Quantitative Method for Road Investment Policy Analysis

GREGORY L. THOMPSON

Preliminary research addresses the question of whether highway departments allocate their limited funds consistent with maintenance and congestion demands. The approach uses a model explaining a state's highway budget allocation to the various counties within the state. Explanatory variables are volume of usage, congestion, and road deterioration in each county. The coefficients of the estimated model enable an interpretation of the influences underlying state roadway policy. The state used for this research is Florida. The model was estimated twice, once with Interstate highway data for each county, and once with state highway data, not including Interstates. Results for both estimations were similar, although stronger for the Interstate estimation. The number of urban lane-miles that a county has explains the size of highway budgets more than any of the other variables does. This result runs counter to the expectation that more congestion would induce greater construction and operational spending to relieve it. The results also suggest that truck-caused damage is being insufficiently addressed. Results are preliminary and more experience is needed with this approach before its veracity can be judged.

Most transportation analysts agree that the escalating highway financial shortfall results from the failure of highway users to pay their way. User fees fail to pay for user-caused road and bridge deterioration, as well as for delays that every user imposes on every other user. They also fail to pay for other externalities. In the past, those who did not benefit directly from roads paid for many of the cost liabilities that users imposed on the system, as did those suffering externalities. Increasingly, however, nonusers resist subsidizing users, while those suffering externalities succeed in gaining compensation from road budgets. User-caused cost liabilities thus remain increasingly unfunded. Inflation compounds the problem.

Highway departments also may compound the effects of the financial shortfall by not allocating the funds that are available in accordance with the greatest maintenance and congestion pressures on the system. This failure of the highway departments is addressed. The question is asked to what extent highway departments allocate their limited funds consistent with maintenance and congestion demands on their road systems. The approach specifies a model explaining a state's highway budget allocation to the various counties within the state. Explanatory variables depict congestion and road deterioration in each county. The coefficients of the estimated model enable an interpretation of forces underlying state roadway policy. The state highway department used for this research is that of Florida.

Department of Urban and Regional Planning, Florida State University, 355 Bellamy Building, Tallahassee, Fla. 32306.

BACKGROUND

Politics usually determines the allocation of state highway budgets to administrative districts and counties. In some states, formula-based allocations prevail; in others, discretionary allocations are the rule; whereas still others use a combination of formulas and discretionary allocations.

Regardless of allocation method, most money likely goes to areas with the greatest political clout. Clout generally reflects population size, but other factors could modify the importance of population. The commitment of special interests, such as developers, and the ideological perspective of engineers and planners within departmental bureaucracies are two potentially powerful modifying factors (*1*).

An allocation process reflecting political clout may or may not reflect maintenance and congestion pressures on roads. Even where population size heavily influences budget allocations, highway dollars may not go to locations where congestion is most severe. This is because population density may be more of a determinant of congestion than absolute population. Developers also may influence expenditures to enhance the value of peripheral development; highway departments may build roads where they are easier to build, or they may build them in anticipation of future traffic rather than because of the pressure of existing traffic.

A method is proposed for determining the extent to which politically driven highway budget allocations reflect maintenance and congestion pressures on roads. The method is inspired by railroad cost studies, which examine fluctuations of different railroad cost accounts as traffic volumes vary. Although railroad cost studies are directed at a different objective than this study, their methods, when applied to highway budget data, would achieve some desired results. However, railroad and highway cost data reflect different assumptions and similar models built on them yield different inferences.

The objective of railroad cost studies is to determine the long-run marginal costs of different types of traffic. Analysts obtain data from cross-sectional samples of railroad companies. Dependent variables are the magnitudes of different railroad cost accounts. Explanatory variables include freight and passenger gross ton-miles, miles of track, and level of investment. The central assumption of such studies is that each railroad company adjusts the size of its plant to optimally carry the traffic for which there is demand, and that it efficiently maintains and operates its system while accommodating such traffic. Under such assumptions, the coefficients for freight and passenger ton-miles indicate the degree to which costs are variable, and in conjunction with the coefficients on track-miles and investment, they reveal the impact of traffic density on cost variability. To the extent that individual railroad managements err by investing too little or too much, or by inefficiently operating their services, the error term grows in magnitude. However, with a sufficiently large sample, the broad statistical regularities between traffic volume and costs should become obvious (*2–4*).

Such studies are possible because the Interstate Commerce Act had required railroads to keep uniform systems of accounts since 1907. Data are thus available. The assumptions underlying the data also likely hold true. As private industries, railroads attempt to operate at a profit, which forces them to adjust their plant and services to economic demand.

Such an approach extended to highway costing yields different results, because of differences between railroad and highway cost data. Because the country has few private highway companies, there is nothing in the highway area analogous to the Interstate Commerce Commission's (ICC's) uniform system of accounts, leaving a difficult task of assembling a cross-sectional highway data base. A study could be based on data files from all state highway departments, but the various departments do not maintain their accounts in similar fashion. Although an alternative approach would be a time series study of expenditures on one or more road segments over their lifetimes, attempts to find historical data in Florida that would enable such a study were fruitless. The only data were state highway budgets and usage and system statistics for each county in Florida.

Superficially, county-based highway data resemble data for a railroad cost study. Highway expenditures could be the dependent variable to be explained, while levels of use and investment could be explanatory independent variables. Despite the existence of such analogies, the assumptions underlying highway data and railroad data are different. Because a highway budget is a political matter, the amounts expended in each category do not necessarily reflect highway demand. Investments may not meet the dictates of demand, or they may far exceed them. Highway authorities may or may not operate efficiently. They may or may not maintain their road facilities. The absence of a profit motive in highways removes the pressure on most highway authorities to react to the market. For such reasons, those attempting to find the marginal costs of highway users have abandoned efforts at inferring the marginal costs of highway traffic from the relationship of state highway budgets and usage and system data (*5*). Instead, they rely on engineering studies of the cost consequences of different types of highway traffic on various components of the highway infrastructure.

Although the railroad costing method when applied to highway cost data is not useful for finding highway marginal costs, it yields the degree to which highway budgets are explained by variables reflecting usage. In this study, explanatory variables include those describing traffic and maintenance pressures, and investment.

APPROACH

A model is used to explain a county's highway budget in terms of traffic pressures in the county. The model is then estimated with two data sets. One set includes county budgets and usage for Florida Interstate highways; the other includes similar information for Florida state highways. Finally, the results are interpreted.

Knowledge of Florida highway budgeting procedures assists in interpreting the results. The Florida Department of Transportation (FDOT) builds and operates all nonlocal roads in Florida, including the Florida Turnpike. Financing for nontoll roads comes both from state and national gas taxes, assisted by registration and truck weight fees. National sources finance up to 90 percent of Interstate budget items, while they finance up to 50 percent of state highways that are part of the federal aid primary, secondary, and urban systems. State financing supplies the remainder of the financing, as well as all of the financing for state highways that are not part of the several systems.

FDOT budgets part of its revenues to statewide activities; part goes to the seven administrative districts in the state. Each district in turn budgets part of its revenues to districtwide projects and part to the counties. The amount that goes to the counties is based to some extent on population and gas tax receipts.

The amounts budgeted to the counties are used as the dependent variable. To the extent that vehicle miles of travel (VMT) is used as an explanatory variable, the model may be doing nothing more than reflecting a formula-driven budgetary process. VMT is the primary determinant of gas tax receipts; however, there is an element of discretion in the budgetary process; hence other considerations may influence budgeted amounts. If so, the model might reveal the other influences.

THE MODEL

In this model, the variable to be explained, designated "COST," is the annual Interstate and state expenditure in each Florida county. COST includes capital and maintenance costs for urban and rural roads. The maintenance category is included with capital because the distinction between the two is small; maintenance costs include heavy road and bridge reconstruction, which many budgeters consider to be capital costs.

Explanatory variables are those that would lead to optimal road investments. Small et al. (*6*) specified a welfare function of road benefits and costs, the first-order conditions of which yielded optimal road pricing and investment criteria. Their optimal-capacity rule stated that road authorities should invest in additional road capacity when the reduction in congestion costs brought about by the added capacity exceeded the added discounted construction costs. The most significant variable affecting the optimal-capacity rule is the ratio of traffic volume to capacity. Congestion costs increase as this ratio increases, making an optimal-capacity investment addition more likely.

Similarly, the durability rule is that when marginal maintenance and user cost savings exceed marginal construction costs, road authorities should invest in stronger pavements. The most significant variable affecting this rule is the axle loading per unit of pavement of a given thickness. As this variable increases, maintenance costs increase, eventually triggering an investment in thicker pavement.

Both rules imply that if road budgets reflected optimal investments, they would tend to increase as either traffic or axle loading increased per unit of pavement. Small et al. (*6*) also argued that axle loadings and traffic volumes acted on road costs interactively.

The variables UPDEN and RPDEN denote urban and rural traffic volume-to-capacity ratios in Florida counties, respectively. UPDEN and RPDEN are defined as urban and rural passenger car equivalent (PCEU and PCER, respectively) miles divided by urban and rural lane-miles (LMU and LMR, respectively) in each county. PCEU and PCER are passenger car miles added to twice the truck miles operated in each county. In symbols, UPDEN = PCEU/LMU, and RPDEN = PCER/LMR.

The accepted measure of axle loadings is the ESAL, which is the equivalent damage done by one axle with an 18,000-lb load. AASHTO-conducted engineering studies during the 1960s concluded that pavement damage increases with the fourth power of axle weight, although Small's (*6*) recent reestimation of equations using this data concludes that the damage increases with the third power. According to Small's reestimation, an automobile with a 1,000-lb axle load does the damage of $(1{,}000^3)/(18{,}000^3)$ ESALs, or 0.0001714 ESAL.

The FDOT does not have data on the number of ESALs using different roads prepared in a manner that could be used for this study. It does have somewhat over 400 classification stations, where 1 day per year it counts the numbers of different types of vehicles passing the stations. Vehicles are classed as motorcycles, automobiles and light trucks, buses, and heavier trucks according to the number of axles on the truck. ESALs can be estimated from such data, but their accuracy would be questionable, because truck weights vary widely for each axle configuration. As Small et al. (*6*) pointed out, heavy trucks with two axles do much more damage than even heavier trucks where the load is spread out over many axles.

Vehicle-miles of urban and rural heavy truck traffic in each county, TVMU and TVMR, respectively, are used as surrogate variables for ESALs. If the ratio of ESALs to TVMU or TVMR is the same in each county, this variable should yield the effect of truck damage on the budgetary process. Although currently there is no way of determining this ratio, it is assumed to be relatively constant.

The measures of urban and rural axle loading per unit of pavement are UTDEN = TVMU/LMU and RTDEN = TVMR/LMR, respectively. Pavement thickness is assumed to be the same everywhere for each category of road.

To capture the interactive effect of volume and axle loadings on a lane-mile of pavement, exponential functions are used: $\exp[C(2) * \text{UPDEN} + C(3) * \text{UTDEN}]$ for urban roads, and $\exp[C(5) * \text{RPDEN} + C(6) * \text{RTDEN}]$ for rural roads. $C(2)$, $C(3)$, $C(5)$, and $C(6)$ are coefficients to be estimated.

A county's road budget, COST, is the first exponential multiplied by the urban lane-miles in the county, plus the second exponential multiplied by the rural lane-miles. There also is a weight, $C(1)$, that determines the relative importance of urban and rural roads on the road budget. Congestion in urban areas places greater budgetary pressure on FDOT primarily because right-of-way costs are so much greater in urban areas.

These considerations yield the following equation, which is the model for this study:

$$\begin{aligned}\text{COST} = {} & C(1) * \text{LMU} * \exp[C(2) * \text{UPDEN} \\ & + C(3) * \text{UTDEN}] + \text{LMR} \\ & * \exp[C(5) * \text{RPDEN} \\ & + C(6) * \text{RTDEN}] + C(7) \qquad (1)\end{aligned}$$

where $C(7)$ is another constant whose value is to be estimated.

Equation 1 was estimated twice, once with Interstate highway data, and once with state highway data.

Of particular interest in interpreting the results are the budgetary implications of marginal changes to the explanatory variables giving rise to the density and truck ratio variables. In the case of the urban variables, UPDEN = PCEU/LMU and UTDEN = TVMU/LMU. Thus, in the case of the urban variables, the marginal changes in COST with respect to PCEU, LMU, and TVMU are of interest. These expressions are given by the partial derivatives of Equation 1 with respect to each of the explanatory variables.

$$\begin{aligned}\partial\text{COST}/\partial\text{PCEU} = {} & C(2) * C(1) * \exp[C(2) \\ & * \text{UPDEN} + C(3) * \text{UTDEN}]/365; \qquad (2)\end{aligned}$$

$$\begin{aligned}\partial\text{COST}/\partial\text{TVMU} = {} & C(3) * C(1) * \exp[C(2) \\ & * \text{UPDEN} + C(3) * \text{UTDEN}]/365; \qquad (3)\end{aligned}$$

$$\begin{aligned}\partial\text{COST}/\partial\text{LMU} = {} & C(1) * \exp[C(2) * \text{UPDEN} \\ & + C(3) * \text{UTDEN}] * \{1 - [C(2) \\ & * \text{PCEU} + C(3) * \text{TVMU}]/\text{LMU}\} \qquad (4)\end{aligned}$$

DATA

FDOT maintains a computerized data base for the state's highway system, from which county level usage and system statistics can be extracted. The system contains lane-miles for Interstate and state highways in each county, broken down into urban and rural categories (LMU and LMR). It also contains VMT data for each county both on Interstate and state highways, again broken into urban and rural categories (VMTR and VMTU). FDOT estimates VMTR and VMTU from traffic counters positioned throughout the state, and the miles of road for which the counters apply. FDOT periodically publishes LMU, LMR, VMTU, and VMTR data by county (*7,8*).

As stated earlier, FDOT maintains a much smaller number of classification stations, from which it is possible to decompose traffic into vehicle categories. FDOT does not print summaries of truck traffic VMT data on different classes or road, although it might be possible to have a special program written that would do this. Instead, to estimate TVMU and TVMR for Interstate and state highways, truck and automobile counts were extracted from a published source (*9*), the counts were organized by county and type of road (urban or rural Interstate; urban or rural state highway), the ratio of trucks was calculated using each category of road in each county (truck factors), and then these ratios were applied to the appropriate VMT data in each county. This work yielded rough estimates of truck travel on urban and rural Interstates and state highways in each county. For some counties, there were not a sufficient number of counting stations to obtain truck ratios for each category of road. In such instances, truck factors were substituted from neighboring counties with similar characteristics.

FDOT did not collect such data for several counties, most notably the urban counties in the Tampa-St. Petersburg area. Because of insufficient data, these counties were excluded from the study.

Budgetary data came from the adopted *Five Year Transportation Plan, 1 July 1989 through 30 June 1994* (*10*). For each county, Interstate and state highway construction and maintenance budgeted amounts were summed over the 5 years of the plan, and then the annual average of each was taken. Construction accounts included items sometimes thought of as maintenance, such as resurfacing roads and strengthening bridges. Maintenance accounts included more routine work. Excepting Orange and Dade counties, significant maintenance entries were made for only the first 2 years of the plan; consequently, to obtain the annual maintenance amount the data were divided by two, except for Orange and Dade counties. For construction, the 5-year total was divided by five. The resulting amounts for state highways were designated "budgeted state highway construction, annual" (BSHCA), and "budgeted state highway maintenance, annual" (BSHMA). The analogous Interstate designations were BIMA and BICA. The dependent variable, COST, is the sum of these variables.

RESULTS

Data Covariance

The nonlinear least squares program in the statistical software package, TSP, Version 5.1., was used to estimate the model for both the Interstate and state highway data sets. Before the equations were estimated, the correlation between the variables was examined. High multicollinearity is observed between PCEU, LMU, and TVMU in both data sets. However, when ratios of the variables were used in the model, the multicollinearity was greatly reduced.

Estimating COST from Equation 1 with Interstate Highway Data

Table 1 presents the results for the estimation of Equation 1 with the Interstate highway data set. Table 2 presents the results for the variables in Equation 1 when placed in a simple linear model and estimated with Interstate data and ordinary least squares. Comparison of Tables 1 and 2 indicates that Equation 1 fits the data moderately better than the standard linear model. This suggests that Equation 1 is a better specification.

Table 3 presents results for the marginal pressures on county road budgets from each of the explanatory variables, as given

TABLE 1 EQUATION 1 ESTIMATED WITH INTERSTATE HIGHWAY DATA

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	105.71851	43.157392	2.4496037	0.020
C(2)	0.0480215	0.0222606	2.1572451	0.039
C(3)	-0.7606273	0.1462690	-5.2001957	0.000
C(5)	-0.0801812	1.0715590	-0.0748267	0.941
C(6)	1.3662039	4.8331762	0.2826721	0.779
C(7)	1098.3378	849.62140	1.2927379	0.206

Number of observations: 37			
R-squared	0.859196	Mean of dependent var	5672.411
Adjusted R-squared	0.836485	S.D. of dependent var	8423.143
S.E. of regression	3406.064	Sum of squared resid	3.60D+08
Durbin-Watson stat	1.930553	F-statistic	37.83270
Log likelihood	-350.1601		

TABLE 2 LINEAR ESTIMATION OF VARIABLES IN EQUATION 1 WITH INTERSTATE HIGHWAY DATA

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	3657.7178	2444.3179	1.4964165	0.145
LMU	77.513343	14.230666	5.4469229	0.000
UPDEN	658.27945	303.73582	2.1672763	0.038
UTDEN	-6589.8667	2652.5079	-2.4843910	0.019
LMR	-3.4863618	13.392698	-0.2603181	0.796
RPDEN	-342.61415	365.03163	-0.9385876	0.355
RTDEN	846.26646	2197.4994	0.3851043	0.703

Least Squares: Dependent Variable is COST			
Number of observations: 37			
R-squared	0.811889	Mean of dependent var	5672.411
Adjusted R-squared	0.774267	S.D. of dependent var	8423.143
S.E. of regression	4001.947	Sum of squared resid	4.80D+08
Durbin-Watson stat	1.733604	F-statistic	21.58012
Log likelihood	-355.5187		

TABLE 3 MARGINAL BUDGETARY IMPACTS OF EXPLANATORY VARIABLES FOR INTERSTATE HIGHWAY SYSTEM

	OBS	BUDGET[a] (1000s)	EST. BUD., URBAN[b] (1000s)	MC LMU[c] (1000s)	MC PCEU[d] ($/mi)	MC TVMU[e] ($/mi)
LEE	1	$1,498	$2,756	$101	$0.010	($0.155)
MANATEE	2	$6,371	$2,065	$104	$0.011	($0.179)
POLK	3	$2,958	$4,498	$104	$0.012	($0.184)
SARASOTA	4	$8,729	$2,196	$101	$0.010	($0.158)
ALACHUA	5	$3,318	$1,380	$78	$0.005	($0.082)
COLUMBIA	6	$1,352	$0	ERR	ERR	ERR
HAMILTON	7	$5,031	$0	ERR	ERR	ERR
MADISON	8	$655	$0	ERR	ERR	ERR
SUWANNEE	9	$1,883	$0	ERR	ERR	ERR
DUVAL	10	$25,221	$26,259	$102	$0.010	($0.165)
NASSAU	11	$4,037	$0	ERR	ERR	ERR
ESCAMBIA	12	$3,180	$6,623	$104	$0.012	($0.187)
GADSDEN	13	$2,098	$0	ERR	ERR	ERR
HOLMES	14	$2,368	$0	ERR	ERR	ERR
JACKSON	15	$1,773	$0	ERR	ERR	ERR
JEFFERSON	16	$981	$0	ERR	ERR	ERR
LEON	17	$2,495	$3,668	$105	$0.012	($0.196)
OKALOOSA	18	$592	$0	ERR	ERR	ERR
SANTA ROSA	19	$300	$0	ERR	ERR	ERR
WALTON	20	$1,098	$494	$104	$0.016	($0.257)
WASHINGTON	21	$803	$0	ERR	ERR	ERR
COLLIER	22	$7,334	$188	$105	$0.012	($0.196)
BROWARD	23	$37,457	$25,516	$104	$0.011	($0.180)
INDIAN RIVER	24	$555	$0	ERR	ERR	ERR
MARTIN	25	$904	$0	ERR	ERR	ERR
PALM BEACH	26	$14,541	$18,456	$102	$0.011	($0.168)
ST LUCIE	27	$661	$1,306	$106	$0.013	($0.209)
SUMTER	28	$3,182	$0	ERR	ERR	ERR
MARION	29	$4,759	$1,625	$104	$0.011	($0.178)
BREVARD	30	$2,804	$6,009	$105	$0.013	($0.202)
FLAGLER	31	$1,395	$0	ERR	ERR	ERR
ORANGE	32	$6,778	$8,820	$101	$0.010	($0.157)
SEMINOLE	33	$7,196	$3,765	$102	$0.010	($0.163)
ST JOHNS	34	$6,891	$0	ERR	ERR	ERR
VOLUSIA	35	$7,010	$6,284	$105	$0.012	($0.195)
OSCEOLA	36	$322	$0	ERR	ERR	ERR
DADE	37	$31,349	$30,597	$87	$0.023	($0.364)

ERR means that there were no urban roads.
a See Data section of text.
b Calculated from the urban half of Equation 1, using the estimated parameters of Table 1.
c Equation 2, with parameters from Table 1.
d Equation 3, with parameters from Table 1.
e Equation 4, with parameters from Table 1.

in Equations 2–4, for each county for which Interstate highway data could be obtained. In particular, Table 3 presents the amount of the Interstate budget allocated to each county, the part of the budget predicted by the urban variables, and the marginal impact of each of the urban variables.

From Tables 1 and 3, it is obvious that LMU explains much of the roadway budget, and that its marginal impact remains remarkably constant, regardless of the size of the budget. Thus, regardless of the number of lane-miles that a county has, it is likely to spend about the same amount per lane-mile in next year's budget as most other counties. Although the coefficient of the density variable is positive and significant, the marginal impact of lane-miles runs counter to the expectation that more congestion would induce greater construction spending to relieve it. This counterintuitive result reflects an appropriation of funds formula largely based on urban lane-miles in each county.

Traffic, measured in PCEUs, offers ambivalent explanatory power. Automobiles generate from $0.002 to $0.006 per mile in federal gas tax revenue; Table 3 indicates that their marginal impact on county budgets ranges from $0.005 to $0.023. No pattern to the variation is apparent. Some counties with heavy congestion, such as Dade, exhibit high marginal impacts of added vehicle miles, but other counties with heavy congestion, such as Orange or Palm Beach, do not.

The marginal contribution of truck traffic is uniformly and decidedly negative, a result far from expectations. This contrary result could derive from a poor measure of ESALs, from multicollinearity, or from the fact that truck damage is being insufficiently addressed in highway budgets. The only additional information bearing on this point is that an increasing amount of deferred maintenance is being incorporated into the state transportation plan (*11*).

Estimating Equation 1 with State Highway Data

Table 4 presents the results of estimating Equation 1 with the state highway data, while Table 5 presents the results of estimating a simple linear model with the same variables that are in Equation 1.

Table 6 presents the marginal impact of the explanatory variables on the state highway budgets in each county. Generally, the results support those from the Interstate data, except that the overall marginal impacts of both LMU and PCEU are considerably smaller, whereas the negative impact of truck traffic is far weaker. The marginal results of all three variables also exhibit much less variation between counties.

CONCLUSIONS

Although interesting, these results are preliminary and need to be carefully reviewed, along with the data underlying them. They suggest that neither traffic congestion nor the wear and tear on roads from heavy truck traffic influence the Florida state highway budget for individual counties. Thus, not only the low level of highway financing, but also its distribution contributes to what most Floridians experience: increasingly congested roads and an accumulating backlog of highway damage caused by trucks.

Most transportation analysts now agree that motorists and truckers do not pay the economic costs of the congestion that they create, while truckers do not pay for the damage that they impose. Although benefits would accrue to users if the state made improvements in these areas, costs to nonusers would more than outweigh their benefits, suggesting that the investments themselves may be inefficient and also inequitable. Although users may be unwilling to pay for what benefits them, there is little justification for the state to pick up their tabs.

Additional models should be estimated with the dependent variable, budgeted highway expenditures, split into two components. One part would be the construction and reconstruction budgets; the other, routine maintenance. Such a procedure may strengthen and clarify the results, particularly for the state highway data, in which the percentage of the budget accounted for by routine maintenance is much higher than for the Interstate budgets.

TABLE 4 ESTIMATION OF EQUATION 1 WITH STATE HIGHWAY DATA

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	25.015938	8.8384451	2.8303550	0.007
C(2)	0.0489636	0.0374722	1.3066663	0.197
C(3)	-0.5378900	0.7769887	-0.6922752	0.492
C(5)	0.6366192	0.1736572	3.6659528	0.001
C(6)	-0.5643309	1.2713711	-0.4438758	0.659
C(7)	1489.1097	795.72483	1.8713877	0.067

Number of observations:	59		
R-squared	0.860812	Mean of dependent var	8507.113
Adjusted R-squared	0.847681	S.D. of dependent var	11340.13
S.E. of regression	4425.837	Sum of squared resid	1.04D+09
Durbin-Watson stat	1.841369	F-statistic	65.55585
Log likelihood	-575.8713		

TABLE 5 LINEAR ESTIMATION OF VARIABLES CONTAINED IN EQUATION 1, USING STATE HIGHWAY DATA

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	-798.97111	1883.1107	-0.4242826	0.673
LMU	31.244161	2.3284122	13.418656	0.000
UPDEN	166.60221	498.41914	0.3342613	0.740
UTDEN	-4686.6620	8444.7017	-0.5549825	0.581
LMR	0.6560692	5.5314618	0.1186068	0.906
RPDEN	1739.2657	907.18198	1.9172180	0.061
RTDEN	-3589.8195	4368.2480	-0.8217985	0.415

Number of observations:	59		
R-squared	0.862546	Mean of dependent var	8507.113
Adjusted R-squared	0.846686	S.D. of dependent var	11340.13
S.E. of regression	4440.268	Sum of squared resid	1.03D+09
Durbin-Watson stat	1.768960	F-statistic	54.38468
Log likelihood	-575.5014		

TABLE 6 MARGINAL BUDGETARY IMPACTS OF EXPLANATORY VARIABLES FOR STATE HIGHWAY SYSTEM

	OBS	BUDGET[a] (1000s)	EST. BUD., URBAN[b] (1000s)	MC LMU[c] (1000s)	MC PCEU[d] ($/mi.)	MC TVMU[e] ($/mi.)
DESOTO	1	$4,152	$677	$24.932	$0.004	($0.040)
GLADES	2	$4,298	$0	ERR	ERR	ERR
HARDEE	3	$2,134	$0	ERR	ERR	ERR
HENDRY	4	$3,451	$269	$24.944	$0.004	($0.040)
HIGHLANDS	5	$5,993	$2,251	$24.829	$0.004	($0.041)
LEE	6	$24,386	$6,457	$24.721	$0.004	($0.043)
MANATEE	7	$13,112	$8,209	$24.832	$0.004	($0.041)
POLK	8	$27,590	$14,348	$25.002	$0.003	($0.038)
SARASOTA	9	$13,971	$8,794	$24.068	$0.004	($0.047)
ALACHUA	10	$10,108	$8,192	$24.707	$0.004	($0.043)
BRADFORD	11	$863	$725	$24.713	$0.004	($0.043)
COLUMBIA	12	$2,712	$2,157	$24.943	$0.004	($0.040)
GILCHRIST	13	$1,258	$0	ERR	ERR	ERR
HAMILTON	14	$796	$0	ERR	ERR	ERR
LAFAYETTE	15	$1,077	$0	ERR	ERR	ERR
LEVY	16	$1,422	$0	ERR	ERR	ERR
MADISON	17	$1,922	$0	ERR	ERR	ERR
SUWANNEE	18	$1,446	$508	$24.957	$0.004	($0.039)
TAYLOR	19	$1,463	$958	$25.012	$0.003	($0.036)
UNION	20	$1,045	$0	ERR	ERR	ERR
CLAY	21	$7,752	$1,859	$24.553	$0.004	($0.044)
DUVAL	22	$47,094	$30,545	$24.713	$0.004	($0.043)
NASSAU	23	$1,785	$1,111	$24.933	$0.004	($0.040)
BAY	24	$8,496	$8,783	$24.743	$0.004	($0.042)
CALHOUN	25	$1,901	$0	ERR	ERR	ERR
ESCAMBIA	26	$13,167	$12,976	$24.700	$0.004	($0.043)
FRANKLIN	27	$3,683	$0	ERR	ERR	ERR
GADSDEN	28	$1,060	$848	$25.016	$0.003	($0.037)
GULF	29	$4,855	$0	ERR	ERR	ERR
HOLMES	30	$1,026	$0	ERR	ERR	ERR
JACKSON	31	$3,706	$499	$25.016	$0.003	($0.037)
JEFFERSON	32	$1,947	$0	ERR	ERR	ERR
LEON	33	$13,251	$7,074	$24.904	$0.004	($0.040)
LIBERTY	34	$283	$0	ERR	ERR	ERR
OKALOOSA	35	$5,454	$8,821	$24.906	$0.004	($0.040)
SANTA ROSA	36	$3,016	$2,007	$24.634	$0.004	($0.043)
WAKULLA	37	$508	$0	ERR	ERR	ERR
WALTON	38	$5,264	$851	$24.966	$0.004	($0.039)
WASHINGTON	39	$941	$0	ERR	ERR	ERR
COLLIER	40	$8,369	$2,887	$24.342	$0.004	($0.046)
BROWARD	41	$26,501	$36,325	$24.300	$0.004	($0.046)
INDIAN RIVER	42	$7,818	$3,055	$24.656	$0.004	($0.043)
MARTIN	43	$18,315	$4,192	$24.633	$0.004	($0.044)
OKEECHOBEE	44	$1,096	$0	ERR	ERR	ERR
PALM BEACH	45	$19,332	$20,544	$24.957	$0.004	($0.039)
ST LUCIE	46	$3,741	$4,554	$24.556	$0.004	($0.044)
CITRUS	47	$7,017	$0	ERR	ERR	ERR
LAKE	48	$5,481	$3,419	$24.815	$0.004	($0.042)
SUMTER	49	$2,047	$0	ERR	ERR	ERR
MARION	50	$5,097	$4,090	$24.648	$0.004	($0.043)
BREVARD	51	$13,484	$18,286	$24.508	$0.004	($0.045)
FLAGLER	52	$2,635	$0	ERR	ERR	ERR
ORANGE	53	$23,180	$17,907	$24.832	$0.004	($0.041)
PUTNAM	54	$5,888	$1,008	$24.845	$0.004	($0.041)
SEMINOLE	55	$9,375	$5,945	$24.755	$0.004	($0.042)
ST JOHNS	56	$8,014	$3,347	$24.616	$0.004	($0.044)
VOLUSIA	57	$20,825	$12,809	$24.622	$0.004	($0.044)
OSCEOLA	58	$2,536	$1,719	$24.824	$0.004	($0.042)
DADE	59	$62,787	$57,109	$23.538	$0.005	($0.050)

Notes:

ERR means that there were no urban roads.

a See data section of text

b Calculated from the urban half of Equation 1, using the estimated parameters of Table 4.

c Equation 2, with parameters from Table 4.

d Equation 3, with parameters from Table 4.

e Equation 4, with parameters from Table 4.

ACKNOWLEDGMENTS

The author would like to thank the Center for Urban Transportation Research for the grant supporting this research and the staff of the Florida Department of Transportation for their comments and provision of data. Terry Kraft, Jack Butler, and Lennon Moore opened their offices and indicated the proper direction. The author particularly appreciates the time that Bob Weinstein and Ray Hubbard spent in helping him find needed information. Richard Staziak and David Blodgett also offered critical perspectives. Thanks are also due to Jim Banes for his tireless efforts in searching for historical data and his laborious coding of the truck factor data.

Finally, thanks are due to James Frank and three anonymous TRB referees for their insightful comments on an earlier draft of this work.

REFERENCES

1. B. E. Seely. *Building the American Highway System: Engineers as Policy Makers*. Temple University Press, Philadelphia, Pa., 1987.
2. J. R. Meyer, M. J. Peck, J. Stenason, and C. Zwick. *The Economics of Competition in the Transportation Industries*. Harvard University Press, Cambridge, Mass., 1959.
3. A. F. Friedlaender and R. H. Spady. *Freight Transport Regulation*. MIT Press, Cambridge, Mass., 1981.
4. T. E. Keeler. *Railroads, Freight, and Public Policy*. Brookings Institution, Washington, D.C., 1983.
5. *State Highway Cost Allocation Guide, Vol. 1*. FHWA, U.S. Department of Transportation, 1984.
6. K. A. Small, C. Winston, and C. A. Evans. *Road Work: A New Highway Pricing and Investment Policy*. Brookings Institution, Washington, D.C., 1989.
7. *State Highway System, Daily Vehicle Miles Traveled, in Thousands*. Statistics Office, Florida Department of Transportation, Tallahassee, June 1989.
8. *State Highway System, Lane Miles*. Statistics Office, Florida Department of Transportation, Tallahassee, June 1989.
9. *Florida 1987 Annual Traffic Classification Report*. Statistics Office, Florida Department of Transportation, Tallahassee, 1987.
10. *Adopted Five Year Transportation Plan, July 1, 1989 through June 30, 1994*. Volumes for Districts 1 through 7. Office of Management and Budget, Florida Department of Transportation, Tallahassee, 1989.
11. *Tentative Five-Year Transportation Plan, July 1, 1989 Through June 30, 1994*. Office of Management and Budget, Florida Department of Transportation, Tallahassee, March 1989, pp. B3–B5.

Publication of this paper sponsored by Committee on Transportation Economics.