Projection of Urban Household Automobile Holdings and New Car Purchases by Type

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ABSTRACT

In this paper a procedure for modeling the choices made in urban American households among personal vehicles on the bases of cost, passenger capacity, and engine technology is discussed, and those preferences to the years 1990 and 2000 are projected. The results of this disaggregate technique are used by the other predictive research tasks undertaken by Argonne National Laboratory in a project entitled Technology Assessment of Productive Conservation in Urban Transportation (TAPCUT). In these projections vehicles with standard spark-ignition (Otto-cycle) engines continue to dominate automobile holdings and new car purchases in either of two socioeconomic scenarios under any of three settings (an existing policy set and two alternative conservation strategies). From 1990, small cars (which seat four or fewer passengers) dominate urban holdings and sales in two of the three TAPCUT energy strategies (the exception being the strategy that emphasizes individual travel), and this holds true with only a minor variation in both socioeconomic scenarios. Advanced-technology vehicles are most successful under the individual travel strategy. Vehicle characteristics are far more significant than demographic descriptors in estimating household vehicle choice when using this modeling approach.

In this paper the method and results of the household vehicle choice model used to forecast the distribution of automobiles bought and used by urban households in each of two projection years (1990 and 2000) are described. These forecasts in turn led to estimates of total demand for and cost of travel, and of the future economic and environmental impacts of automobile production and operation in urban areas for the Technology Assessment of Productive Conservation in Urban Transportation (TAPCUT) project.

The TAPCUT project had the stated goals of providing (a) a description of several alternative strategies that promote energy conservation in urban passenger transportation, (b) a better understanding of the environmental impacts of such strategies, and (c) identification of the constraints on the implementation of such strategies.

Two productive conservation strategies were designed to save energy in urban passenger transportation when substituted for policies currently in place. A reference set of impact forecasts was then prepared for these two strategies. One conservation strategy stressed group travel (e.g., transit and carpooling), whereas the other promoted individual travel in private automobiles. The strategies were designed to cause minimal disruption of life-styles and the economy while achieving reductions in the consumption of aggregate energy, especially that derived from petroleum.

Travel demand analysis was performed for each of three typical cities under policies currently in place and forecast to continue, and also under the alternative strategies (i.e., group travel strategy and individual travel strategy). Environmental impact analysis of the forecast travel demand under each strategy was city specific and included estimation of air and water pollutant loadings along with their associated impacts on human health. Traffic safety impacts were also estimated. Socioeconomic impacts caused by vehicle use and vehicle production were assessed. Impacts on physical environment, resources, health, and safety caused by vehicle and fuels production and infrastructure construction were also addressed. The final step was the overall comparison of policy-driven results to the results obtained under the in-place policy set.

INTRODUCTION TO MODELING VEHICLE CHOICES BY HOUSEHOLDS

General Approach

Disaggregate statistical modeling of vehicle choices by households has a short but stimulating history (1-5). In his comprehensive review of the topic, Tardiff (6) discusses the requirement that all such models define household and vehicle characteristics so that a sufficient (but not excessive) number of dependent variables are available for estimating coefficients of a choice function. Specification of too many variables may introduce a degrees-of-freedom problem. An appropriate course is to establish variables that are interactions of vehicle descriptors, which do not vary across households, and socioeconomic descriptors, which do vary across households. Variables may also be established to correlate the sensitivity of acquiring or holding vehicles by household to employment opportunities and other measures of accessibility to various modes of transportation.

In the TAPCUT modeling system household and work place locations are predetermined by regional population and employment forecasts and the land use policy for each scenario. Aggregate household travel demand by mode is developed by using an extended version of a sketch-planning transportation model called extended short-range generalized policy (XRGP) from household work-trip records and household characteristics that influence the nonwork travel of its members (see paper by Kaplin, Gur, and Vyas elsewhere in this Record). Household vehicle holdings are part of the record of each household's characteristics. To project total holdings and new car purchases by household class it was therefore sufficient to model only the vehicle choice process of households characterized for the XRGP model.

Only a household-based model of vehicle preferences has an output capable of directly feeding the rest of the TAPCUT modeling sequence, which forecasts travel demand and energy use at the level of the standard metropolitan statistical area (SMSA).

Forecasts of automobile holdings at higher levels of aggregation than the household (e.g., regional or national metropolitan totals) would fall short of the resolution of the travel-demand and energy-use model, which is household based. Moreover, the TAPCUT project required personal vehicle data (size class, technology, materials of composition by percentage of total weight, and so on) of the highest possible resolution in order to forecast the resource and environmental impacts of vehicle-related energy policies.

Empirical Considerations

The 1977 Nationwide Personal Transportation Study (NPTS) provides a detailed cross-sectional data base for the disaggregation of automobile holdings and examination of vehicle preferences (7). This 6,000-household sample also provides considerable information that correlates the demographic characteristics of households (income class, number of people, and age and education of household head) and automobile ownership by vehicle type. The TAPCUT project used the urban household data from this survey as its base file of national urban socioeconomic data. Vehicles included in the survey were aggregated to three size classes in a household descriptor file before their use in TAPCUT.

Unfortunately, the NPTS provides no information on the evolution over time of vehicle holdings by specific types of household. In the absence of consistent longitudinal data, it was therefore assumed that these holdings are stable through time within a socioeconomic category but not within a specific household, which can move from one socioeconomic category to another. For example, the vehicle holdings of low-income households remain constant, but an individual low-income household is assumed to change its holdings as it moves into the middle-income category. This in turn assumes that demographic or economic variables principally determine the total holdings of personal vehicles over time. Thus changes in the demographic structure of the national population, disaggregated to the household level, account for growth or decline in the total fleet of personal vehicles. These changes, represented by increases or decreases in the total households in each category, were estimated for TAPCUT through the technique of iterative proportional fitting (IPF) (8).

From this perspective a given NPTS household type (or cell), which is classified according to car ownership plus the four demographic variables previously mentioned, will hold as many automobiles in 2000 as it does in 1977, although not necessarily the same types of automobiles. This structure permits households of a given type to change total travel but not total holdings in response to changes in highway or level of transit service. The type of vehicles held can change in response to changes in automobile operating characteristics such as fuel economy; but, again, the total number held is assumed to remain unchanged.

Prediction of holdings in year x should be logically consistent with prediction of new car sales in year x - n (n = 5,10) because vehicle types that do not succeed in the marketplace, in competition with alternative types, will not be available as holdings or used cars after 5 or 10 years. Similarly, a projection of household fleet distribution that shows a vehicle virtually disappearing from household fleets in a forecast year points to a cessation in sales of that vehicle before the forecast year, even though a standard logit probability distribution would guarantee it some fraction of sales in that same year. Adjustments to forecast results are required whenever automobile holdings and new car purchases, which are projected independently, do not agree.

Principal Assumptions

In summary the model selected to project urban household automobile holdings and new car purchases had to accommodate two basic assumptions. First, individual households change their total holdings of personal vehicles only as their respective demographic status changes. Second, the characteristics of the vehicles held are a joint function of the household demographic profile specified for a given projection year and the attractiveness or salability of an available type of personal vehicle.

MODEL FORM AND PROCEDURE

Input-Output

The disaggregate vehicle stock allocation model (DVSAM) was used to estimate vehicle holdings for each of the projection years. The model uses an incremental logit equation to estimate vehicle holding probabilities for existing technology vehicles and a simple logit equation to estimate holding probabilities for new technology vehicles. It is derived from a vehicle choice model developed by Lave and Train (4,9).

The principal purpose of using an incremental analysis, as opposed to running the Lave-Train model directly, is to evolve vehicle-holdings patterns from predetermined conditions at a given window in time, thus avoiding the time and cost of generating annual new car sales estimates and applying a cumulative scrappage function. This is accomplished by incorporating given information on the distribution of holdings (in this case, the 576 x 8 NPTS array) and by using the model mainly to predict changes in this distribution. A vehicle-holdings file that uses 1977 NPTS data was created for 1980. For all subsequent projection years, the output vehicle sales file from the DVSAM run for the preceding forecast year was used as the base year file.

To maintain consistency with the vehicle total treated in the Lave-Train choice set and to avoid diluting future probability distributions through the introduction of spurious choices, the maximum permitted size of any vehicle type choice set is 10 in DVSAM.

Given a change in the utility of automobile type a_i, for example, to household type h (as computed by the Lave-Train function), and given the base probability of this utility resulting in a new car sale, the predicted probability of the holding can be expressed as follows:

$$P'h(a_i) = \exp[\Delta U^h_{a_i} P^h_o(a_i)] / \left\{ \exp[\Delta U^h_{a_j} P^h_o(a_j)] \right\} \quad (1)$$

where

A = choice set of vehicle types available in both base and forecast years,
j = all competing vehicle types in the set,
$\Delta U^h_{a_i}$ = change in utility of vehicle type a_i to household h, and
$P^h_O(a_i)$ = base sales probability for vehicle type a_i.

Because this choice set expands in each successive projection year (from 6 vehicles in 1980 to 8 in 1990 and to either 9 or 10 in 2000), it is necessary to partition the logit procedure to predict the share of newly introduced vehicles according to their computed absolute utility. Shares of all vehicles in a given year are first distributed according to a standard logit formula (by using absolute utilities); then the normalized percentage share of all vehicles that appear for the first time in that year's choice set (i.e., new technology vehicles) is subtracted from one. The remaining percentage represents the aggregate share for conventional, or established, vehicles. This share is distributed among those vehicles by incremental logit according to the computed change in the utility function from base to forecast year, as shown in Equation 1.

Thus for all but one of the strategy and scenario combinations, six established and two new vehicle technologies are defined for 1990, and eight established technologies and one new one are defined for 2000. The exception is scenario I under the individual travel strategy, in which two new technology vehicles are defined for the year 2000. In each case standard and incremental logit formulas are applied sequentially. Figure 1 shows the data file flow of the DVSAM.

brated model must be considered unacceptable for purposes of consistent forecasting.

Therefore, the Lave-Train function was calibrated away from 1977 equilibrium by systematically modifying the dummy variable coefficients for all Otto vehicles in order to replicate available information on 1980 sales and holdings distributions that use the logit function. This was accomplished through use of a recursive technique to alter the utility values. In this technique the upper or lower bounds on the percentage share of holdings are specified for any vehicle type(s) with which a dummy variable is associated; then the current value of the share is multiplied by the log ratio of the nearest desired bound and the current value; subsequently, the utility computation and logit procedure iterates to closure.

PROJECTED HOUSEHOLD AUTOMOBILE FLEET HOLDINGS AND NEW CAR SALES BY SCENARIO

Two economic and social-organization scenarios were defined for the TAPCUT project; they differed in

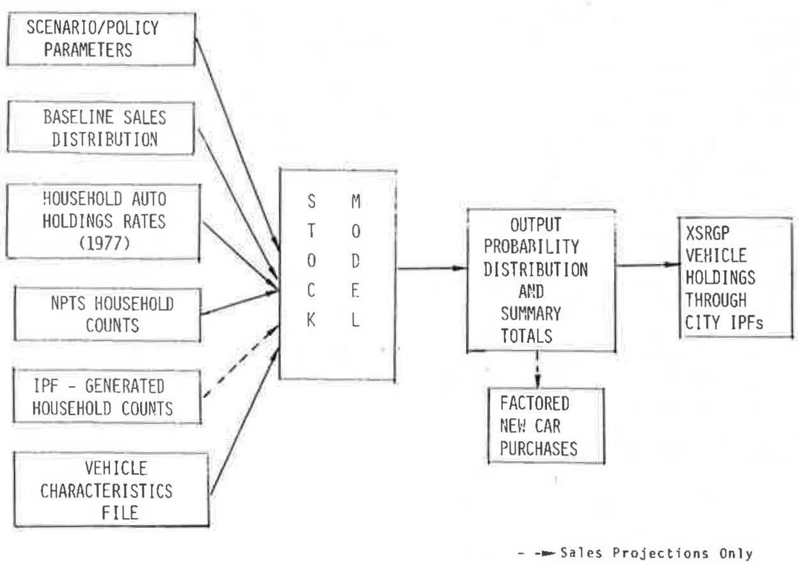

FIGURE 1 Data file flow in DVSAM.

Adjustments

A pronounced and inescapable result of the first stock estimation--developing a 1980 distribution from the empirical 1977 values--was its failure to replicate the dramatic movement to smaller cars since 1978. In the 1977 NPTS holdings the considerable bias toward large cars (the curb weights of more than 43 percent of automobiles and vans exceed 3,700 lb) creates an inertia in the logit distribution that imposes past results on future projections. This is particularly strong when, as in the TAPCUT scenario I individual travel policy setting, mileage and performance improve at a consistent pace across all vehicle types. Indeed, as holdings distributions incremented only on 1977 holdings are modeled beyond 1980, the trend in automobile acquisitions and holdings by size tends in a direction exactly opposite to what has been observed over the past 3 years. Even if the recent move toward smaller vehicles is held to be short term and eventually reversible (which does not appear entirely reasonable given expected changes in household composition and size), this anomalous behavior of the uncali-

gross national product (GNP) growth rate, social organization, retail fuel price, total metropolitan population, average household income, environmental regulations, and types of fuel available for transportation. The two scenarios can be briefly distinguished as scenario I--a wealthy economy with high technological success--and scenario III--a relatively poor economy with low technological success. National urban and city-specific forecasts of population and employment characteristics were prepared under each scenario. Additional data regarding these scenarios may be found in LaBelle et al. (8).

Prototype cities were selected by using a factor-analysis technique that identified extreme cities along three dimensions relevant to transportation energy use (10). One dimension, called Megatown, identifies large cities with satisfactory transit systems. The second dimension, Sprawlburg, typifies newer, fast-growing, sprawl cities. The Slowtown dimension identifies midwestern industrial cities that are smaller in population than the other two. All metropolitan areas in the nation were related to these three dimensions; an expansion method was then developed to make national urban forecasts based on the detailed forecasts of the three typical cities selected to represent the three dimensions.

Automobile and transit vehicle characteristics were projected in detail under several sets of policy and scenario conditions. Three different sets of vehicles were used in the analysis: set C, the expected technologies, was used for the in-place policy and group travel strategy in both scenarios; set A, designed as the best technology for both conservation and performance, was tested for the individual travel strategy in the optimistic scenario; and the third set, a modification of set C, was tested in the other scenario under the individual travel strategy. Vehicles were characterized by size class, engine type, fuel economy, emissions profile, purchase price, operating costs, materials composition, and (for personal vehicles) performance.

Household Fleet Holdings in a Typical City

Figures 2-7 show year-2000 distributions of automobile holdings across several vehicle and demographic characteristics in the SMSA of the TAPCUT city Sprawlburg. Sprawlburg values are given here because this city type is the most influential in the TAPCUT expansion procedure for generating a national profile of urban travel effects.

Figures 2 and 3 show the distribution of the automobile fleet in Sprawlburg by vehicle technology under each policy or strategy in scenarios I and III, respectively. The technology mix is nearly identical under the in-place and group travel settings in both scenarios, but there are significant technological differences between vehicles in the individual travel strategy in scenario I and those in scenario III. In scenario I vehicles are uniformly superior in each technology to those available under the in-place policy, and cars with reciprocating external-combustion (Stirling-cycle) engines are not available under any other policy. Not surprisingly, because of identical vehicle characteristics, the percentage distribution across technologies is similar between scenarios for each of the first two strategies. Vehicles with standard spark-ignition (Otto-cycle) engines dominate all distributions, with diesels achieving their highest penetration (15.5 percent) under the individual travel strategy in Scenario I. Penetration by electric cars reaches only 2.3 percent under the group travel strategy in both scenarios, a performance attributable to relatively high operating cost (which includes replacement of battery packs) and the range limitations of electric cars. Only under the group travel strategy (with high petroleum fuel taxes) does the life-cycle cost of electric cars become competitive with that of heat-engine cars on a per-mile basis.

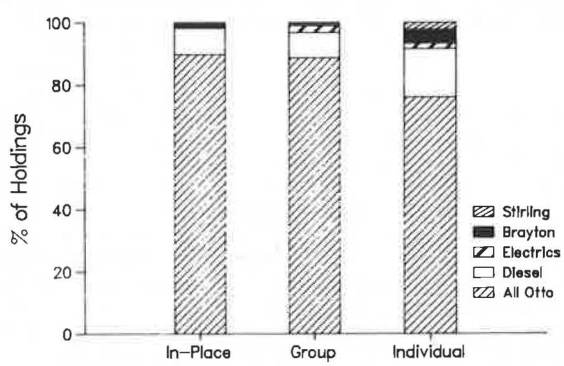

FIGURE 2 Fleet distribution by vehicle technology in Sprawlburg by strategy in scenario I in 2000.

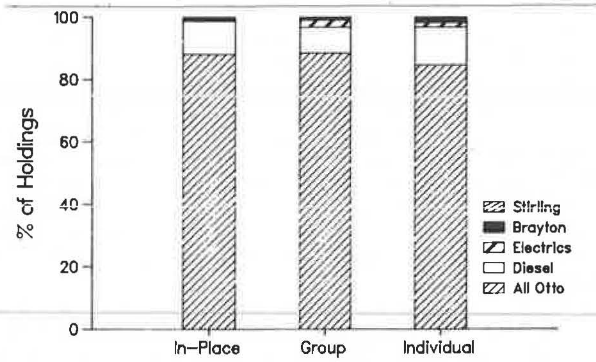

FIGURE 3 Fleet distribution by vehicle technology in Sprawlburg by strategy in scenario III in 2000.

Figures 4 and 5 show the distribution of the Sprawlburg household fleet by vehicle size under each energy strategy in scenarios I and III, respectively. From 1990, small cars dominate urban holdings and sales under the in-place policy and the group travel strategy in both TAPCUT scenarios, and this phenomenon is manifested in the year-2000 fleet distribution. The trend to these four-passenger cars is damped under the individual travel strategy by improved mileage and performance in every vehicle of the choice set.

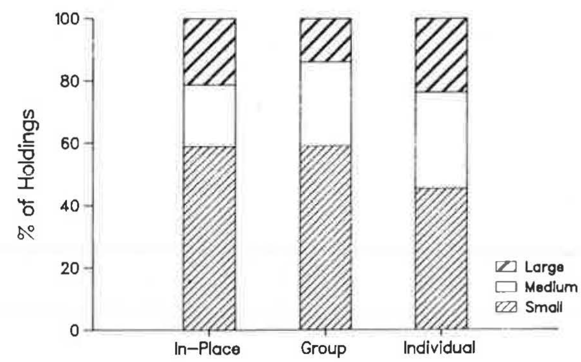

FIGURE 4 Fleet distribution by vehicle size in Sprawlburg by strategy in scenario I in 2000.

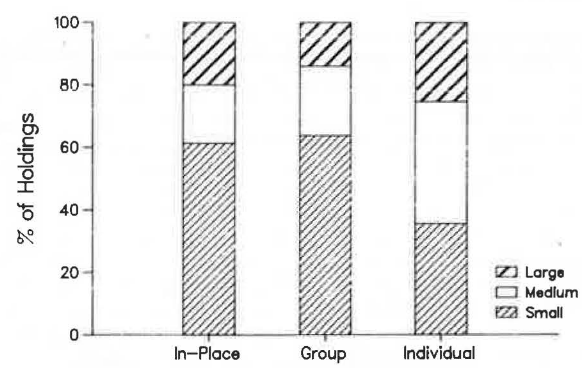

FIGURE 5 Fleet distribution by vehicle size in Sprawlburg by strategy in scenario III in 2000.

Figures 6 and 7 have been included to emphasize that scenario variables--in this case income distribution--do not vary by policy. The number of households allocated to each income group and the number of automobiles held by each are fixed throughout the scenario. This means that although the ownership pattern by size and technology varies across policy settings, the total holdings, and thus the percentage of vehicles held by each income class, are not affected by policy-directed changes.

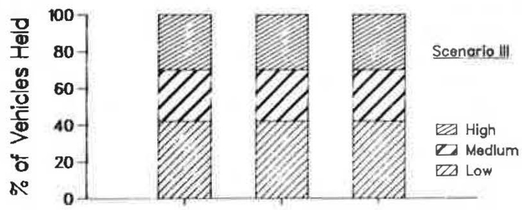

FIGURE 6 Fleet distribution by income class in Sprawlburg by strategy in scenario I in 2000.

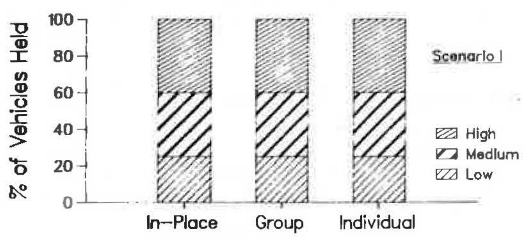

FIGURE 7 Fleet distribution by income class in Sprawlburg by strategy in scenario III in 2000.

Sales Projections

Overview

To assess the resource and production impacts of the vehicle technologies defined for the TAPCUT project it was necessary to generate estimates of new car sales by type to urban households for each of the calendar projection years. Because in a new car market only the specific utility of each vehicle type relative to its competitors in the same model year is of interest, a standard logit function that incorporates the computed utility of each new vehicle in the choice model was used to estimate the distribution of new car sales.

The Lave-Train function calibrated to a 1980 sales distribution (obtained from the Oak Ridge National Laboratory "Market Shares" report for February 1981) was used. Resulting sales shares are given in Table 1. Vehicle characteristics were obtained directly from the parameters of new model-year vehicles characterized for 1990 and 2000. Future-year demographics (i.e., number or distribution of household cell types) were obtained through IPF of the 1977 NPTS file distribution as augmented by national urban totals for each demographic dimension forecast for each TAPCUT scenario in 1990 and 2000. Vehicle totals are obtained from the IPF-determined household cell totals multiplied by the NPTS automobile ownership rate by cell, and urban vehicle sales are then assumed to be equal to this total times 0.1109 (that is, 11.09 percent of vehicles in a fleet for a calendar year are sold during that calendar year according to the urban vehicle age distribution developed for TAPCUT). This procedure forces a convention that each household type participates in the new car market in proportion to the average number of vehicles it held in the base year. No vehicle-holding household type is excluded from that market, irrespective of income group.

TABLE 1 New Cars with Otto-Cycle and Diesel Engines Sold in Urban Areas During 1980, by Size

Car Size	Engine Type	Market Share (%)	Total No. Sold
Small	Otto	36.73	2,703,466
Medium	Otto	42.13	3,100,927
Large	Otto	15.15	1,115,097
Van	Otto	3	220,811
Small	Diesel	0.71	52,259
Medium	Diesel	1.40	103,045
Large	Diesel	0.88	64,771
Total			7,360,376

Estimated sales of new diesels by size are distributed within the technology according to the distribution by size of new Otto vehicles, except as follows. Maximum sales constraints have been imposed on diesel (and electric) vehicles in 1990. Assume that for diesels this maximum is equal to 16 percent of total sales (as the TAPCUT approach specifies for scenario I) and that the utility of the diesel vehicle as characterized results in a 35 percent share in the first iteration of the model. Therefore, 19 percent has to be given back to competing modes. After a finite number of iterations (usually less than eight) the diesel share is reduced to the desired 16 percent. This share is then distributed within the diesel technology to size classes according to the normalized portion of the 19 percent returned to each Otto vehicle at the end of the iterations. Thus the constrained 16 percent takes on the characteristics of the shadow market for diesel cars represented by the unconstrained 35 percent. In many cases this is at variance with the size-class distribution of the Otto market, which is often more oriented to larger vehicles (which should be expected because the size of the benchmark diesel car is characterized as intermediate). Such a result embeds the assumption that the thrust of current size-class trends in the diesel vehicle market will continue into the future. It does not admit the possibility of a small, super-efficient diesel capturing most of the four-passenger (and smaller) market.

Vehicles of nonconventional or emerging technology that were included in choice sets were not distributed by size class after their respective total sales shares were determined. Rather they retained the size class of the target-market prototypes of U.S. Department of Energy research and development programs that focus on personal vehicles. Thus a car with a gasoline-turbine (Brayton-cycle) engine is always a large vehicle (including some vans in scenario I under the individual travel strategy). Similarly, cars with reciprocating external combustion (Stirling-cycle) engines and electric cars are always classed as medium-sized (five-passenger) vehicles. The decision not to distribute these vehicles across size classes was based in part on their relatively small penetration in both TAPCUT scenarios and, for heat-engine cars, the late date of their market entry (making size diversification largely uneconomic in the TAPCUT time frame). There are also severe technological problems inherent in attempting to downsize cars with Brayton and Stirling engines to two- and four-passenger capacities.

In a few instances the decline in holdings of certain conventional vehicle types between 1990 and 2000 precluded their participation in the 2000 new vehicle market. The sales share for these types in 2000 was simply subtracted from total vehicles sold; no substitute vehicle was selected to fill this gap, and thus the absolute total of sales in these instances is less than the value given by the following formulation: (0.1109 • urban vehicle total).

Scenario I New Car Sales

The results of the personal-vehicle sales model and size-class distribution applied to scenario I automobiles and vans for each strategy setting in 1900 and 2000 are given in Tables 2-4. Figures 8-10 show the purchase trends over time by size class across all technologies for each scenario I strategy setting.

As indicated by the data in the tables, unconventional-technology vehicles achieve modest gains in sales through 2000 under the in-place policy and group travel strategy, but they perform strongly under the individual travel strategy best-technology fleet. Electric cars account for 2 and 6 percent of year-2000 sales, respectively, under the in-place policy and the group travel strategy, whereas the corresponding results for the Brayton-cycle car are 3.7 and 3.3 percent.

Under the individual travel strategy only the advanced battery-powered car with the lithium-metal sulfide battery succeeds among electric cars in competition with heat-engine cars in the year 2000 (3.75 percent of sales). Braytons and Stirlings in the same year penetrate 9.4 and 15 percent of the new car market, respectively. This would appear to be consistent with the adventurous cast of scenario I and the resulting attitudes of both car manufacturers and the car-buying public toward vehicles in the marketplace.

As the data in Figures 8-10 illustrate, the sale of small cars to urban households increases under all strategy settings, with the rate of increase lowest under the individual travel strategy. There, medium-sized cars lead in total sales. By contrast, the sales collapse of the medium Otto-cycle under the in-place policy, and the group travel strategy is consistent with its virtual disappearance from

TABLE 2 Projected Urban Sales of New Cars by Size and Engine Type in Scenario I Under In-Place Policy

		1990 Estimates[a,b] (10^6)				2000 Estimates[a,c] (10^6)			
Car Size	Engine Type	Uniform Charge	Stratified Charge	Turbo-charge	All Units	Uniform Charge	Stratified Charge	Turbo-charge	All Units
Small	Otto cycle	1.719	1.509	0.964		3.354	2.945	1.882	
Medium	Otto cycle	1.415	1.242	0.794		0.219	0.192	0.123	
Large	Otto cycle	0.636	0.559	0.357		0.604	0.531	0.339	
Mini	Otto cycle	-	0.151	-		-	0.284	-	
Small plus mini	Diesel				0.220				0.572
Medium	Diesel				0.402				0.036
Large	Diesel				0.449				0.099
Van	Diesel				0.035				0.074
Medium	Electric (lead-acid battery)				0.034				0.171
Medium	Electric (nickel-zinc battery)				0.260				0.064
Large	Brayton cycle				-				0.439

[a]These are manufacturing estimates, with equivalent sales assumed.
[b]Total urban nonfleet sales of new cars projected for 1990, all sizes and engine types = 10,512,000.
[c]Total urban nonfleet sales of new cars projected for 2000, all sizes and engine types = 11,928,000.

TABLE 3 Projected Urban Sales of New Cars by Size and Engine Type in Scenario I Under Group Travel Strategy

		1990 Estimates[a,b] (10^6)				2000 Estimates[a,c] (10^6)			
Car Size	Engine Type	Uniform Charge	Stratified Charge	Turbo-charge	All Units	Uniform Charge	Stratified Charge	Turbo-charge	All Units
Small	Otto cycle	1.453	1.276	0.815		2.624	2.303	1.472	
Medium	Otto cycle	1.961	1.722	1.101		0.422	0.370	0.236	
Large	Otto cycle	0.424	0.381	0.245		0.142	0.125	0.080	
Mini	Otto cycle	-	0.130	-		-	0.265	-	
Small plus mini	Diesel				0.357				0.282
Medium	Diesel				0.450				0.151
Large	Diesel				0.082				0.014
Van	Diesel				0.028				0.022
Medium	Electric (lead-acid battery)				0.043				0.401
Medium	Electric (nickel-zinc battery)				0.034				0.169
Large	Brayton cycle								0.439

[a]These are manufacturing estimates, with equivalent sales assumed.
[b]Total urban nonfleet sales of new cars projected for 1990, all sizes and engine types = 10,512,000.
[c]Total urban nonfleet sales of new cars projected for 2000, all sizes and engine types = 9,389,000.

TABLE 4 Projected Urban Sales of New Cars by Size and Engine Type in Scenario I Under Individual Travel Strategy

		1990 Estimates[a,b] (10^6)				2000 Estimates[a,c] (10^6)			
Car Size	Engine Type	Uniform Charge	Stratified Charge	Turbo-charge	All Units	Uniform Charge	Stratified Charge	Turbo-charge	All Units
Small	Otto cycle	1.601	1.406	0.899		1.548	1.360	0.868	
Medium	Otto cycle	1.479	1.298	0.830		0.756	0.664	0.424	
Large	Otto cycle	0.605	0.530	0.339		0.476	0.417	0.267	
Mini	Otto cycle	-	0.036	-		-	0.039	-	
Small plus mini	Diesel				0.510				0.785
Medium	Diesel				0.466				0.379
Large	Diesel				0.191				0.239
Van	Diesel				0.317				0.329
Medium	Electric (lead-acid battery)				0.004				0.004
Medium	Electric (nickel-zinc battery)				0.001				0.005
Medium	Electric (lithium-metal sulfide battery)								0.447
Large	Brayton cycle								1.042
Van	Brayton cycle								0.082
Medium	Stirling cycle								1.793

[a]These are manufacturing estimates, with equivalent sales assumed.

[b]Total urban nonfleet sales of new cars projected for 1990, all sizes and engine types = 10,512,000.

[c]Total urban nonfleet sales of new cars projected for 2000, all sizes and engine types = 11,924,000.

household fleet preferences in the holdings model (Figures 8 and 9). This is in part attributable to its unsatisfactory competitive position over time, specifically with reference to vehicle characterization in the stock model; that is, its market is squeezed from both sides as large cars are downweighted and small cars improve dramatically in performance. It is also partly an effect of the demographic changes that actually occur in the scenario. These changes apparently preclude creation of a viable market for a spartan general-purpose car targeted for low-income households.

Surprisingly, medium-sized (five-passenger) cars are shown to retain the momentum of the healthy 1980 sales performance of this size class right up to 1990--with especially strong results in the early years of the group travel strategy--in response to steeply rising fuel costs. This trend accords with encouragement of multiple-person occupancy of vehicles under the group travel strategy, but it is not driven by that encouragement. However, the momentum is not sustained as household size diminishes and fast-growing operating costs ultimately move the great majority of car owners to choose four-passenger cars.

Diesel car sales stabilize at 5 to 15 percent of total sales by 2000; they perform best, as expected, under the individual travel strategy. The penetration is low relative to some current forecasts of diesel market share; this is explained by the ceiling imposed on 1990 sales of diesel fuel as a supply

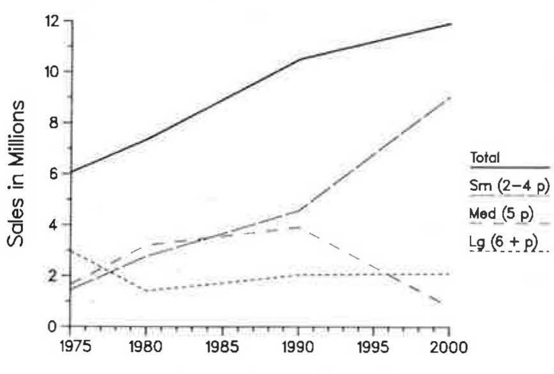

FIGURE 8 Projected urban sales of new cars by size in scenario I under in-place policy.

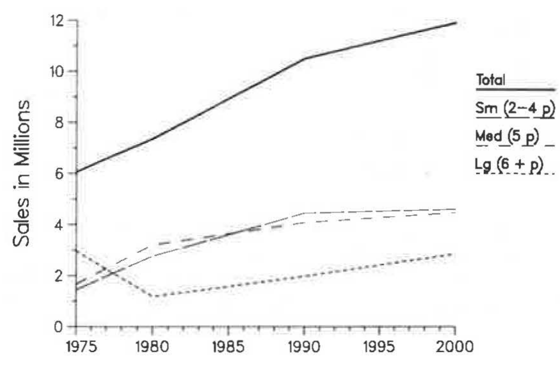

FIGURE 10 Projected urban sales of new cars by size in scenario I under individual travel strategy.

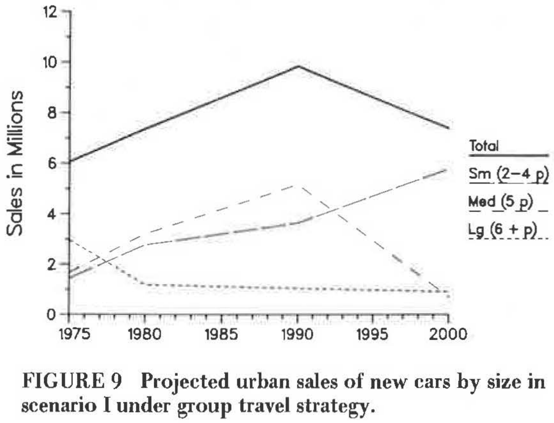

FIGURE 9 Projected urban sales of new cars by size in scenario I under group travel strategy.

constraint, a constraint that effectively caps post-1990 diesel car sales also. Diesel technology was represented in the vehicle choice model by a single surrogate with the combined characteristics of five- and six-passenger diesel cars, and the diesel cars therefore competed primarily against Otto-cycle cars in the large and medium-sized classes. However, the progress of diesel fuel economy, price, and performance is low after 1990 relative to improvements in most other vehicles in the choice model. Combined with the declining market for large cars after 1990, the diesel fares rather poorly under all strategies.

Scenario III New Car Sales

The data in Tables 5-7 project car-size and engine-type distributions to vehicles in scenario III under each of the three strategy settings, respectively. Figures 11-13 project sales of cars by size class (for 1990 and 2000) for the same three strategies in the same scenario. Scenario III vehicle options and level of technology available to buyers under the in-place policy and group travel strategy are identical to their scenario I counterparts. That is, buyers under the in-place setting as applied in scenarios III and I have the same new car options to choose from, the only difference being the respective scenario new car purchase prices, which reflect the differing cost of financing (8 percent in scenario I and 12 percent in scenario III). Group travel options are also the same in the two scenarios; group travel vehicles differ from those of the in-place setting only in that the medium-sized Otto is improved in each scenario. Therefore, it is not surprising that scenario III forecasts (Figures 11 and 12) are similar to those for the corresponding strategy settings applied in scenario I (Figures 8 and 9).

Individual travel vehicles in scenario III differ from their scenario I counterparts in that they represent modest across-the-board technological improvements relative to in-place vehicles rather than significant new departures in technology or materials utilization. The medium Otto under group travel in scenario III is the same as the medium Otto under individual travel in that scenario; all available vehicles under individual travel have improved in fuel economy and performance comparable to that of the medium Otto defined for the group travel strategy, but they have done so at the expense of increased weight and purchase cost. Not surprisingly then, the year-2000 sales distribution among the three size classes under the individual travel strategy does not indicate the massive swing

TABLE 5 Projected Urban Sales of New Cars by Size and Engine Type in Scenario III Under In-Place Policy

		1990 Estimates[a,b] (10^6)				2000 Estimates[a,c] (10^6)			
Car Size	Engine Type	Uniform Charge	Stratified Charge	Turbo-charge	All Units	Uniform Charge	Stratified Charge	Turbo-charge	All Units
Small	Otto cycle	1.598	1.404	0.896		2.843	2.497	1.595	
Medium	Otto cycle	1.369	1.202	0.768		-	-	-	
Large	Otto cycle	0.516	0.454	0.289		0.516	-	-	
Mini	Otto cycle	-	0.165	-		-	0.336	-	
Small	Diesel				0.318				0.529
Medium	Diesel				0.348				0.035
Large	Diesel				0.364				0.068
Van	Diesel				0.036				0.068
Medium	Electric (lead-acid battery)				0.050				0.372
Medium	Electric (nickel-zinc battery)				0.038				0.133
Large	Brayton cycle								0.394

[a]These are manufacturing estimates, with equivalent sales assumed.
[b]Total urban nonfleet sales of new cars projected for 1990, all sizes and engine types = 9,815,000.
[c]Total urban nonfleet sales of new cars projected for 2000, all sizes and engine types = 9,386,000.

TABLE 6 Projected Urban Sales of New Cars by Size and Engine Type in Scenario III Under Group Travel Strategy

		1990 Estimates[a,b] (10^6)				2000 Estimates[a,c] (10^6)			
Car Size	Engine Type	Uniform Charge	Stratified Charge	Turbo-charge	All Units	Uniform Charge	Stratified Charge	Turbo-charge	All Units
Small	Otto cycle	1.359	1.193	0.762		2.156	1.893	1.209	
Medium	Otto cycle	1.841	1.617	1.034		-	-	-	
Large	Otto cycle	0.339	0.297	0.190		0.619	-	-	
Mini	Otto cycle	-	0.145	-		-	0.279	-	
Small	Diesel				0.168				0.223
Medium	Diesel				0.531				0.131
Large	Diesel				0.189				0.011
Van	Diesel				0.029				0.022
Medium	Electric (lead-acid battery)				0.069				0.421
Medium	Electric (nickel-zinc battery)				0.052				0.158
Large	Brayton cycle								0.245

[a]These are manufacturing estimates, with equivalent sales assumed.
[b]Total urban nonfleet sales of new cars projected for 1990, all sizes and engine types = 9,815,000.
[c]Total urban nonfleet sales of new cars projected for 2000, all sizes and engine types = 7,367,000.

TABLE 7 Projected Urban Sales of New Cars by Size and Engine Type in Scenario III Under Individual Travel Strategy

		1990 Estimates[a,b] (10^6)				2000 Estimates[a,c] (10^6)			
Car Size	Engine Type	Uniform Charge	Stratified Charge	Turbo-charge	All Units	Uniform Charge	Stratified Charge	Turbo-charge	All Units
Small	Otto cycle	1.118	0.982	0.627		1.553	1.364	0.871	
Medium	Otto cycle	1.315	1.156	0.739		1.083	0.951	0.607	
Large	Otto cycle	1.024	0.900	0.575		0.639	0.561	0.359	
Mini	Otto cycle	-	0.137	-		-	0.310	-	
Small	Diesel				0.183				0.497
Medium	Diesel				0.507				0.321
Large	Diesel				0.462				0.189
Van	Diesel				0.029				0.028
Medium	Electric (lead-acid battery)				0.037				0.029
Medium	Electric (nickel-zinc battery)				0.024				0.009
Large	Brayton cycle								0.904

[a]These are manufacturing estimates, with equivalent sales assumed.
[b]Total urban nonfleet sales of new cars projected for 1990, all sizes and engine types = 9,815,000.
[c]Total urban nonfleet sales of new cars projected for 2000, all sizes and engine types = 10,275,000.

to small cars observed under the group travel strategy and in-place policy, although the emergence of a similar, if damped, trend is evident (Figure 13).

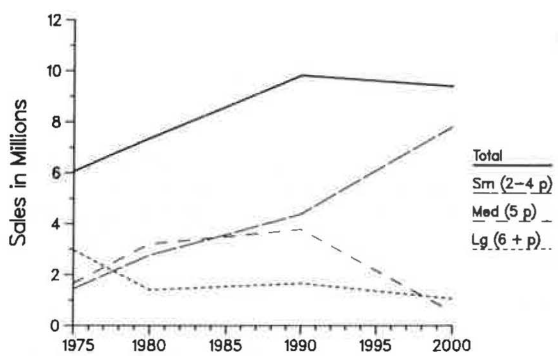

FIGURE 11 Projected urban sales of new cars by size in scenario III under in-place policy.

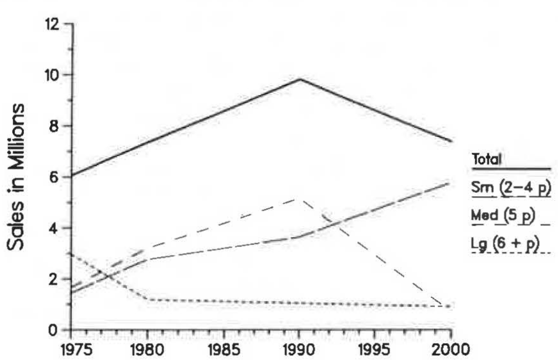

FIGURE 12 Projected urban sales of new cars by size in scenario III under group travel strategy.

As in scenario I, new technologies achieve modest gains in sales through 2000. In scenario III under in-place policy electric vehicles reach a 5.4 percent sales penetration of the urban household market. The group travel strategy, in which total car sales are lower, raises that penetration to 7.9 percent in 2000. However, electric cars are overwhelmed by superior heat-engine technology in scenario III under the individual travel setting, in which their penetration falls to less than 1 percent

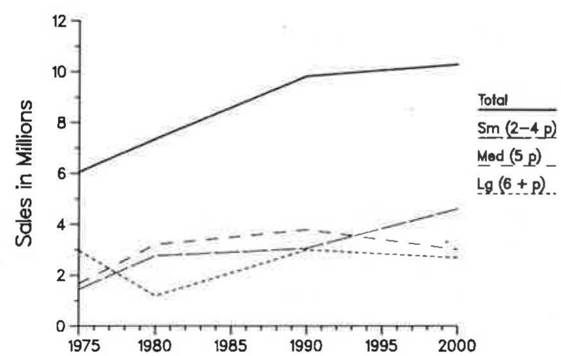

FIGURE 13 Projected urban sales of new cars by size in scenario III under individual travel strategy.

of year-2000 sales. The six-passenger car with a Brayton-cycle engine attracts 8.8 percent of urban car buyers under the individual travel strategy in 2000; it fares less well (but credibly) under the other two strategies. Diesel, again, achieves only 5 to 10 percent of sales across the strategy settings in 2000.

Given the slightly improved technology set of the individual travel strategy, size-class trends in Figure 13 exhibit a pattern similar to that under individual travel in scenario I (Figure 10). Large and medium-sized cars remain in the market after 2000, although small cars are clearly in the ascendant.

COMPARISON OF TAPCUT RESULTS AND PREVIOUS FORECASTS

Distributions

The data in Table 8 compare DVSAM results against certain other published year-2000 forecasts of vehicle stock and sales by technology share and size mix. In all cases DVSAM distributions are urban-only, whereas others are nationwide. Moreover, aggregation to size classes in several of the studies followed procedures different from those used for

TAPCUT. For example, Shackson and Leach (11) used 1979 model-year body platform rather than U.S. Environmental Protection Agency (EPA) classifications to define vehicle size, which resulted in many EPA midsized cars being classified as large by Shackson and Leach, but they were classified as medium sized in TAPCUT. The Shackson and Leach mix-shift case, in which the share of large car sales declines to 10 percent by 2000 whereas midsized and small car sales increase, is given in the data in Table 8.

exclusively to four-passenger car production unless this huge market is to be conceded to imports. This size mix is probably the most controversial result of the DVSAM and the one at greatest variance with most other published forecasts, which envision a continued strong showing by the midsized and compact (five- and six-passenger) vehicles through the end of the century. However, none of these other forecasts were driven by fuel price increases as steep as those under the TAPCUT strategies. The failure of the medium-sized car in the TAPCUT projection stems from the unsatisfactory performance characteristics of that car relative to the competition in all but scenario I under the individual travel strategy.

TABLE 8 Comparison of Vehicle-Size and Engine-Technology Market Shares for the Year 2000 in TAPCUT and Five Other Projections (percentage of total market)

		Vehicle Size (%)									
		Sales Mix			Fleet Mix (holdings)			Engine Technology (%)			
Source of Projection	Date	Small	Medium	Large	Small	Medium	Large	Otto	Diesel	Electric	AHE[a]
TAPCUT, scenario I, in-place policy	1/82	76	7	17	61	19	20[b]	87	7	2	4
TAPCUT, scenario I, individual travel strategy	1/82	39	37	24	36	39	25[b]	57	15	4	24
TAPCUT, scenario III, in-place policy	1/82	83	6	11	59	20	21[b]	83	8	5	4
Mellon Institute *(11)*	8/80	52	38	10	-[d]	-[d]	-[d]	57	30[e]	-[d]	13
Lawrence Livermore Laboratory *(12)*	12/80	-[d]	-[d]	-[d]	-[d]	-[d]	-[d]	70	28	2	0
Energy and Environmental Analysis, Inc. *(13)*	7/81	-[d]	-[d]	-[d]	-[d]	-[d]	-[d]	73	27	0	0
Oak Ridge National Laboratory *(14)*	5/81	33	47	20	-[d]	-[d]	-[d]	85	15	0	0
Argonne National Laboratory *(15)*	8/79	-[d]	-[d]	-[d]	40	25	35	-[d]	-[d]	-[d]	-[d]

[a]Advanced heat-engine technology.
[b]Sprawlburg only.
[c]Imports assumed by Argonne National Laboratory to be evenly divided between small and medium-sized cars.
[d]Data unavailable.
[e]May include high-technology Otto share.

Technology Penetration

With the exception of the scenario I individual travel strategy, TAPCUT forecasts appear somewhat pessimistic on the future of light-duty diesel vehicles (in household use) relative to other published projections. This is attributable in the context of year-2000 sales to the superior qualities of TAPCUT Otto-cycle cars competing with diesels: diesels retain the sales share achieved by 1990 but do not increase that share thereafter. In contrast, TAPCUT is relatively optimistic on electric vehicles; the stock model has identified a market (generally in the low- to middle-income range) in which the overall characteristics of electric cars characterized for TAPCUT are found to be desirable. Nevertheless, operating cost and performance limitations of all but the very high technology electric vehicles (available only in scenario I, individual travel strategy) inhibit significant market growth.

Advanced heat-engine vehicles capture a high market share only in the scenario I individual travel strategy, where two such vehicles are available in 2000. In all strategy and scenario combinations, Otto-engine vehicles continue to account for no less than 57 percent, and up to almost 90 percent, of sales in the year 2000.

Size Mix

In five of the six TAPCUT strategy and scenario combinations small Otto (primarily four-passenger) vehicles dominate both fleet and sales shares by the year 2000. The explicit presence of a small diesel car in the DVSAM choice set might have divided the small-car share more evenly between technologies, but small cars would still account for a majority of the fleet at the end of the century. By this projection, medium-sized and large cars could not realistically be scrapped fast enough, and domestic production lines would have to be devoted almost

Final Observation

Throughout the stock-modeling process the characteristics of a vehicle, rather than scenario demographics, determined its fleet share and its ultimate fate. Such marginal effects as the number of two-person households, which appears to influence the slight difference between scenario I and scenario III under the in-place policy in the small car share of the market, also play a role. But such effects are secondary in the central decision-making process modeled across the entire spectrum of households. That process consists of determining whether a car is a winner or a loser relative to the competition. Apparently there is no natural household market for any type of vehicle in the DVSAM. Although its results may not articulate a future plausible to all analysts, the model clearly indicates that car owners will continue to seek the best value for their personal transportation dollars, irrespective of the socioeconomic or political tenor of the times.

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Projection of Typical Characteristics of Automobiles and Transit Vehicles for Policy Analysis

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ABSTRACT

In this paper the characteristics of three future automotive technology sets are described, starting from historical data and projected forward in time along paths suggested by given alternate future socioeconomic environments. The characterizations include quantified projections of automobile and transit vehicle weight, performance, fuel economy, consumer price, operating cost, materials of construction, fuels and environmental residuals associated with their manufacture, operating pollutants, and infrastructure-related energy expenditures, emissions, and cost. Brief descriptions of rationale and calculational procedures are also given, and selected results are presented. The breadth of the vehicle characterizations permits the effects of policy options on most facets of the urban transportation section to be examined. The methodologies developed in this work are generalized, and hence can be used with alternate assumptions in a variety of investigations. For purposes of the Technology Assessment of Productive Conservation in Urban Transportation (TAPCUT) policy analysis, each technology set consisted of six sizes of personal automobiles, each propelled by conventional