RESOURCE PAPER

Estimating Revenues from User Charges, Taxes, and Fees

Identifying Information Requirements

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In a statement on national transportation policy in the United States contained in *Moving America: New Directions—New Opportunities* (*1*), one of the clear messages was a significantly reduced role for the federal government. The fundamental assumption underlying this policy prescription was that the transportation network was mature. The major concern therefore should be with maintaining this system and encouraging more efficient use of facilities. The shift would be toward projects that complete the system and extend the useful life of facilities. The principal thrust was expected to be in management strategies involving pricing, vehicle control, and other instruments that focus on efficiency. States found they had additional responsibilities in policy, planning, and program development.[1]

Since the 1990 statement, however, infrastructure investment seems to have found its way to the top of the policy agenda in the United States as well as in other countries. The recently enacted Transportation Equity Act for the 21st Century (TEA-21) contained among its provisions a significant amount of monies for transportation (mostly highway) investment. Underlying this change of faith was the belief that investments in public capital would improve productivity, economic growth, and international competitiveness.

With the "crumbling" infrastructure needing replacement and the growing demand for new facilities, state departments of transportation (DOTs) are faced with establishing a set of programs that will satisfy the management and efficiency provisions contained in *Moving America* (*1*) and the financing and investment responsibilities contained in the evolution of TEA-21. If they are to invest in airport, highway, and transit capital, they need to understand how levels of investment in transportation affect our economic health (as Eberts discusses in another resource paper in these proceedings). Once this mechanism is understood, they need to put in place a planning process that will lead to a set of investments yielding the economic and social returns so desired (as Pozdena shows in his paper, also in these proceedings). Finally, all of this activity must be financed in some way, and forecasts of funds available for projects need to be made.

The problems just identified cross all modes of transportation. In some cases, additional problems such as international passenger travel and freight shipment demands make the planning and investment process even more complex. This paper will concentrate on highway transportation and will assess how well states are able to forecast revenues from taxes and fees levied on highway users and whether the models they employ in forecasting revenues are appropriate for the task. In addition, the paper investigates whether the information relied upon by these models is sufficiently accurate to support reliable forecasts, and how this information might be improved. (The focus will be on the highway sector although similar questions arise in aviation.) The paper then moves beyond questions of current practice and examines new methods of financing transportation infrastructure investments and their information needs for forecasting.

After a brief review of the evolution of highway finance and its components, the next section of this paper reviews variables that currently are used in forecasting state highway revenues, and it assesses the quality and

accuracy of available measures of these variables. Factors that may affect the reliability of current information are explored, new options for measuring specific variables are examined, and their information requirements are outlined.

In the next section, the adequacy of current revenue forecasting models is investigated. This section poses two questions: First, how accurate are current models, and what assumptions do they impose? Second, are the models adequate for forecasting revenues in a world that places different demands on its transportation systems? This section also will identify the additional information demands that are likely to be imposed by new or improved forecasting models.

The next section examines the information needs that are likely to result from introducing new revenue instruments. This section requires a somewhat speculative examination of the specific financing measures states may be considering to augment their current revenue sources, including highway tolls and new forms of user taxes or fees. If states move toward closer linkage of user charges with actual road use, what additional information will need to be collected to ensure that accurate revenue forecasts can be made, and how can it be collected? Finally, the last section contains a summary and identification of critical research questions.

Evolution of Highway Finance

The growth and development of states' highway finance systems have reflected changes in several factors. These include developments in revenue collection technologies, an evolutionary process to legislation, a general disinterest in reviewing highway finance on a regular basis, and a move away from a user benefit principle to one of minimizing voter revolt. Starting with the movement away from tolls and property taxes to finance roads that began in the early 1920s, states increasingly relied on user taxes to finance highways.[2] The linkage of roads to property benefits was no longer as clear as that between use of a road and the benefits received by its users. In the language of economics, taxes on road users were adopted and implemented in a context of highways exhibiting the attributes of both private and public goods—attributes such as excludability, congestion, cross subsidy, and cost economies. This trend toward increased reliance on traditional user charge mechanisms generally has continued over the past several decades, more recently with some minor shift toward reliance on general taxation. At the same time, many European and Third World nations are seriously turning to toll finance—and in many cases, even outright privatization—to finance continued road building.

The principal sources of revenues used to finance highway construction in the United States have included state and federal fuel taxes, vehicle registration fees, motor-vehicle weight fees, sales taxes (revenue derived from sales taxes on vehicles and equipment), road and bridge tolls, and driver's license fees. Vehicle registration fees were the earliest forms of user tax to be widely adopted by states, partly because they could be implemented easily and were simple to administer since they were typically paid only once per year in a lump sum. This feature made them highly visible to motorists, with the result that they tended not to be changed frequently. However, registration fees are typically a "flat fee" (with some differentiation by vehicle classes) and thus have limited revenue-generating potential. Currently, about a third of the states base registration fees for light vehicles on weight, whereas half retain the flat fee system and the remainder base the fee on some combination of weight, horsepower, value, and age. The exact weightings on these characteristics tend to reflect political judgments and perceptions of equity among owners of different types of vehicles.

Fuel Taxation

Motor-fuel taxation, first introduced by Oregon in 1919, rapidly spread to other states: by 1929, all 48 states taxed gasoline, and 3 years later a one-cent-per-gallon federal fuel tax was enacted as part of the Revenue Act of 1932.[3] The weighted average state motor-fuel tax for gasoline has increased from 3.35¢ per gallon in 1930, the first full year in which taxes were collected in all states, to 18.5¢ in 1995. This figure compared closely to the federal tax on gasoline, which stood at 18.4¢ per gallon during 1995, although the federal levy on diesel fuel was considerably higher, at 24.4¢ per gallon.

Prior to 1980, fuel tax rates were changed infrequently and typically in small increments (generally by 1 percent or less). The stability in fuel tax rates was enabled by continuing growth in fuel consumption, which produced a continuing rise in total fuel-tax revenues. At the same time, because highway expenditure levels tended to be adjusted to correspond to growing revenues, there was little pressure to increase fuel tax rates in order to accelerate construction. After 1983, however, a number of states began to increase their fuel tax rates aggressively, often in increments as large as 3¢ per gallon, and there continues to be some adjustment by a minority of states in their per-gallon fuel tax rates. Whereas most states have retained the original convention of fixed tax rates per gallon of fuel sold at retail, others have indexed the per-gallon rate to some measure of general price inflation. Still others impose the tax as a sales

or value-added tax—a fixed percentage of the dollar value of sales—levied either specifically on fuels or on all retail spending. The exact form taken of a state's fuel tax has a significant impact on the amount of revenues it generates, although this impact can vary with changes in overall economic conditions. As an illustration, the recent robust growth in travel, spurred by the booming U.S. economy, falling wholesale gasoline prices, and declining average fuel efficiency of the U.S. vehicle fleet, has produced rapid growth in gasoline consumption and in fuel-tax revenues collected by states that rely on the traditional per-gallon fuel tax structure.

Vehicle Registration Fees

Registration practices and taxation policies for commercial vehicles differ greatly among the states: some register a tractor-semitrailer combination as a single unit, whereas others register the tractor and the semitrailer separately. Some states register and tax buses similarly to trucks; others treat buses in the same way as automobiles, presumably because of their passenger-carrying function. For the most part, weight-based vehicle fees have been used in licensing trucks, but more recently some states (17 to date) have begun to levy fees on the basis of some combination of weight and annual distance traveled. A few states (notably, Virginia and Kentucky) levy a fuel tax surcharge on vehicles having three or more axles, whereas still others (Arizona, Pennsylvania, and New York) impose a gross tax on commercial trucks. Despite this wide variation in licensing fee practices, however, the magnitude of revenues generated from this source is relatively minor.

One factor complicating the assessment and collection of both vehicle registration fees and fuel taxes on commercial trucks is the interstate and international (Canada and Mexico) nature of their operations. The diversity of tax structures creates both tax competition among individual states and the potential for adoption of retaliatory taxation by adjacent or nearby states. However, several regional alliances of states (e.g., New England) have been formed in order to minimize the revenue diminution that typically accompanies such tax rivalry. In these agreements, states jointly establish how trucks will be treated in the home state and in adjacent or nearby jurisdictions. Registration fees generally are prorated on the bases of the amount of mileage recorded in each jurisdiction. Fuel-tax revenues tend to be generally "self-prorating" because of their collection by states in which fuel sales occur (as long as interstate tax differentials are not large enough to induce significant changes in sales patterns).[4]

Other Revenue Sources

The remaining sources of revenue, which are minor at the state level, include property taxes and assessments, driver's licensing fees, and personal property taxes levied on motor vehicles. In addition, many states now employ general-revenue bond financing for highway construction projects.[5]

More recently, some states have employed new tax instruments that include both road tolls and state sales taxes. Toll revenues generally are restricted to use on the facilities where they are collected, because facilities with tolls tend to be either bridges or tunnels, and they are often newly constructed facilities. Presently 29 states operate a total of 37 toll highways and 44 toll bridges; in 1989, tolls collected from vehicles using these facilities provided $3.01 billion in revenues for highway financing. At the same time, a few states have introduced dedicated (or "earmarked") sales taxes to finance selected investments in transportation infrastructure, often in response to voter-approved ballot initiatives.

The increased reliance on this form of financing stems from a number of factors, but the most important of these is undoubtedly reluctance on the part of state legislatures to adopt the tax rate or fee increases necessary to generate additional revenues from more traditional financing sources. Like tolls, the money collected from state sales taxes generally are earmarked for a particular set of investments, often specified in detail in the ballot initiatives approving their use.

Summary of Revenue Sources

Figure 1 illustrates highway revenue sources. What is most evident from the data is the dominant role that fuel taxes and fees play as a source of revenue for financing highway spending. The figure also illustrates the variability of revenue sources over time.

Tables 1 through 5 provide a detailed, state-by-state examination of the level and variability in taxation rates and in revenues from fuel taxation and vehicle registration fees and other taxes associated with vehicles. Table 1 shows the variability in tax rates among states as well as across types of fuels. The asterisk beside a state name indicates there are exceptions and conditions in the application of the tax. This complexity creates a significant challenge to developing a medium- to long-run forecasting model.

In Tables 2 through 5, the levels and changes in the revenues from two major sources of tax and fee revenue are examined. Table 2 shows the gross and adjusted total tax receipts from fuel taxes and other fuel-related fees. The adjustment results in a reduction in revenue due

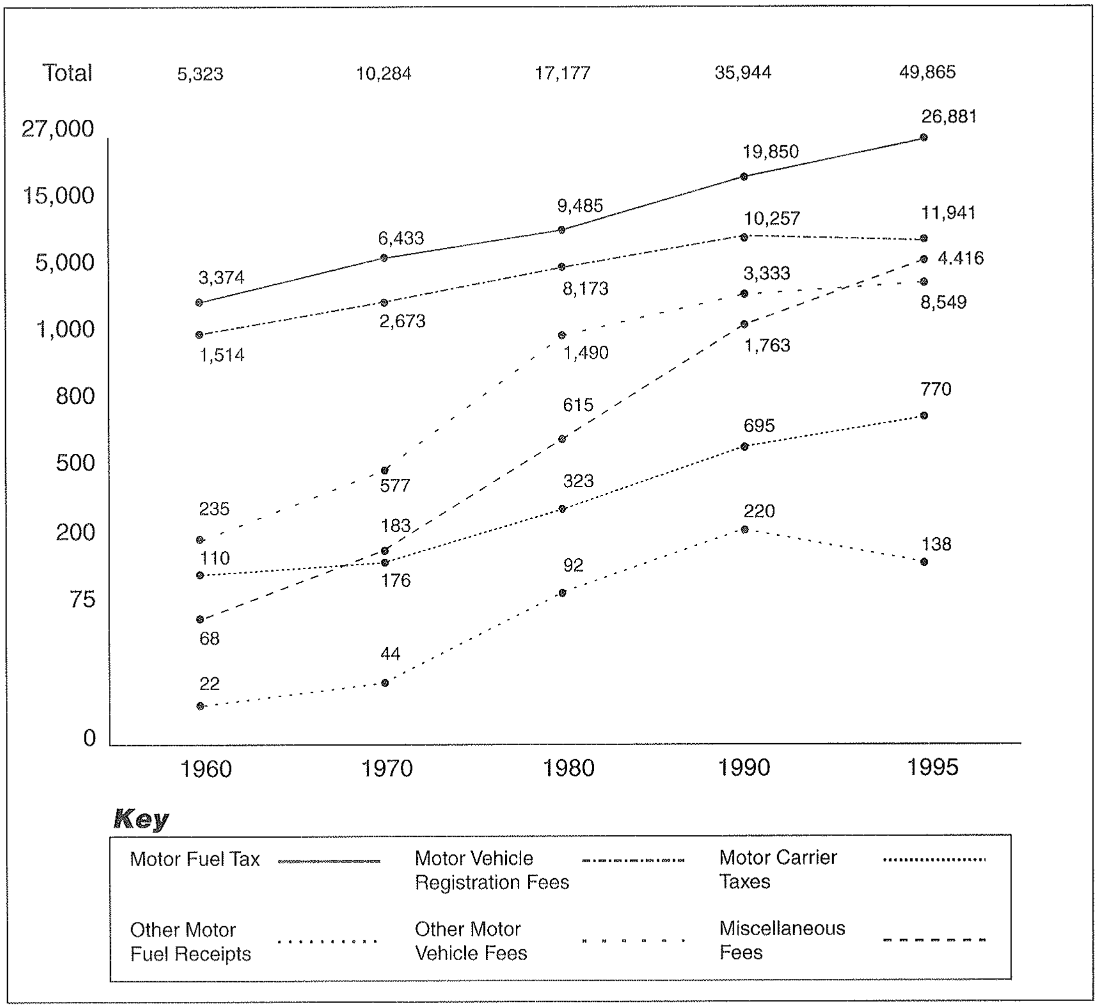

FIGURE 1 State highway user tax revenues (millions of dollars) (2).

to reimbursements and exceptions. Changes from one year to the next are illustrated in Table 3. In Column 1, for example, Alaska, Louisiana, North Carolina, Pennsylvania, and Utah have large reductions in tax revenues. A significant proportion of U.S. states exhibit large changes in revenue from one year to the next. Pennsylvania, for example, has a 3.8 percent increase in 1994–95, an 8.5 percent decrease in 1995–96, and a turnaround of a 14.32 percent increase in 1996–97. Even a simple time-series model for short-term forecasting would face challenges with such variability.

Table 4 illustrates the revenues available from license fees and other motor-vehicle-related taxes. (The table is a subset of a more detailed set of information and is condensed for presentation.) It is clear that a sizable proportion of "other" taxes is included in this source of revenues. Table 5 shows the year-to-year changes in revenue levels contained in Table 4. Unlike fuel-tax revenues, these series show remarkable stability with no subset of states having more fluctuation than others in this revenue source and very little intertemporal variation.

The Role of Revenue Forecasting

As the exhibits illustrate, states traditionally have relied on fuel taxes as the primary source of revenue to fund roadway construction, rehabilitation, and maintenance. In planning their year-to-year activities and accompanying spending levels in each of these categories, states thus require forecasts of revenues that will be available from the "pass-back" of federal fuel-tax revenues they receive, as well as from the fuel taxes, fees, and other charges they levy on highway users.[6] The Federal Highway Administration (FHWA), which is required to present to Congress the forecasts of revenues available in the Federal Highway Trust Fund, relies on information provided by the states in developing its forecasts.

Three approaches can be considered in producing forecasts. One is a simple model that uses previous values of revenues in each category, perhaps with a weighting structure on more recent values. This approach simply matches a function to the data and extrapolates the values to create a forecast. A second approach would use some econometric time-series techniques, such as the Box-Jenkins or ARIMA. Univariate Box-Jenkins models are sophisticated extrapolation methods using past values to generate forecasts. Despite not providing any explanation for the movement of variables, this approach is valuable because it is easy, inexpensive, and requires a minimum of information. This can be used in conjunction with other forecasts and can serve as a starting point for more sophisticated approaches. The "Achilles heel" of the time-series approach to forecasting is the misspecification of the dynamic structure. When lack of information or specification errors make econometric models impractical, the Box-Jenkins model is considered a superior form of time-series forecasting.

The third approach, causal forecasting, develops an econometric model that explains the underlying causes or sources of variation in the factors that effect revenues from fuel taxes and registration fees. This would use relevant demographic and economic variables in a set of behavioral equations to produce the forecast. This approach is information intensive and is subject to a number of errors. Nonetheless, it is the richest approach since once the model parameters are estimated they can be used to develop forecasts of the dependent variables.

Producing revenue forecasts requires projections of a state's fuel-tax structure and rates, the number of gallons of each type of fuel subjected to taxation that is expected to be sold, the number of vehicles expected to be registered during future years, and residual revenues from other sources, including excise taxes, licensing fees, and earmarked transfers from the federal government. Unfortunately, the only piece of information among these variables that tends to be predictable with any certainty is the state's tax structure and rate of taxation.[7] Total vehicle miles traveled (VMT) and the average fuel efficiency of the vehicle fleet will determine the number of gallons of each type of fuel sold. The present stock of vehicles varies with changes in the demographic makeup and economic status of households, and prevailing macroeconomic conditions will determine the number of licensed vehicles.

State policy makers and transportation officials require accurate revenue forecasts to plan investments as well as to set tax rates and fee levels that will achieve fiscal targets. There is some economic risk and sizable political risk in overforecasting revenues—that is, in producing forecasts that exceed actual revenue collections. If states are not able to accurately forecast revenues from taxes and fees levied on highway users, transportation planning agencies will be in jeopardy of having certain projects delayed, and prolonged delays of controversial projects may cause the consensus in support of them to be reconsidered or ultimately to unravel. In the case of projects that already have begun, overestimation of future revenues may subject political officials to the risk of having to adjust existing tax rates or fees or even to introduce new taxes or seek a new source of financing.

Recognizing the sources and consequences of these risks, there are three fundamental questions that policy makers should be asking that will assist in identifying the weaknesses in information and modeling. They are as follows:

- *Accuracy of information employed by current forecasting models:* With the focus on the current set of models used in revenue forecasting, are the variables used in these models measured accurately? If not, what are the sources of inaccurate measurements and what is needed to improve their reliability?
- *Adequacy of current forecasting models:* Are the models that currently are being used to forecast revenues satisfactory to meet future needs? What are their specific conceptual and empirical shortcomings, and how should they be redesigned to adequately reflect future changes in their likely use in transportation planning and policy making? How are proposed changes in the models used to forecast revenues likely to affect their information requirements?
- *Evolution of current forecasting models and information requirements:* How will new revenue instruments be integrated into the current set of forecasting models? The evolution of alternative bases for financing highways results in increasingly diverse and potentially complex informational requirements. Hence, there are different demands placed on both state and federal institutions responsible for generating information relied upon in forecasting revenues.

The Current Models: Information Demands

Because of the nearly universal policy of basing highway spending levels on revenues, both the federal and state governments depend critically on forecasts of revenue from taxes and fees levied on users for planning highway expenditures. The federal gasoline tax of 18.4¢ per gallon is approximately equal to the average state levy, so that total tax revenues average about 36¢ per gallon of fuel sold; Table 1 provides the complete breakdown, state by state. At the same time, however, it is equally important to examine developments in the world petroleum market and their effects on the wholesale or pretax price of gasoline, which had been declining but has risen sharply in recent months. In assessing the implications of

TABLE 1 Tax Rates on Motor Fuel, 1997 (Cents per Gallon)

	Gasoline		Diesel		LPG		Gasohol	
State	Rate	Date	Rate	Date	Rate	Date	Rate	Date
Alabama*	18	06/01/92	19	06/01/92	17	06/01/92	18	06/01/92
Alaska	8	07/01/61	8	07/01/61	—	—	—	—
Arizona*	18	07/01/90	18	07/01/90	18	07/01/90	18	07/01/90
Arkansas*	18.6	07/01/96	18.6	07/01/96	16.5	04/01/91	18.6	07/01/06
California*	18	01/01/94	18	01/01/94	6	01/01/76	18	01/01/94
Colorado*	22	01/01/91	20.5	01/01/92	20.5	01/01/92	22	01/01/91
Connecticut	39	01/01/97	18	09/01/91	—	07/01/96	38	01/01/97
	36	07/01/97					35	07/01/97
Delaware*	23	01/01/95	22	01/01/95	22	01/01/95	23	01/01/95
D.C.	20	10/01/94	20	10/01/94	20	10/01/94	20	10/01/94
Florida*	12.8	01/01/97	24.6	01/01/97	15.8	01/01/97	12.8	01/01/97
Georgia	7.5	07/01/71	7.5	07/01/71	7.5	07/01/71	7.5	07/01/71
Hawaii	16	07/01/91	16	07/01/91	11	07/01/91	16	07/01/91
Idaho*	25	04/01/96	25	04/01/96	18.1	04/01/96	22.5	07/01/94
Illinois*	19	01/01/90	21.5	01/01/90	19	01/01/90	19	01/01/90
Indiana*	15	04/01/88	16	04/01/88	—	—	15	04/01/88
Iowa	20	01/01/89	22.5	01/01/89	20	01/01/89	19	01/01/89
Kansas*	18	07/01/92	20	07/01/92	17	07/01/92	18	07/01/92
Kentucky*	16.4	07/15/94	13.4	07/15/94	15	07/01/86	16.4	07/15/94
Louisiana*	20	01/01/90	20	01/01/90	16	07/01/93	20	01/01/90
Maine	19	07/17/91	20	04/01/89	18	07/17/91	19	07/17/91
Maryland	23.5	05/01/92	24.25	07/01/93	23.5	07/01/93	23.5	05/01/92
Massachusetts*	21	01/01/91	21	01/01/91	9.5	01/01/97	21	01/01/91
Michigan*	15	01/01/84	15	01/01/84	15	01/01/84	15	01/01/84
	19	08/01/97					19	08/01/97
Minnesota*	20	05/01/88	20	05/01/88	15	07/01/95	20	05/01/88
Mississippi*	18.4	07/01/93	18.4	07/01/93	17	01/01/89	18.4	07/01/93
Missouri*	17	04/01/96	17	04/01/96	17	04/01/96	17	04/01/96
Montana*	27	07/01/94	27.75	07/01/94	—	—	27	07/01/94
Nebraska*	25.3	01/01/97	25.3	01/01/97	25.3	01/01/97	25.3	01/01/97
	24.9	04/01/97	24.9	04/01/97	24.9	04/01/97	24.9	04/01/97
	24.8	07/01/97	24.8	07/01/97	24.8	07/01/97	24.8	07/01/97
	24.5	10/01/97	24.5	10/01/97	24.5	10/01/97	24.5	10/01/97
Nevada	24.75	01/01/97	27.75	01/01/97	23	10/01/92	24.75	01/01/97
					22	07/01/97		
New Hampshire*	18.7	06/07/93	18.7	06/07/93	18	06/16/91	18.7	06/07/93
New Jersey*	10.5	07/01/88	13.5	07/01/88	5.25	07/01/88	10.5	01/01/92
New Mexico*	18.875	07/01/96	19.875	07/01/96	3	01/01/96	18.875	07/01/96
New York*	22.40	01/01/97	22.35	01/01/97	8	10/01/90	22.35	01/01/97
	22.80	04/01/97	22.65	04/01/97			22.65	04/01/97
North Carolina*	22.6	01/01/97	22.6	01/01/97	22.6	01/01/97	22.6	01/01/97
North Dakota*	20	01/01/96	20	01/01/96	20	01/01/96	20	01/01/96
Ohio*	22	07/01/93	22	07/01/93	22	07/01/93	22	07/01/93
Oklahoma*	17	07/01/89	14	07/01/89	17	07/01/89	17	07/01/89
Oregon*	24	01/01/93	24	01/01/93	24	01/01/93	24	09/01/93
Pennsylvania*	22.35	09/01/91	22.35	09/01/91	22.35	09/01/91	22.35	09/01/91
	25.9	05/01/97	26.0	05/01/97	25.9	05/01/97	25.9	05/01/97
			30.8	10/01/97				
Rhode Island*	29	07/08/94	29	07/08/94	29	07/08/94	29	07/08/94
South Carolina	16	01/01/89	16	01/01/89	16	01/01/89	16	01/01/91
South Dakota*	18	04/01/88	18	04/01/88	16	04/01/88	16	04/01/88
	21	05/01/97	21	05/01/97	19	05/01/97	19	05/01/97
Tennessee*	20	04/01/89	17	04/01/90	14	04/01/89	20	04/01/89
Texas*	20	10/01/91	20	10/01/91	15	01/01/87	20	10/01/91
Utah*	19	04/01/87	19	04/01/87	19	04/01/87	19	04/01/87
	19.5	06/01/97	19.5	06/01/97	19.5	06/01/97	19.5	06/01/97
	24.5	08/01/97	24.5	08/01/97	24.5	08/01/97	24.5	08/01/97
Vermont*	16	07/01/89	17	07/01/89	—	—	16	07/01/89
	20	08/01/97					20	08/01/97
Virginia*	17.5	07/01/92	16	07/01/92	10	01/01/94	17.5	07/01/92
Washington*	23	04/01/91	23	04/01/91	—	—	^23	05/01/94
West Virginia*	25.35	05/01/93	25.35	05/01/93	25.35	05/01/93	25.35	05/01/93
Wisconsin*	23.7	04/01/96	23.7	04/01/96	23.7	04/01/96	23.7	04/01/96
	23.8	04/01/97	23.8	04/01/97	23.8	04/01/97	23.8	04/01/97
Wyoming*	9	07/01/89	9	07/01/89	—	—	9	01/01/95
Weighted Avg.	**19.05**		**19.50**		**14.18**		**20.01**	
Federal Tax	**18.4**	10/01/97	**24.4**	10/01/97	**13.6**	10/01/97	**13.0**	10/01/97

TABLE 2 State Motor-Fuel Tax Revenues and Related Receipts (Thousands of Dollars)

	1997		1996		1995		1994	
State	Gross Collections	Adj. Total Tax Receipts	Gross Collections	Adj. Total Tax Receipts	Gross Collections	Adj. Total Tax Receipts	Gross Collections	Adj. Total Tax Receipts
Alabama	542,221	540,195	533,257	530,399	534,767	530,779	522,124	518,243
Alaska	18,906	17,187	20,960	18,756	21,791	20,016	23,450	21,883
Arizona	499,370	490,497	484,348	478,129	460,812	458,997	430,454	427,881
Arkansas	351,117	351,117	354,456	340,052	344,348	329,862	332,171	319,063
California	2,820,580	2,730,407	2,763,367	2,635,798	2,725,847	2,617,883	2,584,707	2,443,550
Colorado	447,795	442,262	445,266	439,774	433,013	427,220	420,369	414,540
Connecticut	546,553	544,663	499,517	498,120	462,824	461,619	432,081	430,858
Delaware	103,412	103,195	93,542	93,345	97,850	97,597	89,130	88,902
D.C.	32,529	32,570	31,987	32,028	34,821	34,862	35,880	35,924
Florida	1,400,107	1,400,795	1,310,236	1,300,895	1,275,008	1,276,616	1,202,944	1,200,062
Georgia	393,662	386,559	415,622	412,268	388,228	385,093	378,297	375,583
Hawaii	68,799	67,784	68,095	67,167	67,763	66,881	67,594	66,345
Idaho	202,419	194,170	188,858	179,514	157,808	149,905	151,733	143,280
Illinois	1,136,898	1,122,838	1,164,395	1,134,506	1,131,311	1,097,265	1,112,736	1,073,959
Indiana	703,766	695,106	671,811	664,718	670,551	665,555	618,090	613,186
Iowa	397,701	380,777	388,410	374,546	371,130	358,517	360,189	347,639
Kansas	313,902	311,834	299,231	296,996	290,941	289,078	286,146	283,821
Kentucky	413,776	406,004	400,874	400,698	377,504	377,433	364,047	363,820
Louisiana	589,912	500,272	699,060	529,232	505,690	492,839	497,002	474,108
Maine	155,570	150,741	150,504	145,803	138,964	134,306	143,143	138,639
Maryland	630,508	618,571	622,158	604,614	621,140	601,268	610,458	600,042
Massachusetts	598,547	590,775	599,660	591,807	578,218	570,639	563,308	555,541
Michigan	825,746	809,483	766,491	752,129	762,366	764,215	735,637	735,806
Minnesota	546,182	527,142	522,146	507,770	499,282	486,979	491,981	481,329
Mississippi	334,100	332,859	336,018	334,857	328,619	327,607	319,549	318,787
Missouri	632,969	631,720	591,994	591,526	535,374	535,258	500,857	500,355
Montana	177,809	167,107	179,535	167,857	158,202	154,844	160,011	150,261
Nebraska	293,014	279,931	261,782	249,759	248,840	235,311	249,914	235,691
Nevada	274,169	265,327	242,198	233,563	226,353	217,370	215,468	207,087
New Hampshire	123,687	121,409	116,183	116,902	110,647	111,010	107,006	107,021
New Jersey	488,049	488,216	464,170	463,664	431,181	431,165	441,427	440,876
New Mexico	232,707	230,908	224,128	223,780	246,959	246,449	224,674	225,230
New York	1,414,144	1,400,662	1,330,152	1,325,956	1,521,405	1,518,624	1,369,669	1,364,813
North Carolina	975,439	986,335	1,210,795	1,184,149	927,654	903,356	919,079	898,790
North Dakota	99,374	97,615	97,619	93,112	85,621	81,282	86,486	82,303
Ohio	1,426,954	1,365,308	1,394,619	1,341,859	1,329,351	1,301,962	1,278,089	1,256,379
Oklahoma	387,843	382,276	371,656	367,146	360,573	356,233	358,348	352,800
Oregon	387,521	378,293	374,573	364,425	369,967	360,706	355,557	347,208
Pennsylvania	1,538,470	1,533,638	1,317,925	1,314,011	1,424,605	1,425,219	1,369,864	1,370,177
Rhode Island	124,974	124,665	123,848	123,518	120,633	120,262	116,259	120,108
South Carolina	396,222	394,130	387,048	384,942	393,295	393,629	382,594	382,819
South Dakota	107,480	101,008	97,933	91,273	93,933	86,696	95,230	87,804
Tennessee	683,188	670,104	680,383	662,619	669,620	650,543	651,009	633,125
Texas	2,459,891	2,396,826	2,386,361	2,319,576	2,302,528	2,240,355	2,226,096	2,168,643
Utah	265,044	257,605	220,831	214,380	208,184	201,672	196,858	190,890
Vermont	71,111	69,811	67,667	67,405	67,463	70,192	64,882	68,206
Virginia	735,764	732,313	696,429	693,348	696,587	693,689	685,719	682,423
Washington	702,845	699,997	681,669	668,487	668,465	656,419	650,724	638,689
West Virginia	271,110	270,784	262,247	261,612	276,805	276,358	276,399	275,810
Wisconsin	707,102	685,336	696,820	675,345	666,993	646,468	648,914	630,268
Wyoming	54,056	53,225	54,683	53,461	49,788	50,607	51,451	50,637
Totals	**29,105,014**	**141,947**	**28,363,517**	**2,761,759**	**2,747,162**	**2,698,871**	**26,455,804**	**25,941,204**

SOURCE: Motor-fuel taxes and related receipts, Bureau of Transportation Statistics.

TABLE 3 Changes in Revenues from Fuel Tax Receipts

	1996–97		1995–96		1994–95	
	Change in Gross Collections	Change in Total Tax Receipts	Change in Gross Collections	Change in Total Tax Receipts	Change in Gross Collections	Change in Total Tax Receipts
Alabama	1.65%	.81%	–0.28%	0.07%	2.36%	.36%
Alaska	–10.86%	9.13%	–3.96%	6.72%	–7.61%	9.33%
Arizona	3.01%	.52%	4.86%	.00%	6.59%	.78%
Arkansas	–0.95%	.15%	2.85%	.00%	3.54%	.27%
California	2.03%	.47%	1.36%	.68%	5.18%	.66%
Colorado	0.56%	.56%	2.75%	.85%	2.92%	.97%
Connecticut	8.61%	.55%	7.35%	.33%	6.64%	.66%
Delaware	9.54%	.55%	–4.61%	4.56%	8.91%	.91%
Dist. of Columbia	1.67%	.66%	–8.86%	8.85%	–3.04%	3.05%
Florida	6.42%	.13%	2.69%	.87%	5.65%	.00%
Georgia	–5.58%	6.65%	6.59%	.59%	2.56%	.47%
Hawaii	1.02%	.91%	0.49%	.43%	0.25%	.80%
Idaho	6.70%	.55%	16.44%	6.49%	3.85%	.42%
Illinois	–2.42%	1.04%	2.84%	.28%	1.64%	.12%
Indiana	4.54%	.37%	0.19%	0.13%	7.82%	.87%
Iowa	2.34%	.64%	4.45%	.28%	2.95%	.03%
Kansas	4.67%	.76%	2.77%	.67%	1.65%	.82%
Kentucky	3.12%	.31%	5.83%	.81%	3.56%	.61%
Louisiana	–18.50%	5.79%	27.66%	.88%	1.72%	.80%
Maine	3.26%	.28%	7.67%	.89%	–3.01%	3.23%
Maryland	1.32%	.26%	0.16%	.55%	1.72%	.20%
Massachusetts	–0.19%	0.17%	3.58%	.58%	2.58%	.65%
Michigan	7.18%	.09%	0.54%	1.61%	3.51%	.72%
Minnesota	4.40%	.67%	4.38%	.09%	1.46%	.16%
Mississippi	–0.57%	0.60%	2.20%	.17%	2.76%	.69%
Missouri	6.47%	.36%	9.56%	.51%	6.45%	.52%
Montana	–0.97%	0.45%	11.88%	.75%	–1.14%	.96%
Nebraska	10.66%	0.78%	4.94%	.78%	–0.43%	0.16%
Nevada	11.66%	1.97%	6.54%	.93%	4.81%	.73%
New Hampshire	6.07%	.71%	4.76%	.04%	3.29%	.59%
New Jersey	4.89%	.03%	7.11%	.01%	–2.38%	2.25%
New Mexico	3.69%	.09%	–10.19%	10.13%	9.02%	.61%
New York	5.94%	.33%	–14.38%	14.53%	9.97%	0.13%
North Carolina	–24.13%	20.06%	23.38%	3.71%	0.92%	.51%
North Dakota	1.77%	.61%	12.29%	2.71%	–1.01%	1.26%
Ohio	2.27%	.72%	4.68%	.97%	3.86%	.50%
Oklahoma	4.17%	.96%	2.98%	.97%	0.62%	.96%
Oregon	3.34%	.67%	1.23%	.02%	3.89%	.74%
Pennsylvania	14.34%	4.32%	–8.09%	8.46%	3.84%	.86%
Rhode Island	0.90%	.92%	2.60%	.64%	3.63%	.13%
South Carolina	2.32%	.33%	–1.61%	2.26%	2.72%	.75%
South Dakota	8.88%	.64%	4.08%	.01%	–1.38%	1.28%
Tennessee	0.41%	.12%	1.58%	.82%	2.78%	.68%
Texas	2.99%	.22%	3.51%	.42%	3.32%	.20%
Utah	16.68%	6.78%	5.73%	.93%	5.44%	.35%
Vermont	4.84%	.45%	0.30%	4.13%	3.83%	.83%
Virginia	5.35%	.32%	–0.02%	0.05%	1.56%	.62%
Washington	3.01%	.50%	1.94%	.81%	2.65%	.70%
West Virginia	3.27%	.39%	–5.55%	5.64%	0.15%	.20%
Wisconsin	1.45%	.46%	4.28%	.28%	2.71%	.51%
Wyoming	–1.16%	0.44%	8.95%	.34%	–3.34%	0.06%

TABLE 4 State Motor-Vehicle and Motor-Carrier Tax Receipts (Thousands of Dollars)

	1997			1996		
STATE	Automobiles (including taxicabs)	Trucks and Truck Tractors	Total Receipts	Automobiles (including taxicabs)	Trucks and Truck Tractors	Total Receipts
Alabama	3,989	54,373	147,704	3,615	37,030	177,366
Alaska	11,957	9,466	31,758	11,872	9,532	30,932
Arizona	23,018	63,532	259,456	22,940	61,820	247,700
Arkansas	21,610	57,283	114,959	23,451	30,570	120,598
California	3,141,491	1,397,975	5,205,428	2,778,390	1,553,811	4,985,706
Colorado	66,179	56,670	211,939	64,881	52,963	203,793
Connecticut	20,525	4,332	245,200	108,846	22,974	238,920
Delaware	9,572	5,280	71,918	9,187	5,246	70,016
Dist. of Columbia	12,921	1,915	54,737	14,283	2,117	55,179
Florida	236,630	131,923	940,084	229,897	127,958	931,611
Georgia	133,457	31,447	249,064	102,995	65,913	245,742
Hawaii	55,907	11,643	82,881	54,673	12,417	83,035
Idaho	21,530	18,283	103,724	16,336	15,052	94,660
Illinois	320,265	201,460	746,505	349,832	187,259	764,186
Indiana	40,547	126,185	243,352	39,977	123,360	235,160
Iowa	183,600	86,200	320,922	163,500	87,600	304,541
Kansas	41,561	69,403	150,476	39,991	67,505	142,817
Kentucky	18,275	22,607	545,753	18,190	22,020	530,836
Louisiana	32,282	31,977	172,601	32,596	33,078	177,612
Maine	20,649	13,308	76,289	20,015	13,950	78,571
Maryland	98,971	35,165	761,117	95,339	35,308	742,747
Massachusetts	78,134	77,661	337,880	72,684	75,711	303,742
Michigan	380,465	159,817	688,287	357,676	151,788	674,148
Minnesota	339,004	151,433	571,167	317,082	137,806	504,184
Mississippi	30,572	27,165	124,787	29,877	27,298	125,380
Missouri	76,827	103,877	255,648	77,606	106,119	256,632
Montana	6,057	6,092	55,934	6,701	5,218	52,351
Nebraska	19,073	27,152	78,919	16,433	32,276	76,945
Nevada	45,154	19,495	129,823	42,871	18,509	109,597
New Hampshire	20,984	21,204	86,048	20,558	19,766	83,077
New Jersey	179,051	30,920	554,600	172,505	50,170	594,755
New Mexico	27,817	27,188	217,495	27,215	25,932	208,218
New York	230,425	66,512	772,189	226,596	66,272	719,823
North Carolina	84,448	115,271	318,930	90,180	105,612	387,029
North Dakota	18,682	15,986	48,059	18,973	16,086	47,904
Ohio	245,530	150,521	645,547	240,632	144,392	604,184
Oklahoma	245,775	45,583	422,353	240,851	43,191	389,462
Oregon	28,984	28,544	327,696	30,916	27,289	325,913
Pennsylvania	221,146	204,547	668,049	187,719	221,291	639,011
Rhode Island	18,801	8,674	64,172	16,958	9,031	62,776
South Carolina	30,625	26,265	105,710	24,094	35,143	106,719
South Dakota	11,147	25,263	46,637	10,874	23,854	44,714
Tennessee	41,680	62,522	206,307	49,780	56,389	202,364
Texas	441,079	307,610	2,864,885	419,957	307,402	2,742,591
Utah	15,570	19,735	81,421	10,833	13,201	66,165
Vermont	15,450	8,769	70,486	16,051	8,878	88,098
Virginia	31,825	14,961	724,532	31,250	13,768	697,963
Washington	618,229	323,983	1,070,543	377,556	307,079	1,000,759
West Virginia	27,701	32,308	209,570	25,529	33,789	205,981
Wisconsin	112,592	128,438	316,885	132,510	105,853	311,009
Wyoming	5,015	30,030	48,470	4,390	28,900	44,686
Total	**8,162,778**	**4,697,953**	**644,520**	**7,697,683**	**4,787,496**	**22,137,908**

SOURCE: Motor-fuel taxes and related receipts, Bureau of Transportation Statistics.

TABLE 4 *Continued*

1995			1994		
Automobiles (including taxicabs)	Trucks and Truck Tractors	Total Receipts	Automobiles (including taxicabs)	Trucks and Truck Tractors	Total Receipts
3,789	50,821	172,681	37,039	363	163,407
11,978	9,571	29,022	11,788	9,365	30,007
22,345	52,119	212,256	21,423	50,413	253,211
23,806	29,612	109,516	26,335	26,404	104,233
2,258,429	1,099,483	3,942,979	2,661,682	1,209,347	4,454,589
54,297	40,366	162,363	54,701	36,832	148,821
106,601	22,500	238,115	108,171	22,831	244,521
9,399	5,392	106,842	9,191	10,313	69,262
15,638	2,318	55,949	14,194	2,104	56,125
214,777	122,531	886,769	213,282	118,020	913,277
98,983	63,092	236,027	117,548	38,651	225,141
53,785	12,502	78,927	53,412	12,827	75,058
16,113	15,105	92,348	15,765	15,765	86,477
351,041	201,395	757,108	326,325	195,099	721,470
39,002	121,531	231,147	47,056	135,777	230,066
158,100	83,900	293,558	152,300	81,100	278,738
39,591	66,276	133,858	38,688	63,049	134,772
17,369	21,138	774,672	18,247	21,038	458,888
31,109	30,523	158,418	28,803	30,889	164,286
20,155	13,398	68,947	19,126	13,432	76,185
93,777	34,985	658,661	92,806	35,465	664,197
75,322	72,987	294,755	58,163	69,235	302,878
308,317	164,799	616,310	311,033	136,472	583,744
311,520	106,404	456,164	319,505	107,835	500,440
29,314	26,637	116,983	28,969	27,555	110,630
76,122	101,559	239,992	76,193	106,362	250,357
6,611	5,253	50,487	6,496	5,213	48,370
16,163	28,133	70,762	16,242	26,755	64,362
39,328	16,979	99,721	36,850	15,909	95,891
20,689	18,892	81,056	19,176	18,386	78,327
169,452	61,285	617,717	166,043	62,015	553,458
26,913	25,012	293,307	26,094	23,868	209,981
257,168	71,956	735,527	254,984	69,594	751,618
78,020	86,588	312,195	78,639	83,023	303,749
18,925	17,099	48,104	18,844	17,123	48,283
240,019	142,006	573,422	236,854	137,215	619,424
225,116	41,843	365,966	208,532	41,126	346,783
27,025	26,143	309,217	30,880	27,441	315,320
174,541	220,612	614,346	172,546	220,530	507,823
18,538	8,902	58,795	18,538	8,902	67,581
29,442	24,982	101,532	31,946	36,527	114,716
10,949	23,295	43,806	12,562	20,715	41,089
68,396	40,367	198,424	63,131	48,838	188,500
419,607	272,722	4,232,301	433,616	282,523	2,461,458
10,565	14,421	62,863	10,430	13,153	58,560
15,825	8,629	130,195	15,080	8,507	81,588
32,265	17,696	898,189	25,735	26,035	534,032
544,039	297,344	937,061	520,591	289,838	918,162
16,914	39,209	323,746	23,546	34,519	193,161
131,590	91,418	291,087	129,896	95,678	296,775
4,544	27,793	41,628	4,043	6,654	40,580
7,043,323	4,199,423	22,675,821	7,423,039	4,243,630	20,340,371

TABLE 5 Changes in Revenues from Vehicle Registrations

	1996–97			1995–96			1994–95		
	From Cars	From Trucks	Total Receipts	From Cars	From Trucks	Total Receipts	From Cars	From Trucks	Total Receipts
Alabama	0.09	0.32	–0.20	–0.05	–0.37	–0.03	–8.78	0.07	0.05
Alaska	0.01	–0.01	0.03	–0.01	0.00	0.06	0.02	0.02	–0.03
Arizona	0.00	0.03	0.05	0.03	0.16	0.14	0.04	0.03	–0.19
Arkansas	–0.09	0.47	–0.05	–0.02	0.03	0.09	–0.11	0.11	0.05
California	0.12	–0.11	0.04	0.19	0.29	0.21	–0.18	–0.10	–0.13
Colorado	0.02	0.07	0.04	0.16	0.24	0.20	–0.01	0.09	0.08
Connecticut	–4.30	–4.30	0.03	0.02	0.02	0.00	–0.01	–0.01	–0.03
Delaware	0.04	0.01	0.03	–0.02	–0.03	–0.53	0.02	–0.91	0.35
D.C.	–0.11	–0.11	–0.01	–0.09	–0.09	–0.01	0.09	0.09	0.00
Florida	0.03	0.03	0.01	0.07	0.04	0.05	0.01	0.04	–0.03
Georgia	0.23	–1.10	0.01	0.04	0.04	0.04	–0.19	0.39	0.05
Hawaii	0.02	–0.07	0.00	0.02	–0.01	0.05	0.01	–0.03	0.05
Idaho	0.24	0.18	0.09	0.01	0.00	0.02	0.02	–0.04	0.06
Illinois	–0.09	0.07	–0.02	0.00	–0.08	0.01	0.07	0.03	0.05
Indiana	0.01	0.02	0.03	0.02	0.01	0.02	–0.21	–0.12	0.00
Iowa	0.11	–0.02	0.05	0.03	0.04	0.04	0.04	0.03	0.05
Kansas	0.04	0.03	0.05	0.01	0.02	0.06	0.02	0.05	–0.01
Kentucky	0.00	0.03	0.03	0.05	0.04	–0.46	–0.05	0.00	0.41
Louisiana	–0.01	–0.03	–0.03	0.05	0.08	0.11	0.07	–0.01	–0.04
Maine	0.03	–0.05	–0.03	–0.01	0.04	0.12	0.05	0.00	–0.10
Maryland	0.04	0.00	0.02	0.02	0.01	0.06	0.01	–0.01	0.05
Mass.	0.07	0.03	0.10	–0.04	0.04	0.03	0.23	0.05	–0.03
Michigan	0.06	0.05	0.02	0.14	–0.09	0.09	–0.01	0.17	0.05
Minnesota	0.06	0.09	0.12	0.02	0.23	0.10	–0.03	–0.01	–0.10
Mississippi	0.02	0.00	0.00	0.02	0.02	0.07	0.01	–0.03	0.05
Missouri	–0.01	–0.02	0.00	0.02	0.04	0.06	0.00	–0.05	–0.04
Montana	–0.11	0.14	0.06	0.01	0.01	0.04	0.02	–0.01	0.04
Nebraska	0.14	–0.19	0.03	0.02	0.13	0.08	0.00	0.05	0.09
Nevada	0.05	0.05	0.16	0.08	0.08	0.09	0.06	0.06	0.04
New Hamp.	0.02	0.07	0.03	–0.01	0.04	0.02	0.07	0.03	0.03
New Jersey	0.04	–0.62	–0.07	0.02	–0.22	–0.04	0.02	–0.01	0.10
New Mexico	0.02	0.05	0.04	0.01	0.04	–0.41	0.03	0.05	0.28
New York	0.02	0.00	0.07	–0.13	–0.09	–0.02	0.01	0.03	–0.02
N. Carolina	–0.07	0.08	–0.21	0.13	0.18	0.19	–0.01	0.04	0.03
N. Dakota	–0.02	–0.01	0.00	0.00	–0.06	0.00	0.00	0.00	0.00
Ohio	0.02	0.04	0.06	0.00	0.02	0.05	0.01	0.03	–0.08
Oklahoma	0.02	0.05	0.08	0.07	0.03	0.06	0.07	0.02	0.05
Oregon	–0.07	0.04	0.01	0.13	0.04	0.05	–0.14	–0.05	–0.02
Pennsylvania	0.15	–0.08	0.04	0.07	0.00	0.04	0.01	0.00	0.01
Rhode Island	0.10	–0.04	0.02	–0.09	0.01	0.06	0.00	0.00	–0.15
S. Carolina	0.21	–0.34	–0.01	–0.22	0.29	0.05	–0.09	–0.46	–0.13
S. Dakota	0.02	0.06	0.04	–0.01	0.02	0.02	–0.15	0.11	0.06
Tennessee	–0.19	0.10	0.02	–0.37	0.28	0.02	0.08	–0.21	0.05
Texas	0.05	0.00	0.04	0.00	0.11	–0.54	–0.03	–0.04	0.42
Utah	0.30	0.23	0.19	0.03	0.05	0.05	0.01	0.09	0.07
Vermont	–0.04	–0.01	–0.25	0.01	0.03	–0.48	0.05	0.01	0.37
Virginia	0.02	0.08	0.04	–0.03	–0.29	–0.29	0.20	–0.47	0.41
Washington	0.07	0.05	0.07	0.06	0.03	0.04	0.04	0.03	0.04
West Virginia	0.08	–0.05	0.02	0.34	–0.16	–0.57	–0.39	0.12	0.40
Wisconsin	–0.18	0.18	0.02	0.01	0.14	0.06	0.01	–0.05	–0.02
Wyoming	0.12	0.04	0.08	–0.04	0.04	0.07	0.11	0.76	0.03

these developments for revenues generated by fuel taxes, it is important to identify the structure of the federal and each state's fuel tax, including whether the tax is levied on a value-added basis or as a fixed amount per gallon, as well as whether the state's general sales tax also applies to gasoline sales.

Calculating and Forecasting Fuel-Tax Revenues

Figure 2 displays the forecasting of automobile fuel efficiency. In calculating and forecasting total tax revenues likely to be generated by fuel purchases and usage, two variables are critically important: (*a*) total VMT by vehicles operating on each different type of fuel that is taxed, and (*b*) the average fuel efficiency of the fleet of vehicles operating on each different type of fuel. The fundamental accounting identity determining revenues from fuel taxation is

$$R \equiv \sum_i t_i \cdot G_i \qquad (1)$$

where

R = total revenue from fuel taxes;
t_i = the state tax rate on each particular type of fuel (gasoline, diesel, gasoline-alcohol blends, natural gas, etc.); and
G_i = the (equivalent) number of gallons of each type of fuel subjected to taxation at sale.

Of the variables entering this identity, only the tax rates on different types of fuel (the values of t_i) are known with certainty; the number of gallons of each type of fuel subject to taxation (the values of G_i) must be forecast for each future period comprising the planning horizon.[8] In turn, the number of gallons of each type of fuel sold will be a function of total VMT by vehicles operating on that fuel type and their average fuel efficiency (expressed in miles per gallon, MPG, or gallon equivalent). The identity relating fuel sales to these variables is

$$G_i \equiv \text{VMT}_i \,/\, \text{MPG}_i \qquad (2)$$

In turn, however, both VMT_i and MPG_i will be influenced by other variables (some of which, such as the per-gallon price of fuel, may affect both VMT and MPG). Formally,

$$\text{VMT}_i = f\left(x'\right) \qquad (3a)$$

$$\text{MPG}_i = g\left(x''\right) \qquad (3b)$$

Equations 3a and 3b simply show that VMT_i is a function of some vector of variables x', whereas average fuel efficiency of vehicles operating on that fuel (MPG_i) will

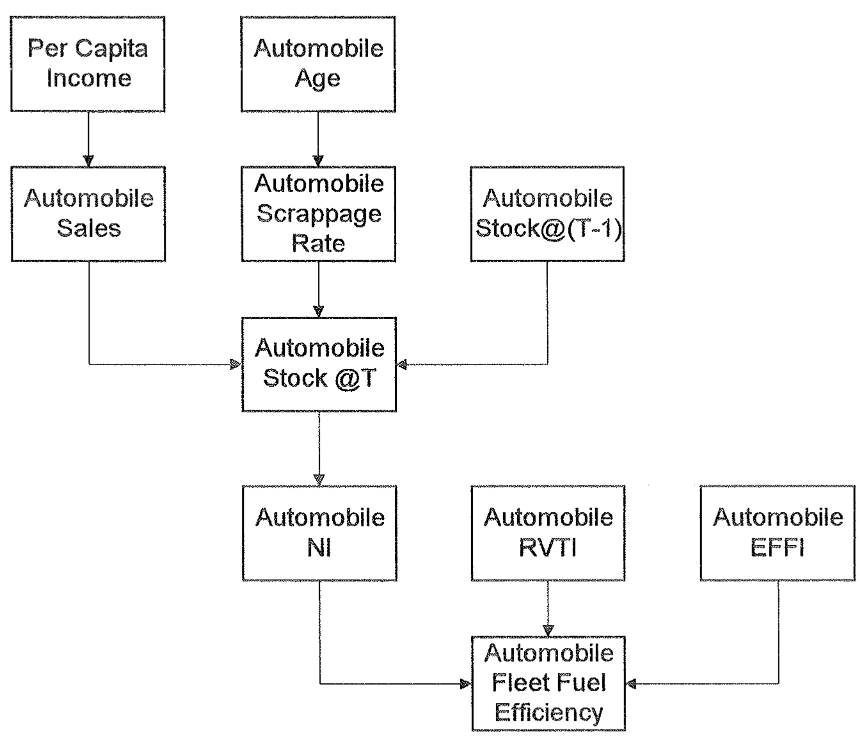

FIGURE 2 Forecasting automobile fuel efficiency. (Notes: NI is the proportion of automobile in *I*th age cohort; RVTI is the relative vehicle use by automobile in *I*th age cohort; and EFFI is the fuel efficiency of automobile in *I*th age cohort.)

be some function of another vector of variables x'', although these vectors may share some common variables. Therefore, total consumption of each type of fuel (G_i) also will depend on the variables that influence travel by vehicles using that fuel and their average efficiency:

$$G_i = h\left[\text{VMT}_i\left(x'\right), \text{MPG}_i\left(x''\right)\right] \quad (4)$$

(A more sophisticated model would consider whether different fuels are taxed at different rates, and it would incorporate the effect of differential taxation on the level of VMT recorded in vehicles operating on these different types of fuel.)

The value of this framework is that it makes clear that we need to understand the factors that influence the variables VMT_i and MPG_i, together with the form of their relationship to these two variables. Thus, the reliability with which revenues can be forecast depends, first, on the accuracy of available measures of the variables included in Equations 2 and 3 and, second, on our understanding of the relationships represented by Equation 3. Of equal importance will be the accuracy of models representing those relationships and on the reliability of available forecasts of the specific variables contained in x' and x''. Depending upon the state of information and knowledge in each of these areas, the most effective way to improve the reliability of revenue forecasts may entail improving measures of critical variables (or generating entirely new measures), developing more complete models of the relationships among them, or improving our ability to forecast the variables that influence travel behavior and vehicles' fuel efficiency—or a combination of these measures.

In the models for travel by vehicles operating on different fuels (VMT_i), shown above as Equation 3a, data on VMT usually are collected from state transportation departments. Economic and demographic variables that influence VMT (the elements of x' in Equation 3a) typically are obtained from departments dealing with economic activity and demographic information, such as state finance and commerce departments. Measures of each of these variables at the state level are required to develop a model suitable for estimating VMT. Analysts seeking to develop such models must distinguish between information that is available as continuing time series (typically monthly or annually) and information that is gathered by survey and is therefore only occasionally available, and they also must explore how these different types of data can be integrated and used. Another alternative is to explore the availability of cross-sectional data for substate geographic units (such as counties or municipalities), although the current state of cross-sectional VMT data within states appears to be crude.[9]

Measuring Fuel Use, VMT, and Fuel Efficiency

As Schipper (3) observes, the fact that fuel consumption, travel, and fuel efficiency are identically related according to Equation 1 means that measuring any two of those three variables enables us to estimate the third. However, reliable and continuous data are widely available only for consumption of different types of fuel—typically as a by-product of their taxation—so that either travel (VMT) by vehicles operating on each type of fuel or their average fuel efficiency (MPG) must be estimated in order to determine the third variable. (Two important caveats are that states typically do not estimate the distribution of sales of each type of fuel to different types of vehicles—for example, the distribution of gasoline sales among motorcycles, automobiles, and trucks—nor are they able to estimate reliably purchases of fuel within their borders for use in neighboring states.)

The procedure used by many states to estimate VMT is a "scaling" approach, in which year-to-year changes in loop-detector traffic counts are used to scale upward or downward an estimate of statewide VMT for the previous year; this procedure also is used often in short-term forecasting of VMT (typically within the current year). Many states operate statewide networks of loop detectors and permanent traffic counting stations, although these provide information on vehicle volumes—and thus indirectly on numbers of vehicle trips—and not on the distance or duration of the trips. Most states also have movable traffic counters that provide traffic counts in additional locations, but typically not on a continuous time-series basis. Many counties collect information on average daily traffic at permanent and some mobile sites. Although some employ these data in an attempt to measure total VMT, the resulting estimates are crude since vehicle counts alone convey no information on trip lengths and these sites tend to be located in older areas where development is mature and the level of growth of newer areas is rarely observed. As a result, there is widespread suspicion that these measures tend to underestimate growth in statewide VMT.

Using the sample of historical VMT data gathered on segments of different roadway types and locations, future VMT can be forecast using an econometric model that includes among its explanatory variables household or statewide income measures, fuel prices, and other important variables. Often such models are specified using a so-called "stock adjustment" framework, in which the previous year's value of the dependent variable, VMT, appears as an explanatory variable, since this often improves the performance of such models when used for forecasting. Where a state's historical time series of annual VMT data is too short to permit a reliable estimation of such a model's parameters, more frequent data (monthly or quarterly) can be used. This procedure re-

quires that seasonal or other factors that vary by month or quarter also be included in the model, as well as monthly or quarterly estimates of the desired explanatory variables be available. Although it might be desirable to develop separate models for VMT recorded by vehicles operating on different fuels, historical data of this detail rarely are available. This generally results in forecasts of total VMT being "apportioned" among vehicles operating on different fuels using information on their relative representation in a state's registered fleet and any available estimates of how their average usage differs.

Another approach to estimating state-level VMT would be to use individual vehicles' odometer readings (Charles Lave of the University of California at Irvine has done some work in California), recorded in sequential years to develop estimates of average annual use per vehicle of different types. These data could be obtained from annual inspection programs, which many states conduct to verify the condition of vehicles' safety or emissions control equipment, or from odometer readings recorded at the time vehicles are registered in a state. The major complication with this procedure is that it also requires separate estimates of the number of vehicles of each type operating in the state throughout the year. This number can differ from the number registered or inspected because of resales, seasonal registration, selective exemptions from inspection programs, and other factors. Although this procedure appears to offer a promising alternative to VMT estimates based on annual fluctuations in traffic counts, it appears to have been attempted only experimentally to date.

The most common procedure for independently estimating the average fuel efficiency of the vehicle fleet (the variable MPG) is to develop a "vintaging" model of a state's vehicle fleet, similar to so-called cohort survival models used to forecast population growth. Developing such a model requires an age distribution of the vehicle fleet for some initial year, together with estimates of future new vehicle sales, the fraction of vehicles of each age or model year that will be retired from the fleet, the fuel efficiency of each model year represented in the fleet when it was new, and the rate at which fuel efficiency deteriorates with the passage of time. (An additional complication is that fuel efficiency ratings for new vehicles do not match their actual on-road performance, so the "gap" between these measures must be estimated.) This approach is illustrated below.

This discussion of data requirements for forecasting fuel-tax revenues and the procedures that commonly are used to estimate critical variables suggests two conclusions. First, the available estimates of state-level VMT probably are inadequate and require significant improvement in their reliability. California provides a good example of a state that measures VMT only in a limited number of locations and for a limited number of years, with estimates for the intervening years interpolated from values for the years in which VMT is measured. Similarly, local estimates of VMT are expanded to the entire state based on data collected on a relatively limited—and certainly older—part of the system. States need to invest more in collecting information on three attributes of VMT: the number of miles, the location of the miles, and the average trip length.

The second conclusion is that the models used to estimate travel and fleet fuel efficiency are relatively simple and essentially embody accounting rather than behavioral relationships. There are few linkages to variables other than aggregate income. Little or no attention is paid to the impact of different policies, for example, CAFE, on constituent variables such as fuel efficiency or VMT. Perhaps more significant is these models' general lack of responsiveness to changes in fuel tax rates or other components of transportation prices.

Are the Models Adequate?

The previous section focused on the accuracy of the data used to calculate the variables in developing revenue forecasting models. This section asks whether those models are structured in a way that adequately reflects the underlying economic and social influences on travel and fuel use and hence on fuel-tax revenues. The models used by most states to forecast travel and other variables affecting fuel-tax revenues appear to be accounting identities or simple statistical relationships predicting one of the components of revenues. They are simplistic and nonbehavioral. For example, in Indiana's revenue forecasting model, total VMT recorded by commercial vehicles (VMT_{COM}) is predicted from the number of combination truck tractors registered in the state (TT_{reg}) using the following equation:

$$VMT_{COM} = -1964.88 + 0.1077 \cdot TT_{reg} \qquad (5)$$

In turn, a measure of the state's gross product (analogous to the gross domestic product, or GDP, at the national level) is used to forecast TT_{reg}. Aside from the apparent unreasonableness of the negative constant term in Equation 5, the model is not "causal," in the sense that it fails to include any variables likely to influence the usage of trucks within the state.

Similarly, the revenue forecasting model used by California's State Budget Office is a regression model with the previous year's consumption of fuel as its only "explanatory" variable. In other words, it is a simple trend model. The specific measure used by the model is gasoline consumption, and the model is used every two years to generate forecasts of fuel-tax revenues over a 7-year

future horizon. (The state considered introducing a fuel efficiency variable in the model but decided against it because fuel efficiency was changing too much and it was not worth the extra effort, in their view!) One common but disturbing feature of such models is their implicit assumption that the demands for travel, vehicles, and fuel are not responsive to changes in social, demographic, and economic variables. This leads to the particularly troublesome implication that there is no response of fuel use to changes in fuel prices, either through the number and type of vehicles owned or the amount each one is driven; in economic terms, the demand for fuel is assumed to be perfectly inelastic. The penetration of sports utility vehicles (SUV) into the vehicle fleet over the past five years is a clear example of why such an approach is inadequate.

The argument can be made that there is some more or less general underlying behavioral model in which the long-run structure of transportation and fuel demand, hence fuel-tax revenues, is determined by a set of economic and demographic variables.

Vehicle use may exhibit a long-run trend, but households and businesses also adjust their use of available vehicles in the short term in response to their changing demands for travel. Over the longer run, however, they are likely to change the number of vehicles they own. Thus, one can think of households making decisions about the number and type of vehicles to purchase based on demographic considerations including family size, composition, and age structure as well as on economic factors such as their incomes and the prices of vehicles and fuel. At the same time, the household will make accompanying decisions about how much to use each vehicle in order to meet its members' collective demands for travel.

If fuel prices change—for example, if they increase—households are likely to alter the usage of each vehicle they own because the fuel efficiencies of those vehicles may not correspond to what the household would have purchased at higher fuel prices. (In economic terms, the household is in "disequilibrium.") On average, an increase in fuel prices would be expected to reduce the average number of miles driven by household members in the vehicles they own, thereby reducing the total number of vehicle miles they drive. With permanently higher fuel prices, however, the household may change the number or—more likely—the fuel efficiency of the vehicles it owns by selling one or more vehicles and possibly purchasing others. After it does so, the total number of vehicle miles it drives may return to a level closer to (although still below) what prevailed before the increase in fuel prices. As this example illustrates, the behavioral response to a change in any one of the variables ultimately determining fuel consumption and tax revenues may be quite complicated.

The "true" behavioral relationships of these intermediate variables to the underlying demographic and economic influences are complex, as illustrated by the ex- ample of changes in vehicle use in response to fuel price variation. Vehicle use is in turn only one of the determinants of total VMT (vehicle ownership, which also is quite complex, being the other). It would not be realistic for each state to try to model the entire behavioral system for forecasting purposes. What states probably need is some simplified model that captures the important behavioral responses but also "tracks" well for forecasting purposes. Therefore, one useful way to think about a model for forecasting is that demographic and economic variables affect fuel consumption through their influence on the intermediate variables that mathematically determine fuel consumption, namely VMT and vehicle fuel efficiency.

Reduced-Form Equation

A potentially useful approach is to estimate a "reduced form" equation for VMT that is derived from careful specification of the structural form.[10] Fuel efficiency can be modeled in the same way (econometric estimation of a reduced-form model), or we can do it "mechanically" using the cohort-survival approach. VMT would be the left-side variable and the right-side variables would be gross domestic product (GDP), price gas, and fuel efficiency. The price of gas/fuel efficiency would measure cost/mile. The right-side variables would come from state DOTs and other departments in the state government. Also included on the right side would be the degree of urbanization, per-capita road miles. Broad macro influences, household demographics, and location characteristics would be of interest as well. Building on these examples, states as well as the federal government could develop models that perform well in forecasting but also satisfactorily capture the critical responses to changes in fuel prices, tax rates, and fleet fuel efficiency (the SUV effect, for example). There are several examples of this approach in the literature (*4,5*).

As an illustration of the approach just described, Schimek (*5*) has estimated a time-series model of gasoline and travel demand. In the model, the per-capita demand for (highway) gasoline, G_H, would be a function of the price of fuel, P_F, and annual per-capita income, Y_t:

$$G_H = f\left(P_{F,}\ Y_t\right) \qquad (6)$$

However, gasoline demand can be decomposed into three key influences: the stock of vehicles, the fuel efficiency of the vehicle stock, and the usage of the vehicle stock. The systems of equations would be as follows:

- Vehicle ownership or stock equation: vehicles per capita = vehicle stock/population.
- Vehicle use equation: annual VMT/vehicle = total VMT/total gasoline consumption.
- Vehicle stock fuel efficiency: total VMT/total gasoline consumption.

From this system of three equations emerges the accounting identity, as we saw earlier, of

$$G = S/N \cdot D/S \div D/TG \tag{7}$$

where

S = vehicle stock,
N = population,
D = distance driven, and
TG = total gas consumption.

The value of the disaggregation is that by modeling the three factors separately, you are able to take account of the separate influences and the differences in adjustment periods for each of the factors. In effect, you can obtain more precise estimates of the parameters and hence more accurate forecasts.

Model components for gasoline demand are the following:

$$\text{Stock:} \quad S/N = f_S\left(P_F, Y_t, P_V\right) \tag{8}$$

$$\text{Efficiency:} \quad D/TG = f_E\left(P_F, Y_t, T\right) \tag{9}$$

$$\text{Usage:} \quad D/S_t = f_U\left(P_F, Y_t, S/N, D/TG, D74, D79\right) \tag{10}$$

where T is a time trend running from 1978 through 1994 used to control for the CAFE standards and $D74$ and $D79$ are dummy variables to control for gas-rationing years. These estimates are based on annual data for the entire United States from 1950 through 1994 inclusive. The model is estimated to control for the impact of the introduction of the CAFE, which turns out to be quite important. The long-run price elasticity of demand for gasoline was estimated to be −0.7, which is less than thought (−1.02), whereas the income elasticity is estimated to be 1.43. This latter estimate is similar to the previous literature.

Estimates also are available for the parameters of the three-equation model. In the stock equation, the fuel price elasticity is −0.14, in the VMT equation it is −0.26, and in the fuel efficiency equation it is 0.23. Therefore, a 1 percent decrease in real gas prices will increase vehicle holdings by 0.14 percent, increase VMT by 0.26 percent, and reduce the average fuel efficiency of the stock by 0.23 percent. Thus, this model indicates the long-run rebound effect may be as high as −0.3.

The impact of changes in income is measured in all three equations as well. The income elasticity of vehicle holdings is 1.14, of vehicle usage is 0.29, and of vehicle fuel efficiency is −0.06. Therefore, a 1 percent increase in real income will increase average vehicle holdings by 1.14 percent, increase vehicle use (measured in VMT) by .29 percent, and reduce average vehicle efficiency by 6 percent.

The importance of using models that are more sophisticated should be evident from these estimates. First, there are quite significant differences in the impact of prices on important variables that would be used to forecast revenues: usage, vehicle efficiency, and vehicle holdings.

Second, the models illustrate the relative importance of the economic variables and their influence on fuel consumption. Gasoline demand is more income than price elastic so if price/income trends continue, per-capita consumption of fuel will rise, as will tax revenues. The influence of income on fuel consumption occurs for the most part through vehicle ownership with a small effect on vehicle usage. Price affects fuel consumption through changes in fuel efficiency and reductions in VMT. Prices do not affect vehicle ownership to a significant degree, and the price effect on VMT is much greater than the price effect on fuel efficiency.

Third, it is possible to examine the impact of institutional, strategic, and policy changes on demand and hence on revenues. The introduction of CAFE standards has lead to a measurable long-run increase in driving associated with the reduced vehicle operating cost due to fuel efficiency standards. Do we need models that are more sophisticated? That is an open question, since on the one hand the disaggregation clearly shows some significant differences in the impacts on variables used in forecasting revenues, but on the other hand the parameters also exhibit significant long-term stability. So yes, we need better models, but we do not have to reestimate them every year or two. Perhaps the essential question is, what you are trying to forecast and why?

Suggested Modeling Approach

The argument has been made that the models now in use in many states are simplistic whereas in other states they are relatively sophisticated. The variance in modeling design and forecasting reliability is reasonably high. Perhaps it would be desirable to develop a generic forecasting model that could serve as the basis for all states to develop forecasts. States would have the opportunity to augment the basic model to meet their particular needs and circumstances. (FHWA takes information [forecasts] from these diverse set of models and aggregates it to yield nationwide measures.)

The gap between what is used now in the forecast of state revenues and what we have earlier argued is a

desirable full structural model is large. To close this gap in a meaningful yet practical way, it may be prudent to proceed as follows: set out the full structural model to ensure the causal relationships are well understood, and then step down to a manageable reduced-form model. The manageability of the reduced-form model would be dictated to a significant degree by the availability of data. The gap between the structural and reduced-form model would provide information to states as to the types of data they should be collecting to augment their revenue forecasting models. (Estimating the reduced form might represent a reasonable compromise between what we do now, which is somewhat simplistic, and estimating the entire structural system, which is arguably too complicated for many states to manage.)

The structural model might take the form of estimating two relationships, the amount of travel (VMT) and the fuel efficiency of the fleet, and use an accounting identity for total fuel consumption. This would provide the requisite information to forecast fuel tax and registration fee and other fee revenues.

Total VMT is determined by a system with a structural form consisting of two equations and an accounting identity. The appropriate behavioral unit is probably the individual household, in which case the system determines annual VMT/household rather than total annual VMT, and we need another equation for the number of households. It also would require household-level data, which are difficult and expensive to come by. (One of the most difficult problems is the need for panel data to obtain enough cross-sectional variation in fuel and vehicle prices among households to identify coefficients on these variables.) Therefore, estimating the model using annual time-series data at the national or state level, rather than household-level data, could be done, albeit with some concerns for aggregation bias. The structural system could take the following form, where the subscript t indicates time periods:

$\left(\textit{Average vehicles/household}_t\right) = f_1$ (average household size$_t$, fraction of total households of each type or composition$_t$, fraction at different stages in family "life cycle$_t$," average household income$_t$, fraction of households with different locations$_t$ [such as central city, suburban, or rural], vehicle prices$_t$, fuel price$_t$)

$\left(\textit{Average annual VMT/vehicle}_t\right) = f_2$ (average household size$_t$, average household income$_t$, fuel price$_t$/ average MPG$_t$, average vehicles/ household$_t$)

$\left(\textit{Total annual VMT}\right)$ = average vehicles/household$_t$ · average annual VMT/vehicle$_t$ · number of households

The reduced form of this system would be

$\left(\textit{Total annual VMT}_t\right) = f_3$ (average household size$_t$, fraction of total households of each type or composition$_t$, fraction at different stages in family "life cycle$_t$," average household income$_t$, fraction of households with different locations$_t$, vehicle prices$_t$, fuel price$_t$, average MPG$_t$)

States and the federal government could estimate this equation if the quality of the data measuring the dependent variable was improved. This assumes that the demographic, vehicle-price, and fuel-price data were adequate. The "forecasting behavior" of the model could be improved by using the lagged value of the dependent variable on the right side with the appropriate econometric corrections.

Fuel efficiency can be modeled analogously for the other determinant of fuel consumption. One possible structural form could be represented as

New MPG$_t$ = f_1 (income$_t$, fuel price$_t$, vehicle technology$_t$)

Fleet MPG$_t$ = f_2 (new MPG$_{t-1}$, new MPG$_{t-2}$, ..., new MPG$_{t-T}$)

where

new MPG$_t$ = the average fuel efficiency of new cars sold during year t,
income$_t$ = some measure of per-capita or household real income during year t,
fuel price$_t$ = the average retail price of fuel during year t,
vehicle technology$_t$ = some proxy for continuing progress in engine design (such as horsepower/cubic inch of engine displace), and
T = some arbitrary but reasonable upper limit on the lifetime of vehicles.[11]

Since all of the variables in new MPG$_{t-1}$, new MPG$_{t-2}$, and so on on the right-hand side are endogenous, the reduced form of this system would be

Fleet MPG$_t$ = f_3 (income$_t$, fuel price$_t$, vehicle technology$_t$)

Total fuel consumption is obtained by combining average MPG and adding the accounting identity:

Total annual fuel consumption$_t$ ≡ total annual VMT$_t$ · fleet average MPG$_t$

These three equations would produce a structural system for total fuel consumption. Since VMT and MPG have some explanatory variables in common, the reduced form of this system would not be more complicated that that for either of those two variables. Therefore, the reduced form could be represented as

$$\begin{pmatrix}\text{Total annual}\\ \text{fuel}\\ \text{consumption}\end{pmatrix} = f_1\,(\text{average household size}_t\text{, fraction of total households of each type orcomposition}_t\text{, fraction at different stages in family “life cycle}_t\text{,” average household income}_t\text{, fraction of households with different locations}_t\text{, vehicle price}_t\text{, fuel price}_t\text{, vehicle technology}_t)$$

In using this model, the states could forecast fuel tax revenues from the total annual fuel consumption. It would not even require improving the data on VMT and MPG, because it bypasses that stage, albeit at the cost of losing the ability to understand the behavioral response to changes in the explanatory variables.

Although the purpose of this paper is not to develop an alternative model for forecasting, proposing the alternative approach does suggest several research problems, which is what the paper ultimately is supposed to do. Three areas of potential research are

- Better measures of the relevant variables, including exploration of the use of household survey data (such as the Nationwide Personal Transportation Survey, or NPTS) or panel surveys to estimate household-level models;
- More insightful modeling of the "structural forms" that determine household automobile ownership and use, as well as the fuel efficiency of vehicles purchased by households; and
- Improved econometric techniques for estimating the reduced-form equations for total VMT (or VMT/household), fleet fuel efficiency, and total fuel consumption, using both annual time-series data at the national or state level and household cross-section or panel data.

Evolving Revenue Sources, Models, and Information Requirements

The traditional approach to highway finance and basing expenditures on the revenues raised within the system has led to the development of the present information base used in investment decisions and operations management. The use of conventional taxes and fees such as vehicle registration fees and fuel taxes provides the basis for designing forecasting models such as those described earlier. However, information needs may be changing as alternative financing instruments are developed and a more businesslike approach is taken in infrastructure management.

One important driver of the move to new fiscal instruments has been the unwillingness of states to increase fuel taxes. This reluctance is based partly on the growing revenues from the economy that has experienced high and sustained rates of growth. At the same time, there has been a shift to greater fiscal prudence and the unpopularity of any tax increases. There are other factors at work as well. The lack of investment in maintaining infrastructure over the past few decades has led to a call for reinvestment on a broad scale. (This is in addition to the argument that investments in public infrastructure will increase productivity.) This will require significant revenue. There is also a changing view of highway management, a shift from what used to be "needs" based to one in which benefits and costs are a critical part of the decision process. What is now required is information oriented to economic management rather than engineering operation and maintenance.

Financing new roads and facilities such as bridges and tollways has placed greater reliance on facility-based charges. "HOT lanes" and other examples of charging fees for the use of facilities have served to increase the awareness of this source of revenue. With increasing congestion in a number of the nation's cities and with the potential for using transportation demand management strategies for both congestion and pollution control, fuel taxes may be displaced or augmented by carbon-based taxes (6). In either case, the challenge of forecasting revenues is daunting because now the issue is setting the right price that will assure a desired outcome (level of traffic) rather than simply predicting revenues. In other words, price now becomes a signal for use and investment rather than a means of financing identified "needs." Furthermore, the problems of transportation finance change significantly as revenues either go to specific projects or are placed in the general revenue fund. In the latter case, transportation must compete with other demands (education, defense, health care) for this public capital.

In addition to tolls, states are pursuing a number of other innovative financing strategies. These have related to taking advantage of new provisions in federal highway funding programs. A number of states have undertaken to raise new funds in areas such as revolving trust funds, tax-supported toll roads, lease purchase agreements, fuel taxes indexed to the consumer price index, and public-private partnerships. If states maintain their current practice of setting expenditures equal to revenues and prioritizing projects until the money runs out, the new sources of revenues will place quite different demands on the forecasting models and therefore the information base. If states take a more economically efficient approach to transportation planning whereby they evaluate projects on their economic merit and set taxes and fees to fund what are economically desirable projects, new models and different information will be needed.

The current system appears to be well entrenched, yet a number of forces are pushing in the direction of different financing approaches, different management philosophies, and consequently, different information needs. If we believe these changes are more than a short-term aberration, we need to ask what models will be needed and what will be the type of information required in these models for forecasting revenues.

Summary and Proposed Research Statements

The paper takes an evolutionary approach to the examination of information requirements for forecasting revenues for state highway departments. Two primary attributes are data accuracy and data availability. Looking at the current set of models, we can ask, are the data used accurate and how might they be improved? How would this be accomplished? Next we ask the question, setting aside the issue of data accuracy, are the models that are presently in use correct and if not, how should they be modified? How will these changes alter the data requirements and who will assume responsibility for this? Finally, we ask, with the new and innovative financing methods available under TEA-21 and given the reluctance on the part of states to increase taxes and fees, what information is needed to forecast revenues when there is a portfolio of financing instruments? These questions can be formalized into the following research statements.

Improving Estimates of State-Level VMT

Description of Research Problem

Available estimates of state-level VMT are inadequate and require significant improvement in their reliability. A number of states measure VMT only in a limited number of locations and for a limited number of years, with estimates for the intervening years interpolated from values for the years in which VMT is measured. Similarly, local estimates of VMT are expanded to the entire state based on data collected on a relatively limited—and certainly older—part of the system. States need to invest more in collecting information on three attributes of VMT: the number of miles, the location of the miles, and the average trip length.

Work To Be Performed

VMT estimates can be obtained from three sources: surveillance, household surveys, and odometer readings. The research would involve activities in all three areas. There is an increasing number of modern surveillance techniques and surveillance locations; freeways are equipped with cameras, for example. This research would explore alternative technologies for collecting data. They would be evaluated in terms of cost and accuracy, and once a technology is selected, a time series of data of VMT including trip length and vehicle counts would be collected. The second source of improving VMT is household surveys. Total VMT can be obtained from the current Nationwide Personal Transportation Study (NPTS) by combining information from different files. It also is possible for urban areas (and perhaps states) to use the NPTS to obtain more detailed information at the subnational level by increasing the sample size in a given area. These survey data would yield information on household behavior. The third source for VMT information is odometer data. Odometer data can be collected in those states that inspect vehicles on an annual basis. From this source, it is possible to construct a data set that has VMT by number, age, and type of vehicle. The unit of observation would be the vehicle.

This research project would provide improved VMT data from three sources. It would identify the approach that is cost-effective yet maintains data quality. It would provide a basis of comparison across methods. Finally, it would have different behavioral units from the three sources and this would flow naturally into the improved modeling project discussed below.

Cost Estimate: $600,000

Developing a Generic Starting-Point Model for Forecasting State Revenues

Description of Research Problem

The argument has been made that the models now in use in many states are simplistic whereas in other states they are relatively sophisticated. The variance in modeling design and forecasting reliability is reasonably high. Perhaps it would be desirable to develop a generic forecasting model that could serve as the basis for all states to develop forecasts. States would have the opportunity to augment the basic model to meet their particular needs and circumstances.

Work To Be Performed

The gap between what is used now in the forecast of state revenues and what we have earlier argued is a desirable full structural model is large. To close this gap in a meaningful yet practical way, it may be prudent to proceed as follows: set out the full structural model to ensure the causal relationships are well understood, and then step down to a manageable reduced-form model. The manageability of the reduced-form model would be dictated to a significant de-

gree by the availability of data. The gap between the structural and reduced-form model would provide information to states as to the types of data they should be collecting to augment their revenue forecasting models.

The structural model might take the form of estimating two relationships, the amount of travel (VMT) and the fuel efficiency of the fleet, and use an accounting identity for total fuel consumption. This would provide the requisite information to forecast fuel tax and registration fee and other fee revenues. The appropriate behavioral unit is probably the individual household, in which case the system determines annual VMT/household rather than total annual VMT. It also would require household-level data, which are difficult and expensive to come by. Therefore, estimating the model using annual time-series data at the national or state level, rather than household-level data, could be done, albeit with some concerns for aggregation bias. The model could be estimated on national data and then provided to each state, which could re-estimate the model if so desired, or the parameter estimates for the national-level model could be used to forecast revenues.

Cost Estimate: $400,000

Developing a Model of Commercial-Vehicle VMT

Description of Research Problem

The research into structural models of VMT for light vehicles has not carried over into commercial-vehicle VMT. We need a better understanding of how trucking, both private and for hire, is used by different industries. We find, for example, that VMT between Canada and the United States has increased since the North American Free Trade Agreement was signed. A major source of this VMT are industries specializing according to their competitive advantage and industries adopting strategies that place specific product production in specific locations (e.g., the automobile sector). As economic activity shifts between countries and among states, we can expect more truck VMT, but it also may involve significant redistribution of activity. Trucking registration fees present another set of challenges for forecasting since regulations governing registration can lead to gaming behavior by trucking firms. As rules change, forecasting becomes more difficult.

Work To Be Performed

This project would develop a model of truck use at the firm level to provide estimates of both the number of vehicles as well as the use of vehicles in the private trucking segment. A second model would examine two issues: the decision to use for-hire rather than private trucking and the amount of for-hire trucking to use. An integral part of this modeling effort is to develop an understanding of how different industries use more or less trucking and how the distribution of economic activity affects the level of VMT.

Cost Estimate: $700,000

Examining the Highway Finance Implications of Alternative Revenue Instruments

Description of Research Problem

The traditional approach to highway finance has led to the development of the present information base used in investment decisions and operations management. The use of conventional taxes and fees such as vehicle registration fees and fuel taxes provides the basis for designing current forecasting models. However, information needs may be changing as alternative financing instruments are developed and a more businesslike approach is taken in infrastructure management. States' legislators also are enabling local governments to earmark funds for specific purposes. Revenue streams also are being tied to specific investment projects. There is a need to explore the implications of changes in methods of financing transportation projects for the institutional relationships, forecasting approaches, and informational requirements. For example, if a broad-based carbon or energy tax were adopted, revenues would flow into a general revenue fund rather than be earmarked for transportation purposes. Highways, transit, and other modes of transportation would compete with other government demands for funding.

Work To Be Performed

The project would examine the jurisdictional, financial, and economic consequences and the information demands of three changes to revenue sources: (*a*) the movement to allow local governments to use traditional revenue sources to fund specific projects (e.g. bonds, sales taxes); (*b*) the movement away from fuel taxes and to economy-wide carbon or energy taxes; and (*c*) the move to rely more heavily on road tolls and road pricing. The purpose of this research is to explore the far-reaching implications of changes in the structure of highway finance.

Cost Estimate: $350,000

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NOTES

1. The financial burden also was to be transferred away from general revenue financing toward user financing to "the maximum extent practicable." Thus, states and municipalities were to take a hard look at their existing fiscal arrangements and increase the amount that they captured from user charges or taxes on those facilities. Private-sector investment was to be partnered. The level of government and legal impediments, constraints, and distortions was to be removed, or reduced, to facilitate the implementation of the new policy.

2. The prevailing view of highway finance was practical as well as conceptual. The ownership and use of automobiles could be taxed easily and cheaply. Furthermore, the benefits of a well-developed road system were not simply local in nature, so neither should the responsibility for financing it remain strictly local.

3. By 1986, diesel fuel was taxed by all of the states. In some states, contrary to economic efficiency, diesel fuel is taxed at a higher rate than gasoline mainly because of the greater fuel efficiency achieved by diesel-powered vehicles.

4. Two organizations, the International Fuel Tax Association (IFTA) and International Registration Permits (IRP), are involved in redistributing tax revenue among states. Trucks pay fuel where it is burned, not where they bought it. They must report to IFTA the mileage in each state and pay those states on a pro-rata basis according to where they traveled. Fee payments for registration are handled in a similar fashion. Trucking firms report for each truck where it traveled and redistribute payments, through IRP, for using trucks in a different area than the state in which they are registered.

5. This practice has a number of drawbacks. These include exposure to financial market risk, a wide variance in individual states' credit ratings, and exposure to political risk due to the potential of legislators to support bond financing only for projects that clearly benefit their own constituents.

6. This can be viewed as the curse of the "needs" approach to transportation planning and highway expenditure. The current practice is to have revenues determine the capital program. Projects will be undertaken until revenues run out, and this is what makes the reliability of revenue forecasting so critical. The alternative is to develop a capital program based on some objective function and set taxes and fee levels to generate sufficient revenues to undertake the economically efficient projects.

7. Even this is not quite true, as illustrated in Table 1.

8. A similar identity would hold for revenue from registrations—with the G_i replaced by the number of vehicles of each class that are registered, and similar problems of information adequacy applying.

9. The question is, do states have decent data with some precision on VMT at the statewide level? FHWA has had a project over the past 10 years aimed at improving these data, since it uses these state data to predict the revenue accruing to the federal government.

10. Most existing models have assumed that the three components of demand (automobile ownership, VMT, and fuel efficiency) are determined simultaneously and have estimated the equations for each in their reduced form.

11. In the Fleet MPG equation, f_2 probably would be some sort of distributed-lag function. Thus, the parameter estimates on new MPG_{t-1}, new MPG_{t-2}, and so on would subsume several variables for which there *could* be explicit structural form equations, including the gap between test and on-road MPG, deterioration in vehicles' MPG with age and accumulated mileage, and so forth.

REREFENCES

1. *Moving America: New Directions—New Opportunities.* U.S. Department of Transportation, 1990.
2. *Transportation Financing.* American Public Works Association, Kansas City, 1997.
3. Schipper, L., et al. *Mind The Gap: The Vicious Circle of Measuring Automobile Fuel Use.* University of California Transportation Center, 1995.
4. Wheaton W. The Long Run Structure of Transportation and Gasoline Demand. *The Bell Journal of Economics*, Vol. 13, No. 2, Autumn 1982, pp. 439–455.
5. Schimek, P. Gasoline and Travel Demand Models Using Time Series and Cross-Section Data from United States. In *Transportation Research Record 1558*, TRB, National Research Council, Washington, D.C., 1996, pp. 83–89
6. *Guidance on the Use of Market Mechanisms to Reduce Transportation Emissions.* Office of Policy, Planning and Evaluation, Environment and Transportation Sectors Division, U.S. Environmental Protection Agency, draft April 1997.

BIBLIOGRAPHY

Blum, U., G. Foos, and M. Gaudry. Aggregate Time Series Gasoline Demand Models: Review of the Literature and New Evidence for West Germany. *Transportation Research*, Vol. 22A, No. 2, 1988, pp. 75–88.

Brown, J., et al. *The Future of California Highway Finance.* Report to California Policy Seminar and University of California Energy Institute, Dec. 1998.

California Motor Vehicle Stock, Travel and Fuel Forecast. California Department of Transportation, Nov. 1997.

Federal, State, and Local Transportation Financial Statistics: Fiscal Years 1982-94. Report BTS 97-E-02. Bureau of Transportation Statistics, U.S. Department of Transportation, Sept. 1997.

Gittings, G. L. and B. R. Narayan. Federal Highway Revenue Estimation: Cost Allocation Perspective. In *Transportation Research Record 1558*, TRB, National Research Council, Washington, D.C., 1996, pp. 1–7.

Greene, D., et al. *Aggregate Vehicle Travel Forecasting Model.* Report ORNL-6872. Oak Ridge National Laboratory, May 1995.

Guidance on the Use of Market Mechanisms to Reduce Transportation Emissions. Office of Policy, Planning and Evaluation, Environment and Transportation Sectors Division, U.S. Environmental Protection Agency, draft April 1997.

Innovative Transportation Financing. American Association of State Highway Officials, Washington, D.C., April 1995.

James, V. E. An Econometric Forecasting Model of Highway Travel and Gasoline Demand in New York State. In *Transportation Management Conference Proceedings*, 1994.

Lockwood, S. C., H.B. Caldwell, and G. G. Williams., et al. Highway Finance: Revenues and Expenditures. In *Transportation Research Record 1359*, TRB, National Research Council, Washington, D.C., 1992, pp. 11–18.

Moving America: New Directions—New Opportunities. U.S. Department of Transportation, 1990.

Navai, R. Transportation Financing: A Critical Review of Transportation Pricing. *Transportation Quarterly*, Vol. 52, No. 1, Winter 1998, pp. 71–83.

Nix, F., and J. Jones. *Highway Finance: Theory and Practice.* Transportation Association of Canada, 1995.

Pickrell, D., and P. Schimek. Growth in Motor Vehicle Ownership and Use: Evidence from the Nationwide Personal Transportation Survey. *Journal of Transportation and Statistics*, Vol. 2, No. 1, May 1999, pp. 1–19.

Schimek, P. Gasoline and Travel Demand Models Using Time Series and Cross Section Data from United States. In *Transportation Research Record 1558*, TRB, National Research Council, Washington, D.C., 1996, pp. 83–89.

Schipper, L. Measuring the Long-Run Fuel Demand of Cars: Separate Estimations of Vehicle Stock, Mean Fuel Intensity, and Mean Annual Driving Distance. *Journal of Transport Economics and Policy*, Vol. 31, No. 3, Sept. 1997.

Schipper, L., et al. *Mind The Gap: The Vicious Circle of Measuring Automobile Fuel Use.* University of California Transportation Center, 1995.

Transportation Financing. American Public Works Association, Kansas City, 1997.

Transportation Revenue Forecasting Guide. U.S. Department of Transportation, June 1987.

Understanding the Highway Finance Evolution/Revolution. American Association of State Highway Officials, Washington, D.C., Jan. 1987.

Varma, A., K. C. Sinha, and J. Spalding. *The Development of a Highway Revenue Forecasting Model for Indiana.* Report FHWA/IN/JHRP-91-5. School of Civil Engineering and Indiana Department of Transportation, 1991.

Wheaton W. The Long Run Structure of Transportation and Gasoline Demand. *The Bell Journal of Economics*, Vol. 13, No. 2, Autumn 1982, pp. 439–455.

Williams, G., and T. Howard. Highway Finance: Past, Present and Future. *Public Roads*, Summer 1994, pp. 13–17.