

Projections of Automobile Ownership and Use Based on Household Lifestyle Factors

Douglas P. Sharp

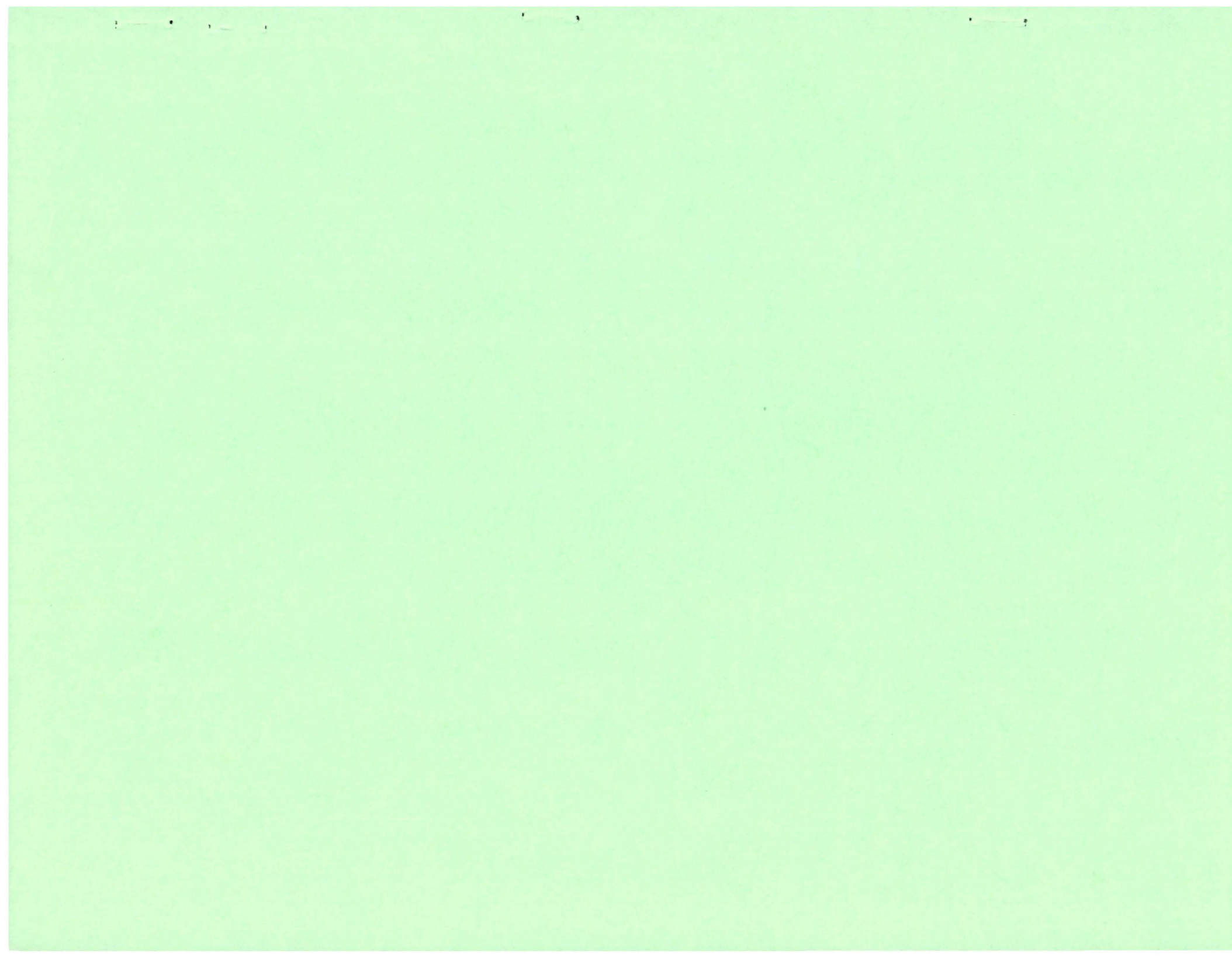
**Environmental Systems Engineering Program
and
Institute for Research on Interactions of Technology and Society
University of Pittsburgh**

Under ORNL Subcontract No. 7356



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**PROJECTIONS OF AUTOMOBILE OWNERSHIP AND USE
BASED ON HOUSEHOLD LIFESTYLE FACTORS**

Prepared by

**Douglas M. Sharp
Environmental Systems Engineering Program
and
Institute for Research on Interactions of Technology and Society
University of Pittsburgh
Pittsburgh, Pennsylvania 15261**

Prepared for

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Department of Energy**

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FOREWORD

This report is one of a series covering various specific topics related to transportation energy consumption. Projections of Automobile Ownership and Use Based on Household Lifestyle Factors is the result of work done by Environmental Systems Engineering Program, Institute for Research on Interactions of Technology and Society, University of Pittsburgh, under ORNL Subcontract No. 7356. The work was done in support of Oak Ridge National Laboratory's transportation energy project, which is an area of study for the Data Management and Analysis Group of the Energy Division and is under the direction of Dr. Andrew S. Loeb1.

This document was prepared under subcontract to Oak Ridge National Laboratory. The assumptions, views, and conclusions expressed in the document are those of the authors and are not to be interpreted as those of ORNL, Union Carbide Corporation, Nuclear Division, or of the Department of Energy.

proposal and two subsequent reports. In particular Linda Zemotel, a graduate student involved in the first three months of the research, developed much of the data used to specify parameters in the projections.

The final stage of this research was conducted within IRITS. Dr. Reginald Baker, Assistant Director of IRITS, provided considerable editorial skill during the production of this document. Pauline Keefer heroically typed the many drafts and final version of this report.

Dr. Andrew Loeb1 and Dr. David Greene, both of the Oak Ridge National Laboratory provided helpful suggestions as monitors of this research.

The considerable debt owed by the author to the aforementioned individuals and institutions is doubly felt because the substance of this research forms the heart of the authors Ph.D. dissertation which will be submitted for approval in August, 1978. As always any deficiencies of this report are the responsibility of the author.

ACKNOWLEDGMENTS

This report is the third and final product of a year of research funded by the Energy Research and Development Administration which focused on household lifestyle as it relates to automobile ownership and use. It is appropriate that the efforts of the following individuals and institutions who participated in this research be acknowledged.

Dr. Norman P. Hummon, Director of the Institute for Research on Interactions of Technology and Society (IRITS), was the principal investigator on this research. To mention all of the benefits that this research has derived from his involvement would be impossible. However, several crucial roles that he played in it should be mentioned. His original ideas and previous works regarding social roles and the automobile were the foundation from which this research was conducted. As principal investigator he helped guide the initial proposal for this research through several rounds of discussion and was responsible for seeing to it that documents promised in the proposal were produced. In his role as principal investigator and as the author's academic advisor he provided crucial assistance during the analytical phase of the research. And as Director of IRITS he made available the resources of that institution for the production of this document.

Philip Patterson, of the Department of Energy, provided the initial enthusiasm and effort which led to the funding of this research. It was his belief in the importance of lifestyle type factors which made this research project possible.

The early stages of this research were conducted within the Environmental Systems Engineering (ESE) Program. The ESE Program provided the computer time needed for conducting the analyses presented in this and two previous reports. The ESE staff also supported the production of the initial

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The purpose of this research is to project to the year 2025 the total number of automobiles that would be owned by American households, (total ownership) and the total number of miles that these vehicles would be driven per day (total use) given certain assumptions about the future of U.S. society. These assumptions relate to demographic, economic, and geographical attributes of U.S. society which are relevant to the automobile. The impacts of these assumptions have been analyzed via a set of projection models which explicitly recognize the relationship between these particular attributes of society and the automobile.

Part I of this report presents an overview of the research. The results from the projections are presented in Part II. The methodology used to generate these projections is discussed in some detail in Part III.

In a "base case" projection the number of automobiles and average daily travel of Americans double by 2025 due to increases in population, headship rates (households per population), and incomes. Economic variables account for about half of this increase as indicated by a "no economic growth" projection in which ownership and daily travel increase just over 40% and 50% respectively. Other projections explore the effects of differing assumptions regarding rates of household formations, population growth and income growth. Model projections suggest that changed work schedules and the reemergence of cities as growth areas will have only slight impacts on future travel and vehicle ownership.

PART I - OVERVIEW

A. The Conceptual Framework

Looking back over the past 80 years of U.S. history reveals that the automobile has had an extraordinary impact on U.S. society. In his first book on the automobile James Flink enumerated some of these impacts:

... since its introduction in the United States in 1895 the motor vehicle has been the most significant force shaping the development of modern American civilization.

- Henry Ford created a new class of semiskilled industrial worker and set a new standard of remuneration for manual labor.
- At General Motors under Alfred P. Sloan, the decentralized, multidivisional structure of the modern industrial corporation, modern management techniques and consumer installment credit as we know it were pioneered in the 1920's.
- Automobile sales became the backbone of a new consumer-goods-oriented economy that emerged during the 1920's.
- Patterns of courtship, residence, socialization of children, education, work habits, and use of leisure time were radically altered by the adoption of the automobile.¹

A look at the U.S. in the 1970's shows the continued importance of the automobile to U.S. society. In 1970 Americans made 87.3 billion automobile trips, using over 85 million cars, resulting in 776 billion vehicle miles of travel (VMT). Over half of all families owned one car in 1970 and one quarter owned two or more. It is clear that the automobile continues to play a central role in the current day-to-day life of Americans.

Because of the great historical significance of the automobile and its continued importance in the present, any attempt to project its ownership and use 50 years into the future should be based on a methodology which accounts for at least some of the dominant processes of societal evolution. This requirement is fulfilled in the current research by applying the general concept of household lifestyle.

The household, rather than the individual, is used for analysis because decisions by American consumers regarding the automobile are made on the basis of the total needs and resources of each household,

not on the needs and resources of individuals. When purchasing cars, the incomes of all household wage earners are likely to be considered as a single resource. Even if there is only one wage earner, all licensed drivers are likely to make use of the household's automobile(s). Additionally, the needs of non-licensed persons which necessitate automobile travel will also affect the number of automobiles owned and the distance they are driven.

American households own and use their automobiles in order to participate in a wide range of activities. Thus, any explanation of ownership and use of the automobile must also attempt to explain the participation of households in different activities. Such a requirement cannot be fulfilled by a simple one dimensional description of households. Rather, a broad characterization of households is required. This research fills this need by using the concept of a household's lifestyle. Household lifestyle is defined in terms of a household's size and age, the social roles contained within it, the resources available to it, and the density and variety of activities open to it. This definition provides an extensive yet detailed typology of households.

Specifically, lifestyle is defined by the three general dimensions of household lifecycle stage, income and location. Life cycle stage is an indicator of the social roles present in different households, as well as, the size and age of the household. Associated with different roles is participation in various activities which in turn lead to travel. Income is recognized as the resource pool from which automobile purchase and operating costs are paid. Location is considered as a measure of the density and variety of activity sites surrounding a household which generate travel. Individually these three dimensions provide very different but important information bearing on the ownership and use of the automobile by American households. In combination they provide a realistic framework for projecting automobile ownership and use.

There is an additional advantage to this conceptualization. The use of a household life cycle stage typology for defining lifestyle, allows these projections to be made using the well developed set of techniques of mathematical demography. In this way the research is given a solid foundation in both a cross sectional sense and longitudinal sense.

B. Projection Versus Prediction

One point that should be made clear from the outset is the distinction between projections and predictions. One of the clearest statements of this distinction, which is also used in this research, was set forth by Nathan Keyfitz (1972), the noted mathematical demographer. Keyfitz defined projections as the "numerical consequences of the assumptions chosen." Specifically, in his own field this meant:

"The numbers [projections] are conditional on the assumptions being fulfilled: if birth and death rates move in a certain fashion, and net migration is of such an amount, then the total population and its age-sex distribution will be such and such".²

In this way projections are statements of the consequences of initial assumptions and differ from predictions which are statements of what will actually happen. Based on this distinction Keyfitz warns that:

...the user [of population projections] is typically not a professional demographer and he wants a prediction of what will actually happen in the future. The calculation of future population presented as an innocent (indeed tautological) projection by its author, is accepted as a prediction by the reader.³

Although this discussion by Keyfitz is in the context of demography and, thereby, pertains to the population projections in this research, his comments also apply to the ultimate projections of automobile ownership and use presented in this report. Various assumptions regarding several dimensions of U.S. society that are relevant to the automobile are made and carried 50 years into the future. The use of the term prediction for any one of these projections is valid only if the assumptions underlying the projection are realistic.

C. Variables Used

The two variables analyzed in this research are the number of automobiles owned by a household - referred to generally as ownership, and the number of vehicle miles of travel made in one day (DVMT) by a household - generally referred to as use. These variables are considered at the individual household level and at the aggregate national level. At the household level they are referred to as average ownership and average use. At the national level they are referred to as total ownership and total use.

The definitions of the three principal dimensions of the lifestyle concept are presented in Table 1. Life cycle stage is defined in terms of three variables - the age of the head of the household, the presence or absence of spouse, and the presence or absence of children. Previous research has shown that these three variables provide an effective means for distinguishing different types of households.⁴ Household income is defined by four broad income classes <\$5,000, \$5,000 to \$9,900, \$10,000 to \$14,000, \$15,000+. In 1970 these classes roughly approximated quartiles. Location is defined by a trichotomy of urban, suburban and rural residential locations.

D. Presuppositions

In carrying out this research some assumptions were made which remained constant for all the projections. Such fixed assumptions are referred to as presuppositions. The simpler term of assumption is used to indicate conditions which are specified differently for each projection. Three presuppositions are presented in this section - the limit on income effects, the use of cross sectional models and the continued availability of resources such that demand is always fulfilled.

One of the most important aspects of the lifestyle typology is the categorization of the income dimension. The use of a maximum income class (\$15,000+) presupposes an eventual limit on income effects. Initially,

TABLE 1
Definition of Major Lifestyle Dimensions

<u>Life Cycle Stage</u>			
<u>Life Cycle Stage</u>	<u>Age of Head</u>	<u>Spouse Present ?</u>	<u>Children Present ?</u>
I	18 - 44	No	No
II	18 - 44	Yes	No
III	18 - 44	Yes	Yes
IV	45 - 64	Yes	Yes
V	45 - 64	Yes	No
VI	45 - 64	No	No
VII	65+	Yes	-
VIII	65+	No	-
IX	18+	No	Yes

<u>Income</u>	
<u>Income Class</u>	<u>Amount of Household Income</u>
I	\$ 0 - \$ 4,900
II	\$ 5,000 - \$ 9,900
III	\$10,000 - \$14,900
IV	\$15,000+

Location

Urban = Central City - SMSA
Suburban = Non Central City - SMSA
Rural = Non SMSA

growth in income from the base period will have a positive impact on ownership and use. However, once all households have attained the highest income class, continued growth in income will have no further effect.

This presupposition of a limit on income effects may lead to conservative estimates of ownership and use. It is possible that growth of household income beyond \$15,000 could lead to higher levels of ownership and use. The specification of income as a categorical dimension seems preferable, however, to the alternative specification of income as a continuous dimension. Such a continuous specification presupposes that ownership and use grow linearly with income. Thus, constant growth of income would lead eventually to all households owning four cars and driving them 100 miles every day. Such an outcome appears highly improbable when one considers the limits of a twenty-four hour day and speed limits of 55 MPH.

Another presupposition underlying these projections is represented by the use of cross sectional models of household ownership and use. Such cross sectional models presuppose that the ownership and use patterns of different types of households as observed in 1970 remain the same over time. What is being projected then is the distribution of households within the life cycle stage - income - location typology. Behavior in any single class of households remains constant.

A third presupposition states that the supply of goods and services needed to support the projected levels of ownership and use will rise to meet the projected demand. Thus, resource and supply constraints always contain considerable slack.

E. Assumptions

Up to this point the discussion has focused on the interaction between the three dimensions of household lifestyle and the automobile. The actual projection, however, requires that attention be paid to the larger systems or processes which over time generate the observed distribution of households across the three dimensions of the lifestyle typology.

With respect to each of these systems there is an associated set of parameters which must be given numerical specification. The values assigned to these parameters reflect the assumptions underlying each projection.

The larger system relating to the life cycle stage dimension is the demographic system. This system contains two different sets of parameters which require specification. First, the age specific fertility rates need to be specified for each five year period. Second, the proportions by which households are estimated from the population need to be specified.

Income, naturally, is derived from the economic system. However, rather than construct a large macroeconomic model, the economic system has been simplified to a single parameter, the annual rate of growth of household income.

The location of households is the result of the interaction of both economic and demographic systems. However, the detail required to fully model location goes beyond the resources of this research. Thus, the distribution of households across the locational dimension is exogenously specified.⁵

The use of regression in the use model provides an opportunity for evaluating variables beyond those proposed within the lifestyle concept. Two such variables are the number of employed persons in the household and the geographic region of the country.

Another dimension not specifically part of the lifestyle concept but found to be important is time. The use model contains variables for the day and month of travel. These dimensions must also be specified for each projection.

Thirteen projections were generated in the course of this research. The principal reason for having so many projections was to evaluate the sensitivity of future automobile ownership and use to changes in each of the dimensions of household lifestyle. In some respects such projections

are artificial. Parameters associated with each dimension are specified differently from one projection to the next, but within each projection these parameters are held fixed throughout each projection period. In actuality these parameters are likely to change over the course of the next 50 years. Thus, the interest in these projections lies primarily in the relative differences in automobile ownership and use between projections and not in the actual values attained.

Several additional projections trace the impacts of simulated societal trends. In these latter projections, parameters are modified throughout each projection. The interest in these projections is more in how the impacts of the assumed trend unfold throughout the projection period.

As a benchmark for these various projections, one projection was developed based on assumptions reflecting a best guess of what the future will be. The projection based on this set of assumptions is titled the Base Case. This projection assumes a continuation of present trends in household formation, a rise in fertility to a level associated with ultimate zero population growth, an annual income growth rate of 2.5% and the continued movement of American households into a suburban living environment. Household employment and the distribution of travel across time are both held constant at 1970 levels.

A brief description of the other projections follows:

Constrained Projection - The age distribution of the population is held fixed according to the 1970 distribution. The size of the population is allowed to grow as in the Base Case.

Economic Projections - Four such projections are presented having annual income growth rates of 0%, 1%, 4% and 6%, respectively.

Demographic Projections - Five such projections are presented. Three are specified with fertility rates which remain constant over the projection period. The first of these three has fertility rates which are smaller than those in the Base Case. The remaining two of these three projections have fertility rates which are larger than those in the Base Case. The fourth of these five projections is specified with fertility rates which vary in a manner so as to replicate the World War II baby boom.

The fifth demographic projection simulates an acceleration in the existing trend toward single individual households.

Additional Projections - One projection assumes the change to a four day work week. Another assumes the return of households to the central cities.

F. Computational Procedure

The computational procedure used to analyse these assumptions is as follows:

1. The U.S. age-sex specific population was projected by five year increments to the year 2025 using the cohort component method.
2. Estimates of households were developed from the projection of population using a set of household proportions which were projected using the Census Bureau methodology.
3. The remaining lifestyle factors of income and location were projected for each life cycle stage.
4. Estimates of future total ownership and use were then computed by applying the set of cross sectional models of ownership and use for each lifestyle class.

G. Summary of Projections

Examination of the various projections of total ownership and use reveals one predominant theme - there is very likely to be a break from previous trends in the growth of ownership and use. Between 1940 and 1970 the number of automobiles owned by Americans and the number of miles these automobiles were driven grew at a constant rate. Over the next 50 years, however, total ownership and use are likely to continue to grow but at a decelerating rate. In fact by 2025 total ownership and use may reach a stable plateau.

The basis for this deceleration in growth is due to both demographic and economic systems. The level of fertility for the next 50 years is expected to be very close to the level associated with zero population growth. The leveling of the population at a fixed size is likely to occur at or just beyond the year 2025. Furthermore, the maturation of the baby boom progeny will lead to a reduction in average travel expected of households.

In the economic domain the continued growth of household income will lead to most if not all households having incomes of over \$15,000 (in 1970 dollars). Most households will fall into the maximum income class and further growth in income will yield only modest increases in ownership and use. Thus, income will no longer be a binding constraint for most American households. Rather the number of people in the household and the time available for travel will take over as the dominant constraints on total ownership and use.

An additional conclusion, which is implicit in what has already been said, is that demographic factors are equally as important as economic factors in determining future levels of automobile ownership and use. The variation observed in the demographic projections is equal to that seen in the economic projections. Furthermore, demographic factors have a much more complex effect on the automobile than do economic factors. Variation in the annual income growth rate leads to different times at which the limit on income effects is reached. Variations in fertility rates, however, can lead to accelerating growth, decelerating growth and even a decline in ownership and use.

PART II - PROJECTIONS

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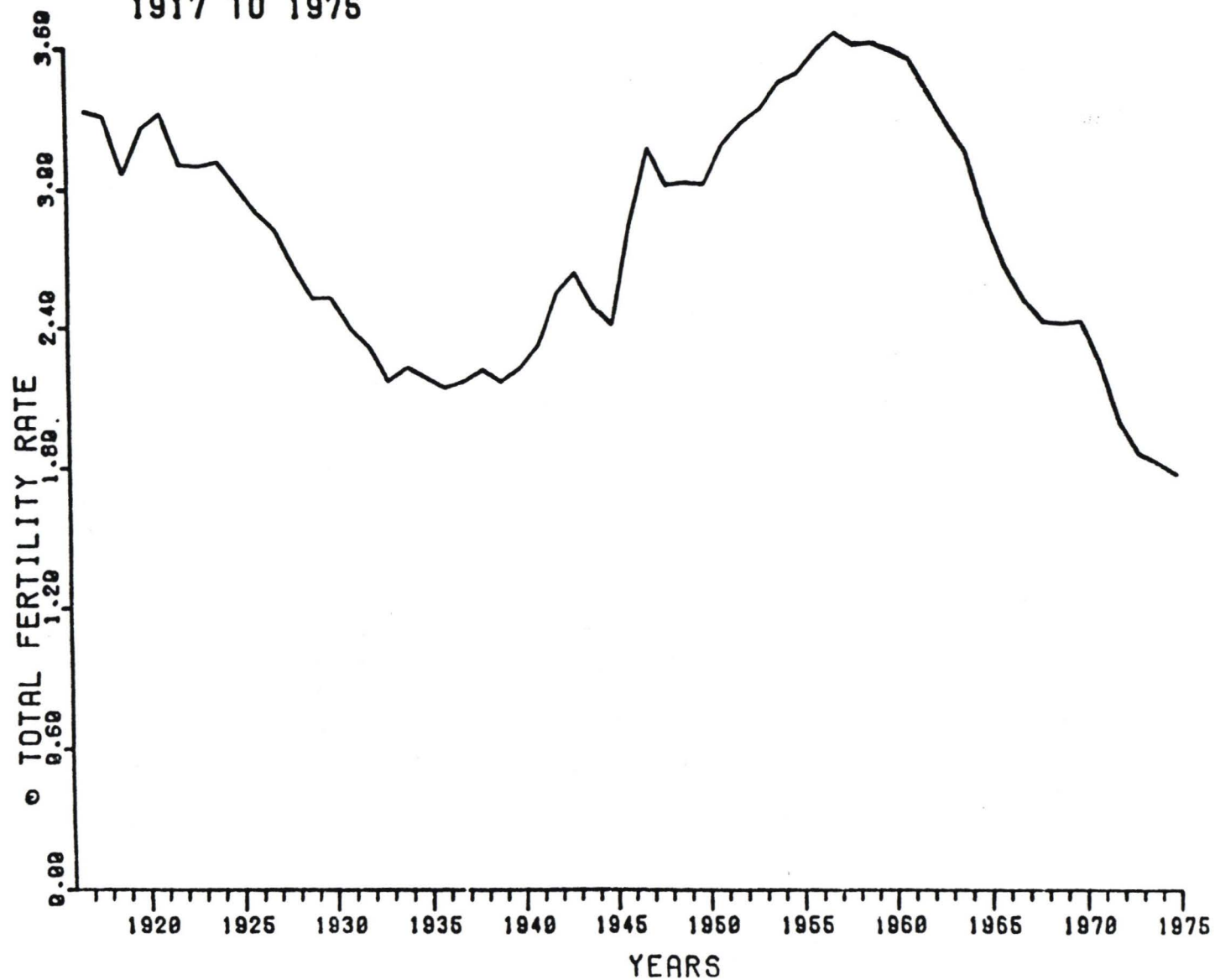
A. The Base Case

The demographic parameters of the projection methodology consist of the age specific birth rates and household formation rates. A common characterization of the birth rates is the total fertility rate, TFR, which is the sum of the age specific birth rates (times 5 if 5 year cohorts are being considered). TFR represents the number of children likely to be born to a woman if she were exposed to the set of birth rates observed for a specific period in time. The TFR, when compared to survival rates, is a measure of the rate at which a population is growing. For example, in the U.S., a TFR of 2.1 (given current survival rates) represents zero population growth.* The TFR between 1917 and 1975 hit a maximum of 3.7 in 1957 and a minimum of 1.8 in 1974. See Figure 1. The projection of TFR over a fifty year period is naturally a very tricky business as this figure reveals. Indeed, it is hard to argue convincingly for any single future value or sequence of values for TFR. Thus, the selection of a TFR of 2.1 was somewhat arbitrary and was used as a convenient benchmark representing zpg.

The remaining set of demographic parameters is related to the household formation process, and consists of a very large number of parameters. There are eleven different types of proportions used in estimating households and nine age cohorts are considered. Thus, 99 parameters must be specified. This task was completed for the Base Case by employing the standard methodology developed by the Census Bureau.⁶ Namely, regression models of the type $\ln(p) = B_0 + B_1 t$ (where p is the proportion being projected B_0 and B_1 are coefficients and t is time (years)) were fit to data for 1960 through 1976. These models were then used to estimate future values of the proportions. The data and predicted values from these models are presented in Sharp (1978).

*Reference to a TFR of 2.1 as representing zero population growth is somewhat misleading. Actually with TFR of 2.1 and current survival rates, population would continue to increase for about the next 50 years, but at a decelerating rate. After about 2035, however, the population would remain fixed in size.

FIG. 1. TOTAL FERTILITY RATE
FOR THE U.S.
1917 TO 1975



The economic parameters consist of the rate at which real income grows, and the number of employed persons in the household. The rate of income growth for the Base Case was set at 2.5%. In the historical context this represents the average rate at which real income grew between 1951 and 1970. See Figure 2. Employment between 1960 and 1970 held fairly constant at about 1.25 employed persons per household. For the Base Case, employment was held at this level.

Location is defined in terms of an urban/suburban/rural tri-chotomy. According to several authors the proportion of the population living in suburban areas will continue to grow. This trend is a result of the annexation of rural lands adjacent to metropolitan areas which will achieve suburban status in the coming decades. Specifically by the year 2000 the population is likely to be distributed in the following manner:

<u>Metropolitan Location</u>	<u>1970</u>	<u>2000</u>
Urban	31.4%	10.6%
Suburban	38.0	62.3
Rural	30.6	27.2

The temporal variables, day of the week and month of the year, reflect the weekly and yearly pattern of life in the U.S. For the Base Case the proportion of travel occurring in each day of the week and each month of the year was left constant throughout the projection period.

In the Base Case, both the total number of automobiles and DVMT driven doubles in the course of the projection period. See and Figures 3 and 4. This increase is due to a 25% increase in the population, an increase in the headship rate (ratio of number of households to population) from .50 to .59, and increases in the average number of automobiles owned by households from 1.25 cars to 1.44 cars and the average number of miles driven from 31.5 DVMT to 38.5 DVMT.

FIG. 2. HISTORICAL VALUES OF MEDIAN INCOME
FOR FAMILIES AND OVERSEAS INDIVIDUALS
IN 1967 DOLLARS: 1927 TO 1970

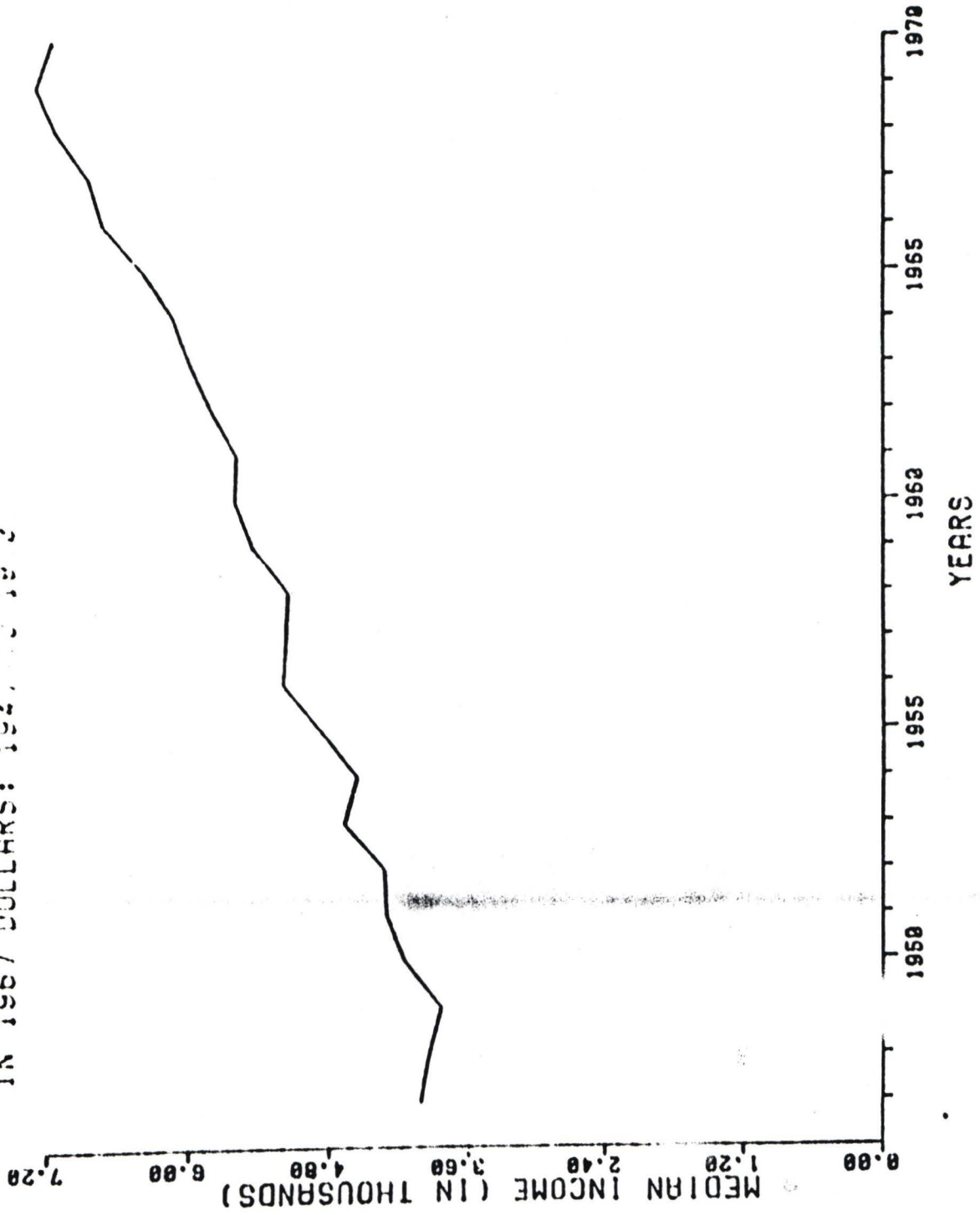


TABLE 2 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
USING BASE CASE ASSUMPTIONS

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVMT)</u>		<u>Households</u>	<u>Pop.</u>
	<u>Total</u> (x10 ⁶)	<u>Avg. H.H.</u>	<u>Total</u> (x10 ⁹)	<u>Avg. H.H.</u>		
1975	86.9	1.25	2.20	31.6	69.6	210.3
1980	97.6	1.28	2.50	32.7	76.5	218.3
1985	108.2	1.30	2.81	33.9	83.1	226.4
1990	117.3	1.33	3.10	35.2	88.3	233.7
1995	125.5	1.36	3.35	36.3	92.3	239.5
2000	134.1	1.39	3.59	37.2	96.6	244.4
2005	142.9	1.41	3.83	37.8	101.3	249.1
2010	151.0	1.43	4.04	38.2	105.8	253.6
2015	157.0	1.44	4.20	38.4	109.4	257.5
2020	161.2	1.44	4.31	38.5	112.2	260.3
2025	164.4	1.44	4.40	38.5	114.4	262.3

FIG. 3. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP 1975 TO 2025
USING BASE CASE ASSUMPTIONS

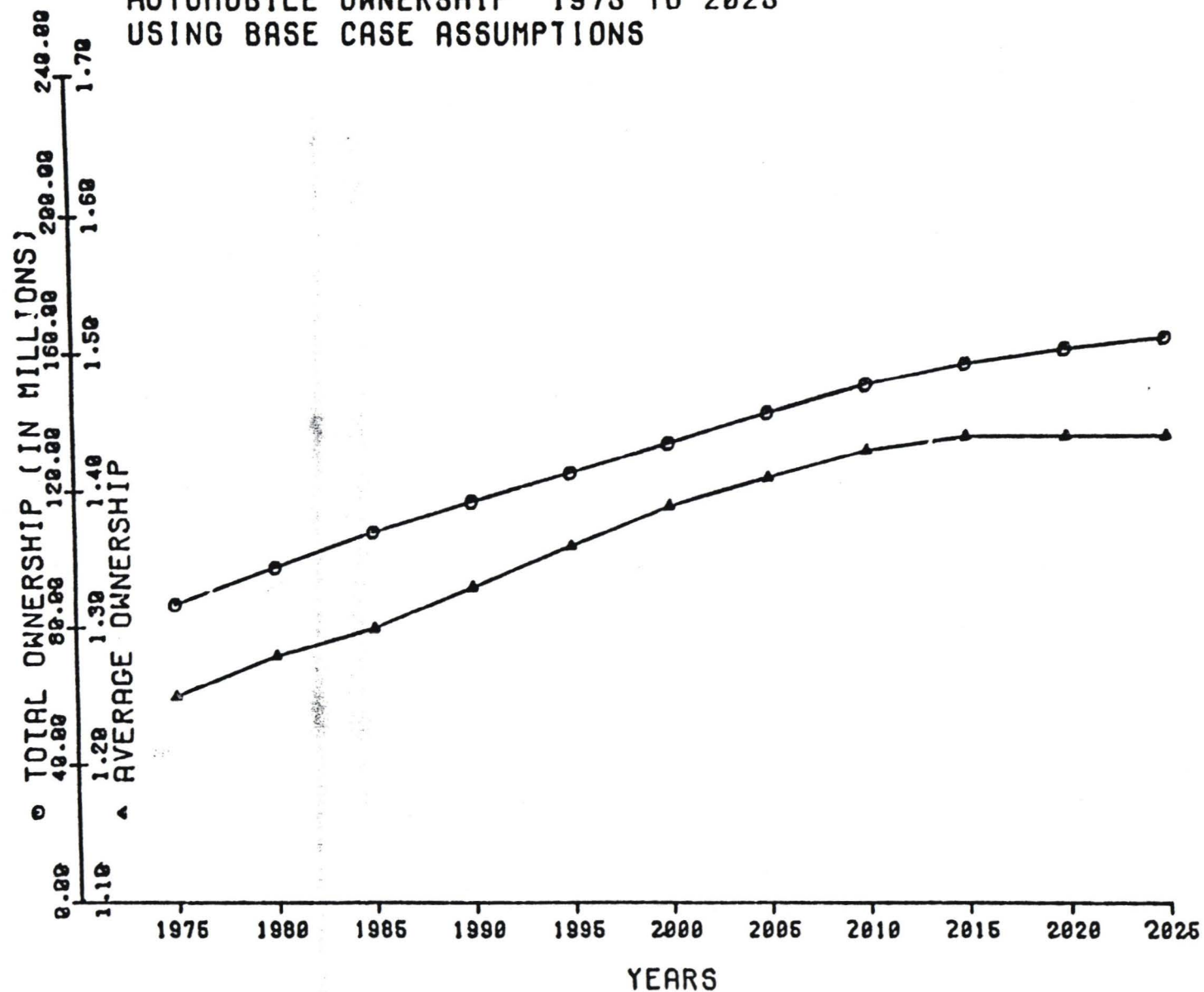
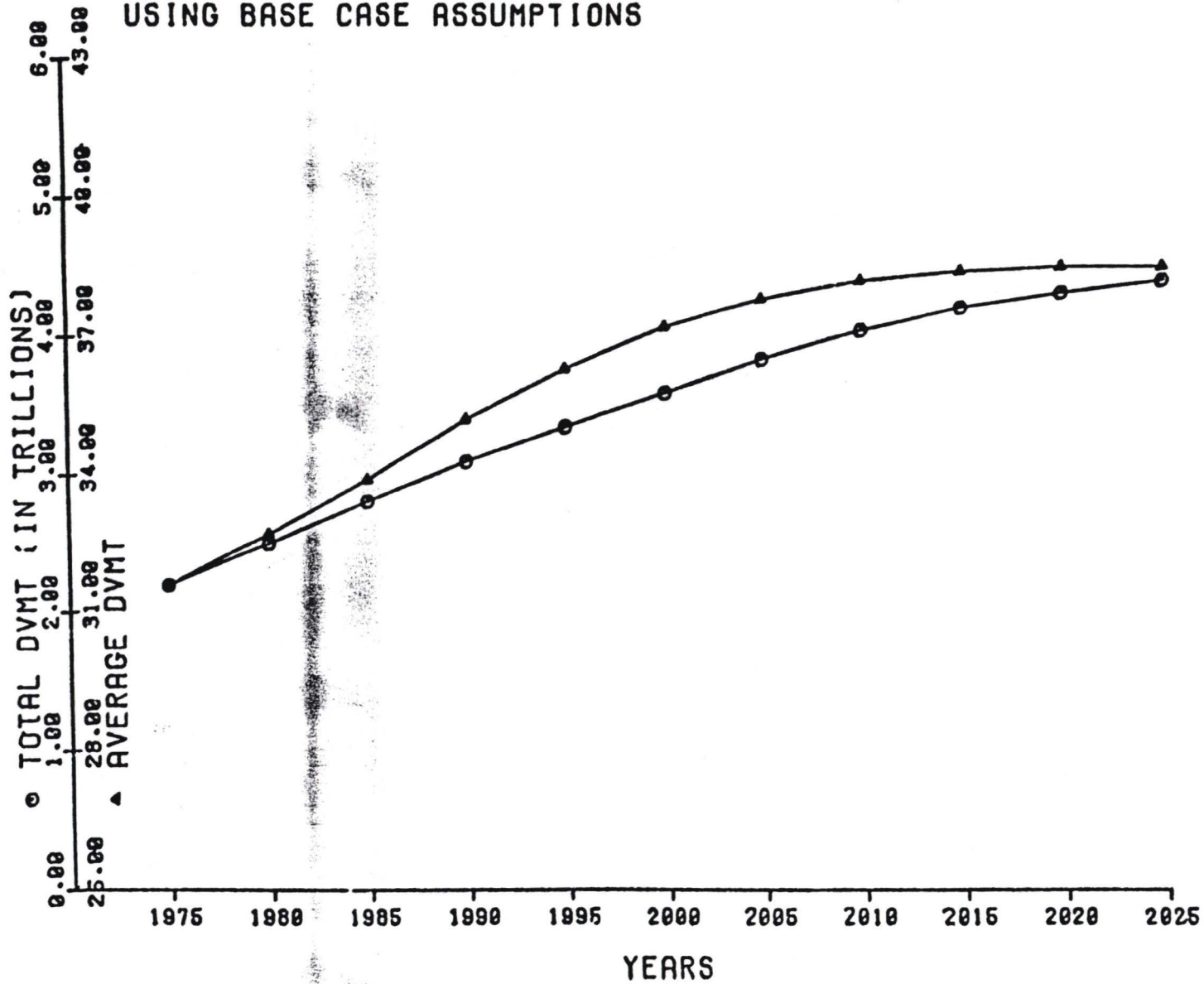


FIG. 4. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
DAILY VEHICLE MILES OF TRAVEL 1975 TO 2025
USING BASE CASE ASSUMPTIONS



Perhaps the most interesting aspect of the Base Case is the attenuation of these increases due to a redistribution of the population into different life cycle stages. In the course of the projection period, the proportion of the population in life cycle stages characterized by low ownership and use rates increases substantially. See Table 3. The most dramatic changes are the increase of 9.0% in Life Cycle Stage I (young single individuals) from 6.4% to 15.4% of all households and the decrease of 8.1% in Life Cycle Stage III (young couples with children) from 27.3% to 19.2% of all households. The depressing effect of the maturation of the population becomes clear when one holds the distribution of households across the life cycle stages constant and allows only the total number of households to increase as in the Base Case. The results for such a Constrained Projection are presented in Table 4 and Figures 5 and 6.

The redistribution of households in the Base Case has a significant effect on ownership and use. Had the distribution of households stayed constant from 1970 onward, (as in the Constrained Projection) then average ownership and use would have risen to 1.52 cars and 42.2 DVMT, respectively, instead of 1.44 cars and 38.5 DVMT. These higher rates would have resulted in total ownership of 173.9 million cars (6% increase over the Base Case) and total use of 4.83 trillion DVMT (10% increase over the Base Case). Such a result is a good example of the complex effect of demographic factors on ownership and use.

One of the major causes for the increase in average ownership and average use in the Base Case is the growth in household income. Even as households move into life cycle stages with lower ownership and use rates, these rates increase due to economic growth. The distribution of households across ownership classes for 1975 and 2025 are shown in Table 5. The income distribution for households for the two years is shown in Table 6. This last table makes clear the limit on income effects. Even a modest growth rate of 2.5% results in over three quarters of all households having incomes of over \$15,000 (1970 dollars) in 2025.

TABLE 3 DISTRIBUTION OF HOUSEHOLDS ACROSS
LIFE CYCLE STAGE CLASSES 1975 - 2025

<u>YEAR</u>	<u>LIFE CYCLE STAGE</u>									
	<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>	<u>V</u>	<u>VI</u>	<u>VII</u>	<u>VIII</u>	<u>IX</u>	<u>Σ</u>
1975	6.4	6.2	27.3	10.7	14.0	5.9	9.5	8.8	11.2	100.0
1980	8.1	6.2	27.8	9.4	12.8	5.6	9.5	9.0	11.6	100.0
1985	9.5	6.0	28.7	8.4	11.7	5.2	9.4	9.1	11.9	100.0
1990	10.4	5.6	28.7	8.4	11.0	4.9	9.4	9.2	12.3	100.0
1995	11.0	5.1	27.7	9.0	11.0	5.0	9.3	9.1	12.7	100.0
2000	11.8	4.8	25.3	10.2	12.1	5.5	8.8	8.6	13.0	100.0
2005	12.7	4.4	22.8	11.1	13.4	5.1	8.3	8.0	13.1	100.0
2010	13.4	4.1	21.1	11.2	14.3	6.5	8.4	7.8	13.2	100.0
2015	14.0	3.8	20.5	10.4	14.5	6.4	9.1	8.0	13.3	100.0
2020	14.7	3.7	20.1	9.5	13.8	6.0	10.3	8.5	13.5	100.0
2025	15.4	3.5	19.2	9.3	12.8	5.6	11.5	9.1	13.6	100.0

TABLE 4 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
USING A FIXED AGE DISTRIBUTION

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVMT)</u>		<u>Households</u> (x10 ⁶)	<u>Pop.</u> (x10 ⁶)
	<u>Total</u> (x10 ⁶)	<u>Avg. H.H.</u>	<u>Total</u> (x10 ⁹)	<u>Avg. H.H.</u>		
1975	86.9	1.25	2.20	31.6	69.6	210.3
1980	98.7*	1.29	2.54*	33.2	76.5	218.3
1985	110.5*	1.33	2.89*	34.8	83.1	226.4
1990	120.1*	1.36	3.21*	36.4	88.3	233.7
1995	129.2*	1.40	3.49*	37.8	92.3	239.5
2000	138.1*	1.43	3.77*	39.0	96.6	244.4
2005	146.9*	1.45	4.03*	39.8	101.3	249.1
2010	155.5*	1.47	4.30*	40.6	105.8	253.6
2015	163.0*	1.49	4.51*	41.2	109.4	257.5
2020	169.4*	1.51	4.68*	41.7	112.2	260.3
2025	173.9*	1.52	4.83*	42.2	114.4	262.3

* = Avg x Households

FIG. 5. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP 1975 TO 2025
ASSUMING A FIXED AGE DISTRIBUTION

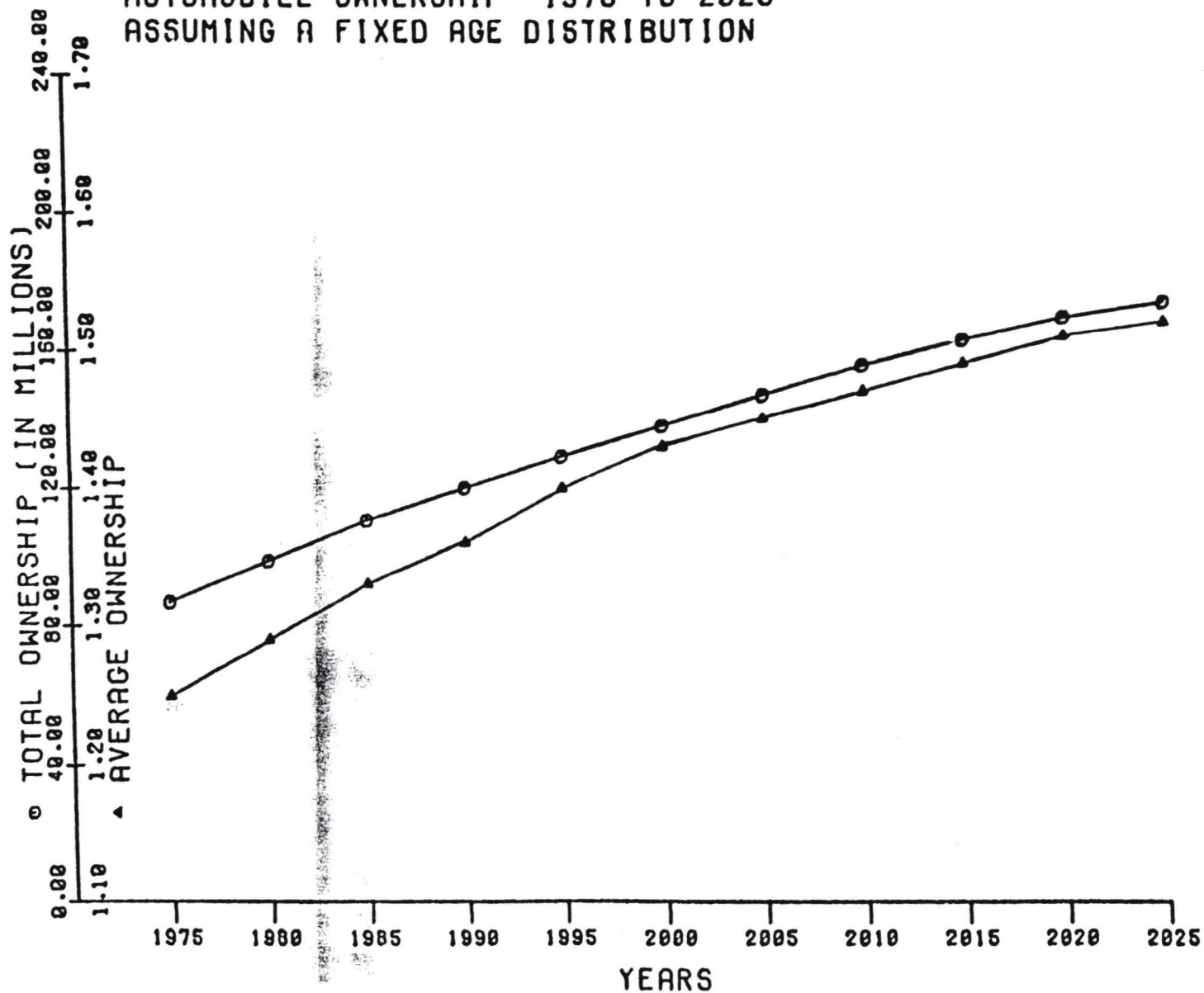


FIG. 6. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
DAILY VEHICLE MILES OF TRAVEL 1975 TO 2025
ASSUMING A FIXED AGE DISTRIBUTION

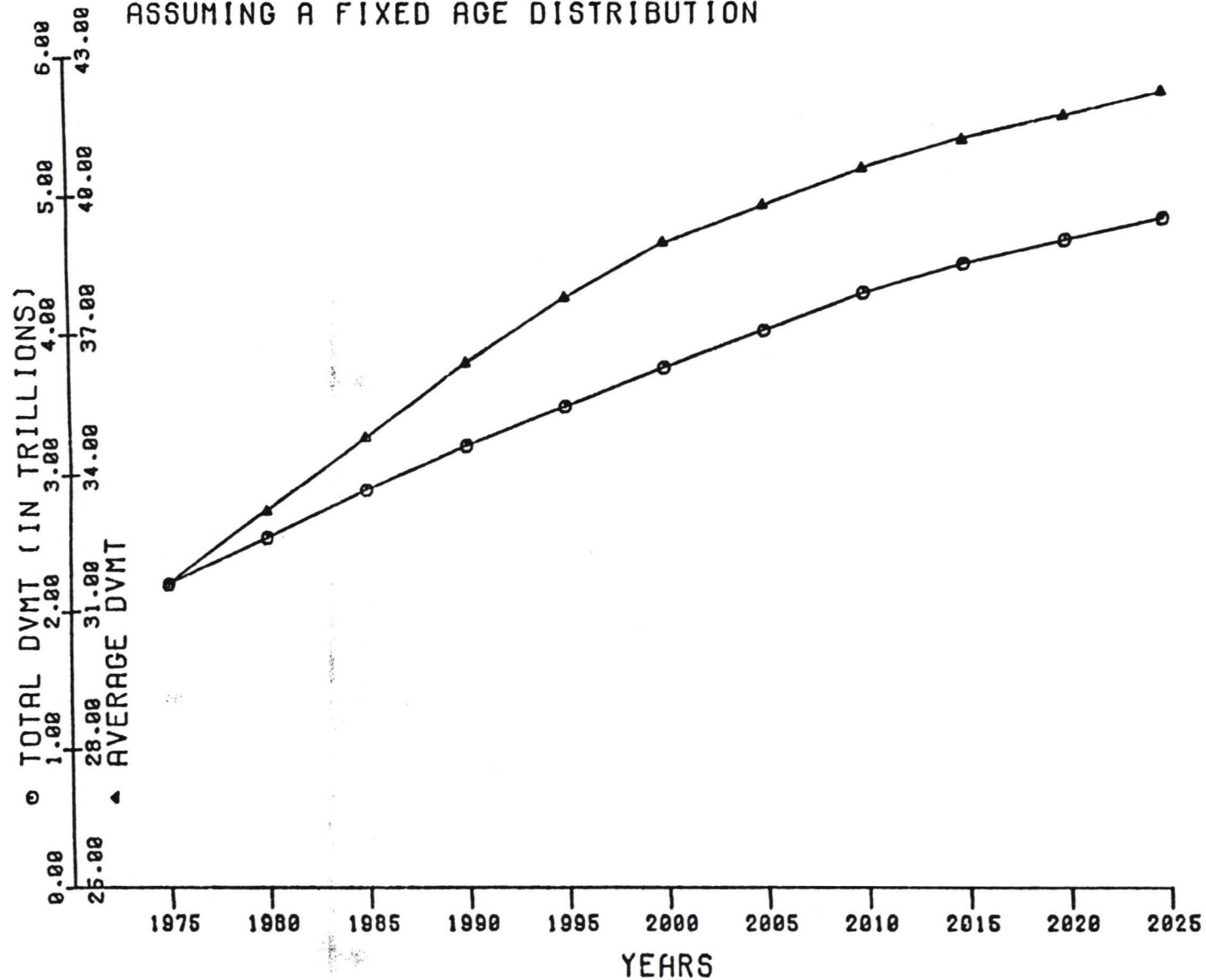


TABLE 5 Distribution of Households Across Ownership Classes

Year	Number of Automobiles in Household				
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3+</u>	<u>Σ</u>
1975	17	47	30	6	100
2025	12	42	37	10	100

TABLE 6 Distribution of Households Across Income Classes

Year	Income Class				<u>Σ</u>
	<u><\$5,000</u>	<u>\$5-9,999</u>	<u>\$10-14,999</u>	<u>\$15,000 +</u>	
1975	26	28	24	22	100
2025	7	8	7	78	100

B. Economic Projections

The next set of projections depicts the effect of various income growth rates on ownership and use. Growth rates of 0%, 1%, 4% and 6% were specified in these four projections. The remaining variables were left as per the Base Case.

These various growth rates led to a wide range of ownership and use levels by the year 2025. See Tables 7 to 10 and Figures 7 to 14. The No Growth Projection driven entirely by population growth and its spatial redistribution into suburban areas, had final values of total ownership and use of 130.0 million automobiles and 3.18 trillion DVMT, respectively. These values represent increases of 43.2% and 52.1% respectively over 1975 values. Here again we see the effect of the redistribution of the population into life cycle stages with low ownership and use rates: the number of households increased by 54.4% between 1975 and 2025. This increase was far greater than the increases in ownership and use.

This effect is highlighted by the changes in average household ownership and average household use. Save for momentary pauses, they both decreased throughout the projection period from 1.20 to 1.14 automobiles per household and from 30.0 to 27.8 DVMT per household.

The 1% Growth Projection yielded considerably higher values of total ownership and use by 2025. Total ownership increased by nearly three quarters from 85.1 million autos to 148.2 million. Total use increased by almost four fifths from 2.09 trillion DVMT to 3.18 trillion DVMT. Average household ownership and use rose rapidly over the first thirty years of the projection period due to the 1% income growth rate. Subsequently, they both leveled off at 1.30 automobiles per household and at about 33.7 DVMT per household.

A growth rate of 4% led to still higher values for both total and average household ownership and use. Total ownership almost doubled from 88.4 million to 171.5 million. Total use experienced a similar increase

TABLE 7 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
ASSUMING A 0% ANNUAL INCOME GROWTH RATE

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVMT)</u>		<u>Households</u> (x10 ⁶)	<u>Pop.</u> (x10 ⁶)
	<u>Total</u> (x10 ⁶)	<u>Avg. H.H.</u>	<u>Total</u> (x10 ⁹)	<u>Avg. H.H.</u>		
1975	83.8	1.20	2.09	30.0	69.6	210.3
1980	91.1	1.19	2.26	29.6	76.5	218.3
1985	98.2	1.18	2.44	29.4	83.1	226.4
1990	103.8	1.18	2.60	29.5	88.3	233.7
1995	108.4	1.17	2.72	29.5	92.3	239.5
2000	113.5	1.18	2.83	29.3	96.6	244.4
2005	119.2	1.18	2.96	29.2	101.3	249.1
2010	124.1	1.17	3.06	28.9	105.8	253.6
2015	127.3	1.16	3.13	28.6	109.4	257.5
2020	128.9	1.15	3.16	28.2	112.2	260.3
2025	130.0	1.14	3.18	27.8	114.4	262.3

FIG. 7. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
 AUTOMOBILE OWNERSHIP 1975 TO 2025
 ASSUMING A 0% ANNUAL INCOME GROWTH RATE

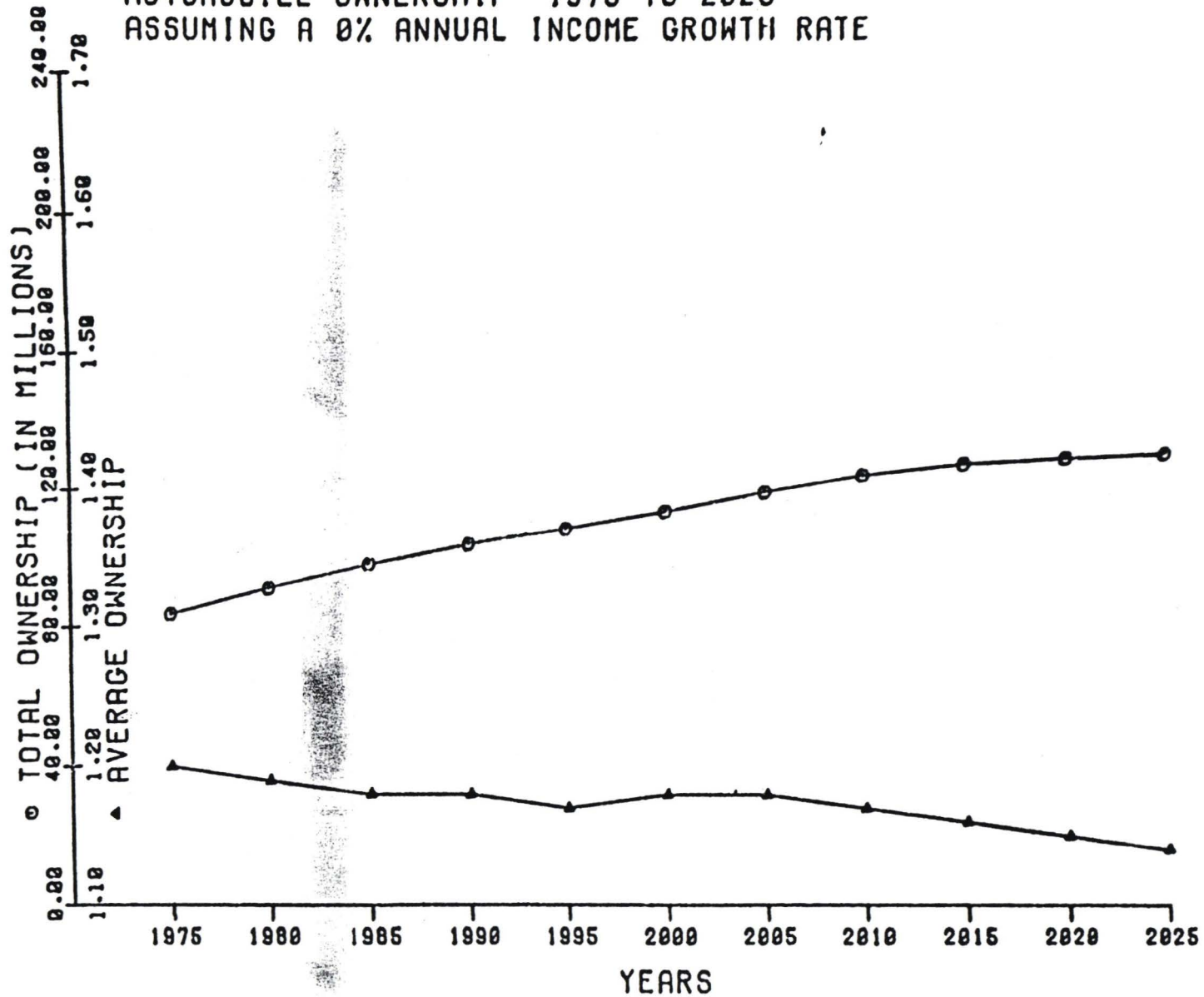


FIG. 8. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
DAILY VEHICLE MILES OF TRAVEL 1975 TO 2025
ASSUMING A 0% ANNUAL INCOME GROWTH RATE

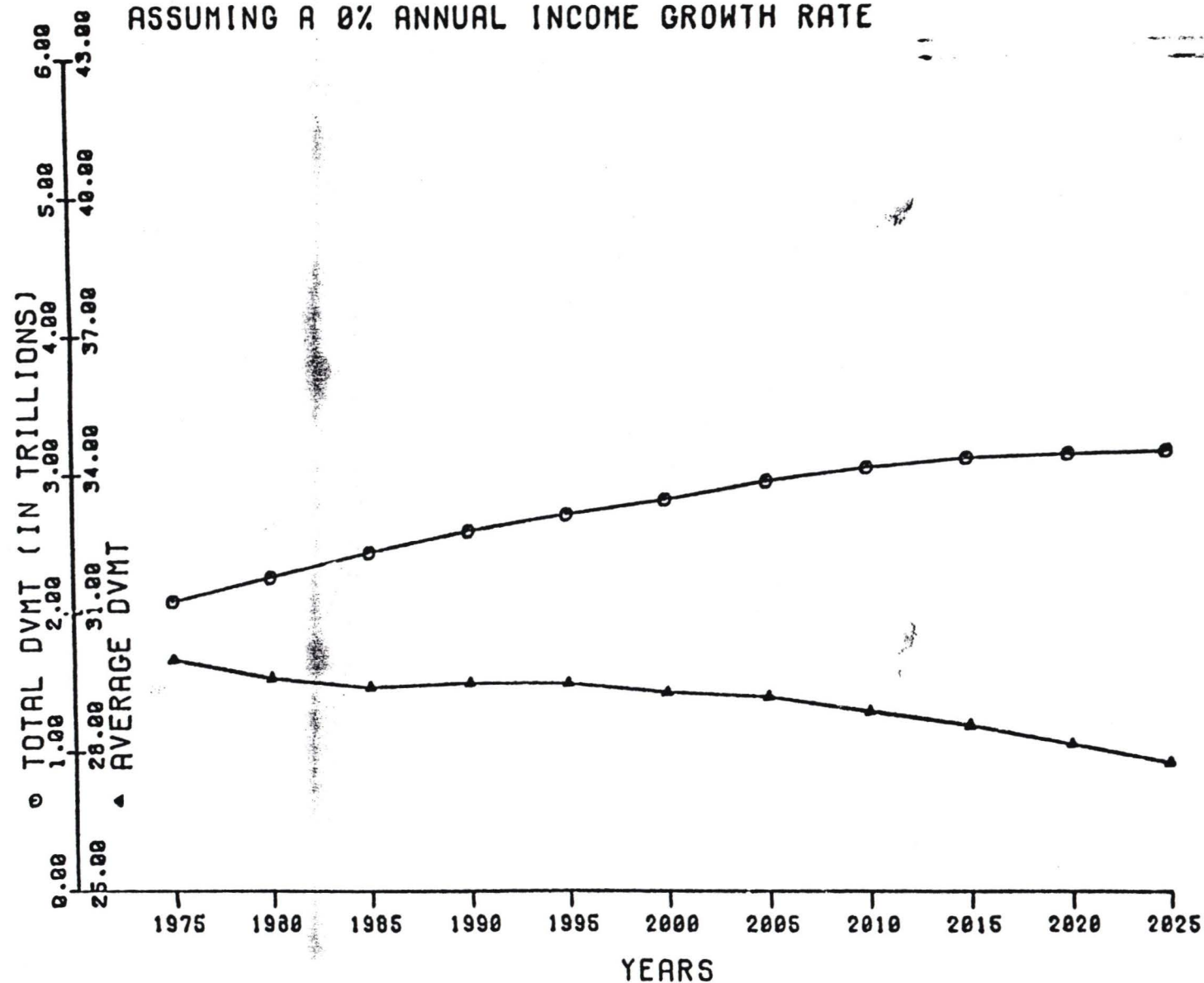


TABLE 8 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
ASSUMING A 1% ANNUAL INCOME GROWTH RATE

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVMT)</u>			
	<u>Total</u> (x10 ⁶)	<u>Avg. H.H.</u>	<u>Total</u> (x10 ⁹)	<u>Avg. H.H.</u>	<u>Households</u> (x10 ⁶)	<u>Pop.</u> (x10 ⁶)
1975	85.1	1.22	2.14	30.1	69.6	210.3
1980	93.7	1.23	2.36	30.8	76.5	218.3
1985	102.4	1.23	2.60	31.3	83.1	226.4
1990	109.5	1.24	2.81	31.8	88.3	233.7
1995	116.0	1.26	3.00	32.5	92.3	239.5
2000	122.8	1.27	3.17	32.9	96.6	244.4
2005	130.3	1.29	3.36	33.2	101.3	249.1
2010	137.1	1.30	3.54	33.5	105.8	253.6
2015	142.2	1.30	3.68	33.7	109.4	257.5
2020	145.3	1.30	3.77	33.6	112.2	260.3
2025	148.2	1.30	3.85	33.7	114.4	262.3

FIG. 9. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP 1975 TO 2025
ASSUMING A 1% ANNUAL INCOME GROWTH RATE

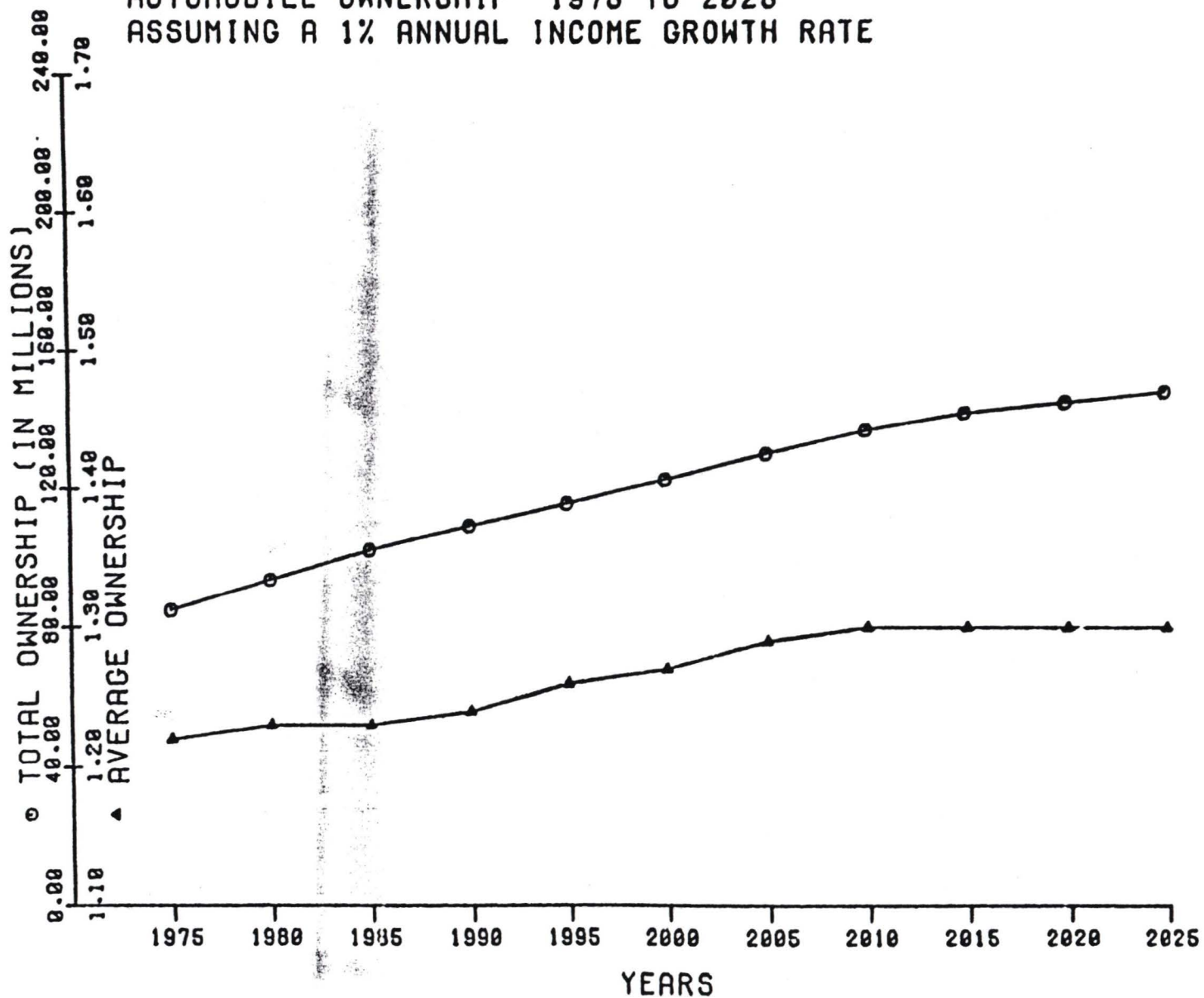


FIG. 10. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
DAILY VEHICLE MILES OF TRAVEL 1975 TO 2025
ASSUMING A 1% ANNUAL INCOME GROWTH RATE

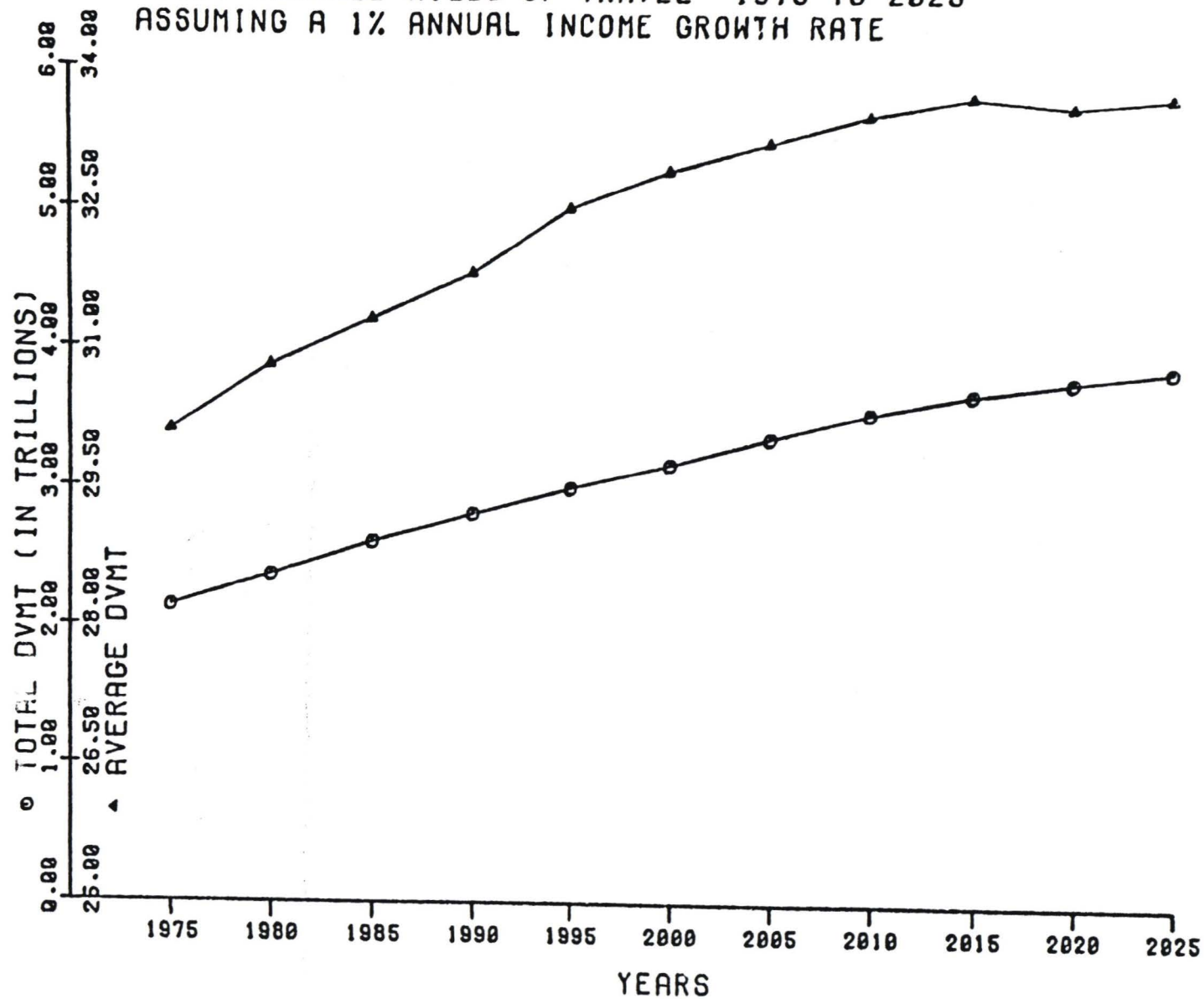


TABLE 9 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
 AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
 ASSUMING A 4% ANNUAL INCOME GROWTH RATE

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVMT)</u>		<u>Households</u>	<u>Pop.</u>
	<u>Total</u> (x10 ⁶)	<u>Avg. H.H.</u>	<u>Total</u> (x10 ⁹)	<u>Avg. H.H.</u>		
1975	88.4	1.27	2.26	32.4	69.6	210.3
1980	100.9	1.32	2.62	34.3	76.5	218.3
1985	113.2	1.36	3.00	36.1	83.1	226.4
1990	123.8	1.40	3.34	37.9	88.3	233.7
1995	132.3	1.43	3.59	38.9	92.3	239.5
2000	141.1	1.46	3.83	39.6	96.6	244.4
2005	150.2	1.48	4.06	40.1	101.3	249.1
2010	158.3	1.50	4.26	40.3	105.8	253.6
2015	164.3	1.50	4.42	40.4	109.4	257.5
2020	168.4	1.50	4.53	40.4	112.2	260.3
2025	171.5	1.50	4.61	40.3	114.4	262.3

FIG. 11. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
 AUTOMOBILE OWNERSHIP 1975 TO 2025
 ASSUMING A 4% ANNUAL INCOME GROWTH RATE

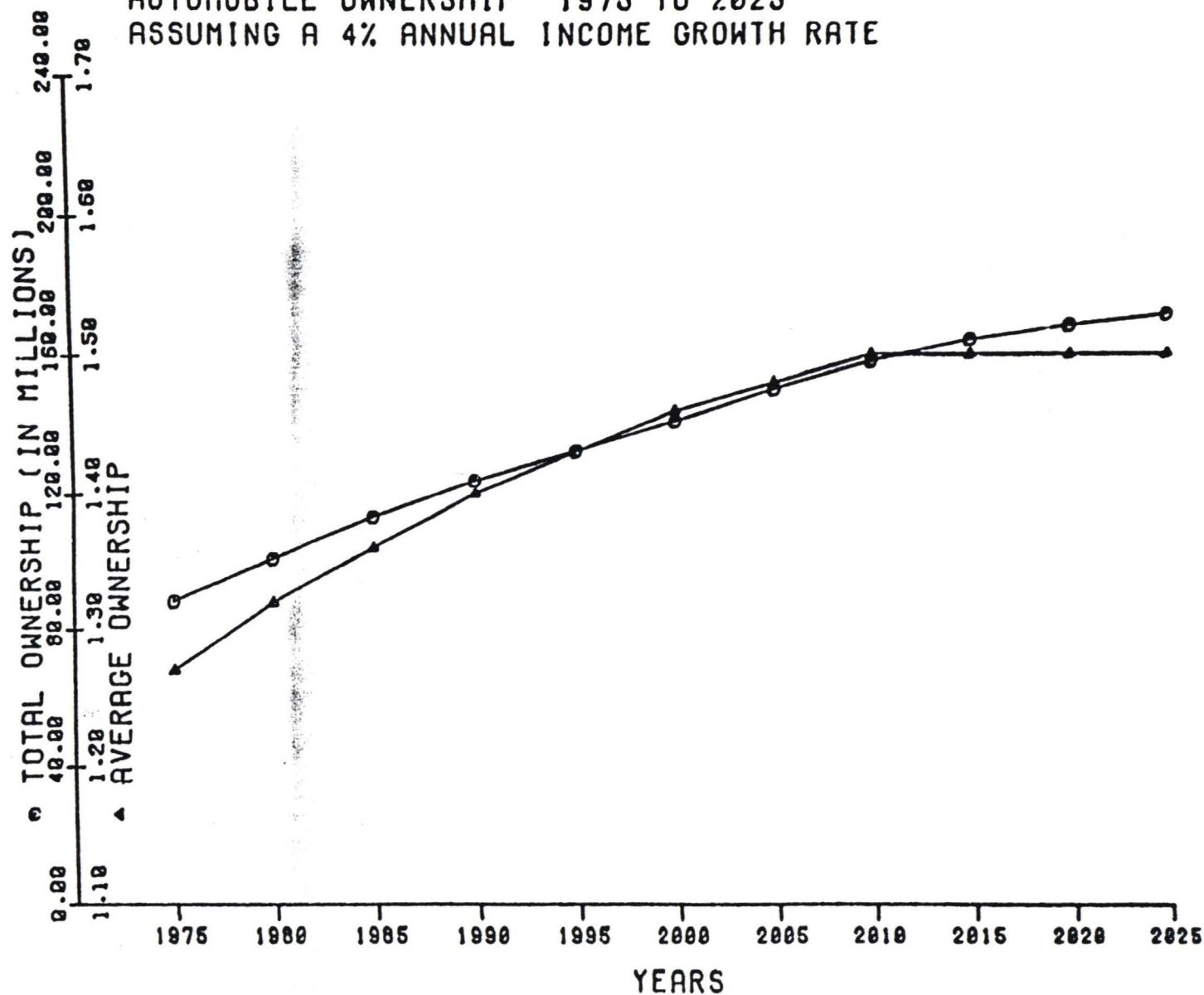


FIG. 12. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
DAILY VEHICLE MILES OF TRAVEL 1975 TO 2025
ASSUMING A 4% ANNUAL INCOME GROWTH RATE

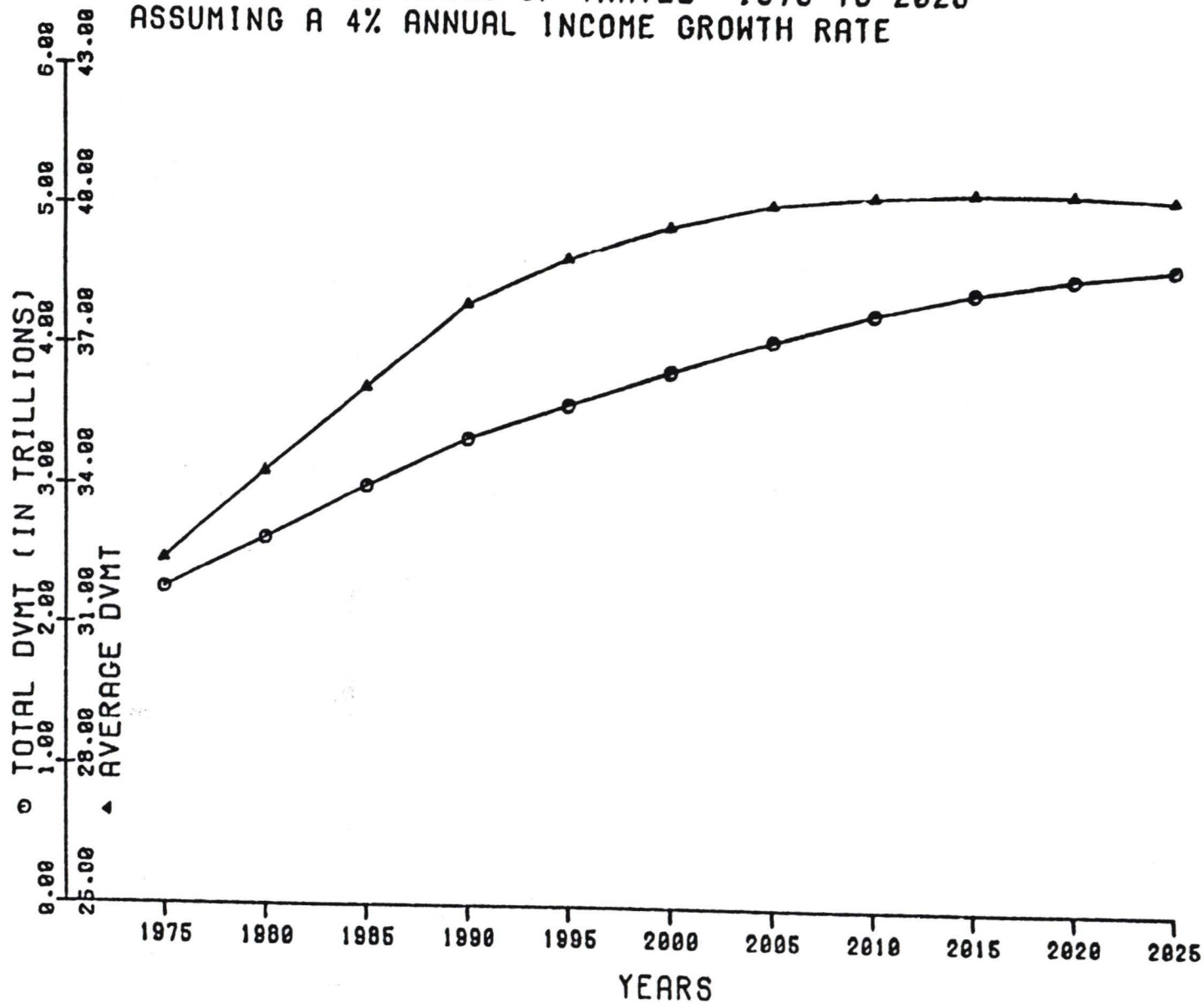


TABLE 10 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
ASSUMING A 6% ANNUAL INCOME GROWTH RATE

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVMT)</u>			
	<u>Total</u> (x10 ⁶)	<u>Avg. H.H.</u>	<u>Total</u> (x10 ⁹)	<u>Avg. H.H.</u>	<u>Households</u> (x10 ⁶)	<u>Pop.</u> (x10 ⁶)
1975	90.7	1.30	2.34	33.7	69.6	210.3
1980	105.0	1.37	2.78	36.3	76.5	218.3
1985	118.3	1.42	3.19	38.4	83.1	226.4
1990	129.2	1.46	3.52	39.9	88.3	233.7
1995	137.9	1.49	3.77	40.8	92.3	239.5
2000	146.6	1.52	3.99	41.3	96.6	244.4
2005	155.2	1.53	4.21	41.5	101.3	249.1
2010	162.9	1.54	4.40	41.6	105.8	253.6
2015	168.2	1.54	4.54	41.5	109.4	257.5
2020	171.6	1.53	4.63	41.3	112.2	260.3
2025	174.0	1.52	4.69	41.0	114.4	262.3

FIGURE 14

FIG. 14. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
DAILY VEHICLE MILES OF TRAVEL 1975 TO 2025
ASSUMING A 6% ANNUAL INCOME GROWTH RATE

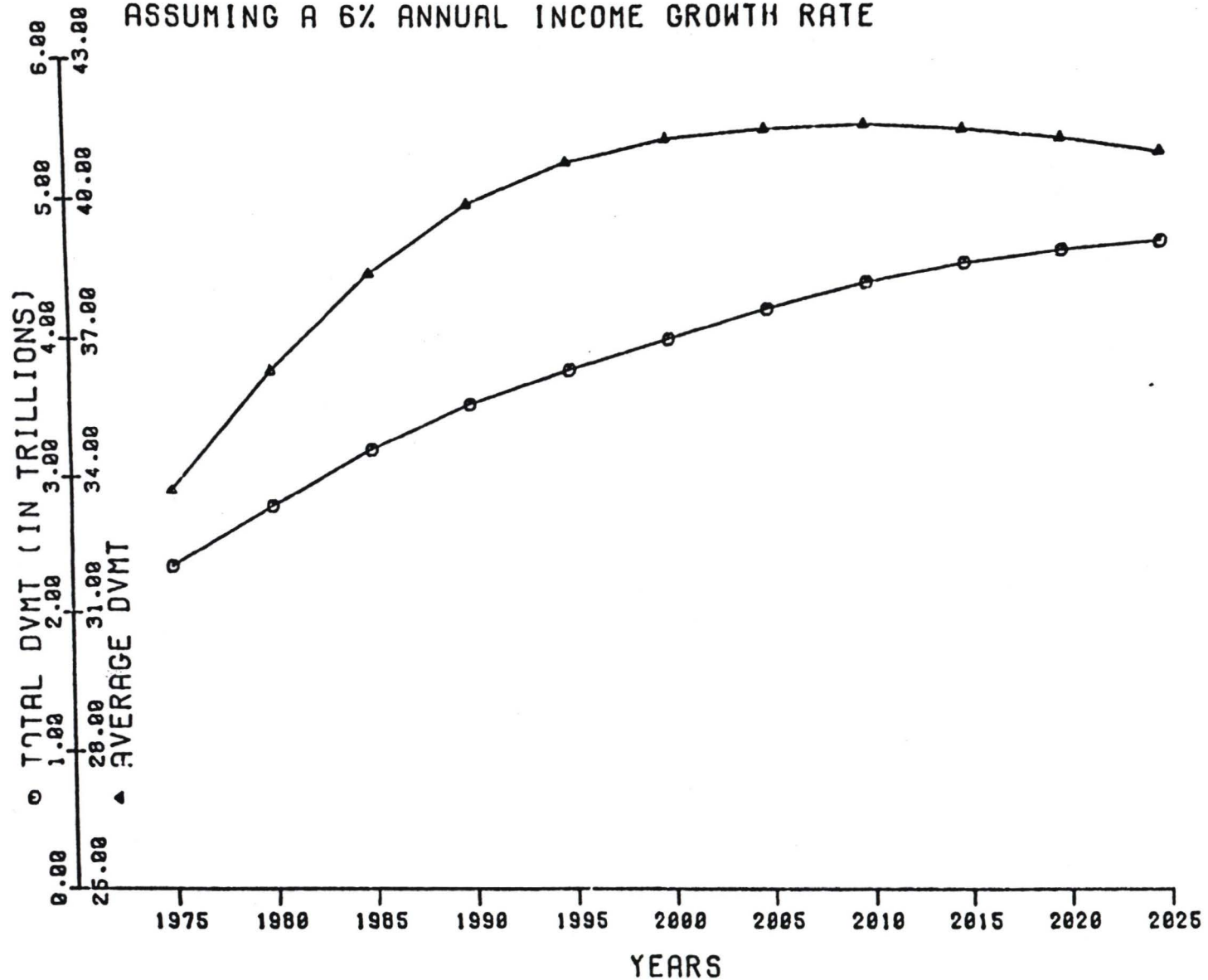
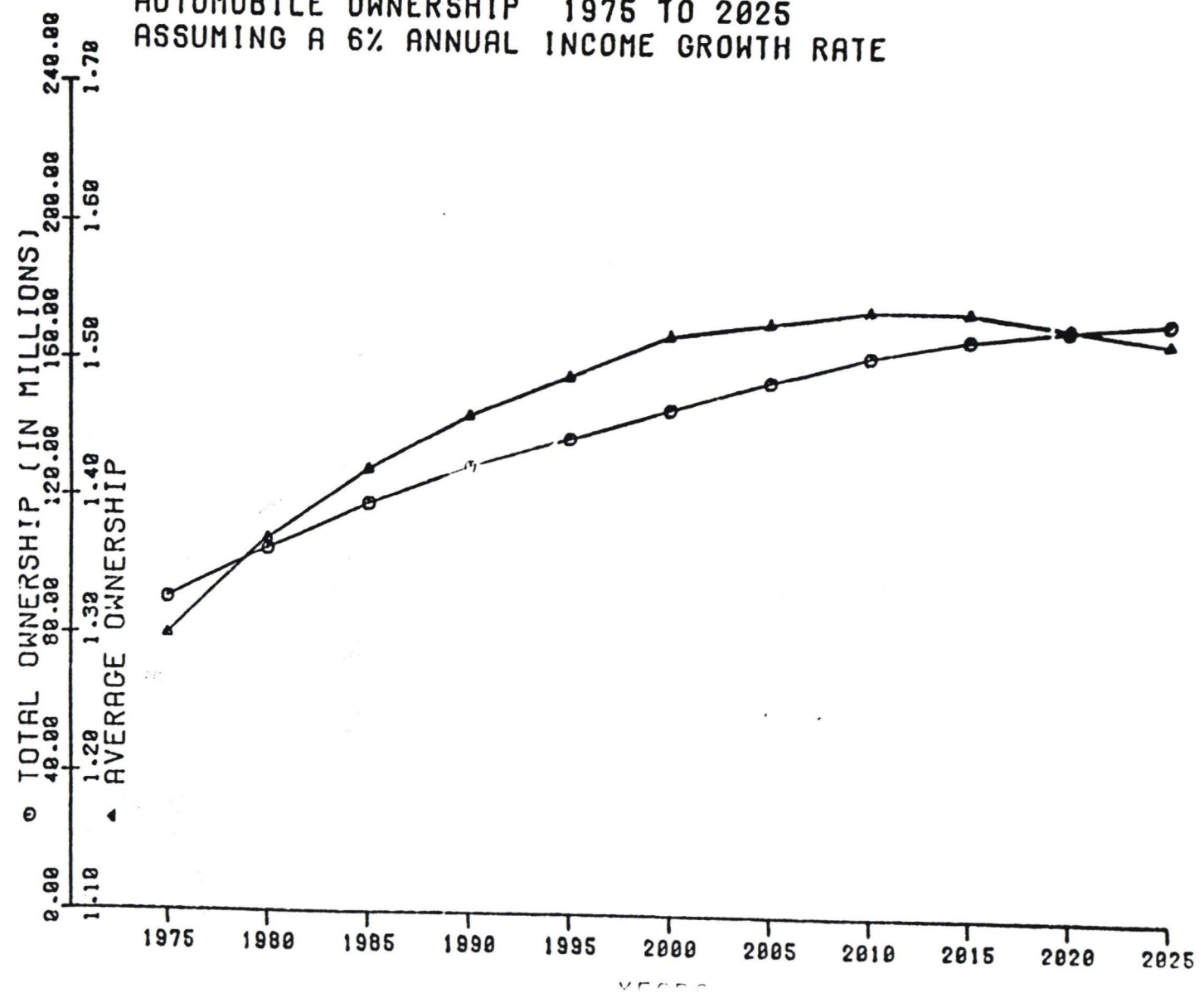


FIG. 13. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
 AUTOMOBILE OWNERSHIP 1975 TO 2025
 ASSUMING A 6% ANNUAL INCOME GROWTH RATE



from 2.25 million DVMT to 4.61 million DVMT. Average household ownership rose to 1.5 automobiles per household and average household use rose to about 40.4 DVMT per household.

The final economic projection depicted an extremely high rate of growth in income, 6%. In this projection the limit of income effects is actually attained. Only modest gains were made in this projection over the 4% Growth Projection. The greatest difference between the 6% Growth Projection and the 4% Growth Projection is the shorter time it took the average rates of ownership and use to reach the plateau of values described in the previous projections. Total ownership eventually rose to a value of 174.0 million automobiles, only 2.5 million automobiles over the 4% Growth Projection. Total use ultimately reached a value of 4.69 trillion DVMT, only .08 trillion DVMT over the 4% Growth Projection. Average household ownership reached a plateau of 1.52 automobiles in the year 2000. Similarly average household use reached a plateau of just over 41.3 DVMT.

C. Demographic Projections

The Demographic Projections depict the effects of changes in birth rates and household formation rates on ownership and use. As with income, a wide range of parameter values were specified in five different projections. Three projections depict the impact of constant Total Fertility Rates (TFRs) of 1.9, 2.5 and 3.0. Two additional projections are specified by continuously varying parameters. One of these, the Baby Boom Projection, duplicates the age specific birth rates observed over the period 1935 to 1975. This projection is meant to replicate the changes in fertility associated with the World War II baby boom. The other projection, the Household Transition Projection, depicts the transition of American society to a future in which the dominant household configuration is the single individual household.

While one would not expect the age specific birth rates to remain fixed over the next fifty years, the use of a fixed regime of fertility,

characterized by its total fertility rate, is useful for illustrative purposes. In the 1.9 TFR Projection, we see a population growing at a rate which will eventually lead to population decline. With a TFR of 1.9 and a fixed set of survival rates, population reaches a maximum in 2015 and thereafter declines. Interestingly enough, because of the maturation of the population into older single individual households, and because of the continuation of the historical trend toward single individual households among younger persons, the number of households does not reach such a maximum.

With income effects beginning to reach their limit and the leveling off of the number of households, ownership and use also level off at around the year 2015. See Table 11 and Figures 15 and 16. Total ownership reaches a ceiling of approximately 151 million automobiles. Total use reaches a maximum of approximately 105 trillion DVMT.

The larger TFR of 2.5 leads to an ever expanding population. Population increases at an almost constant rate of 11.5 million people every 5 years. The number of households grows at a somewhat less than constant rate around 6 million households every five years. Average ownership and use follow almost identical paths as in the 1.9 TFR Projection. Due to the expanding number of households, however, ownership and use reach values of 192.2 million automobiles and 5.13 trillion DVMT by the year 2025. See Table 12 and Figures 17 and 18.

Whereas the 2.5 TFR Projection exhibits almost constant growth over the projection period, the 3.0 TFR Projection shows total ownership and use growing at an accelerating rate. By the end of the projection period, the total number of automobiles owned by American households is increasing at almost 20 million cars every 5 years compared to 11.7 million in the beginning of the projection period. Total use is increasing at a half trillion DVMT every five years compared to 0.3 trillion in the beginning of the projection. This high growth rate at the end of the projection is due

TABLE 11 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
ASSUMING A TOTAL FERTILITY RATE OF 1.9

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVMT)</u>		<u>Households</u> (x10 ⁶)	<u>Pop.</u> (x10 ⁶)
	<u>Total</u> (x10 ⁶)	<u>Avg. H.H.</u>	<u>Total</u> (x10 ⁹)	<u>Avg. H.H.</u>		
1975	86.9	1.25	2.20	31.6	69.6	208.8
1980	97.6	1.28	2.50	32.7	76.5	215.0
1985	108.2	1.30	2.81	33.9	83.1	221.3
1990	117.3	1.33	3.10	35.2	88.2	226.6
1995	124.6	1.36	3.33	36.3	91.7	230.3
2000	131.8	1.39	3.53	37.2	94.9	232.7
2005	139.0	1.41	3.72	37.8	98.5	234.4
2010	145.2	1.43	3.88	38.2	101.8	235.7
2015	149.2	1.43	3.99	38.4	104.1	236.1
2020	150.9	1.43	4.04	38.4	105.2	235.4
2025	151.2	1.43	4.05	38.4	105.6	233.7

FIG. 15. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
 AUTOMOBILE OWNERSHIP 1975 TO 2025
 ASSUMING A TOTAL FERTILITY RATE OF 1.9

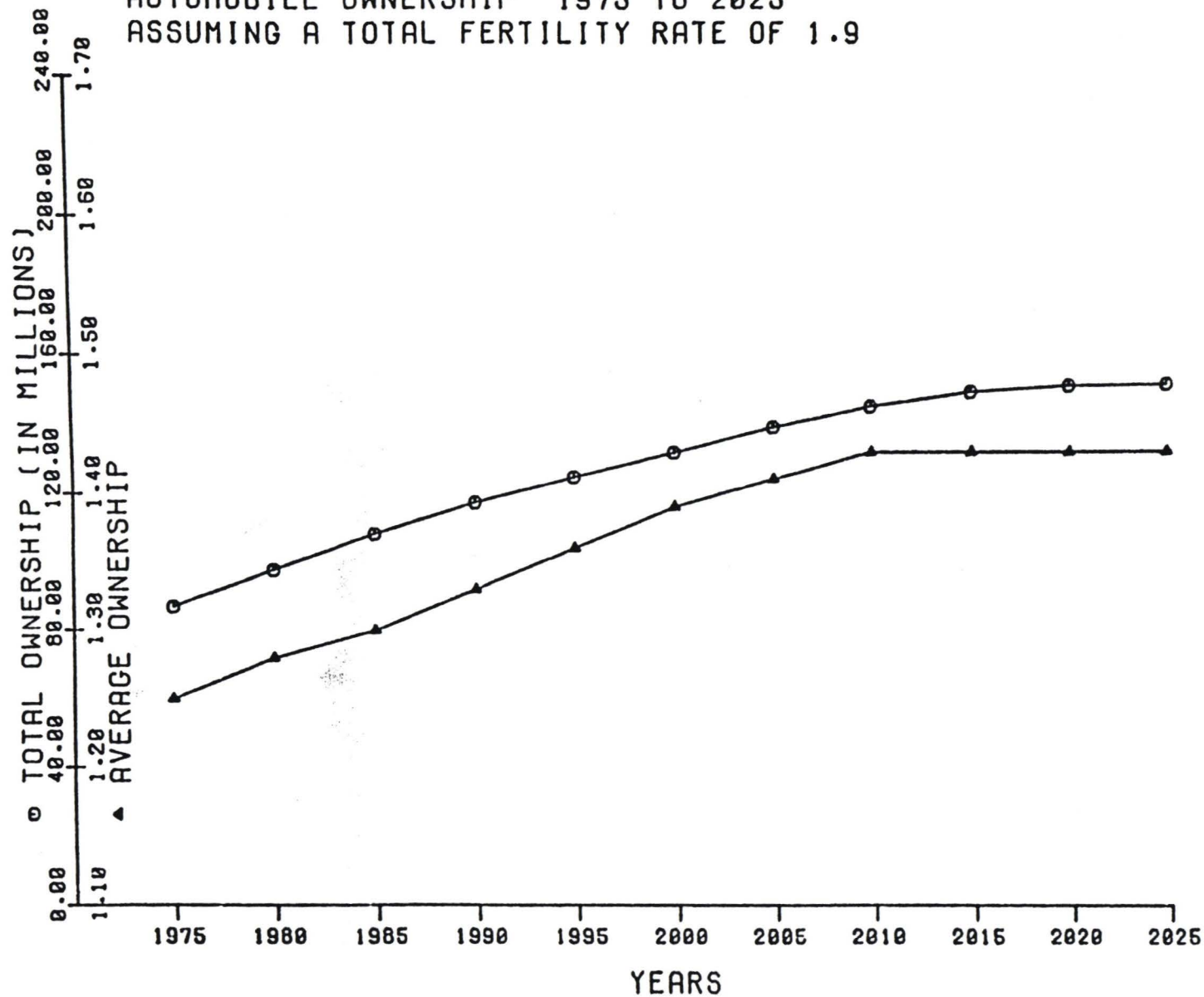


FIG. 16. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
DAILY VEHICLE MILES OF TRAVEL 1975 TO 2025
ASSUMING A TOTAL FERTILITY RATE OF 1.9

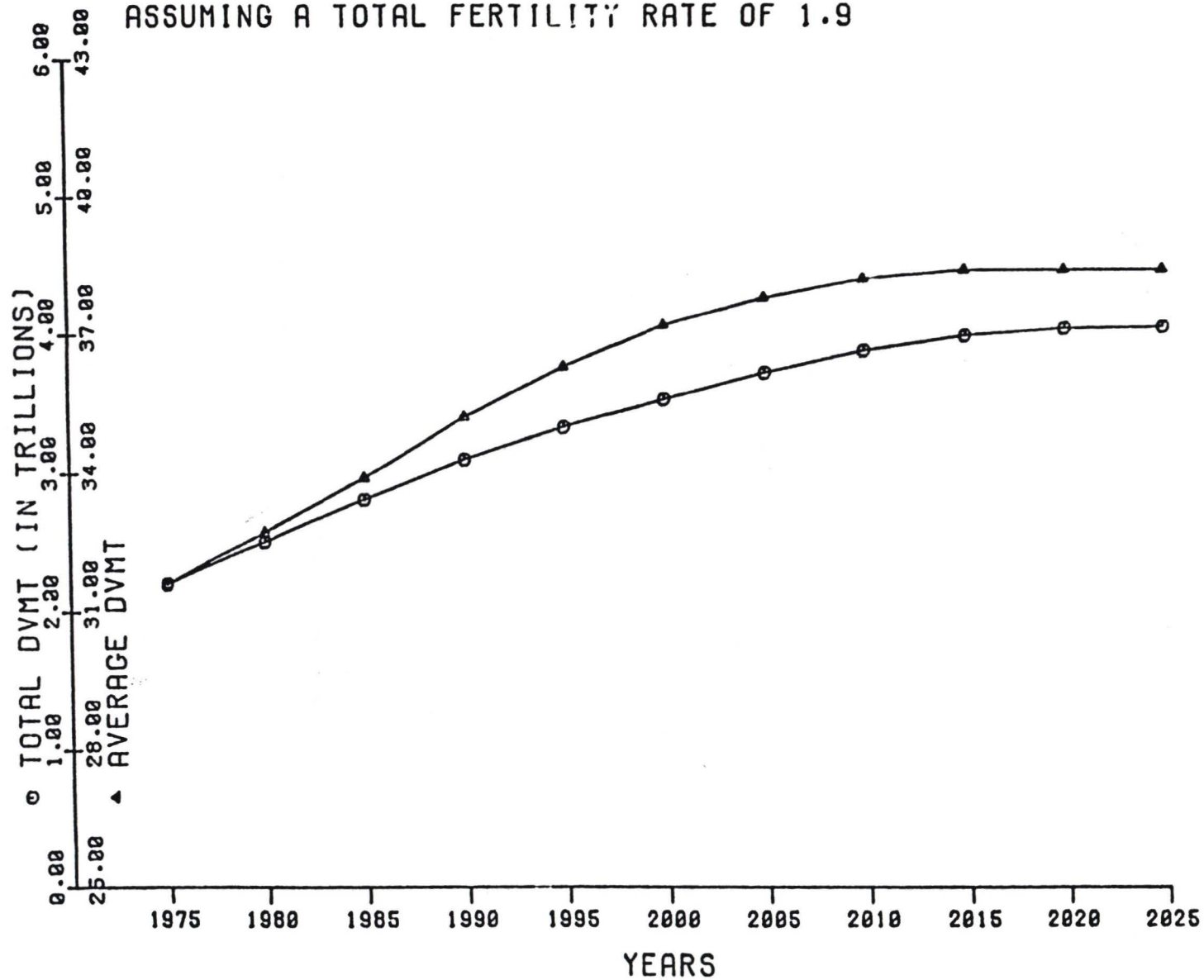


TABLE 12 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
ASSUMING A TOTAL FERTILITY RATE OF 2.5

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVMT)</u>		<u>Households</u> (x10 ⁶)	<u>Pop.</u> (x10 ⁶)
	<u>Total</u>	<u>Avg. H.H.</u>	<u>Total</u>	<u>Avg. H.H.</u>		
	(x10 ⁶)		(x10 ⁹)			
1975	86.9	1.25	2.20	31.6	69.6	213.5
1980	97.6	1.28	2.50	32.7	76.5	224.9
1985	108.2	1.30	2.81	33.9	83.1	236.7
1990	117.4	1.33	3.11	35.2	88.3	247.8
1995	127.1	1.36	3.39	36.2	93.6	258.2
2000	138.6	1.39	3.71	37.1	99.9	268.8
2005	150.8	1.41	4.03	37.7	106.9	280.3
2010	162.5	1.43	4.34	38.2	113.8	292.3
2015	172.8	1.44	4.62	38.4	120.2	304.1
2020	182.4	1.44	4.87	38.5	126.5	315.7
2025	192.2	1.44	5.13	38.5	133.1	327.2

FIG. 17. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
 AUTOMOBILE OWNERSHIP 1975 TO 2025
 ASSUMING A TOTAL FERTILITY RATE OF 2.5

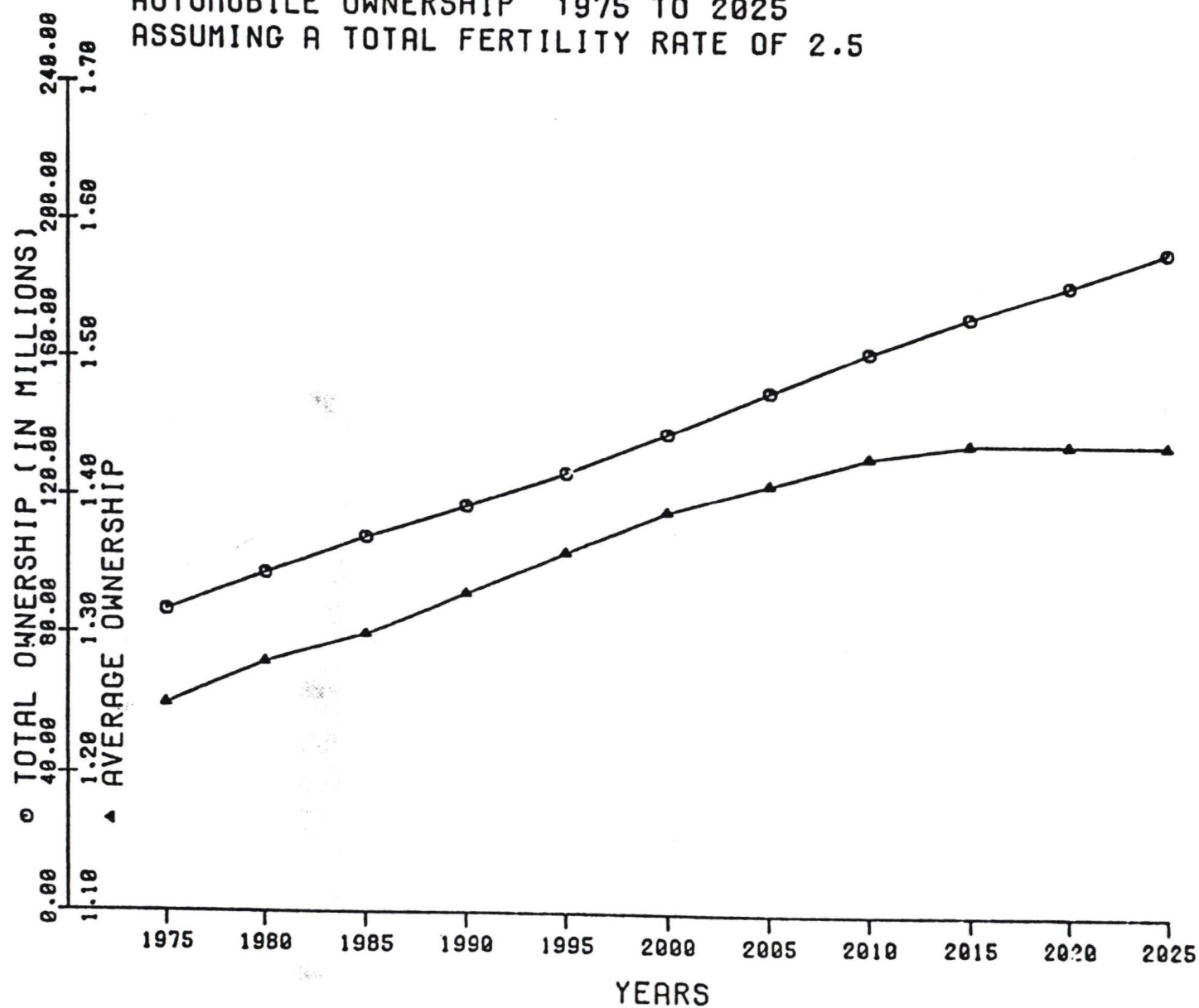
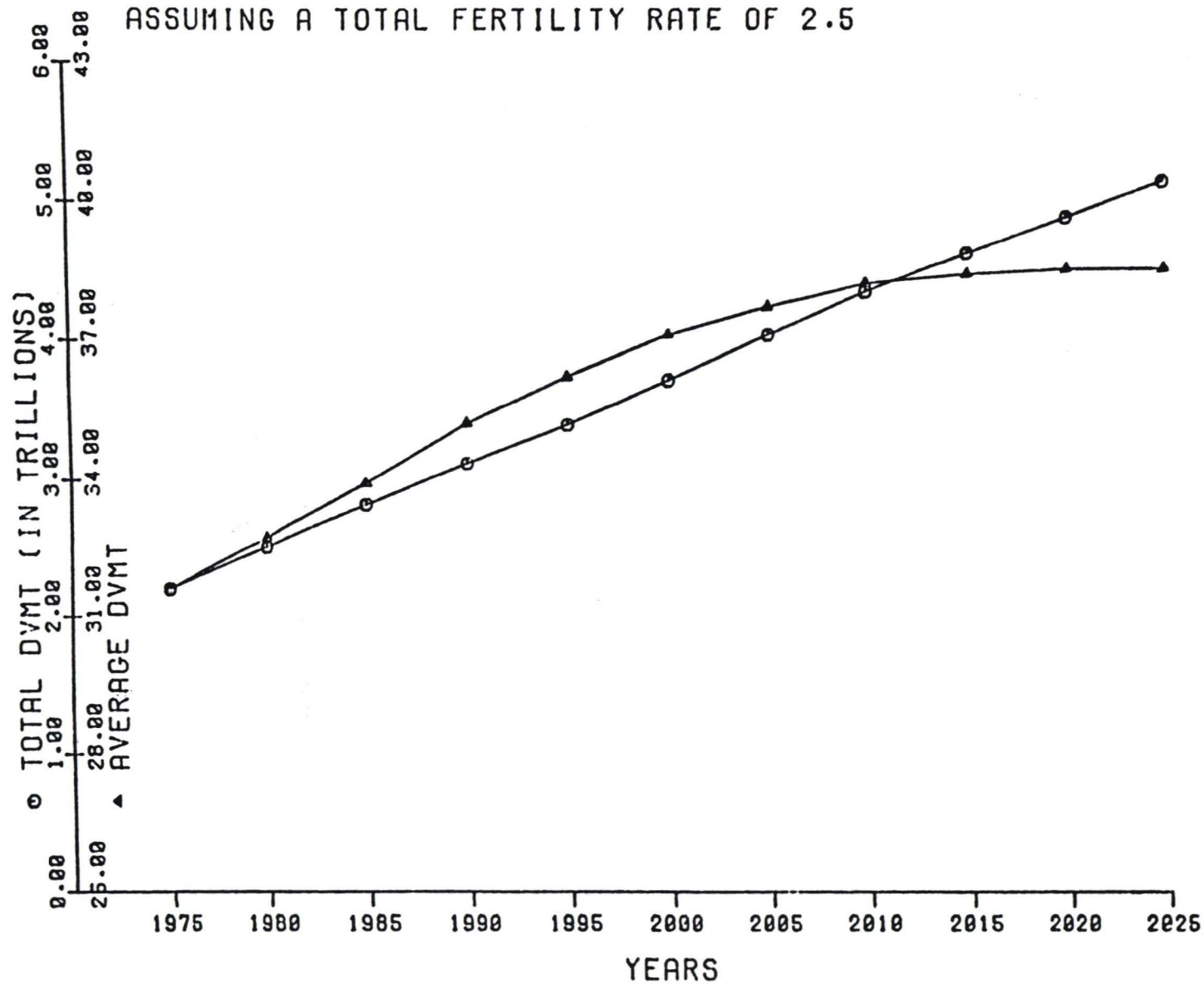


FIG. 18. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
DAILY VEHICLE MILES OF TRAVEL 1975 TO 2025
ASSUMING A TOTAL FERTILITY RATE OF 2.5



solely to the expanding population as average household ownership and use have leveled off at 1.45 automobiles per household and 3^o.5 DVMT per household respectively, at around the year 2015. See Table 13 and Figures 19 and 20.

It is apparent from these three demographic projections and the preceding economic projections, that demographic processes play an equally significant role with respect to the automobile as do economic processes. The range of final values of total ownership and total use was greater for these demographic projections than it was for the economic projections. Furthermore, the demographic projections revealed much greater variation in the rates at which ownership and use changed than did the economic projections. Higher or lower annual income growth rates led only to varying rates at which income effects reached a limit. Varying the total fertility rate, however, led to accelerating, steady and decelerating rates of growth.

Two additional demographic projections depict two different demographic trends. The first projection replicates the age specific birth rates observed over the pre-to post-World War II period. This projection shows the impact of the recurrence of such a swell in fertility. The paths of total ownership and total use observed in this projection are similar to the 2.5 TFR Projection. While there are slightly higher rates of increase in ownership and use at the end of the projection period as compared to the 2.5 TFR Projection, overall, in terms of both average and total, the Baby Boom Projection comes very close to the 2.5 TFR Projection. See Table 14 and Figures 21 and 22.

The Household Transition Projection depicts a transition of households from the nuclear family household toward the single individual household. This transition is assumed to occur between 1975 and 2000. The assumed future values of the household formation rates for this projection appear in Sharp (1978). These household formation rates lead to 57% of all households being headed by single persons by the end of the projection

TABLE 13 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
 AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
 ASSUMING A TOTAL FERTILITY RATE OF 3.0

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVMT)</u>		<u>Households</u> (x10 ⁶)	<u>Pop.</u> (x10 ⁶)
	<u>Total</u> (x10 ⁶)	<u>Avg. H.H.</u>	<u>Total</u> (x10 ⁹)	<u>Avg. H.H.</u>		
1975	86.9	1.25	2.20	31.6	69.6	217.4
1980	97.6	1.28	2.50	32.7	76.5	233.2
1985	108.2	1.30	2.81	33.9	83.1	249.5
1990	117.5	1.33	3.11	35.2	88.4	265.5
1995	129.2	1.36	3.45	36.2	95.3	282.2
2000	144.3	1.39	3.86	37.0	104.1	301.1
2005	160.6	1.41	4.29	37.7	113.9	322.6
2010	177.0	1.43	4.73	38.2	123.9	345.9
2015	193.0	1.44	5.16	38.4	134.2	370.2
2020	210.4	1.45	5.61	38.5	145.6	395.9
2025	229.9	1.45	6.11	38.5	158.5	423.8

FIG. 19. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP 1975 TO 2025
ASSUMING A TOTAL FERTILITY RATE OF 3.0

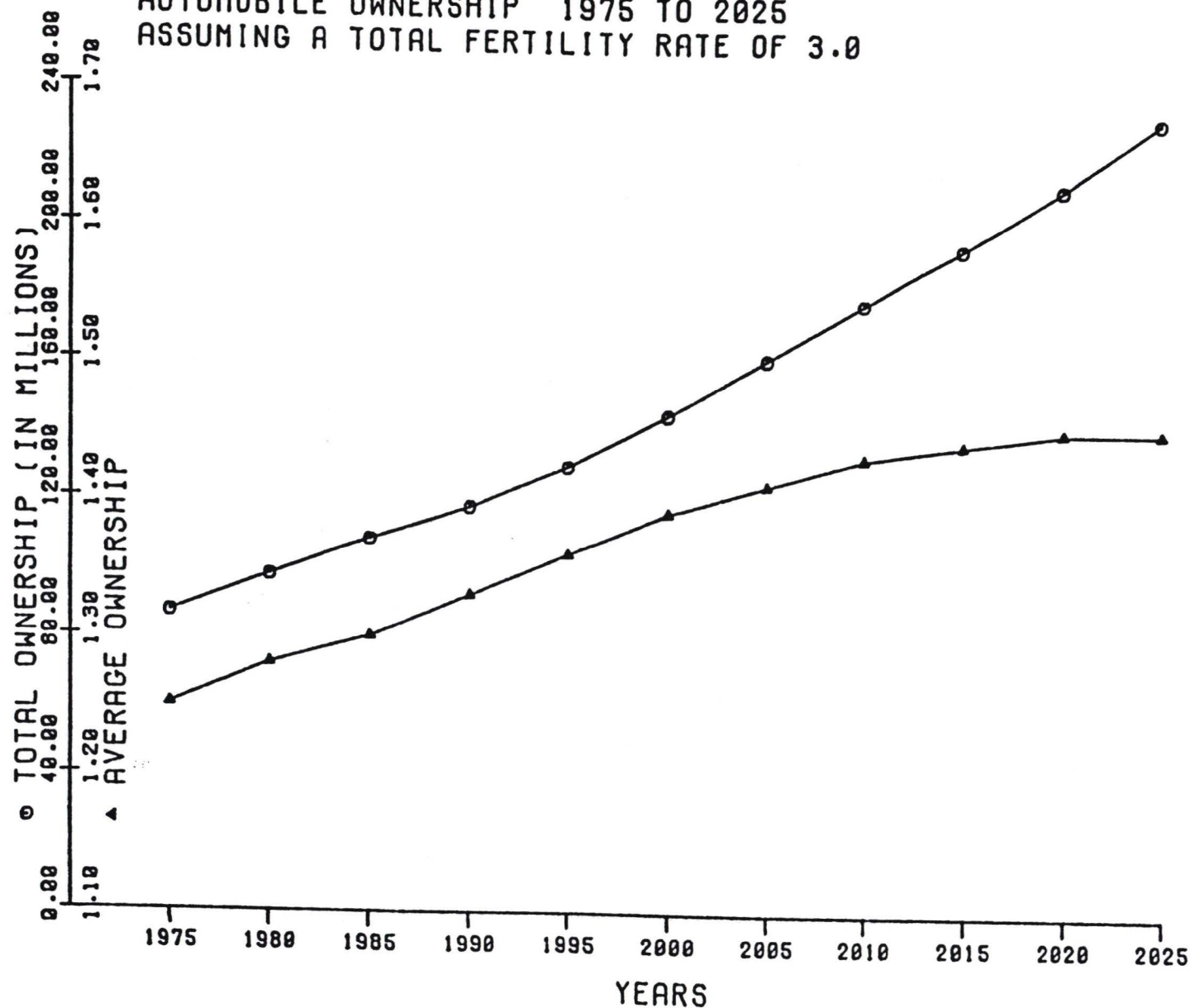


FIG. 20. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
DAILY VEHICLE MILES OF TRAVEL 1975 TO 2025
ASSUMING A TOTAL FERTILITY RATE OF 3.0

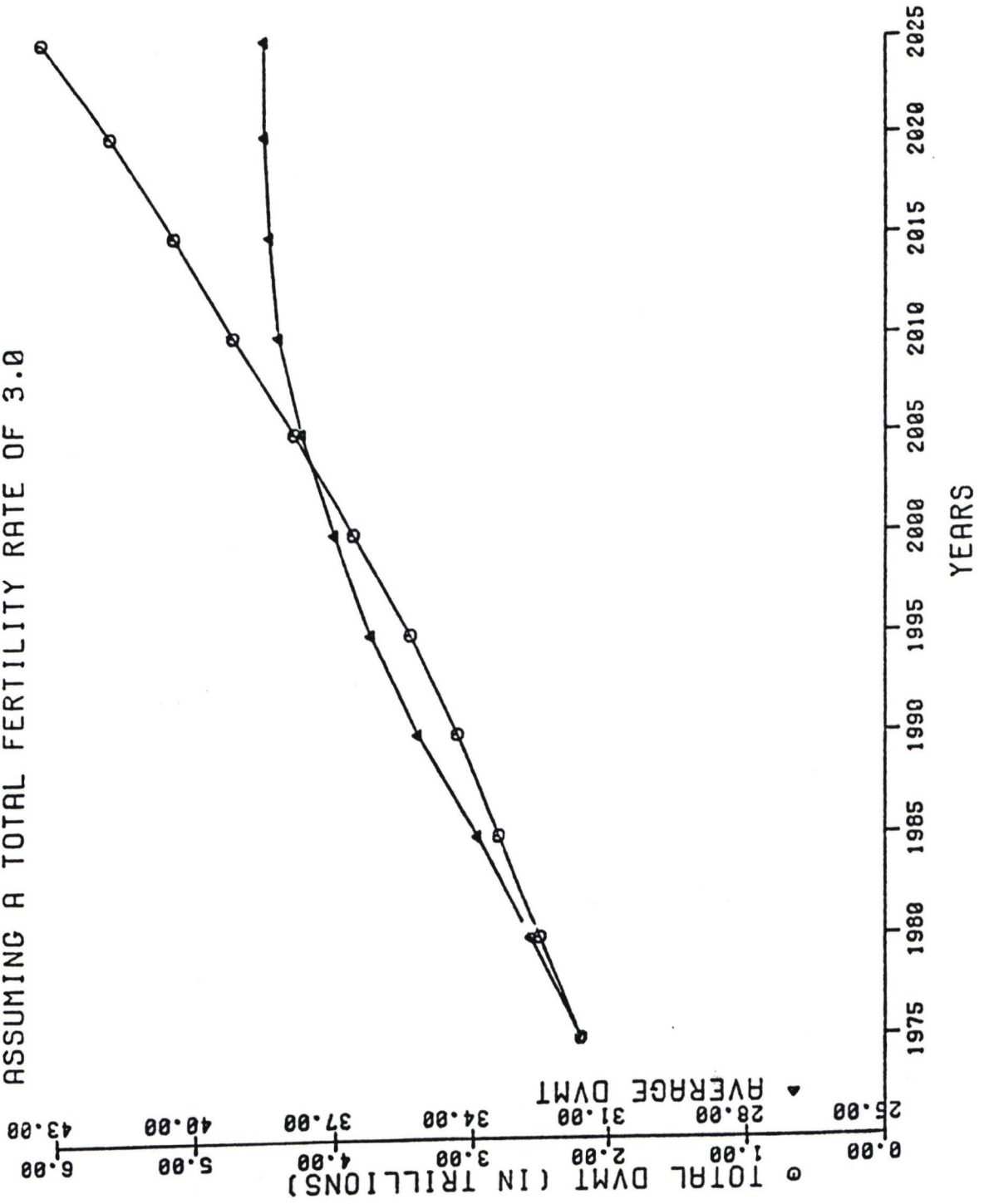


TABLE 14 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
ASSUMING WORLD WAR II BABY BOOM FERTILITY RATES

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVM)</u>		<u>Households</u> (x10 ⁶)	<u>Pop.</u> (x10 ⁶)
	<u>Total</u> (x10 ⁶)	<u>Avg. H.H.</u>	<u>Total</u> (x10 ⁹)	<u>Avg. H.H.</u>		
1975	88.6	1.25	2.25	31.8	70.8	213.1
1980	100.0	1.28	2.57	32.8	78.4	219.9
1985	111.3	1.30	2.90	33.9	85.5	229.2
1990	120.8	1.33	3.20	35.1	91.1	238.4
1995	129.0	1.36	3.45	36.3	95.2	247.9
2000	136.4	1.39	3.66	37.2	98.4	250.3
2005	145.0	1.41	3.89	37.7	103.1	276.4
2010	154.2	1.42	4.12	38.0	108.6	294.7
2015	162.7	1.43	4.25	38.1	114.2	307.5
2020	172.9	1.43	4.62	38.1	121.3	317.8
2025	186.3	1.42	4.96	37.9	130.9	323.2

FIG. 21. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
 AUTOMOBILE OWNERSHIP 1975 TO 2025
 ASSUMING WORLD WAR II BABY BOOM FERTILITY RATES

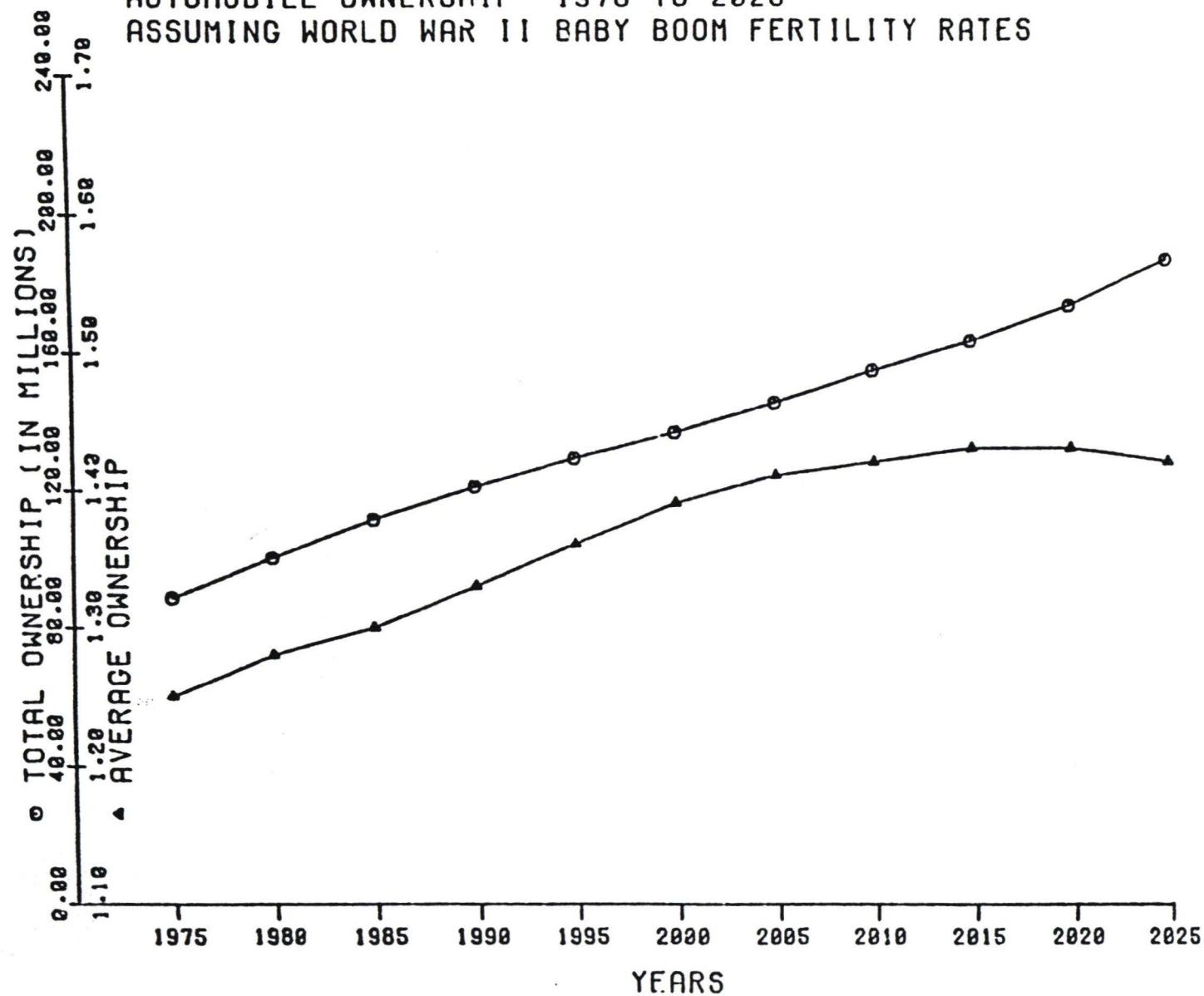
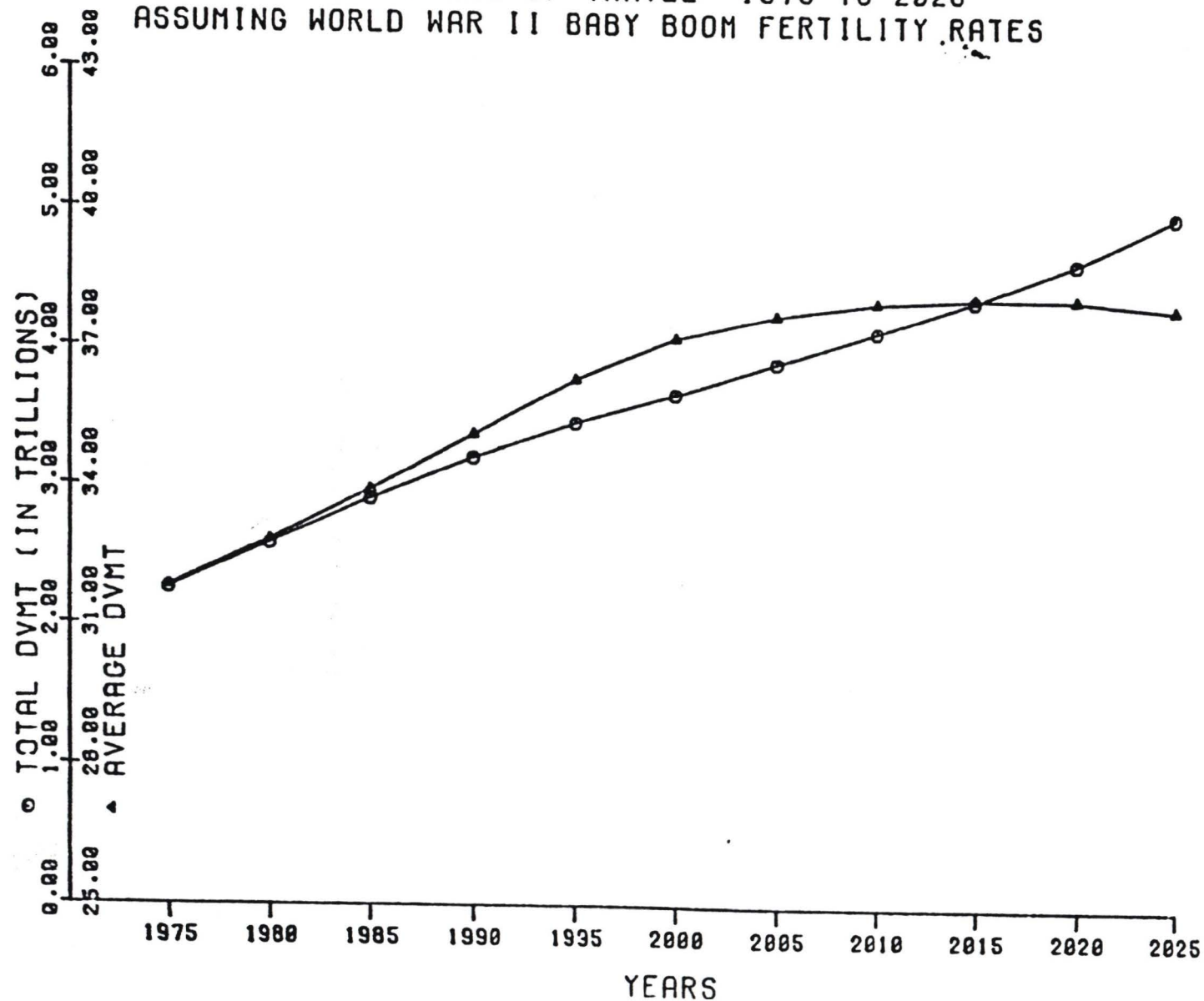


FIG. 22. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
DAILY VEHICLE MILES OF TRAVEL 1975 TO 2025
ASSUMING WORLD WAR II BABY BOOM FERTILITY RATES



period. In the Base Case, single heads represented only 43.7% of all household heads by the end of the projection period. See Table 15.

According to this projection average household ownership and use drop by over 10% between 1980 and 1985, the period of most rapid transition. The number of households, however, increases by over 23% for the same period. Thus, the drop in average household ownership and use is compensated for by the concomitant increase in the number of households. This counter effect produces values of ownership and use which are very similar to those observed in the 1.9 TFR Projection. (Remember that this projection assumes a total fertility rate of 2.1). The total number of automobiles owned by American households over the course of this projection is slightly greater than the number owned in the 1.9 TFR Projection. Total DVMT, however, is slightly lower than in the 1.9 TFR Projection. Thus, it appears that such a household transition has more of a depressing effect on use than it does on ownership. See Table 16 and Figures 23 and 24.

D. Return To The Cities Projection

A popular notion currently being discussed in the media is the return of American households in large numbers to the central cities of the U.S. The basis for such an idea is an expected jump in the cost of energy. It is anticipated that this increase in the cost of energy will lead directly to higher costs of automobile travel, as well as indirectly to higher costs of new housing in suburban areas. According to this view, the closer proximity of activities and the existing stock of housing in the cities will give them a significant advantage over suburban areas in attracting households. Of course such a trend, if it were to occur, would represent a reversal of the net migration flows of the past several decades. However, because of the recent attention given to this idea and the seeming reasonableness of its underlying arguments, its inclusion in this research is justified.

TABLE 15 DISTRIBUTION OF HOUSEHOLDS ACROSS THE LIFE CYCLE STAGE
 TYPOLOGY 1975, 2000, and 2025 ASSUMING A HOUSEHOLD TRANSITION

<u>LCS</u>	<u>1975</u>		<u>2000</u>		<u>2025</u>	
	<u>Base Case</u>	<u>Household Tran.</u>	<u>Base Case</u>	<u>Household Tran.</u>	<u>Base Case</u>	<u>Household Tran.</u>
I	6.9	6.9	11.8	15.4	15.4	13.8
II	6.2	5.9	4.8	3.4	3.5	3.0
III	27.3	26.3	25.3	18.7	19.2	16.4
IV	10.7	10.3	10.2	7.1	9.3	6.8
V	14.0	13.4	12.1	8.4	12.8	9.8
VI	5.9	6.1	5.5	10.9	5.6	12.4
VII	9.5	9.7	8.8	5.8	11.5	6.8
VIII	8.8	9.4	8.6	12.7	9.1	14.2
IX	<u>11.2</u>	<u>12.1</u>	<u>13.0</u>	<u>17.7</u>	<u>13.6</u>	<u>16.9</u>
	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 16 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
ASSUMING A HOUSEHOLD TRANSITION

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVMT)</u>		<u>Households</u> (x10 ⁶)	<u>Pop.</u> (x10 ⁶)
	<u>Total</u>	<u>Avg. H.H.</u>	<u>Total</u>	<u>Avg. H.H.</u>		
	(x10 ⁶)		(x10 ⁹)			
1975	87.6	1.23	2.20	31.0	71.1	210.3
1980	97.4	1.26	2.47	31.9	77.5	218.3
1985	111.8	1.17	2.65	27.6	95.7	226.4
1990	121.0	1.18	2.90	28.3	102.1	233.7
1995	128.3	1.22	3.11	29.6	105.3	239.5
2000	135.8	1.25	3.32	30.6	108.6	244.4
2005	143.4	1.28	3.52	31.3	112.3	249.1
2010	150.3	1.30	3.69	31.9	115.8	253.6
2015	155.4	1.31	3.83	32.3	118.7	257.5
2020	159.1	1.32	3.94	32.6	120.9	260.3
2025	161.8	1.32	4.01	32.7	122.7	262.3

FIG. 23. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP 1975 TO 2025
ASSUMING A HOUSEHOLD TRANSITION

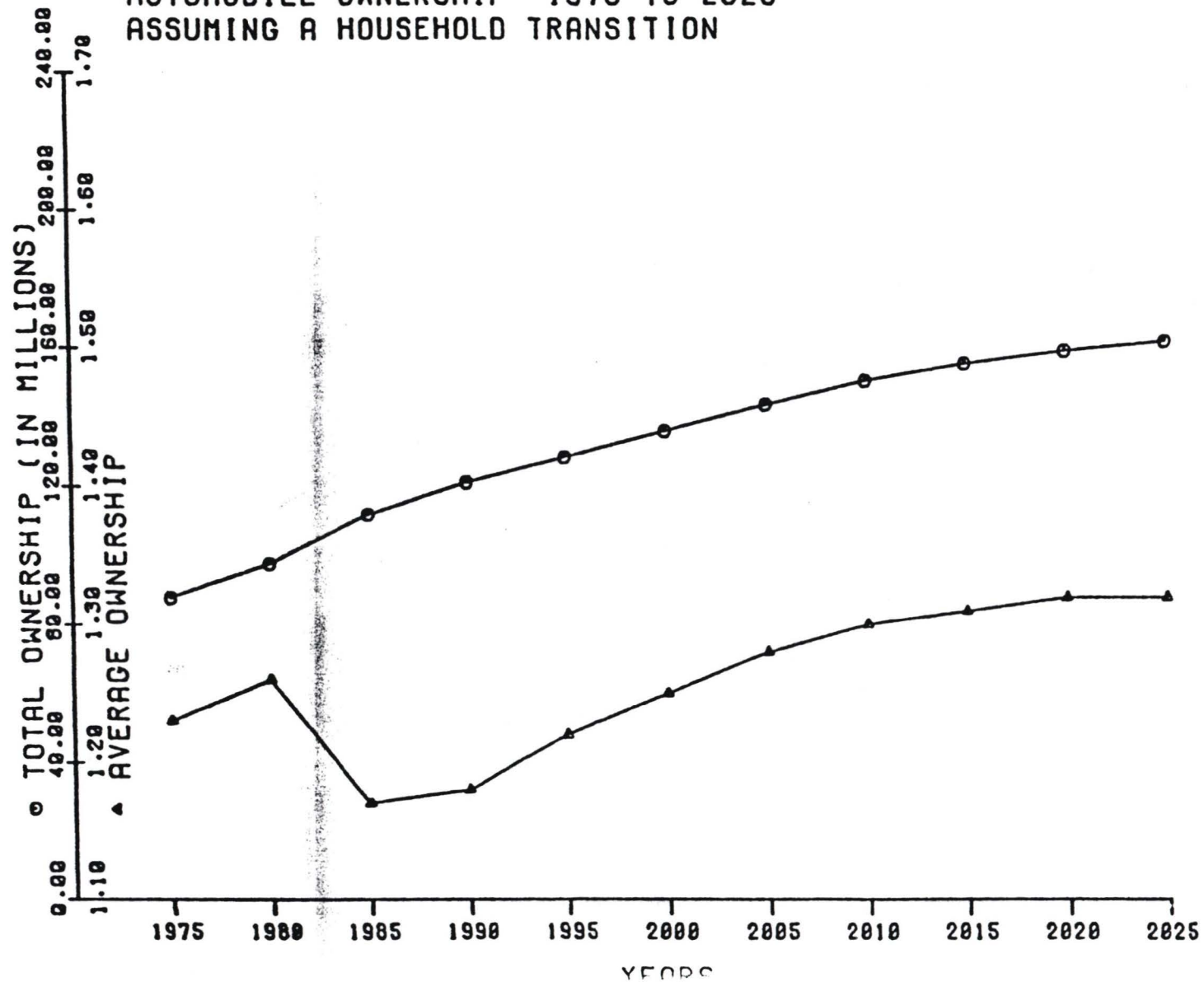
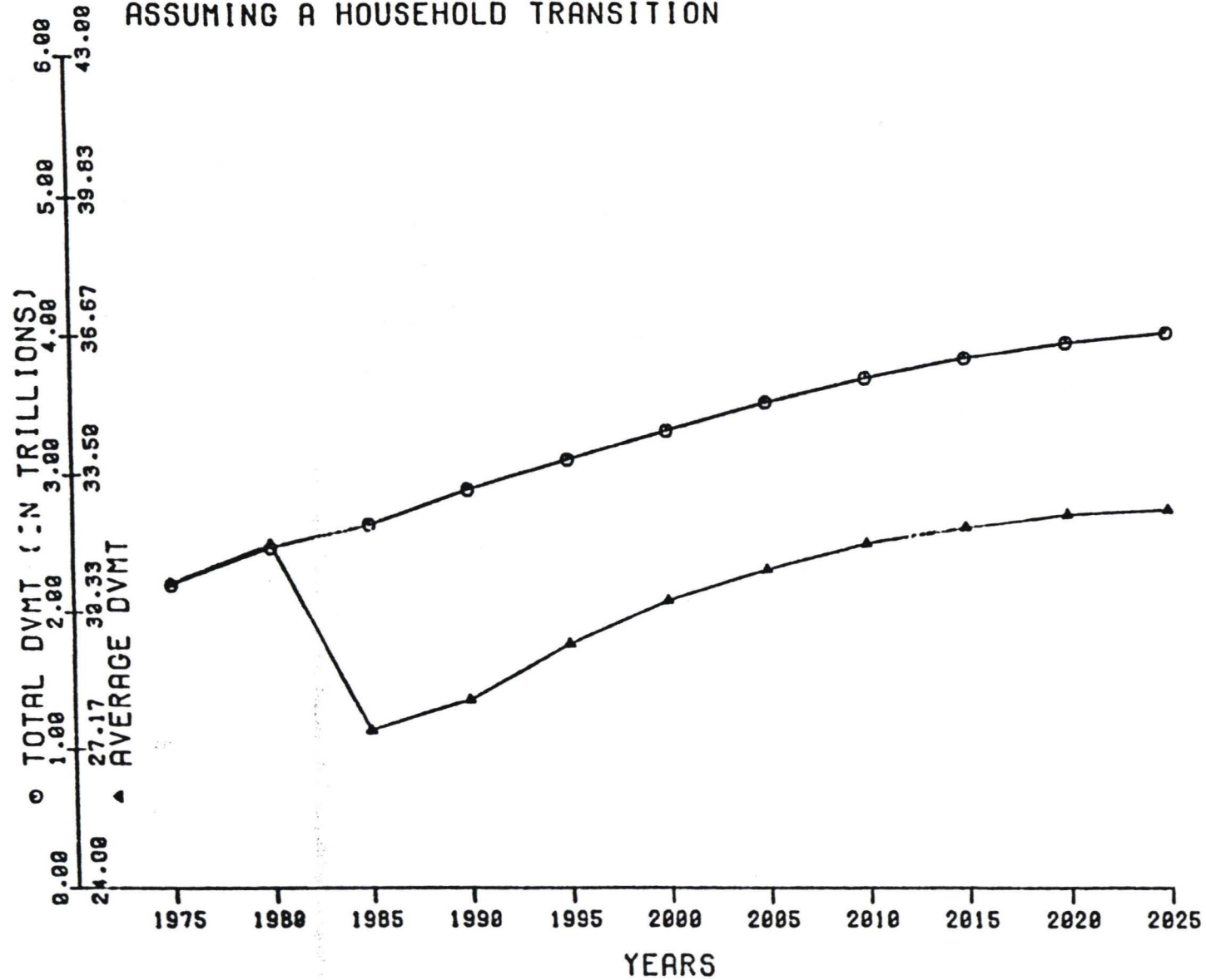


FIG. 24. PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
DAILY VEHICLE MILES OF TRAVEL 1975 TO 2025
ASSUMING A HOUSEHOLD TRANSITION



The return to the Cities Projection was implemented by specifying a 50% reduction in the proportion of the population currently (1970) living outside central cities. This loss in proportion would be gained by the central cities. This redistribution of the population is assumed to occur over the first half of the projection.

The assumptions of this projection lead to a modest decline in total DVMT relative to the Base Case. See Table 17. By the end of the projection period, total use has beached 4.21 trillion DVMT. Average travel per household has risen to 36.8 DVMT. (Total ownership is unaffected from the Base Case due to the nature of the ownership model.)

One qualification which this conclusion deserves is that the definitions of urban, suburban, and rural is somewhat approximate. Thus, this result should be taken as tentative. A more accurate definition of the location dimension in terms of density and variety of activity might lead to somewhat different results. On the other hand, one should not lose sight of the fact that life cycle stage, income, time and employment account for a great deal of the explained variation in travel behavior, and that, having controlled for these variables, there is little difference between households in the three locational classes. A redefinition of location is not likely to change this fact. Thus, an increase in the proportion of households living in central cities will probably not bring about much of a savings in DVMT.

E. Four Day Work Week

A trend which seems likely to continue is the contraction of the work week. The ultimate outcome of this trend could conceivably be the four day work week. In order to evaluate the impact of such a trend, the Four Day Work Week Projection was developed.

The transition to a four day work week was assumed to be completed by the year 1990. All other parameters were set as in the Base Case.

TABLE 17 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
ASSUMING A RETURN TO THE CITIES

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVM)</u>			
	<u>Total</u> (x10 ⁶)	<u>Avg. H.H.</u>	<u>Total</u> (x10 ⁹)	<u>Avg. H.H.</u>	<u>Households</u> (x10 ⁶)	<u>Pop.</u> (x10 ⁶)
1975	86.9	1.25	2.20	31.6	69.6	210.3
1980	97.6	1.28	2.49	32.6	76.5	218.3
1985	108.2	1.30	2.77	33.4	83.1	226.5
1990	117.3	1.33	2.99	33.9	88.3	233.7
1995	125.5	1.36	3.20	34.6	92.3	239.5
2000	134.1	1.39	3.42	35.5	96.6	244.4
2005	142.9	1.41	3.65	36.1	101.3	249.1
2010	151.0	1.43	3.86	36.5	105.8	253.6
2015	157.0	1.43	4.02	36.7	109.4	257.5
2020	161.2	1.44	4.13	36.8	112.2	260.3
2025	164.4	1.44	4.21	36.8	114.4	262.3

The effect of the four day work week on total travel was surprisingly slight. Total DVMT increased by only a small amount over the Base Case. See Table 18. This modest increase was partially due to a 6.7% decrease in work travel being offset by a 4.8% increase in social leisure travel. Here again, however, some qualifications are necessary. Because the day of the week dimension was only one of several explanatory dimensions of travel, the impact of a four day work may be underestimated. The decrease in work travel was not one fifth as one might expect from the loss of one of five work days. On the other hand, the increase in social leisure travel was not one half as one might expect from the addition of one day to the normal two day weekend.

The sign of this change in total DVMT, however, is less open to qualification. Social leisure trips, which occur primarily on weekends, are considerably longer, on average, than are work trips which occur primarily on weekdays. Furthermore, the effect of three continuous days of leisure time may have a synergistic effect on social leisure travel. Households may drive longer distances to recreational sites, given a three day weekend. Thus, a four day work week is likely to cause a net increase in total travel by American households.

The results of the preceding section were generated from a fairly complex and diverse set of models. Part III presents a discussion and critique of these models along with suggestions for future research. Four major modeling efforts were undertaken in this study and each will be discussed separately. The four principal models which were developed are:

1. Household Projection Model
2. Income Projection Model Ownership
3. Model
4. Use Model

A final section will briefly describe the data and software used in this study.

TABLE 18 PROJECTION OF TOTAL AND AVERAGE HOUSEHOLD
AUTOMOBILE OWNERSHIP AND USE 1975 - 2025
ASSUMING A FOUR DAY WORK WEEK

<u>Year</u>	<u>Ownership (Autos)</u>		<u>Use (DVT)</u>		<u>Households</u>	<u>Pop.</u>
	<u>Total</u> (x10 ⁶)	<u>Avg. H.H.</u>	<u>Total</u> (x10 ⁹)	<u>Avg. H.H.</u>		
1975	86.9	1.25	2.20	31.6	69.6	210.3
1980	97.6	1.28	2.51	32.8	76.5	218.3
1985	108.2	1.30	2.85	34.3	83.1	226.4
1990	117.3	1.33	3.12	35.4	88.3	233.7
1995	125.5	1.36	3.36	36.4	92.3	239.5
2000	134.1	1.39	3.60	37.3	96.6	244.4
2005	142.9	1.41	3.83	37.9	101.3	249.1
2010	151.0	1.43	4.05	38.3	105.8	253.6
2015	157.0	1.43	4.21	38.5	109.4	257.5
2020	161.2	1.44	4.32	38.6	112.2	260.3
2025	164.4	1.44	4.41	38.5	114.4	262.3

PART III - METHODOLOGY

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A. Household Projection Model

Households were projected by coupling a population projection model with a household proportions model. The two models are very different and will be discussed separately.

Population Projection Model. The population model made use of the cohort component method of projecting population.⁸ This method explicitly recognizes two underlying demographic processes: birth and death. (The U.S. population is assumed to be closed, so migration is not considered.) Specifically, birth rates and survival rates are computed for some base period for various age-sex classes. These rates are then specified in a set of equations which are used to carry the population from an initial year, t , forward Δt years into the future.

The entire set of equations may be specified in matrix notation as:

$$\begin{bmatrix} A_1 & A_2 \\ A_3 & A_4 \end{bmatrix} \begin{pmatrix} p^f \\ p^m \end{pmatrix}_t = \begin{pmatrix} p^f \\ p^m \end{pmatrix}_{t + \Delta t}$$

The matrix on the left hand side is composed of four submatrices. A_1 contains the fertility and survival rates describing the births of female children to living females and the survival of these same living females into the next period. A_2 is a null matrix. A_3 contains fertility rates describing the births of male children to living females. A_4 contains survival rates describing the survival of living males into the next period. p^f is a column vector containing the age specific female population for the specified year. p^m is a column vector containing the age specific male population for the specified year.

Of the two sets of rates mentioned above the fertility rates are of greater significance to the projection because they represent a feedback mechanism: Female children born in the current period represent an increase in the population, but they also have certain probability of

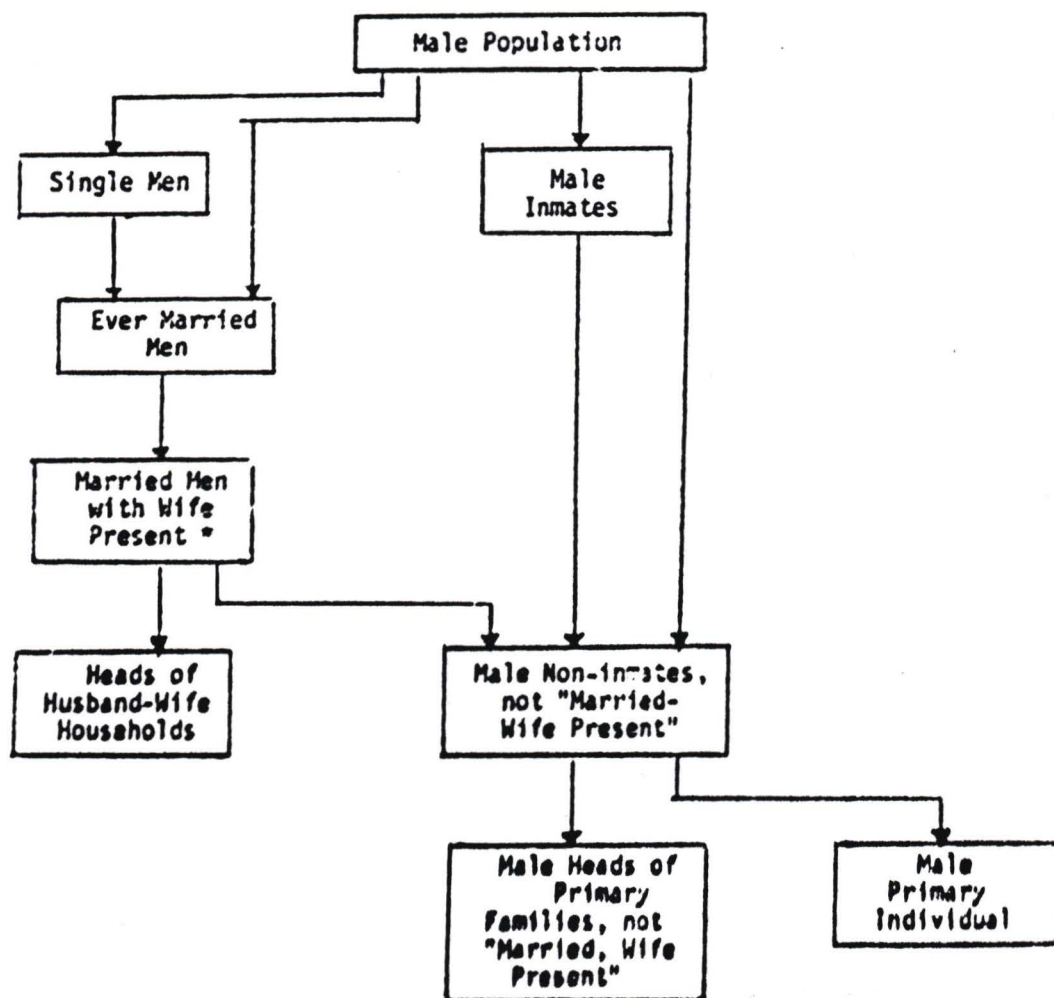
bearing children themselves in subsequent periods. Survival, on the other hand, does not have this feedback effect. Furthermore, the range of values within which future fertility rates are likely to fall corresponds to a much wider range of rates of growth for the population as a whole than does the range of values within which survival rates are expected to fall.⁹ For these reasons this research has implemented a population projection model which allows only for the manipulation of fertility rates.

While the role of fertility is well understood, the forces which drive fertility and cause it to change are generally not well understood. Because of this situation, this research will specify fertility rates exogenously. Save for the Baby Boom Projection, one regime of age specific fertility rates will be used for all projections. In each of the demographic projections these rates will be multiplied by a scalar constant to yield different total fertility rates.

Household Proportions Model. The method used in this research to project household proportions was developed from a procedure used by the Census Bureau.¹⁰ A cross sectional model is used to allocate the adult population to various types of households. The allocations are based upon a sequence of proportions. These proportions are projected by a set of time series models ($P = \exp(B_0 + B_1 t)$ where p is the proportion being projected, B_0 and B_1 are estimated parameters and t is time in years.) The projected sequence of proportions is then applied to the projected population to yield a projection of households. The classes of households which are computed from the population is shown in Figure 2b.

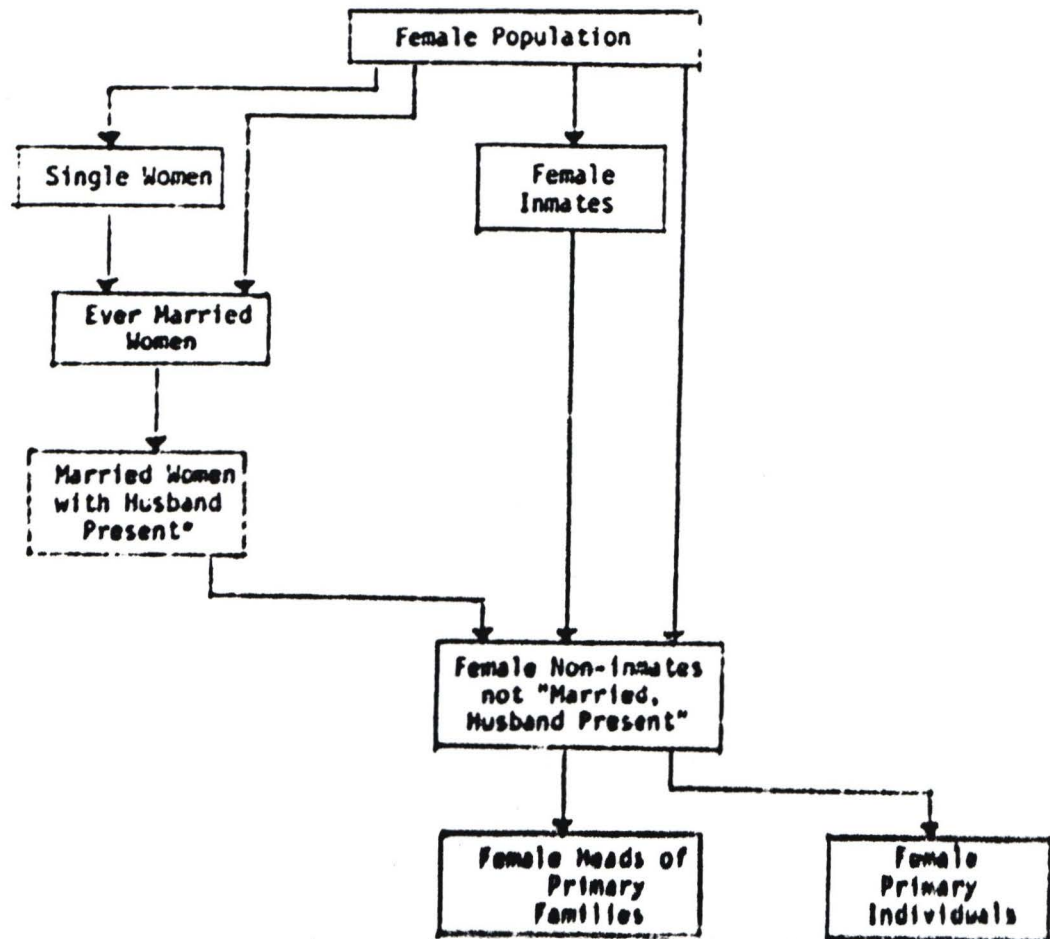
As is apparent from this figure the resultant five categories of households do not match perfectly with the nine classes of the household life cycle stage typology. In order to derive estimates of the number of households in each life cycle stage, two operations were necessary. First, married couples had to be partitioned into married couples with children and married couples without children. The partition was carried out using 1970

FIG. 25. CENSUS BUREAU PROCEDURE FOR COMPUTING HOUSEHOLDS



* This quantity is reconciled with the similarly computed quantity for women.

FIG. 25. (cont.)



* This quantity is reconciled with the similarly computed quantity for men.

proportions. Second, age cohorts and sexes were summed to yield the number of households in each of the nine classes of the life cycle stage typology.

The procedures just described are very close to the procedures followed by the Census Bureau. The difference is due to simplifications made in this research and hence, some loss of detail. Future research might consider a more detailed procedure e.g. use single year cohorts instead of five year cohorts.

There is, however, an improvement that goes beyond the addition of details and which would represent a substantial improvement in the projection of households. One of the requirements for projecting population is a projection of future fertility. The method used by the Census Bureau makes use of a fixed timing pattern of fertility and applies to this pattern a completed cohort fertility rate. The timing patterns used by the Census Bureau were developed by Ansley J. Coale and T. James Trussell.¹¹ Coale and Trussell implemented a model of fertility which recognized fertility as being a process associated with marriage. Thus, their model of fertility is composed of two components: one for nuptiality and one for fertility within marriage or nuptial fertility.

Thus, a topic worth considering for future research is the implementation of a household projection model which would tie together the the projection of the proportion ever married (part of the household proportions model) with Coale and Trussell's model of fertility. The addition of this linkage from the household proportions model back to the population projection model would help avoid possible inconsistencies and would also make the projection of households more sensitive to the household proportions model.

B. Income Projection Model

Household income was projected using a technique employed by the Census Bureau.¹² It is a single parameter technique and avoids the use of a large econometric model of the U.S. economy. The technique

requires a annual growth rate of income be specified for the projection period. This growth rate is then applied against the current income distribution to yield the projected income distribution. This procedure has the benefit that it is simple and allows for a high degree of flexibility. Furthermore, the income dimension may be easily characterized in the discussion of the projections by a single parameter.

Due to the requirements of the ownership and use models, income distributions for each of the nine household life cycle stages were accounted for. Thus, the projection of income was carried out separately for each life cycle stage.

C. Ownership Model

The variable used to represent ownership was the number of automobiles owned by the household. No distinctions were made among the ages, sizes and costs of the automobiles. Ownership took on four values 0, 1, 2, and 3 where 3 stands for 3 or more.

In spite of the cardinal nature of the ownership variable the values of ownership were used only to distinguish different ownership patterns. Because of this assumed categorical nature of ownership and because of an interest in the distribution of households across the four ownership classes, ownership was projected via the use of a three dimensional contingency table. The three dimensions of the contingency table are ownership, life cycle stage and income. Originally, location was to be included as a fourth dimension. Unfortunately, the size and hence the complexity of the contingency table increases exponentially as the number of dimensions in the table increases. Thus, implementation of the complete table, as defined by the conceptual framework, had to be left for future research. In spite of the simplified form of the contingency table, an analysis using log linear models revealed the presence of a complex set of interactions among the dimensions of the table.¹³

Very simply, log linear models explain the joint probabilities appearing in the cells of the table via the use of summary information contained in the marginals derived from the original table. This approach contrasts with regression in which the conditional expectation of one dimension is explained by the distributions of each of the remaining variables. For the three way table under consideration here, one may construct a model using the following terms:

- μ - the mean effect term associated with the entire table.
- μ_A, μ_B, μ_C - the zeroeth order interaction terms associated with the three one dimensional marginals.
- $\mu_{AB}, \mu_{AC}, \mu_{BC}$ - the first order interaction terms associated with the three two dimensional marginal tables.
- μ_{ABC} - the second order interaction term associated with the complete three dimensional table.

One constraint imposed on these models is that for every term present in the model, its lower order relative must also be present. Thus, if μ_{AB} is present, then both μ_A and μ_B must also be present. Naturally, if μ_{ABC} is present, all possible terms must be present. Furthermore, since μ_{ABC} is based on the complete table, such a model (referred to as the saturated model) fits the table perfectly.

The goal in log linear modeling is to find the best unsaturated model (model with one or more terms missing). The best unsaturated model is defined as the model with the fewest number of terms which is still able to fit the table and which is interpretable in terms of the dimensions of the table. In the present instance the simplest unsaturated model which yielded a fit was the just unsaturated model, i.e., the model with all terms present except for the μ_{ABC} term. This relatively complex model may be contrasted with the model which would have fit if there had been complete independence among the three dimensions of the table. In such a case, the model with only the mean effect and zeroeth order interaction terms would have fit the table perfectly. The present table

diverges considerably from such a condition of independence. In fact, The results of the log linear models applied to this table indicate the presence of a very complex set of interactions among the dimensions of the table. Thus, we may conclude that the dimensions of household life cycle stage and household income are significantly related to one another and to automobile ownership, and that variations in ownership for each life cycle stage - income class should be carried through the analysis.

Thus, the three dimensional table was handled in the following way. The conditional probability distribution of ownership given life cycle stage and income class was assumed to remain constant over time. The marginal distribution of households across life cycle stages was projected by the demographic model, and the conditional probabilities of income given life cycle stage were projected using the income growth rate model. A pictorial representation of this procedure appears in Figure 26.

This model may be summarized mathematically as

$$P(ABC) = P(A|BC) \cdot P(B|C) \cdot P(C)$$

where: A = automobile ownership

B = income

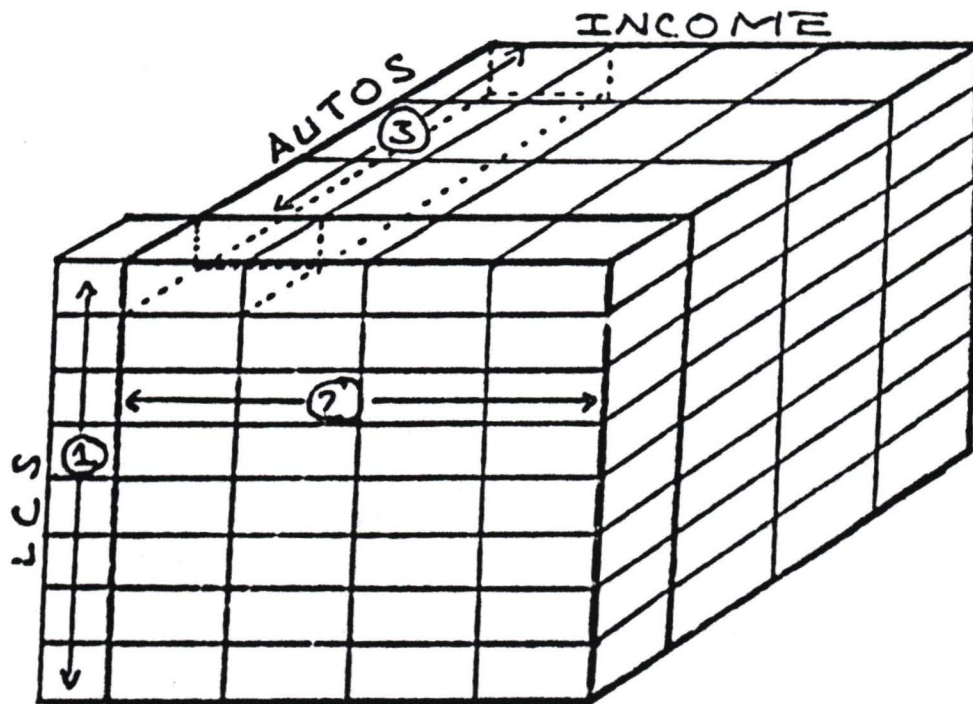
C = life cycle stage

D. Use Model

Data Problems. In an effort to analyze travel at a disaggregate level, daily travel was broken down into eight separate measures based on two dimensions - the purpose of travel (Work, Shop, Educational-Religious-Civic, Social-Leisure) and sex of driver (Male, Female). Eight separate regressions models were estimated, one for each class of travel.

One of the difficulties faced in estimating these models was the limited time period for which detailed data were available. The trip file of the Nationwide Personal Transportation Survey (NPTS) contains data on travel occurring over the course of one day. Because of its limitation to

FIG. 26. PICTORIAL REPRESENTATION OF THE OWNERSHIP MODEL



- 1) Projection marginal probability of life cycle stage.
- 2) Project conditional distributions of income given life cycle stage.
- 3) Apply products of (1) and (2) against conditional distribution of ownership, given income and life cycle stage.

one day of travel, these data exhibited the randomness of household participation in travel generating activities. Compounding this difficulty is the crude measure of location of households. The grossness of the urban/suburban/rural trichotomy undoubtedly generated additional random variation in the measures of travel. Thus, the standard deviations of each measure of travel for each household class, typically, were twice as large as their means. And this situation resulted in the estimated regression models having poor fits to the data.

One means of avoiding this data problem is to look at the NPTS person file rather than the trip file. The person file contains the total mileage each vehicle in the household was driven in the previous twelve months. Thus, the total vehicle miles traveled by the household in one year could be computed. Use of yearly VMT would provide a means of averaging out the random component generated by the limited time scale of the trip file data. Unfortunately, the goal of this research was to delve into the causes of travel at the disaggregate level. The person file cannot be used for such an analysis. Thus, the NPTS trip record file was used. It is suggested, however, that future data collection and research consider travel occurring over the course of a week, month or year.

Estimation Results. The general form of the models finally selected for DVMT is as follows:

$$\begin{aligned}
 DVMT = & B_1 + B_2^* (LCS\ II) + B_3^* (LCS\ III) + B_4^* (LCS\ IV) \\
 & + B_5^* (LCS\ V) + B_6^* (LCS\ VI) + B_7^* (LCS\ VII) \\
 & + B_8^* (LCS\ VIII) + B_9^* (LCS\ IX) + B_{10}^* (SUN) \\
 & + B_{11}^* (MON) + B_{12}^* (TUE) + B_{13}^* (WED) \\
 & + B_{14}^* (THUR) + B_{15}^* (FRI) + B_{16}^* (APR) \\
 & + B_{17}^* (JUL) + B_{18}^* (AUG) + B_{19}^* (OCT) \\
 & + B_{20}^* (MOUNTAIN) + B_{21}^* (SUBURBAN) \\
 & + B_{22}^* (RURAL) + B_{23}^* (EMPLOYED) \\
 & + B_{24}^* (LOWIDINC) + B_{25}^* (UPIDINC) \\
 & + B_{26}^* (MICHINC) + B_{27}^* (AUTOS)
 \end{aligned}$$

where:

LCS	II	=	1 if household is in Life Cycle Stage II, 0 otherwise
LCS	III	=	" " " III, "
LCS	IV	=	" " " IV, "
LCS	V	=	" " " V, "
LCS	VI	=	" " " VI, "
LCS	VII	=	" " " VII, "
LCS	VIII	=	" " " VIII, "
SUN		=	1 if travel occurred on Sunday, 0 otherwise
MON		=	" " " Monday, "
TUE		=	" " " Tuesday, "
WED		=	" " " Wednesday, "
THUR		=	" " " Thursday, "
FRI		=	" " " Friday, "
APR		=	1 if travel occurred in April, 0 otherwise
JUL		=	" " " July, "
AUG		=	" " " August, "
OCT		=	" " " October, "
MOUNTAIN		=	1 if household is in Mountain Division, 0 otherwise
SUBURBAN		=	" " " Suburban Area, "
RURAL		=	" " " Rural Area, "
EMPLOYED		=	number of employed persons in household
LOWIDINC		=	1 if household income is \$5 - 10K, 0 otherwise
UPMIDINC		=	" " " \$10 - 15K, "
HIGHINC		=	" " " \$15K+, "
AUTOS		=	number of automobiles in household

Eight models, one for each sex and trip purpose were estimated. The results are reported in Table 19.

TABLE 19 COEFFICIENTS FOR ESTIMATED USE MODELS

VARIABLE	MODEL							
	WORK		SIOP		ERC		S-L	
	M ¹	F	M	F	M	F	M	F
CONSTANT	-1.6	-2.0	2.2	-0.5	-0.5	-0.6	6.0	-1.2
LCS II	1.0 (1.5)	-1.1* (0.5)	-5.8* (1.0)	-0.3 (0.6)	0.3 (0.5)	0.1 (0.2)	-1.0 (3.4)	-0.7 (1.1)
LCS III	0.2 (1.2)	-1.7* (0.4)	-0.3 (0.8)	0.4 (0.5)	0.6 (0.4)	0.3* (0.1)	-8.2* (2.8)	-0.2 (0.9)
LCS IV	-2.3* (1.3)	-1.3* (0.5)	-1.1 (0.9)	-0.5 (0.5)	0.4 (0.5)	-0.01 (0.2)	-8.2* (3.0)	0.3 (0.9)
LCS V	-3.6* (1.5)	0.9* (0.5)	-2.5* (1.0)	0.04 (0.6)	-0.1* (0.5)	0.1 (0.2)	-10.6* (3.4)	1.1 (1.1)
LCS VI	-3.1* (1.4)	0.3 (0.5)	-2.2* (0.9)	-0.3 (0.6)	0.03 (0.5)	0.3 (0.2)	-6.9* (3.2)	0.6 (1.0)
LCS VII	-4.8* (1.3)	-0.5 (0.4)	-1.2* (0.9)	-0.5 (0.5)	0.1 (0.5)	0.03 (0.2)	-5.7* (2.9)	0.003 (0.9)
LCS VIII	-4.0* (1.6)	1.2* (0.6)	-2.6* (1.0)	2.1* (2.6)	-0.1 (0.6)	0.5* (0.2)	-7.2* (3.5)	2.1* (1.1)

¹ f = female

M = Male

MODEL

<u>VARIABLE</u>	<u>WORK</u>		<u>SHOP</u>		<u>ERC</u>		<u>S-L</u>	
	M	F	M	F	M	F	M	F
SUN	-3.4* (0.7)	-0.8* (0.2)	-2.2* (0.5)	-1.1* (0.3)	-1.1* (0.3)	0.6* (0.1)	3.6* (1.6)	0.8 (0.5)
MON	5.9* (0.9)	1.6* (0.3)	-1.6* (0.6)	0.3 (0.4)	0.1 (0.3)	0.4* (0.1)	-13.8* (2.0)	0.04 (0.6)
TUE	4.8* (0.9)	1.4* (0.3)	-1.2* (0.6)	-0.1 (0.4)	0.6* (0.3)	0.3* (0.1)	-12.5* (2.0)	-0.9 (0.6)
WED	5.9* (0.9)	1.5* (0.3)	-1.2* (0.5)	0.2 (0.4)	0.1 (0.3)	0.3* (0.1)	-14.4* (1.9)	-1.0 (0.6)
THUR	5.6* (0.9)	1.7* (0.3)	-1.3* (0.6)	0.8* (0.4)	0.2 (0.3)	0.5* (0.1)	-12.4* (2.0)	-1.1* (0.6)
FRI	5.1* (0.9)	1.5* (0.3)	-1.0* (0.6)	0.3 (0.4)	0.04 (0.3)	0.3* (0.1)	-9.8* (2.0)	-0.5 (0.6)
APR	0.6 (0.7)	0.2 (0.3)	0.4 (0.5)	1.0* (0.3)	-0.2 (0.3)	0.2* (0.1)	6.1* (1.7)	1.0* (0.5)
JUL	1.0 (0.7)	0.01 (0.3)	0.6 (0.5)	0.6* (0.3)	-0.5 (0.3)	-0.2* (0.1)	7.0* (1.7)	1.0* (0.5)
AUG	-0.2 (0.8)	-0.01 (0.3)	0.3 (0.5)	0.9* (0.3)	-0.1 (0.3)	-0.2* (0.1)	8.8* (1.7)	1.8* (0.5)
OCT	1.4* (0.7)	0.2 (0.3)	0.4 (0.5)	0.2 (0.3)	-0.2 (0.3)	-0.05* (0.01)	7.1* (1.7)	0.7* (0.5)

MODEL

<u>VARIABLE</u>	<u>WORK</u>		<u>SHOP</u>		<u>ERC</u>		<u>S-L</u>	
	M	F	M	F	M	F	M	F
MOUNTAIN	-0.2 (1.3)	-0.02 (0.5)	0.4 (0.9)	-0.7 (0.5)	-0.1 (0.5)	0.2 (0.2)	-4.9* (2.9)	-1.5 (0.9)
SUBURBAN	0.8 (0.6)	0.6* (0.2)	1.0* (0.4)	0.5* (0.2)	-0.03 (0.2)	0.1* (0.05)	1.3 (1.4)	0.5 (0.4)
RURAL	0.5 (0.6)	0.6* (0.2)	1.2* (0.4)	0.8* (0.2)	0.3 (0.2)	0.1 (0.1)	0.3 (1.3)	0.1 (0.4)
LOWMIDINC	1.5* (0.7)	-0.3 (0.2)	0.4 (0.4)	0.1 (0.3)	0.1 (0.2)	0.1 (0.1)	5.0* (1.5)	0.5 (0.5)
UPMIDINC	3.9* (0.8)	-0.5 (0.3)	0.5 (0.5)	0.4 (0.3)	-0.2 (0.3)	0.3* (0.1)	4.8* (1.8)	0.9 (0.6)
HIGHINC	5.8* (1.1)	0.2 (0.4)	0.2 (0.7)	1.3* (0.4)	0.4 (0.4)	0.3* (0.1)	8.8* (2.4)	0.9 (0.8)
EMPLOYED	0.4 (0.4)	1.8* (0.1)	0.2 (0.2)	-0.2* (0.1)	0.1 (0.1)	-0.01 (0.04)	1.3* (0.8)	-0.01 (0.3)
AUTOS	0.5 (0.4)	1.4* (0.1)	1.5* (0.3)	1.6* (0.2)	0.4* (0.1)	0.3* (0.06)	9.4* (0.9)	1.7* (0.3)

The explanatory power of each of these models is limited. They are merely explaining the mean value of DVMT for each purpose of travel-sex of driver class. Such models, however, are useful in that they recognize significant overall differences between these classes. Furthermore, our goal is to develop estimates of total DVMT for households. For such a purpose the ability to predict the mean of a distribution is just as useful as predicting the entire distribution.

The overall statistics of each model are presented in Table 20. Clearly none of the models explain very much of the total variation in the distribution of DVMT. An interesting result of this partition on total DVMT, however, is the difference in the means and variances of the eight distributions being modeled. There is substantial variation between sexes and purposes. Thus, the partition itself explains considerable variation in the data. The frequency distributions relating to the eight partitions are presented in Figures 27 thru 30.

The significance of the various dimensions is presented in Table 21.¹⁴ All but one of the dimensions was significant in three or more models. Of

TABLE 20
SUMMARY STATISTICS FOR USE MODELS

PURPOSE	SEX OF DRIVER	R ²	S.E.	MEAN	STD. DEV.
Work	M	.10	22.6	7.7	23.8
	F	.01	8.1	1.9	8.7
Shop	M	.07	8.0	3.4	10.1
	F	.02	2.7	2.1	9.3
EAC	M	.02	14.0	0.7	8.1
	F	.06	51.4	0.4	2.7
S - L	M	.03	9.4	14.2	32.9
	F	.01	16.3	2.0	19.4

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