

# Long-Run Vehicle Travel Prediction from Demographic Trends

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A simple method is presented for long-run forecasting of highway vehicle miles of travel (VMT) based on the assumption that travel is fundamentally time-constrained. Demographic projections by age cohort and sex are used to produce vehicle travel forecasts that vary according to assumptions about license-holding rates and average miles per licensed driver by age and sex. With constant vehicle miles per driver, 2020 forecasts range from 1.93 to 2.30 trillion vehicle-mi. The greatest potential for increased vehicle travel appears to depend on whether rates of travel per female licensed driver will begin to approach those of men. Equal rates would boost 2020 VMT to 2.84 trillion vehicle-mi.

Forecasting relies on consistency, whether of certain facts, patterns, relationships, or rules. During the past decade, travel demand forecasters have explored the possibility that key parameters of personal travel may be approximately constant, on average, or may obey very simple rules or patterns that remain constant over time. The significant debate over constant travel time, or travel cost, or generalized cost budgets is of this nature (1). The virtue of the constant-travel-time-budget approach is that it recognizes the highly constrained nature of travel, and especially that travel is constrained not only by command over monetary resources but, more importantly, by the availability of time for travel. Traditional econometric forecasting approaches do not take advantage of this constraint by formally incorporating a time constraint (2).

A demographic approach to forecasting travel demand is explored that is similar to methods Maring (3) has called "micro" approaches but that is methodologically akin to constant-travel-time-budget methods. The philosophy that guides these approaches is to reduce the description of the future state of the world required to make a forecast to the fewest and most readily predictable variables possible. Such models are clearly intended for long-range rather than short-range forecasting, and are designed for prediction per se rather than for policy analysis.

Maring (3), for example, relied on the constancy of patterns of household income and vehicle mileage or numbers of licensed drivers and miles traveled to predict vehicle travel as a function of demographic forecasts. Demographic forecasts are likely to be robust, and if the travel patterns selected vary little over time, the forecasts themselves will be approximately correct under a wide range of conditions. Maring's 1974 forecasts for 1984 are exceptionally close to the mark (only 7 percent

low), despite wide fluctuations in fuel prices and economic growth, and even the failure of certain key assumptions.

First the methodology of "micro"-forecasting approaches is examined, showing that these approaches are of the same genre as projection methods based on constant travel budgets and vehicle stocks. Next, a simple model of vehicle travel based on demographic predictions of population by age and sex is described. Given a demographic projection, the key parameters of this model are license-holding rates and annual miles per licensed driver. These parameters are examined to determine their constancy or predictability over time. Finally, the model is implemented as a spreadsheet, and the implications of several demographic and vehicle use trends are explored.

Although the intent is to project total highway vehicle travel, the micro procedures explicitly address only passenger travel (by far the largest component). The premise is not only that total highway vehicle travel is dominated by personal travel (especially by households using automobiles), but that freight traffic is strongly correlated with passenger traffic. Thus, if one is concerned with forecasting total, undifferentiated vehicle miles, explicit forecasting of freight vehicle traffic might not be essential. For many purposes, however, explicit consideration of highway freight activity is essential and other methods would have to be employed.

## DEMOGRAPHIC AND VEHICLE-STOCK-BASED APPROACHES

Interest in travel forecasting by means of constant travel budgets has been chiefly motivated by a desire to reduce the number and complexity of independent or exogenous variables required by forecasting models, so that predictions can be made without having to rely on forecasts of exogenous variables that may be more difficult to predict than travel itself. The best example of this might be the cost of motor fuel, which has proven to be essentially impossible to predict, and with respect to which the amount of travel is widely acknowledged to be inelastic. There may be other reasons for including fuel costs in a model as a determinant of travel, such as to evaluate tax policies or estimate revenues, but there is little justification for including it to increase forecast accuracy.

The desire to increase forecast accuracy while at the same time simplify forecasting models prompted Zahavi (4) and Tanner (5) to look for stable relationships between travel and other factors. These researchers found that the average amount of time spent traveling was relatively constant across wide variations in geography, culture, and technology. This led them

to believe that predictive models of travel behavior could be developed that depended on the average speed of travel and a minimum of other, readily predicted variables. Similarly, energy demand modelers found that vehicle stock utilization rates varied relatively little and in reasonably predictable ways over large fluctuations in income and per-mile travel costs (6). This led them to develop fuel-use forecasting models based on projections of the size and composition of the vehicle stock, assuming constant rates of utilization by vehicle age group (7, 8).

If one accepts the premise that the distribution of driving-age population by age groups is readily predictable 10 to 20 years ahead, the accuracy of forecasts will depend on the constancy or predictability of ratios of drivers per capita in each age group and of miles per driver by age group. An important property of this approach is that both unknown quantities are constrained by definite upper and lower bounds. The rate of licensed drivers per age group is clearly bounded by zero and 1. Indeed, data presented in the following show that licensing rates for most age groups for both men and women appear to be converging on 1. The constraint on vehicle miles per licensed driver is less obvious, but no less real. It arises from the fact that time spent in travel is constrained, and is thus related to the concept of travel time budgets. The total time an individual may spend traveling clearly cannot exceed 24 hr a day. Thus, a trivial upper bound on vehicle travel would be 24 divided by the maximum feasible average speed in miles per hour. But the average individual obviously cannot spend 24 hr a day traveling over an extended period of time. The typical individual (or social average) must sleep, work, eat, and perform numerous other essential functions if society is to continue. From an empirical point of view, this implies that socially average travel times will have much lower upper bounds, perhaps 1 to 2 hr a day (9–11).

From the perspective of economic theory, the upper bound is still 24 hr divided by average speed, but the cost of travel includes two components: monetary costs and the cost of time spent traveling. As the time spent traveling increases, it interferes with other important activities, with the result that the cost of time spent traveling increases at an increasing rate as the amount of time spent traveling increases (2). Thus, it may appear that there is an upper bound of 1 to 2 hr on time spent traveling when in theory it is the time cost of travel that is the binding constraint. For practical purposes, as long as average travel times are approximately constant [there is considerable debate on this point (12)], the mechanism by which they remain approximately constant need not be explicitly included in the model.

Travel-time-budget modelers claim only that the quantity of time spent traveling by all modes of mechanized transport is approximately constant, on average. In the United States, however, 88 percent of passenger miles are traveled on the highway and most of the rest is by air. Thus, at an aggregated national level it may be a reasonable approximation to assume that highway vehicles are the only mode of transport. Finally, if the number of passengers per vehicle (load factor) is approximately constant, constant passenger miles implies constant vehicle miles. Given all of this, the assumption of constant vehicle miles per driver can be seen as equivalent to the constant-travel-time-budget postulate. From this perspective,

the first method is tantamount to projecting the age distribution of the population, predicting rates of driver licensing by age group (a strongly constrained variable), assuming that highway–nonhighway modal shares do not change significantly, assuming that load factors are also approximately constant, assuming that average highway speeds do not change much, and finally, invoking the axiom of approximately constant-travel-time budgets across age groups.

Note that if one accepts the empirical validity of the constant-travel-time hypothesis, it is not necessary to assume that the value of time remains constant or that there are no significant changes in the organization of society. If the constant-travel-time hypothesis is accurate, these vary widely across cultures throughout the world without significant effect on the quantity of time spent traveling.

## THE MODEL

The constant-travel-time-budget assumption leads to an extremely simple forecasting model when the following four factors can be assumed to vary negligibly:

1. Modal shares of passenger travel,
2. Vehicle load factors,
3. Travel velocity, and
4. Fixed and variable costs of travel.

If the previous four conditions can be assumed to be approximately correct, there should be approximately constant vehicle miles per driver. If there are constant vehicle miles per licensed driver, one need only predict the number of licensed drivers, which depends solely on the number of persons of driving age and the rate of license holding. As Maring (3) points out, the age structure of the driving-age population is particularly predictable 10 to 20 years ahead because nearly all the population of driving age will have already been born.

The basic idea, then, is to begin with a robust forecast of the driving-age population and on the basis of historical patterns and trends, assume rates of license holding and miles per licensed driver. The license-holding and mile-per-driver rates are actually parameters that can be varied to produce alternative forecasts. Both demographic forecasts and the necessary parameters are available by sex and age group. Because there are variations in parameters across age groups and the data are available, it makes sense to operate at the level of age and sex cohorts and add up to obtain the total forecast vehicle miles of travel (VMT). The method is captured by the following simple equation:

$$VMT = \sum_i \sum_j (P_{ij} \cdot \delta_{ij} \cdot \mu_{ij}) \quad (1)$$

where

- $P$  = population,
- $\delta$  = rate of drivers' licenses per capita, and
- $\mu$  = annual miles per licensed driver for sex  $i$  (men, women) and age cohort  $j$ .

### TRENDS IN PARAMETERS: 1969 TO 1983

It is essential to the usefulness of this forecasting method that the parameters  $\delta_{ij}$  and  $\mu_{ij}$  remain relatively constant over time. The Nationwide Personal Transportation Study (NPTS) (13-15) provides an opportunity to examine the validity of the postulate that (a) rates of drivers' licenses per capita by age group and sex and (b) vehicle miles per licensed driver by age group and sex are relatively constant over time. Rates of license holding by age are shown in Figure 1 for men and women drivers in 1969 and 1983. These data were taken from the FHWA publication *Highway Statistics*, not from the NPTS (16). The distributions of license-holding rates for men are nearly identical in the two years: only the oldest and youngest age groups are very different from 1.0. The fact that license-holding rates are occasionally greater than 1 is indicative of slight inconsistencies between the population and drivers'-license data. Rates for women drivers, in contrast, increased across the board over the 14-year period.

In brief, license-holding rates show a convergence of men's and women's rates. Rates for men have remained nearly constant (at 1) and the pattern for women has become more similar to that of men and is well on the way to equivalence (Table 1).

Miles per licensed driver, on the other hand, increased consistently for both men and women drivers from 1969 to 1983 in nearly all age groups (Figures 2 and 3). Rates of increase were in the vicinity of 2 percent annually for both men and women (Figures 4 and 5). A strict interpretation of travel-time-budget theory would indicate that such increases must be accompanied by either an increase in average speeds or a movement to

higher income levels, resulting in a modal shift toward motor vehicle travel or a decrease in load factors. Although speed data are scarce, average speeds on rural Interstate highways suggest that speeds may have been lower in 1977 and 1983 than in 1969. On the other hand, most households did move to higher income levels.

The most significant aspect of the statistics on miles per licensed driver is the major difference in miles of travel that still exists between men and women drivers. Vehicle travel by men is nearly twice that of women (Figure 6). That gap did not narrow between 1969 and 1983. Travel by both men and women increased at nearly equal rates so that, unlike rates of license holding, women's driving patterns do not appear to be converging toward those of males. It appears surprising that the social changes that have produced convergence in license-holding rates do not appear to be producing convergence in miles of vehicle travel. This anomalous situation may suggest fruitful directions for future research in travel behavior. It also raises the possibility that significant changes in the roles of women, such as continued increasing participation in the labor force and especially relief from other duties that demand a part of the daily time budget, could result in major increases in travel by women in the future. It will be shown later that if such a trend were to develop, it would be the single most important force for increased highway travel in the coming decades. However, such a trend has yet to emerge.

### PARAMETRIC FORECASTS TO 2020

The simple model described by Equation 1 can be straightforwardly implemented as a spreadsheet model. Alternative

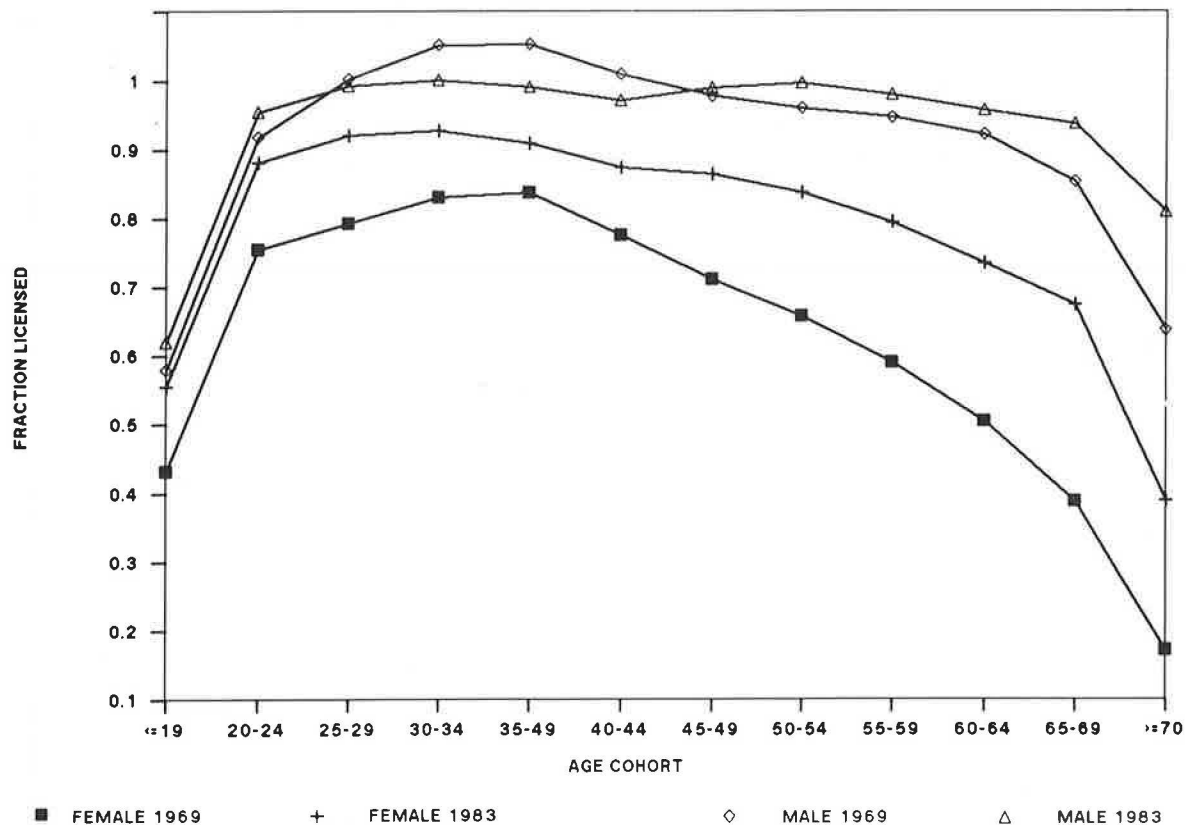


FIGURE 1 Licensed drivers per capita by age cohort and sex, 1969 and 1983 (16).

TABLE 1 VEHICLE TRAVEL PROJECTIONS

	1983 Estimate	2020 Projections						
		Series 14 Population	Census	Census	Census	Equal License	Equal Vehicle	Equal License and
		1983 Age Distribution	Series 14	Series 19	Series 9	Holding	Miles	Vehicle Miles
Vehicle Miles								
Male	1.16E+09	1.54E+09	1.52E+09	1.40E+09	1.67E+09	1.52E+09	1.52E+09	1.52E+09
Female	4.65E+08	6.12E+08	5.71E+08	5.24E+08	6.30E+08	6.75E+08	1.33E+09	1.57E+09
TOTAL	1.63E+09	2.16E+09	2.09E+09	1.92E+09	2.30E+09	2.19E+09	2.84E+09	3.08E+09
Drivers								
Male	80765	107488	108063	98978	119247	108063	108063	108063
Female	73430	96664	93225	85464	102864	115617	93225	115617
TOTAL	154195	204152	201289	184442	222111	223680	201289	223680
Miles Per Driver								
Male	14367	14367	14041	14115	13977	14041	14041	14041
Female	6334	6334	6126	6129	6125	5836	14224	13539
TOTAL	10541	10563	10375	10414	10340	9800	14216	13781
Drivers Per Driving Age Population								
Male	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Female	0.77	0.77	0.74	0.75	0.74	0.92	0.74	0.92
TOTAL	0.85	0.85	0.83	0.84	0.83	0.93	0.83	0.93

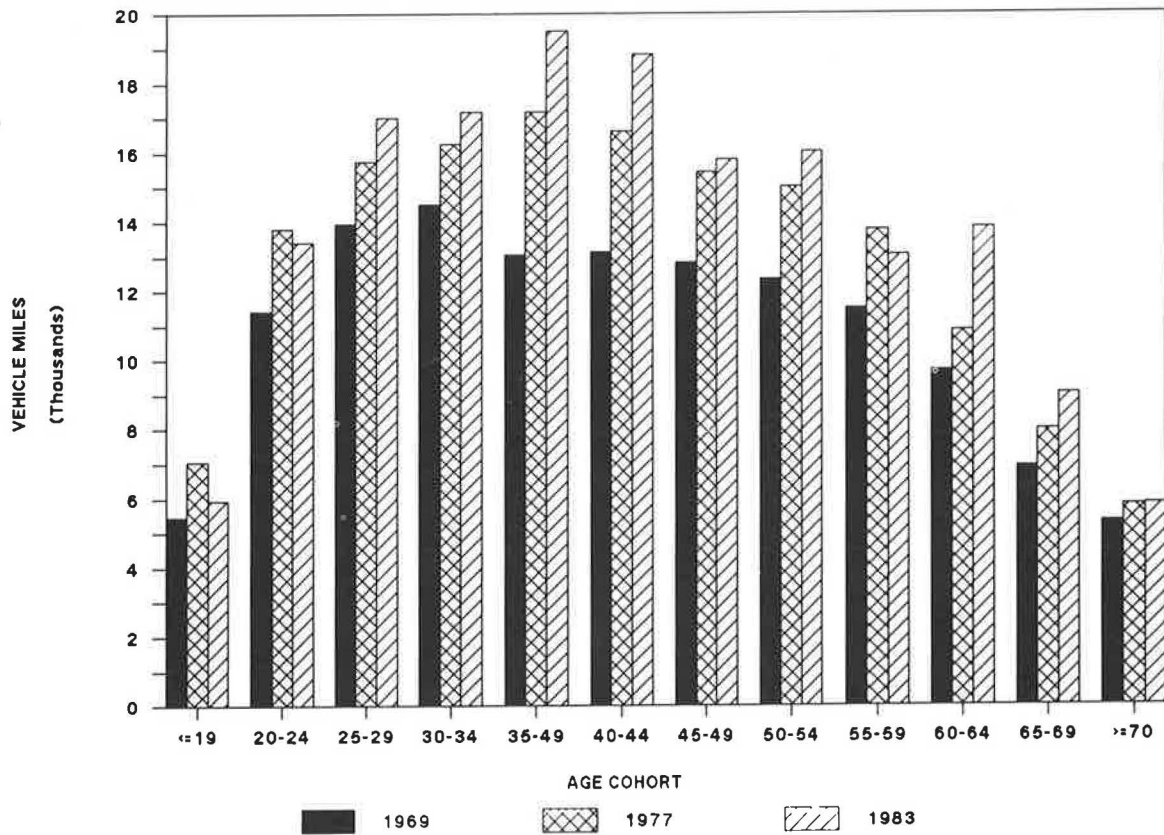


FIGURE 2 Average annual miles per male driver (NPTS data by age).

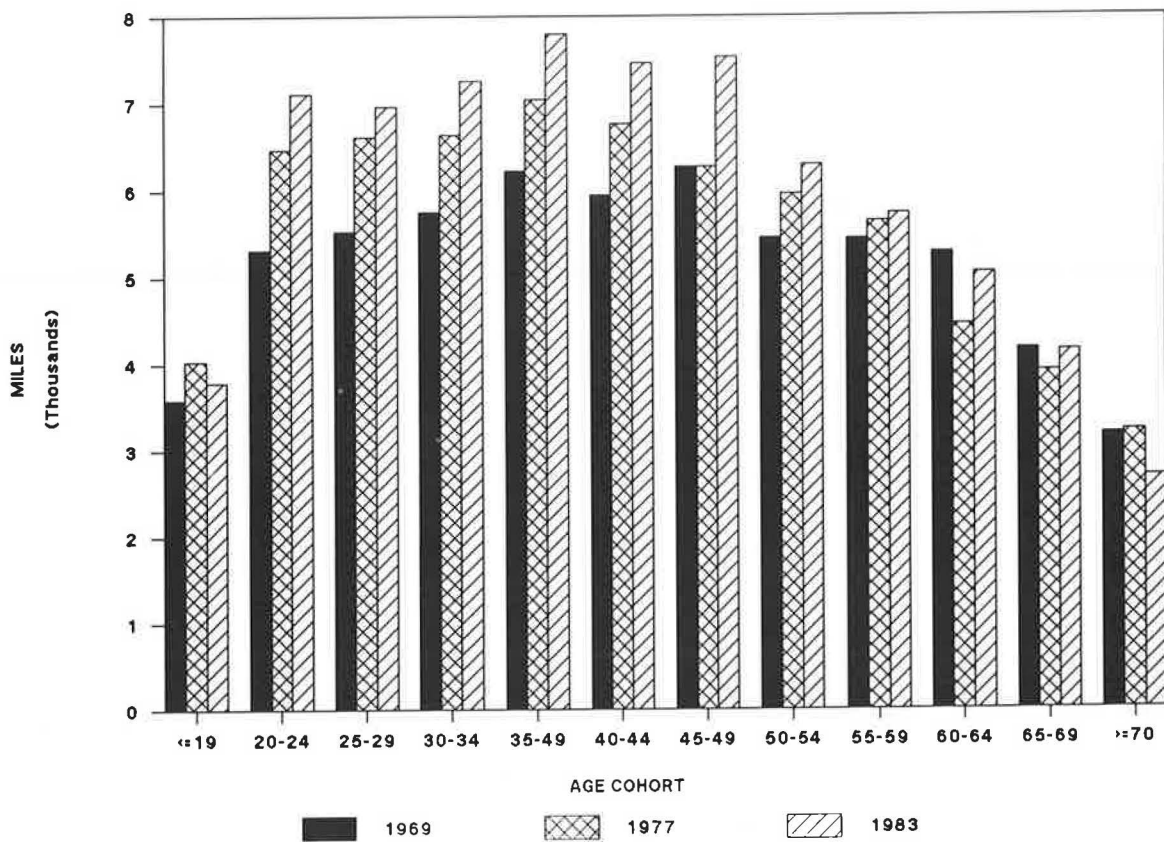


FIGURE 3 Average annual miles per female driver (NPTS data by age).

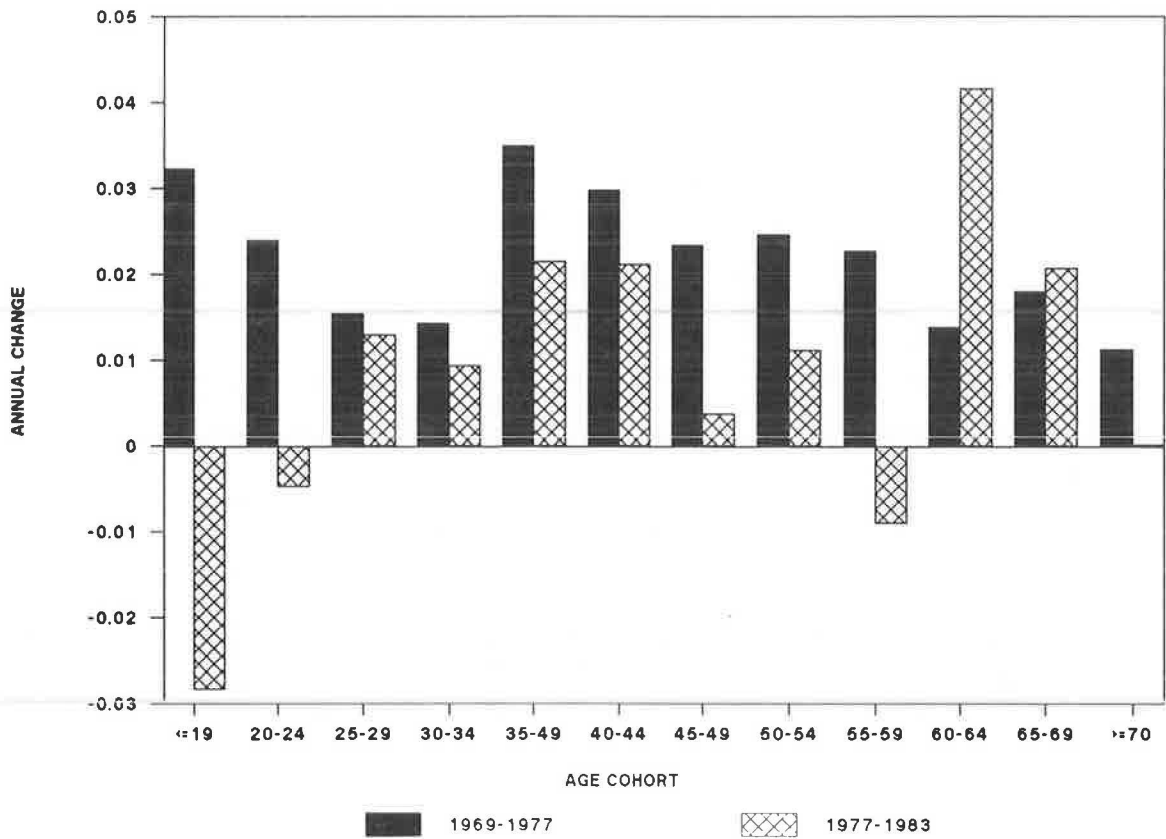


FIGURE 4 Growth rates of miles per driver by age: annual percent change for men.

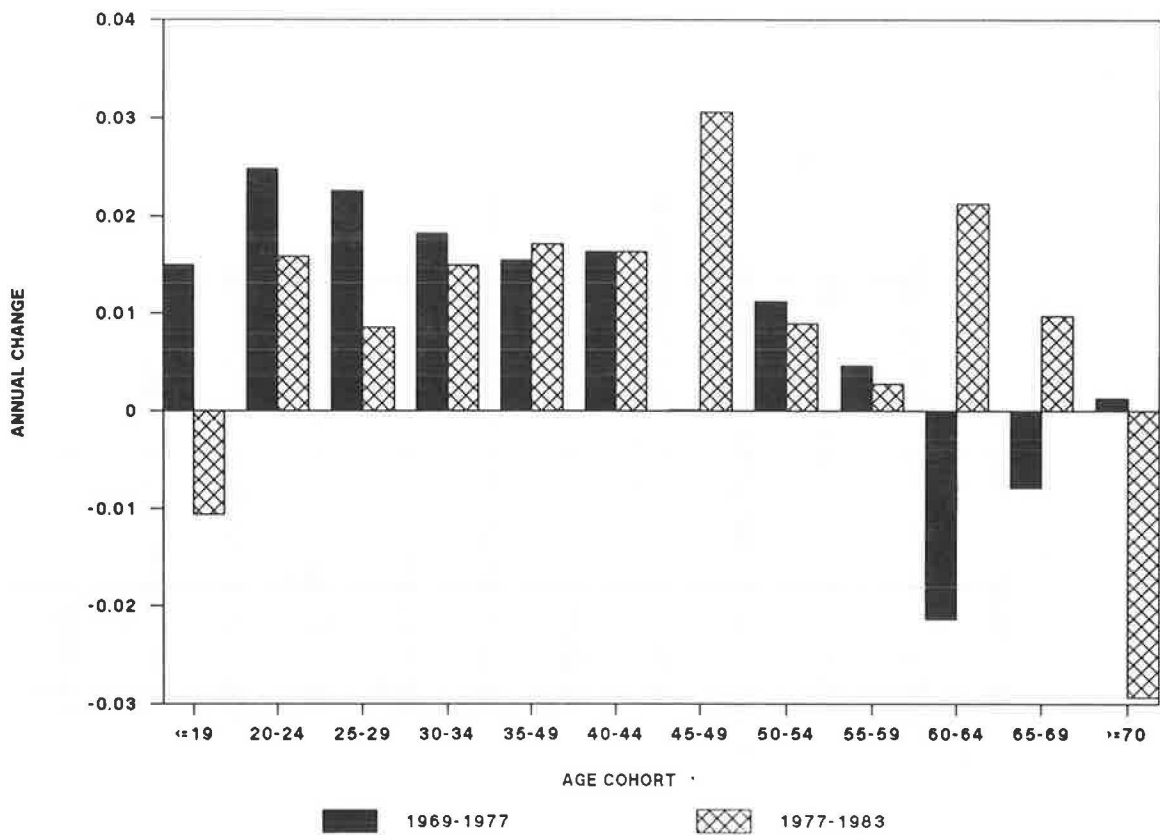


FIGURE 5 Growth rates of miles per driver by age: annual percent change for women.

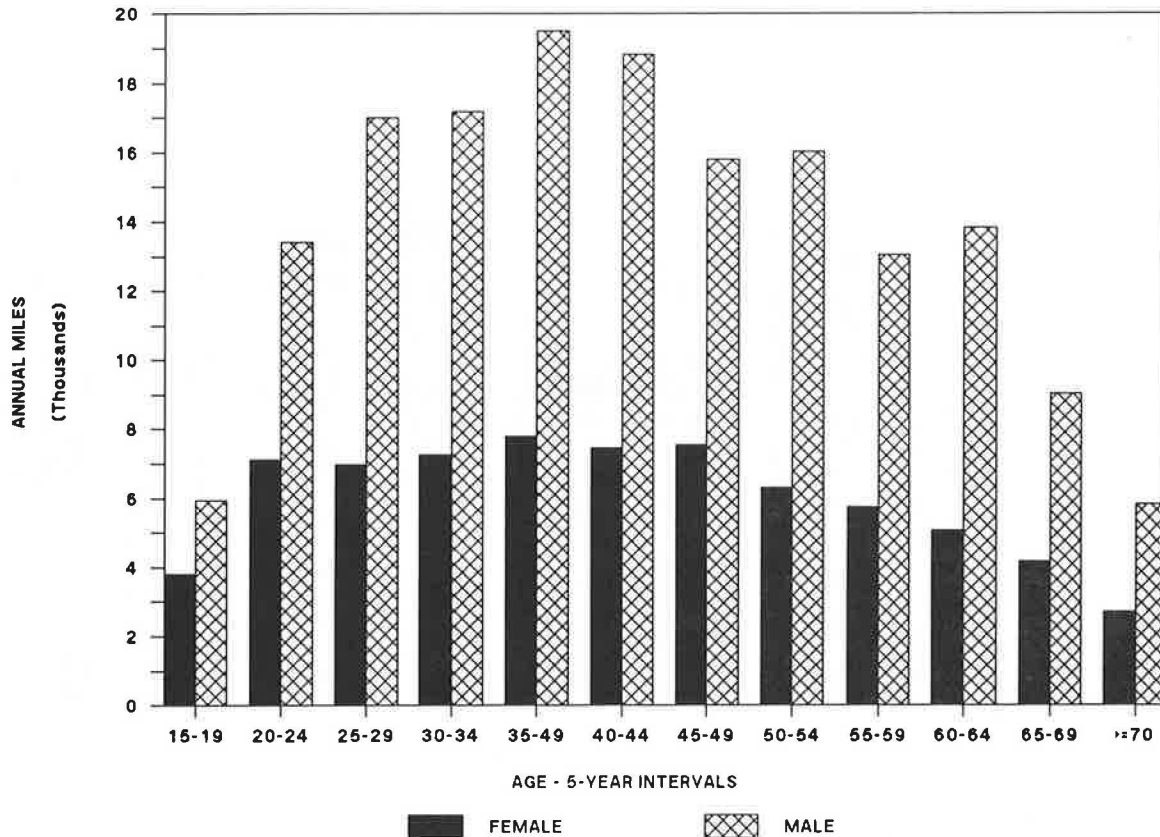


FIGURE 6 Difference between men and women drivers in annual mileage.

forecasts can be produced by using different population projections and by varying assumptions about trends in license-holding rate ( $\delta$ ) and annual miles per driver ( $\mu$ ).

For illustrative purposes, seven such forecasts were made based on three census projections. The Bureau of the Census Series 19, Series 14, and Series 9 projections provided low, medium, and high population projections, respectively, and are believed to bound the range of possible U.S. population totals in 2020 (17). In each of these three projections it was assumed that 1983 values for  $\delta$  and  $\mu$  would hold in 2020. Alternative forecasts could have been produced by allowing  $\mu$  to increase over time. Indeed, as has been seen,  $\mu$  increased at rates from 2 to 3 percent per year from 1969 to 1983. Whether this indicates increased time spent in travel, increased travel speeds, a modal shift toward highway travel, or decreased load factors for vehicles, it is an important trend and worthy of further investigation. However, its implications will not be explored here.

Four variations on the Series 14 projection were created to explore the effect of differing trends on total travel (Figure 7). In the first, Scenario L, it is assumed that license-holding rates for women and men in 2020 would be exactly the same as those for men in 1983. Because, except for the youngest and oldest age groups, the rates are essentially 1.0, Scenario L represents saturation of license-holding rates. In the second, Scenario M, it is assumed that in 2020 rates of annual miles per licensed driver for men and women will equal those of men in 1983. In the third scenario, M+L, the assumptions of Scenarios M and L are combined so that, from the viewpoint of the model, men and women are equivalent in all respects. The final scenario, D, is intended to measure the effect of the aging of the U.S.

population on vehicle travel. It uses the total population predicted by the Series 14 projection for 2020, but redistributes it so that the age distribution is the same as that in 1983. The difference between the Scenarios D and 14 is therefore entirely due to a change in the age distribution of the population.

Although there are nontrivial differences among the three demographic projections, future VMT is clearly most affected by the assumption of equal miles per driver for men and women (Figure 7). VMT is 1.92 trillion in the low-population forecast, 2.09 trillion by the Series 14 projection, and 2.30 trillion for the highest population projection. That is, the total reasonable range of future population projections for 2020 creates a range of VMT forecasts of 2.09 trillion, +10 percent to -8 percent. This is a remarkably small range for a 37-year forecast. Compare, for example, an econometric model with a VMT income elasticity of 1.0 and average annual income growth rates of 1.5 percent versus 2.5 percent versus 3.5 percent. The range of VMT predictions generated by these assumptions would be +43 percent to -30 percent. More important, perhaps, VMT would be predicted to increase 357 percent given high-income growth, and 73 percent under the low-growth assumption. Despite 2 to 3 percent increases in VMT per driver from 1969 to 1983, most are probably not willing to believe that such a rate of growth could continue unabated for the next four decades.

The effect of the license-holding rate trend is even less important. Equating men's and women's license-holding rates at saturation in 2020 results in 2.19 trillion VMT, an increase of only 4.8 percent. Less important still is the aging of the population. Imposing the 1983 age distribution on 2020 population

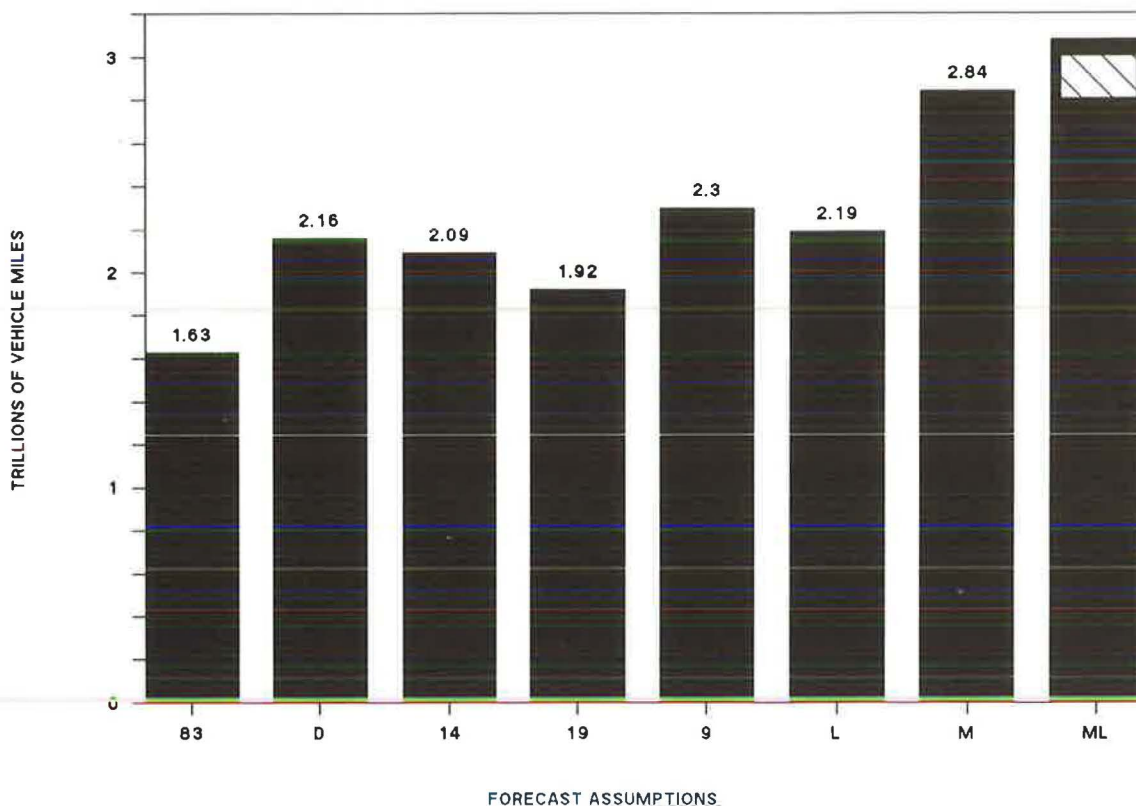


FIGURE 7 Vehicle mile forecasts for 2020.

increases VMT by only 3.4 percent to 2.16 trillion. Thus, the fact that the U.S. population is getting older will be of little consequence for total vehicle travel.

The one factor that has a dramatic effect on total travel is annual miles per female licensed driver. Assigning the same 1983 annual miles to men and women in 2020 results in a forecast of 2.84 trillion VMT, up 36 percent over the unmodified Series 14 forecast. If equal rates of license holding are added to that, the result is 3.08 trillion mi, a 47 percent increase. This potential for increased vehicle travel is particularly intriguing in light of the fact that although women's and men's license-holding rates have been converging, women's and men's driving rates have not. Although one might speculate about possible explanations for this anomaly, a better understanding of men's and women's vehicle travel behavior is clearly important to understanding the potential for greatly increased vehicle travel into the next century.

## CONCLUSIONS

The simple travel forecasting method presented provides a means of developing long-run vehicle travel forecasts based on relatively predictable population patterns and making use of relatively stable parameters such as the average miles per driver and the number of drivers' licenses per capita. The stability of vehicle travel per licensed driver over time depends on the relative constancy of vehicle speeds, vehicle load factors, the modal distribution of passenger travel, and the fixed and variable costs of travel. If, in addition to these, travel time per driver is relatively constant, this simple approach should produce accurate vehicle travel forecasts.

A spreadsheet implementation of this model suggests that future levels of vehicle travel may be most sensitive to the annual miles per female licensed driver. Although license-holding rates for women in all age groups have been rapidly approaching the saturated levels for men, there has been no corresponding convergence of rate of miles per licensed driver. Annual miles per woman driver are approximately half those of men of equal age. Increases in these rates appear to be the largest potential source of vehicle travel growth in the future.

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