2.0917	101,123	125,609	-24,486	-19.5
Fort Lauderdale-Hollywood, Fla.	0.9758	2.57944	2.2323	107,920	126,470	-18,550	-14.7
Albuquerque, N.M.	0.9562	1.29142	1.0952	52,947	83,258	-30,311	-36.4
Tucson, Ariz.	1.0859	1.63622	1.5758	76,182	82,585	- 6,403	- 7.8
Spokane, Wash.	1.9857	0.88666	1.5615	75,490	80,469	- 4,979	- 6.2
Tacoma, Wash.	1.9763	0.88308	1.5478	74,828	73,555	1,273	1.7
Fresno, Calif.	2.0320	1.04730	1.8874	91,246	79,335	11,911	15.0
Orlando, Fla.	0.9967	1.56382	1.3824	66,832	73,162	- 6,330	- 8.7
West Palm Beach, Fla.	1.0956	1.21336	1.1790	56,998	65,694	- 8,696	-13.2
Bakersfield, Calif.	1.3643	0.77332	0.9357	45,236	53,765	- 8,529	-15.9
Amarillo, Texas	0.8247	1.14855	0.8401	40,614	51,144	-10,530	-20.6
Wichita Falls, Texas	0.7581	0.87774	0.5901	28,528	34,887	- 6,359	-18.2
Colorado Springs, Colo.	0.7025	1.14163	0.7113	34,388	39,070	- 4,682	-12.0
Eugene, Ore.	0.8177	1.17216	0.8501	41,098	35,710	5,388	15.1
Abilene, Texas	0.7344	1.21961	0.7944	38,405	34,413	3,992	11.6
Odessa, Texas	0.3936	1.61295	0.5631	27,223	32,571	- 5,348	-16.4
Santa Barbara, Calif.	0.6168	0.81802	0.4475	21,634	30,369	- 8,735	-28.8
Midland, Texas	0.2230	1.63997	0.3243	15,678	24,842	- 9,164	-36.9
Lawton, Okla.	0.3573	1.11627	0.3537	17,100	19,757	- 2,657	-13.4
Billings, Mont.	0.4545	1.08191	0.4361	21,083	23,001	- 1,918	- 8.3
San Angelo, Texas	0.4731	0.81218	0.3407	16,471	21,590	- 5,119	-23.7
Great Falls, Mont.	0.4538	0.97032	0.3905	18,879	21,243	- 2,364	-11.1

[a]Ratio of the 1960 share to the 1950 share, as predicted by the estimating equation.
[b]Column 1 times column 2; results adjusted to add to 100 percent.
[c]Number of automobiles obtained by applying the percents in column 3 to the actual total of automobiles available—4,834,469. "Actual" refers to observed data.

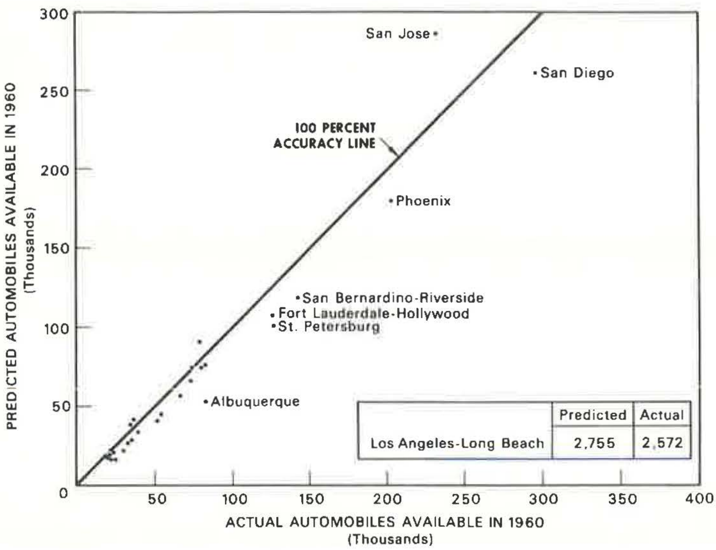

Figure 2. Predicted vs actual 1960 automobiles available in Type A areas.

travel, and the acceptance of automobile dominance by the residents virtually compels consumers in those areas to buy an automobile of any description at the earliest opportunity. With this in mind, it is reasonable to expect a Type A urbanized area to increase its share of automobiles at a rate that would be similar to the rate at which it raised its share of the population in all Type A areas. The coefficient of multiple determination ($R^2_{1.2}$) of 0.7442 means that among Type A urbanized areas 74 percent of the variation in the rates of increase in automobile shares is explained by the population shares. The standard error of estimate ($S_{1.2}$) of 0.2253 indicates that approximately 68 percent of the estimates of change in automobile shares produced by this equation would fall within the rather wide range of ± 0.2253 about the regression line.

Predictive Accuracy of Equation for Type A Areas

Part C of Table 2 gives results of tests in which the equation was used to predict the 1960 to 1950 ratios of automobile shares (column 2) based on recorded rates of change in population shares over the same 10-year period. The estimated growth rates are applied to the 1950 percent distribution to get the estimated 1960 percent distribution. The estimated total number of automobiles available in all Type A areas in 1960 is distributed among the areas on the predicted 1960 percent distribution. Differences between predicted and observed, or recorded data in the last two columns show that the equation generally underpredicts. All but 6 of the 28 urbanized area predictions are on the low side (Fig. 2).

It appears that one or more key underlying variables that might explain much of the 26 percent unexplained variance have been omitted from the analysis. Change in the age distribution of the population might be one factor. An above-average increase in the proportion of the population in the driving-age bracket would probably cause an equation using change in total population as the independent variable to underestimate automobile availability. The reverse, an overestimate of automobile availability, would be probable for an area with a declining proportion of its population in the driving-age group.

Projecting Forecasts to 1975 and 1990

Table 3 demonstrates the step-by-step method of projecting the number of automobiles available in the 28 Type A urbanized areas in 1975. Forecasts of the independent variable and total population had been prepared (in unpublished data) by Stanley Bielak

TABLE 3

PREDICTED AUTOMOBILES AVAILABLE IN TYPE A AREAS FOR 1975

Urbanized Area	Population					Automobiles Available			
	1975		Percent of Total, 1960	Ratio of Percent Shares, 1975-1960	Column 4 Times 0.83404[b]	Ratio of Percent Shares, 1975-1960[c]	Percent of Total		Forecast for 1975[e]
	Number[a] (thousands)	Percent of Total					1960	1975[d]	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Los Angeles-Long Beach, Calif.	9, 156	46.3173	50.3742	0.9194	0.76690	1.0553	56.9830	53.6877	4, 671, 903
San Diego, Calif.	1, 590	8.0433	6.4910	1.2391	1.03346	1.3219	5.4048	6.3787	555, 074
San Jose, Calif.	931	4.7096	4.6798	1.0064	0.83938	1.1278	5.9324	5.9734	519, 805
Phoenix, Ariz.	1, 111	5.6202	4.2854	1.3115	1.09384	1.3822	3.7263	4.5984	400, 153
Sacramento, Calif.	783	3.9609	3.5083	1.1290	0.94163	1.2300	3.3444	3.6726	319, 590
San Bernardino-Riverside, Calif.	569	2.8784	2.9307	0.9822	0.81919	1.1076	2.4786	2.4510	213, 286
St. Petersburg, Fla.	580	2.9340	4.8638	0.6032	0.50309	0.7915	2.0917	1.4781	128, 624
Fort Lauderdale-Hollywood, Fla.	631	3.1920	2.4835	1.2853	1.07199	1.3604	2.2323	2.7112	235, 929
Albuquerque, N.M.	442	2.2359	1.8725	1.1941	0.99593	1.2843	1.0952	1.2558	109, 280
Tucson, Ariz.	573	2.8986	1.7654	1.6419	1.36941	1.6578	1.5758	2.3323	202, 957
Spokane, Wash.	327	1.6542	1.7615	0.9391	0.78325	1.0716	1.5615	1.4939	129, 999
Tacoma, Wash.	318	1.6087	1.6683	0.9643	0.80426	1.0927	1.5478	1.5100	131, 400
Fresno, Calif.	333	1.6845	1.6567	1.0168	0.84805	1.1364	1.8874	1.9149	166, 635
Orlando, Fla.	348	1.7604	1.5597	1.1287	0.94138	1.2298	1.3824	1.5178	132, 079
West Palm Beach, Fla.	301	1.5227	1.3415	1.1351	0.94672	1.2351	1.1790	1.3001	113, 135
Bakersfield, Calif.	217	1.0977	1.1001	0.9978	0.83221	1.1206	0.9357	0.9361	81, 459
Amarillo, Texas	217	1.0977	1.0706	1.0253	0.85514	1.1435	0.8401	0.8577	74, 637
Wichita Falls, Texas	151	0.7639	0.7926	0.9638	0.80385	1.0922	0.5901	0.5754	50, 071
Colorado Springs, Colo.	208	1.0522	0.7779	1.3526	1.12812	1.4165	0.7113	0.8996	78, 283
Eugene, Ore.	132	0.6677	0.7422	0.8996	0.75030	1.0387	0.8501	0.7883	68, 598
Abilene, Texas	137	0.6930	0.7103	0.9719	0.81060	1.0990	0.7944	0.7794	67, 823
Odessa, Texas	125	0.6323	0.6537	0.9673	0.80677	1.0952	0.5631	0.5506	47, 913
Santa Barbara, Calif.	111	0.5615	0.5644	0.9949	0.82979	1.1182	0.4475	0.4468	38, 881
Midland, Texas	94	0.4755	0.4906	0.9692	0.80835	1.0968	0.3243	0.3176	27, 638
Lawton, Okla.	126	0.6374	0.4806	1.3262	1.10610	1.3945	0.3537	0.4403	38, 315
Billings, Mont.	98	0.4958	0.4712	1.0522	0.87758	1.1660	0.4361	0.4540	39, 507
San Angelo, Texas	69	0.3490	0.4565	0.7645	0.63762	0.9260	0.3407	0.2817	24, 514
Great Falls, Mont.	90	0.4553	0.4472	1.0181	0.84914	1.1375	0.3905	0.3966	34, 512

[a]Forecast by U.S. Bureau of Public Roads, Office of Planning, unpublished.
[b]Regression coefficient of 1960 to 1950 ratio of the percent share of total population related to 1960 to 1950 ratio of the percent share of automobiles available.
[c]Column 5 plus the constant in the forecast equation, 0.28840.
[d]Column 7 times column 6. Results adjusted to add to 100 percent.
[e]Independently forecast total of 8,702,000 distributed on forecast 1975 percent shares in column 8.

Source: Adapted from data of U.S. Bureau of the Census; stepwise multiple regression and total forecast estimates from Bureau of Public Roads, Office of Research and Development.

and James McCarthy of the Bureau of Public Roads Office of Planning. The percentage distribution of the population was calculated for 1975 and 1960. The 1975 to 1960 ratios of percent shares were then derived, and these ratios were then multiplied by the regression coefficient. The results for each area were added to the constant in the forecast equation to get an estimate of the ratio of change from 1960 to 1975 in each urbanized area's share of automobiles available. The estimated ratios of change are then applied to the 1960 percent distribution of automobiles available to get a percent distribution for 1975. The new percent shares for 1975 are then applied to an independently forecast total of automobiles available in all Type A areas in 1975 (last column). The forecast of this control total is based on state-by-state forecasts of automobile registrations prepared by state highway agencies. The same procedure was followed in developing 1990 forecasts (Table 4).

Usefulness of Forecasts

The projected numbers of automobiles available in 1975 and 1990 can be used as indicative of the total number of automobiles that would be available in an urbanized area in 1975 and 1990, should the 1950 to 1960 relationship between growth in population and automobiles available be maintained.

Recent trends in highway construction, particularly of urban freeways, indicate that this relationship is likely to be maintained. These trends in Type A areas have generally

TABLE 4

PREDICTED AUTOMOBILES AVAILABLE IN TYPE A AREAS FOR 1990

Urbanized Area	Population					Automobiles Available			
	1990		Percent of Total, 1960	Ratio of Percent Shares, 1990-1960	Column 4 Times 0.83404[b]	Ratio of Percent Shares, 1990-1960[c]	Percent of Total		Forecast for 1990[e]
	Number[a] (thousands)	Percent of Total					1960	1990[d]	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Los Angeles-Long Beach, Calif.	12, 950	43.9803	50.3742	0.8731	0.72820	1.0166	56.9830	52.0886	6, 547, 536
San Diego, Calif.	2, 800	9.5093	6.4910	1.4650	1.22187	1.5103	5.4048	7.3399	922, 625
San Jose, Calif.	1, 280	4.3471	4.6798	0.9289	0.77474	1.0631	5.9324	5.6708	712, 820
Phoenix, Ariz.	1, 580	5.3659	4.2854	1.2521	1.04430	1.3327	3.7263	4.4653	561, 288
Sacramento, Calif.	1, 220	4.1433	3.5083	1.1810	0.98500	1.2734	3.3444	3.8294	481, 356
San Bernardino-Riverside, Calif.	770	2.6150	2.9307	0.8923	0.74421	1.0326	2.4786	2.3014	289, 286
St. Petersburg, Fla.	905	3.0735	4.8638	0.6319	0.52703	0.8154	2.0917	1.5336	192, 774
Fort Lauderdale-Hollywood, Fla.	1, 100	3.7358	2.4835	1.5042	1.25456	1.5430	2.2323	3.0971	389, 305
Albuquerque, N.M.	770	2.6150	1.8725	1.3965	1.16474	1.4531	1.0952	1.4310	179, 877
Tucson, Ariz.	1, 020	3.4641	1.7654	1.9622	1.63655	1.9250	1.5758	2.7276	342, 859
Spokane, Wash.	450	1.5283	1.7615	0.8676	0.72361	1.0120	1.5615	1.4209	178, 607
Tacoma, Wash.	453	1.5385	1.6683	0.9222	0.7692	1.0576	1.5478	1.4720	185, 030
Fresno, Calif.	470	1.5962	1.6567	0.9635	0.8036	1.0920	1.8874	1.8532	232, 947
Orlando, Fla.	530	1.8000	1.5597	1.1541	0.9626	1.2510	1.3824	1.5550	195, 464
West Palm Beach, Fla.	460	1.5622	1.3415	1.1645	0.9712	1.2596	1.1790	1.3354	167, 860
Bakersfield, Calif.	300	1.0188	1.1001	0.9261	0.7724	1.0608	0.9357	0.8925	112, 187
Amarillo, Texas	326	1.1071	1.0706	1.0341	0.8625	1.1509	0.8401	0.8694	109, 284
Wichita Falls, Texas	215	0.7302	0.7926	0.9213	0.7684	1.0568	0.5901	0.5607	70, 480
Colorado Springs, Colo.	384	1.3041	0.7779	1.6764	1.3982	1.6866	0.7113	1.0787	135, 593
Eugene, Ore.	192	0.6521	0.7422	0.8786	0.7328	1.0212	0.8501	0.7806	98, 121
Abilene, Texas	195	0.6623	0.7103	0.9324	0.7777	1.0661	0.7944	0.7615	95, 721
Odessa, Texas	179	0.6079	0.6537	0.9299	0.7756	1.0640	0.5631	0.5387	67, 715
Santa Barbara, Calif.	150	0.5094	0.5644	0.9026	0.7528	1.0412	0.4475	0.4189	52, 656
Midland, Texas	135	0.4585	0.4906	0.9346	0.7795	1.0679	0.3243	0.3114	39, 143
Lawton, Okla.	238	0.8083	0.4806	1.6818	1.4027	1.6911	0.3537	0.5378	67, 601
Billings, Mont.	157	0.5332	0.4712	1.1316	0.9438	1.2322	0.4361	0.4832	60, 738
San Angelo, Texas	76	0.2581	0.4565	0.5654	0.4716	0.7600	0.3407	0.2328	29, 263
Great Falls, Mont.	140	0.4755	0.4472	1.0633	0.8868	1.1752	0.3905	0.4126	51, 864

[a]Forecast by U.S. Bureau of Public Roads, Office of Planning, unpublished.
[b]Regression coefficient of 1960 to 1950 ratio of the percent share of total population related to 1960 to 1950 ratio of the percent share of automobiles available.
[c]Column 5 plus the constant in the forecast equation, 0.28840.
[d]Column 7 times column 6. Results adjusted to add to 100 percent.
[e]Independently forecast total of 12,570,000 distributed on forecast 1990 percent shares in column 8.

Source: Adapted from data of U.S. Bureau of the Census; stepwise multiple regression and total forecast estimates from Bureau of Public Roads, Office of Research and Development.

encouraged urbanization to continue in the traditional low-density land-use patterns that are conducive to automobile travel. If change should occur in this type of urban development, it would likely be at a very gradual rate since these communities are heavily committed, in terms of investment, to highway transportation and the type of urban development that accompanies this form of transportation. Considering the acceptability of the automobile to the public in Type A areas and the life of a highway, it does not seem politically feasible, under the local democratic process, to radically alter the course of urban development and/or the accumulation of automobiles.

The usefulness of the projected number of automobiles available for any single urbanized area depends on several considerations on the part of the user:

1. What is the purpose for which the forecast is needed and the degree of reliability in the forecast figure that the purpose requires?
2. Do the measures of reliability of the forecasting equation satisfy the first consideration?
3. Is the population forecast, which determines the automobile forecast, acceptable in view of the first-hand knowledge of local growth prospects?
4. Can the forecast totals of automobiles available in 1975 and 1990 be reasonably attained in view of major geographic, social, economic, or other constraints?

SUMMARY

This paper has described a method of projecting the number of automobiles available by urbanized area. The method involved the use of the following: urbanized area classifications; data on 1950 to 1960 shifts in shares (among the areas in each type) of the factors associated with increases in automobile availability; multiple-regression analyses of these shifts; development of estimating equations; and the use of independent forecasts at the national and state levels for deriving totals for each class using a stepdown technique.

The classification of urbanized areas into transportation types and regions proved to be useful analytical bases. Differences in the construction of the estimating equations show that factors associated with growth in automobile availability differ from one area type to another, and between regional locations. It was the classification, along with the shift-share approach, that overcame to a large extent the influence of such widely diverse elements as area size, density, and age, and permitted the influence of more relevant factors to come to light.

Type A Areas

In the case of the areas classified as Type A, change in total population (X_2) was the only independent variable found significantly related to growth in automobile availability (Table 1). These are the automobile-oriented areas of the Far West, Southwest, and Florida in which there is little or no alternative mode of transport from which to choose. Typically, these areas are spread out at low density and with considerable distances between residence and work and other locations. An automobile is, therefore, a necessity that a worker is likely to acquire at his earliest opportunity. Forecasts for these areas to 1975 and 1990 presume the continued expansion of these areas at the low, multinucleated densities that are conducive to automobile travel.

Type E Areas

At the other extreme, for areas classified as Type E, the one independent variable significantly related to increased automobile availability is the increase in high-income families (X_6). In these areas, which are not entirely committed to automobile travel, there is often the choice of an alternate mode such as bus, commuter train, or rail mass transit. These areas, typically, are heavily oriented toward a high-density central core that was established before the automobile era and are, therefore, not conducive to heavy automobile traffic. With the high cost of owning, insuring, operating, maintaining, and parking a car in these areas, it is not surprising that an increase in automobile availability should be a function of high-income families.

Other Types

Change in central city population (X_3) emerged from the analysis as one of two variables with positive relationship to change in automobile availability in area Types B, C, and D (Table 1). This result was due mainly to the fact that, for many small areas in each type, the central city comprises most, or almost all, of the entire urbanized area. The urban fringe population is often a small proportion of the area total. Shifts in shares of automobiles available between the areas in each of these types were, therefore, associated with shifts in the more heavily weighted central city population. In other words, there is a predominance of urbanized areas, with 70 or 80 percent or more of their populations in small- and medium-size central cities, in which automobile travel is not so constrained.

Another reason for the central city being an important factor in these analyses is the dominance of the central city in some of the large urbanized areas that have high levels of automobile availability. These central cities cover large land areas at low densities. Included are such areas as Houston, Dallas, and Oklahoma City.

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The Economic Benefits Accruing From the Scenic Enhancement of Highways

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•THE Highway Beautification Act of 1965 (Public Law 89-285, 79 Stat. 1028) is a joint attempt by the federal government and the various state governments to provide for scenic development and road beautification of federally aided highway systems. There are three major sections of the Act: Title 1 and Title 2 deal with provisions for limiting and controlling outdoor advertising and junkyards adjacent to highways, whereas Title 3 is concerned with the need for the landscaping and scenic enhancement of highway systems.

The primary objective of this study was to focus on Title 3 of the Act by concentrating on the problems involved in identifying and quantifying the benefits and costs that result from the beautification of highways.

In undertaking such a study, problems arise as to the selection of the proper method for evaluating the economic effects and social benefits of the scenic enchancement of highways. Also, confusion exists as to what constitutes "scenic enhancement." Moreover, the lack of proper data necessary for the determination and measurement of the effects of highway beautification has proved to be a troublesome factor.

Two procedures yielding two widely different measures of the expected effects of a highway beautification program can be suggested. The first, which has been suggested by the Bureau of Public Roads, is what can be called an economic impact study. This approach is a valid way of measuring the regional effects of scenic enhancement of highways on employment, income, and levels of economic activity in the area of the enhancement project. It fails to measure, however, the total net benefit of the proposed action to the whole nation and therefore it does not reveal whether the project should be undertaken in order to increase the national welfare. Instead, impact studies merely measure the "make work" capacity of a government project; hence, this type of analysis is relevant from the national viewpoint only as a measure of counterrecessionary efficacy—despite its obvious attractions to local real estate interests and local chambers of commerce.

Whereas economic impact studies reveal only the redistributive effects of government action on particular sectors within the economy, the use of the second type of study, a cost-benefit approach, can be made to reveal the costs or disadvantages to the nation as a whole and the benefits or advantages to society of the various alternative government programs, thus developing a systematic basis for analyzing the desirability of public expenditure on a scenic enhancement program. This approach can suggest the magnitude of net gain or loss to society from allocating economic resources to programs for scenic enhancement of highways.

The main problem of utilizing the cost-benefit approach in a study of the effects of a highway beautification program is in correctly enumerating and evaluating the benefits and costs involved. (The same problems are, of course, found in other areas in which cost-benefit analysis has been applied—weapons systems, air pollution, water resources use, etc.) Fortunately, the cost aspect seems to contain no major difficulties and can be readily ascertained from engineering estimates of the cost of scenic enhancement per mile of highway (although the problem of exactly what it is that constitutes

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"scenic enhancement" and how it differs from "highway improvements" has to be thoroughly defined). The identification and economic quantification of benefits is considerably more difficult, however, especially in the absence of market transactions.

THE PRESENT STATE OF THE PROBLEM

The existing literature on the economic importance of scenic beautification of highways is relatively small, thus suggesting that in the past there has not been much interest in the subject. One possible explanation of the cause of the paucity of analysis is that the benefits of beautification have been viewed as being intangible and incapable of being quantified. Accordingly, the use of resources to beautify highways has often not appeared justifiable. On occasion, proponents of beautification have had to argue that, at a minimum, some attempt should be made to preserve the existing natural beauty of the environment. Huff and Johnson (7) wrote, "The problem is not that man manipulates his environment to suit his own purposes. Rather it arises because this tampering has lacked integration and harmony with the physical resource base. Until recently, we have largely disregarded natural processes and misused the natural environment."

The attempt to merely preserve existing natural beauty requires a distinction between seeking to beautify and seeking to minimize ugliness (8). As has already been noted, there is little consensus of what is beautiful, and there exist no precise difinitions of the terms "highway beautification" and "scenic enhancement" (23, p. 10). Accordingly, some advocates of the position of the preservation of existing natural beauty feel that it would be easier to get a consensus of what is ugly.

To ensure that scenic countryside is not despoiled, however, will require resources to be allocated in a way to preserve best the natural beauty of the land. Accordingly, we must evaluate the benefits of beauty despite the incorporeal nature of the subject. As one investigator (13, p. 52) has noted, "The unsavory prospect of assigning numbers to a concept fraught with moral considerations must be balanced against the more unsavory concept of inadequate pollution control, strip-mined landscapes and rings of junkyards around our cities."

Different approaches to highway design and aesthetics have been taken by those interested in making our highways more beautiful. Several authors feel that probably the most important characteristic of a scenic highway is that it be properly integrated into the surrounding area. Tunnard, for example, has emphasized the external and internal harmony of the freeway (17). The State of Washington has established a number of visual criteria to evaluate highways according to their scenic merit (12, p. 18-20). Appleyard, Lynch, and Myer have suggested that the highway designer has to visualize the highway as the motorist and his passengers will see it, and then determine what this implies for highway design (1, p. 2).

Scenic enhancement of highways can have a functional aspect as well. Garmhausen suggests (6, p. 126) that "Aesthetic highway design pays off in added safety. Driver tension and fatigue, which are believed to be hidden causes of many automobile accidents, can be relieved by interesting highways and roadside development." According to this view highway design should be such that the driver can look ahead to see beauty. Safety rest areas should be provided along the road when breathtaking views are afforded.

There are many other ways in which the proper use of landscaping can bring functional beauty to the road rather than merely cosmetic beauty. Plantings along the road can provide erosion control, reduce need for guardrails, possibly reduce mowing requirements, and lessen driver monotony. Other functional uses of plantings include minimization of headlight glare, utilization for snow fencing, noise abatement, road focus, and directional "piloting for driver guidance." Northern states have experienced savings of up to $500 per mile in maintenance costs by using living snow fences (2, p. 78). Other savings can result from either the decreased maintenance requirement or from the increased safety of the highway. Plantings can also be useful to screen undesirable or distractive views, hide litter, and reduce fumes. Finally, it has been pointed out that the scenic qualities of a highway often last longer than the highway itself (16, p. 42; 23, p. 225).

Thus far no attempt has been made to systematically quantify the benefits of highway beautification. Where specific public investment projects are involved, benefit-cost analysis has been used primarily when the benefits have been tangible, i.e., readily measurable by a market process. There has been considerable divergence of opinion on the proper use of benefit-cost analysis when intangible or nonmarket benefits are involved (15, p. 728). Nevertheless, most economists would agree with Tunnard, who feels that the attempt to measure the benefits of highway beautification should be made to "prove that beauty can pay off" (17, p. 205-206).

The major benefits from scenic enhancement of highways, aside from possible reduction in maintenance costs, are increased safety and greater pleasure for the highway user. Thus, it should be possible to hypothesize a relationship between the aesthetic character of the road and the safety that could be tested statistically. To establish conclusive proof of the relationship between visual qualities of the road alignment and accidents or fatalities, it would be necessary to isolate the aesthetic factor by eliminating influences such as traffic volume and traffic stream characteristics, manner of operation, degree of law enforcement, and technical design faults, according to Tunnard (17, p. 205).

In this study, it has been possible to statistically quantify such a relationship between safety and scenic highways. Benefits derived from providing pleasure to highway users can be viewed as being similar to benefits derived from engaging in any outdoor recreational activity. Evaluation of these benefits is a problem that recently has received considerable attention (3, 4).

Certainly, it may be difficult to quantify accurately "the immediate enjoyment which consists of the sense of pleasure experienced immediately before, during, and after participation in outdoor recreation," and it is perhaps even more difficult to measure the long-term benefits that may be both physical and psychic or the type of benefits that may be received by the nation as a whole (5, p. 57-58). Often, statements are made that "outdoor recreation fills some profoundly felt need; that it has personal, unique, and highly variable values for individuals; that outdoor recreation defies any kind of measurement; or simply that it is priceless.... [Nevertheless, most economists believe that] such values are directly reflected in economic values and that there is no irreconcilable conflict between the social values and the more specific economic values" (3, p. 213).

Analysis of a driver's preference for scenic highways provides some clues to the benefits of highway beautification. "Surveys of motorists' desires show that scenic or beautiful highways are preferred by nearly all highway users. Some motorists have such a strong preference for scenic routes that they will travel farther or longer in order to traverse a scenic highway" (23, p. 180).

A study by Michaels (10, p. 107) tends to support the conclusions obtained from the surveys: "It was found that a freeway with complete control of access and good geometric design generates significantly less driver tension than less rigorous designs." In a subsequent publication (9, p. 235), the same author concluded that "Whenever the alternates available are equally stress inducing, drivers will always choose the route that takes the least time. From the results of the study reported, drivers will actually tolerate a time loss, as well as a distance loss, if the total stress to which they may be subjected is perceptibly reduced."

Conceivably, evidence of drivers' preference for scenic highways could be used to measure some of the benefits from scenic enhancement of highways. This is the basis of the approach to the problem in this study.

Thus, possible benefits derived from scenic enhancement of highways appear to fall into three major categories: (a) visual pleasures that make a trip more enjoyable, (b) a possible improvement in safety, and (c) a possible difference in highway maintenance costs. (A possible alteration in the time of trips does not appear to have been seriously considered by other investigators. An apparent lack of data prevented us from analyzing this category.) The measurement of these benefits, once they are identified, however, hinges on the availability of appropriate data to determine the significance and magnitude of the benefits as well as their economic value and particular applicability

TABLE 1

NEW JERSEY HIGHWAY DATA

Variable	Symbol	Description
Scenic classification	S	0 if not scenic, 1 if scenic
Length	L	Length (miles) of highway segment
Volume of traffic	V	Average annual daily traffic ($\times 10^{-2}$)
Accidents	A	Total annual accidents for highway segment
Injuries	I	Total annual injuries for highway segment
Fatal accidents	F	Total annual fatal accidents for highway segment
Lanes	N	Number of lanes for the segment
Roadway width	WN	Road width in one direction (feet)
Median type	M1	0 if undivided, 1 if divided
Median width	MW	Width of median
Traffic signals	R	Number of traffic signals per mile
Access points	C	Number of access points per mile
Access control	C_O	0 full or partial control, 1 no access control
Type area	YP	0 if business area, 1 if rural or residential
Speed limit	P	Speed limit in miles per hour
Median type	M2	0 if other, 1 if barrier median

to the populations of specific states having widely different social and economic characteristics affecting highway use.

Preliminary investigation of the available literature revealed that very little data had been collected primarily for the purpose of allowing selected benefits of scenic enhancement to be analyzed by statistical techniques. Data related to the aesthetic benefits derived from scenic enhancement, for example, seemed to be almost entirely lacking. Given the time limitations of our study, it did not seem that this problem could be surmounted by a sample survey.

Accordingly, data collected from various sources for other purposes were utilized (a) to enumerate and evaluate the persons who engaged in driving for visual enjoyment (benefits), and (b) to see if differences in accident rates could be statistically associated with scenically enhanced highways.

ANALYSIS OF THE RELATIONSHIP BETWEEN SCENIC HIGHWAYS AND SAFETY

Tunnard has argued that scenic highways are safer highways. Accordingly, we attempted to test the hypothesis that when statistical account was taken of other factors such as volume, speed limit, traffic signals, and medians, there was no relationship between scenic highways and reduction in accidents, injuries, and fatalities. Two sources of data were used in this analysis—one related to the New Jersey highways and one related to the highways of Washington State.

New Jersey Highway Data

The data on New Jersey highways, furnished by the New Jersey Highway Department, consisted of observations of 92 segments of New Jersey state highways selected arbitrarily. Eleven highway variables plus the number of accidents, injuries, fatal accidents, and traffic volume were observed on these highway segments. Each road segment was classified as either scenic or not scenic. The variables included in the data and used in our empirical analysis are given in Table 1.

In the regression analysis of the data, three dependent variables were used: accidents per vehicle-mile, injuries per vehicle-mile, and fatal accidents per vehicle-mile. The purpose of regression analysis was to try to explain the variation of these three dependent variables by the variation of the highway characteristics and by whether the highway was scenic or not.

Many possible combinations of variables were tested. In general, a good statistical relationship between fatalities per vehicle-mile and any of the independent variables was not established. On the other hand, the scenic coefficient was normally significant in regressions on injury per vehicle-mile, whereas it was, at best, only occasionally marginally significant in accident per vehicle-mile regressions. The best fitting injury per vehicle-mile regression used only three independent variables: the scenic variable, number of traffic signals, and number of lanes. It is

$$\text{Injury per vehicle-mile} = 0.0547 - \underset{(0.0127)}{0.0289\,S} + \underset{(0.0021)}{0.0043\,R} + \underset{(0.0045)}{0.0168\,N} \qquad (1)$$

where the numbers in parentheses below the coefficients are the standard errors of the coefficient. The R^2 was 0.18 (adjusted for degrees of freedom) and the F-test was 7.87, which means that at the 0.95 confidence level, one can reject the hypothesis that the explanatory variables in this equation do not exert any influence over the dependent variable, injuries per vehicle-mile.

The equivalent equations for accidents and fatalities are as follows:

$$\text{Accidents per vehicle-mile} = 0.0399 - \underset{(0.0179)}{0.0231\,S} + \underset{(0.0030)}{0.0038\,R} + \underset{(0.0064)}{0.0310\,N} \qquad (2)$$

where $R^2 = 0.2115$ and F-test = 9.14, and

$$\text{Fatalities per vehicle-mile} = 0.0024 + \underset{(0.0006)}{0.0009\,S} - \underset{(0.00010)}{0.00002\,R} - \underset{(0.0002)}{0.0003\,N} \qquad (3)$$

where $R^2 = 0.0231$ and F-test = 1.72

The scenic coefficient is not significant for either accidents or fatalities per vehicle-mile. Moreover, the poor fit of the fatalities regression is consistent with results for various combinations of the independent variables. Apparently, the "explanatory" pattern for fatalities involves different variables than those for accidents or injuries.

Although a relationship had been identified (Eq. 1) that disproved the null hypothesis that scenic highways are unrelated to the injury rate, it was felt that because the ability to demonstrate only occasionally a marginally significant effect for accidents and no pattern at all for fatalities, it would be desirable to test these hypotheses against more data.

Washington State Highway Data

It was extremely fortunate that a study of the scenic merit of Washington state highways had just been completed. In this study, Norton and Robertson (12) rated 111 highway segments containing 3,754 miles of Washington state highways for their scenic value. The criteria utilized for obtaining a scenic rating were based on an earlier study (24).

The Norton study merely provided scenic coefficients for 111 different road segments of the Washington state highway system. For these particular segments of road, other information had to be obtained. The job involved matching scenic segments from the Norton study with segments of road from the Washington State Highway Commission's 1965 Rural State Highway System Accident Report. From the Accident Report the following information was obtained: (a) section length (miles); (b) average daily traffic volume; (c) number of fatal accidents; (d) total accidents; and (e) number of persons injured.

The Norton scenic segments were compared with the similar segments of road in the Accident Report and the information was collected. Because of differences in classifying highway segments, it was not possible to maintain 111 segments and consequently the total number of observations was reduced to 89. This was primarily because, at times, two or more Norton scenic segments corresponded to only one segment of the Accident Report, thus requiring two or more separate Norton segments to be spliced together to equal one Accident Report segment. Consequently, the original number of observations was reduced. For example, the Norton survey number 91 is from Elbe to Morton (16.4 miles) and number 92 is from Morton to Kosmos (8.4 miles), but the Accident Report segment covered the area from the GCT of SR141 (Kosmos) to the Pierce County line (Elbe), 22.8 miles. The mileage is fairly close and the difference results from the inclusion of the twon area in the Accident Report and not in the Norton Survey. Because the Accident Report covered the two Norton segments in one entry, one observation was lost. In total there were 21 such overlay matches that resulted in combining two or more Norton segments to equal one Accident Report segment. In all these cases the different scenic coefficients were averaged and applied to the whole of the Accident Report segment. The only other troublesome type of case occurred when two or more Accident Report road segments were equal to one segment in the Norton survey. This problem, however, did not result in losing any observations. In this latter case, traffic volume for the different segments was averaged, and the accident, injury, and fatality information was totaled. In general, the matching of the Norton scenic segments with the road segments of the Accident Report was successful.

Further information on the remaining 89 road segments was required, in particular the number of lanes, the type of road surface, and the width of the road. This information was obtained from the 1966 log of the Washington state highway system. Information was also obtained on the number of major intersections that each of the 89 road survey segments had by consulting the 1966 Washington state highway map. Unfortunately information on the number of traffic signals or the speed limit on these 89 road survey segments was not readily obtainable.

Information about the sample of 89 road segments was then collected to include a scenic coefficient, section length (miles), average daily traffic volume, number of fatal accidents, total accidents, number of persons injured, number of lanes, type of road surface, width of road surface, and number of major intersections. This was the basic information used in the regression analysis. These variables were used in the form given in Table 2 in the regression analysis.

TABLE 2

WASHINGTON STATE HIGHWAY DATA

Variable	Symbol	Description
Scenic coefficient	S	Quantitative rating of scenic merit of highway segment
Accidents	A	Total annual accidents for highway segment
Injuries	I	Total annual injuries for highway segment
Fatal accidents	F	Total annual fatal accidents for highway segment
Traffic volume	V	Average daily traffic volume for highway segment
Road length	L	Highway segment length (miles)
Width	W	Width of road (feet)
Type of surface	T^1	0 if one type surface, 1 if combination of surface types
	T^2	0 if other than asphalt or bituminous, 1 asphalt or bituminous or both
Major intersections	MI	Number of major roads intersecting the highway segment
Lanes	N	Number of lanes in each highway segment

Several different regressions using the various independent variables were tried. Although the R^2 regressions were somewhat lower, the results seemed to be consistent with the New Jersey highway findings—that is, a significant negative relationship between scenic highways and injuries per vehicle-mile. Two of the best equations obtained were as follows:

$$\text{Injuries per vehicle-mile} = \underset{}{0.0748} - \underset{(0.0008)}{0.0019\,S} \tag{4}$$

where $R^2 = 0.0536$ and F-test = 5.98, and

$$\text{Injuries per vehicle-mile} = 0.1174 - \underset{(0.0008)}{0.0019\,S} - \underset{(0.0012)}{0.0019\,W} + \underset{(0.0099)}{0.0165\,T_1} - \underset{(0.0015)}{0.0017\,M_1} \tag{5}$$

where $R^2 = 0.0776$ and F-test = 2.85. No significant relationship was established between scenic highways and either accidents or fatalities.

Although the computation of the scenic coefficient for the Washington highway segments is somewhat arbitrary, it has one big advantage over the 0, 1 "dummy" scenic variable used in the New Jersey study; i.e., it displays degrees of "scenicness" on a scale from 1 to approximately 30. Accordingly, it was possible to fit a logarithmic form to the Washington data. This form remarkably improved the fit of Eq. 5. It thus became

$$\text{Log of injuries per vehicle-mile} = -1.8925 - \underset{(0.0184)}{0.2422 \log S} + \underset{(0.0259)}{0.0714\,W} + \underset{(0.2162)}{0.8058\,T_1} - \underset{(0.0330)}{0.0045\,M_1} \tag{6}$$

where $R^2 = 0.2677$ and F-test = 8.68.

This equation implies, for example, that a 10 percent increase in scenicness (as measured on the Norton scale) would lead to a 2.4 percent reduction in injuries per vehicle-mile, all other things being equal.

The equivalent equations for accidents and fatalities are

$$\text{Log accidents per vehicle-mile} = -1.9129 - \underset{(0.0783)}{0.1567 \log S} + \underset{(0.0249)}{0.0856\,W} + \underset{(0.2079)}{0.5642\,T_1} + \underset{(0.0318)}{0.0273\,M_1} \tag{7}$$

where $R^2 = 0.2350$ and F-test = 7.45, and

$$\text{Log fatalities per vehicle-mile} = -3.7813 - \underset{(0.0939)}{0.0962 \log S} + \underset{(0.0251)}{0.0470\,W} + \underset{(0.2400)}{0.1012\,T_1} - \underset{(0.0326)}{0.0462\,M_1} \tag{8}$$

where $R^2 = 0.0826$ and F-test = 1.99. Accordingly, the logarithmic relationship for the scenic coefficient is marginally significant with respect to accidents and not significant for fatalities.

Conclusions on Scenic Effects on Safety

In conclusion, our analysis definitely indicates that (a) there is a significant negative relationship between scenic highways and injuries; (b) there is some evidence of a

TABLE 3

ESTIMATES OF REDUCED INJURIES AND RESULTING COST BENEFITS

Daily Traffic Volume per Mile of Highway	Annual Traffic Volume per Mile of Highway	Annual Reduction in Injuries per Mile	Annual Reduction in Injury Costs ($)	Capitalized Value ($)
100	36, 500	0.029	87	1, 740
1, 000	365, 000	0. 29	870	17, 400
10, 000	3, 650, 000	2. 9	8, 700	174, 000
20, 000	7, 300, 000	5. 8	17, 400	348, 000
27, 397. 25	10, 000, 000	8. 0	24, 000	480, 000
30, 000	10, 900, 000	8. 7	26, 100	521, 000
40, 000	14, 600, 000	11. 6	34, 800	695, 000
50, 000	18, 300, 000	14. 5	43, 500	870, 000

negative (log) relationship between scenicness and accidents, although a linear arithmetic relationship is not readily discernible; and (c) there is no obvious relationship between scenic highways and fatalities.

Having therefore verified the correctness of our New Jersey highway relationship, at least for injuries, it is possible to compute that, according to Eq. 1, a scenic highway will have approximately eight fewer injuries per year per 10 million vehicle-miles than a nonscenic highway. In 1966, the average nonfatal injury cost in New Jersey was $3,000. This implies that if there is a 1-mile segment of New Jersey highway on which the average daily volume is 27,397.25 vehicles (or 10 million per year), then if this highway is scenic, there will be eight fewer injuries per year than if it is not scenic. Accordingly, scenically enhancing such a nonscenic highway segment will mean a savings to the New Jersey public of $24,000 per year in injury costs. Capitalizing this savings in injury costs at a 5 percent interest rate, the present value over time is $480,000. Consequently, if this hypothetical 1-mile segment of highway is presently nonscenic, then the community could spend up to a maximum of $480,000 for scenic enhancement and be no worse off than before. In fact, to the extent that either less than $480,000 is spent, and/or the users of the highway get increased pleasure merely from using the highway (independent of the improved safety), the welfare of the community will be improved.

Obviously if the highway segment has a different volume of traffic per mile, then a different maximum sum could be spent on scenic enhancement and still improve the welfare. Table 3 lists the estimated annual reduction in injuries per mile and the capitalized cost savings (benefits) that would result from scenically enhancing 1-mile segments of highway having different annual traffic volumes.

BENEFITS DERIVED FROM DRIVING FOR PLEASURE

A survey of 922 households done by the Michigan Survey Research Center in the fall of 1959 was the basic source of data for the analysis in this section. Among the many socioeconomic and attitudinal questions asked of each household was one about the frequency of engaging in pleasure driving during the preceding 12 months.

A multivariate regression analysis of these data was undertaken to isolate the significant variables that influence one's desire to engage in pleasure driving. Our concern was, of course, not only with whether a person went pleasure driving or not, but also the number of times during the year that such an event occurred. The natural approach might be to use days of pleasure driving as the dependent variable, regarding those who did not go as zero days. There is a statistical weakness in this approach, however, because there may be many nonpleasure drivers. This would lead to a concentration of values at zero, although there can be no negative observations. Thus, although an estimated linear regression relation will have a tendency to be above the axis over the relevant range, the relationship will tend to be very flat because of the bunching of the zero observations. This will lead to an underestimate at the high end of the relationship. Thus the normal regression model is likely to be inappropriate when the variation of the dependent variable is bounded and there is a concentration of observations at the boundary.

To avoid this problem, the regression analysis is normally broken into two stages. Initially, the regression analysis is utilized to determine the conditional probability of participation in pleasure driving by a dummy dependent variable with a 0 vs 1 code for no participation during the past 12 months vs participation (regardless of amount). When the first stage, which indicates the major significant explanatory variables that affect the probability of engaging in this activity, is completed, then the zero participants are normally removed from the sample and the actual number of days of participation is used as the dependent variable of the pleasure driving sample population. In the present study, it would have been desirable to carry out both the first and second stage of this regression procedure in order to explain the amount of participation in terms of number of days. Considerable experimentation, however, revealed that because the Michigan survey data had an open-ended terminal class group of all those who participated more than 4 days, it was impossible to significantly distinguish among most of the participants; accordingly, the approach had to be modified at the second stage as explained below.

Table 4 gives the variables used in the analysis. In general, the independent variables tested consist of two types—socioeconomic variables (e.g., age, income, sex,

TABLE 4

VARIABLES CONSIDERED IN ANALYSIS OF DRIVING FOR PLEASURE

Variable	Symbol	Description
Age of car	C	Discrete midpoint values of class intervals
Income	Y	Discrete midpoint values of class intervals
Pleasure driving	D	1 if pleasure driving, 0 if not pleasure driving
Use of car	F1	1 if car used for pleasure, 0 if other uses
	F2	1 if car used for pleasure and/or vacation, 0 if other uses
	F3	1 if car used on vacation, 0 if other uses
Age of head of household	A	Discrete midpoint values of class intervals
Life cycle	L1	1 if children in household, 0 if no children in household
	L2	1 if children under 14 years of age in household, 0 if no children under 14 years of age in household
Urbanization	U1	1 if suburban or rural location, 0 if urban location
	U2	1 if rural location, 0 if other location
Occupation	O1	1 if white-collar, 0 if blue-collar
	O2	1 if not working, 0 if employed
Region	G1	1 if Northeast or North Central, 0 if other
	G2	1 if Northeast, 0 if other
Sex	SX	1 if male, 0 if female
Race	R	1 if white, 0 if nonwhite

race), and locational or physical variables (i.e., variables related to region of the county, urban-nonurban environment, and age of car).

Pleasure driving is apparently a ubiquitous phenomenon with almost 80 percent of the households in the sample indicating some engagement in this activity in the 12 months prior to the survey. Moreover, 12 percent indicated that they wished to participate even more often than they had in the past year. Unfortunately, the data do not indicate whether the inaccessibility of facilities or some other factor is constraining participation in pleasure driving.

Factors That Affect Driving for Pleasure

This analysis has provided some interesting results. It was found, for example, that the age of the car was not a significant variable in explaining the probability of participation. Apparently if an individual goes pleasure driving, his demand for this activity is not impaired by the age of his car. Moreover, neither the region of the country nor the degree of urbanization of the area in which the respondent resides affects the probability of his engaging in this activity.

Income, age, the sex of the respondent, and whether he is employed full-time or not are the major factors that explain the probability of driving for pleasure.

The best equation was found to be

$$D = 0.7406 - \underset{(0.0011)}{0.0047\,A} - \underset{(0.0261)}{0.0511\,SX} + \underset{(0.0166)}{0.0902\,Y} - \underset{(0.0010)}{0.0050\,Y^2} - \underset{(0.0459)}{0.1372\,O_2} \qquad (9)$$

where $R^2 = 0.1525$ and F-test = 32.77. This equation may be interpreted by substituting the particular value of a variable describing an individual. If the classical assumption of orthogonal variables holds (that is, independence in the statistical sense), then the magnitudes derived from substituting each of the values describing a particular individual in this equation are additive, and yield a conditional probability of driving for pleasure, given the particular values that have been used to describe this individual. Furthermore, if a certain characteristic pertaining to an individual is unknown, then the mean value for this variable can be substituted, and the probability becomes a conditional probability, given each particular characteristic known and the mean value for the substituted variables.

The constant term in the equation is 0.7406. The magnitudes in the equation are added to and subtracted from this value to yield the conditional probability. The coefficient of age is -0.0047; hence, as the age of the sample person increases, the probability of driving for pleasure falls at the rate of 0.0047 for each yearly increase in age. Thus the probability of a 40-year-old individual going pleasure driving is 0.094 less than a 20-year-old who has all the same socioeconomic characteristics except age. Accordingly, despite the fact that driving does not require strenuous physical activity, or agility normally associated with youth, age does reduce the probability of participation.

The importance of income is fairly obvious, at least at low levels of income, because some minimum is required to own or at least operate a car for pleasure. Our analysis shows that 40 percent of the sample population whose income is below the $3,000 poverty line did not participate in pleasure driving at all. This compares with 24 percent whose income is between $3,000 and $4,999, 12 percent of the $5,000 to $7,499 income group, and 8.6 percent of the $7,500 to $9,999. Only in the $10,000 and over group does the proportion of the population not participating reverse this downward trend; 20.5 percent in the highest income group did not participate.

The conditional probability analysis of the effect of income shows that the probability of pleasure driving increases with rising income to a level of approximately $17,840, when it begins to decline. This suggests not only that some income above the poverty level is necessary to engage in pleasure driving, but also that at the highest income levels the pull of competing activities (either recreational or vocational) reduces the probability of pleasure driving for the rich. Accordingly, both the very rich and the very poor are less likely to drive for pleasure.

We attempted to delve further into this interesting income effect to find out what proportion of the population indicated a preference to engage in even more pleasure driving activity than they did in the observed 12-month period. We found that 16.4 percent of the below-$3,000 class wanted to pleasure drive more than they did before. This compares with 11.3 percent for the $3,000 to $4,999 class, 9.3 percent for the $5,000 to $7,499 class, 12.1 percent for the $7,500 to $9,999 class, and 11.1 percent for the $10,000 or more class. Thus the top two classes show increasing preference for more pleasure-driving activity. Since it would not appear that lack of income would be the constraint for these high-income individuals, it may well be that the pull of vocational activities limits the pleasure driving of the rich.

The level of income is a reflection of the opportunity cost between leisure and work. Although the average factory worker's income may be restricted somewhat by a standard work week, additional income can be earned by moonlighting. Even more important, the higher incomes of executives and professionals are often directly associated with the number of hours per day, and/or days per week, and/or weeks per year, that they work. Thus, for these individuals the opportunity cost in terms of a day's loss in income by engaging in pleasure driving may be very great. Consequently, it is not surprising to find this opportunity cost effect outweighing the income effect for pleasure driving at high-income levels.

Despite this pronounced income effect, we have not been able to identify differences in the probability of participation between white-collar and blue-collar occupations. We note, however, that people who are not normally in the labor force (that is, housewives, students, retired people, etc.) have a significantly lower probability of pleasure driving (even after their income level is taken into account) than those who normally are in the labor force. According to our equation, a worker has a probability of driving for pleasure 0.1372 higher than a person with the same socioeconomic characteristics who is outside the employed labor force. Thus, it appears that the availability of leisure time itself may be a necessary condition but is not a sufficient condition for increasing the probability for engaging in this activity.

The most surprising result obtained is that the probability of engaging in pleasure driving is 5 percent greater for females than males. A similar but more restrictive finding was obtained in the 1960 National Recreation Survey, which indicated the percentage of females who went driving for pleasure exceeded males in general and especially in the 18 to 24 age category.

Finally it might be noted that we were unable to identify a significant relationship between variables such as race or degree of urbanization and driving for pleasure. Preliminary results of a similar regression analysis of the National Recreation Survey of 1960 yielded approximately the same relationship.

Estimate of the Amount of Pleasure Driving in New Jersey

The final empirical work attempted to obtain projections of participation probability and days of pleasure driving estimates for each of the counties of New Jersey through the year 2000. Using the probability equation given below and inserting appropriate values for the relevant exogenous characteristics for the population of each of the counties for each year, an estimate of the dependent variable, probability of driving for pleasure, can be computed. These can be used to generate a conditional probability table for pleasure driving. The basic equation for the probability of driving for pleasure is

$$DP = 0.7406 + 0.0902\,Y - 0.0050\,Y^2 - 0.0511\,SX - 0.0047\,A - 0.1372\,O_2 \quad (10)$$

From Eq. 10 the conditional probabilities of driving for pleasure in New Jersey were derived for the years 1968 to 2000 and for the counties for the decade years until 2000. For the age variable, the median age for each of the age groupings 18 to 44 and 45 to 64 years was used. For the open-ended class of 65 and over, the median age was determined to be 74.

The 1960 median family income for each county and the state was obtained (21), and an annual growth rate of 1.75 percent was applied to the 1960 level of median family

TABLE 5

1960 CONDITIONAL PROBABILITIES OF DRIVING FOR PLEASURE IN ATLANTIC COUNTY

Age	Male	Female
18 to 44	0.8112	0.8623
45 to 64	0.7007	0.7518
65 and over	0.6114	0.6625

TABLE 6

1960 CONDITIONAL PROBABILITIES OF DRIVING FOR PLEASURE IN NEW JERSEY

Age	Male	Female
18 to 44	0.8654	0.9165
45 to 64	0.7549	0.8060
65 and over	0.6656	0.7167

income. The 1.75 percent rate of growth of income was assumed to be in line with past trends of income. The values thus obtained for each year were squared to obtain the Y^2 values for the counties and the state up to the year 2000.

The value for the O_2 variable (percent of over 18 years of age population who are not employed) was obtained for each county in the following manner. From the 1960 county population, all those under 18 years of age were subtracted. The 1960 total of employed persons in the civilian labor force for each county was determined (21). Thus, the percent of population of employed persons over 18 years of age could be determined. Subtracting the fraction of employed persons from unity determined the fraction of each county's population in 1960 that was not working. The value of O_2 determined was used for each county.

The necessary calculations were carried out to determine the conditional probabilities for the counties and the state for each year through the year 2000. For example, the conditional probability of driving for pleasure in Atlantic County in 1960 is given in Table 5. The table can be interpreted as follows: The probability of going pleasure driving for a male between the ages of 18 and 44 and possessing the mean value of the 1960 Atlantic County population for the other significant variables is 0.8112. Alternatively one can interpret the 0.8112 coefficient as indicating that 81.12 percent of males between 18 and 44 in Atlantic County in 1960 went pleasure driving.

For New Jersey in 1960, the conditional probability of driving for pleasure is given in Table 6. Similar conditional probability tables were developed for the state for each year through the year 2000 and for each county for 1970, 1980, 1990, and 2000.

Once the conditional probabilities were determined for the necessary years for the state and the counties, the number of participants for each county and year could be estimated. For New Jersey and for each county in the state, population estimates for each cell were obtained by combining information from various published and unpublished sources. The conditional probabilities were then multiplied by the population of the corresponding cells to determine the number of participants in driving for pleasure.

Thus, for example, Table 7 shows that in Atlantic County in 1960 19,035 males between 18 and 44 years of age went pleasure driving, and Table 8 indicates that 913,473 males in that age category in the state engaged in pleasure-driving activities. Similar tables were derived for each county and for each of the years mentioned.

The next step was to determine the total days of participation in driving for pleasure. From ORRRC Study Report 19 (13), it was calculated that each participant in driving for pleasure participated 40.2 days per year. Then 40.2 was multiplied by the number of New Jersey participants in driving for pleasure to determine the total number of days

TABLE 7

1960 NUMBER OF PARTICIPANTS DRIVING FOR PLEASURE IN ATLANTIC COUNTY

Age	Male	Female
18 to 44	19,035	22,909
45 to 64	12,687	15,536
65 and over	6,213	8,296

TABLE 8

1960 NUMBER OF PARTICIPANTS DRIVING FOR PLEASURE IN NEW JERSEY

Age	Male	Female
18 to 44	913,473	1,023,148
45 to 64	488,219	544,718
65 and over	163,832	223,613

TABLE 9

1960 NUMBER OF DAYS OF PARTICIPATION, DRIVING FOR PLEASURE IN ATLANTIC COUNTY

Age	Male	Female
18 to 44	765, 225	920, 961
45 to 64	510, 028	624, 561
65 and over	249, 776	333, 482

TABLE 10

1960 NUMBER OF DAYS OF PARTICIPATION, DRIVING FOR PLEASURE IN NEW JERSEY

Age	Male	Female
18 to 44	36, 721, 626	41, 130, 533
45 to 64	19, 626, 393	21, 897, 683
65 and over	6, 586, 056	8, 989, 236

of participation in driving for pleasure. Thus, multiplying each cell in Tables 7 and 8 by 40.2 yielded Tables 9 and 10 respectively. Consequently, according to these calculations, males between 18 and 44 years of age in Atlantic County drove for pleasure a total of 765,225 days during 1960, and the same category of drivers drove 36.7 million days in 1960 in the state. Using this approach one could estimate the actual number of driving days for each county and the state as a whole through the year 2000.

Because the purpose of this analysis is to get some measure of present benefits that would result from using scenic highways, it is obvious that the present value of all the days of driving activity in the state is the factor of interest. Accordingly, the days of participation were discounted from 1968 to 2000 at a 5 percent per year rate to obtain the present value of participation days (in units of discounted days) in 1968. This result is given in Table 11.

If a series of arbitrary dollar values of a day's driving for pleasure is applied to the magnitudes in Table 11, a table of present values of benefits would be derived. Thus, for example, if on the average it would be worth $0.01 to each driver for each day he goes pleasure driving, then the present value of benefits derived from pleasure driving for the Atlantic County population is approximately $815 thousand; for the New Jersey population through the year 2000 it is $31. 3 million. Of course, if a day is worth $0.10, then the value of benefits would be $8.15 million for Atlantic County and $313 million for the state.

Accordingly, Table 11 can be a useful guide for policy-makers. If these decision-makers believe a pleasure-driving day is worth $0.10, then multiplying each item in Table 11 by 0.10 yields an estimate of benefits for each county. This should then be compared with the existing stock of scenic highways in each county and the costs of

TABLE 11

SUM OF TOTAL DISCOUNTED DAYS DRIVING FOR PLEASURE
1968 to 2000

County	Present Value of Future Days Driving for Pleasure (in thousands of days)	County	Present Value of Future Days Driving for Pleasure (in thousands of days)
Atlantic	81, 462	Monmouth	233, 344
Bergen	368, 758	Morris	182, 610
Burlington	122, 367	Ocean	93, 417
Camden	182, 762	Passaic	202, 564
Cape May	24, 688	Salem	27, 274
Cumberland	57, 261	Somerset	109, 747
Essex	377, 844	Sussex	36, 394
Gloucester	64, 659	Union	238, 096
Hudson	234, 939	Warren	38, 073
Hunterdon	37, 181	Total	3, 130, 225
Mercer	134, 946		
Middlesex	281, 839		

further scenic enhancing in the stock of highways in deciding how to allocate expenditures on highway building and enhancement. If, for example, County X is already well-endowed with scenic roads (as measured, perhaps, by some index that takes into account the miles of scenic roads per participant as well as other variables such as volume), then it might be desirable to spend funds for scenic enhancement in a less well-endowed county such as County Y, even if the estimates of benefits for County Y were smaller than the estimates of benefits for County X. Moreover, if, for example, County Z was found to have no existing scenic roads although its benefit estimate was $10 million, then it would improve the welfare of the community to spend up to $10 million on scenic enhancement with solely this purpose in mind.

SUMMARY

Our analysis has shown that there is a significant relationship between scenic highways and a reduction in injuries. Table 3 provides estimates of the maximum amount that could be spent on scenic improvement of nonscenic highways and still not involve any net social cost to society. These sums vary, of course, with traffic volume per mile.

We have also been able to estimate the number of days the population of each county in New Jersey will engage in pleasure driving through the year 2000. This projection has been reduced to a present value figure that can provide a guideline for policy decisions on the need for scenic highways in the counties of New Jersey.

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