Impact of Mandatory Fuel Economy Standards on Future Automobile Sales and Fuel Use

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This paper provides a basis for projecting and evaluating the impact of mandatory fuel-economy standards and gasoline taxes on automobile sales and fuel consumption. The analytical procedures are based on explicit estimates of the cost to improve the technical efficiency of new automobiles and a behavioral model of consumer choice of automobile by market class. Alternative policies are evaluated in terms of their impacts on fuel consumption, sales-weighted fuel economy, automobile sales, scrappage of vehicles, fleet composition, and vehicle kilometers of travel. Increases in gasoline prices were found to have considerable potential for reducing automotive fuel consumption but only at the expense of creating equally sizable reductions in vehicle kilometers of travel and in the number of automobiles sold. Fuel-economy standards, such as those contained in the Energy Policy and Conservation Act of 1975, also appear to have a significant beneficial effect on fuel consumption but relatively little impact on automobile sales and travel. Early indications suggest, however, that the standards incorporated in the existing legislation may be unattainable and that revisions in both the standards and the penalty structure might produce better results.

Now that energy conservation has become a national priority, much of the concern about fuel conservation naturally focuses on automobiles. Automobiles consume almost a third of the nation's petroleum products; it is widely assumed that much of this consumption is inessential and could be eliminated by more fuel-efficient vehicles, travel patterns, and life-styles. One automobile is now in use for each 2.3 Americans (including children), and the average automobile travels about 18 500 km/year (11 500 miles/year) and consumes 3300 L (870 gal) of gasoline along the way. Among the many opportunities for conservation implicit in these statistics are reductions in the widespread ownership and use of automobiles and improvements in the fuel efficiency of individual vehicles.

Although this report concentrates on opportunities for improved fuel efficiency, it recognizes that, because of the complex ties that exist among the U.S. automobile industry, the consumer, and the federal government, other areas cannot be ignored. Some of these ties are direct, such as government standards on automotive safety, emissions, or fuel economy. Others are indirect, such as the connection between automobile sales and energy costs. Attempting to analyze an industry as large and complex as the U.S. motor vehicle industry necessarily involves simplification, and in turn this simplification restricts the range of problems for which analytic structure is appropriate.

This paper describes projections based on a forecasting model for the automotive sector, which was developed for the purpose of examining various government policies that affect new-automobile fuel economy—specifically, excise taxes and rebates, fuel economy standards, and policies that influence the price of gasoline. The aim is to simulate how future automobile sales, the stock of automobiles in use, vehicle kilometers of travel, new-automobile prices and fuel economies, and automotive fuel consumption will be affected by various policies that might be enacted by the federal government. The paper focuses on a specific family of policies, namely, fuel economy standards for new automobiles. It examines how variations in the standards themselves and in the associated penalties for noncompliance can influence policy effectiveness. The aim of the investigation is to develop some preliminary information on the likely effects of the Energy Policy and Conservation Act (EPCA) and to explore whether changes in that legislation might enhance its effectiveness or lessen any of its undesirable side effects.

ENERGY POLICY AND CONSERVATION ACT

The Energy Policy and Conservation Act of 1975 (Pub. L. 94-163) will impose mandatory fuel-economy standards on automobile manufacturers starting in 1978 and continuing through 1985. These standards are given below (1 km/L = 2.35 miles/gal):

Year	Standard (km/L)
1978	7.65
1979	8.08
1980	8.50
1981 to 1984	To be determined by the Secretary of Transportation
1985	11.69

Between 1981 and 1984, the Secretary of Transportation must set fuel economy standards that will (a) provide for the maximum feasible fuel economy levels in each year from 1981 through 1985 and (b) result in steady progress toward meeting the 1985 goal of 11.69 km/L (27.5 miles/gal). The 1985 goal may be changed by the Secretary of Transportation, but any change that reduces the 1985 standard below 11.05 km/L (26 miles/gal) or raises it above 11.69 km/L must be submitted to Congress for approval.

The fuel economy standard is applied to the average fuel economy of all automobiles manufactured by each firm. Manufacturers whose sales-weighted fleet fuel economy is below the standard are liable to a civil penalty of $11.76 for each 0.1 km/L ($50/mile/gal) that their fleet average is below the fuel economy standard for each automobile manufactured. Because these penalties may not be treated as expenses in computing corporate income taxes, their after-tax effect is approximately twice the statutory level; e.g., an extra kilometer per liter of fuel economy offsets expenses of about $235/automobile for a manufacturer whose output falls beneath the fuel economy standard.

CONSUMER DEMAND FOR AUTOMOBILES

The methodology used in making these forecasts combines two distinct parts: automobile demand prediction and automobile industry simulation. The automobile demand model is based on the following set of econometric relations:

$$N_t = (286\,721.3)\,[O_t^* - (\text{autos}_t - D_t)]^{0.2178}\,(X_t^*)^{-1.7039} \quad (1)$$

$$O_t^* = \left(\sum_I H_I P_{It}\right) HHLD_t \quad (2)$$

$$H_I = 0.017\,86\,I^{0.4743} \quad (3)$$

$$S_t = 1/(1 + \exp\{-[-4.1749 - 1.8660(X_t^S) + 3.5093(X_t^M) + 5.6428(S_{t-1})]\}) \quad (4a)$$

$$M_t = 1/(1 + \exp\{-[-4.1749 - 2.0765(X_t^M) + 3.5450(X_t^S) + 0.2589(X_t^L) + 5.6428(M_{t-1})]\}) \quad (4b)$$

$$L_t = 1/(1 + \exp\{-[-4.1749 - 0.4299(X_t^L) + 1.8117(X_t^M) + 5.6428(L_{t-1})]\}) \quad (4c)$$

$$SPG_t = 0.4068 - 0.0784(P_n)_t - 0.0155(U_t) \quad (5)$$

$$KMT_t/HHLD_t = -85\,244.5 + 24\,275 \log(DI_t HHLD_t) - 3546.6 \log(CPKM)_t + 10\,196.6\,(\text{autos}_t/HHLD_t) \quad (6)$$

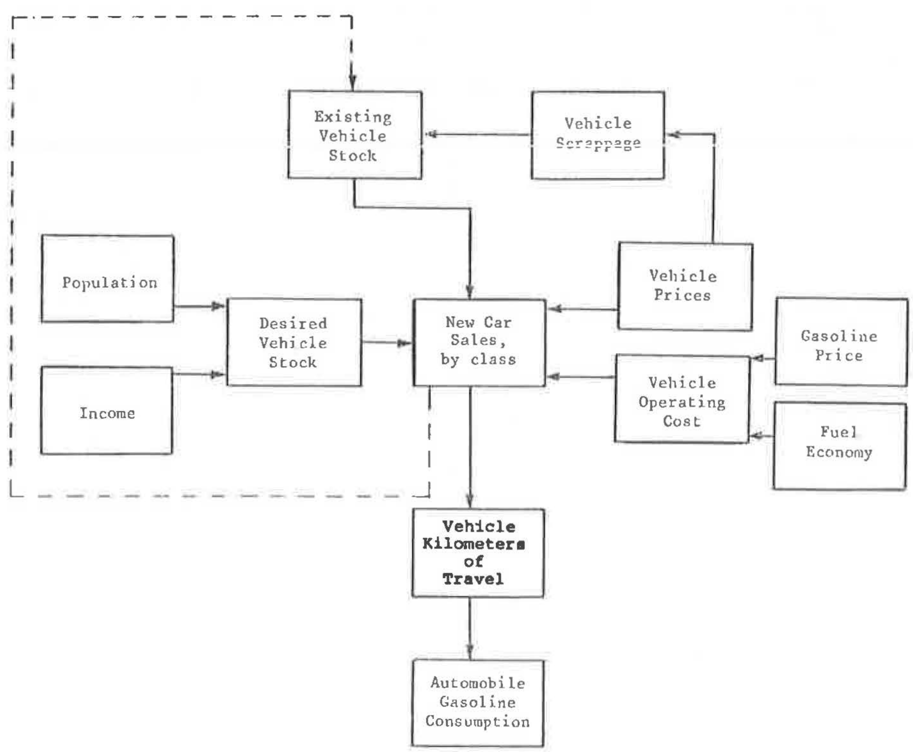
where

N_t = total new automobile sales in year t;
O_t^* = target ownership of automobiles in year t;
$(\text{autos})_t$ = stock of automobiles on hand as of January 1 of year t;
D_t = number of automobiles scrapped during year t;
X_t^* = index of the real generalized price of new automobiles (1967 = 1.00);
P_{It} = fraction of total households in year t with income (I);
$HHLD_t$ = total number of households existing in year t;
H_I = characteristic automobile ownership for households with income (I);
I = average household income;
S_t, M_t, L_t = market shares of small, medium, and large automobiles respectively in year t;
X_t^S, X_t^M, X_t^L = index of the real generalized price of small, medium, and large automobiles respectively relative to that of all new automobiles in year t (1967 = 1.00);
SPG_t = rate of scrappage in year t of vehicles 8 or more years old (an index relative to the average rate for vehicles in each age group);
$(P_n)_t$ = index of the real price of new automobiles in year t (1967 = 1.00);
U_t = unemployment rate in year t;
DI_t = total real disposable income in year t;
KMT_t = total vehicle kilometers traveled in year t; and
$CPKM_t$ = index of the fleet real gasoline cost per mile in year t (1967 = 1.00).

These relations are applied recursively for each year of the forecast period, as shown in Figure 1.

Central to the model is the forecasting procedure for sales of new automobiles (Equations 1 through 4). Projections of new-automobile sales are based on a modified stock-adjustment concept in which the "desired" stock of automobiles (Equations 2 and 3) is determined from population and income forecasts and the "actual" stock of vehicles is based on previous stock less scrappage. The degree to which actual stock attains the desired level is based on the cost of purchasing and operating new vehicles (Equation 1). Sales by vehicle size class are determined by a market-shares estimator that is based on the prices of purchasing and operating vehicles in each class (Equation 4). The total number of vehicles scrapped, which is applied in forecasting new-automobile sales, is based on the detailed age composition of the automobile fleet. The scrappage rate of the older vehicles in the fleet is computed based on the replacement costs (i.e., costs of new automobiles) that prevail at the time of replacement (Equation 5). Vehicle kilometers of travel are computed based on the stock of vehicles, the affluence of the population, and the costs of operating a vehicle (Equation 6). The fuel consumed

Figure 1. Automobile sales forecasting model.



in driving the projected number of kilometers is calculated by distributing total vehicle-fleet travel to individual vehicle types (age and size class) and then computing fuel consumption by using fuel economies characteristic of each of these vehicle types.

The rationale for this process is to integrate vehicle ownership, sales, use, and fuel consumption harmoniously with expected future demographic, economic, and policy factors, as detailed elsewhere (1, 2). The aim of this paper is to apply this structure to determine how various federal energy policies would affect automotive energy consumption and personal mobility.

AUTOMOBILE INDUSTRY RESPONSE TO POLICY STEPS

Before the results of the automobile demand forecasting process are examined, a brief discussion of the responses the automobile manufacturing industry is expected to make to the types of federal policy that will be examined will be helpful. The industry-simulation aspect of the methodology is based on an assessment of feasible technological improvements and their costs as well as a set of assumptions about how the automobile industry as a whole would choose various technological combinations in response to alternative policy conditions. The automobile industry is assumed to act to minimize the generalized price of vehicles within each vehicle size class. The generalized price of an automobile is defined as

$$Y_{c,t} = C_{c,t} + bG_t/F_{c,t} \qquad (7)$$

where

$Y_{c,t}$ = generalized price of a new vehicle of class c in year t;
$C_{c,t}$ = price of a new vehicle of class c in year t;
b = 52 853, a constant that reflects the lifetime, discounted, perceived kilometers of travel of the automobile;
G_t = price of gasoline in year t; and
$F_{c,t}$ = fuel economy of a new vehicle of class c in year t (km/L).

That is, the automobile manufacturers act to minimize the sum of the purchase price and the perceived lifetime operating cost of the vehicle. Operating cost, as used here, includes only gasoline costs; maintenance, insurance, and other operating costs are assumed to be unaffected by the policy alternatives being analyzed. The constant (b) is based on actual annual travel patterns recorded in the Nationwide Personal Transportation Survey of the Federal Highway Administration (3); an annual discount rate of 10 percent and a perception factor of 80 percent, which reflects consumers' imperfect awareness of future operating costs, are assumed.

If fuel economy standards and noncompliance penalities are in force, then the automobile manufacturers are assumed to respond by producing vehicles that minimize the generalized net price of penalties and that are priced to pass penalty payments along to consumers. That is, the automobile makers are assumed to continue to improve fuel economy up to the point where the marginal cost of improving it (i.e., the added new-automobile price) is equal to the marginal penalty payments that would be avoided by making the improvements. This can happen in either of two ways, depending on whether or not the standards are ultimately met, as discussed below.

Standards Met

Manufacturers might in some instances meet fuel economy standards only because of fuel cost savings, and as a result the imposition of a standards program would produce no further changes. Alternatively, setting penalties lower than the statutory level might be sufficient to prompt manufacturers to comply by making only some limited improvements. In both of these situations, the marginal penalty payment associated with an increase in vehicle fuel economy is zero because no further penalty savings are to be gained by the manufacturer once the prescribed standard has been met.

Compliance with fuel economy standards might theoretically be accomplished by automobile manufacturers in various ways: One vehicle class could be upgraded substantially, in terms of fuel economy, while others remain virtually unchanged, or all vehicle classes might be upgraded approximately to the same extent. It is assumed here that improvements are made to each vehicle class so that the marginal cost of fuel economy improvements less the marginal value of the associated fuel savings is equal for all vehicle classes. This assumption results in improvements being made in an even-handed fashion across all vehicle classes, subject to the costs of those improvements. Whether or not an individual vehicle class is itself above standard has no particular bearing on whether or not fuel economy improvements will be made to vehicles of that class.

Standards Not Met

Each manufacturer would be willing to spend only an amount per additional kilometer per liter of fuel economy up to the amount of the after-tax penalty per kilometer per liter; at some point, therefore, it is more economical to pay penalties than to make further technological improvements. As a result, the marginal penalty reductions eventually fall to either of two values: zero, if standards are met, or the after-tax value of the penalty if standards are not met. In the second case, all vehicle classes would be upgraded to the point where an equilibrium is struck between penalty payments and other factors such as price and fuel savings (4, 5).

ASSUMPTIONS

The projections in this paper examine automobile-related behavior through the next 25 years. Obviously, the growth rates and the consumption patterns that characterize the automobile industry today cannot be expected to continue that long. The table below compares some general trends from the past 25 years with the assumptions used and the results projected here.

	Rate of Growth (%)			
Period	Population of Households	Disposable Income per Capita	Real Price of Automobiles	Real Price of Gasoline
1950 to 1975 (actual)	2.05	2.10	-1.52	0.25
1975 to 2000 (assumed)	1.65	2.00	1.00 (baseline) 1.59 (EPCA)	0

The major assumptions used in this analysis relate to future growth rates in (a) the population of households, (b) disposable income per household, (c) the price of gasoline, and (d) the price of new automobiles. The table presented above gives projected growth rates for these items compared with the actual growth rates experienced during the past quarter century and includes census data for households, Bureau of Economic Analysis data for disposable income, and data from the consumer price index for gasoline and automobile prices. As the table indicates, future growth in the number of households is expected to taper off slightly, the growth in disposable income per capita is expected to slow down, the historic decline in real automobile prices is projected to reverse itself, and the price of gasoline is expected to remain fixed in terms of constant dollars. These assumptions and other market-saturating influences will tend to dampen somewhat the rapid growth in automobile sales, ownership, use, and fuel consumption evident during the period from 1950 to 1975.

These projections are also based in part on assumptions about future federal policy on safety and the environment. It is assumed that the statutory emissions standards of the Clean Air Act of 1970 will be enforced starting in 1978. The table below gives the assumptions made in this study about pollutant emissions, based on the exhaust emission test procedure applied by the U.S. Environmental Protection Agency (1.6 g/km = 0.06 oz/mile):

Year	HC (g/km)	CO (g/km)	NO_x (g/km)
1975	0.932	9.323	1.927
1976	0.932	9.323	1.927
1977	0.932	9.323	1.243
1978 and after	0.255	2.113	0.249

It is also assumed that continued vehicle improvements in the areas of crash avoidance, crashworthiness, and damageability will be mandated between now and 1990. The following table gives projected vehicle improvements in these categories (1 km = 0.62 mile):

Year	Crash Avoidance	Crashworthiness	Damageability
1980	Improved hydraulic brake systems, hoses, fluids	Upgraded bumpers in low corner impacts, improved system integrity	Redesigned steel bumpers
1985	Antilock brakes	Passive belt system, upgraded side and roof structure, 32-km/h side impact, and 48-km/h roll-over	Soft-face bumpers with steel back beams
1990	No further changes	Upgraded front, side, roof, and rear structure; 54-km/h front impact; 48-km/h side and rear impacts; and 48-km/h rollover	No further changes

POLICY OPTIONS

The six policies examined in this analysis are given in Table 1. These policy alternatives assume that the safety and environmental policies previously summarized are in effect. (All prices are in constant 1974 dollars.)

All but the first policy option involve government policies directed toward improving fuel economy and reducing fuel use. The Secretary of Transportation may set the 1985 fuel economy standard at or between the stringent (11.69 km/L) and moderate (11.05 km/L) levels and must specify the corresponding 1981 and 1984 standards to provide a smooth transition between the 1980 and the 1985 standards.

Two additional policy options were also tested that assume that fuel taxes of \$0.10/L (\$0.40/gal) are applied in 1976 and maintained thereafter. In one of these, the gasoline tax was tested for the baseline case to determine the impact of the tax alone; in the other the gasoline tax was examined in conjunction with the moderate EPCA standards.

POLICY IMPACTS

Fuel Economy of New Automobiles

Table 2 gives the forecast sales-weighted fuel economies of each of the alternatives for the years 1978 to 1985. The highest 1985 fuel economy results from combining EPCA with doubled civil penalties (policy 6). At 10.49 km/L (24.7 miles/gal) in 1985, this option represents a 15 percent improvement in sales-weighted fuel economy over that of the baseline case (policy 1). As currently mandated, EPCA with either moderate or stringent standards will result in a 1985 sales-weighted fuel economy of about 9.87 km/L (23.2 miles/gal). The domestic sales-weighted fuel economy of 9.61 km/L (22.6 miles/gal) implies that the domestic automobile industry will be liable for \$1.7 billion of civil penalties in 1985 under the moderate standard and \$2.6 billion under the stringent standard. Because the sales-weighted fuel economy of foreign automobiles is forecast to be 11.56 km/L (27.2 miles/gal), foreign manufacturers as a group do not face civil penalties. Although individual foreign manufacturers may be liable, the number of automobiles involved would be so small as to make any foreign liability insignificant in comparison with projected domestic liability.

Gasoline taxes may reduce fuel consumption, but their impact on sales-weighted fuel economy appears to be marginal, particularly when a \$0.10/L (\$0.40/gal) gasoline tax is applied in addition to EPCA standards. Increased gasoline costs affect the operating cost of large automobiles more than those of small and mid-sized automobiles, but an inelastic demand inhibits any sizable reduction in sales of large automobiles. The increased operating cost for small and mid-sized automobiles tends to reduce their sales more substantially because the demand for smaller automobiles is more elastic. The additional technological stimulus afforded by a gasoline tax also appears to be marginal; the potential for technological improvements in fuel economy in each vehicle size class has been largely exploited under the EPCA. The net effect of both market shifts and technological improvements, created by combining the EPCA with gasoline-tax policies, is an increase of only 0.04 km/L (0.1 mile/gal) in 1985 sales-weighted fuel economy (Table 2). The gasoline tax applied to the baseline case would have a larger (although still marginal) impact of 0.13 km/L (0.3 mile/gal) in 1985. The greater potential of gasoline taxes to improve fuel economy outside the EPCA framework is explained by the fact that the most cost-effective technological fuel economy improvements are attributed to the fuel tax increase instead of to EPCA.

Automobile Sales

Mandatory fuel economy standards have conflicting effects on automobile prices and sales: They tend to raise average automobile costs by precipitating technological fuel economy improvements and by requiring payment of civil penalties that are ultimately reflected in the purchase price of inefficient automobiles. They can reduce lifetime vehicle costs by lowering expected vehicle operating costs.

The net impact of mandatory EPCA standards on automobile sales is negligible until 1981 but becomes substantial by 1983 (Table 3). If the moderate standard is assumed to be in force, automobile sales, relative to the baseline, are down by 0.1 million in 1981, by 0.5 million in 1983, and by 0.9 million in 1985. The drop in 1985 automobile sales attributable to EPCA enforcement thus respresents a 7.1 percent reduction from baseline sales, the greatest projected percentage sales loss for any year between 1976 and 2000. If the stringent standard mandated by EPCA is maintained, the loss of sales in 1985 increases to 1.4 million automobiles (or 11.1 percent). This further reduction in sales is caused by the increase in the civil liability, which is assumed to be passed on to buyers of new automobiles. The stringent standard adds a substantial civil penalty but does not have much impact on the marginal incentive for manufacturers to improve the fuel economy of new automobiles. Higher sales-weighted fuel economies (Table 2) are achieved by combining doubled civil penalties and moderate standards, i.e., by doubling the marginal incentive to improve fuel economy. The higher sales-weighted fuel economies produce lower aggregate civil penalties than do the statutory civil penalties or the stringent standard combined with penalties. In fact, automobile sales are not much lower under the double-penalty option than they are under the single-penalty option. The projected maximum difference in sales between these two options is 0.3 million automobiles in 1985 (2.6 percent) and is generally less than 0.1 million in subsequent years.

The most severe impacts on automobile sales are created when the \$0.10/L (\$0.40/gal) gasoline tax is applied, either with or without the EPCA standards. The gasoline tax alone immediately reduces sales by 30.6 percent or 3.7 million automobiles. This loss diminishes to 12.7 percent (1.6 million automobiles) in 1985 and remains about the same thereafter. When the gasoline tax is applied with the EPCA standards, sales are reduced by an additional 0.5 to 0.8 million automobiles in 1985 and after.

Table 1. Major fuel-economy policies studied.

Policy	Type	Assumptions
1	Baseline	No government policy for improved fuel economy and reduced fuel use; fuel price of \$0.16/L from 1976 through 2000
2	Gasoline tax	No government policy for improved fuel economy and reduced fuel use; fuel price of \$0.26/L from 1975 through 2000 (possibly by means of \$0.10/L increase in the federal excise tax on gasoline)
3	EPCA (moderate)	Mandatory EPCA fuel-economy standards; 1985 standard of 11.05 km/L; constant fuel price of \$0.16/L
4	EPCA (stringent)	Mandatory EPCA fuel-economy standards; 1985 standard of 11.69 km/L; fuel price held to \$0.16/L from 1975 through 2000
5	EPCA (moderate) and gasoline tax	Mandatory EPCA fuel-economy standards; 1985 standard of 11.05 km/L; fuel price held to \$0.26/L from 1975 through 2000
6	EPCA (moderate) and double penalties	Mandatory EPCA fuel-economy standards; 1985 standard of 11.05 km/L; fuel price held to \$0.16/L; doubled civil penalties for noncompliance (\$235/automobile per kilometer per liter by which a manufacturer's sales-weighted fuel economy is below the mandated standard)

Note: 1 L = 0.26 gal; 1 km/L = 2.35 miles/gal.

Table 2. Projected fuel economy for six policies.

	Fuel Economy (km/L)					
Year	1	2	3	4	5	6
1978	7.752	7.752	7.698	7.968	7.934	8.088
1979	8.143	8.185	8.423	8.423	8.372	8.577
1980	8.686	8.776	8.895	8.895	8.955	9.087
1981	8.734	8.827	9.202	9.253	9.304	9.393
1982	8.789	8.912	9.444	9.457	9.533	9.788
1983	8.874	8.976	9.567	9.563	9.674	10.043
1984	8.938	9.104	9.661	9.699	9.788	10.299
1985	9.066	9.206	9.852	9.886	9.895	10.494

Note: 1 km/L = 2.35 miles/gal.

Table 3. Projected automobile sales for six policies.

	Automobile Sales (000 000s)					
Year	1	2	3	4	5	6
1980	12.0	10.3	12.0	11.9	10.3	12.0
1985	12.6	11.0	11.7	11.2	10.3	11.4
1990	12.9	10.9	12.2	11.8	10.3	12.2
1995	14.1	11.7	13.2	12.7	11.0	13.2
2000	15.0	12.3	14.0	13.5	11.6	14.0

Table 4. Projected vehicle kilometers of travel for six policies.

	Vehicle Kilometers of Travel (trillion/year)					
Year	1	2	3	4	5	6
1980	1.95	1.77	1.96	1.96	1.77	1.98
1985	2.24	2.01	2.24	2.22	2.01	2.27
1990	2.51	2.27	2.46	2.42	2.24	2.48
2000	3.11	2.78	3.04	2.99	2.74	3.06

Note: 1 km = 0.62 mile.

Vehicle Kilometers of Travel

Data given in Table 4 show that all of the policies examined here that include mandatory fuel-economy standards have only a marginal impact on vehicle kilometers of travel. The maximum percentage reduction in vehicle kilometers of travel from the baseline—3.6 percent—would be achieved in 2000 under policy 4 (EPCA with stringent standards). Under the double-penalty case, vehicle kilometers of travel in 2000 are reduced by only 1.6 percent. The high sales-weighted fuel economy associated with this policy option results in the lowest driving cost per kilometer and thus relatively high vehicle kilometers of travel.

Substantial reductions in vehicle kilometers of travel are projected to occur under policies that substantially increase the gasoline tax. A 10.3 percent reduction in travel in 2000 is projected with a \$0.10/L (\$0.40/gal) gasoline tax (policy 2), and a reduction of 11.9 percent in 2000 is expected if EPCA is also adopted (policy 5). Despite the lower cost of driving associated with higher fleet fuel economy, the impact on the total automobile fleet of the gasoline tax combined with EPCA results in less travel than is projected if only gasoline taxes are imposed. This is significant, however, only after 1990 when the cumulative sales impact on fleet size is more significant.

Fuel Consumption

Mandatory fuel economy standards could contribute substantially to reduced fuel use, but it will be several years before significant fuel savings are realized by enacting these policies. Table 5 gives projected fuel consumption for each of the six policies examined here. (All results in this paper assume that the fuel economy of new vehicles reported by the U.S. Environmental Pro-

Table 5. Projected gasoline consumption for six policies.

Year	Gasoline Consumption (000 000 m^3/year) 1	2	3	4	5	6
1980	284	261	283	283	260	283
1985	271	241	259	257	233	254
1990	283	252	260	257	235	248
1995	312	276	283	279	255	267
2000	348	307	315	310	283	297

Note: 1 m^3 = 264 gal.

tection Agency is actually achieved by operating vehicles. More recent studies have shown that actual fuel economy tends to fall beneath federal estimates. In separate analyses, we have found that adjusting for this factor has significant implications on future projections of fuel consumption but that it creates only relatively small changes in the fuel savings attributable to alternative policies.)

EPCA achieves a 4 to 5 percent reduction in fuel use from the baseline by 1985 and an 8 to 9 percent reduction by 1990. The lower limit in each year assumes the moderate standard and the upper limit assumes the stringent standard. If the moderate standard is applied with double civil penalties, fuel savings increase to 6 percent in 1985 and 12 percent in 1990. In 2000, the double-penalty structure results in savings of 15 percent compared with savings of 9 to 11 percent for EPCA. After 1989 the double-penalty policy results in greater fuel savings than does the gasoline tax, but the EPCA standards result in less fuel savings than does the gasoline tax throughout the projection period. The only policy alternative tested that results in greater fuel savings than the double-penalty option is that of moderate standards combined with a gasoline tax (policy 5): This alternative results in 17 percent fuel savings in 1990 and 19 percent fuel savings in 2000.

PROJECTED GROWTH OF AUTOMOBILE OWNERSHIP AND USE

Although the results presented above show distinct differences in consumer behavior relative to the automobile, these differences appear relatively minor when the projections are compared with the experience of the preceding 25 years. The table below gives the annual percentage growth rates for various categories of automobile ownership and use. Actual data include census figures for households, Federal Highway Administration statistics for vehicle kilometers of travel, and data from Automotive News for automobiles in use (1 km = 0.62 mile):

Category	Rate of Growth (%) Actual (1950 to 1975)	Base-Case Projection (1975 to 2000)	EPCA Projection (1975 to 2000)
Automobiles in use	4.26	1.60	1.28
Automobiles per household	2.33	-0.05	-0.37
Annual vehicle kilometers of travel	4.30	2.50	2.37
Per automobile	0.04	0.89	1.08
Per household	2.36	0.84	0.71

The growth rates of automobiles in use and of vehicle kilometers of travel are projected to fall by about 60 and 40 percent, respectively.

The slowing of the growth of automobile stock is attributable to two factors—the decline in the growth rate of the population and a slight decrease in automobile ownership per household attributable to higher vehicle prices. Vehicle kilometers of travel per household are projected to grow at about a third of the rate experienced during the past 25 years. Annual vehicle kilometers of travel per automobile, roughly constant in the preceding quarter of a century, are expected to increase slightly.

CONCLUSIONS

The forecasts presented here reflect some tapering off of the rapid growth in automobile ownership and use experienced in the past quarter century. Nevertheless, they imply 80 percent more automobile travel than occurs today—a figure that will have drastic energy consequences unless action is taken to prevent the amount of fuel consumption by automobiles that is implied by these figures. The relative attractiveness of fuel economy policies, however, cannot be determined by their impact on a single indicator such as fuel consumption. The combined effect on automobile sales, sales-weighted fuel economy, travel, and fuel consumption must be taken into consideration.

Lower fuel consumption is a desirable result, and it can be achieved by any of the following: (a) improving sales-weighted fuel economy, (b) reducing automobile sales (and ownership), or (c) reducing travel per automobile. To the extent that a policy reduces fuel consumption by improving sales-weighted fuel economy and does so with minimal impacts on automobile sales and travel, it achieves an important conservation goal without adversely affecting goals related to economic health or personal mobility. Judged by this standard, moderate fuel-economy standards with double civil penalties appear to achieve the most desirable impact. Fuel consumption is reduced by 12.4 percent in 1990 and automobile sales and vehicle kilometers of travel are down by only 5.4 percent and 1.3 percent respectively, relative to the baseline. In contrast, the gasoline tax examined here reduces 1990 fuel consumption by slightly less (11 percent), but automobile sales and vehicle kilometers of travel are down by much more—15.5 percent and 9.8 percent respectively. The moderate fuel economy standards achieve 1990 reductions of 8.2 percent in fuel use, 5.4 percent in automobile sales, and 1.9 percent in vehicle kilometers of travel. The stringent standards result in reductions in automobile sales and travel of 8.5 and 2.6 percent respectively. These impacts are not as favorable as those achieved by using the double-penalty approach, but they compare very favorably with gasoline taxes, offer considerable conservation benefits compared with the baseline policy, and result in relatively minor economic and travel disbenefits.

None of the options tested here that incorporate mandatory standards produced industrywide fuel economies in excess of the standards for 1985 and after. However, this is partly a result of the assumptions about pollutant emissions. Relaxing these emissions standards would help the cause of achievable fuel economies.

Although substantial uncertainties are implicit in the analytical procedures used here, their impact on relative conclusions about policy effectiveness is apt to be less than their impact on absolute forecasts of fuel use, automobile sales, and vehicle kilometers of travel for each policy alternative. Assumptions about future population growth, economic conditions, safety and environmental regulations, and automotive technology are subject to error, but such errors tend to affect all projections in similar ways. Very substantial errors would be required to alter the rankings of the various policies.

Based on these rankings and the judgment that less fuel use and more mobility are desirable, the mandatory fuel economy standards of the Energy Policy and Conservation Act offer an effective approach to resource conservation but one that appears open to improvement by an increase in the severity of the penalties and a decrease in the stringency of the standards. These modifications would tend to reduce the civil penalties that automobile companies and consumers must pay while increasing the marginal incentive to produce and consume fuel-efficient automobiles.

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**Mr. Kulash was with Jack Faucett Associates, Inc., when this research was performed.*

Energy-Saving Potential of Transit

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In a study initiated by the Federal Energy Administration in response to growing national concern over the rapidly expanding rate of energy use and possible fuel shortages, an analysis was done of the energy efficiencies of various urban passenger transportation modes, including automobile and bus, rail rapid and commuter rail transit, and dial-a-ride. The study was primarily concerned with the potential impacts and energy efficiencies of short-term policies designed to induce automobile drivers to shift to transit. Policies to induce such mode shifts were grouped as scenarios for evaluation. Possible transportation energy savings for urbanized areas as well as reductions in vehicle kilometers of travel were first estimated for individual representative cities and then expanded to provide a national estimate for each of four tested scenarios.

Two major study tasks were undertaken in the Federal Energy Administration's evaluation of policies to enhance public transportation (1):

1. Determine the energy consumption and efficiency of transportation modes in urbanized areas and
2. Evaluate scenarios designed to achieve shifts from the automobile mode to public transportation, estimate the possible energy savings, and recommend scenarios to be implemented.

Major emphasis was placed on obtaining more definitive national estimates of urban transportation energy efficiency than had previously been available and on determining quantitatively which strategies for shifting travel from the automobile to transit could achieve significant energy savings. The amount of energy that could be conserved through individual actions and groups of actions was specifically estimated.

It should be pointed out, however, that this study was designed to provide only a macroscale estimate of the possible energy savings in individual cities and in the nation. Moreover, all data were derived from currently available material; compilation of new data was not possible. For these reasons, the energy savings determined in this study should be considered estimates and should not be taken as detailed forecasts.

NATIONAL ENERGY-USE CHARACTERISTICS FOR URBANIZED AREAS

Any analysis of energy conservation potential must be based on a description of existing energy use and efficiency. Person-travel energy consumption and efficiencies in urbanized areas are a function of the amount of person travel involved, average passenger loadings, and the applicable vehicular fuel consumption rates. National estimates of these and related characteristics, which were developed particularly for use in this study, were derived from data originally collected by the U.S. Department of Transportation (2, p. 52), the American Public Transit Association (3), and others.

Average urban energy consumption rates for individual vehicle types were estimated as follows (1 MJ/km = 1525 Btu/mile):

Vehicle Type	Energy Consumption Rate (MJ/km)
Automobile	7.2
Bus	
Gasoline-minibus	17
Diesel	22.8
Propane	30
Rail car	
Rapid	40.6
Commuter	74.1