ARIZONA DEPARTMENT OF TRANSPORTATION

REPORT NUMBER: FHWA/AZ 86/197

THE TECHNICAL FEASIBILITY, SOCIO-ECONOMIC IMPACT AND ENVIRONMENTAL BENEFITS OF ALTERNATE ENERGY VEHICLES AS RELATED TO THE STATE OF ARIZONA

Volume 1: Technical Summary
Final Report

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16. ABSTRACT

This study analyzes the potential market penetration in Arizona of various types of alternate energy vehicles. This market penetration is analyzed in terms of changes in the price of fuel, tax incentives, costs of conversion and consumer attitudes.

While the study analyzes data only through 1985, many conclusions and responses related to the previous rapid rise in fuel prices may be relevant in light of the rapid price increases of early 1987.

Short term market penetration, in the absence of legal intervention, is expected to amount to a very small fraction of the total operating fleet of motor vehicles.

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Technical Summary

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SECTION 1

BACKGROUND

1.1 THE BEGINNING (1981): ENERGY AVAILABILITY/COSTS AND POLLUTION CONCERNS.

The genesis for this particular study on Alternate Energy (AE) Transportation Systems started with a request for proposal (RFP), issued in late 1981 by the Arizona Transportation Research Center (ATRC), to study the effect of electric vehicles and AE transportation systems influx on highway revenue funds and pollution reduction in the state of Arizona. In part, the 1981 interest in studying the impact of AE systems and electric vehicles was driven by the seemingly "ever-increasing" costs of gasoline. In the three year span from 1978 to 1981 the average United States Labor Day price of gasoline (averaged for all types of gasoline) virtually doubled from approximately 69 cents per gallon to a price of $1.37 per gallon. At that time (1981) there seemed to be little doubt that gasoline costs would continue to rise (at a modest rate at best), petroleum energy supplies would diminish and pollution problems would continue to increase in the urban/metropolitan regions of the United States. Technical, economic, and marketing research studies conducted around 1980 to early 1982 on the commercial feasibility [1] * and potential demand for electric vehicles [2,3] suggested that the electric

*Note: Numbers in brackets designate references listed at the end of report.

vehicle, and other forms of AE transportation systems [4], offered a promising alternative to the petroleum consumption and pollution problems of the internal combustion engine (ICE) vehicles. Consumers seemed to be aware of the energy problem and energy conservation was becoming fashionable, as evidenced by the energy consumption data shown in Figures, 1-1 and 1-2 taken from reference 5.

In late March of 1982, Northern Arizona University (NAU) responded to the ATRC request for proposals related to Electric Vehicles and Alternate Energy Systems. Approximately a year and one-half later (i.e. November, 1983) NAU was awarded a contract (ADOT Contract No. 83-86) from the Arizona Department of Transportation (ADOT) to perform a two-year study on "The Technological Feasibility and Socio-Economic Impact of Alternate Energy Vehicles as related to the state of Arizona". The research project (No. HPR-1(28) item 197) was administered by the ATRC.

1.2 THE BASIC PROBLEM: A MULTI-DISCIPLINARY APPROACH

The 1981 problem of increasing petroleum costs has, at least temporarily, diminished as a major force of influence likely to cause consumer adoption of AE transportation technology. During the approximately 2 year time span from the RFP concept of this study (late 1981) to the time of the contract award (late 1983) the average costs of gasoline fell approximately 10 cents per gallon, with the current prices of gasoline dropping even farther, to about 90 cents per gallon, as shown by Figure 1-3. The results of this study, however, have shown that consumers likely to purchase AE vehicles do not consider the price of fuel as a key factor in adopting a new technology.

For several reasons, the rapidly growing urban areas of Phoenix and Tucson, Arizona, seem to have good potential for alternate energy vehicle markets. First, both areas are faced with increasing pollution problems and loss of federal revenues for air quality violations. Air quality standards during Winter of 1985-86 were violated in both Phoenix and Tucson. The Arizona population tends to be acutely aware of air pollution (and violations) and is willing to take positive steps to control it. Next, Arizona's abundant coal reserves, hydroelectric power, nuclear power, and broad distribution network for home-heating natural gas offer the potential for some near term (5 to 15 years away) alternatives to the pollution problems created by standard internal combustion engine vehicles. Unfortunately, concomitant with the pollution (and perhaps long term cost) advantages of the Alternate Energy Transportation systems there is the basic problem that highway revenue badly needed for repair and new roads would diminish from the traditional source of gasoline taxes if the use of gasoline were reduced through the penetration of a significant number of AE vehicles into the Arizona vehicle market if taxation alternatives were not implemented.

This study examined the above basic problem by means of an interdisciplinary approach. First, the socio-psychological characteristics of consumer lifestyles in Arizona were examined and evaluated relative to susceptibility for change, as related to behavioral attitudes which would influence the marketing of, or lack of interest in, electric, hybrid electric or other alternative technology vehicles. Next the technological feasibility of AE vehicles and associated costs were integrated into a marketing/socio-economic demand study to determine which trends and factors were most likely to impact the level of AE vehicle market penetration in Arizona. The above factors were combined with various fuel/vehicle scenarios and costs (i.e. crisis situation, rationing, no-rationing, etc.) and used in the development of a AE vehicle market penetration forecast model for the state of Arizona. The forecast model was designed to enable parametric studies on various AE vehicle fee schemes and incentives to enable ADOT management to assess what types of fee approaches and policies would best suit the joint economic and environmental needs of the state, the utility companies, and the consumer. Figure 1-4 illustrates a schematic of how the multi-disciplinary areas and study results were integrated into the NAU forecast model. The figure also identifies the respective project directors for each of the primary research areas.

1.3 GOALS AND OBJECTIVES

The primary goal of this research project was to develop an Alternate Energy Vehicle (AEV) forecast model which would enable ADOT management to:

1) Estimate potential highway revenue loss (if any) due to penetration of AEV's;

2) Evaluate possible user fee schemes for recovery of lost highway revenue; and

3) Make technically sound policy decision and legislative recommendations relative to taxation of AEV systems.

In order to achieve the primary goal of this research effort it was necessary that certain key issues and basic data be identified and examined in the areas of socio-behavioral sciences, economics and demand penetration of AEV systems, AEV technology/costs and infra-structure, and systems modeling. A summary of the key objectives in each of the above areas are as follows:

A. Behavioral Study Objectives:

1. Identify the attitude and behavioral characteristics of AEV users and non-users. (Data indicates that most multi-car families are more affluent, but the most affluent or middle/upper classes are not really motivated to adopt alternative technologies. The less affluent young and elderly classes are more likely to consider alternate technologies);

2. Assess the current level of public knowledge about electric vehicles and other alternate energy systems such as compressed natural gas and propane powered vehicles.

3. Identify the advantages and disadvantages (real and

imagined) of alternate technologies for transportation.

B. Technology Study Objectives:

1. Identify the most likely forms of alternate energy vehicle systems for the immediate (0 to 5 years away), near term (5 to 15 years away), and for long term (15 to 25 years away) time frames;

2. Estimate the costs to consumers for the most likely AEV systems;

3. Review alternate energy key issues likely to result in fluctuations in petroleum and natural gas prices;

4. Estimate energy availability and possible AE use scenarios for input to the economics/demand penetration study and the Forecast model.

C. Economic/Demand Penetration Study Objective:

1. Identify key economic factors and other related system parameters which can be measured currently and then be used to specify forecasting and/or prediction models suitable for estimating demand for AE vehicles.

2. Evaluate the demand/penetration effects of various differences relative to conventional ICE vehicles such as higher costs for AEV's, limited range, lower pollution, lower operating costs, etc.;

3. Coordinate with the behavioral studies group to adjust as appropriate the demand/penetration likelihood based on user/consumer preferences and attitudes.

D. Systems Modeling Study Objective:

1. Identify the key modeling parameters associated with the behavioral study, economics/marketing penetration study, and the AEV technology study;
2. Integrate the findings of the various study groups to develop an interdisciplinary forecasting and/or prediction model to enable ADOT to investigate the likelihood of AEV market penetration into the state of Arizona and also allow assessment of certain user fee schemes;
3. Investigate the sensitivity of the model to changes in the operating environment (i.e. variations in parameters);
4. Assess the ability of the model to make reasonable predictions;
5. Develop and document the model, and the resulting computer code, in such a manner as to make it useful to ADOT personnel (i.e. have simplified desk top personal computer version of the code along with the larger main frame version and write the code in a language(s) that makes it easily portable;
6. Provide a user seminar to ATRC and ADOT personnel.

1.4 RESEARCH APPROACH

In developing a model to assess the impact of alternative fuels, the NAU team of investigators reviewed extensive literature and research which dealt with 1) descriptions of alternative fuel scenarios and fuel crises, 2) expert's predictions of likely alternative fuels, and 3) cost/benefit studies related to alternative fuel projects. Many of these studies have used computer models based on data extrapolated from experts or based on a limited number of interviews with consumers. In some cases, models were developed to predict the feasibility of mass production of selected technologies. <u>Most of the forecasts indicate limited potential for alternative vehicles</u>. For example, electric vehicles are perceived as having a limited range, lengthy refueling, limited performance, and limited load carrying capability. These factors negatively impact the development of mass production for the general consumer or private market and are well articulated in the research. Consumer behavior, attitudes, knowledge, misconceptions and preferences were not included in the above studies.

Discussions held with electric vehicle manufacturers and the NAU research team [6] reinforces the importance of the role of human factors in this interdisciplinary study. For instance, a lack of knowledge of the consumer attitudes (either conscious or subconscious) related to what the consumer expects to see when looking under the hood of an electric vehicle, or what fears and apprehensions (real or imagined) the consumer may have regarding servicing, repair-ability and <u>trade-in value</u> of an AEV may represent a major block to the successful marketing of AEV's in the state of Arizona, in spite of the many attractive features of

AEV's when considering environmental and energy factors. Issues such as energy availability, costs, technical performance and comfort and convenience, as well as safety, are also important AEV marketing considerations.

The NAU AE research team felt that the above behavioral factors could provide valuable input for a more accurate model of demand penetration of AEV's into the state of Arizona and, subsequently, a more accurate forecast model of fuel consumption. Therefore, extensive demographic research was undertaken, through the use of personal interviews and surveys, to model an average driver. This demographic information was obtained to 1) develop a profile of the average driver in Arizona, and 2) to make comparisons between Arizona samples and national statistics. The socio-behavioral surveys were made by direct contact with consumers at malls or shopping areas in Flagstaff, Phoenix and Tucson. The NAU research team set up an alternate energy display complete with a working electric vehicle and a hydrogen powered vehicle or CNG vehicle. Consumers were attracted to the vehicles and expressed willingness to complete the entire survey questionnaires illustrated in appendices A and B. The Flagstaff survey was conducted first as a trial run and, based upon the consumer response, the survey questionnaire was then modified slightly for use in the Phoenix and Tucson areas. Details of the socio-behavioral characteristics of Arizona drivers are presented in section 3 of this report.

By using the research from the social and behavioral sciences it is possible to gain a fundamental understanding of the assumptions, and possible misperceptions used by a consumer during the purchase or rejection of a new or innovative technology. For example, several years ago, the state of Hawaii tried to encourage "gasohol" consumption with the intent that local sugar cane industries could supply the alcohol thus reducing the states heavy dependence on oil or petroleum imports [7]. Originally gasohol (a mixture of about 10% alcohol, such as methanol, with 90% gasoline) created certain problems with standard vehicle designs (such as drying out of seals and subsequent leaking of fuels) and appropriate warnings were issued to consumers. The negative impact of these warnings persisted and affected consumption. In an attempt to overcome these negative impacts, several companies changed the "gasohol" label to "high octane booster". The label change coupled with a <u>reduced state sales tax incentive</u> on the "high octane booster" fuel resulted in greatly improved consumer usage in the state of Hawaii [7]. A similar trend is occurring in the mainland United States. For whatever reason, the label "gasohol" does have a negative impact on consumers whereas "high octane" does not.

Market or <u>demand penetration</u> of AE vehicles seems to be affected by similar consumer attitudes and misperceptions. As a result, the market or demand penetration study of this project also used a consumer type of survey to determine: 1) key buying trends; 2) willingness to purchase AEV's; and 3) likely <u>percent of penetration</u> of AEV's into the state of Arizona. Past similar studies [8, 9, 10] have looked at consumers in general and the results have very limited reliability to the Arizona market. This study focused on the target groups most likely to adopt the technology, with the assumption that other segments of the Arizona population will follow the behavior of these groups if price and performance meet the expectations of the public.

The market or vehicle demand survey was designed to provide quantitative estimates of the value Arizona consumers place on various vehicle attributes. This information was then used to determine the threshold price at which various consumers would be willing to switch to alternately fueled vehicles of a variety of alternate types. The primary output of the demand/marketing survey was a statistical result (analysis of variance) which was used to evaluate the relative importance of various vehicle attributes to consumers. This data was helpful in determining which of the wide variety of possible alternative technologies was most plausible to the residents of Arizona. In addition the statistical results provided the basis for estimates of the market penetration of various alternate technologies under given scenarios. To support such estimates the scenarios had to specify selling prices and fuel costs of each vehicle configuration.

Data on AE vehicle types, costs for new or converted designs, fuel/energy economy data, fuel/energy costs, likely performance data, and future scenario data based on likely energy availability of AEV systems were supplied by the AE technology study section of this report. Details of the AE technology study are contained in section 2 of this report. Figure 1-5 illustrates the close integration of the technological, social-behavioral, and marketing/demand penetration studies with the NAU Forecast model development.

The vehicle demand survey was administered to various service groups in conjunction with a 30 minute technical slide presentation designed to familiarize the survey audience with the potential alternate vehicle technologies. It was felt that such a presentation was necessary in order to develop knowledge among respondents sufficient to provide reasonable data. It should be noted that the social-behavioral survey study tested respondents to ascertain their level of knowledge about AEV systems without the benefit of a technical presentation (the socio-behavioral survey study did however use a display of AE vehicles to attract consumers to the survey area). Figure 1-66 illustrates some of the vehicle characteristics examined in the study of quantitative cost estimates likely to be paid for various attributes. In addition to the vehicle cost/attribute questions related to Figure 1-6 the initial market survey also tested for demographic information as a cross-check on the socio-behavioral demographic data and consumer characteristics. A complete set of marketing survey questionnaires are contained in Appendice C and D. Based upon the marketing/economic results obtained from the vehicle attribute study a second phase of surveys were conducted to determine the estimate of market penetration under various fuel/energy supply scenarios. Five basic scenarios were examined in this phase of the market demand penetration study. Scenarios included considerations such as:

1.) Future gasoline and alternate energy prices remain relatively constant with current costs;

2.) Future gasoline prices continue to drop at a rate similar to that shown in Figure 1-3 for the years 1981 through 1985 such that gasoline costs become the same or less than alternate energy;

3.) Future gasoline prices rise and alternate energy sources such as natural gas become much cheaper than gasoline;

4.) Fuel/energy prices remain as in scenario 1, but state government incentives are allowed for alternate energy vehicle systems; and

5.) A petroleum energy crisis occurs which drastically raises the price of gasoline but AE vehicle conversions are also very costly.

Figure 1-7 illustrates the relationship of scenarios to vehicle types and costs, tested in the demand penetration study phase of this research project. Figures 1-8, 1-9, and 1-10 present, respectively, a brief summary of the consumer demand approach, the vehicle choices presented to the respondents, and a summary of the demand results.

The forecasts of fuel use and ADOT revenues under alternate energy penetrating scenarios required that the demand survey data be integrated with the ASU ADTFUEL model [11] to generate:

1. Vehicle miles traveled by vehicle type;
2. Use tax revenues by vehicle type;
3. Total vehicle purchases per year by type; and
4. License tax revenues by vehicle type.

The demand survey data provides the basis for estimates of taxpayer response to any tax change since any tax/license fee will change either the purchase price or operating cost of a vehicle. Details of the demand survey and market penetration studies are presented in sections 5 through 6 of this report.

The results of the demand penetration survey study indicated that the compressed natural gas (CNG) vehicle was the most likely AE system to penetrate the Arizona transportation vehicle market in the next 5 to 15 years. As a result of the above the NAU Forecast Model (termed NAUFC) was developed by taking into account the most likely AEV system and associated costs.

The NAU Forecast Model predicts the penetration of CNG technology vehicles into the private fleet of Arizona. Regular demand studies should be made to ascertain if there is any change in the type of AE system likely to penetrate the Arizona market. Any changes with associated costs, etc., can be easily input to the NAU Forecast Model by a change of variables and certain parameters discussed in detail in section 6 of this report. Figure 1-11 illustrates the general input provided to the NAU Forecast Model. The NAU Forecast (F6) Model is written in two versions, Fortran and Pascal. The NAU-FC Model can be run on either a micro-computer such as a Vax, or a larger main frame such as the Honeywell DPS-8. A desk-top personal computer version is also available but does not have the accuracy capability of the larger machine versions of the program.

The NAU-FC Model allows user inputs such as: 1) duration (years) of simulation desired; 2) specific downstream year for introduction of AEV technology; 3) future hypothesized values for the prices of gasoline and AE fuel; and 4) fuel tax rates. The NAU-FC Model output provides, for various scenarios, information on: AEV penetration; miles traveled; and amount of gasoline used. Thus, the user inputs can be used by the modeler to test the sensitivity of the system output, such as gallons of gasoline reduction, to factors such as sales tax incentives on AE vehicles versus higher taxes on the gasoline vehicles thereby stimulating a certain amount of penetration toward the AEV's. As shown by Figure 1-11 the model was constructed using data from several sources.

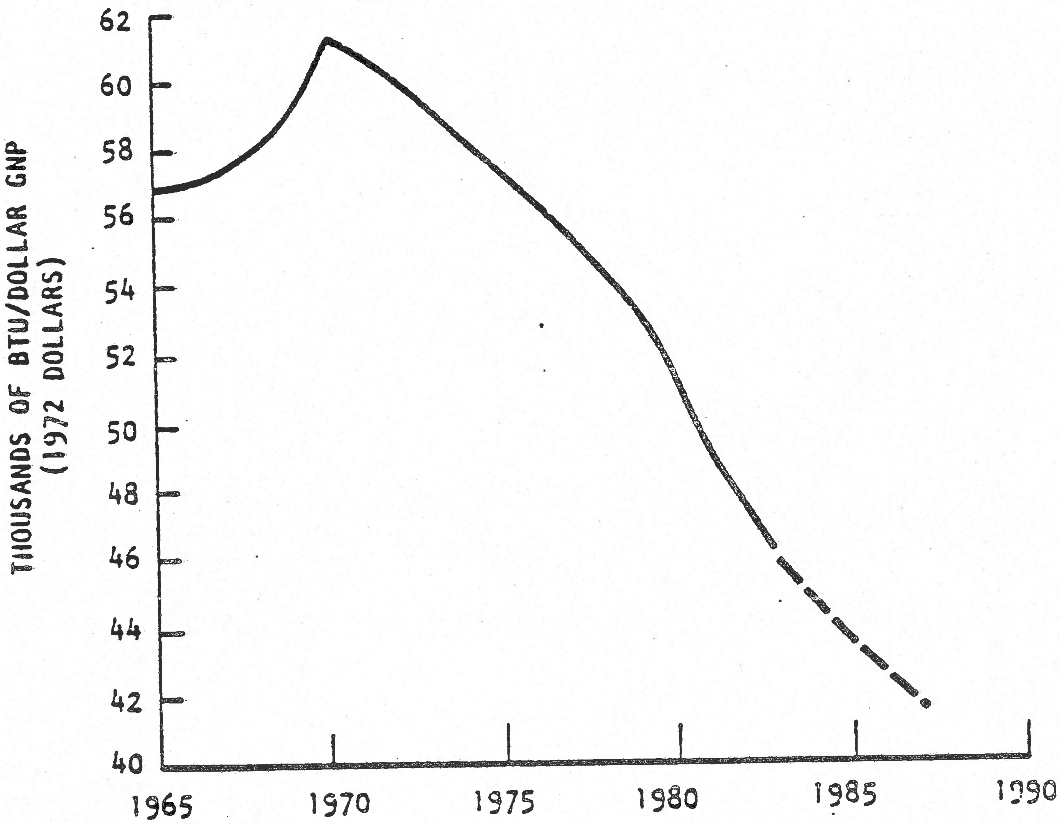
The data for Arizona fleet size and miles traveled in Arizona are from the Arizona State University (ASU) multi-linear regression models developed for ADOT in 1981 under grant number N-800-266 [11]. The data for innovation and penetration levels are from the NAU behavioral, technological, and market studies. Due to the fact that the ASU model assumed incorrectly in 1981 that the price of fuel was going to continue rising (see Figure 1-3) it was necessary for the NAU research team to request updated registration data from ADOT for the years from 1982 to 1985. Figure 1-12 illustrates a list of the data requested from ADOT. Some of the data was provided from the ADOT to the NAU research team; in many instances however it was necessary for the NAU research team to use national average data and adjust for the Arizona population in order to correct the ASU data base used in the NAU-FC model. It is strongly suggested that the ADOT maintain a yearly update of the NAU information gathered thus far to keep the ASU input current and as accurate as possible.

Although great effort was taken in this study to provide accurate quantitative data, several assumptions were also required and went into the model. Thus the output of the model is only as good as the uncertainty of the future scenarios, energy prices, and conversion/manufactured vehicle costs. In general the NAU-FC model results indicate that the model is good enough to predict general trends, but not exact quantities. As noted, details of the forecast model along with illustrative examples are contained in section 6 of this report. In addition, a Volume II: User Manual for the NAU-Forecast Model has also been generated which details the operation of the code.

Figure 1-13 illustrates the major phases, amount of funding, and time schedule used in the 2 year NAU study. It should be noted that although the NAU/ADOT contract was actually executed in late 1983, the teaching schedules of the NAU faculty had been established through May of 1984 and hence the contract work did not get underway until the summer of 1984.

FIGURE 1.1

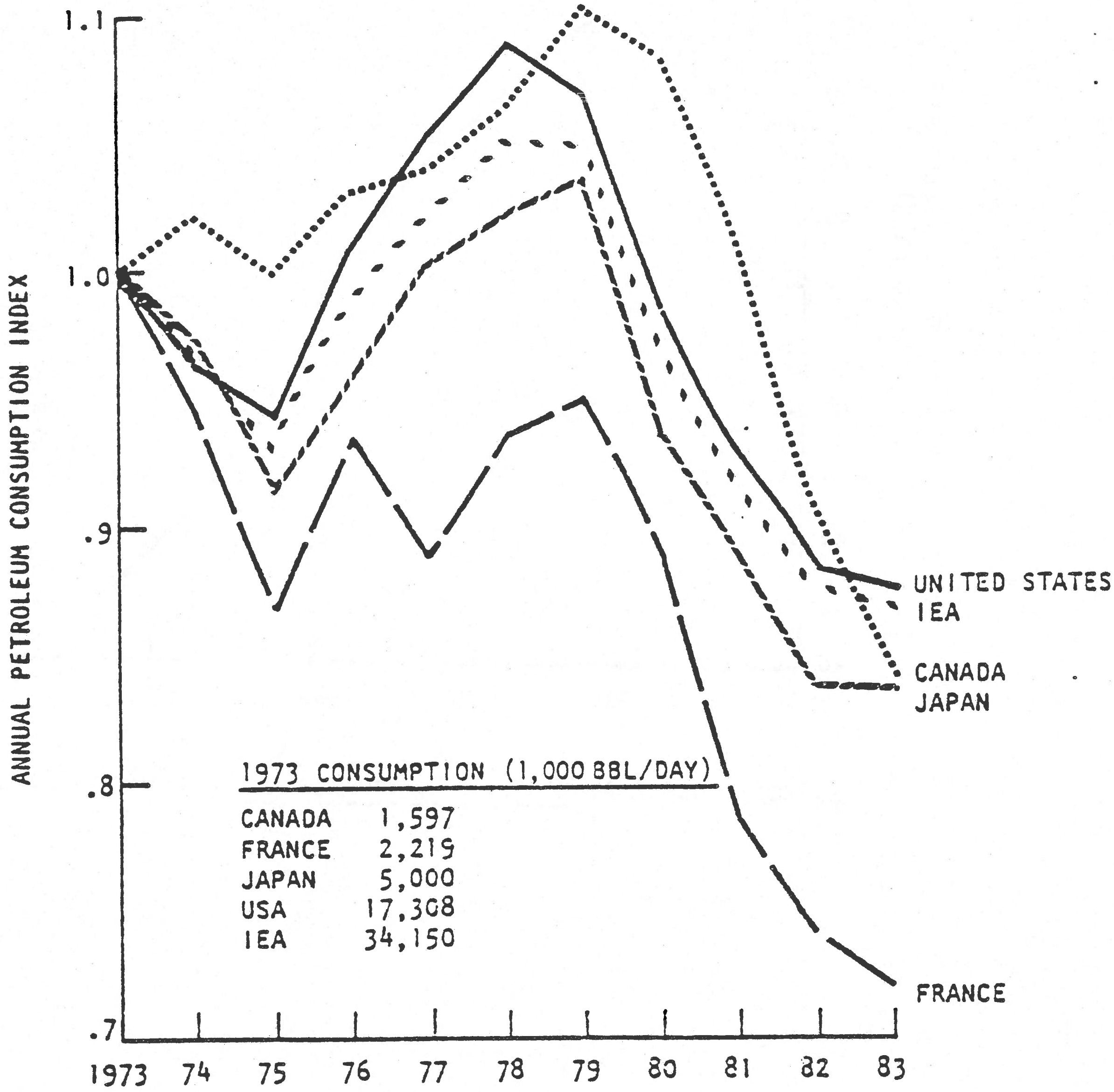
U.S. PRIMARY ENERGY CONSUMPTION
PER UNIT OF GNP



SOURCE: DOE/EIA, MONTHLY ENERGY REVIEW, MARCH 1984.

FIGURE 1.2

CHANGES IN PETROLEUM CONSUMPTION SINCE 1973 FOR SELECTED INDUSTRIALIZED COUNTRIES



SOURCE: DOE/EIA MONTHLY ENERGY REVIEW, APRIL 1984.

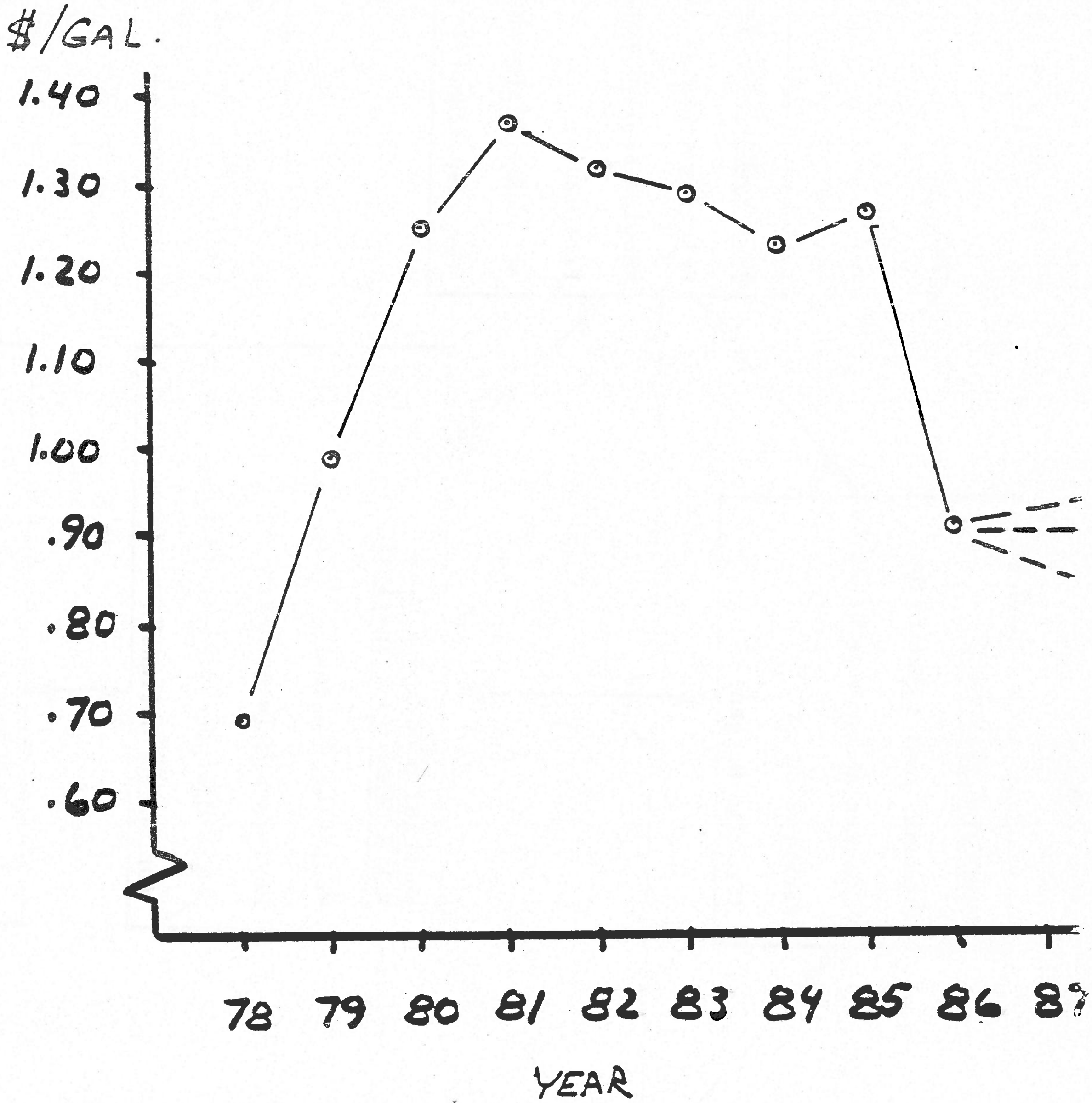


FIG. 1.3 GASOLINE COSTS (U.S

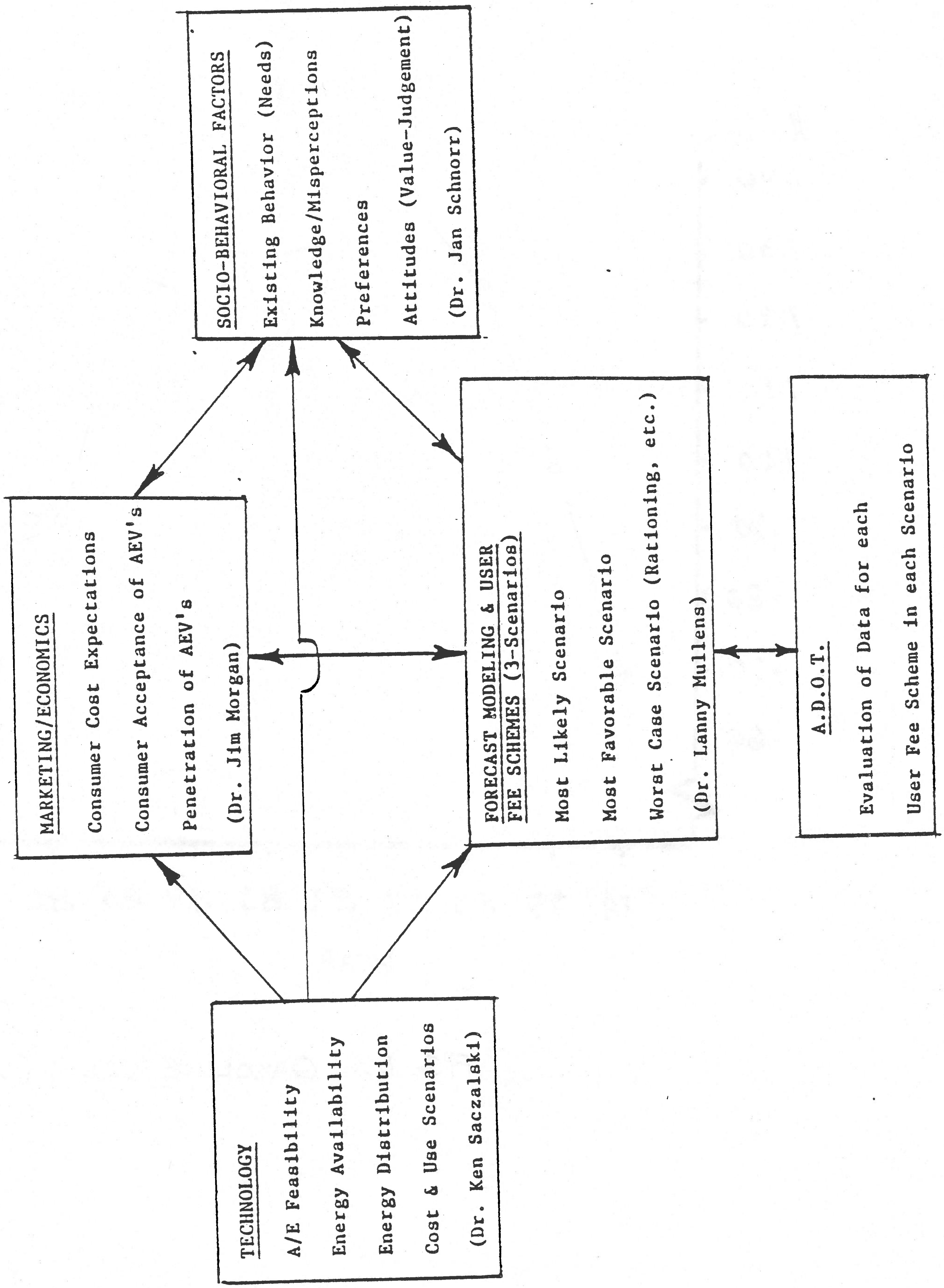

SOCIO-BEHAVIORAL FACTORS
Existing Behavior (Needs)
Knowledge/Misperceptions
Preferences
Attitudes (Value-Judgement)
(Dr. Jan Schnorr)
MARKETING/ECONOMICS
Consumer Cost Expectations
Consumer Acceptance of AEV's
Penetration of AEV's
(Dr. Jim Morgan)
FORECAST MODELING & USER FEE SCHEMES (3-Scenarios)
Most Likely Scenario
Most Favorable Scenario
Worst Case Scenario (Rationing, etc.)
(Dr. Lanny Mullens)
A.D.O.T.
Evaluation of Data for each
User Fee Scheme in each Scenario
TECHNOLOGY
A/E Feasibility
Energy Availability
Energy Distribution
Cost & Use Scenarios
(Dr. Ken Saczalski)

FIGURE 1.4

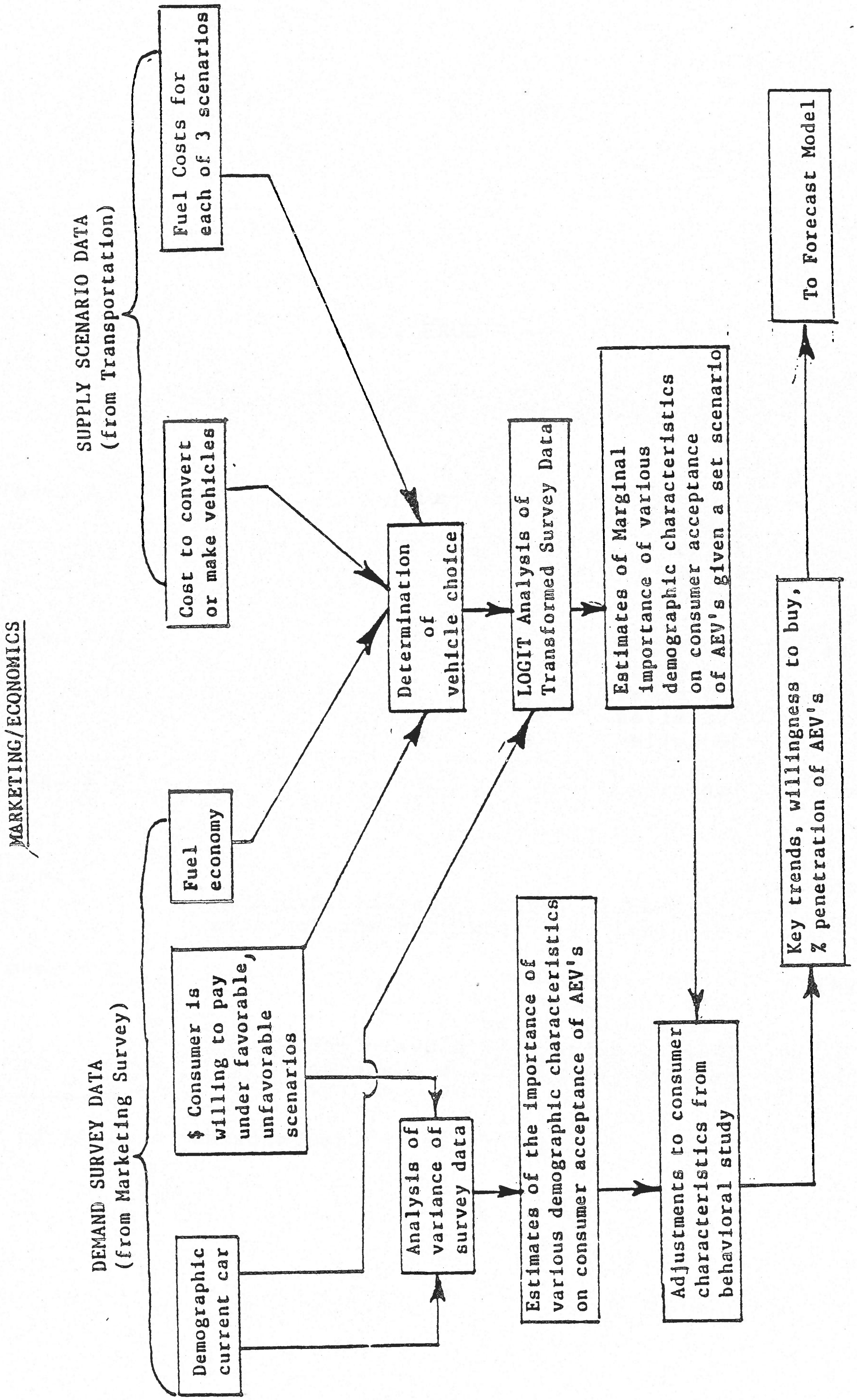

MARKETING/ECONOMICS
DEMAND SURVEY DATA
(from Marketing Survey)
SUPPLY SCENARIO DATA
(from Transportation)
Demographic current car
$ Consumer is willing to pay under favorable, unfavorable scenarios
Fuel economy
Cost to convert or make vehicles
Fuel Costs for each of 3 scenarios
Analysis of variance of survey data
Determination of vehicle choice
LOGIT Analysis of Transformed Survey Data
Estimates of the importance of various demographic characteristics on consumer acceptance of AEV's
Estimates of Marginal importance of various demographic characteristics on consumer acceptance of AEV's given a set scenario
Adjustments to consumer characteristics from behavioral study
Key trends, willingness to buy, % penetration of AEV's
To Forecast Model

FIGURE 1.5

FIGURE 1.6

TENTATIVE LIST OF ATTRIBUTE LEVELS

Fuel Cost Per 10000 Miles of Travel	4 Levels
$ 250	
$ 500	
$ 750	
$1000	
Range Before Refueling	3-4 Levels
50 miles	
100 miles	
150 miles	
300 miles	
Passenger Capacity	2 Levels
2	
4	
Trunk Capacity	2 Levels
1/2 that of Typical Current Compacts	
Identical to Typical Current Compacts	
Type of Fuel/Refueling Time	3-4 Levels
Gasoline/Quick Fill	
Electric/Overnight	
CNG-LNG/Quick Fill & Overnight	
Hydrogen/Quick Fill & Overnight	
Total Attribute Combinations	144 to 256

FIGURE 1.7

SUPPLY SCENARIO SPECIFICATIONS

	SCENARIO 1	2	3	4	5
Purchase Price AV-Conventional Vehicle:					
Car 1 (Natural Gas)	$ 800	$1800	$ 800	$ 800	$ 1800
Car 1A (Natural Gas with with home refueling)	$1500	$2500	$1500	$1500	$ 2500
Car 2 (Hybrid-Retrofit)	$2200	$2200	$2200	$2200	$ 3200
Car 2A (Hybrid-Mfg.)	$1700	$2700	$1700	$1700	$2700
Fuel Cost Per Mile					
Natural Gas - Gasoline	- 1	- 5	- 3	- 1	-3
Other Scenario Features:					
Sales Tax Exemption for AVs	No	No	No	Yes	No
Rationing	No	No	No	No	Yes

CONSUMER DEMAND SURVEY APPROACH

ADMINISTER SURVEY AS PART OF A PRESENTATION DESCRIBING AV TECHNOLOGIES

SURVEY SERVICE ORGANIZATIONS, COMMUNITY COLLEGE/UNIVERSITY CLASSES (ATTEMPT TO SURVEY GROUPS AS REPRESENTATIVE AS POSSIBLE OF THE GENERAL POPULATION)

USE DEMOGRAPHIC DATA GATHERED WITH SURVEYS TO ADJUST SURVEY RESULTS TO REPRESENT THE POPULATION

FIGURE 1.8

VEHICLE CHOICES PRESENTED:

TYPICAL CURRENT VEHICLE

TYPICAL CURRENT VEHICLE IMPROVED MILEAGE

VEHICLE WITH 200 MILE RANGE 12 MINUTE REFUELING (CNG/HYDROGEN)

AS ABOVE WITH OVERNIGHT HOME REFUELING TO A 75 MILE RANGE (CNG)

HYBRID VEHICLE - GASOLINE OPTION 350 MILE RANGE 6 MINUTE REFUELING PLUS ALTERNATE SOURCE OVERNIGHT REFUELING FOR A 75 MILE RANGE (GASOLINE - CNG/GASOLINE - ELECTRIC)

AS ABOVE WITH HALF OF TRUNK SPACE USED BY ALTERNATE FUEL TANK (GASOLINE - CNG RETROFIT)

VEHICLE WITH 50 MILE RANGE AND OVERNIGHT REFUELING (ELECTRIC)

AS ABOVE WITH 100 MILE RANGE (ELECTRIC)

AS ABOVE WITH 350 MILE RANGE (ELECTRIC)

FIGURE 1.9

PRELIMINARY RESULTS

- SIGNIFICANT NUMBER OF RESPONDENTS WOULD CONSIDER SWITCHING TO CNG VEHICLES AT CURRENT OR MARGINALLY IMPROVED PRICES

- SHORT RANGE LONG REFUELING TIME OF ELECTRIC VEHICLES MAKE THEM AN UNATTRACTIVE ALTERNATIVE FOR MOST CONSUMERS

- UNDER RATIONING OPERATING COSTS BECOME LESS IMPORTANT

- TECHNOLOGIES TREATED
  - CNG
  - HYDROGEN
  - ELECTRIC
  - CNG - GASOLINE
  - ELECTRIC - GASOLINE

FIGURE [illegible] 10

SIMULATION - FORECAST MODELING

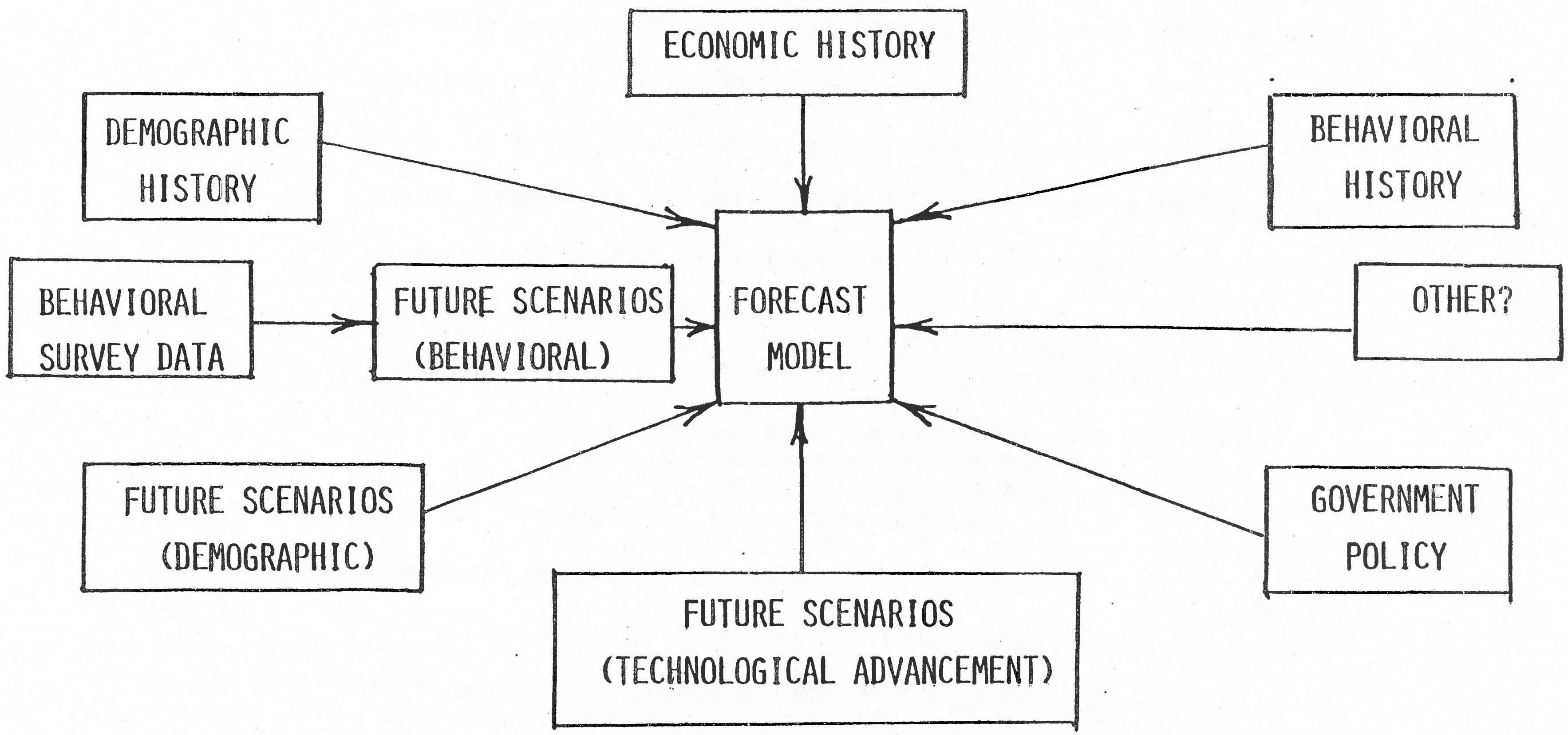


FIGURE 1.11

ARIZONA VEHICLE REGISTRATION DATA REQUESTED
FOR NAU ADOT SPONSORED RESEARCH PROGRAM (83-86)

(For Years 1968, 1973, 1978, 1983)

1. Number of Licensed Drivers in Arizona

    A. Number of Males and Females
    B. Number of Drivers Below 20 years of age.
    C. Number of Drivers 20 to 34 years of age.
    D. Number of Drivers 65 years of age and above.

2. List or number of registrations for alternate energy vehicles by type (i.e., Electric, Propane, Natural Gas, etc.) and whether commercial or private.

3. Number of private registrations vs. commercial registrations.

4. Total number of registrations for cars, buses and trucks.

5. Average number of vehicles per household, if possible.

6. Average miles per vehicle per year.

7. Average amount of fuel used per year by each vehicle type.

FIGURE 1.12

MAJOR PHASES OF A/E STUDY & TIME SCHEDULE

	SUMMER 1984	FALL 1984	SPRING 1985	SUMMER 1985	FALL 1985	SPRING 1986	SUMMER 1986
1. TECHNOLOGICAL FEASIBILITY OF ALTERNATE ENERGY	X	X	X				
2. A/E FUEL DISTRIBUTION INFRA-STRUCTURES	X	X	X				
3. ENERGY AVAILABILITY, COST & USE SCENARIOS	X	X	X				
4. BEHAVIORAL ATTITUDES, ECONOMICS MARKETING	X	X	X	X	X		
5. FORECAST MODELING, USER FEE SCHEMES, & CODE DEVELOPMENT			X	X	X	X	
6. USER MEETINGS, SEMINARS & WORKSHOPS ON USE OF CODE					X	X	X

TOTAL FUNDS AVAILABLE FOR PROJECT - $ 88,500.00

FIGURE 1

SECTION 2

AE TECHNOLOGICAL FEASIBILITY

2.1 ENERGY AVAILABILITY: SOME POSSIBLE FUTURE SCENARIOS

In his interim report on "Alternate Energy - Issues and Perspectives" [12], Dr. William M. Brown of the Hudson Institute notes several world events which have obvious implications on the availability of U.S. petroleum supplies and the subsequent levels of petroleum prices to U.S. consumers. Figure 2.1 shown below lists some of the potential energy related events cited in reference 12.

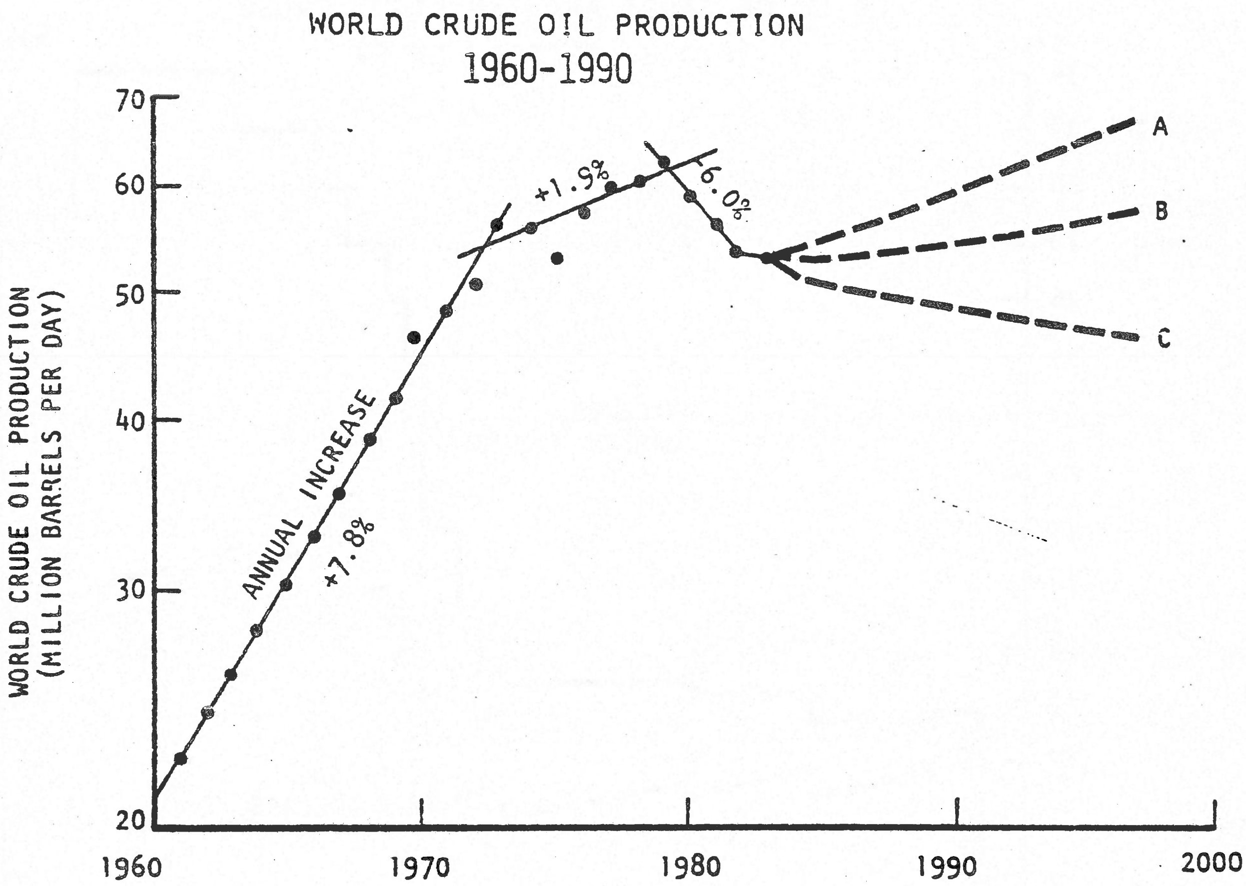
1. Energy Conservation and Energy Efficient Designs
2. Saudi Arabian Pricing and Production Incentives
3. Deregulation of Natural Gas Prices
4. Energy Taxes in Import-dependent Nations
5. Energy Production Incentives for Conventional and Unconventional Energy Sources
6. Mexican Oil and Gas Production
7. Soviet Oil and Gas Exports
8. Outcome of the Iran-Iraq War
9. Soviet Incursion into Iran

Figure 2.1 Possible Energy Related Events Which Would Impact Fuel Prices

As noted in section 1.1 and shown in figure 1.2 the U.S. and other selected industrialized nations have adopted rather successful energy conservation measures since the first energy crisis of the early 1970 time frame. The impact of these conservation measures has resulted in drastic reductions in energy consumption levels. In addition, the level of world crude oil production has started to decline due to a surplus in world petroleum supplies (related in large part to successful conservation measures) which resulted in lower demand and subsequently lower prices to certain petroleum producing nations such as Saudi Arabia. These trends of lower production levels and reduced costs in terms of U.S. dollars paid per barrel of crude oil are shown in figures 2.2 and 2.3, respectively. The result of these conservation and production measures as related to the price of gasoline paid at the pump by U.S. consumers was dramatically illustrated by figure 1.3 which shows a drop of about 34% in consumer gasoline costs from 1981 to 1986.

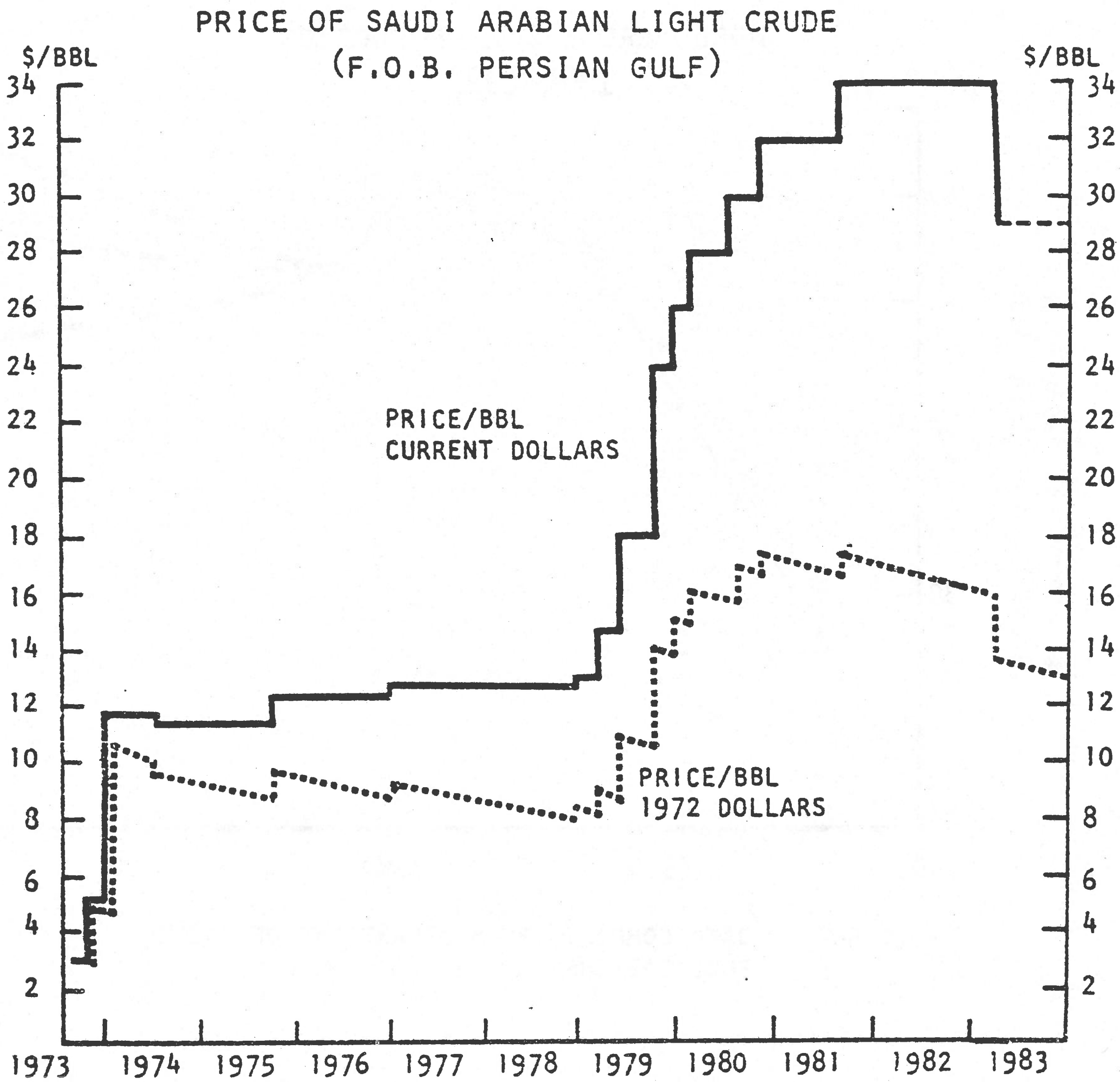
It is interesting to note that during the time period prior to 1981, and up to as recently as 1984, most forecasters associated with large institutions, such as CONOCO and TEXACO, were predicting a relatively stable world demand for oil with future growth of about one to two percent for the next 20 years [12]. In line with the demand predictions were similar predictions of a steady increase in gasoline prices for the U.S. consumer (in spite of the actual downward trend since 1981 exhibited in figure 1.3). Similar predictions were used in the ASU/ADOT Forecast Model [11]. Contrary to the above prediction, Dr. William M. Brown has suggested [12] that a more likely scenario for future energy prices, at least for the next five

FIGURE 2.2



SOURCE: DATA COMPILED FROM DEPARTMENT OF ENERGY PUBLICATIONS.

FIGURE 2.3



SOURCE: PETROLEUM ECONOMIST, AS COMPILED BY W.M. BROWN.

years (i.e. 1985 to 1990), would be the downward trend that is evident today in 1986. Furthermore, in 1980 and 1981 when all other forecasters were predicting a rise in the cost per barrel of crude oil (and noting the strength of OPEC), Dr's. William M. Brown and Herman Kahn predicted that OPEC's oil exports would shrink (which they did) and that oil prices would decline (which they did) [13, 14]. Furthermore, in his 1984 report to the NAU Alternate Energy Research Project Group, Brown [12] suggested that the price of crude oil would more than likely drop to less than $15.00 per barrel by 1985 (current 1986 prices are approximately $13.50 per barrel).

Obviously, in light of the above recommendations by Brown [12], one scenario implemented in this AE study included that of decreasing petroleum prices at the rate of about 3% per year, for at least the next decade, with a bottom out price of about 65 cents per gallon. As noted, the above scenario (termed scenario - 1 hereafter) was driven primarily by energy conservation and the pricing and production rates of certain OPEC members. Brown points out that higher energy taxes applied to petroleum products used in import-dependent nations would continue to encourage energy conservation measures and help maintain the more stable and somewhat lower fuel costs.

Another factor which has in the past played a significant role in increasing U.S. dependency on foreign oil imports was the U.S. federal government control on natural gas (NG) prices [12, 15]. As the NG prices were held artificially low and manipulated by the federal government there was less and less monetary incentive for U.S. and world energy producers to continue to produce natural gas. Figure 2.4 illustrates the well head price of natural gas in $ per thousand cubic feet for the years since the 1954 Supreme Court ruling (which allowed government regulation of NG) up to the 1980 time frame.

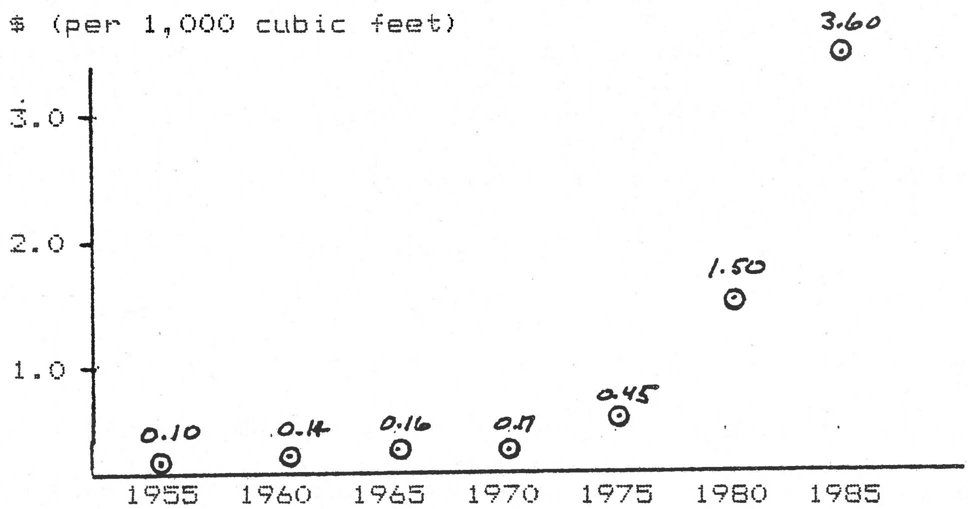


Figure 2.4 Average Gas Prices at the Well Head per 1,000 Cubic Feet
(Data Compiled by K. J. Saczalski)

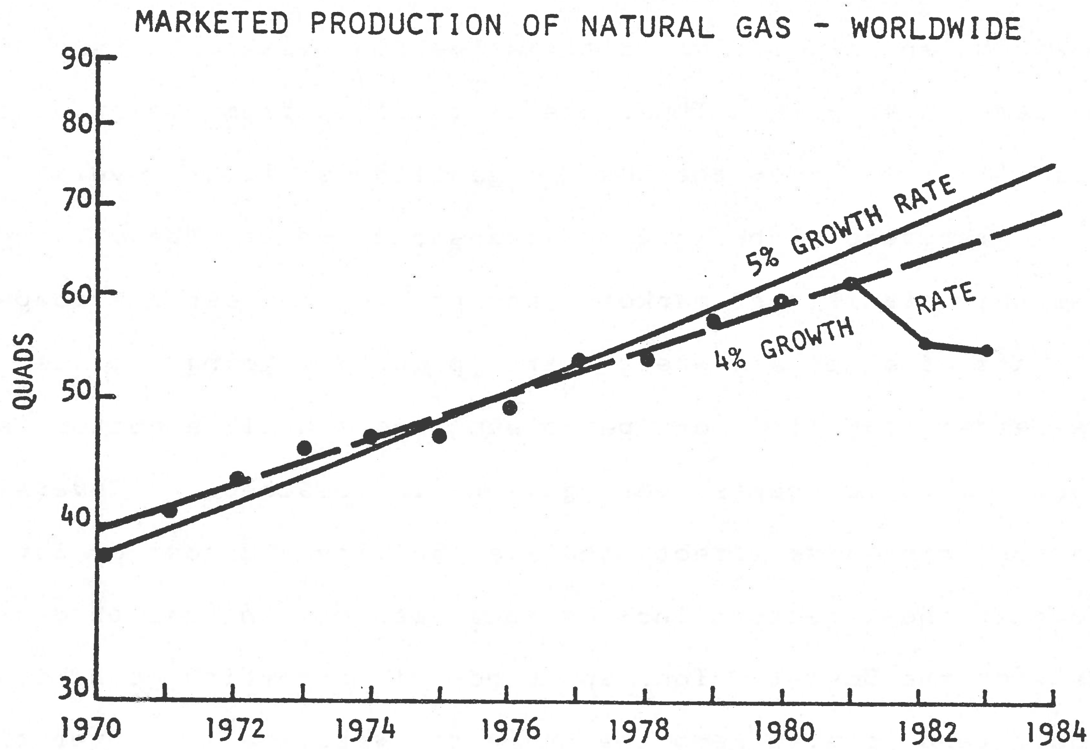
One result of the U.S. government control on natural gas prices is the fairly low level of market production for both the U.S. and the world as illustrated by figure 2.5. Oppenheimer [15] notes that "from the well head to the point of end use, natural gas enjoys significant cost advantages over oil". Brown also feels that with deregulation the price of natural gas should rise enough to make it more attractive to produce NG but at the same time it will be cheaper than oil due to the tremendously lower production costs when compared to processing and shipping of crude oil.

The Phoenix and Tucson areas have a very well laid out natural gas pipeline throughout the urban/metropolitan areas. Ease of access of NG for an AE transportation source, coupled with a relatively cheaper cost per mile and cleaner emissions, makes NG an attractive alternative to gasoline transportation systems in Arizona. Thus, the competition from deregulated NG is also likely to keep the cost of gasoline at lower levels.

Because of the large infra-structure of the oil industry, and the significant market, any potentially serious competitive threats of alternate energy are probably going to be met by decreased gasoline or petroleum costs until a bottom level of about 65 to 70 cents per gallon is reached. Several other factors can also effect the availability and cost of petroleum. Some of these factors include increased oil and gas production in Mexico, the Soviet Union, and other oil exporting countries which would tend to also keep the price of gasoline low over the next several years. Brown feels that the economic problems currently faced by Mexico will, for various obvious reasons (i.e. bad credit and no international loans for increased oil exploration and production), only maintain current oil production levels at best (see figure 2.6) [12].

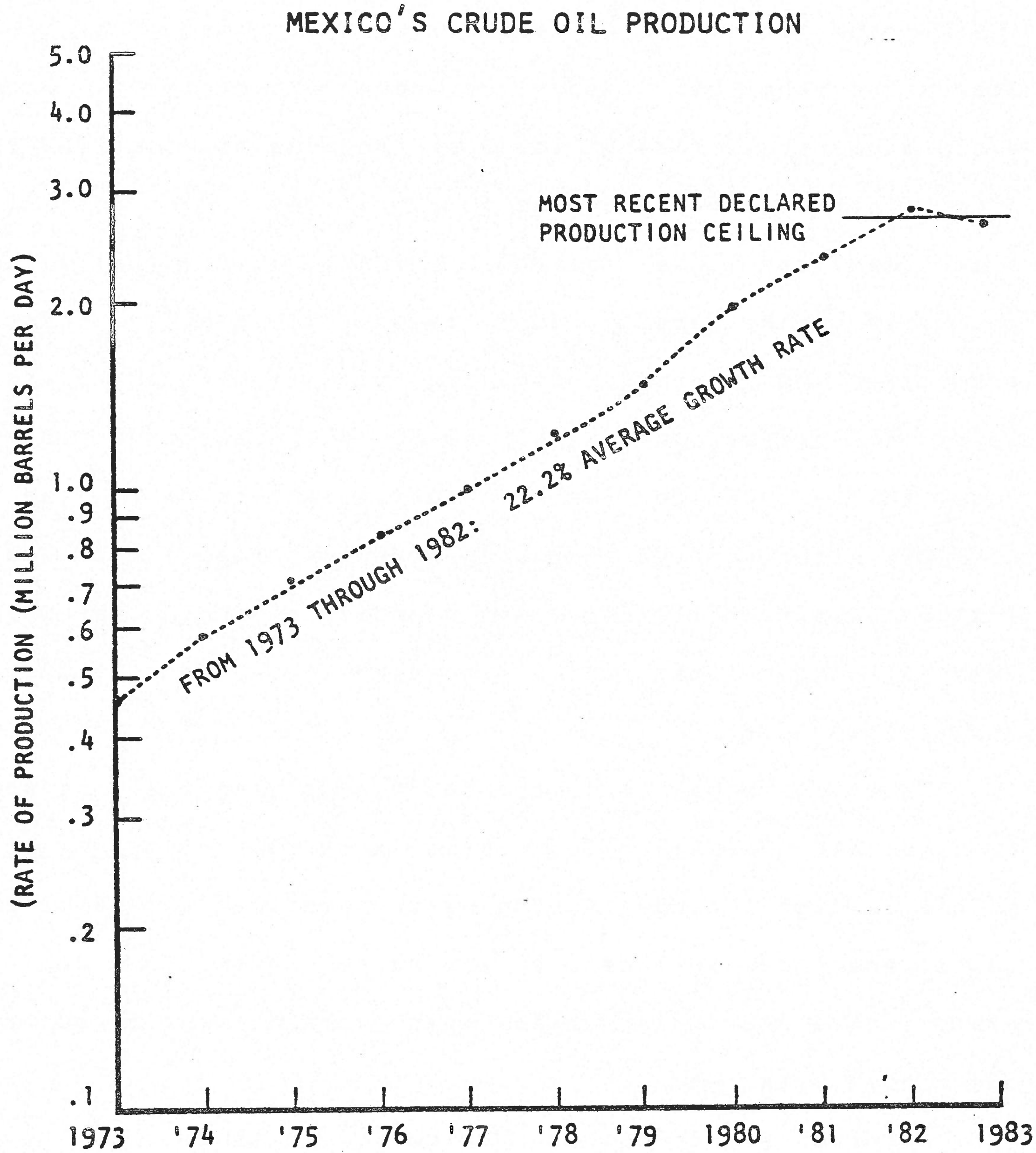
An important factor which could result in a return to <u>increased petroleum costs</u> deals with the development of a crisis situation. Obviously we cannot predict with any certainty when

FIGURE 2.5



DATA SOURCES: BASIC PETROLEUM DATA BOOK, OIL & GAS JOURNAL.

FIGURE 2.6



SOURCE: DEPARTMENT OF ENERGY, ENERGY INFORMATION ADMINISTRATION DATA and if a crisis event is likely to happen; however, it is remotely possible that the IRAN-IRAQ situation could lead to a restriction on the availability of oil imports to the United States and other oil import dependent countries. Brown [12] explores several possibilities of outcome of the IRAN-IRAQ war which might lead to increases in oil prices. One possibility is that IRAN can take control of IRAQ, and eventually the other countries in the Persian Gulf region, ultimately reducing oil production and thereby increasing petroleum costs to almost any level they prefer, such as 40 to 50 dollars per barrel, for at least the next decade. Other negative factors could also trigger a crisis situation and increased consumer gasoline prices. For instance, while not likely, an incursion by the Soviet Union into IRAN (ala-Afghanistan) could also lead to unfriendly control over the Persian Gulf.

Thus, in addition to the decreasing gasoline cost scenario-1, the NAU Research Team also included a crisis situation scenario which included rationing of gasoline, increased gasoline costs, and increased costs of trying to convert to a dual fuel/AE system (due to anticipated high demand and low supply of AE conversion kits, etc.).

A third scenario which is quite feasible, and in fact is almost necessary if there is to be any significant influx of AEV's into the Arizona market, deals with the use of federal and/or state incentives to convert to AEV's such as CNG powered vehicles. Discussions held with gas industry [16] and automotive industry representatives [17] indicates that unless a significant market for AEV's is available (say 20,000 units per year) there will not be any mass-produced and dedicated AEV systems but more than likely only dual fuel conversions on conventional I.C. engine vehicles. Through the use of <u>incentives</u>, such as the sales tax reduction concept used in Canada for buyers of NG powered vehicles or vehicles converted to run on both NG and gasoline, the state of Arizona can encourage greater use of cleaner, less polluting, alternate energy systems. Ultimately (after sufficient time for turn-over of new vehicles and AEV's in the Arizona fleet) the incentives could provide for a large enough market to encourage the automotive industry to develop AE vehicles along with the necessary maintenance, repair and servicing infra-structure desired by the consumer.

The scenario 1 is the least favorable to market/demand penetration of AEV's into the state of Arizona. The third scenario discussed above (i.e. government incentives) is perhaps the most favorable to market/demand penetration of AEV's if one could assume that the price of gasoline was stable or at least increasing relative to the price of cheaper alternate energy sources.

In light of all of the above, and due to the uncertainty of the future, the NAU Alternate Energy Project Research Team selected five alternatives for examination in this study:

a.) Scenario-1 assumes that the relative prices of gasoline and cheaper alternate energy fuels, such as CNG, remain relatively constant over time. In addition it is assumed that AEV's are configured and priced competitively with the standard gasoline powered vehicles;

b.) Scenario-2 assumes the cost of gasoline to <u>drop</u> over the next decade and the cost of converting a vehicle to operate in a dual fuel (AE and gasoline) mode to be about $1500. Furthermore, this scenario assumes that there is only a minimal savings by using an alternate fuel source such as NG;

c.) Scenario-3 assumes that the cost of gasoline increases and that the difference in fuel costs afforded by using an AE system is about a 40% savings versus gasoline costs. The cost of purchase of an AE vehicle is assumed to be as in scenario-1;

d.) Scenario-4 is like scenario-1 with respect to fuel and vehicle costs except in this scenario various AEV adoption incentives are allowed; and

e.) Scenario-5 represents the crisis situation discussed previously where gasoline rationing is considered along with higher cost of gasoline and attractively lower AE costs.

2.2 ALTERNATE ENERGY TRANSPORTATION SYSTEMS

The national and world needs for transportation account for about 20% of all present energy use [18]. Currently, petroleum is the primary fuel/energy source for gas turbines, jet engines and internal combustion engines (ICE), such as the standard gasoline powered spark ignition (SI) type engines and the diesel fuel powered compression ignition (CI) engines. Concern with the environment, and the cost and availability of future petroleum supplies, has encouraged the research and development of numerous AE systems and energy sources or fuel modifiers. Table 2.2.1 lists the AE systems or energy/fuel sources researched in this phase of the study.

DIESEL FUEL

LIQUIFIED PETROLEUM GAS (LPG-PROPANE)

GASOHOL (10% ALCOHOL/90% GASOLINE MIX)

ETHANOL (FROM FERMENTATION)

METHANOL (FROM COAL & BIOMASS)

METHANE/NATURAL GAS (COMPRESSED-CNG & LIQUIFIED-LNG)

HYBRID DUAL FUEL SYSTEMS (GASOLINE & CNG or LPG)

ELECTRIC (BATTERIES)/HYBRID ELECTRIC

FLYWHEELS AND MECHANICAL ENERGY STORAGE DEVICES

HYDROGEN POWERED SYSTEMS

SOLAR AND FUEL CELL POWER

TABLE 2.2.1 SOME ALTERNATE ENERGY SYSTEMS AND POTENTIAL ENERGY SOURCES FOR TRANSPORTATION

2.2.1 ELECTRIC AND HYBRID/ELECTRIC: A DARK-HORSE AE SYSTEM FOR ARIZONA

Studies conducted by Arthur D. Little, Inc. [9] and ORI, Inc. [19] suggest that by the year 1990 the potential market for electric vehicles (EV) in warm and temperate climates of the U. S. will be about 2,700,000 vehicles. The warm climate and relatively flat terrains of the Phoenix and Tucson urban/metropolitan areas are features that would allow electric vehicles to operate at maximum performance. In addition, as noted previously, Arizona's abundant coal reserves, hydroelectric power, and nuclear power should eventually make electric power economically attractive if petroleum costs start to rise significantly. Finally, the electric power industry finds overnight charging of EV's a nice way to balance daytime/evening power demands and increase income without significant capital investment. The Arizona Public Service (APS) Utility Company has been successfully experimenting with a fleet of electric vehicles since the early 1980 time period [20].

Saczalski of the NAU College of Engineering & Technology has also examined the commercial feasibility of electric and hybrid electric vehicles for the colder winter climates and hilly regions of Flagstaff, Arizona [1]. An Electric Passenger Car Company hybrid/electric modified Ford Pinto station wagon was used in the NAU study. The results of the above study indicated that hybrid electric vehicles were technologically feasible and could compare reasonably well in energy costs to the ICE counterparts, however, battery maintenance and reliability of component parts, as well as replacement parts, and lack of servicing capabilities detracted from the commercial feasibility of such vehicles. The results of the study did indicate however that the above vehicles optimum use would be for trips under 30 miles in short commuter travel, downtown shopping, and errand running, in a relatively flat terrain and warm climate such as the valley areas of Phoenix and Tucson.

In virtually all current EV systems, however, lead/acid batteries are the source of energy. Figure 2.7 shows that the lead/acid batteries are poor in both energy density and specific peak power, as compared to most of the other AE systems illustrated [21]. Future battery systems (to be commercially available in the early 1990 time frame) such as the sodium sulfur (NaS) and the aluminum-air batteries [22] offer some improvement and potential for use as an Arizona AE system. The advantage of the aluminum-air battery is that it would allow a range of about 100 to 125 miles before requiring a refill of distilled water. About 3 to 4 water refills would be possible before the aluminum core would have to be turned in for reprocessing by the aluminum industry (i.e. like returning a glass bottle for deposit). Thus these batteries might be able to provide a range of about 350 to 500 miles to an electric vehicle, however, some mechanism of refuel or easy trade-in would have to be worked out before the improved batteries could become feasible. The Lawrence Livermore Laboratory [23] is actively working on the practical aspects of

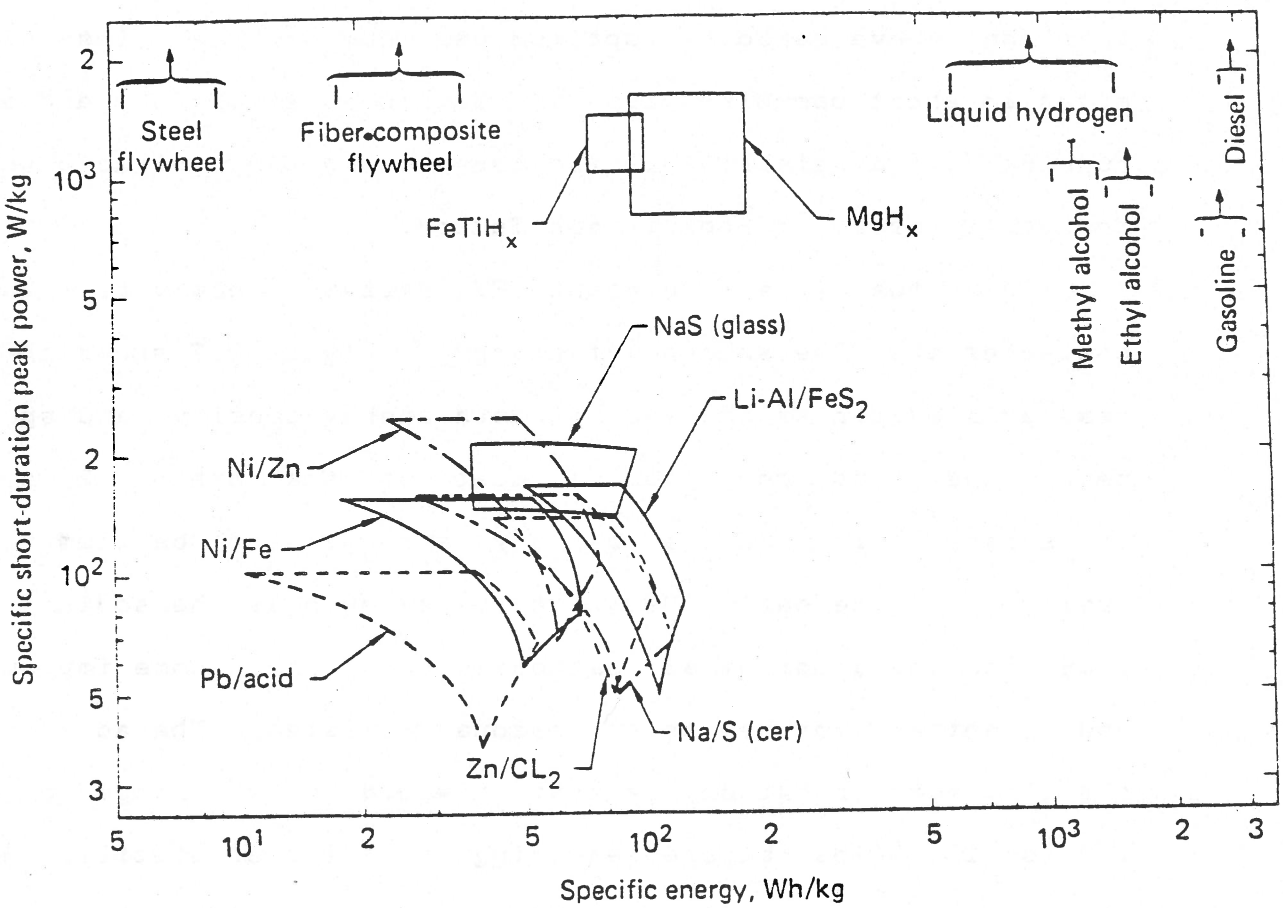

Steel flywheel
Fiber-composite flywheel
FeTiH$_x$
MgH$_x$
Liquid hydrogen
Methyl alcohol
Ethyl alcohol
Gasoline
Diesel
NaS (glass)
Li-Al/FeS$_2$
Ni/Zn
Ni/Fe
Pb/acid
Na/S (cer)
Zn/CL$_2$
Specific short-duration peak power, W/kg
Specific energy, Wh/kg

FIGURE 2.7

the problem and there is some optimism that the aluminum industry may be willing to assist in making the "trade-in" aluminum-air batteries a commercially feasible entity some time in the next few years. If such an improved battery system comes about in the near future, it is quite likely that the electric or hybrid/electric vehicles could become a potential candidate for penetration into the Arizona AE market. For instance, a consumer survey study conducted by Dan Shein at a Phoenix Electric Vehicle Mini-Fair in May of 1981 [24] found that while most consumers drove less than 50 miles per day, they expected a potential range of greater than 100 miles in any AE vehicle that they would consider purchasing. The aluminum-air battery system seems to satisfy at least the above consumer requirement.

2.2.2 FEASIBILITY OF ALTERNATE ENERGY TRANSPORTATION SYSTEMS

The complex manufacturing infra-structure associated with current automotive production, and the tremendous expense of developing new infra-structures for major deviations from current automotive propulsion systems, suggests that the AE systems most likely to replace gasoline in the next 10 to 20 years will be those systems which are amenable to internal combustion engine conversions or adaptability. The one possible exception to the above, cited in the previous section, is the electric and hybrid/electric vehicle with improved longer range batteries.

Two alternate fuels which have been used as popular substitutes to gasoline are the diesel and propane fuels.

Propane, a liquified petroleum gas (LPG), is a clean burning fuel which is produced as a result of processing crude oil at the refinery. To facilitate storage and transport, propane is liquified by a process of compressing and/or cooling. Approximately 270 gallons of vapor can be compressed into one gallon of liquid. Propane remains in a vapor state at atmospheric pressure and normal temperatures. When used as a motor fuel, propane is drawn into an internal combustion SI engine in a vapor state, and as such, mixes readily with intake air. Propane engine fuel is produced to an accepted specification (HD5) to assure uniform quality and smooth performance when used with the spark ignition type IC engine conversions.

Diesel fuel is also a derivative of crude oil processing.

Only 17% of a barrel of crude oil can be made into diesel fuel. Diesel fuel is used in compression ignition type internal combustion engines. As diesel fuel usage increases an excess of gasoline will become available resulting in possible lower costs of gasoline, but higher diesel fuel costs due to simple supply and demand.

The price of diesel fuel in the Flagstaff area is about one cent per gallon greater than unleaded gasoline. Similarly the price of LPG (propane) will also fluctuate and increase with the supply of gasoline and demand for propane. It should be pointed out, however, that a strong LPG market currently exists in the U.S. transportation sector. Arizona, on the other hand, seems to show a decline in the use of LPG for transportation purposes. Details on the U.S. and Arizona LPG and CNG markets and tax laws are contained in Section 4.

Thus, the prices of both diesel and LPG have risen with increased demand and both fuels currently cost slightly more than gasoline. In the State of Arizona, (Tucson and Phoenix), three major companies are responsible for most LPG conversions: 1) CAL-GAS, 2) Petrolane, and 3) DOXOL. Several smaller companies market conversion kits but do not offer installation. Approximately 750 conversions costing about $1,000, have been made since 1983 and this number reflects a substantial decline from the 1970's when gas supplies were more limited. Most conversions from motor gasoline to propane were by private companies and government owned fleet vehicles. <u>Some fleets that</u>

were converted during the 1970's have been reconverted back to conventional fuels because of the increased LPG costs. Because of the above processing and high fuel cost factors, as well as other factors such as emissions from diesels and safety/conversion costs for LPG, neither LPG or diesel fuels are considered as AE candidates likely to replace gasoline. Figure 2.8 illustrates the dramatic drop off in percent of new vehicle sales in the U.S. of diesel passenger cars and propane conversion up through 1983 [27].

Solar and fuel cell power which have been recommended as alternatives to gasoline powered transportation systems [25], are also not considered as feasible AE systems. Current solar devices are costly and inefficient (only about 16% of the absorbed energy from the sun in converted to AE use). Although some solar powered research vehicles have been built and tested in the U.S., Japan and Australia, none of these vehicles have been capable of providing the range, speed performance and size/comfort/safety features required for consumer marketing. Fuel cells offer some potential for improved energy efficiency and use in AE transportation systems, however, with the exception of a small amount of basic research being carried out at some universities and national laboratories there does not appear to be any serious industrial work being carried out on the commercial implementation, and development of infra-structure, of fuel cells for AE transportation systems.

Another AE approach which is not considered feasible in this study deals with the use of mechanical energy storage devices such as the composite flywheel and hydraulic accumulator. The reasons for not considering mechanical energy storage devices as feasible AE transportation substitutes for gasoline are apparent in Figure 2.9 which illustrates a comparison of the energy density (i.e. amount of energy stored in a unit of mass or weight of the system which produces the energy) for various future (1990) batteries, hydrogen energy systems (hydrides and liquid hydrogen), and mechanical energy storage devices [26]. The extremely low energy density of the mechanical type devices, coupled with their relatively high specific power capability (see Figure 2.7), suggests that these AE systems could most likely be used only as hybrids in conjunction with some other higher energy density source.

The most likely AE replacements for gasoline in the next 10 to 20 years appears to be: alcohol and alcohol extenders (i.e. "gasohol"); CNG dual fuel systems (i.e. vehicles which are capable of running on either gasoline or CNG); dedicated CNG powered vehicles; and hydrogen powered vehicles [26]. All of the above AE sources are capable of good performance on standard IC engines with relatively minor adaptations to the engine and fuel metering system. Also, each of the above AE sources has the capability of significantly reducing the level of most pollutants encountered in gasoline and diesel powered vehicles. With the exception of hydrogen, the alcohols and the CNG are actually cheaper or at least competitive pricewise with gasoline. The

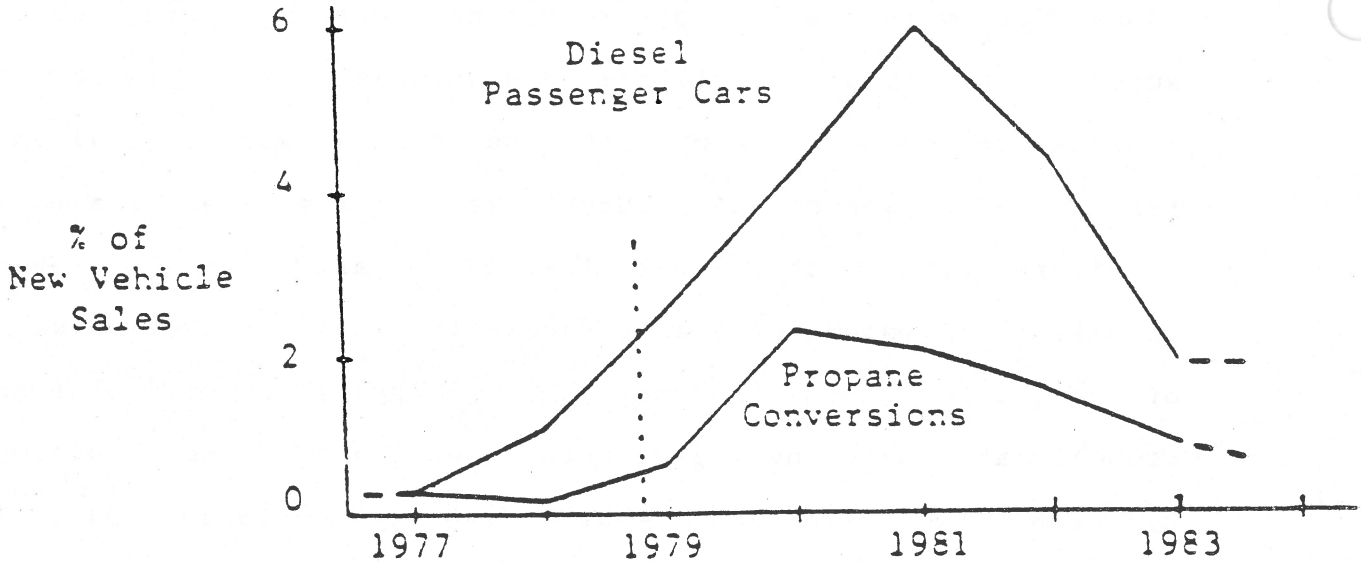


FIGURE 2.8

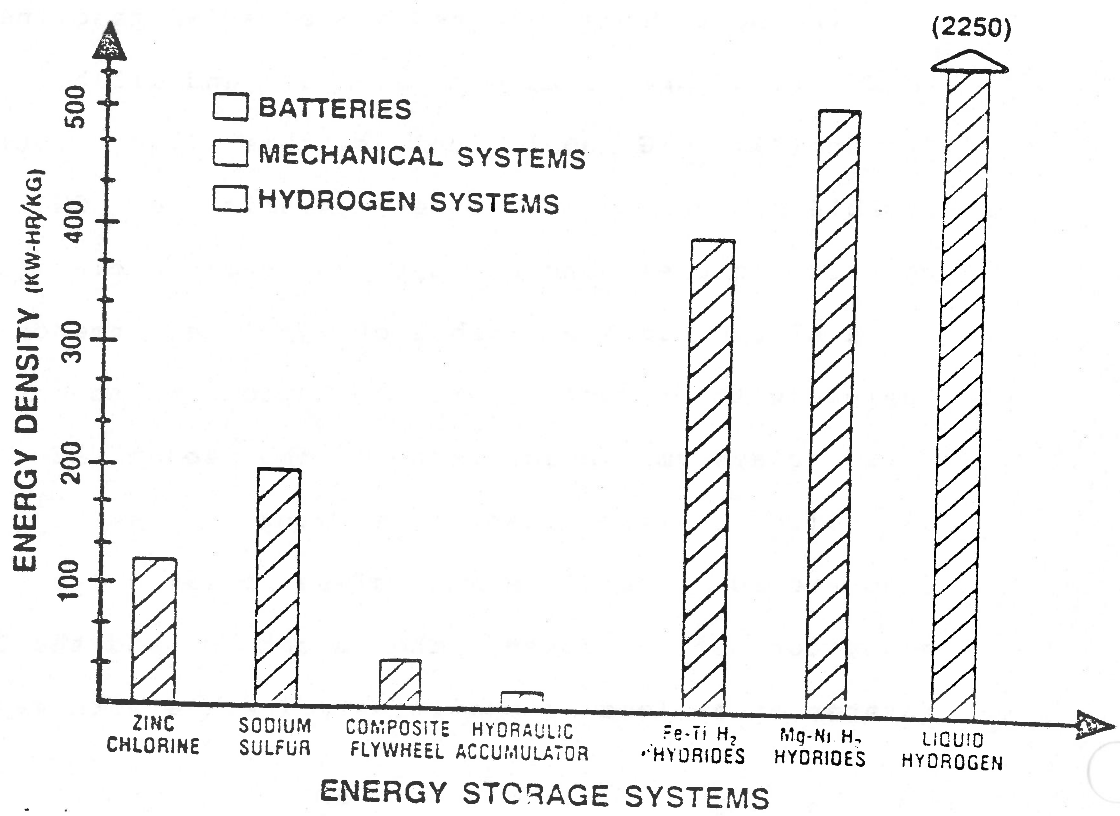


FIGURE 2.9

"gasohol' mix of 90% gasoline and 10% alcohol (ethanol) represents an immediate mechanism for "stretching" current U.S. reserves of gasoline. The biggest obstacle foreseen in the immediate conversion to blends of ethanol, even with only a 10% blend, is that more ethanol would be required than could be produced from available solid wastes and plant fermentation. As a non-lead octane enhancer "gasohol" sales have risen from 500 million gallons in 1980 to about 6 billion gallons currently.

Both ethanol and methanol have been used as the primary fuel source for automobiles. Methanol, currently derived from the abundant U.S. supply of natural gas, can be produced in large quantities. Methanol can also be produced from coal. Current 1985 best estimates put the amount of U.S. coal energy reserves at about 25 times the reserves of U.S. petroleum energy supplies [28]. The Ford Motor Company of the U.S. has initiated the development of methanol powered vehicles. The early problems encountered by "gasohol" corrosion of fuel system components have been alleviated by Ford through the use of appropriate non-corroding fuel system materials such as nickel plated parts [17]. Figure 2.10 outlines some of the unique features of the 1983 Ford Escort methanol system. A fleet of approximately 500 Ford methanol powered automobiles have been provided to the State of California, with another 100 vehicles (approximately) going to Canada, Pennsylvania and the City of Baltimore. A total of 33 fuel stations are provided in Southern and Northern California, and these stations are open to the general public [17]. The large U.S. supply of natural gas and coal suggests that methanol could be an excellent near term (5 to 15 years away) replacement to gasoline.

Germany and New Zealand have also considered using methanol as a substitute for gasoline. Ford has provided some vehicles to Germany which ran on 15% methanol and 85% gasoline. The U.S. difference in price between a conventional gasoline powered vehicle and a new methane powered vehicle is only about 5% (roughly $500 on a $10,000 vehicle). Ford is currently researching the possibility of an engine which can run on either gasoline or methanol [17]. Because of the gasoline/methanol differences in air/fuel ratios and timing, as well as cold start problems and flammability of methanol, the above cited dual fuel concept is a most challenging task.

Brazil, due to its large sugar cane growing capability, has since 1975 emphasized the use of ethanol (derived from fermentation and solid wastes) in vehicles to reduce its previous dependence of importing approximately 85% of its oil. The Ford Motor Company has since about 1979 provided a large number of ethanol powered passenger vehicles to Brazil. Ethanol uses the same fuel distribution system already in place for gasoline in Brazil. As of July of 1984 Brazil was importing only 48% of their oil needs - a dramatic reduction in imports of almost 45%. The Brazilian ethanol passenger car mix increased from 28.5% in 1980 to approximately 88% in 1983. As of 1984 there were 1,200,000 ethanol vehicles in Brazil. Some work has also been

Scientific Research Laboratory
Research Staff

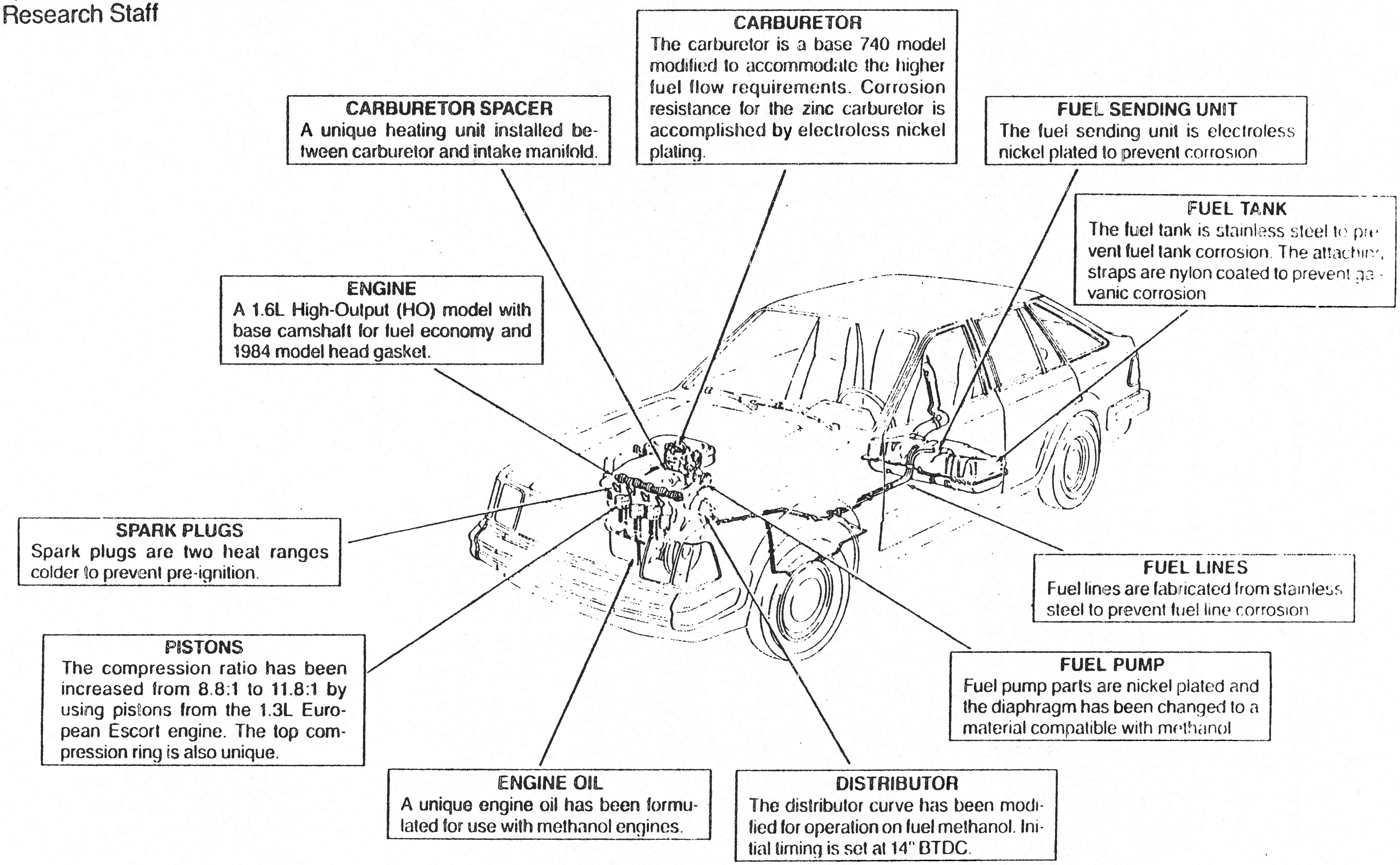


FIGURE 2.10

started by Ford Motor Company, and others, on the use of alcohol and diesel blends [29]. Obviously, there is a significant technological data base which suggests that the U.S. could begin serious production of methanol/ethanol vehicles in the next 5 to 15 years (near term).

Table 2.2.2 summarizes the NAU research team selection of the most likely AE replacements to gasoline transportation systems for the immediate, near term and long term time frames.

ALCOHOLS, ALCOHOL BLENDS	(Immediate to Near Term- 0 - 5 years)
DUAL FUEL (CNG/GASOLINE) CONVERSIONS, DEDICATED CNG	(Near to Medium Term - 5 - 15 years)
HYDROGEN	(Long Term - 15 - 25+ years)

TABLE 2.2.2 MOST LIKELY AE SYSTEMS

2.2.3 CNG: THE MOST PROMISING AE ALTERNATIVE FOR ARIZONA

The most promising AE alternative for the State of Arizona appears to be the CNG dual fuel conversion system. The results of the demand/penetration study, contained in sections 5, 6 and 7 of this report, indicate that of all of the potential AE systems surveyed the CNG dual fuel conversion system was the only AE system which Arizona drivers were willing to pay above standard vehicle prices for. In part the preference for a good dual fuel vehicle capability may be due to the senses of security associated with being able to choose from either systems in case of a future energy crisis. From a technological point of view the CNG energy source also offers many more advantages than disadvantages.

CNG as a motor vehicle fuel is currently being used on a large scale in Italy, New Zealand and Canada [30]. All of these countries have used tax incentive programs as seed money for the development of public refueling stations and for conversion of existing petroleum fuel vehicles. To a lesser extent the U.S. is using CNG, but in most applications this is limited to private fleet vehicle conversions and the lack of public refueling stations presents a current drawback for the private consumer. A 1982 report by the American Gas Association [16] indicated that the costs of running CNG vehicles as compared to gasoline powered vehicles were on the average 39% cheaper to operate. The average cost of converting a gasoline fueled vehicle to a dual fueled (gasoline and CNG) is approximately $1,500 dollars. This includes all of the necessary hardware needed to run the vehicle on both fueling sources. As a rough estimate of the refueling site costs, $1 per displaced gallon of gasoline can be used (i.e. if 40,000 gallons of gas used per year were displaced by 40,000 equivalent gallons of CNG the cost of the refueling site would be approximately $40,000) [16]. A gallon of gasoline has the BTU energy equivalent of about 108 cubic feet of natural gas. When compressed at a pressure of about 2600 psi the natural gas occupies about 1 cubic foot of space. Natural gas is the largest domestic source of energy in the U.S. and it currently accounts for 31% of the primary U.S. energy consumption. The American Gas Association (AGA) reported in 1980, that the proven reserves amount to 195 trillion cubic feet, in addition to this the AGA estimates that an additional 1000 trillion cubic feet are available for recovery. The current yearly consumption in the U.S. is about 17 trillion cubic feet. Experts in the industry estimate the U.S. has a known 60 year supply, based on current use levels. These estimates don't include the vast reserves of Mexico and Canada or the extraction of natural gas from unconventional sources such as tight sands, devonian shales, coal seams and geopressured aquifers. The potential for synthetic natural gas produced from coal is still being explored, however, current U.S. funding levels for synthetic fuel projects is declining due to the effects of energy conservation, lower gasoline prices, and increased supplies of gasoline.

CNG is a relatively new fueling source in the U.S. and as such most areas of the country have not adopted regulations governing the installation of retrofit vehicle equipment or the refueling site. American Gas Association, has published a proposed set of regulations (NFPA #52). These regulations outline the design of equipment and the building of the refueling site. The CNG fuel cylinders are regulated by the U.S. Department of Transportation and must be hydrostatically tested every 5 years, to insure their continued safe operation.

Each cylinder is equipped with a safety device referred to as a burst disc, with a fusible material. The fusible material is an alloy which will flow when the temperature reaches 100 degrees centigrade (212 degrees fahrenheit) and the burst disc is designed to rupture at a pressure of 3775 psi which will allow the gas to escape. The alloy will flow, allowing the burst disc to rupture if the pressure reaches 3775 psi. The burst disc installed in these cylinders is made of inconel material which is impervious to etching of natural gas. If replaced they should be of like material to prevent future failure resulting in leakage.

In addition to the above, the cylinders must be labeled with the words "CNG ONLY" in letters at least 1 inch high in contrasting color and in a location which will be visible after installation.

The cylinder cost averages approximately $67.00 per gallon of compressed natural gas (CNG) or about $1,000.00 dollars for the same range of a conventionally fueled vehicle [16]. Since in most vehicle applications the on board CNG capacity is limited to the average daily driven mileage, the cost of the cylinders can be determined by taking the average number of miles driven divided by the vehicles average mileage per gallon and multiplying this by $67.00.

The total conversion price per vehicle will average $1,500, inclusive of all necessary equipment for conversion to dual fuel capacity. The dual fuel capacity is a bonus because it allows the user to choose the most economical fuel source.

Compressed natural gas achieves close to the same mileage as a conventionally fueled vehicle so the number of equivalent gallons of CNG required is limited by the necessary required range.

Because natural gas is lighter than air, there is no risk of pooling of the spilled fuel as compared to petroleum fuels. The dissipation of natural gas (because it's lighter than air), and the limited fuel to air mixture required for combustion, all but eliminates the possibility of explosion. A double redundant design being used in modern CNG cylinders eliminates the possibility of the cylinder becoming a "bomb" and exploding in the event of an accident. The gasoline fuel tanks of a dual fuel vehicle are substantially more dangerous than the CNG cylinders. The equipment necessary for conversion is usually purchased in a package from a CNG equipment supplier. Included will be the compressed gas tanks, the pressure regulator, fuel selection solenoid and gas mixer. The refueling station equipment should include compressor, cascade (if quick fill), refueling stations and the related safety equipment. Again, this is usually purchased in a package and can be custom tailored to the individual needs of the consumer [31].

CNG is a clean burning fuel when it is burned, CNG produces half the amount of nonmethane hydrocarbons as gasoline. The majority of the emissions from a CNG powered vehicle are simple water vapor. Emissions are discussed in more detail in Section 2.3. Both the Ford Motor Company and Toyota have initiated production on a limited number of CNG only light trucks. More details are given in Section 4 of this report under the marketing section. Figure 2.11 illustrates some of the features of the Ford CNG truck.

There are two basic types of refueling systems, fast fill and slow fill, but combinations are frequently utilized depending upon the needs of the end user. The fast fill system will fill the vehicles in about the same time as a conventional (gasoline) filling system. The slow fill system is designed for the user that has a vehicle that returns to the fueling site for extended periods of time, usually 8-12 hours. Both systems require compressors and the necessary piping for the transfer of the compressed gas to the vehicles.

The fast fill system cost includes the compressor station and the necessary high pressure storage system. The advantage of the fast fill system is it allows for refueling of the vehicles without having to remain at the refueling site for extended periods of time. A disadvantage is that the time between vehicle

The natural gas-fueled Ford Ranger shown on the right was engineered by Ford Motor Company at its Scientific Research Laboratory in Dearborn, Michigan. The diagram shows the unique components. The natural gas Ranger is part of Ford's continuing worldwide research effort to develop vehicles capable of operating efficiently on alternative fuels. Ford sees vehicles operating exclusively on natural gas as a cost-saving option for fleets where vehicles return to a central base each day.

Natural Gas Benefits

Compressed natural gas offers several potential advantages over gasoline as an engine fuel:

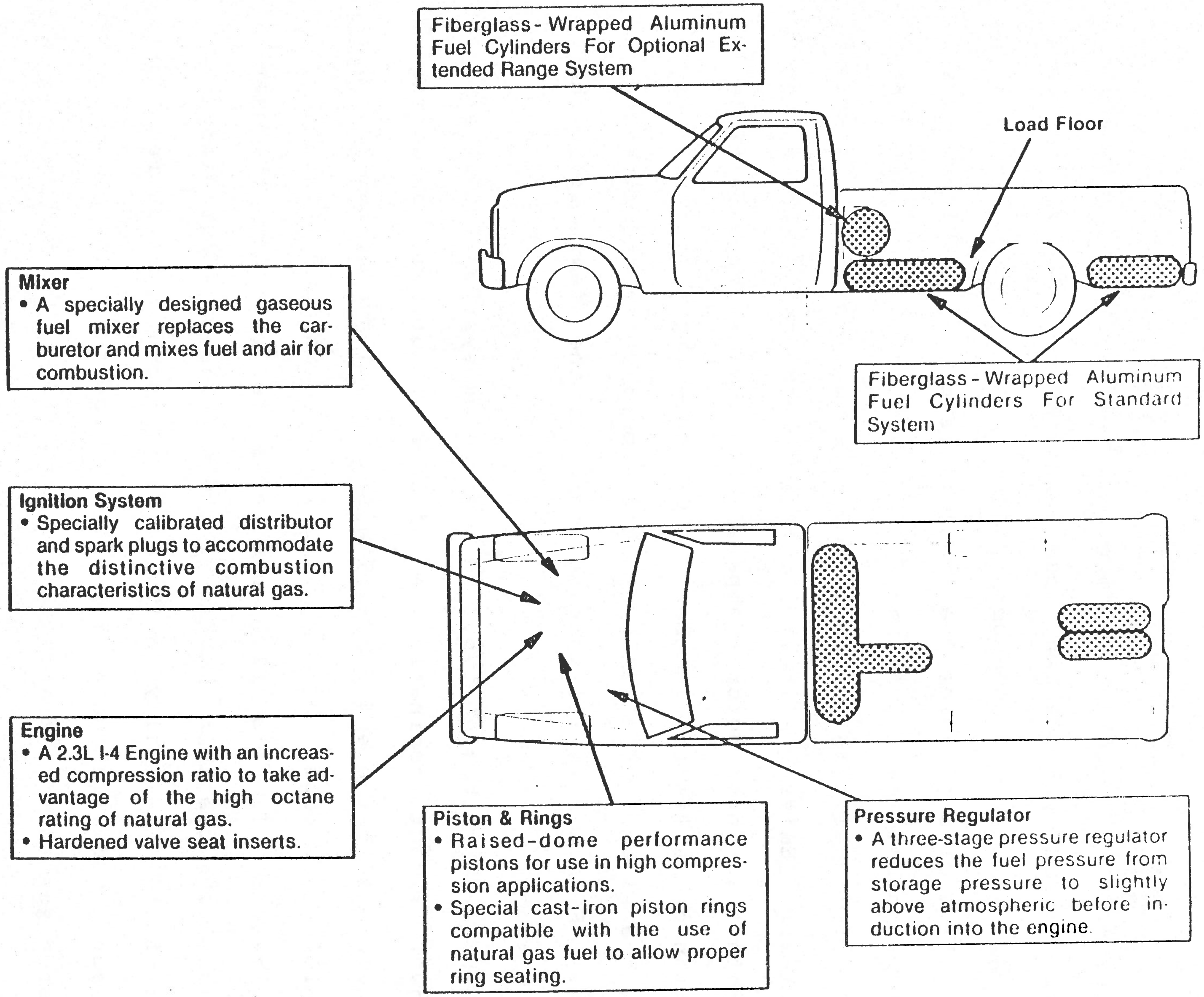
- Lower fuel costs
- Longer engine life
- Reduced maintenance costs
- Smoother engine operation

Natural Gas Inhibitors

There are some drawbacks to universal application:

- Refueling Station investment costs
- Limited vehicle range

Fuel Economy (Auto Trans.)	Natural Gas Ranger	Gasoline Powered Ranger
EPA City Cycle	21 mpg	22 mpg
Performance 0-50		
Seconds	13.0	12.7
Range (@ 3000 psi Fill Pressure)		
Standard Fuel System —	125 miles	
Extended Range System —	225 miles	



Ford Scientific Research Laboratory
Research Staff

FIGURE 2.11

refueling determines the compressor capacity needed, thus the shorter the time span between refueling the greater the compressor capacity required. A typical fast fill system will cost anywhere from $60,000 to about $120,000.

The equipment required for a fast fill system includes:

1) Compressor: this boosts the pressure of the natural gas from delivery pressure of about 5 psi to 3600 psi. The suppliers of compressors are varied and the compressor chosen should meet the refueling demands of the end user. A typical vehicle converted to CNG with 2 storage tanks has the capacity to store 700 cubic feet of natural gas at 2400 psig. To fill within 10 minutes a vehicle whose tanks are empty would require a compressor of 70 cfm capacity. This would only allow 6 vehicles per hour to be refueled. By adding storage containers that could be filled in advance a downsized compressor could be utilized. The compressor capacity needed is larger than that required for a slow fill station.

2) High pressure gas storage containers: these are commonly called a cascade. The cascade is a group of cylinders equally divided into three separate zones low, medium and high pressure, these zones are interconnected so that the cascade operates as one unit. The cascade zones are initially filled with CNG in sequence by the compressor to the normal operating

pressure of the system. The highest pressure zone is refilled first followed by successively lower pressure zones. This sequence is called priority fill. These zones allow for multiple vehicle refueling without drawing directly from the compressor. The cascade gives the user the equivalent of a gasoline storage tank on which to draw for refueling vehicles. The cascade is directly connected to the compressor and the zones are interconnected with pressure regulators and safety devices. The size of the cascade can be scaled to the amount of fast fill stations needed.

3) Refueling station: the size and location is determined by the users needs. The station looks like a typical gasoline refueling station except instead of pumps quick fill hoses for connection to CNG vehicles are in place.

The slow fill system is designed for the fleet user whose vehicles experience extended periods of time between the need for refueling. Because the refueling process requires between 8 to 12 hours (or more depending upon the compressor capacity) the need for parking facilities for connection to the slow fill system is required. The size of these facilities depends of the number of vehicles to be refueled at one time. It is possible to establish the refueling capacity in the existing company vehicle parking area. The slow fill system, because of the extended time required for refueling needs, needs only the compressor with the necessary pressure regulation equipment to determine if the vehicles have completed refueling and the connections for transferring the CNG to the vehicle. Slow fill systems can cost anywhere from $600.00 to $10,000. The obvious cost savings are apparent.

The mix fill station allows the user to custom tailor the refueling operation to the projected needs.

A new application of an old product has been introduced by Dual Fuel Inc. of Montebello, California, it is the Haskel CNG amplifier system. This pump eliminates the first two compressor stages by using the high pressure gas line (usually around 350 psi) to drive the pump and compress the natural gas. The problem with this type of pump is that the user must be located near a gas supplier's high pressure line and be able to discharge the "used" (lower pressure, around 60 psi) back into the distribution system.

The complete installed costs for a fast, slow or mix fill station depends on the needs of the user and the logistics of the refueling site.

2.2.3a HOME UNIT (SLOW FILL) CNG SUPPLY

The major drawback or disadvantage associated with dedicated CNG or CNG duel fuel conversion systems in Arizona is that there are no natural gas compression or fill-up stations available to the general consumer. One possible means for overcoming the above problem would be through the use of an overnight slow fill home refuel system which compresses the natural gas supplied to the residence. As noted in reference 32, this method of general consumer refueling of CNG powered vehicles would take advantage of the existing and well-developed residential system of natural gas. The city of Phoenix for example has a very good grid work of high passive natural gas lines (about every mile) which feed the low pressure (5-7 psi) residential units. Currently more than 40 million homes in the U.S. use natural gas and the number is expected to rise due to the low cost of natural gas as compared to heating oil.

The concept recommended by Dr. Vadim Kopytoff at the June 1984 NAU/ADOT research project review meeting and also advocated by Dr's Amos Golovoy and Roberta J. Nichols of the Ford Motor Company [32] would use a multi-stage home compressor unit to compress the natural gas from the home gas system into fuel storage cylinders on the vehicle. For safety purposes the compressor and fill station should be located in an open area. The compressor must be capable of pressuring the natural gas from about 5 to 7 psi at the incoming service line to the desired storage pressure in the vehicle tanks, which would vary between about 300 to 2400 psi.

Costs for the higher performance multi-stage compressors capable of achieving several 1000 psi pressure would be in the neighborhood of $10,000.00. Lower cost units with lower pressure capabilities limit the range of the vehicle. Selection of a unit would depend on factors such as reliability, and safety. In any event, home fill units, while not inexpensive, are available and if prices of these compressor units drop in the next few years the home fill method of CNG could become feasible.

2.2.3b DUAL FUEL CAPACITY

Dual fuel capacity is the combination of the existing fuel system with CNG. Since CNG is able to use the same engine designs as conventional fuels the end user is allowed the option of choosing the most economical fuel source.

The range of a CNG powered vehicle is limited to the amount of fuel carried on the vehicle. This limitation can be overcome by installing more CNG tanks, but in most vehicle applications space is at a premium. The on board storage requirements should be limited to the amount of fuel needed for average daily use. By including the existing fuel system the end user is allowed the margin of safety to go over the average daily use.

A problem with keeping the dual fuel capacity as compared to utilizing only a dedicated (CNG only) vehicle is the weight differential between the two systems. The weight difference is minimal but could effect the mileage on smaller vehicles, but the savings in fuel costs in most instances will overcome the space and weight problems.

2.2.3c DUAL FUEL CONVERSION COSTS

The cost for converting a vehicle depends upon the vehicle type, the amount of load carried and the desired range. The cost of the conversion kit not inclusive of the labor needed to mount it varies between $400 and $500 dollars. The conversion kit includes all of the necessary hardware to convert the existing gasoline or diesel system to a dual fuel capacity. The components of the conversion kit include:

1) The natural gas fill: valve the connection from the refilling station to the onboard cylinders. This valve is designed as a "break away" valve. It shuts off the flow of gas if the vehicle drives or rolls away from the refueling site.

2) High pressure fuel line and the master manual shut-off valve: these transfer the high pressure gas to the pressure reducer and allows the user to manually shut off the CNG supply to the engine.

3) Pressure reducer: this reduces the high pressure gas (2400-3000 psi) to atmospheric pressure. It is a three stage reducer combined into one unit. The first stage reduces the cylinder pressure from 2500 psi to 35 psi, the second stage reduces the pressure from 35 psi to .015 psi, the third stage meters the gas into the engine according to the requirements of engine speeds and load. This device governs the flow of gas that when combined with air in the fuel mixer will reach the

engine manifold.

4) Natural gas solenoid valve: this shuts off the natural gas to the engine when it's not running or the vehicle is running on gasoline. The solenoid valve is usually equipped with a natural gas shut-off delay for switching from CNG to other fuels. This eliminates stall when switching fuels.

5) Natural gas mixer: allows for correct fuel to air mixture before ingestion into existing vehicle carburetor. The mixer operates on the diaphragm controlled, variable venturi principle and meters the correct volume of natural gas into the air stream over the full range of engine air-flow demands [31].

6) Fuel selection switch: located inside passenger area of vehicle. It allows the driver to choose the type of fuel to run the vehicle on.

7) Dual curve ignition timing box: this advances the timing of the engine 15 degrees automatically (tied into the fuel selection switch) to optimize the fuel chosen for maximum performance.

In addition, $200 should be budgeted for labor and miscellaneous parts per vehicle.

The conversion price does not include the cost of the compressed gas cylinders. Cost run about $67.00 per gallon equivalent of gasoline. Therefore, if the equivalent of 6 gallons of gasoline or about 120 miles range are desired, the cost would be about $400.00 for the storage cylinders. These cylinders can be constructed of either plain steel, fiber wrapped steel or fiber wrapped aluminum. The fiber wrapped aluminum and steel cylinders have the advantage of greater capacity with reduced weight. These cylinders are designed to operate up to 3000 psi, and incorporate a double redundant safety feature that eliminates the possibility of explosion. Each cylinder has a legend stamped into the neck portion of the cylinder. The explanation of the legend is given by the following example:

<u>Example</u>: <u>D.O.T. 3AA 2400 (Printed Legend Stamped on Bottle)</u>

D.O.T. is the Department of Transportation or regulating body with control over certification and manufacture of cylinders. 3AA indicates the grade of material used to manufacture.

2400 indicates working pressure of the cylinder at 21 degrees centigrade (70 degrees fahrenheit).

PSI indicates manufacturer's code as registered with the D.O.T.. Numerals are serial numbers of cylinders. These are for record keeping purposes.

The date of certification is stamped on each cylinder by an independent third party. Each cylinder must be recertified by the end of each five year period.

2.3 HYDROGEN AS A POSSIBLE FUTURE AE SYSTEM

Hydrogen, in a hydride composition, appears to be very promising for an AE transportation system. Several research studies have been completed which demonstrate the technical feasibility of using hydrogen as an AE replacement for gasoline [26, 33]. Figure 2.9 illustrated the currently available high energy density of hydrogen as compared to unavailable energy density levels of future battery designs. Other advantages of hydrogen include its availability, recyclability, desireable combustion characteristics and clean burning characteristics. The hydrogen energy source has been adapted to standard IC spark ignition engines by Zavaleta [26], through the use of a rather simple hydrogen/air metering device. The performance of the hydrogen powered IC engine modification was actually better than the same engine performance when run with gasoline, the original fuel source for that particular engine design [26]. Figure 2.12 illustrates the Zavaleta hydrogen/air metering concept (H_2 design[3]) V-8 SI engine. Figures 2.13 and 2.14 demonstrates the road performance characteristics of the various Zavaleta hydrogen concepts versus the gasoline powered version of the engine.

Combustion of hydrogen and air results in by-products of water and a very small amount of nitrous oxide, thus giving a clean burning fuel. Energy density by mass shows a three to one advantage of hydrogen over gasoline; however, based on the energy density by volume the hydrogen is not quite as promising a fuel source over gasoline due to the lower heating value of the

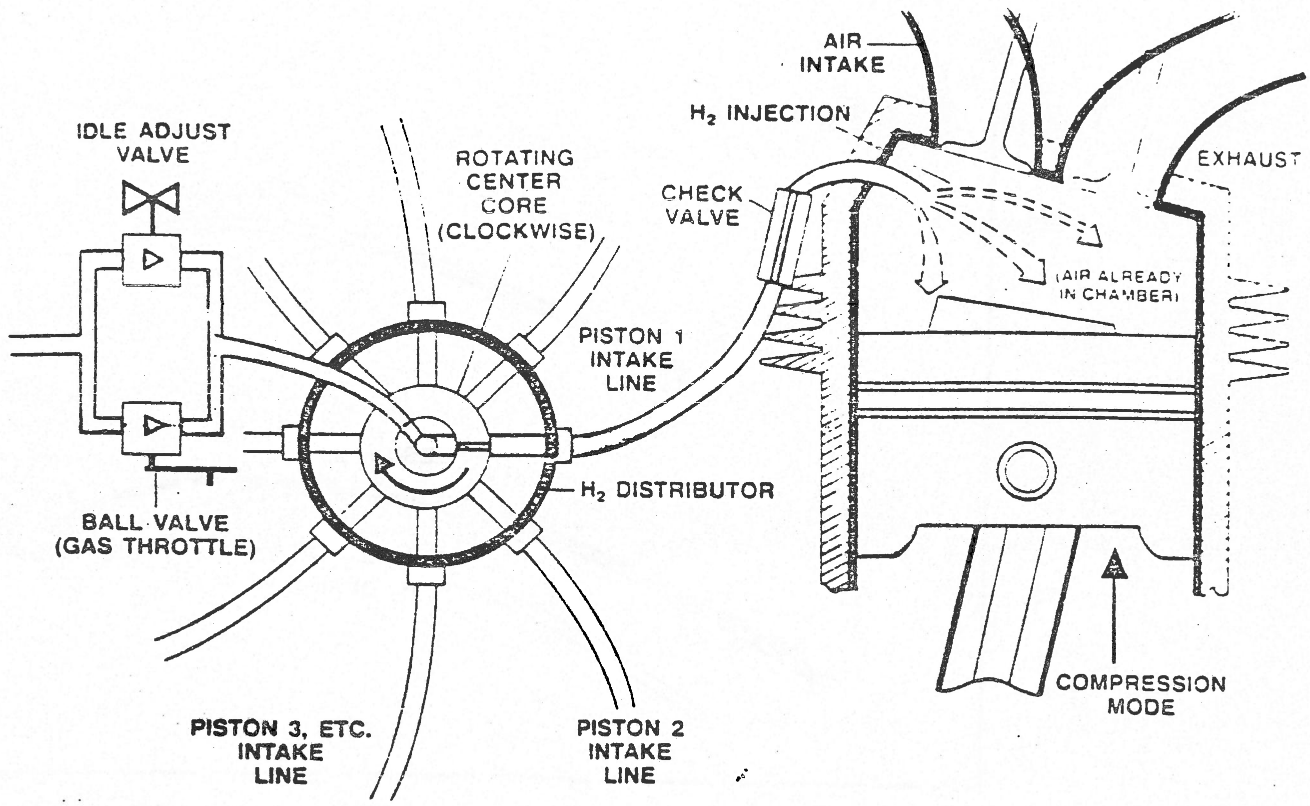


Fig. 2.12A Direct Cylinder Injection Schematic of Hydrogen Engine Design-3

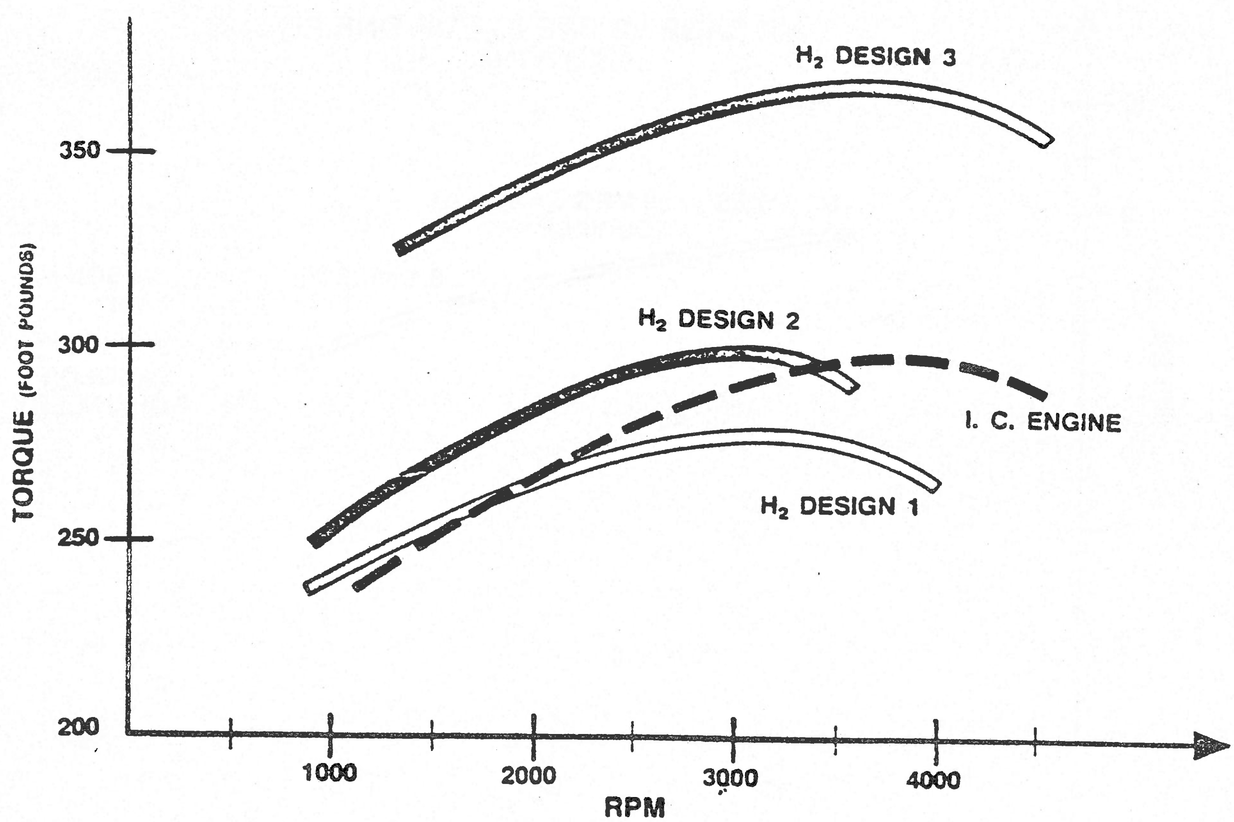


Fig. 2.12B Torque vs RPM Engine Performance Curves

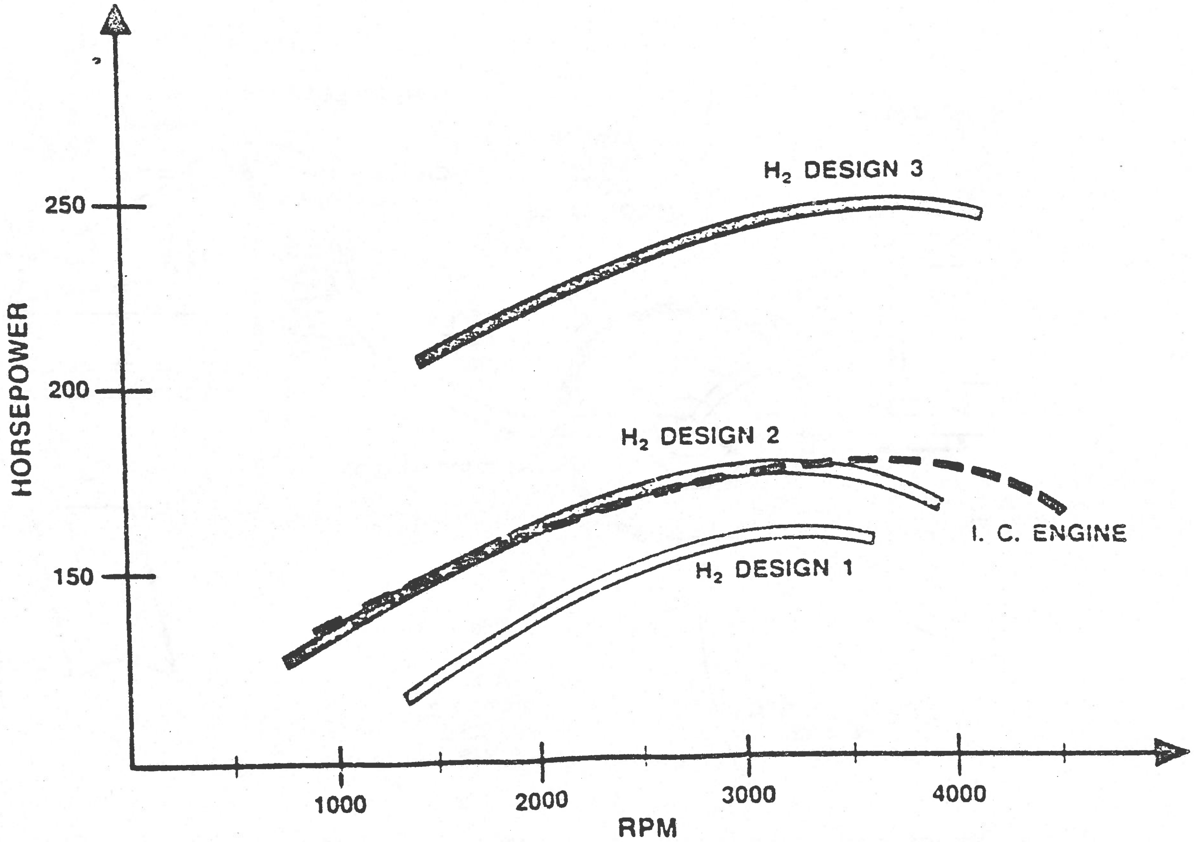


Figure 2.13 Horsepower vs RPM Engine Performance Curves

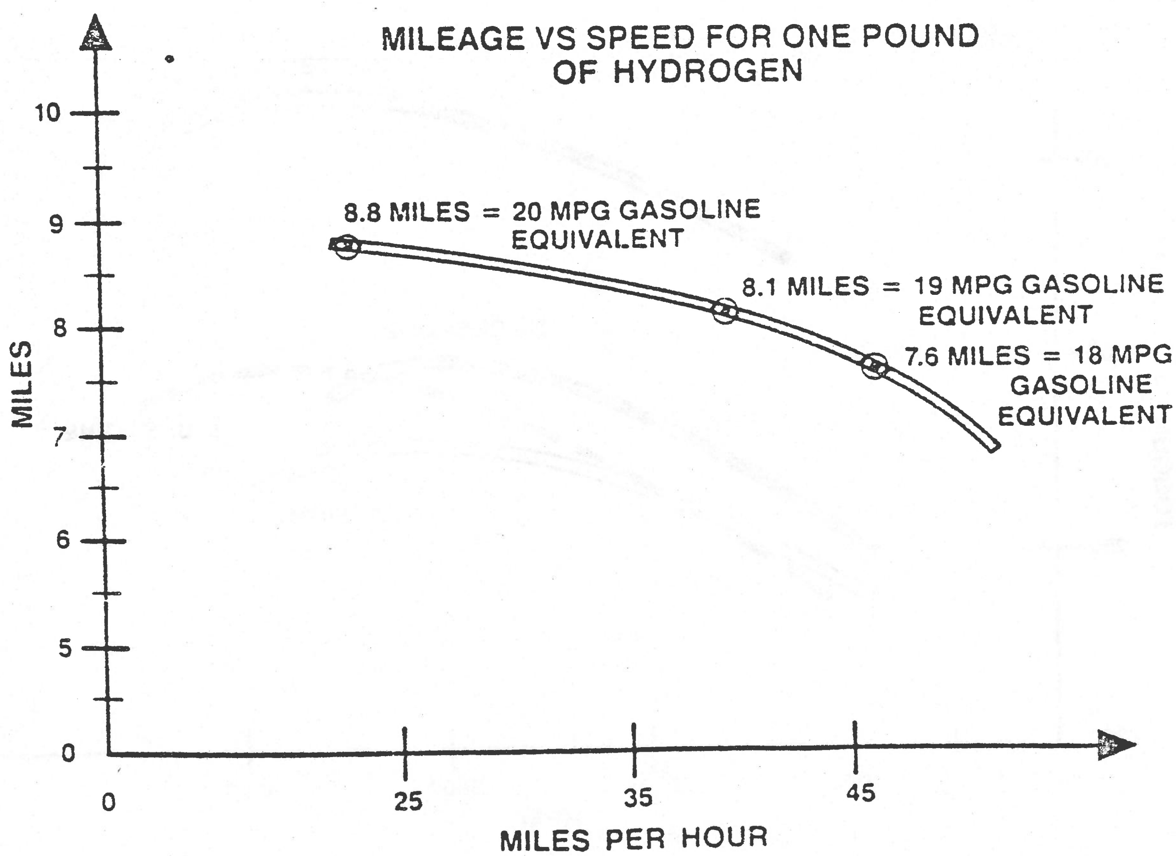


Figure 2.14 Continuous Speed Performance for Hydrogen Engine Design-1

hydrogen. Flammability limits for hydrogen are greater than for gasoline, thereby resulting in a much larger range of fuel mixtures for which a hydrogen engine can operate. In addition to the above, hydrogen also possesses a faster flame speed and lower ignition energy than does gasoline, thus resulting in more favorable combustion characteristics when compared to gasoline. Table 2.3.1 provides a comparison of key properties of hydrogen versus isoctane (gasoline).

TABLE 2.3.1

	H_2	Isooctane
ENERGY DENSITY (Mass)	61,000 BTU/LB	20,500 BTU/LB
ENERGY DENSITY (Volume)	320 BTU/FT^3	950,000 BTU/FT^3
FLAMMABILITY LIMITS	Vol % in Air	
(lean)	4%	1%
Range		
(rich)	75%	6%
FLAME SPEED	180 cm/sec	40 cm/sec
MINIMUM IGNITION ENERGY	.02 MJ	1MJ

PROPERTIES OF HYDROGEN AND ISOOCTANE

Also, experience has shown that flammable fuels and gases, such as gasoline, propane, methane, and hydrogen, can be handled safely when suitable precautions are taken [34]. In comparison to other fuels, hydrogen does present a hazard because of its wide range of flammability and its low spark ignition energy as shown in Table 2.3.1. Furthermore, hydrogen is more likely to leak from containers than would other fuels or gases due to the obvious small molecular size of the hydrogen and the resulting low viscosity of the gas. Thus, safe containment and protection from sparks or other ignition hazards are essential in the design of a crashworthy hydrogen powered vehicle.

Data from reference 35 indicates that the cost for hydrogen production ranges form 31 to 61 cents per pound of gas. Based on an energy equivalent basis it is calculated that 2.2 pounds of hydrogen would be equivalent to 1 gallon of gasoline for the lowest performer of the hydrogen engine designs ("H_2 Design-1") and therefore even in the least promising design the equivalent cost per gallon for the hydrogen would be $1.34 or about 6.7 cents per mile. For the improved "H_2 Design-3" the cost per mile for hydrogen would be about 4.5 cents per mile which is comparable to some of the figures cited in the hydrogen AE study conducted by Kukkonen [33] of the Ford Motor Company. Kukkonen is not very optimistic about the future of hydrogen as an AE transportation replacement to gasoline. His study provides an excellent overview of the differences in costs for hydrogen and electric vehicle designs of various weights, ranges, system efficiencies and methods of obtaining hydrogen and electric energy sources. One factor which has not been covered thoroughly however, in reference 33 is the effect of improved efficiency in IC engines through the use of ceramics and other high technology materials which are being researched and utilized by several Japanese automotive engine manufacturers. This technology, would be applicable to any of the AE sources cited in this report that are adaptable to the IC engine. While the hydrogen AE source is a long way off (say 25 + years) it is not likely to be 100 years away as suggested by Kukkonen.

2.4 COST, SAFETY AND EMISSION BENEFITS OF THE MOST LIKELY AE SYSTEMS

As noted in Section 1.1, a major problem in the Phoenix and Tucson urban/metropolitan areas deals with the environmental pollution caused primarily by gasoline powered vehicles. Air quality standards were violated in both cities during the winter of 1985-86. The above violations could lead to significant loss of federal revenues for state projects. By considering the encouragement of the most likely AE systems identified in Section 2.2 of this report the State of Arizona could gain much greater benefits than would be possible by fuel taxes or vehicle registrations.

First of all, with regard to fuel costs the AGA has published data which indicates that natural gas is a more cost effective AE replacement to gasoline if a vehicle is driven more than 15,000 miles annually. This information is shown in Figure 2.15, along with comparison of fuel costs for propane (LPG), methanol, and electric vehicles. By far, the CNG fuel either in a dual fuel mode or in a dedicated mode can provide cost savings to the consumer and ultimately to the State of Arizona through drastic reduction of hazardous emissions and gasoline pollution products. The cost for CNG vehicle fuel at the present time is billed by Southwest Gas of Tucson on a large industrial customer rate. Southwest Gas is leaning toward creating a new rate structure that would accurately reflect the cost of delivering the gas to the customer. The cost of providing CNG as a motor vehicle fuel is less than the cost of delivering the gas to a housing subdivision or an industrial customer. The amount of fuel consumed by the average vehicle is approximately the same amount as delivered to three medium size houses. The obvious cost savings to the gas supplier can be passed on to the consumer once new rate structures are in place.

Currently neither the State of Arizona or the federal government have the means of collecting taxes on CNG as a motor fuel. The current users are figuring in the equivalent taxes in the total costs of the CNG and are placing the uncollected tax into a reserve fund in case the motor fuel taxes are ever applied. The projected cost of the motor fuel tax is 13 cents per gallon. This is the same amount of tax that is currently levied on gasoline and diesel.

2.4.1 FUEL SAVINGS

The current fuel savings of CNG when compared to the costs of conventional fuel (i.e. gasoline, diesel or LPG) range from 5 cents per equivalent gallon to 40 cents. The cost savings are influenced by the supplier of the natural gas, capital costs and electric rates. Scottsdale, Arizona is currently saving approximately 13 cents per gallon where as Southwest Gas of Tucson is saving between 25 to 30 cents per gallon. The cost savings for an average vehicle getting 18 miles per gallon driven for 12,000 miles per year, based on the average savings of 26.5 cents per equivalent gallon would be $176.67 dollars per year. If the life of the vehicle were considered to be 125,000 miles the total projected cost savings (assuming both natural gas rates and gasoline cost remained the same or increased proportionally) would be $1840. As the spread between the costs of natural gas and gasoline increase the amount of fuel savings would rise also. If the amount of mileage driven per year is increased the fuel cost savings would rise proportionately.

2.4.2 FEDERAL, STATE AND LOCAL REGULATIONS

The federal Department of Transportation regulates the tanks used for CNG compliance with current compressed gas regulations, the end user comes in contact with these regulations by means of hydrostatic testing of the tanks every 5 years. The testing is required to insure that the tanks will operate safely in every day use. All of the major dealers of CNG tanks sell only tanks that conform to existing DOT regulations. The fueling system of the vehicle must conform to the regulations governing gasoline or diesel fuels. The major difference is the cut off switches that cut off the natural gas supply when switching fuels. The setup and the maintenance of the refueling station comes under local building and fire regulations.

2.4.3 ENVIRONMENTAL CONCERNS

CNG is a clean burning fuel, (see Figure 2.15) the amount of non-methane hydrocarbons produced are half that produced by gasoline. The lack of the hydrocarbons in CNG emissions means that the level of smog produced is smaller. CNG exhaust contains almost no carbon monoxide, sulphur or suspended particulates, all of which are found in abundance in gasoline, LPG and diesel exhaust. In fact, most CNG fuel exhaust is made of simple water vapor. The weather and the climate do not seem to present a major problem for dual fuel vehicles. Cold weather starting is enhanced due to CNG's vaporous state. Some problems in the fuel delivery system due to cold weather have been experienced by some users. For example, the grease in the pressure gage system will thicken and give a false low pressure reading until the system warms up. Circulating the engine coolant around the first stage of regulation seems to eliminate this problem.

Maintenance of the refueling site in cold weather should also be taken into account. The user in cold weather climates might want to inclose the compressor station for easing regular maintenance.

Figure 2.15

Emissions of Alternatively Fuel Vehicles (grams/mile)					
Fuel	Non-Methane				
	HC	CO	NOx	SOx	Particulates
Compressed Natural Gas	0.26	0.03	1.23	Neg.	Neg.
Gasoline	0.54	8.35	1.92	0.71	0.08
Methanol	0.25	2.90	0.55	Neg.	Neg.
Electricity	0.03	0.10	2.28	1.58	0.04

Assumes 80% of SOx removed in fossil fuel electric generation. Assumes 95% of particulates removed in fossil fule electric generation. Emissions attributed to battery recharging of electric vehicles are not included.

2.4.4 VEHICLE COMPARISONS

A) Types of Vehicles:

CNG alternative fuel conversions on all types of vehicles, ranging from small cars with 4 cylinder engines up to vehicles having 22,000 pounds gross vehicle weight have been successfully accomplished in recent years. The rear suspension of the smaller vehicles may have to be enlarged to compensate for the additional weight of the CNG cylinders. The dedicated vehicle allows the user to take advantage of the lower cost of natural gas and can eliminate the additional weight caused by incorporating dual fuels. If the vehicle manufacturers make the decision to produce a dedicated vehicle the cost should be comparable to that of a gasoline powered vehicle. Because CNG vehicles require no pollution control equipment to conform to present emission standards or a catalytic converter, the cost savings could also be passed on to the consumer.

B) Range:

The range of the CNG powered vehicle is limited by the amount of fuel carried on board. Space seems to be the main limiting factor due to the size of the CNG tanks. If the vehicle is converted to run on only natural gas and the existing conventional fuel system is removed, the CNG tanks can be placed where the gas tank was located. The major vehicle manufacturers are expressing an interest in manufacturing a dedicated CNG vehicle. Ford Motor Company has manufactured 20 Ranger pick-up trucks for testing the feasibility of CNG design. The Ranger pick-ups were distributed to natural gas company fleets to study the effect of CNG as a motor fuel. Toyota has plans to introduce a dedicated CNG vehicle to the United States market.

C) Power:

There is no significant loss of power when compared to conventional fuels if the engine is in good working condition. The user may notice a slight lagging when accelerating on CNG. This can be over come if the engine is tuned correctly (to the vehicle manufacturers specifications) and the difference in timing is taken into account. To be correctly timed to take advantage of the burn properties of CNG, the engine timing should be advanced 15 degrees. This is due to the faster burn rate inherent in natural gas. The increased weight of the dual fuel vehicle will have an effect on smaller vehicles but is unnoticeable in larger cars and trucks.

D) Engine Life:

Since CNG has an octane number higher than gasoline (around 130) its use in high compression engines poses no problems and will operate without pre-ignition. The elimination of "knock" with out the addition of lead as an anti knock reduces the build-up of carbon in the engine. The oil life is extended because the CNG is not mixing with the oil.

This allows for an extended life of the viscosity of the oil. The engine life can be increased by 150 to 200 percent using CNG. The decrease in maintenance costs should be taken into account when deciding to convert to CNG.

E) Driving Patterns:

Since there is a lack of currently available public refueling stations the most likely early application of CNG vehicles is for fleet operators that are based out of a central location. The costs of the refueling site can be minimized if duplication can be avoided. The location of the refueling site should be as close to the center of the company's range of business as possible. This will allow the CNG user to limit the amount of CNG carried on board the vehicles, thus reducing the cost of CNG cylinders. The choice of refueling systems should include considerations of the number of vehicle refueling per day. If the CNG user can afford the amount of cylinders per vehicle to provide enough natural gas for average daily use, a slow fill system can be utilized. If the vehicles will require more than one refueling per day a fast or mix fill system will have to be used.

F) Mileage Limitations:

Typical CNG cylinders can hold between 300 to 1000 cubic feet at 3000 psi. Depending upon the size of the vehicle and the number of cylinders a typical 2 tank installation will provide from 60 to 200 miles of range. If the vehicle is dual fuel the addition of the gasoline mileage must also be taken into account. If the vehicle were designed as a dedicated vehicle the mileage provided would be comparable to that of a gasoline vehicle. The vehicle designed by Ford is rated at over 30 mpg with a 200 plus mile range.

G) Safety:

CNG vehicles are safer than petroleum fueled vehicles. Some of the reasons for the excellent safety record of methane-fueled vehicles, according to Dr. Winston Porters' 1979 10 year study are:

1) Natural gas is lighter than air, this eliminates the possibility of puddling in the event of an accident.

2) Natural gas is more difficult to ignite than gasoline or propane. The temperature of ignition for CNG is about 1300 degrees fahrenheit and for gasoline 800 degrees.

3) The required air to fuel mixture is quite limited usually in the range of 17 to 1. The large air to fuel mixture helps reduce the possibility of fire in the event that a CNG cylinder is ruptured.

4) Natural gas is non-toxic. The vehicle emissions contain negligible amounts of CO. This allows for the use of natural gas powered vehicles to be operated safely indoors.

5) The systems design strength.

If a leak in the CNG system should occur the natural gas will rise and dissipate into the atmosphere. The ignition point of natural gas is higher than gasoline usually about 1300 degrees as compared to 800 degrees fahrenheit for gasoline. The ignition point of CNG is so high that a cigarette will not ignite it. Insurance underwriters have recognized the safety of CNG and consider it to be as safe or safer than any other vehicle fuel.

2.4.5 SUMMARY:

CNG's use as a vehicle fuel is promising for the fleet user. It provides a clean alternative to conventional petroleum fuel basing and allows the dual fuel user to choose the most economical fuels and the reduced vehicle maintenance costs should be considered when the decision to convert is being made. The natural gas supply industry is showing an interest in helping the fleet operator with the conversion decision and the forecast domestic supply is over 60 years including projected growth rates. The cost of CNG should be expected to rise over the current rates due to supply and demand, but CNG should still show savings when compared to conventional fuels. The cost of conversion to CNG is significantly front loaded, but the end user must keep in mind that once the equipment is purchased the conversion kits on the vehicles may be removed and put to use on new or other vehicles in the company fleets. The refueling station can be used with all converted vehicles and replacement won't be needed for 20 years.

In areas of emission controls the use of CNG allows the user to meet the emission requirements without adding any additional equipment. The major component of CNG exhaust is water vapor, with a reduction of non-methane hydrocarbons.

SECTION 3

SOCIO-BEHAVIORAL CHARACTERISTICS

3.1 INTRODUCTION

3.1.1 THEORETICAL ORIENTATION

The acceptance and use of energy alternatives by the American public is a slow process which appears to be similar to the acceptance of any new technology or innovation. According to Rogers (1983) early adopters of innovation are 1) higher social status, 2) more educated, 3) have greater exposure or access to information, and 4) are more favorable to change and risk. Only 2.5% of the population are classified as "Innovative" or risk taking individuals (see Figure 3.1). These are unique individuals who implement innovation very early and appear to have more financial freedom than the "Early Adopters" (13.5%).

The diffusion of innovation perspective attempts to explain the adoption of new technologies by examining the attributes of the technology, the charac-teristics of the adopter, and the adoption decision process. These factors determine the rate that the new technology progresses through the five adoption stages (from innovative to later adopters).

Rogers emphasizes that change in adoption is caused by reduced uncertainty about the product due to increased interpersonal communication about its value.

A more complete explanation of the innovation process was proposed by Schnorr & Levi (1983). In the two-stage process, the image of the technology becomes transformed from a statement of passive personal values to the active participation in a social process. The early adopters use the image to make a statement about themselves to society. As the image is accepted by society (or rejected) it becomes institutionalized. By focusing on the image and its transformation, many of the potential failures can be understood and avoided.

During the first stage of adoption, the image reflects the personal values as well as economic, social and environmental values of the adopters. In many cases, it is not economically rational to adopt a new technology. The product is still under development so its reliability is uncertain and its cost is high due to a lack of mass production. Although some early adopters are risk oriented capitalists, most do not act like risk oriented entrepreneurs in other areas of their life. People "rationalize" their investment by misestimating the technology's reliability and payback.

The social status value of a new technology relates to the fashion pro-cess. In a country where technological progress is a widely held ideal, displaying the adoption of a new technology creates the potential of becoming a trend setter. Trend setting involves a limited number of people for a limited duration, eventually the fashion/fad either takes off or disappears.

Both the economic and social justifications for adopting a new technology are types of "egoistic" values: innovations are adopted because of the benefits which the individual receives. A third factor is the environmental or "altruistic" values which innovation represents. Adopting innovations is a statement about an individual's view of the proper relationship between people and their environment.

Because the personal values of the adopters are connected to the new technology during this stage, it is important for people to display the image they have adopted. This helps to explain the enthusiasm of these early adopters.

In the second stage of the adoption of a technology, the image has changed from a passive personal value to an active social value. The technology is no longer new, but is evaluated relative to the variety of available technologies displayed to consumers.

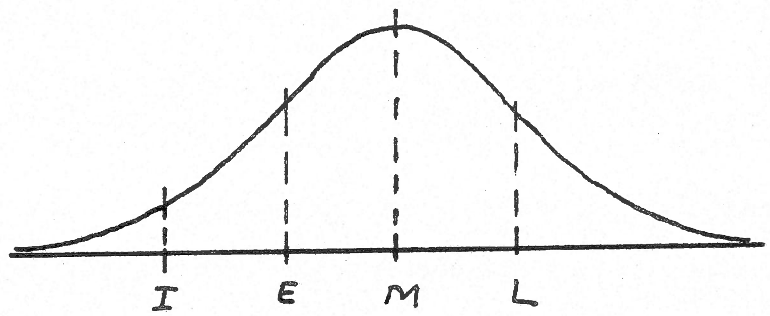
This transformation of the image changes the perceived attributes of the technology and the reasons used to justify its adoption. In the early stage, compatability of the technology with one's values is more important than the relative advantage of the new technology. In the second stage, relative advantage becomes more important. Economic and social status concerns change from risk taker and trend setter to economic rationality and fashion follower. Once this second stage is reached, the rate of adoption increases rapidly.

3.1.2 ASSUMPTIONS

Since the Arizona Department of Transportation is concerned about potential losses in revenue and the benefit in pollution reduction associated with alternative energy vehicles, this phase of the research effort focuses on identifying people most likely to adopt these technologies in addition to identifying the technologies most likely to be adopted. The "Innovators" and "Early Adopters" are assumed to be higher social status, more educated, have greater exposure or access to information and are more favorable to change or risk.

Thus, the early adopters are not representative of the normal population - rather, they are the "elite" of society. Therefore, the sampling techniques will analyze and compare demographic factors but no attempt will be made to achieve random sampling.

FIGURE 3.1



I	Innovators	2 %
E	Early Adopters	13 %
M	Majority	68%
L	Laggards	16%

Rogers, 1983. Diffusion of Innovations, (3rd Ed) New York: Free Press

3.2 SURVEY RESEARCH

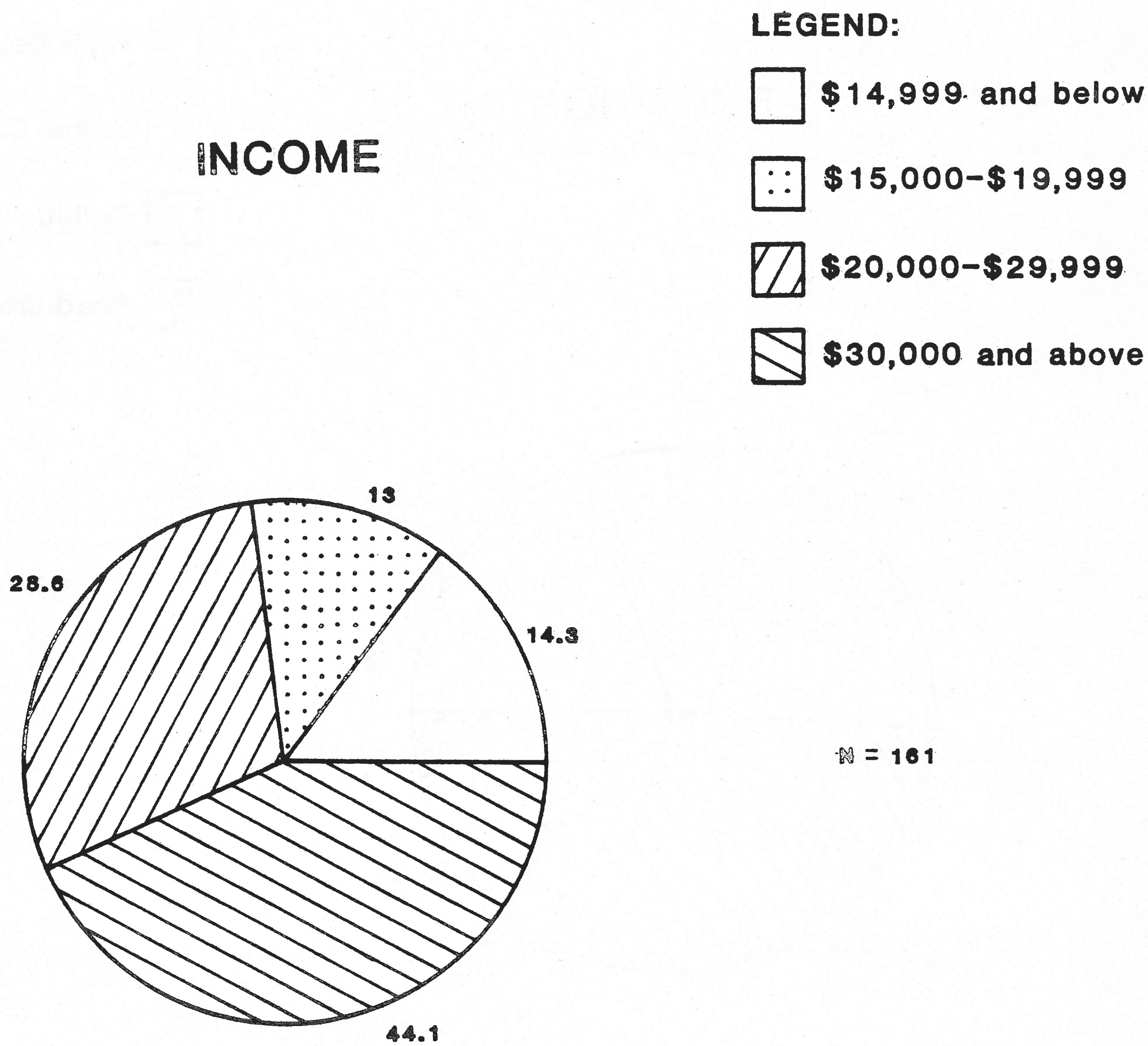
A preliminary survey was developed and tested in Flagstaff (Appendix A). Following inspection and analyses, the survey was revised and administered in Tucson (N=77) and Phoenix (N=96, Appendix B). Numerous demographic comparisons were also made between samples.

A multiple regression was performed on the survey using demographic variables as predictors. By doing this, the researchers were attempting to reduce the number of demographic variables to the most relevant factors for future research.

In addition, Factor Analyses (FA) were completed 1) to summarize patterns of intercorrelations among variables, and 2) to reduce the large number of variables to a smaller cluster.

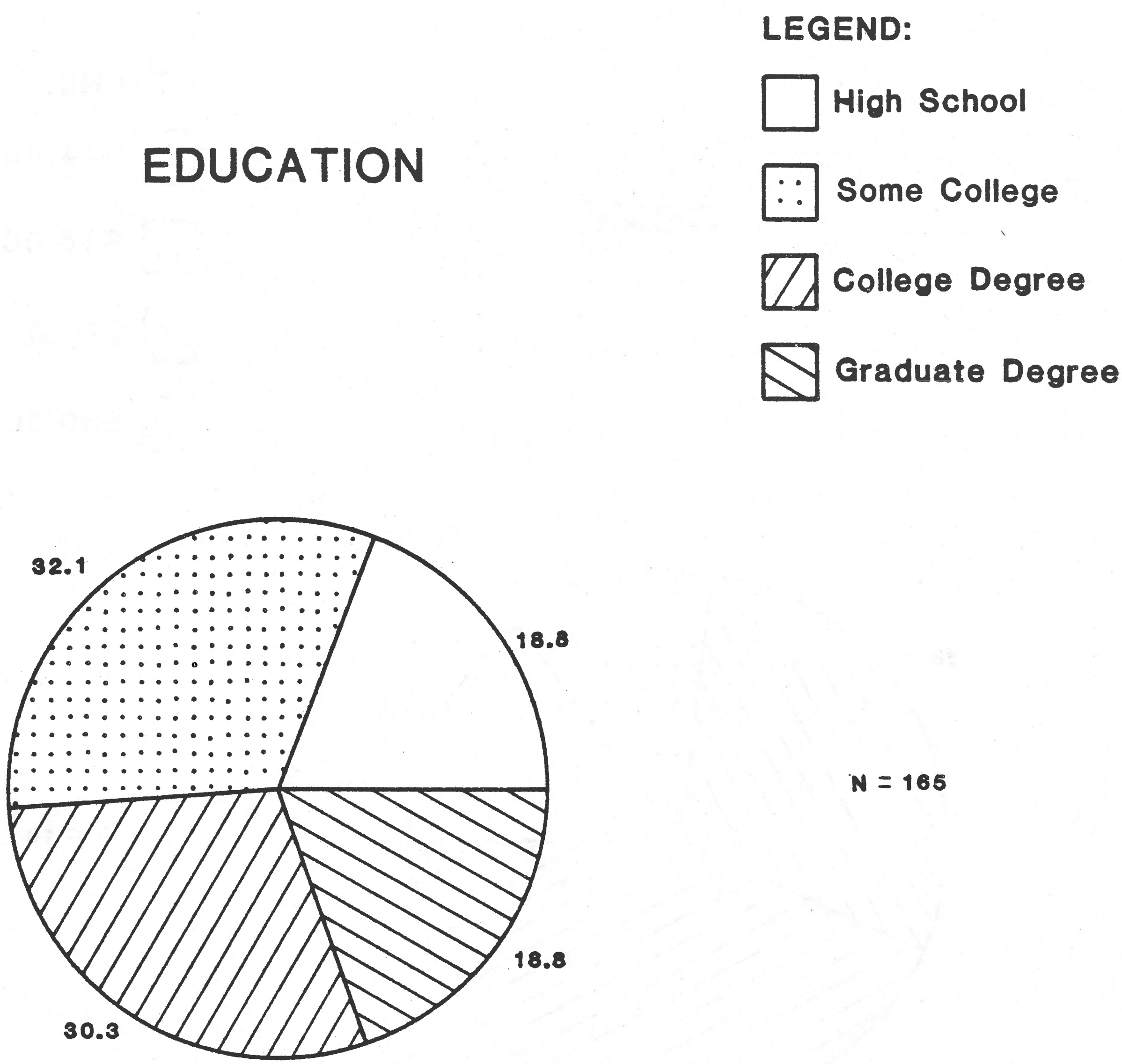
The regression analyses and factor analyses were computed on the survey responses from Tucson and Phoenix (FA Sample). The demographic information and survey responses for the sample questions are presented in Figures 3.2 THROUGH 3.29 where each figure represents the response to specific questions Q1 through Q28, respectively.

Figure 3.2



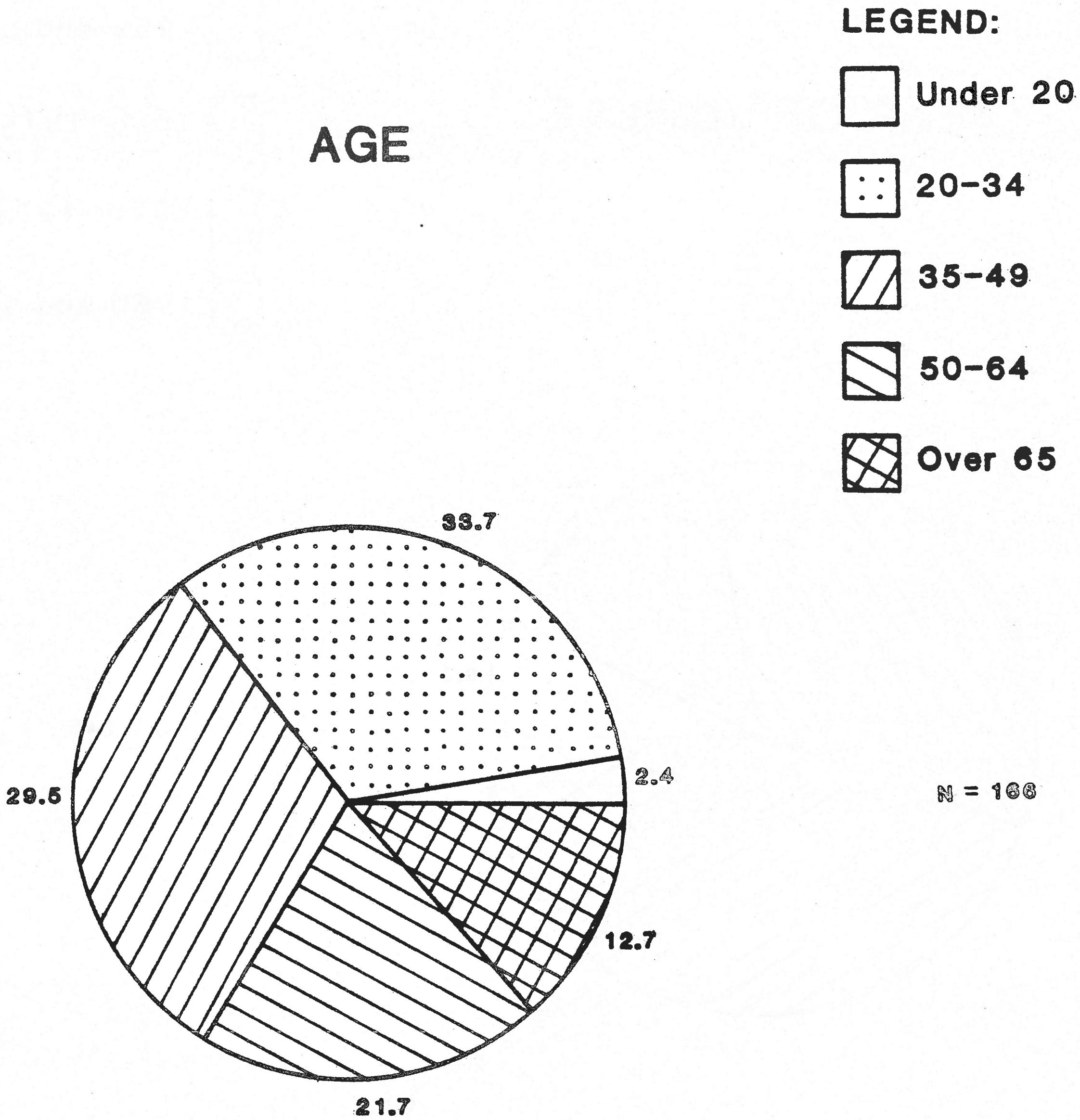
FA Sample

Figure 3.3



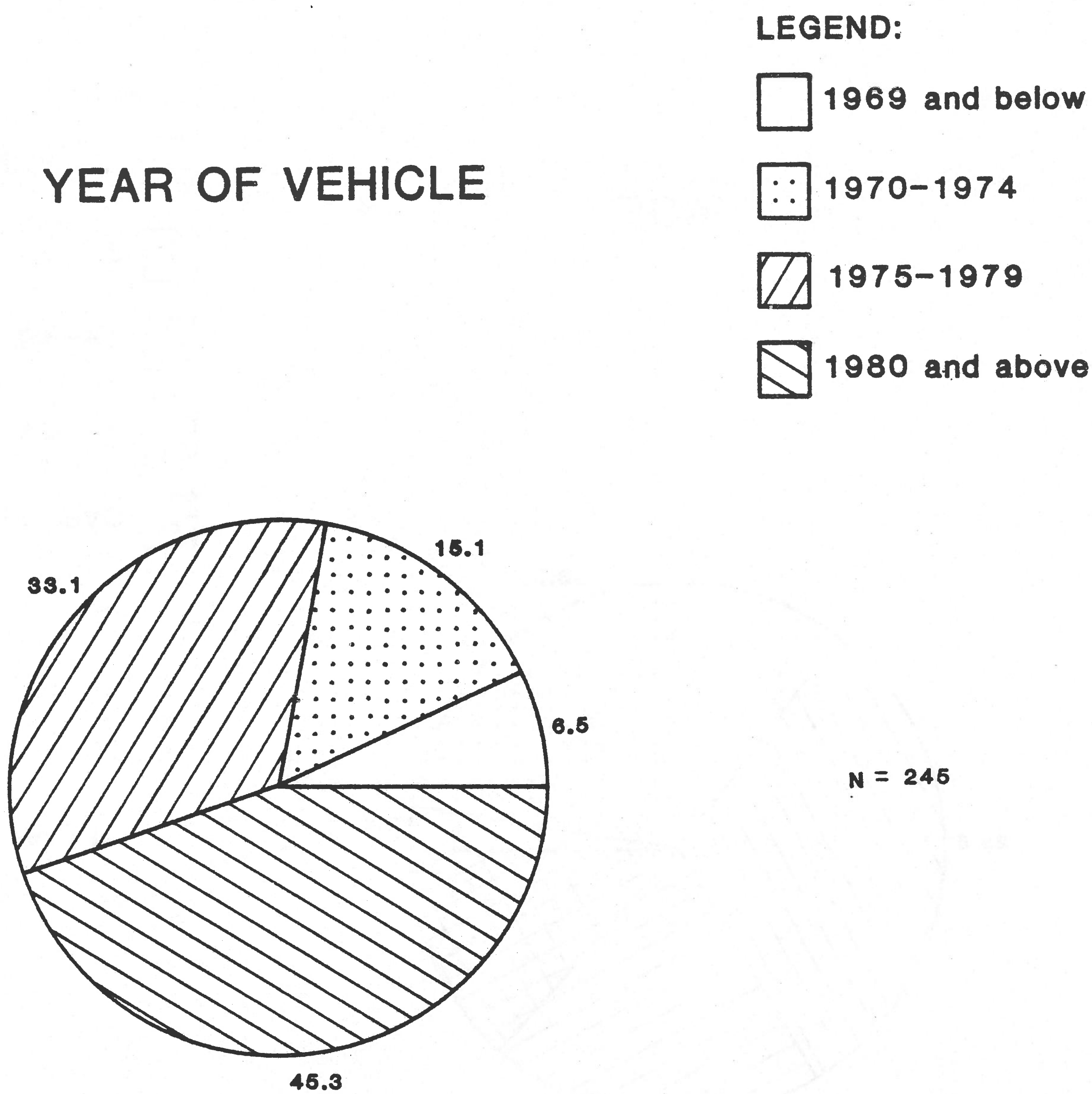
FA Sample

Figure 3.4



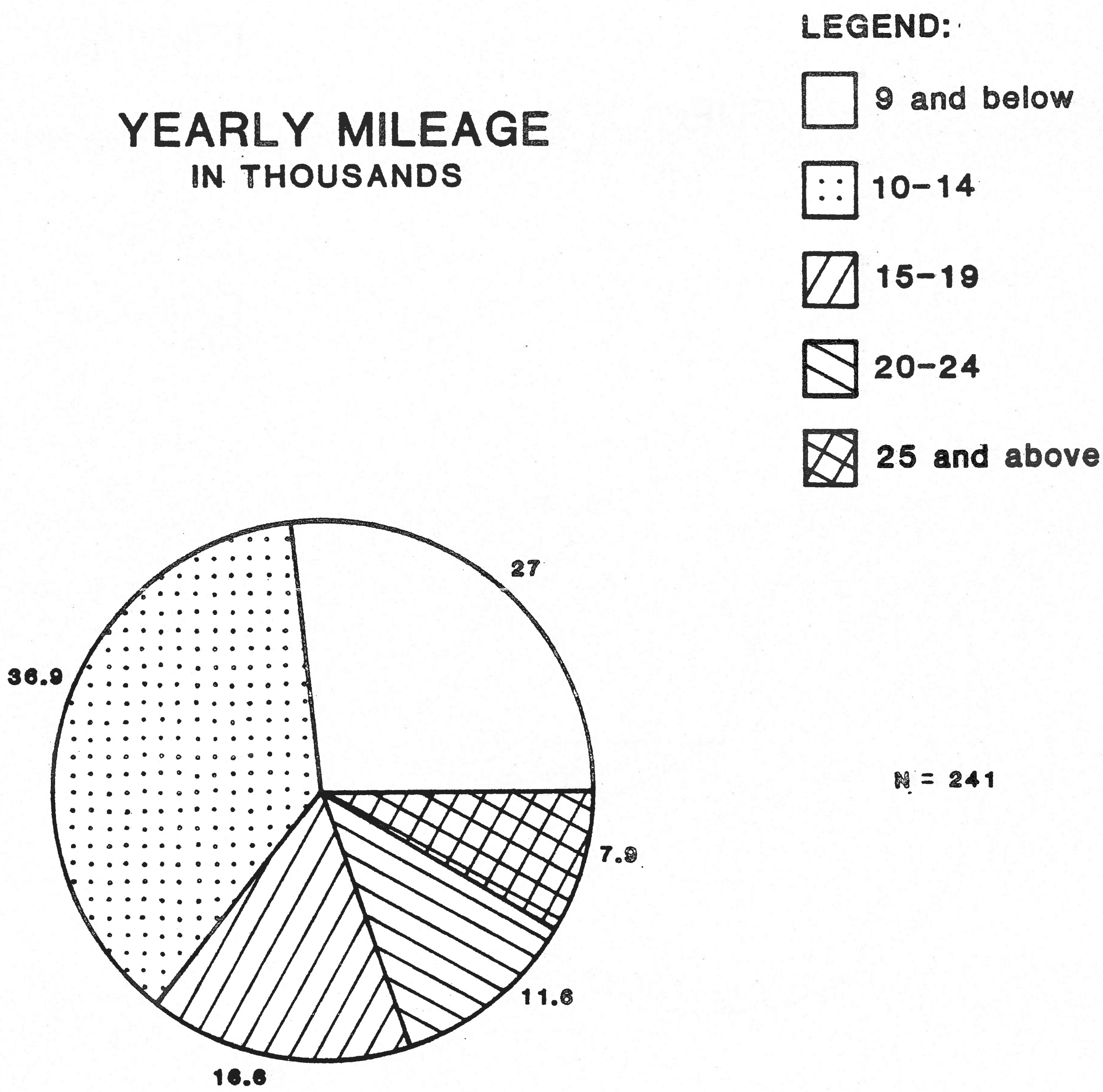
FA Sample

Figure 3.5



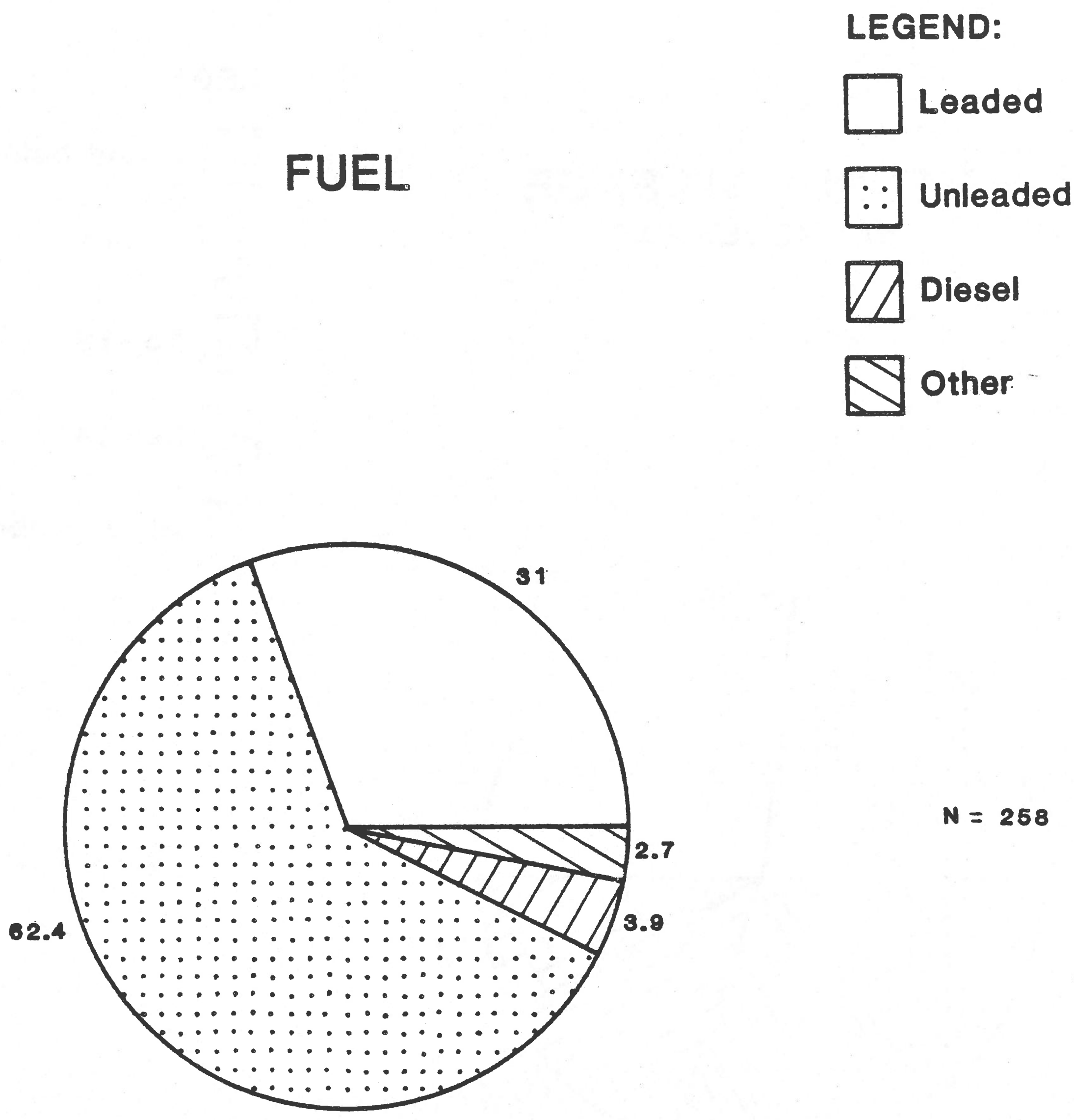
FA Sample

Figure 3.6



FA Sample

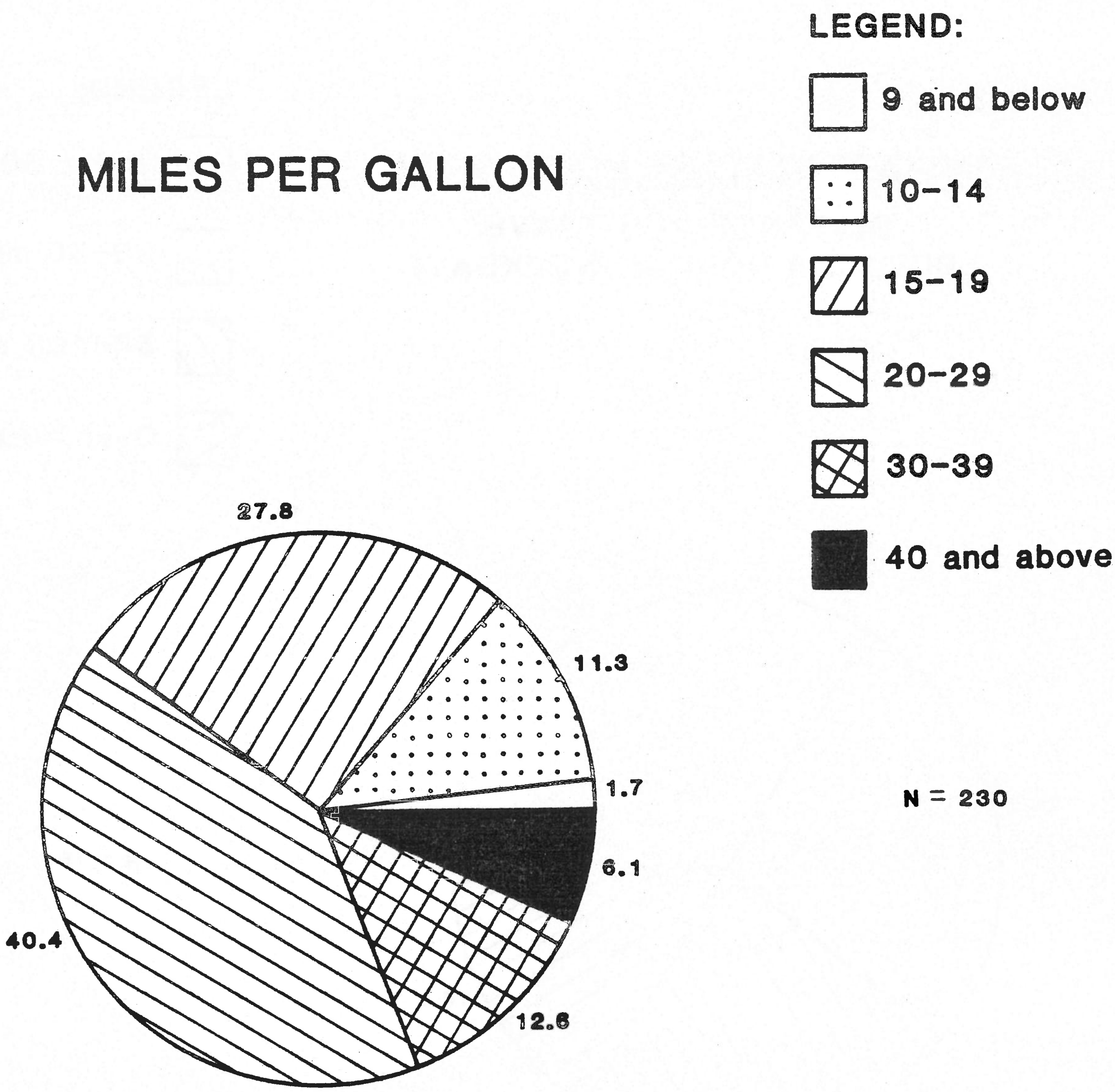
Figure 3.7



FA Sample

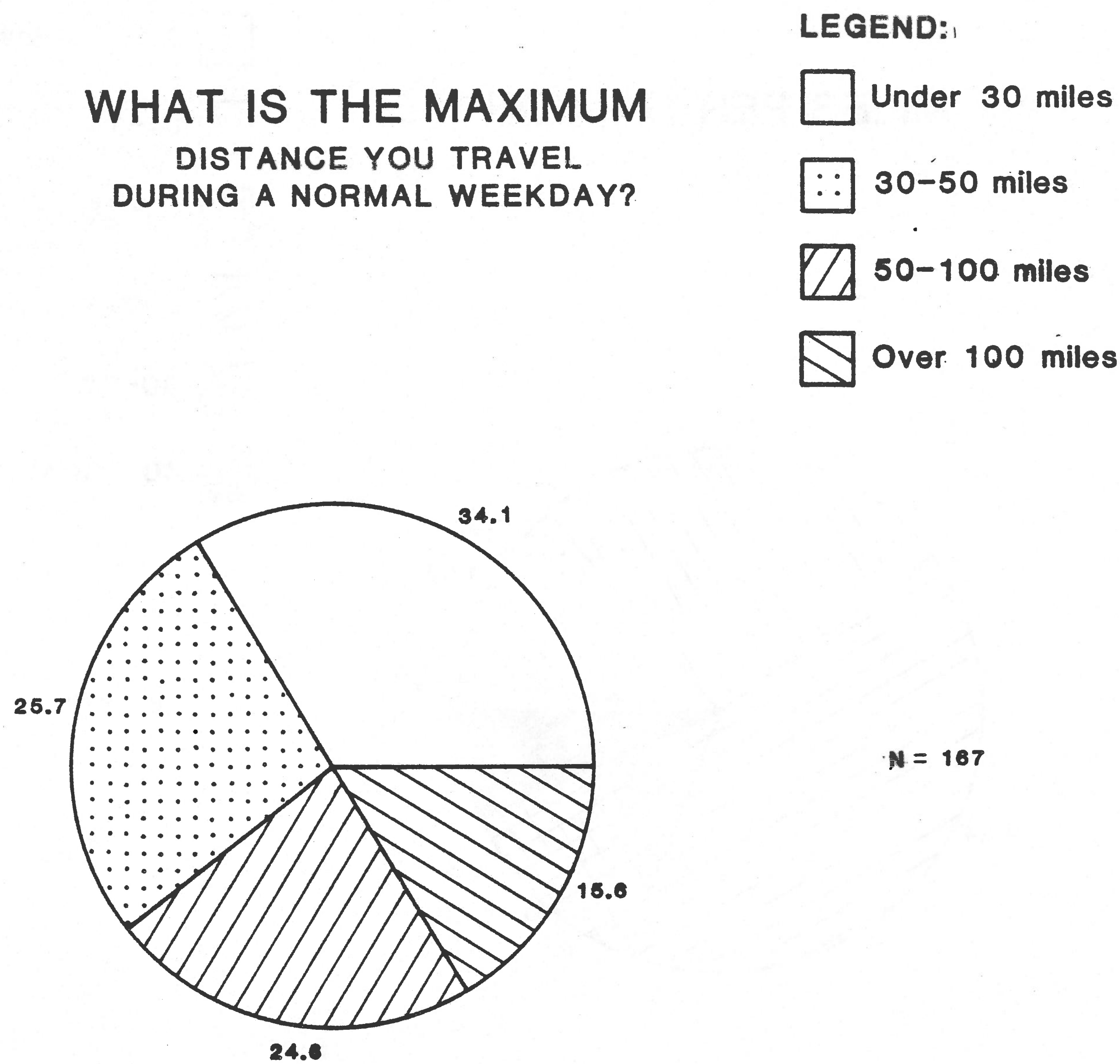
Figure 3.8

MILES PER GALLON



FA Sample

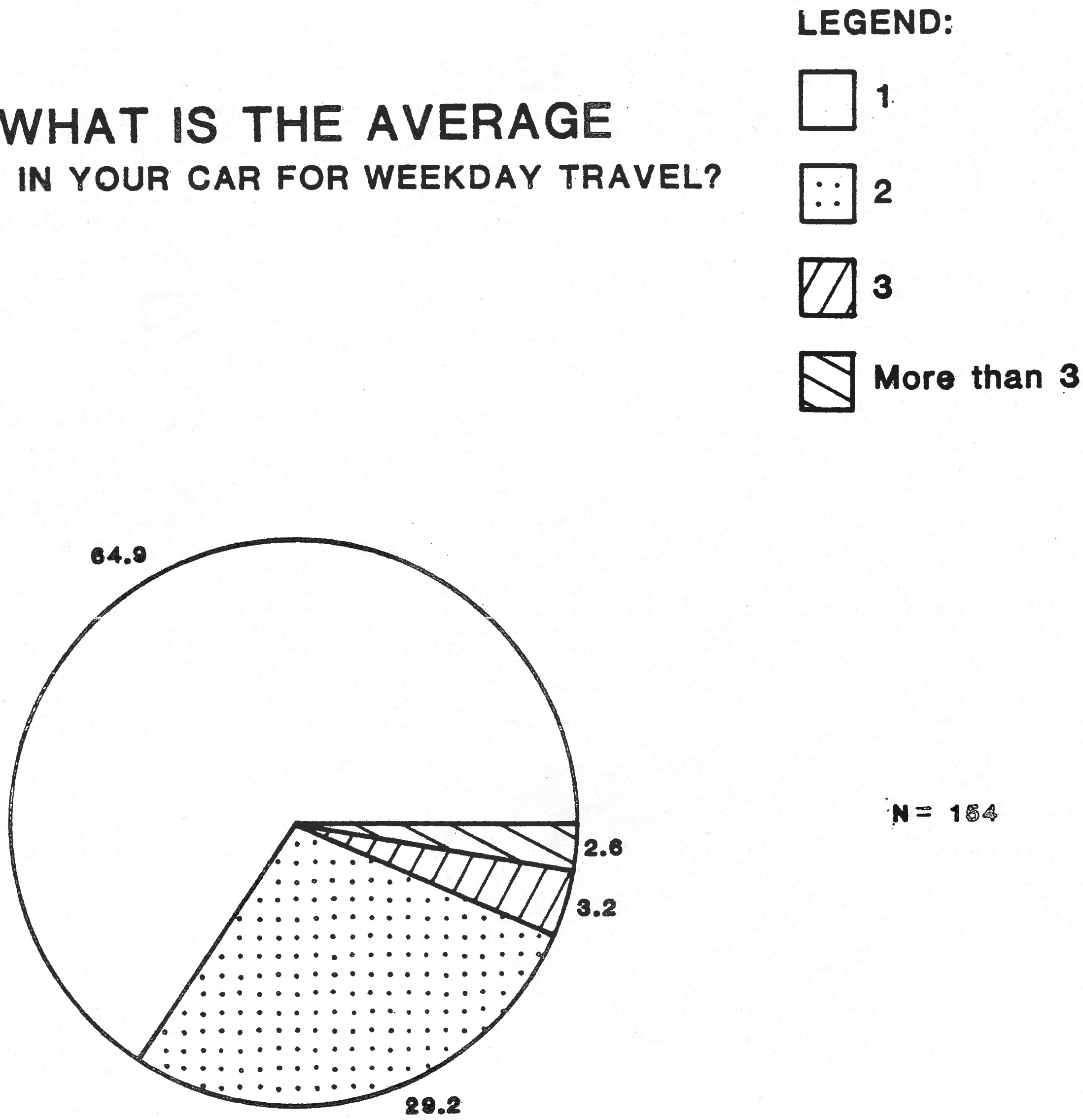
Figure 3.9



FA Sample

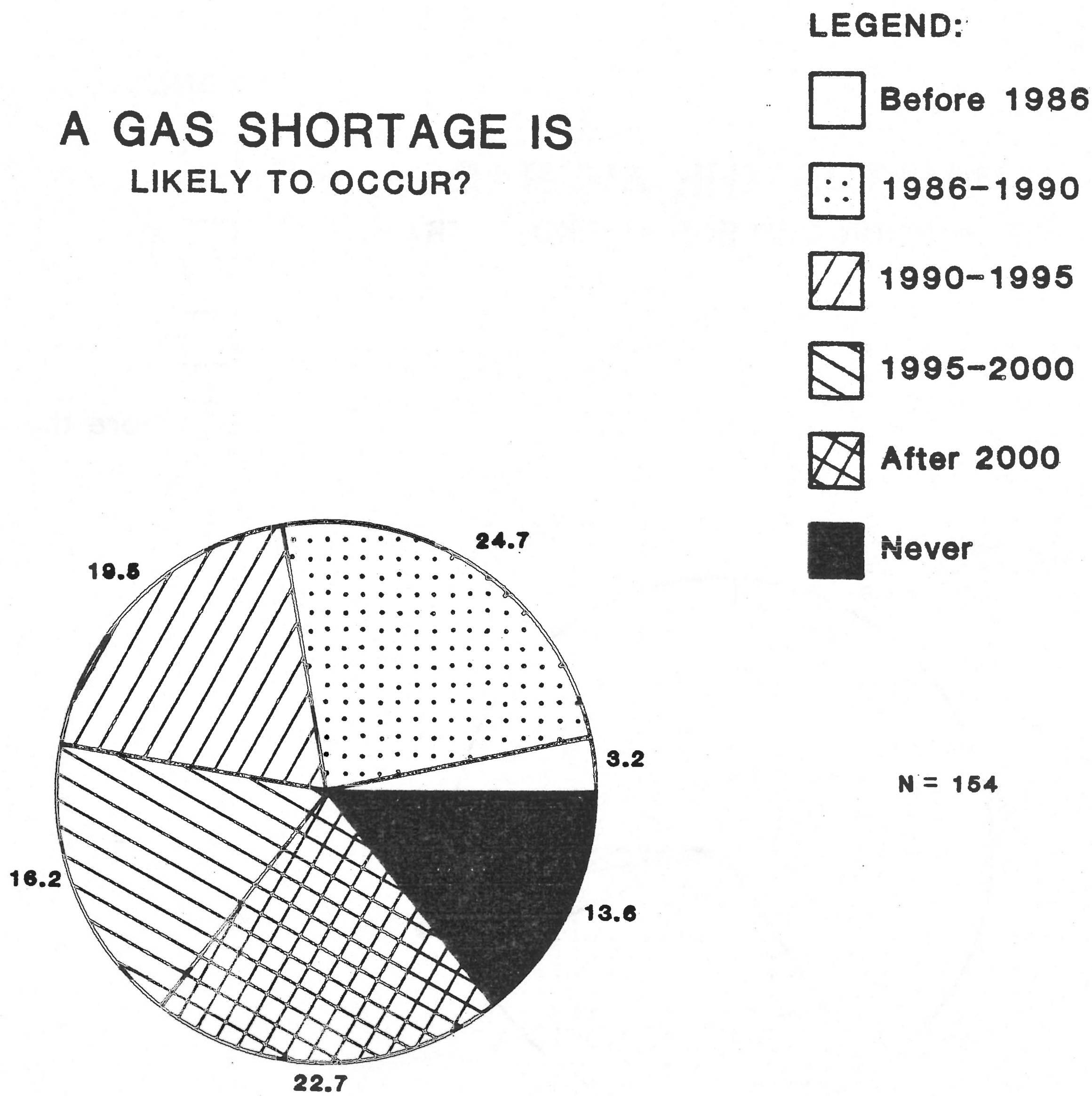
Figure 3.10

WHAT IS THE AVERAGE
NUMBER IN YOUR CAR FOR WEEKDAY TRAVEL?



FA Sample

Figure 3.11



FA Sample

Figure 3.12

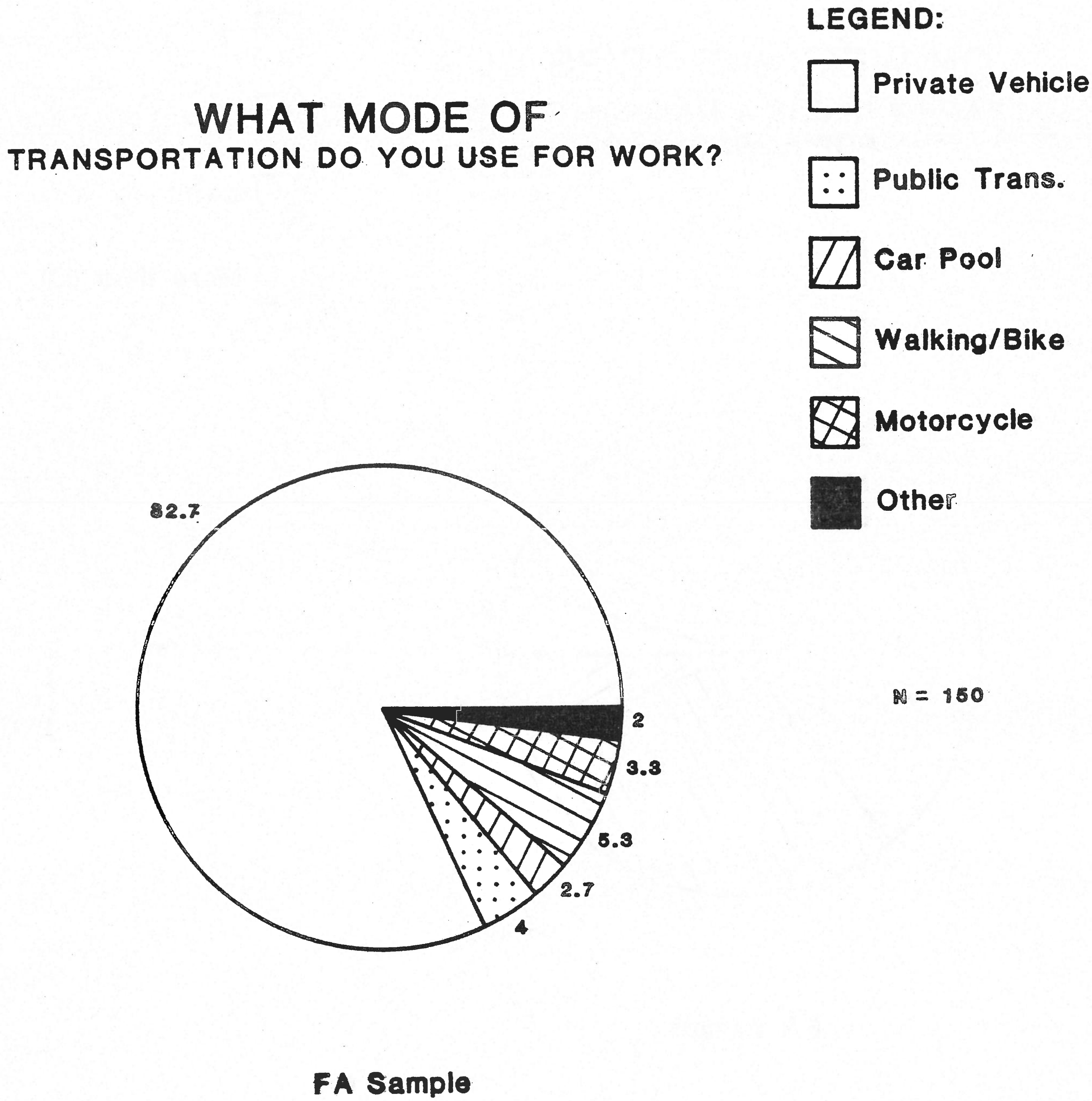
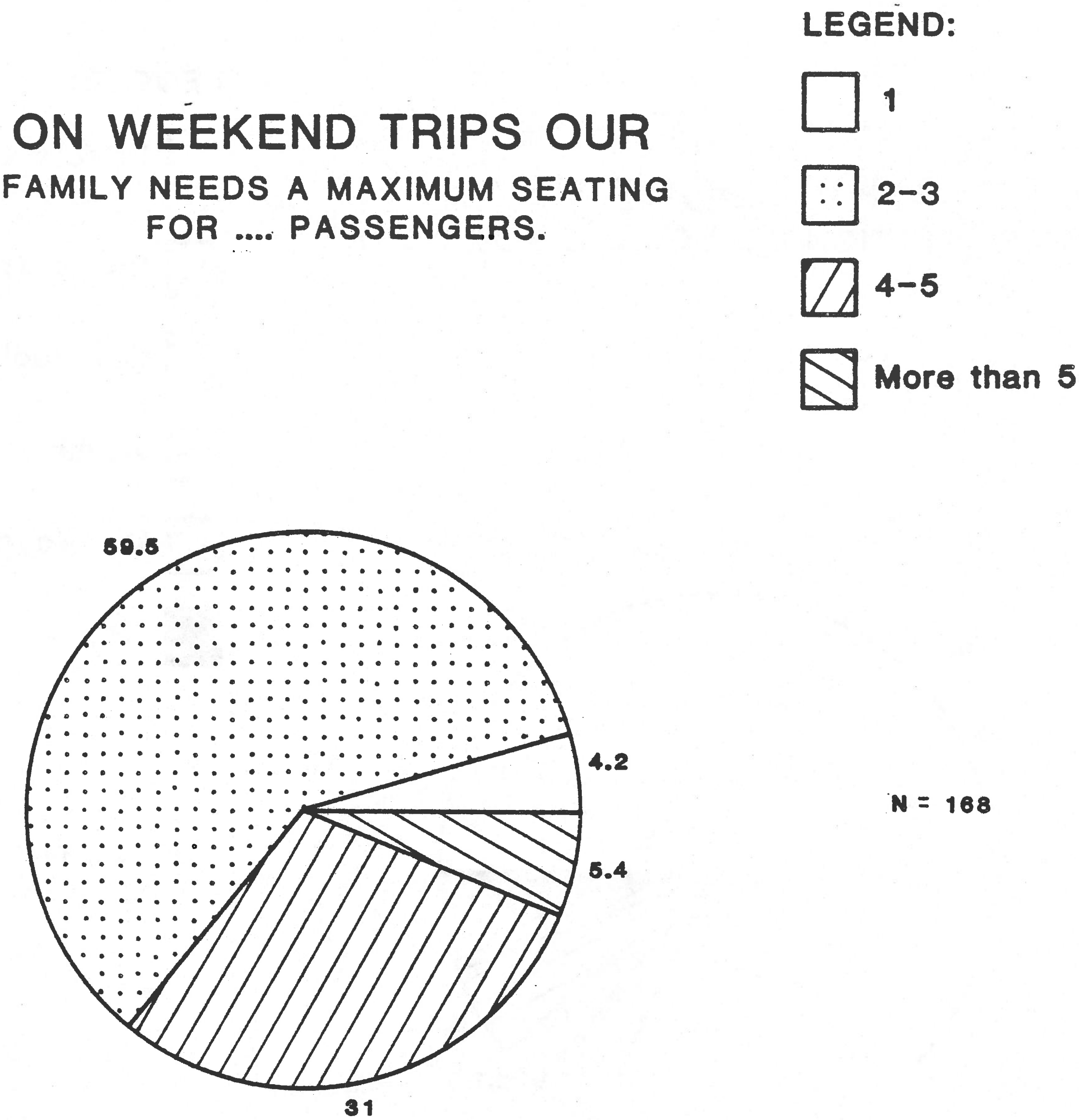

WHAT MODE OF
TRANSPORTATION DO YOU USE FOR WORK?
LEGEND:
Private Vehicle
Public Trans.
Car Pool
Walking/Bike
Motorcycle
Other
82.7
2
3.3
5.3
2.7
4
N = 150
FA Sample

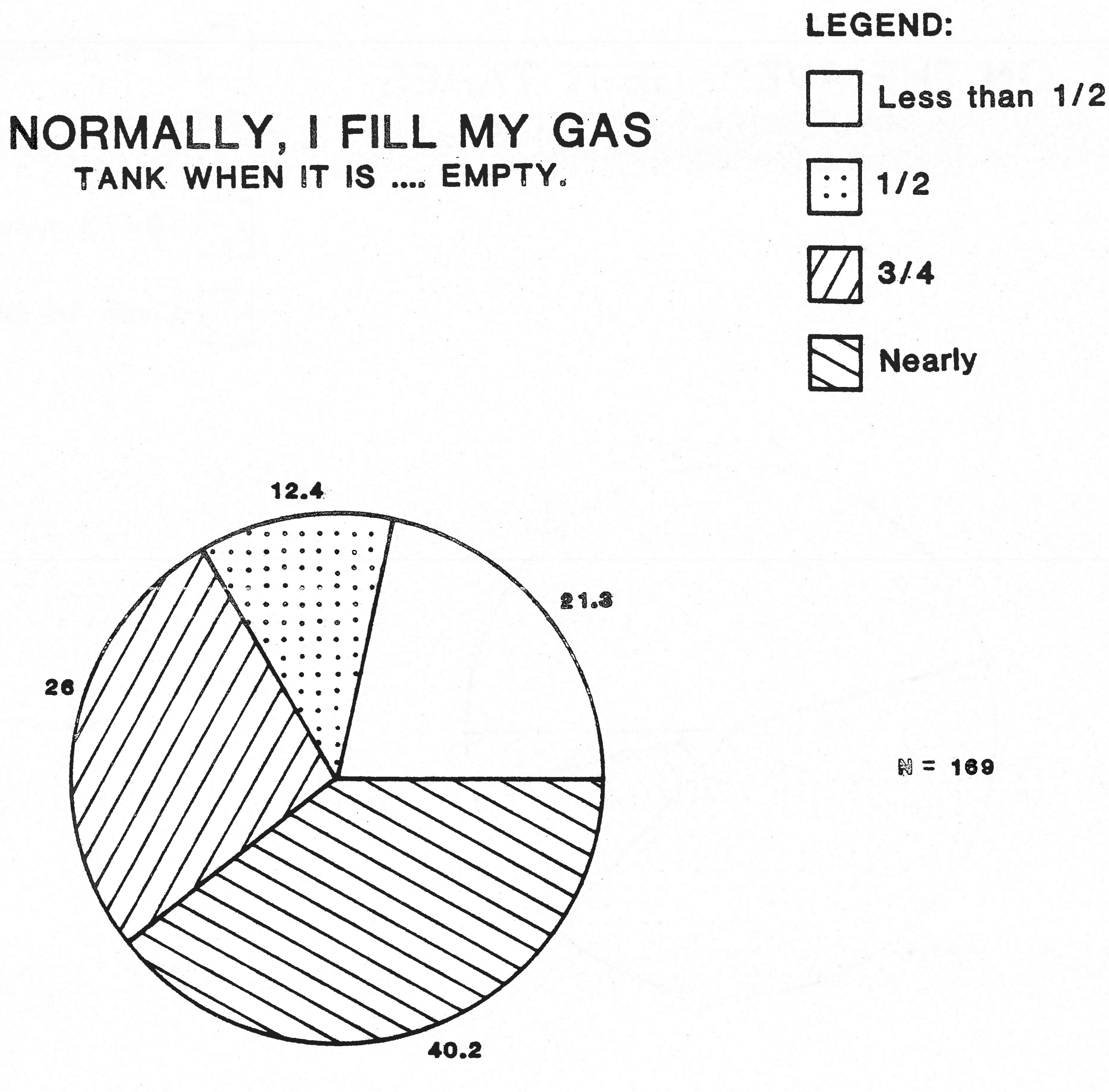
Figure 3.13

ON WEEKEND TRIPS OUR
FAMILY NEEDS A MAXIMUM SEATING
FOR .... PASSENGERS.



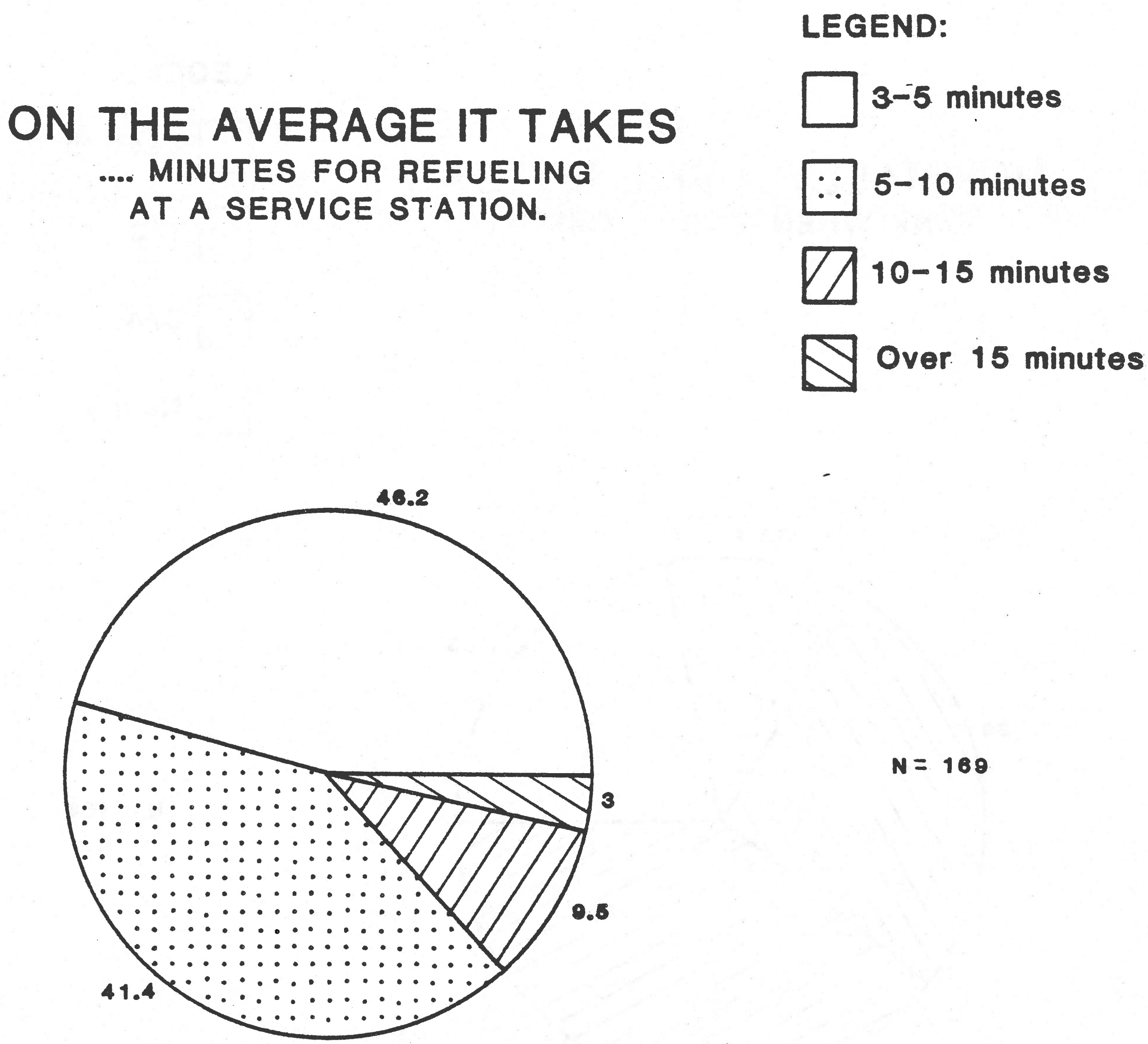
FA Sample

Figure 3.14



FA Sample

Figure 3.15



FA Sample

Figure 3.16

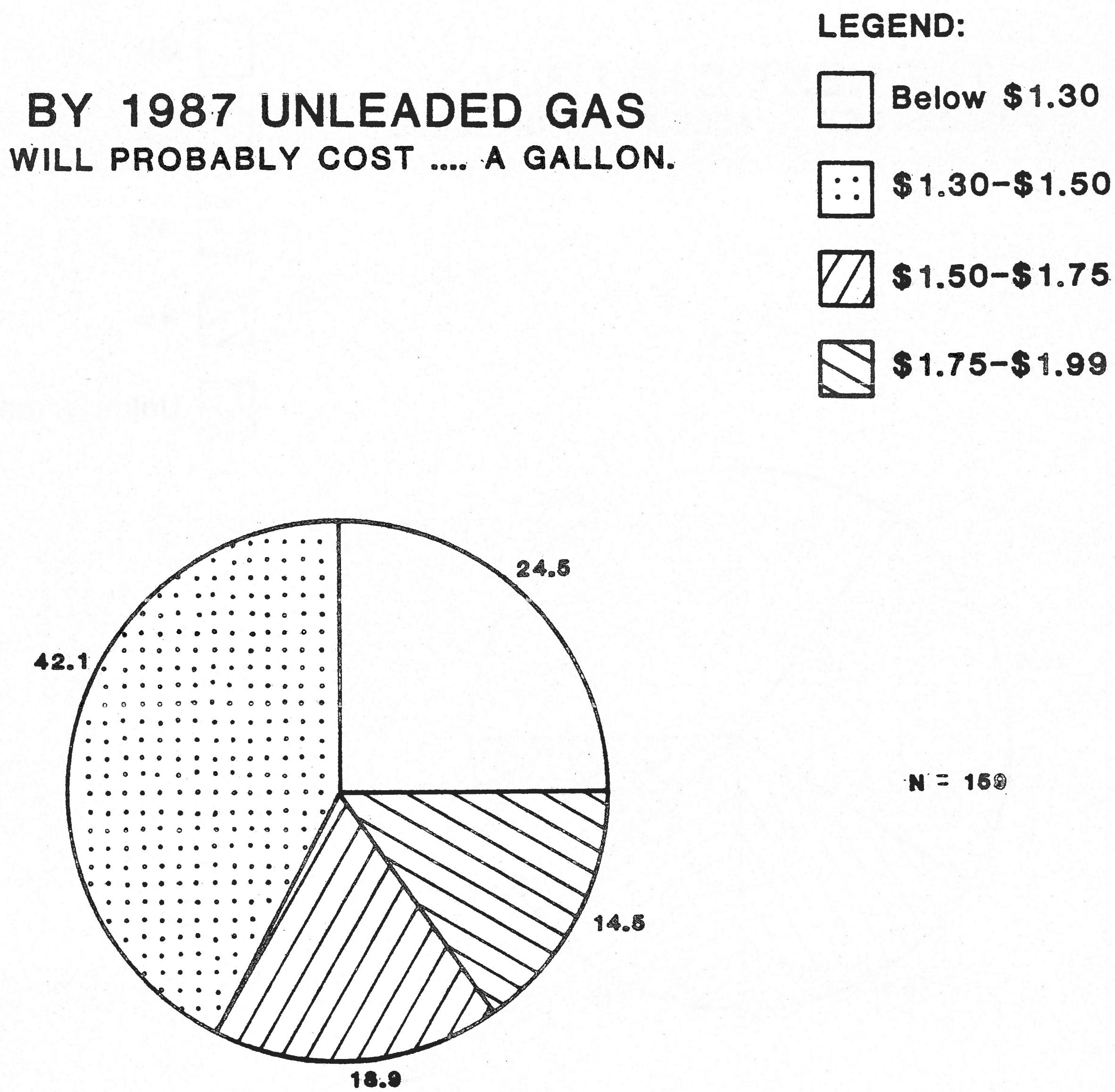

BY 1987 UNLEADED GAS
WILL PROBABLY COST .... A GALLON.
LEGEND:
Below $1.30
$1.30-$1.50
$1.50-$1.75
$1.75-$1.99
24.5
42.1
14.5
18.9
N = 159
FA Sample

Figure 3.17

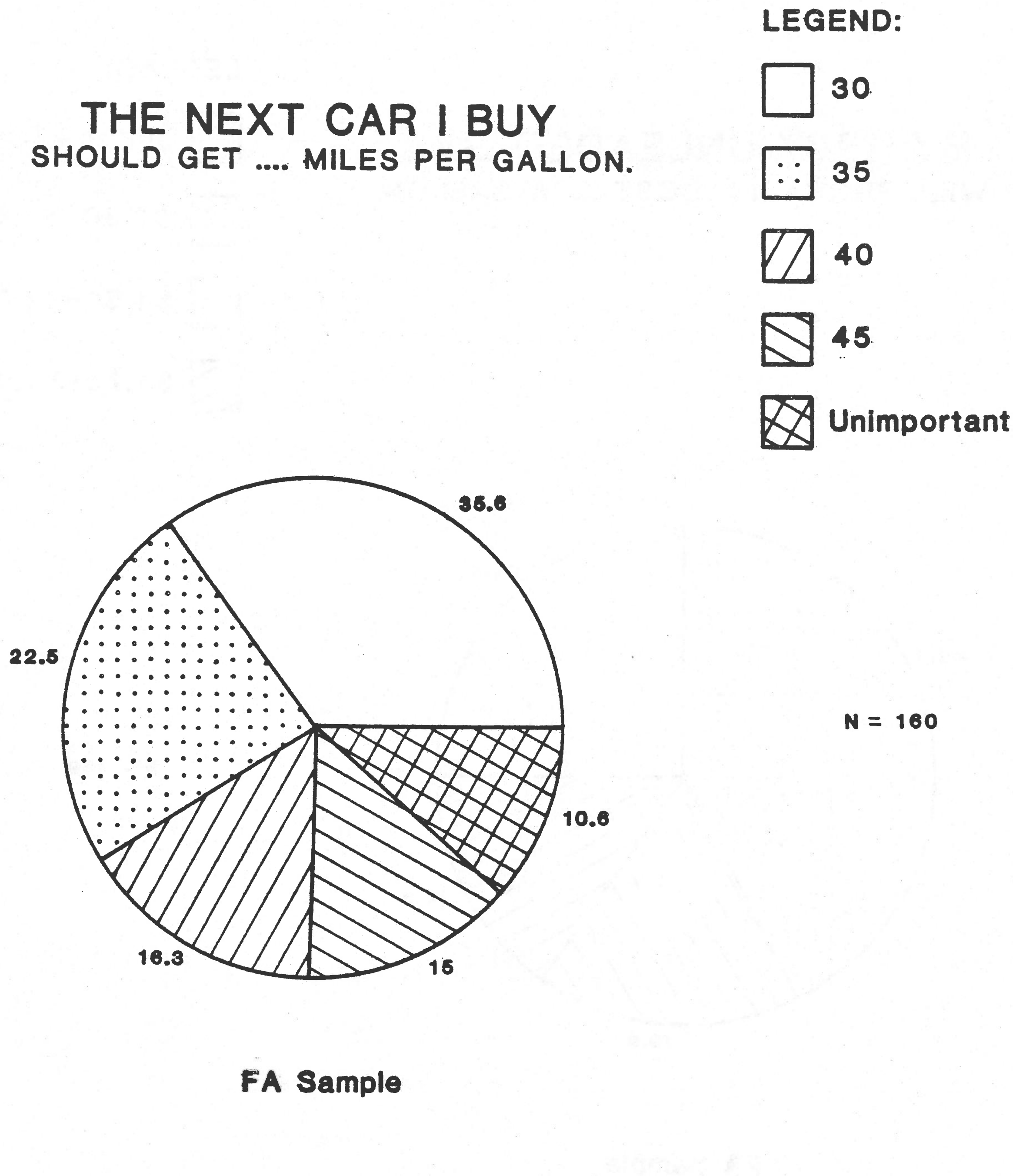
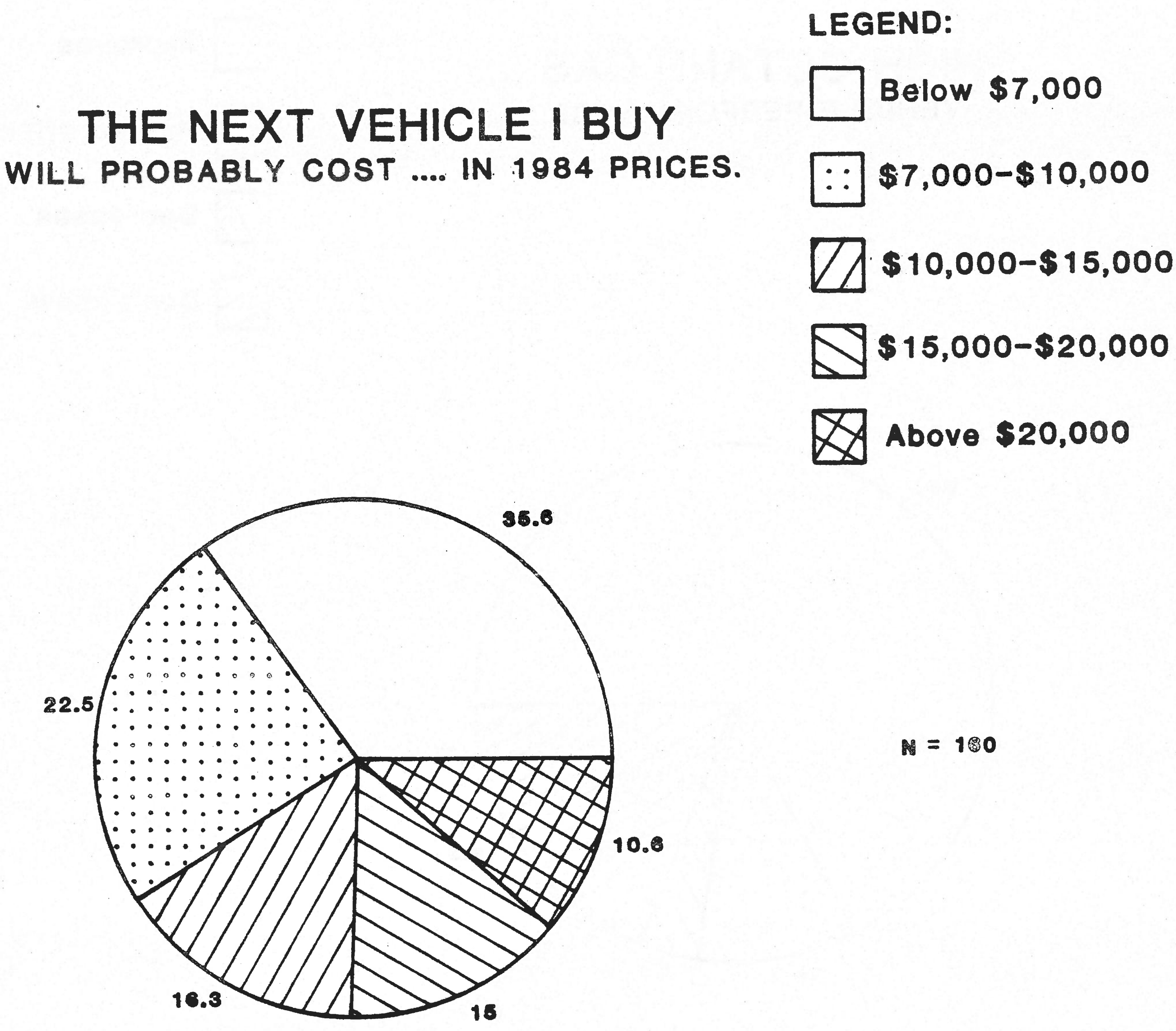
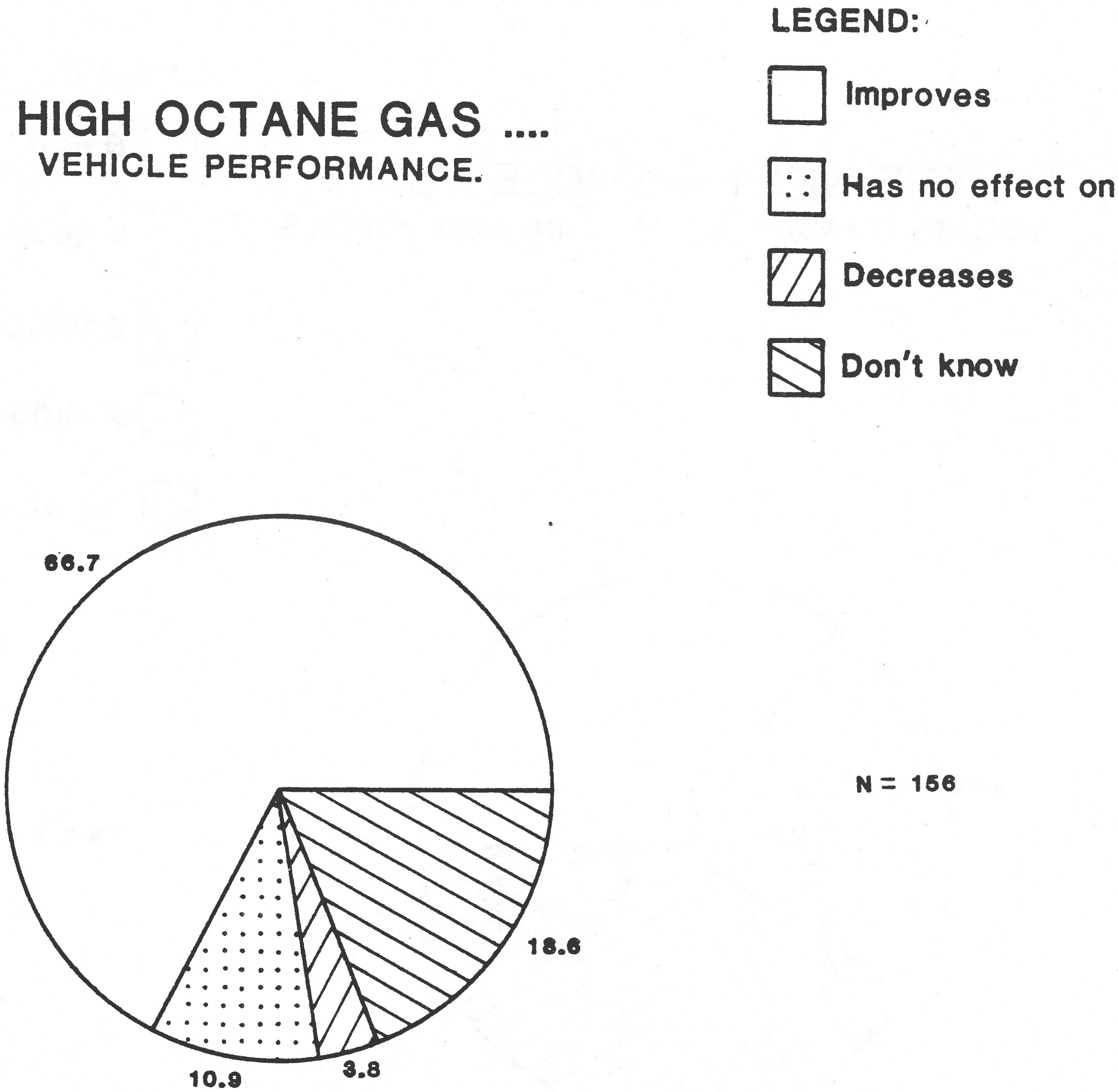

THE NEXT CAR I BUY
SHOULD GET .... MILES PER GALLON.
LEGEND:
30
35
40
45
Unimportant
35.6
22.5
10.6
16.3
15
N = 160
FA Sample

Figure 3.18



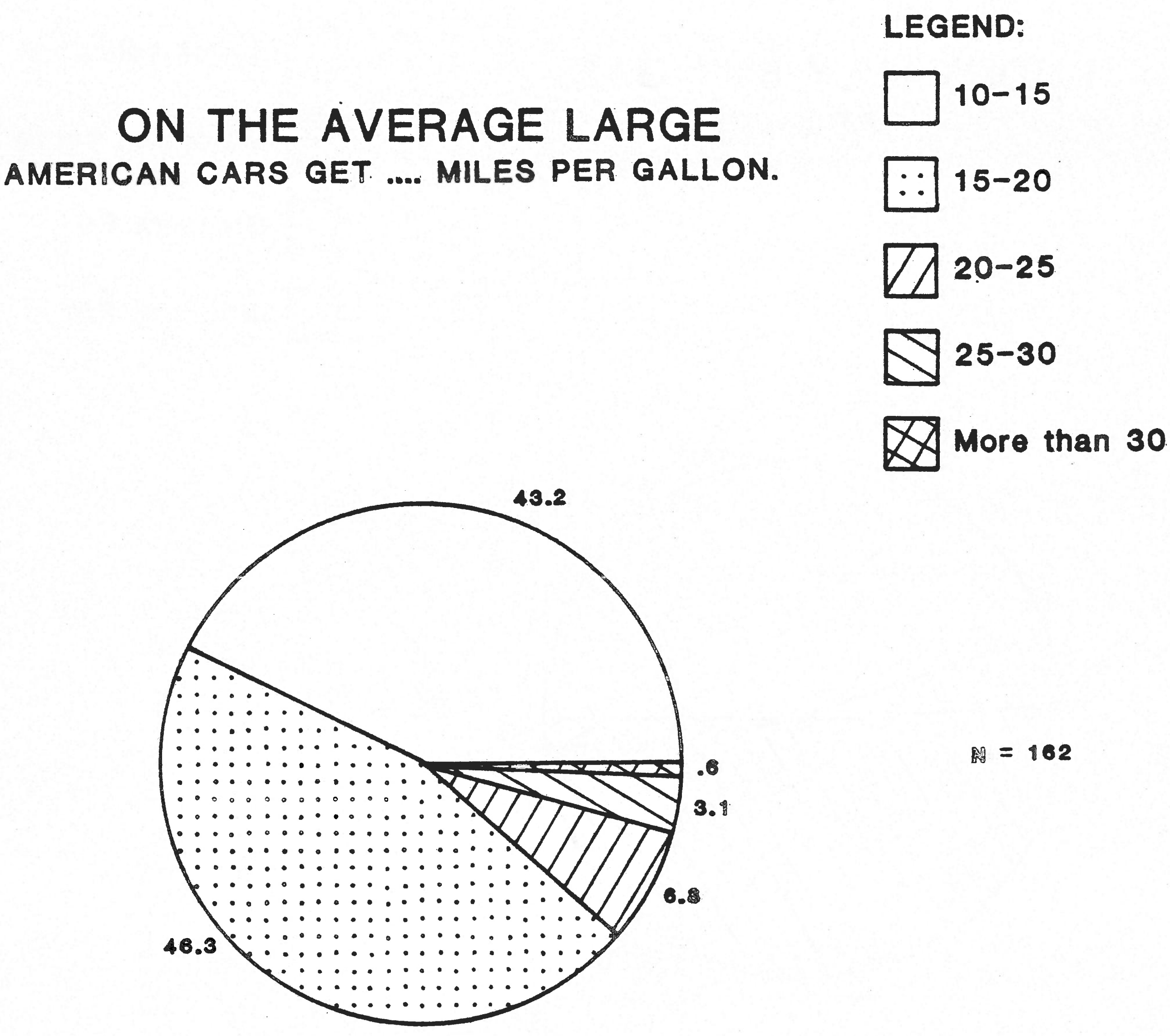
FA Sample

Figure 3.19



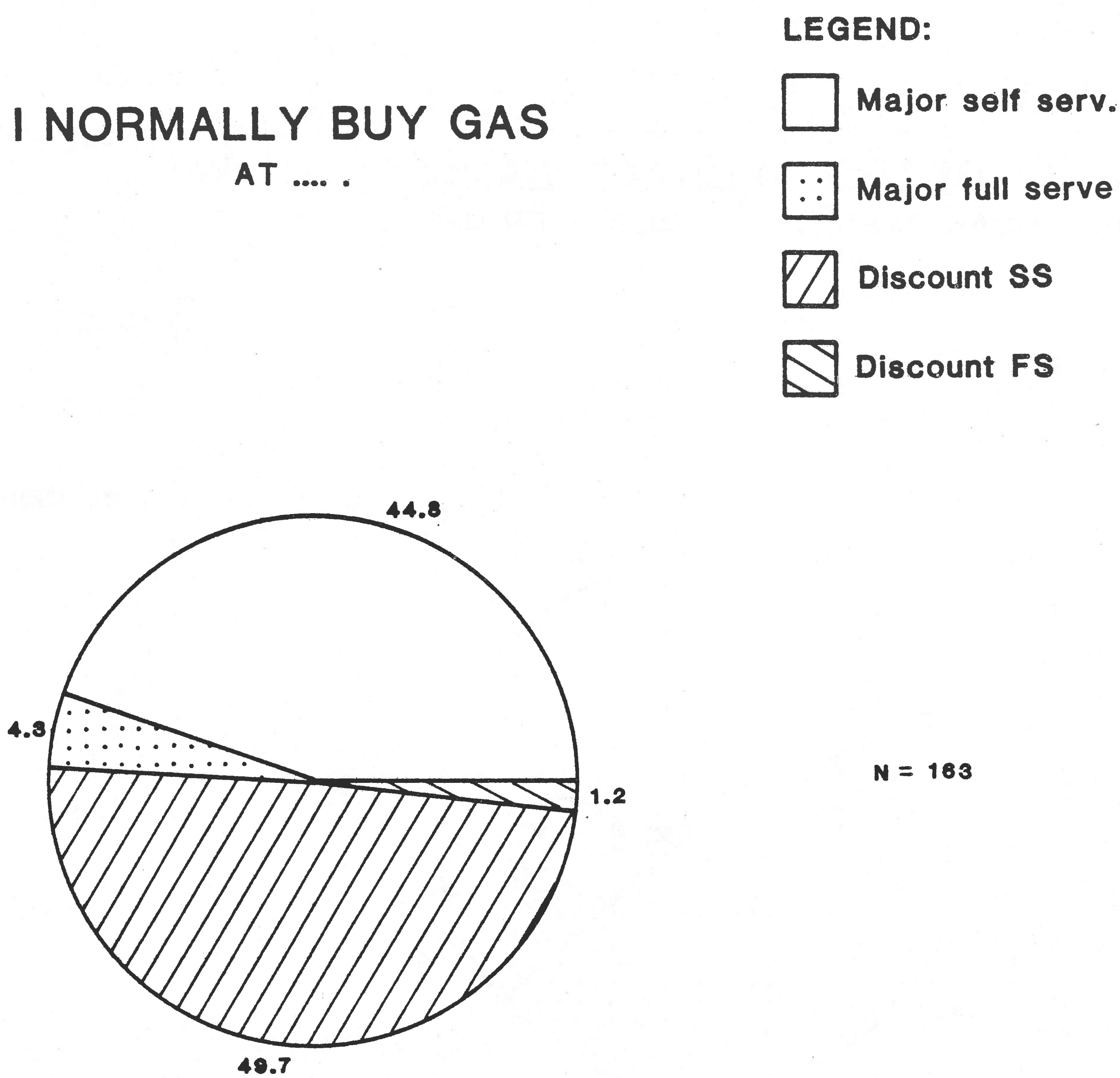
FA Sample

Figure 3.20



FA Sample

Figure 3.21



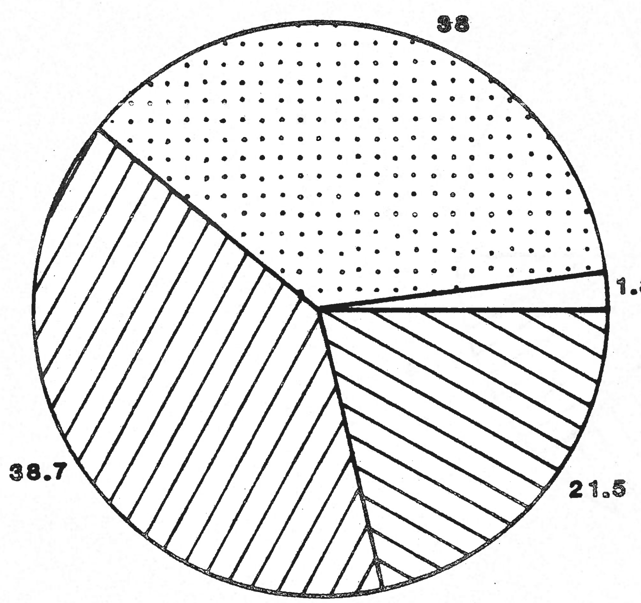
FA Sample

Figure 3.22

ON LONG TRIPS I WANT A
VEHICLE THAT HAS A REFUELING DISTANCE OF .... MILES.

LEGEND:

- Under 200
- 200-300
- 300-400
- Over 400



N = 163

F.A Sample

Figure . 3.23

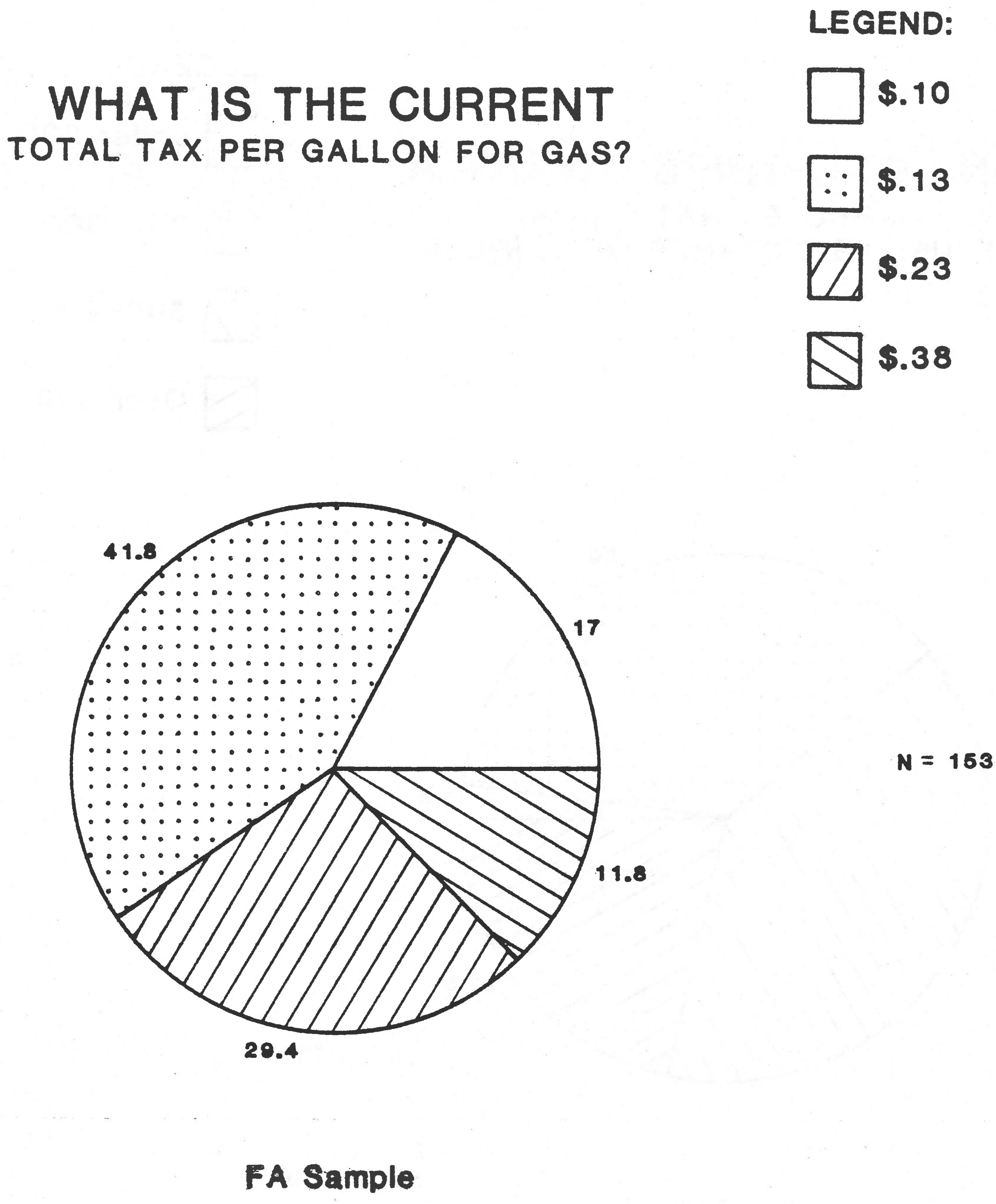

WHAT IS THE CURRENT
TOTAL TAX PER GALLON FOR GAS?
LEGEND:
$.10
$.13
$.23
$.38
41.8
17
11.8
29.4
N = 153
FA Sample

Figure 3.24

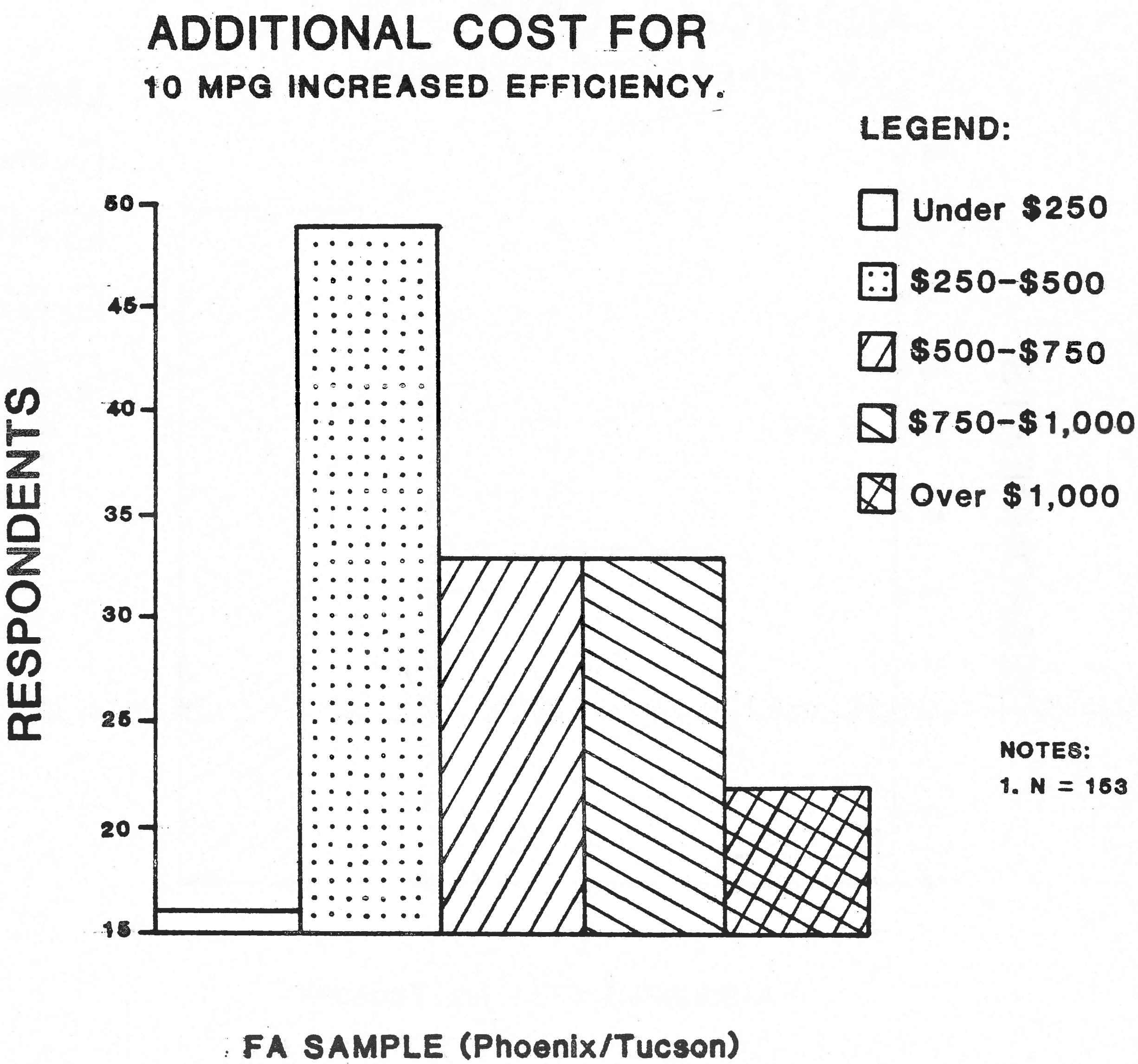
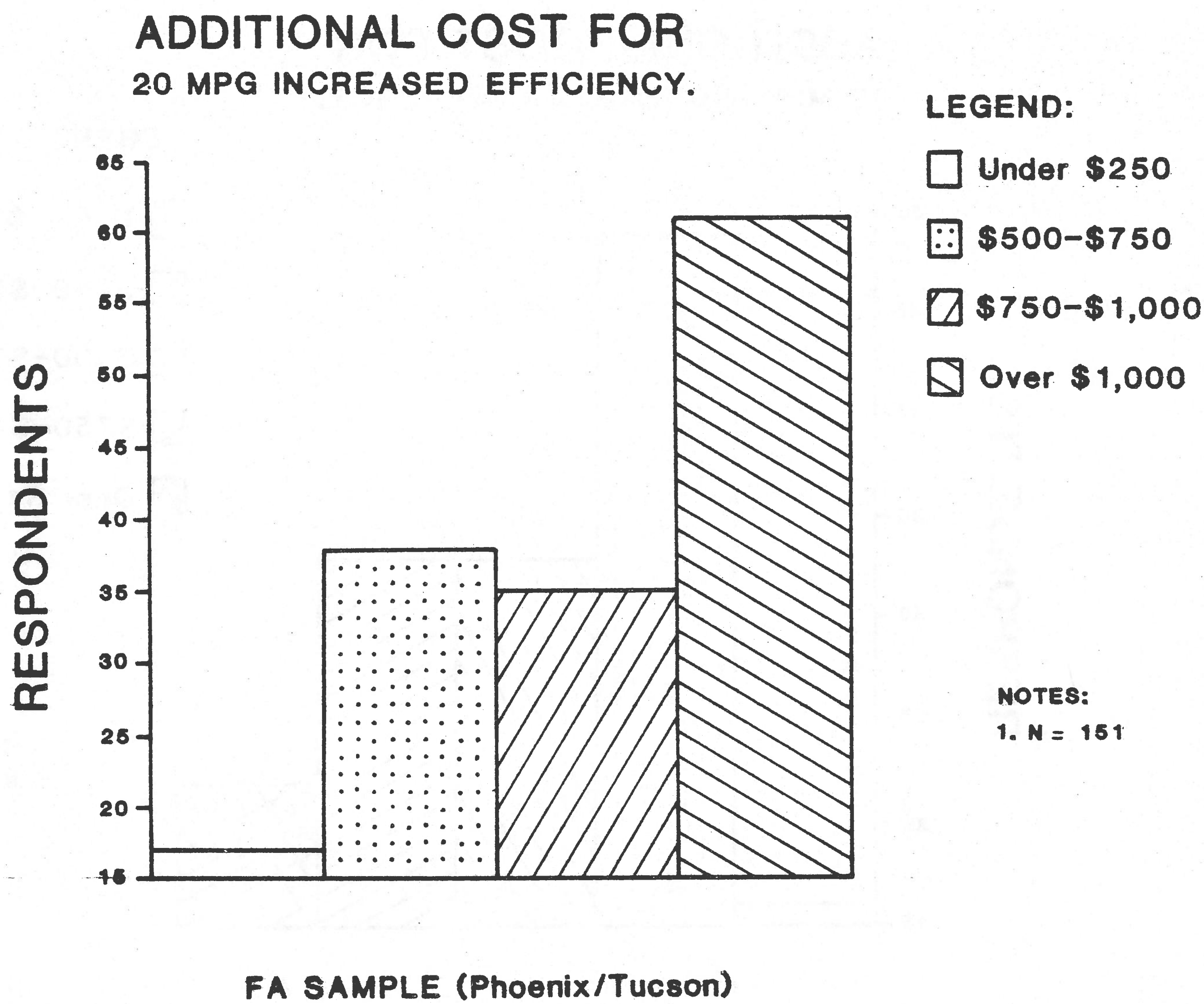

ADDITIONAL COST FOR
10 MPG INCREASED EFFICIENCY.
LEGEND:
Under $250
$250-$500
$500-$750
$750-$1,000
Over $1,000
RESPONDENTS
50
45
40
35
30
25
20
15
NOTES:
1. N = 153
FA SAMPLE (Phoenix/Tucson)

Figure 3.25



ADDITIONAL COST FOR
20 MPG INCREASED EFFICIENCY.
RESPONDENTS
65
60
55
50
45
40
35
30
25
20
15
LEGEND:
Under $250
$500–$750
$750–$1,000
Over $1,000
NOTES:
1. N = 151
FA SAMPLE (Phoenix/Tucson)

Figure 3.26

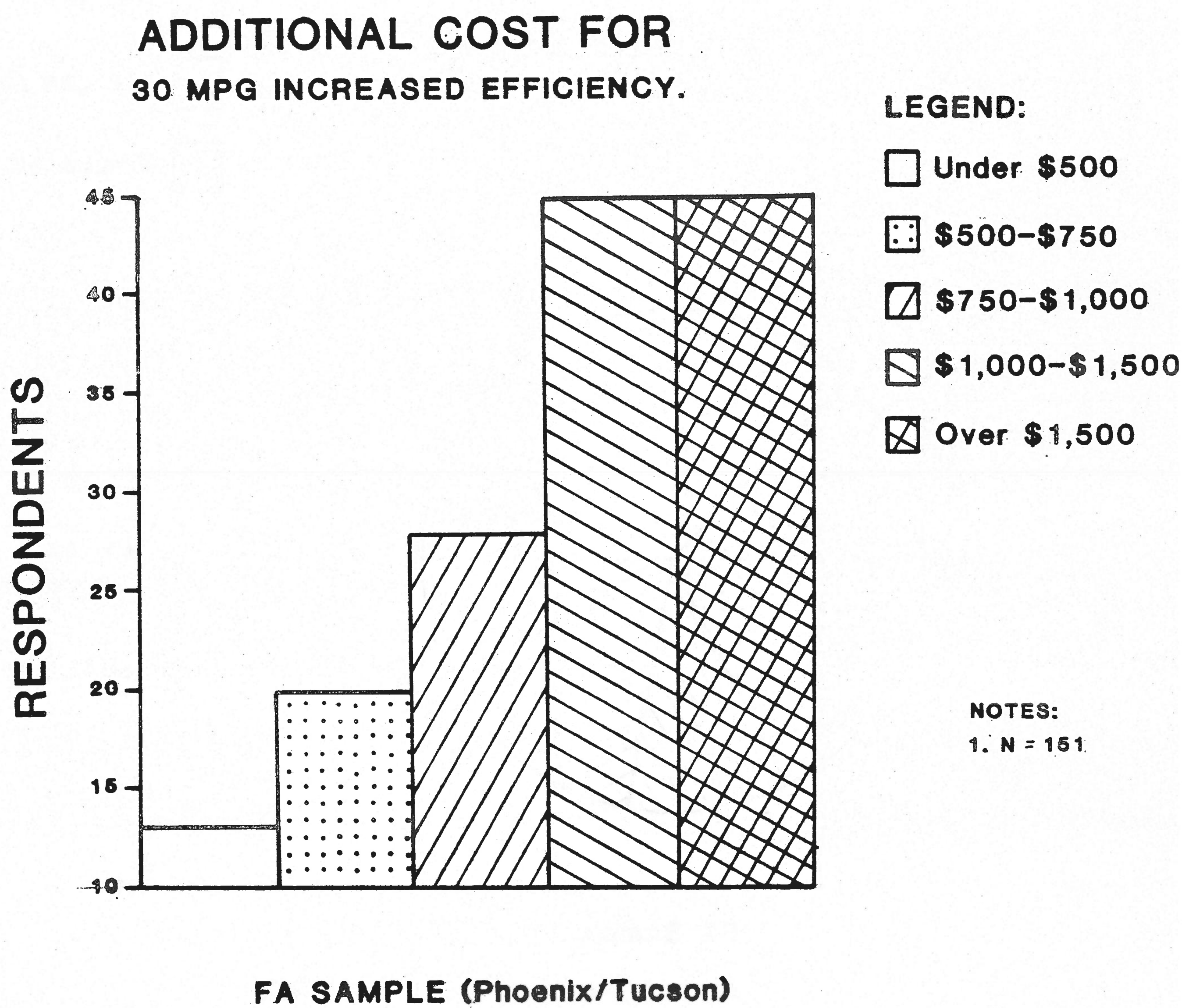

ADDITIONAL COST FOR
30 MPG INCREASED EFFICIENCY.
RESPONDENTS
45
40
35
30
25
20
15
10
FA SAMPLE (Phoenix/Tucson)
LEGEND:
Under $500
$500-$750
$750-$1,000
$1,000-$1,500
Over $1,500
NOTES:
1. N = 151

Figure 3.27

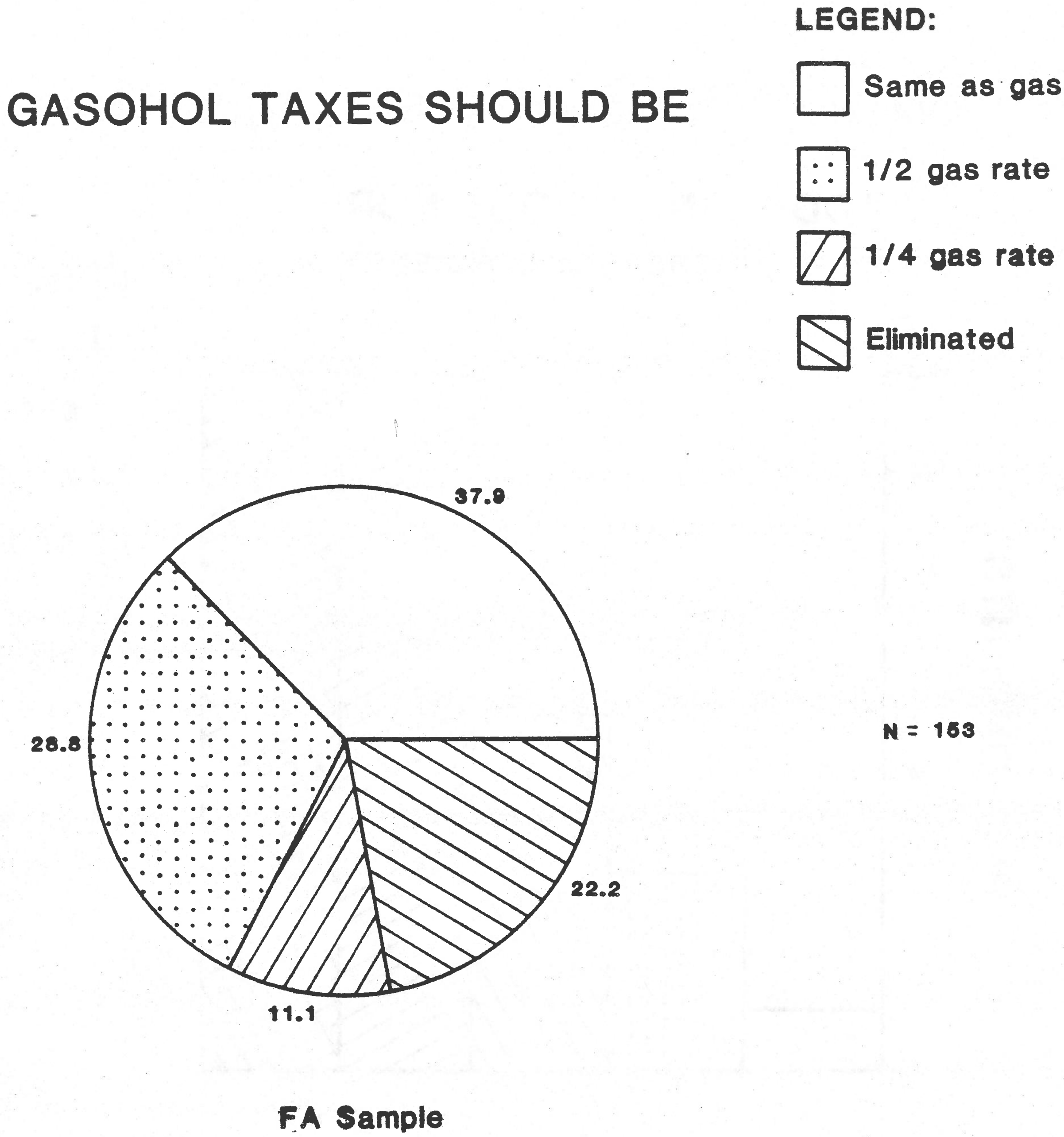
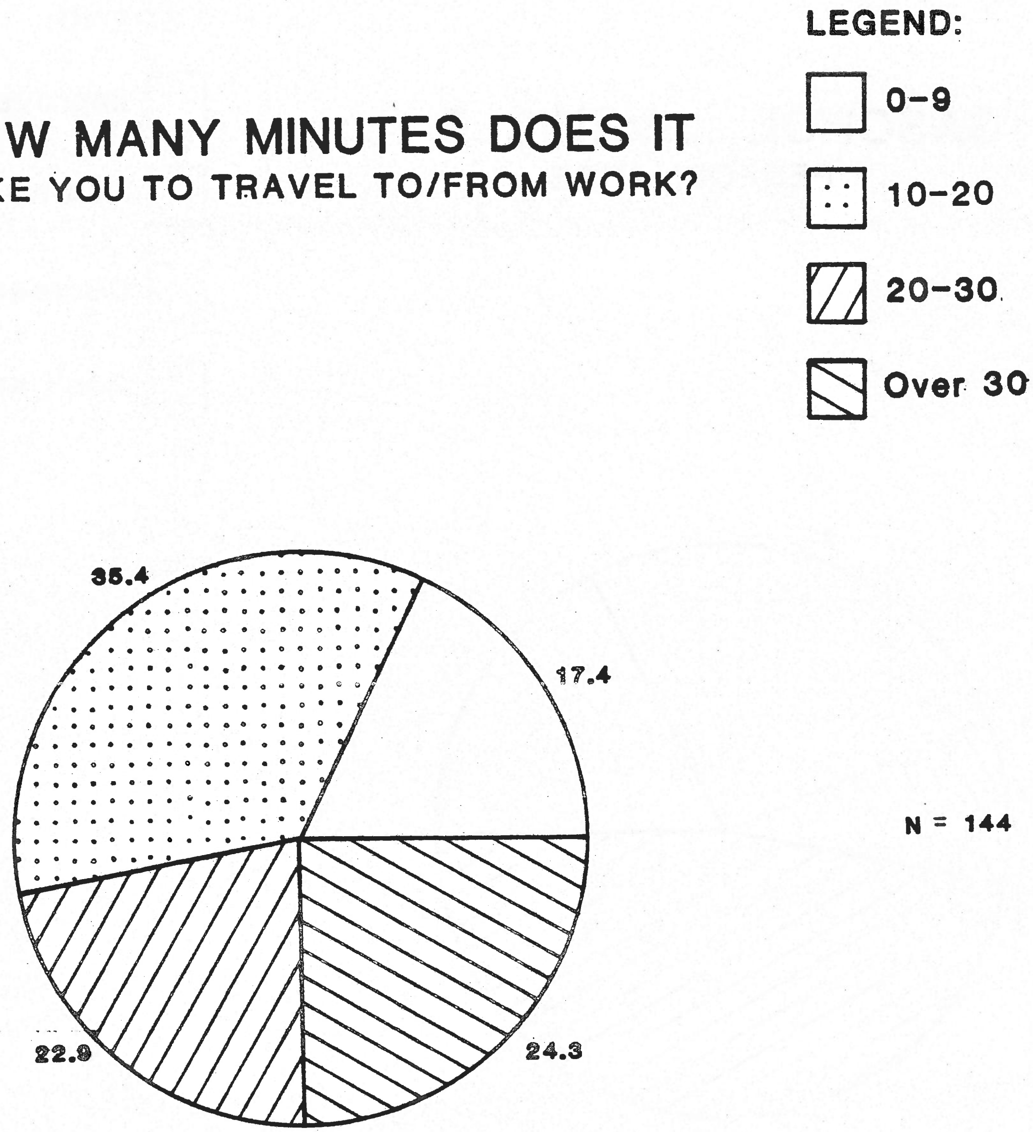

GASOHOL TAXES SHOULD BE
LEGEND:
Same as gas
1/2 gas rate
1/4 gas rate
Eliminated
37.9
28.8
11.1
22.2
N = 153
FA Sample

Figure 3.28

HOW MANY MINUTES DOES IT TAKE YOU TO TRAVEL TO/FROM WORK?



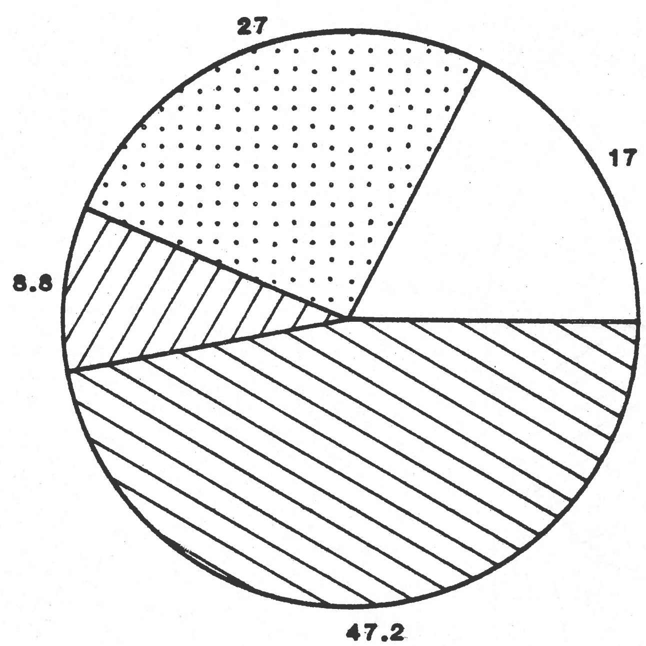
FA Sample

Figure 3.29

GASOHOL .... VEHICLE
PERFORMANCE.

LEGEND:

- Improves
- Has no effect on
- Decreases
- Don't know



N =159

FA Sample

3.3 REGRESSION ANALYSIS (SPSS NEW REGRESSION)

A multiple regression was performed on the survey using demographic variables as predictors. The stepwise regression program was run with an inclusion criteria of probability of correlation equal to or greater than .05.

For interpretation purposes, an arbitrary criteria of 10% was adopted for R Squared. Although all the questions in Table 3.3.1 were significant at the .05 level only 3 questions met the R Squared or shared variance criteria. Income and TYM (Total Yearly Mileage) were significant predictors for cost of new vehicles. Higher incomes and higher total yearly mileages were associated with being willing to pay more for the next new car. On Question 19 - Gasohol taxes should be same or lower, Education and Age had negative weights, thus indicating older people and well educated people wanted similar taxes for gasohol while younger and less educated people wanted less taxes on gasohol. Questions 16, 17 and 18 were dealing with the willingness to pay extra for increased MPG and Education and Income were significant predictors. Higher incomes and higher education were associated with willingness to pay extra for improved gas mileage.

The remaining eight significant questions had only one demographic predictor in the regression equations. Thus it appears that Income, Education, Total Yearly Mileage and Age are the most important demographic predictors.

TABLE 3.3.1

Demographic Variables as Predictors for Survey Questions

Predictor	Question	Part. CORR	Mult. R	R Squared	SIG F
INC TYM	10-(Cost of next vehicle)	.386 .242	.500	.250	.000
ED AGE	19 (Gasohol taxes)	-.294 -.211	.337	.114	.000
ED INC	WTP * (Increased MPG)	.221 .173	.332	.110	.000
TYM	1 (Weekday Mileage)	.262	.262	.069	.002
AGE	6 (tank filled)	-.242	.242	.058	.003
ED	12 (MPG)	.227	.227	.051	.006
INC	15 (gas tax)	.222	.222	.049	.009
TYM	2 (weekend commuting)	.195	.195	.038	.023
INC	5 (weekend capacity)	.187	.187	.035	.024
AGE	8 (gas costs)	-.183	.183	.034	.029
AGE	13 (service station)	-.182	.182	.033	.029

* Average of questions 16, 17, 18: Amount extra willing to pay for vehicle which gets 10, 20 or 30 MPG better mileage respectively.

TABLE 3.3.2

Regression Equations for Selected Variables

10:X = 1.18 + .377 (INC) + .020 (TYM)

19:X 3.75 + -.262 (ED) + -.165 (AGE)

WTP:X = 1.945 + .248 (ED) + .182 (INC)

(Unstandardized B Weights)

3.4 FACTOR ANALYSIS OF MALL SURVEY DATA FACTORS

3.4.1 PROCEDURE

Factor analyses (FA) of the data from the Tucson and Flagstaff mall surveys were carried out using the SPSS FACTOR program. Factor analyses (FA) is designed to analyze shared variances only (not unique or error variance). The method used was principle factors extraction, without iteration, followed by VARIMAX orthogonal rotation. VARIMAX rotation simplifies the original factor matrix by rotating the matrix to the position which yields variable loadings on each factor as close as possible to zero or one. This results in the simplest and most interpretable factors obtainable. VARIMAX rotation results in a factor matrix identical to the original unrotated matrix in terms of the amount of variance of each variable expressed, and percent of total sample variance described.

Two sets of factor analyses were conducted. The survey questions were factored first separately, and then in combination with the demographic variables. For each of these analyses the Tucson and Phoenix subsamples were factored independently and then pooled, yielding three factor solutions in each analysis. The six resulting factor matrices were then compared for common factor and subfactor structures. Only components with Eigenvalues greater than 1.00 were retained for interpreting results (Kaiser's Rule)*.

* Maraschuib & Levin, Multivariate Statistics in the Social Sciences, Brooks/Cole: Monterey, CA 1983.

3.4.2 LIMITATIONS OF THE DATA

The number of cases involved in the subsamples was not adequate for reliable factor extraction with the number of variables involved, so the resulting factor solutions should be considered to have heuristic value only. The sample size was adequate when the subsamples were merged, though still on the small side. Examination of the correlation matrices showed that the variables are quite complex, with many weak intercorrelations and few strong ones.

For the purposes of exploratory factor analysis, no major limitations of the data appear to be present, aside from the small size of the samples and the complexity of the variables. The assumptions of the factor procedure seem to be met by the data.

3.4.3 RESULTS

Inspection of the pooled factor analyses of the separate survey questions and then in combination with the demographic variables revealed similar factors with the same variables loading under the same factors. Income and total yearly mileage were the only relevant demographic characteristics emerging from FA loading on Factor 1 and Income emerged again on Factor 3. These demographic variables also emerged in the regression analyses.

Since the addition of the demographic factors did not add substantially to the interpretation of the factor analyses, only the factor analyses dealing with the survey questions (without demographics) will be described in more detail. The Eigenvalues and percent of variance accounted for by the eight significant factors on the survey questions are presented in Table 3.4.2.

In the Tucson subsample, the number of cases reported on each variable ranged from 65 to 73, which is low for a matrix of such complexity. The correlation matrix revealed 18 correlations of .25 or greater, and 3 correlations greater than or equal to .35. Eight factors with Eigenvalues greater than or equal to 1.0 were obtained in the unrotated factor matrix. These eight principle factors accounted for 68.4% of the total sample variance. From 52% to 79% of the variance in each variable was expressed in the principle factor matrix.

In the Phoenix subsample, the number of cases reported on each variable ranged from 78 to 96. The correlation matrix revealed 12 correlations of .25 or greater, and 2 correlations greater than or equal to .35. Eight factors with Eigenvalues greater than or equal to 1.0 were obtained in the unrotated factor matrix. These 8 principle factors accounted for 84.5% of the total sample variance. From 45% to 80% of the variance in each of the 19 variables was expressed in the principle factor matrix.

In the combined sample, the number of cases reported on each variable ranged from 144 to 169. The correlation matrix revealed only 9 correlations of .25 or greater and none higher than .32. Eight factors with Eigenvalues greater than or equal to 1.0 were obtained in the unrotated factor matrix. These eight principle factors accounted for 61.8% of the sample variance. From 45% to

71% of the variance in each variable was expressed in the principle factor matrix.

Table 3.4.3 presents the major factors with highest loadings for the subsamples and combined samples. For each factor, only the highest loadings (.45) are reported*. Since the factors and variable loadings were consistent across samples and with the pooled or combined sample, the researchers will limit discussion to the factor analyses of the combined sample.

The VARIMAX rotated Factor Matrix is presented in Table 3.4.4 while the loadings, communalities and proportion of variance and covariance are presented in Table 3.4.5. Communality values vary from .00 to .63. With a cut of .45 for inclusion of a variable in interpretation of a factor, only 1 question was not included in the factors*. Failure of the question to load on a factor reflects heterogeneity of the question on the survey. Variables have been ordered and grouped by size of loading to facilitate interpretation and loadings under .45 (20% variance) have been replaced by zeros. Of the eight original factors, two factors (1 and 4) had three items loading highly while the remaining factors had only two items loading highly. With the rotation and deletion of insignificant items (Table 3.4.5), Factor 8 falls below the criteria (SSL = 1.00) for inclusion.

Examination of the factors and loadings revealed associations between behaviors, beliefs, knowledge and expectations of

* Tabachnick & Fidell, Using Multivariate Statistics. Harper & Row. Philadelphia 1985.

consumers and these relationships were used to label the extracted factors (Table 3.4.6).

The first factor has as its major loaders, Q7: Refueling time, Q5: Weekend occupancy and WTP (Q16-18): Willingness to pay for mpg. This factor is labeled consumer awareness. Basically consumers needing a high weekend occupancy tend to take longer refueling. This probably indicates they drive larger vehicles. At the same time, these consumers indicate they are willing to pay extra for increased fuel efficiency. Inspection of the survey responses (Fig. 3.24 through 3.26) indicates that if consumers own vehicles getting 15 mpg, they want at least 35 mpg and are willing to pay at least $1000 more to get this efficiency.

The Second Factor (Fuel Supplies) has as its major loaders, Q3: Expected gas shortage and Q8: Expected gas price increases. Inspection of the loadings indicates that these variables relate to this factor in opposite fashions (opposite signs). Consumers believing there is no gas shortage in the future estimate high gas prices in several years while consumers believing there will be a gas shortage estimate low gas prices in the next several years.

The next factor dealt with refueling needs with the following loadings, Q13: Refueling station and Q6: Refueling habits. Most of the consumers indicated they used self-service discount service stations and this report was verified by a pilot study in Flagstaff. Although some consumers "top-off" their tanks, the majority fill when the tank is almost empty. This behavior indicates that consumers are not worried about availability of fuel.

The Fourth Factor is a combination of "Americana travel habits" with the following loadings - Q14: Refueling range, Q12: Expected U. S. vehicle mileage and Q9: Desired mpg. Consumers indicated a desire for a long range vehicle (at least 200 mile refueling) for travel as well as high mpg (35 mpg). Americans tend to have a "freedom to travel" image. In Arizona, the Americana travel image is complicated by the long distances between cities. Unfortunately this does necessitate a longer refueling range.

The Fifth Factor (Affluent Image) loads on Q4: Mode of transportation and Q10: Expected vehicle cost. Most consumers indicated they used a private vehicle for work transportation and were willing to pay more for their next vehicle. Factor 5 correlate strongly with income - thus, more affluent consumers use their private vehicle for commuting and are willing to pay extra or more for comfort, performance, status, etc.

The Sixth Factor (Commuter Needs) has as its major loaders, Q1: Weekday mileage and Q20: Commuter distance. Consumers indicating high weekday mileage also indicated long commutes. This would be expected in Arizona because of the distances within the state and the type of urban sprawl occurring.

The last Factor (Fuel Knowledge) had loadings on Q15: Knowledge of octane and Q19: Knowledge of gasohol. Although knowledge of octane loaded higher than Q19, both loadings indicate that consumers are relatively informed or totally ignorant about octane and gasohol. Only 18.6% of consumers didn't know the effect of octane on vehicle performance (Fig. 3.19), while 47.2% of consumers didn't know the effects of gasohol on vehicle performance (Fig. 3.29). A majority of consumers (66.7%) knew that high octane improves performance but only a few consumers (17.%) knew gasohol improves performance.

TABLE 3.4.1

Factor Analyses on Survey Questions

and Demographic with Survey Questions

(VARIMAX Rotated Factors)

Demographic with Survey Questions		Survey Questions	
Loadings *	Factor 1	Loadings *	Factor 2
Q7	.560	Q7	.692
Q5	.673	Q5	.673
WTP **	.667	WTP **	.587
Factor 4		Factor 2	
Q3	.775	Q3	-.78
Q8	.591	Q8	.648
Factor 3		Factor 3	
Q13	.660	Q13	.726
Q6	.711	Q6	.708
Factor 5		Factor 4	
Q14	.702	Q14	.725
Q12	.572	Q12	.587
Q9	.463	Q9	.521
Factor 1		Factor 5	
Q4	-.472	Q4	-.728
Q10	.757	Q10	.725
Factor 8		Factor 6	
Q1	.768	Q1	.725
Q20	.632	Q20	.698
Factor 7		Factor 7	
Q11	.770	Q11	.770
Q21	.760	Q21	.770
Factor 9		Factor 8	
Q15	.666	Q15	.760
Q19	.702	Q19	.586

* Only variables loading .45 or higher on factors are reported in table.

** WTP Average of questions 16, 17, 18: Amount extra willing to pay for vehicle which gets 10, 20 or 30 MPG better mileage respectively.

TABLE 3.4.2

Eigenvalues of Unrotated Factors of Survey Questions

FACTOR	EIGENVALUE	PCT. OF VARIANCE
1	2.199	11.6
2	1.815	9.6
3	1.560	8.2
4	1.389	7.3
5	1.280	6.7
6	1.272	6.7
7	1.99	6.3
8	1.025	5.4
		61.8

TABLE 3.4.3

Major Factor and Loadings for Subsamples and Combined Sample on Survey Questions (VARIMAX Rotation)

	Factor Loadings		
Survey Question	Combined	Tucson	Phoenix
	Factor 1	Factor 2	Factor 2
Q7	.692	.253	.452
Q5	.673	.805	.789
WTP	.587	.621	.601
	Factor 2	Factor 5	Factor 1
Q3	.78	.809	.764
Q8	.648	.523	.642
Q9	.445	---	.756
	Factor 3	Factor 1	Factor 8
Q13	.726	.695	.734
Q6	.708	.355	---
	Factor 4	Factor 1	
Q14	.725	.597	N/A
Q12	.587	---	---
Q9	.521	.786	---
	Factor 5	Factor 8	Factor 4
Q4	.728	.326	.826
Q10	.725	.829	.336
	Factor 6	Factor 3	Factor 3
Q1	.725	.722	.307
Q20	.698	.266	.819
	Factor 7	Factor 6	Factor 5
Q11	.77	.657	.551
Q21	.77	.805	.754
	Factor 8	Factor 3	
Q15	.760	.664	N/A
Q19	.580	.666	N/A

FIGURE 3.4.4

VARIMAX ROTATED FACTOR MATRIX FOR COMBINED SAMPLE

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
Q1	.13482	.11893	-.06429	.04146	.09623	.72537	-.04180	-.25490
Q2	.35866	.18648	.17315	-.33360	.20776	-.40049	-.06238	-.25074
Q3	-.00925	-.79998	.15672	-.06739	.12997	.00594	.09898	-.09976
Q4	.04112	.05270	.04656	.08418	-.72816	-.19114	-.06229	-.10361
Q5	.67252	.05995	-.13057	-.07060	.17949	.10866	-.01357	-.07112
Q6	.00468	-.12882	.70825	-.07378	-.21469	.28763	.07896	.07910
Q7	.69224	-.07071	.32519	.00219	-.12463	.06644	.08804	.08778
Q8	.13468	.64826	.25256	.05787	.04928	-.03831	.26331	-.10676
Q9	-.19518	.44498	.31063	.52081	.03852	.00901	.07142	.11470
Q10	.23235	-.04351	-.03784	.15273	.72498	-.10103	-.04276	-.05277
Q11	.11832	-.04599	.14961	.08855	-.05580	-.01928	.76972	.09912
Q12	.35890	-.21467	-.11250	.58654	-.26722	-.14920	.21194	-.16617
Q13	.03212	.16578	.72638	.12184	.07146	-.09201	-.05626	-.13114
Q14	.06524	.13793	.05171	.72482	.13230	.12360	-.07830	.05250
Q15	.08161	-.09231	-.06187	.18316	.20427	-.04451	-.04033	.76020
WTP	.58706	.08060	-.03485	.20864	.09216	.10896	-.06128	.17047
Q19	.07017	.33507	.01453	-.23941	-.23198	-.03491	.09646	.58622
Q20	.18034	-.13470	.26219	.02836	.05692	.69821	.09389	.14265
Q21	-.[illegible]3928	.14656	-.14438	-.08381	.07520	.07900	.76985	.07865

FIGURE 3.4.5

FACTOR LOADING, COMMUNALITIES (h^2), PERCENTS OF VARIANCE AND COVARIANCE FOR EIGHT-FACTOR PRINCIPAL FACTORS EXTRACTION AND VARIMAX ROTATION FOR TRANSPORTATION PREFERENCES

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Communalities
Question	Loading	Loading	Loading	Loading	Loading	Loading	Loading	Loading	(h^2)
7	.692	.000	.000	.000	.000	.000	.000	.000	.47
5	.672	.000	.000	.000	.000	.000	.000	.000	.45
WTP	.587	.000	.000	.000	.000	.000	.000	.000	.34
3	.000	-.799	.000	.000	.000	.000	.000	.000	.63
8	.000	.648	.000	.000	.000	.000	.000	.000	.41
13	.000	.000	.726	.000	.000	.000	.000	.000	.52
6	.000	.000	.708	.000	.000	.000	.000	.000	.49
14	.000	.000	.000	.724	.000	.000	.000	.000	.52
12	.000	.000	.000	.586	.000	.000	.000	.000	.34
9	.000	.000	.000	.520	.000	.000	.000	.000	.27
4	.000	.000	.000	.000	-.728	.000	.000	.000	.51
10	.000	.000	.000	.000	.724	.000	.000	.000	.52
1	.000	.000	.000	.000	.000	.725	.000	.000	.52
20	.000	.000	.000	.000	.000	.698	.000	.000	.48
21	.000	.000	.000	.000	.000	.000	.769	.000	.59
11	.000	.000	.000	.000	.000	.000	.769	.000	.59
15	.000	.000	.000	.000	.000	.000	.000	.760	.57
19	.000	.000	.000	.000	.000	.000	.000	.586	.34
2	.000	.000	.000	.000	.000	.000	.000	.000	.00
SSL	1.26	1.03	1.00	1.13	1.04	1.00	1.18	.92	8.56
Proportion of Variance	6.63	5.42	5.26	5.94	5.47	5.26	6.21	4.84	
Proportion of Covariance	14.72	12.03	11.68	13.20	12.15	11.68	13.78	10.74	

TABLE 3.4.6

ORDER (BY SIZE OF LOADINGS) IN WHICH VARIABLES CONTRIBUTE TO FACTORS FOR TRANSPORTATION SURVEY

FACTOR	DESCRIPTION OF VARIABLE LOADING	LABEL
1	Refueling time Weekend occupancy Willingness to pay for mpg	Consumer Awareness
2	Expected gas shortage Expected gas price increase	Fuel Supplies
3	Refueling station Refueling habits	Refueling needs
4	Refueling range Expected U.S. vehicle mileage Desired mpg	Americana Travel Habits
5	Transportation mode Expected vehicle cost	Affluent image
6	Weekday mileage Commuter distance	Commuter needs
7	Knowledge of octane Knowledge of gasohol	Fuel knowledge

Note: Most important variables are listed first.

SECTION 4

AE FUEL TAXES/INCENTIVES AND LPG/CNG MARKETS

During this decade, the consumption of LPG has been increasing in the U.S. transportation sector but is on the decline in Arizona. In 1980, 508,011,000 gallons of LPG were sold nationwide and this figure increased by 8.4% in 1981. Sales of LPG for internal combustion engine use rose 16.3% from 553,909,000 gallons in 1981 to 643,946,000 gallons in 1982. (State Energy Data Report, U. S. DOE 1981, 1982)

All other categories of end users (Gas utilities, residential and commercial, industrial, chemical manufacturing) have shown systematic declines during the last decade. Survey respondents attributed the growth to increased use of propane fueled vehicles. Most conversions from motor gasoline to propane were by private companies and government owned fleet vehicles. It should also be noted that companies selling less than 100,000 gallons a year are exempt from filing Federal forms (EIA-174) so that the actual consumption may be much higher.

States with high consumption of LPG for transportation purposes are listed in Table 4.2.1. States with high reserves of natural gas have higher consumption patterns. States with selected motor fuel taxes on alternative fuels are listed in Table 4.2.2, while consumption patterns during the last three years are presented in Table 4.2.3.

The consumption pattern for Arizona is probably underestimated since small distributors are not required to file

EIA‡74 reports.

ADOT maintains registrations on alternative fuel vehicles (see Table 4.2.4). However, such registrations represent only original installation. Total conversions of dual conversion systems are not present in these registrations.

Major LPG and CNG distributors and installers were interviewed in the Phoenix and Tucson areas during December and January OF 1984. All LPG installers reported declining installations in the last several years, and indicated that a 20 to 30 cent differential in gasoline and LPG prices is necessary for economical justification. Recent declining gasoline prices with increasing LPG prices has negatively impacted conversions. The majority of conversions were for pickup trucks and agricultural applications, and cost between $800 to $1200. Installers also indicated that many conversions were for Mexican Nationals where gasoline prices are much higher than LPG.

Southwest Gas has been conducting a CNG research project in Tucson since 1982 and is actively promoting CNG for transportation. The utility has had CNG vehicles for 12 years which have been monitored by the research division in Las Vegas (Bob Raisons - (702) 876-7304). Southwest Gas highly recommends CNG Fuel Systems, Ltd., (Canada) and has assisted numerous companies with fleet conversions. Southwest reported a $52,000 savings in gasoline during 1982.

At the present time, no Arizona road use tax is being paid by CNG users (no state taxation has been established). Southwest

Gas has calculated a conversion factor for CNG to gasoline (1.08 SCF CNG = 1 gallon gasoline) and is holding road use tax money in an escrow account until the Arizona Department of Transportation request payment.

During November of 1984, the American Gas Association sponsored a National Rally to promote CNG for transportation. Dr. Jeffrey Seisler was the manager of the Natural Gas Vehicle Project (703) 8418400, and has compiled cost comparison data for CNG and gasoline vehicles.

Past research indicated negative marketing aspects of CNG systems: 1) long refueling times, 2) excessive compressor cost, 3) danger of high pressure (2200 - 3000 psi) systems, 4) heavy weight of high pressure steel tanks, 5) high conversion cost for dual systems. These issues have been addressed by the industry and are being solved. CNG Fuel Systems has a rapid fill system (3 - 5 minutes). Of course, compressors for rapid fill systems are more expensive than slow fill and overnight system. Future Fuels, Inc. is developing a low pressure system (200 psi) for CNG which will store CNG in a pellet similar to a hydrogen hydride system. Alcoa has developed two special high pressure aluminum tanks (3000 psi) which decreases weight significantly.

Although conversion costs range from $1500 to $2000, the economic payback is very rapid (2 to 5 years) and fleet conversions are economically feasible.

CNG Fuel Systems, Ltd. has a national network in Canada for private consumers as well as industrial and commercial users.

However, in the U.S., CNG Fuel Systems, Ltd. is marketing only to the industrial market.

New Zealand has even a more extensive conversion rate than Canada. In 1984, one company, CNG Fuels Systems, Inc., had 3,000 conversions. CNG conversions started in 1978 with federal incentives added in the early 80's. Approximately 65,000 vehicles have been converted with 250 public refueling stations. The conversion rate is dramatically impacted by government subsidies. In Canada, if conversion is made within 30 days of purchase of a new vehicle, there is 1) no sales tax on the transaction (7%), 2) a $500 (U.S. dollars) tax credit is given on federal income tax, and 3) $500 is rebated to the consumer by the local utility. There are also incentives for building public refueling stations. The Federal Government gave out 200 grants of $100,000 each for construction of public refueling stations.

During the last 15 years, the AGA representative estimated there had been about 30,000 CNG conversions in the U.S. Last year there were approximately 3,000 conversions, and market representatives estimate that conversion rate should double each year. Thus, this year, there should be 6,000 conversions and in 1986 there should be 12,000 conversions. Remember, these projections are aimed primarily at the commercial fleet market. As the fleet market expands, independent CNG service stations are expected to develop and this will open the CNG market to the average consumer. As yet, projections have not been made on this market.

AGA representatives estimate that a full service CNG station would cost about $100,000. This would include numerous fast fill stations (3-5 minutes). The principle cost of such a station is the compressor and regulators. Currently, many fleets use slowfill systems (overnight) because the compressors are relatively cheap. The cheapest compressor is about $300 and can fill 2 vehicles overnight (with a pressure of 2200 psi).

The slow fill systems rely on equipment that was designed and introduced 30-40 years ago, while the rapid fill systems are new technological advancements designed specifically for transportation with 3,000 psi for refueling pressures. With fleet conversions increasing, it is expected that most industries will convert to the new equipment to speed refueling times. As more conversions occur the price of conversion per vehicle will decrease. Currently, it costs about $2,000 to convert one vehicle to CNG. However, this figure does not include the compressor and other equipment necessary to refuel the vehicle. It costs about $3,000 to provide a slow fill refueling station for 2 vehicles and $30-$50,000 for a fleet refueling station.

The largest CNG fleet owner in Arizona is Southwest Gas in Tucson followed by Scottsdale. Other CNG operators include: Phoenix Airport, and Pima Community College.

It should be noted that marketing of CNG in the U.S. should increase substantially in the next year because Toyota will be marketing CNG vehicles to Utilities. This program will begin in 1986 and is expected to increase rapidly, since Toyota has the best maintenance and repair record of all vehicle manufacturers. The entry of a major manufacturer into CNG fuels will positively affect the image of CNG as well as the market.

The CNG conversion for Toyota of America will be handled by NCF Bealy, and Toyota of Orange will be responsible for marketing and delivery of vehicles. The President of NCF Bealy, Norman Fawley, also indicated that he is currently negotiating with Ford Motor Company for a production line CNG vehicle. Fawley indicated a preference by numerous utilities to buy "American made" products.

The largest CNG fleet (3,000) in California is operated by Southern Cal Gas and all the conversions were completed by Dual Fuels. Both Dual Fuels and Southern Cal Gas are subsidiaries of Pacific Lighting. Southern Cal Gas started its conversion program in 1970 and now has 13 refueling stations between Bakersfield and northern San Diego with 80-85% of the facilities being slow fill.

According to Dual Fuels, there are between 300-500 other CNG vehicles in the L.A. basin area.

California gives CNG users the option of two tax systems. Users can pay 1) the normal road use tax ($.07 a gallon) or 2) a flat fee by weight. For passenger cars and light trucks the flat fee is $36.00 a year. If a vehicle is driven less than 9000 miles a year with a 20 mpg efficiency, the owner would most likely choose the per gallon tax rate. As mileage goes up, it is financially expedient to select the flat user fee.

TABLE 4.1

STATES WITH HIGH LPG CONSUMPTION

FOR INTERNAL COMBUSTION FUEL (1982)[1]

	(THOUSANDS OF GALLONS)
TEXAS	86,839
CALIFORNIA	71,294
ILLINOIS	34,915
OKLAHOMA	30,362
FLORIDA	25,899
OHIO	25,022
ARKANSAS	23,665
KENTUCKY	20,080
MICHIGAN	19,619
MISSISSIPPI	18,785

1 State Energy Data Report, U.S. DOE 1982.

TABLE 4.2

STATES WITH SELECTED MOTOR FUEL TAXES (1982)

ON ALTERNATIVE FUELS

STATE	TYPE OF FUEL	TAX (PER GALLON)
ALASKA	LPG	Exempt
ARIZONA	LPG & CNG	.13
ARKANSAS	LPG	.075
CALIFORNIA	LPG & LNG	.06
	CNG	.07
HAWAII	CNG	Exempt
	LPG	.06
KANSAS	LPG	.10
MASSACHUSETTS	LPG	.08
MICHIGAN	LPG	.13
MISSISSIPPI	LPG	.08
	CNG	.10
MONTANA	CNG	Exempt
NEW JERSEY	LPG & CNG	.04
OHIO	CNG	Exempt
OKLAHOMA	CNG	Exempt
RHODE ISLAND	CNG	Exempt
SOUTH DAKOTA	LPG & CNG	.11
TENNESSEE	LPG	.09
	CNG	.13
TEXAS	LPG & CNG	.05
UTAH	LPG	Exempt
WYOMING		

TABLE 4.3

PROPANE FOR TRANSPORTATION USES[1]

(THOUSANDS OF GALLONS)

STATE	1980	1981	1982
ARIZONA	8,630	9,149	8,239
CALIFORNIA	57,189	67,343	71,294
KANSAS	12,201	114,972	17,318
MASSACHUSETTS	2,918	3,625	3,528
MICHIGAN	14,181	W	19,619
NEW JERSEY	W	12,630	12,007
TENNESSEE	6,702	5,647	11,140
ARKANSAS	15,631	13,474	23,665
UTAH	1,599	W	6,197

1 State Energy Data Report, U.S. DOE 1981, 1982

W = Data withheld to avoid individual company data.

TABLE 4.4

Registration of Alternative Fuel Vehicles[1]

CATEGORY	BUTANE	PROPANE	OTHER	ELECTRIC
A	24	21	8	52
B	3	1	-	-
C	57	282	1	19
I	6	26	2	2
D	-	6	-	-
E	-	-	-	-
	90	336	11	73

1 T. R. Jakes, Arizona Motor Vehicle Department, 1984.

Categories:
- A Passenger Vehicles
- B Commercial Vehicles
- C Non-Commercial 1/2 Top Pick-Up and Vans
- D Buses
- E Taxis

SECTION 5

SUMMARY OF ESTIMATES OF DEMAND FOR AND MARKET PENETRATION OF ALTERNATIVELY FUELED VEHICLES IN ARIZONA

The rate at which alternatively fueled vehicles (AVs) may be expected to penetrate the market depends upon the interaction of demand and supply factors. The prospective demand for a product which is not yet available in the marketplace is highly speculative. To estimate this demand a questionnaire was administered to 186 Arizona residents along with a 30 minute presentation describing AVs. Survey respondents were told that each AV's safety and reliability characteristics were comparable to current vehicles, and were to assume that facilities for servicing and refueling of AVs were available at an adequate.

Survey respondents were asked to indicate the price which they would be willing to pay for a standard current vehicle; then they were asked to indicate how much they would be willing to pay for each of seven AVs. Characteristics of the seven vehicles are described in Table 5.1. Respondents were asked to assume that AVs were identical to the current vehicle in all respects except those characteristics described in the table. The seven AV choices relate to three classes of AVs; vehicles designed to use natural gas as their sole fuel (or conceivably hydrogen at some future date), vehicles designed to utilize either gasoline or natural gas as fuel (these hybrid vehicles are designed to use natural gas for local commuting and gasoline for longer trips), and vehicles designed to utilize electricity as fuel using batteries. All of the AVs except the electric vehicle with 350 mile range are feasible with current technology. Survey respondents valuations of the AVs relative to a standard current vehicle are shown in Table 5.2. It is clear that hybrid vehicles are the most preferred AV type, while demand for electric vehicles will remain quite low unless their range can be extended to 350 miles, and even then the overnight refueling time is seen as a major disadvantage. Valuation of purely natural gas vehicles is substantially below that of the current gasoline vehicles, but substantially above the average value placed on currently feasible electric vehicles.

Nonprice rationing of gasoline (in the form of 45 minute lines for gasoline refueling for several months) would significantly increase the relative value placed on AVs according to survey respondents (see Table 5.2). Relative values placed on AVs are generally about 10 percent higher under rationing, and the dual fuel hybrid is valued at 110 percent of the price of a standard current vehicle.

There was little systematic relationship between demographic characteristics of respondents and their valuations of AVs. Higher income respondents tended to value AVs somewhat lower in general, while the relative valuation of AVs tended to increase with education level. No consistent relationship was noted between AV valuation and any other respondent demographic characteristic.

The valuations presented in Table 5.2 are limited in two respects. First they do not consider differentials in the likely costs of producing the various AVs; while the value placed on the purely natural gas vehicles by survey respondents was less than that placed on dual fuel hybrids, the cost of producing the former would also be less than the cost of producing the hybrid vehicles. Secondly, differentials in fuel cost have not been considered. Respondents were asked to evaluate the AVs assuming no difference in fuel cost. A separate question was used to estimate each respondents valuation of increased fuel economy. This allows simulation of the impact of various fuel cost alternatives on vehicle purchase decisions.

Estimates of sales of AVs were made by combining vehicle cost and fuel economy figures with the demand estimates described above. Due to the low demand for electric vehicles they were not included in this phase of the analysis. Five scenarios providing combinations of AV selling price and fuel economy were developed and used in simulation runs. In each simulation a vehicle purchase decision was determined for each survey respondent based on his or her valuation of AVs and of fuel economy and based on the assumptions of the given scenario. Figures for penetration rates for two of those scenarios are presented in Figures 5.1 and 5.2. The first scenario, see Table 5.3, is the least favorable set of circumstances under which any penetration of AVs could be expected. It is assumed that no penetration will occur in the absence of at least some fuel cost savings, the first scenario assumes a full cost saving of only 1/2 cent per mile using the alternative fuel (presumably natural gas). Purchase prices of AVs are relatively high due to small scale of production of these vehicles. Scenario 2 is much more favorable to AV development.

The fuel cost of natural gas is 3 cents per mile lower than that for gasoline. (Gasoline prices well in excess of $2 per gallon would likely be required to achieve this differential.) Purchase prices of the AVs are also lower under this scenario due to the assumption of large scale production of AVs. Projected penetration levels assuming that each of the four natural gas using AVs is available are presented at the top of Table 5.4. The data represents penetration in terms of the percentage of all car purchases which are AVs. The specific type of AV purchased is not indicated in the table, but the Manufactured Dual Fuel Hybrid (Car 2A) is the vehicle preferred by a majority of AV purchasers, with a significant minority choosing the strictly natural gas vehicle (Car 1). In evaluating the implications of the penetration rates indicated it is important to note that the vehicle fleet turns over rather slowly. Thus, perhaps 15 years of sales at the indicated rate would be required before the proportion of the vehicle fleet made up of AVs would reach the indicated level. In addition, a certain level of expected sales and the presence of a minimal refueling infrastructure would be required before manufactured AVs become feasible. Thus initial penetration of AVs likely must take the form of Retrofit Hybrid Vehicles. The lower half of Table 5.4 considers penetration of just this type of AV.

The results presented here <u>suggest that there is a significant potential market for natural gas powered AVs</u>. Hybrid vehicles appear to be the most practical alternative for initial penetration, although some potential for purely natural gas vehicles appears to be present once an adequate supply infrastructure has been developed. Penetration of AVs will require the presence of a significant fuel cost saving and the expectation that this fuel cost differential will continue for many years. The recent declines in gasoline prices have eliminated any fuel cost savings from the use of natural gas in the current market. Substantial and prolonged increases in the price of gasoline would be required to make any significant AV penetration become feasible.

TABLE 5.1

DESCRIPTION OF VEHICLES EVALUATED BY DEMAND SURVEY RESPONDENTS

STANDARD CURRENT VEHICLE

- Range before refueling: 350 miles
- Refueling time: 6 minutes

CAR 1 NATURAL GAS/HYDROGEN

- Range before refueling: 200 miles
- Refueling time: 12 minutes

CAR 1A NATURAL GAS

- Range before refueling: 200 miles
- Refueling time: 12 minutes
- May be refueled at home overnight for commuting.

CAR 2 RETROFIT DUAL FUEL HYBRID

- Range: 350 miles (Gasoline), 75 miles (Natural Gas)
- Refueling: 6 minutes (Gasoline), Overnight (Natural Gas)
- One half of trunk space lost to fuel tanks.

CAR 2A MANUFACTURED DUAL FUEL

- Range: 350 miles (Gasoline), 75 miles (Natural Gas)
- Refueling: 12 minutes (Gasoline), Overnight (Natural Gas)

CAR 3 ELECTRIC 50 MILE RANGE

- Range before refueling: 50 miles
- Refueling time: Overnight

CAR 3A ELECTRIC 100 MILE RANGE

- Range before refueling: 100 miles
- Refueling time: Overnight

CAR 3B ELECTRIC 350 MILE RANGE

- Range before refueling: 350 miles
- Refueling time: Overnight

TABLE 5.2

RESPONDENTS MEAN VALUATIONS OF ALTERNATELY FUELED VEHICLES RELATIVE TO A STANDARD CURRENT VEHICLE

Type of Vehicle	Nonrationing Scenario Price Ratio**	Rationing Scenario Price Ratio**
Car 1 Natural Gas/Hydrogen	.72	.82
Car 1A Natural Gas with Home Optional Refueling	.74	.90
Car 2 Retrofit Dual Fuel Hybrid	.87	.97
Car 2A Manufactured Dual Fuel Hybrid	.97	1.10
Car 3 Electric 50 Mile Range	.31	.38
Car 3A Electric 100 Mile Range	.41	.53
Car 3B Electric 350 Mile Range	.72	.84

** Ratio of price offered for the alternate vehicle to price offered for a standard current vehicle.

TABLE 5.3

SUPPLY SCENARIO SPECIFICATIONS

Purchase Price AV-Conventional Vehicle:		SCENARIO 1	SCENARIO 2
Car 1	(Natural Gas)	$1800	$ 800
Car 1A	(Natural Gas with with home refueling)	$2500	$1500
Car 2	(Hybrid-Retrofit)	$2200	$2200
Car 2A	(Hybrid-Mfg.)	$2700	$1700
Fuel Cost Per Mile Saving of Natural Gas vs. Gasoline		0.5 ¢	3.0 ¢

TABLE 5.4

PREDICTED AV PENETRATION RATES AND 95% CONFIDENCE INTERVALS

ON AV PENETRATION RATES UNDER ALTERNATIVE SCENARIOS

ALL NATURAL GAS USING AVs MARKETED

	Scenario 1	Scenario 2
Upper 95% C.I.	29.9%	81.0%
Predicted	14.2%	65.7%
Lower 95% C.I.	6.1%	46.1%

ONLY RETROFIT HYBRID MARKETED

	Scenario 1	Scenario 2
Upper 95% C.I.	20.8%	36.1%
Predicted	6.6%	29.8%
Lower 95% C.I.	1.9%	9.7%

PREDICTED AV PENETRATION RATE
AS A FUNCTION OF FUEL COST SAVINGS

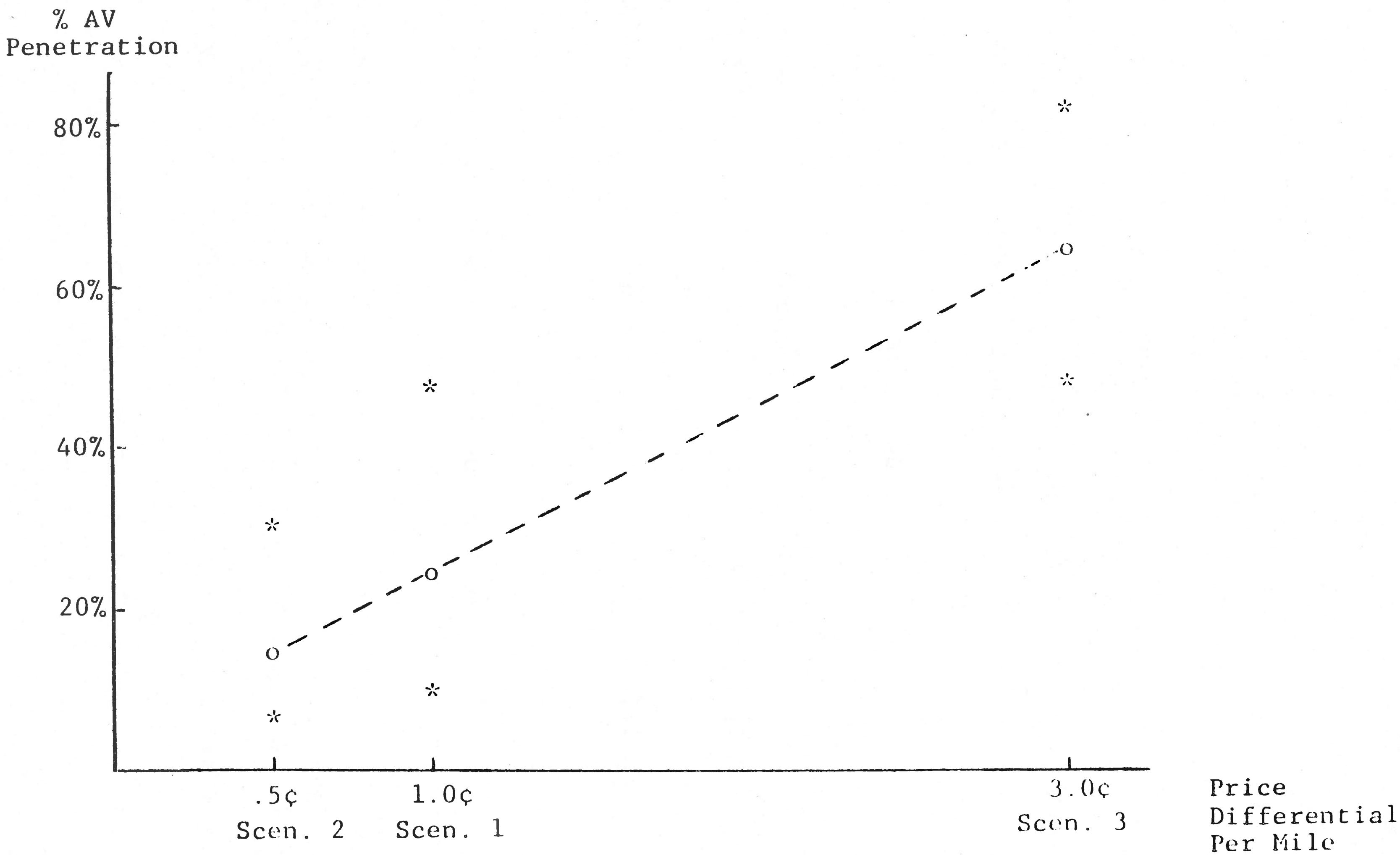


FIGURE 5.1

PREDICTED AV PENETRATION RATE
AS A FUNCTION OF FUEL COST SAVINGS
ONLY RETROFIT HYBRID VEHICLE AVAILABLE

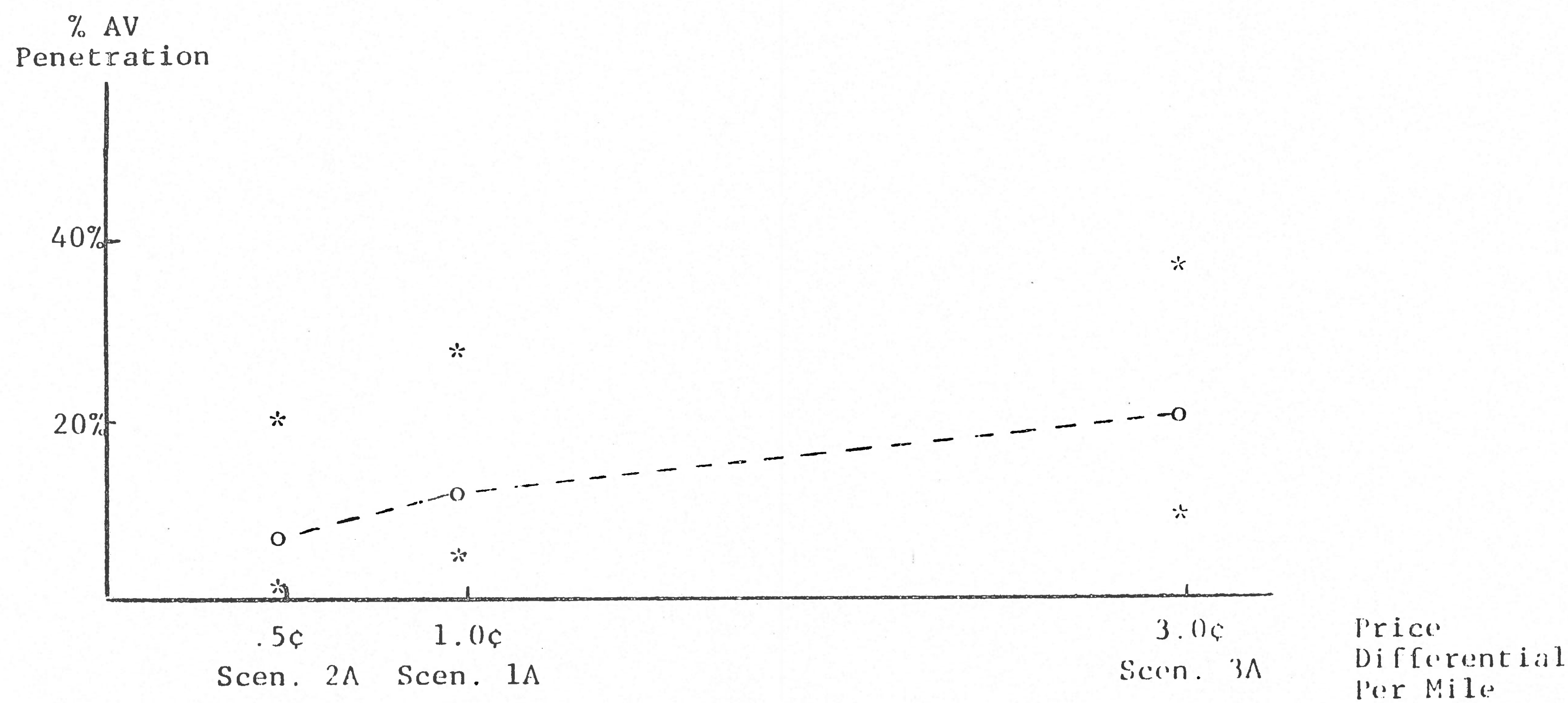


FIGURE 5.2

SECTION 6

A SURVEY OF PROSPECTIVE CONSUMER DEMAND FOR ALTERNATIVELY FUELED VEHICLES

The attitudinal survey described and summarized in the previous chapter provides a great deal of qualitative information about peoples attitudes and habits with respect to cars and driving. However, it stops short of gathering data which can be used to estimate consumer demand for alternate vehicles in quantitative (dollar) terms. This consumer vehicle demand data has been gathered using a separate survey instrument whose use and results are summarized in the section of the report.

The decision to administer a separate questionnaire in order to obtain consumer vehicle demand data was based on two primary considerations. First, there was concern that excessive questionnaire length might adversely affect the response rate to a single combined questionnaire. Second, we felt that the average consumer would need to see or hear a rather substantial discussion of alternate vehicle characteristics in order to appropriately evaluate them.

The consumer vehicle demand survey and the results obtained from it are described below. The survey methodology is described in Section 6.1. Demographic characteristics of the group responding to the survey are summarized in Section 6.2. Next simple descriptive statistics of respondent reactions to alternate vehicles are presented and discussed in Section 3.

Finally, a statistical analysis of the survey results using analysis of variance procedures is presented. The results of this survey are also used in Section 7 where they are combined with supply condition scenarios to obtain predictions of vehicle choice.

6.1 METHODOLOGY

6.1.1 SURVEY OBJECTIVES

In constructing the consumer vehicle demand survey emphasis was placed on ensuring that the instrument was capable of meeting three primary objectives. First, the instrument had to produce quantitative estimates of the price individuals were willing to pay for various alternate vehicles. it had to produce results which could be used to predict an individual's vehicle choice for any given scenario of supply conditions. Secondly, our methodology needed to be one which guaranteed that survey respondents received adequate information regarding alternate vehicle technologies prior to filling out the survey instrument. Finally, the survey needed to be as representative as possible of the population. It had to be administered in a way which maximized response rate and thus minimized the chance of bias through those with favorable attitudes toward alternate vehicles being more likely to take the time to fill out a survey form. Further, it was essential that the demographic characteristics of surveyed population be known so that survey results could be adjusted to reflect state population characteristics.

6.1.2 REVIEW OF LITERATURE

Demand for a complex product like an automobile is typically viewed in both the economics and the marketing literature as a demand for the bundle of attributes or characteristics which the automobile possesses. In the case of an automobile attributes like comfort, styling, passenger room, trunk space, performance (acceleration rate and cruising speed) and reliability would typically be important determinants of consumer demand for that automobile. This type of treatment of demand for a product follows the theoretical work in economics of Lancaster [1966] who hypothesized that consumers use a good or goods in combination as inputs to produce an output in the form of a set of attributes which in turn provides utility or satisfaction. The demand for any good is thus derived from the set of utility providing attributes which it contains.

A similar concept has been used by many other economists in measuring quality. Attributes of a product are used as measures of the quality of the product. In empirical work based on historical data, differentials in the market prices of products with different attribute sets (hedonic price indices) have been used as measures of the value consumers place on the various attributes and thus by implication the importance of each attribute in determining product quality, (or in Lancaster's terms the utility level provided by the product). Studies have covered such items as cars, tractors, washing machines, carpets, and houses, e.g., Grilliches [1971].

In marketing there is a large literature of studies utilizing "determinant attribute" analysis, see for instance Myers and Alpert [1968] to assess which product attributes are most important in a consumers purchase decision. Again these studies for the most part deal with existing products. The studies have shown that the weight of an attribute in a consumers purchase decision depends upon both the perceived importance of the attribute and the perceived amount of variability across products with respect to the attribute. For instance airline passengers have indicated that safety is the most important airline attribute. However, since they perceive very little difference among airlines with regard to safety, safety is not very important to the consumers airline choice. Similarly, vehicle range on a tank of gas and time required for refueling have not shown up as important attributes in automobile studies since existing vehicles do not vary greatly with respect to these attributes. However, several of the alternate vehicles treated here do vary considerably from the norm for range and refueling characteristics so that these attributes may become very important in this study.

Very few studies of consumer demand for alternately fueled vehicles have been undertaken. Most of the information on prospective alternate vehicle demand is based on expert opinion rather than surveys of actual consumers. Two alternate vehicle related studies which did survey vehicle consumers were reviewed extensively in developing the methodology for this survey. A study by Wagner, Naughton, and Brook [1978] focused on the potential for alternate vehicles, primarily electric, as commercial fleet vehicles. In this study fleet managers were asked to rate the relative importance of various vehicle attributes such as seating and trunk capacity, performance, economy, reliability, range and refueling time. Respondents were also asked to indicate the minimum acceptable performance levels required in their fleet vehicles with respect to various attributes. The study did not ask the fleet managers to indicate the price which they would pay for various vehicle attributes. Thus commercial fleet demand for alternate vehicles cannot be derived from this study. What it does provide is an evaluation of the relative importance of various vehicle attributes and an upper limit on the demand for a given alternate vehicle based upon minimum performance requirements. That is if 35 percent of the survey respondents indicated a minimum range requirement greater than 50 miles, demand for an alternate vehicle with a 50 mile range could never exceed 65 percent of the market.

Estimates of the importance of various vehicle attributes in dollar terms are provided by a panel study conducted by Arthur D. Little Inc., EPRI [1981] and Beggs, Rardell and Hausman [1982]. This study surveyed 193 compact and subcompact car owners whose daily commuting travel did not exceed 50 miles. The respondents were asked to evaluate a set of cars some of which were specified to be electric and some of which were specified to be gasoline powered. The evaluation was in the form of ranking a set of 16 cards each of which contained a description of a car. Respondents ranked the cars from the one they would be most likely to choose to the one they would be least likely to choose. The vehicles were described to the respondents in terms of their characteristics with respect to nine attributes; purchase price, fuel cost, fuel type (refueling time), range, top speed, acceleration, number of seats, air conditioning, and type of warranty provided. The permutations of these attributes were varied randomly across the survey sample.

Ordered logit analysis was used to transform the respondents rankings of vehicles into estimates of the price differentials required by the respondents to compensate for differences in various attributes. For example in the survey the average household was willing to pay about $6500 to avoid a 50 mile range as opposed to a 200 mile range in an electric vehicle ($4900 for a gasoline vehicle), $3900 for a top speed of 65 miles per hour as opposed to 45 miles per hour, $2000 for rapid as opposed to slow or average acceleration, and $2100 to $3700 (depending on range) to avoid the overnight recharge time of electric vehicles. The analysis tested for a variety of interactions between the various attributes but none were found to be significant beyond those alluded to in the summary above. One important limitation of the study which its authors noted was the fact that the limited range of prices used (only prices of $2000, $3000, $4500 and $6000 were considered) limited the accuracy of comparisons of vehicles with widely varied characteristics. Despite this limitation the Arthur D. Little study presents an interesting approach to quantification of the demand for alternate vehicles which was very helpful to us in designing our consumer demand survey.

6.1.3 SURVEY DESIGN

Upon consideration of the level of knowledge needed to reasonably evaluate one's response to alternate vehicle technologies it was decided that a presentation of at least 20 to 30 minutes duration describing the various alternate vehicle technologies would be necessary prior to survey administration. The need for formal presentations in conjunction with the survey made it virtually impossible to obtain a truely random sample. Given time and funding limitations it was decided that the most appropriate method for obtaining sample responses would be to administer the survey to a variety of service clubs and student groups. Presentations were made in the Phoenix area, in Tucson and in Flagstaff. In order to keep the survey as representative as possible of the population, a variety of general membership service organizations were surveyed and almost all of the students surveyed were community college students (where a broad range of age and income groups are represented). However, using this survey method we were not able to control for the distribution of demographic characteristics of the sample such as age, income and education level to ensure those distributions to be identical to the population distributions. Actual distributions of survey respondents and of the Arizona Population with respect to various demographic variables are presented in the next section of this Chapter. Since demographic characteristics of the sample could not be controlled it was essential that demographic data be obtained from respondents so that survey results could be adjusted to reflect population characteristics. The methodology of this adjustment is discussed in Section 7.

The survey instrument used evolved considerably from the initial prototype. A pilot survey was conducted using a questionnaire which was very similar to that used in the Arthur D. Little panel survey described above. It was felt that 16 vehicles was too large a number to evaluate in the limited time offered by a service club meeting setting. Also the use of a limited set of vehicle prices seemed inappropriate given the wide range of alternate vehicles to be evaluated. Thus respondents were asked to indicate the price they would be willing to pay for each of the vehicle choices rather than simply ranking them and each respondent was asked to evaluate only six alternative vehicles. Five vehicle attributes (fuel economy, acceleration, number of passengers, trunk space, and range/refueling time) were varied within and across the sample questionnaire.

Results from the pilot administration of this survey were unsatisfactory. Oral feedback from respondents and the sample survey results obtained clearly indicated that respondents were not able to perform reasonable comparisons involving such a large number of variables in the limited time available. Clearly there was a need to cut back on the number of attributes treated. Attention had to be focused on the attributes which were most likely to vary sharply across alternate vehicle types and at the same time to be crucial to the buyers perception of a vehicle's value.

We determined that the key attributes which must be evaluated were range/refueling time, which we combined into a single attribute since the Arthur D. Little study found significant interaction between them when treated as separate attributes, and fuel cost. Performance (acceleration) characteristics of most types of alternate vehicles have improved significantly in recent years as is indicated in Section 2 so that characteristics similar to those of current gasoline vehicles should be possible with most types of alternate vehicles. The vehicle seating capacity is an issue only with respect to electric vehicles. The marginal cost of expanding seating capacity is higher for electric vehicles than for gasoline vehicles. However, this is not the case for other alternate vehicle types. Failure to evaluate the impact of seating capacity limits the surveys effectiveness in evaluating electric vehicle options, but this did not in fact constitute an important limitation as we will see. Trunk capacity is an issue with respect to vehicle retrofits using fuels in gaseous form. Since retrofit vehicles are likely to be an important source of the initial penetration of alternate vehicles, it was decided that one vehicle option with half the trunk space removed to accommodate retrofit fuel tanks would be retained. In general in assessing various alternative scenarios we will assume that any successfully marketed alternatively fueled vehicles must achieve performance levels at least roughly equivalent to existing vehicles with respect to attributes not treated in the survey.

An additional factor which could potentially have a major effect on consumers valuation of alternate vehicles is the presence or absence of nonprice rationing of gasoline. Alternate vehicles are often discussed in the context of a "crisis" petroleum supply situation. Governments engaged in rationing measures during past "crisis" situations (reduced hours of service station operation and odd/even license plate refueling days) and have prepared plans for more extensive rationing efforts in the event of a major petroleum supply cut back. It was felt that this could best be dealt with by administering two separate sets of questionnaires rather than by adding an additional variable for each respondent to consider. Thus each administration of the revised questionnaire uses only one of the two sets of questionnaires, but across presentations the rationing and non-rationing survey forms are alternated.

Based on the considerations described above a revised questionnaire was devised. The revised questionnaire was administered to 12 groups of respondents. A presentation lasting 25 to 40 minutes describing various alternate vehicle technologies (alcohols, natural gas, hydrogen, electric and hybrid vehicles) preceded the administration of the survey.

The presentation included several statements beyond those included in the descriptions on the survey forms which may have influenced respondents evaluations of alternate vehicles. Natural gas, hydrogen and electric vehicles were described as being potentially significantly less polluting than gasoline vehicles. It was suggested that natural gas and hydrogen engines would also likely require less frequent periodic maintenance (oil changes and tune ups) than gasoline engines because of their cleaner burning nature. Tank safety issues with fuels in gaseous form were discussed. Respondents were told that tanks providing safety equivalent to that of a gasoline tank appear to be feasible currently or in the near future and that equivalent tank safety could be assumed in responding to the questionnaire.

Two forms of the questionnaire were used, one assuming no gasoline rationing (Appendix C) and one assuming that gasoline rationing is expected to occur (Appendix D). The form of the anticipated rationing is described at the bottom of the first page of the survey form. Respondents are asked to assume that there will be 2 or more periods of gasoline rationing over the life of the vehicle lasting several months during which gasoline refueling will require an average of 45 minutes in gasoline lines and service station hours may be restricted. Rationing is assumed to have no affect on availability and refueling times for any of the alternate vehicles.

The first section of questions in the revised questionnaire consists of the age, income and education level information which was discussed above. The second set of questions provides information about current vehicle ownership and use. It provides some data about current use patterns and how they relate to acceptance of potential new technologies. This set of data also allows us to measure the frequency of new car purchase among various demographic groups within the sample so that groups purchasing new cars more frequently are weighted more heavily in the analysis. This weighting procedure is described more fully below. The first two sets of questions were also used as control variables to facilitate comparison of this survey with the attitude survey. These two sets of questions are identical across the two alternative survey forms.

The final set of questions asked the survey respondent to indicate the price they would be willing to pay for each of 9 alternative vehicles whose characteristics are described. These questions represent the heart of the survey. Respondents were asked to carefully review the scenario presented (see the bottom of the first page of Appendix C and D respectively) before answering these questions. These descriptions of course vary between the rationing and non-rationing scenario. However, the only variation between the two questionnaires with respect to the alternative vehicle descriptions (pages 2 and 3 of the questionnaire) are changes in the refueling time for vehicles using gasoline engines.

The vehicles which respondents were asked to evaluate in the final section of the questionnaire were designed to be as representative as possible of the technologies most likely to become viable alternatives to the traditional gasoline engine within the next 25 to 50 years. Initially respondents were asked to indicate how much they would be willing to pay for a current "typical" full sized gasoline powered vehicle. Examples of such vehicles, (e.g. Ford LTD, Chevrolet Citation, Chrysler E Series) were provided. Respondents were then asked how much they would be willing to pay for the same car if its gas mileage were improved enough to reduce operating costs by 2 cents per mile (10 miles per gallon assuming the initial car averaged 20 miles per gallon). The differential in price here was used to establish the trade-off between initial outlay and operating expense which is essential in evaluating each respondent's expected reaction to various scenarios which cause major changes in operating expenses for various types of vehicles. The 7 remaining vehicle descriptions encompass three basic types of alternate vehicles.

The first alternate vehicle type, Car 1, is one with a slightly reduced range (200 miles) and increased refueling time (12 minutes). This is designed to be typical of a compressed natural gas (CNG) or hydrogen powered vehicle. An alternate form of this vehicle allowing overnight refueling to a range of 75 miles in addition to service station refueling with a 200 mile range, Car 1A, would apply only to the natural gas fueled vehicle and assumes the individual's home is served by natural gas.

The second vehicle type is a hybrid of gasoline and either natural gas or electric power (Cars 2 and 2A). The hybrid vehicle is designed to use either of its two fuels by simply turning a switch which controls the type of fuel used. The gasoline natural gas hybrid could be produced by modifying an existing gasoline powered vehicle to accommodate the second fuel while the gas electric hybrid would be designed as a hybrid with a relatively small 20 to 30 horsepower gasoline engine used to generate electricity for the batteries. In either case the vehicle is designed to achieve standard range and refueling characteristics when operating as a gasoline powered vehicle. In addition, it is capable of a 75 mile range from home with overnight refueling utilizing either natural gas or electric lines, Car 2A. An alternate form of this vehicle, Car 2, is presented in which half the vehicle's normal trunk space is removed to provide the second power source. This would typically be the case for a retrofitted vehicle and might also be the case for some designed hybrids.

The third type is one providing limited range and overnight refueling, Cars 3 and 3B. This vehicle type was intended to be representative of a purely electric vehicle. Three variants of this vehicle were presented, one with a range of 50 miles (Car 3), one with a range of 100 miles (Car 3A) and one with a range of 350 miles (Car 3B). The first two options were designed to represent the range characteristics likely to be achieved by this type of car in the relatively near future while the third was included primarily in an attempt to isolate the importance of the overnight refueling attribute.

As was indicated above this questionnaire was administered to 12 groups of respondents. A total of 186 usable responses were obtained and this represented about two thirds of the possible number of responses based upon the number of individuals attending the presentations. Nonresponses and unusable responses appeared to stem primarily from the complexity of the questionnaire and, in the case of service club groups, time constraints on respondents rather than reflecting any systematic bias with regard to the type of individual willing to complete the form. However, this type of bias obviously cannot be ruled out. Characteristics of the survey respondents are explored further in the next section.

6.2 DEMOGRAPHIC CHARACTERISTICS OF SURVEY RESPONDENTS

The format of the consumer alternate vehicle demand survey, that is, the fact that it was administered to pre-existing groups of respondents, made it impossible to gather a random sample of individual respondents. The best that could be done was to try to pick groups which were as varied and as representative of the population as possible, while at the same time gathering demographic data which could be used to adjust for any major biases which might appear in the sample tests.

Table 6.1 shows the distribution of groups which were surveyed. The groups include 3 service clubs, 5 community college and 1 university class, and 3 other groups. The college classes surveyed were from a variety of disciplines and were associated with schools in varied socio-economic and geographic settings. The service clubs inherently tend to be dominated by individuals of above average income, but the groups surveyed are ones which would not be expected to have any obvious bias for or against alternate vehicles. Overall, the groups surveyed are ones which would be expected to hold unbiased views toward alternately fueled vehicles, although they are not fully representative of the Arizona population demographically.

Tables 6.2 through 6.7 present demographic characteristics of alternate vehicle demand survey respondents. Where possible Arizona population characteristics are included as well. In addition, survey respondents are divided into those who were given a rationing scenario and those responding to a nonrationing scenario.

Table 6.2 presents age distribution data. Survey respondents are reasonably representative of the Arizona population. However, there is a tendency, especially under the rationing scenario, for survey respondents to come disproportionately from the middle age groups while the young and old are somewhat underrepresented.

Table 6.3 displays the distribution of education level among survey respondents and in the Arizona population. Survey respondents tended to come predominately from higher educated groups. In fact, individuals with a high school education or less are virtually unrepresented in the survey. There is some rationale for surveying predominately higher educated individuals, since they are more likely to be the innovators (as described in a previous chapter) whose acceptance of a new product is crucial to its success. However, the virtually complete lack of individuals with high school or lower education among the survey respondents does constitute a major limitation on the representativeness of the sample.

Table 6.4 presents the distribution of family income. Survey respondents tend to come predominately from higher income families and particularly from families with incomes over $50,000 per year, while almost half of Arizona families have incomes below $15,000. It is appropriate that the survey overrepresent upper income families to some extent, however, because those with higher incomes tend to buy new cars more frequently. To determine the proportion of new cars purchased by families in various income categories it is necessary to adjust population proportions for the freqency with which families in a given income range purchase new vehicles. This data is presented in Table 6.5. Comparing Table 6.5 responses with the survey respondent data from Table 6.4 we see that upper income families are still somewhat over-represented but the degree of bias toward upper income groups becomes much smaller.

Table 6.6 indicates the number of vehicles owned by survey respondent families. Almost 70 perdent of respondents owned two vehicles or more, with two being the most popular number. Arizona population figures on the distribution of number of vehicles owned are not available.

Table 6.7 indicates the county of residence of survey respondents as compared to the geographic distribution of Arizona population. Maricopa County is somewhat over-represented and the nonmetropolitan counties are under-represented in the sample.

The tables presented here have shown the survey respondents to be reasonably representative of Arizona population in most respects. Where biases have been found they can, in most cases, be corrected by adjusting the results generated from the sample. One area of concern is the distribution of education level where those with high school education or less are virtually unrepresented by the sample.

6.3 SURVEY RESPONDENT'S REACTIONS TO ALTERNATELY FUELED VEHICLES

This sub-section describes the reaction of the NAU survey respondents to the various alternately fueled vehicles described above. The mean response and the distribution of responses are presented. All valuations of alternate vehicles are couched in relative terms, comparing the price offered for an alternately fueled vehicle to the price the respondent offered for a standard current vehicle. Comparisons are presented in the form of the ratio of the price offered for an alternate vehicle to that offered for a standard current vehicle.

Table 6.8 presents a summary of survey respondents' average valuations of the various alternately fueled vehicles under both rationing and nonrationing scenarios. Several features of the responses are immediately apparent. The alternate vehicles are almost uniformly given a lower value than a standard current vehicle by the average respondent. This is not surprising since the alternate vehicles tend to have undesirable range refueling characteristics and fuel cost savings are not considered in these valuations. It is clear that all of the alternate vehicles are more highly valued under the rationing scenario. The presence of gasoline rationing increases the value placed on a nongasoline vehicle by $1000 to $2000 (a .1 to .15 increase in the alternate vehicle's price ratio) across the various alternate vehicle types. The hybrid vehicle alternatives are clearly the most preferred form of alternate vehicle with the manufactured dual fuel hybrid actually being valued more highly than a standard current vehicle under the rationing scenario. Electric vehicles with a range which is currently feasible (50 to at most 100 miles) are the least preferred of the alternate vehicle types by a wide margin. The 100 mile range car is valued barely half as highly as a typical gasoline powered car even under conditions of gasoline rationing.

While the mean responses presented in Table 6.8 are important, reactions to the vehicles varied widely across respondents so it is important to look at the distribution of responses as well. Figures 6.1 through 6.14 present the distributions of responses in price ratio terms for each vehicle under both the nonrationing and the rationing scenarios. The pattern of responses across the set of vehicles and the alternative scenarios clearly indicates that there is a wide variation in the reaction of various respondents to alternately fueled vehicles. In addition, the responses do not appear to conform fully with the normal distribution. There appear to be a greater proportion of extreme reactions and particularly extreme negative reactions than would be predicted by the normal distribution. Variations in responses also appear to be somewhat wider under the rationing scenario than under the nonrationing scenario. Interpretation of individual figures is left to the reader.

In addition to comparisons of each alternate vehicle to a standard current vehicle it is possible to compare the vehicles to each other. It is particularly instructive to examine the respondents' relative valuations of highly similar vehicles, to compare for instance car 1 and 1A, cars 2 and 2A, and each of the variants of car 3.

Car 1 and 1A are designated as vehicles with a 200 mile range and are intended to represent natural gas vehicles. The sole difference between the two vehicles is that vehicle 1A includes the option of home refueling for commuter trips of up to 75 miles. Figure 6.15 indicates that less than 20 percent of respondents (about 30 percent under rationing, Figure 6.16) are willing to pay a premium greater than 5 percent of the vehicle's purchase price for this feature. In fact more than half the respondents are unwilling to pay any premium for home refueling capabilities in this type of vehicle. Safety concerns may have been a factor here although no mention of safety issues is made in the questionnaire. At any rate the results suggest that the number of individuals who would be interested in home refueling devices for natural gas vehicles is rather small.

Vehicles 2 and 2A are the dual fuel hybrids and they differ only in that Vehicle 2A is manufactured and has a full sized trunk, whereas Vehicle 2 is a retrofit with only half of normal trunk space available. Figures 6.17 and 6.18 indicate that over half of our respondents would pay a premium greater than 5 percent for the manufactured vehicle and over 15 percent of respondents would pay a premium of 25 percent or greater. As was mentioned earlier, the premiums offered seem in some cases to be considerably larger than would be expected on the basis of trunk space alone. Some respondents evidently had concern over the safety and/or reliability of the retrofit vehicle which influenced their relative valuation of these vehicles.

TABLE 6.1

LIST OF RESPONDENT GROUPS FOR THE CONSUMER ALTERNATE VEHICLE DEMAND SURVEY

SERVICE CLUBS:

- Phoenix Kiwanis Club
- Optimist Club of Phoenix
- Tucson Optimist

COLLEGE CLASSES:

- Future Studies - Phoenix College (2 Sections)
- Current Issues - Scottsdale Community College
- Auto Repair - Northern Arizona University
- Principles of Management - Pima Community College (2 Sections)

OTHER GROUPS:

- Arizona Council of Safety Supervisors (Trucking Industry)
- Association of Energy Engineers (Presentation at Conference in Phoenix)
- Summer Energy Institute (Presentation to a Group of Elementary and Secondary School Teachers from throughout Arizona)

TABLE 6.2

PERCENTAGE AGE DISTRIBUTION OF SURVEY RESPONDENTS
RELATIVE TO THE AGE DISTRIBUTION OF THE ARIZONA POPULATION

AGE	ARIZONA POPULATION *	CONSUMER ALTERNATE VEHICLE DEMAND SURVEY		
		OVERALL	NON-RATIONING SCENARIO	RATIONING SCENARIO
Under 20	12.8%	6.5%	7.5%	5.4%
20 - 34	32.2%	29.0%	22.6%	35.5%
35 - 49	20.9%	39.8%	36.6%	43.0%
50 - 64	18.9%	17.2%	21.5%	12.9%
Over 65	15.2%	7.5%	11.8%	3.2%

* Source: Computed as the percentage of Arizona population aged 16 and above in the specified group based on 1980 Census Data, U. S. Department of Commerce [1983].

TABLE 6.3

PERCENTAGE DISTRIBUTION OF EDUCATION LEVEL AMONG SURVEY RESPONDENTS RELATIVE TO THE EDUCATION LEVEL DISTRIBUTION OF THE ARIZONA POPULATION

EDUCATION LEVEL	ARIZONA POPULATION *	CONSUMER ALTERNATE VEHICLE DEMAND SURVEY		
		OVERALL	NON-RATIONING SCENARIO	RATIONING SCENARIO
Less than High School	27.6%	.5%	1.1%	0.0%
High School	34.3%	1.1%	1.1%	1.1%
Some College	20.6%	44.1%	38.7%	49.5%
College Graduate	8.8%	30.1%	35.5%	24.7%
Masters Degree or Above	8.6%	24.2%	23.7%	24.7%

* Source: Computed as the percentage of Arizona population aged 25 and above in the specified Education Level based on 1980 Census Data, U. S. Department of Commerce [1983a].

TABLE 6.4

PERCENTAGE DISTRIBUTION OF FAMILY INCOME LEVEL AMONG SURVEY RESPONDENTS RELATIVE TO THE FAMILY INCOME LEVEL DISTRIBUTION OF THE ARIZONA POPULATION

		CONSUMER ALTERNATE VEHICLE DEMAND SURVEY		
INCOME LEVEL	ARIZONA POPULATION *	OVERALL	NON-RATIONING SCENARIO	RATIONING SCENARIO
Below $15,000	46.8%	8.9%	13.8%	4.3%
$15,000 - $20,000	14.9%	7.8%	5.7%	9.7%
$20,000 - $30,000	19.6%	18.9%	12.6%	24.7%
$30,000 - $50,000	14.4%	31.1%	23.0%	38.7%
Over $50,000	4.3%	33.3%	44.8%	22.6%

* Source: Computed as the percentage of Arizona families whose income is in the specified group. Based on 1980 Census Data, U. S. Department of Commerce [1983], adjusted to reflect changes in mean income level through 1984 (U. S. Department of Commerce [1985]).

TABLE 6.5

PERCENTAGE DISTRIBUTION OF NEW CARS PURCHASED BY FAMILY INCOME LEVEL FOR ARIZONA FAMILIES *

INCOME LEVEL	RATE OF NEW CAR PURCHASE (NEW CARS PURCHASED PER YEAR)	PERCENTAGE OF TOTAL NEW CARS PURCHASED
Below $15,000	.148	27.6%
$15,000 - $20,000	.218	12.9%
$20,000 - $30,000	.286	22.3%
$30,000 - $50,000	.456	26.5%
Over $50,000	.623	10.8%

* Rate of new car purchase by Income Level was derived from the consumer alternate vehicle demand survey. The income distribution for the Arizona population was weighted by this factor to obtain the percentage distribution of new cars purchased by income level.

TABLE 6.6

PERCENTAGE DISTRIBUTION OF NUMBER OF VEHICLES OWNED AMONG SURVEY RESPONDENTS

NUMBER OF VEHICLES OWNED	CONSUMER ALTERNATE VEHICLE DEMAND SURVEY		
	OVERALL	NON-RATIONING SCENARIO	RATIONING SCENARIO
1	30.6%	35.5%	25.8%
2	46.8%	43.0%	50.5%
3	16.7%	15.1%	18.3%
4	5.9%	6.5%	5.3%

TABLE 6.7

PERCENTAGE DISTRIBUTION OF COUNTY OF RESIDENCE AMONG SURVEY RESPONDENTS RELATIVE TO THE DISTRIBUTION OF COUNTY RESIDENCE OF THE ARIZONA POPULATION

		CONSUMER ALTERNATE VEHICLE DEMAND SURVEY		
RESIDENCE	ARIZONA POPULATION *	OVERALL	NON-RATIONING SCENARIO	RATIONING SCENARIO
Maricopa County	55.5%	69.4%	66.7%	72.0%
Pima County	19.6%	17.7%	19.4%	16.1%
Other	24.9%	12.9%	14.0%	11.8%

* Source: Computed as the percentage of total Arizona population residing in the specified County based on 1980 Census Data, U. S. Department of Commerce [1980].

TABLE 6.8

RESPONDENTS MEAN VALUATIONS OF ALTERNATELY FUELED VEHICLES RELATIVE TO A STANDARD CURRENT VEHICLE

Type of Vehicle		PRICE DIFFERENTIAL Nonrationing	Rationing
1.	Natural Gas	- $3287	- $1792
1A.	N.G. with Home Refueling	- $3098	- $1258
2.	Hybrid - Retrofit	- $2101	- $1047
2A.	Hybrid - Manufactured	- $ 923	+ $ 16
3.	Electric 50 Mile Range	- $7699	- $5425
3A.	Electric 100 Mile Range	- $6689	- $4212
3B.	Electric 350 Mile Range	- $3505	- $1812

FIGURE 6.1

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 1 (NATURAL GAS/ HYDROGEN) UNDER THE NONRATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 1 TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

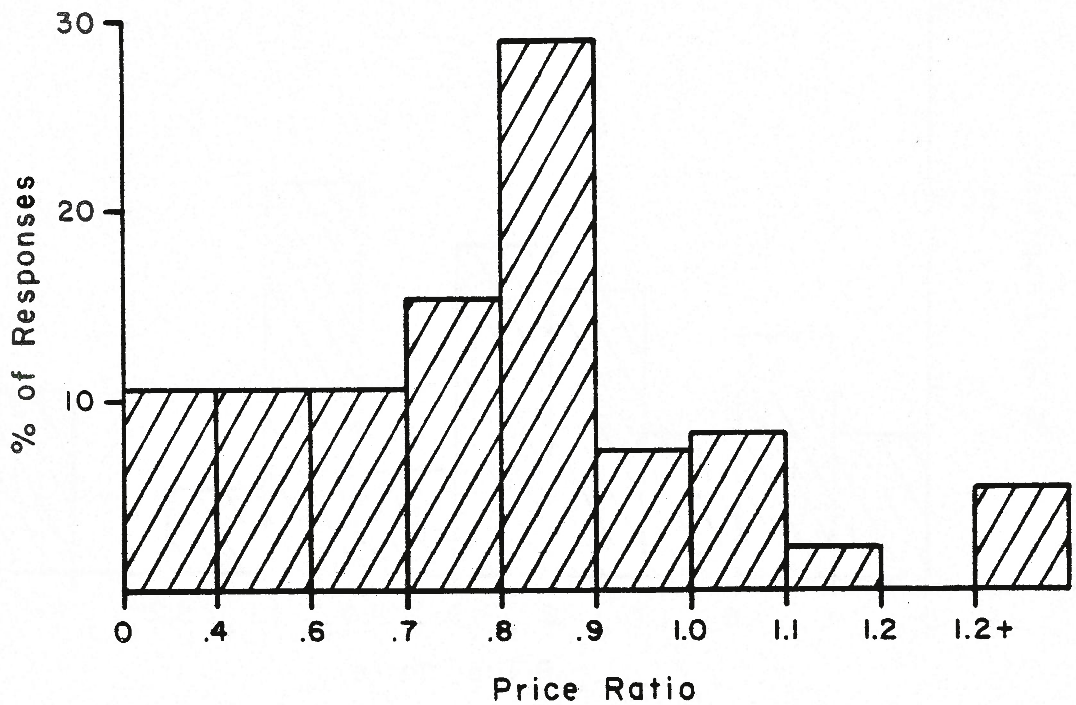


FIGURE 6.2

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 1 (NATURAL GAS/ HYDROGEN) UNDER THE RATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 1 TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

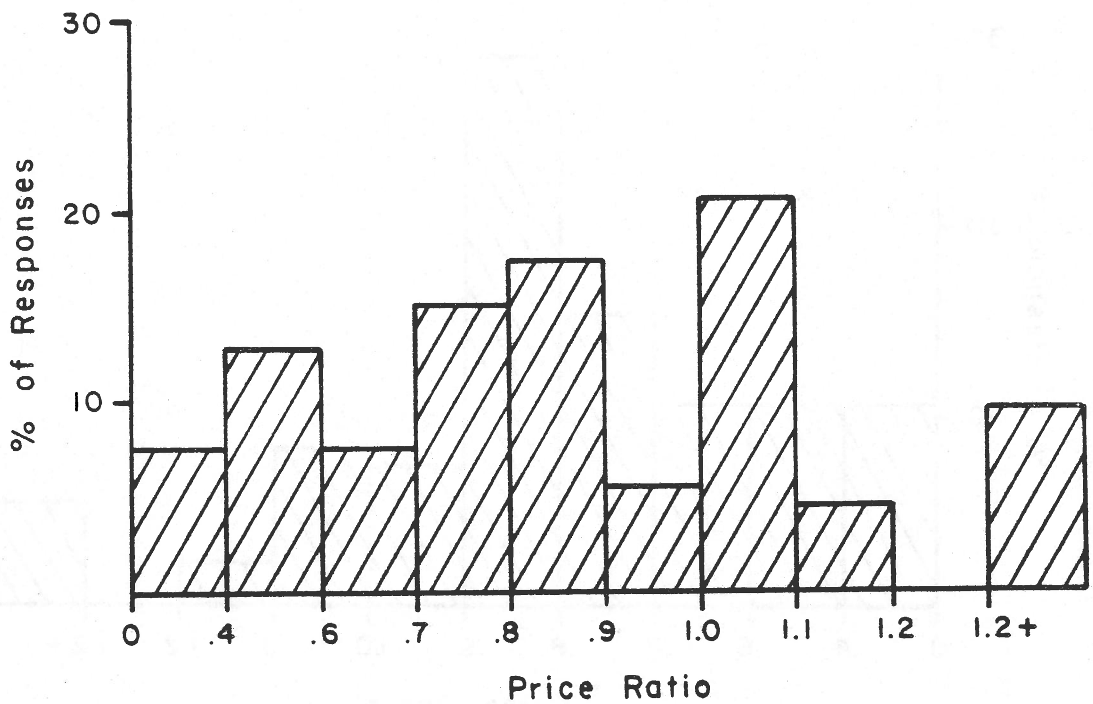


FIGURE 6.3

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 1A (NATURAL GAS/ HYDROGEN WITH HOME REFUELING) UNDER THE NONRATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 1A TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

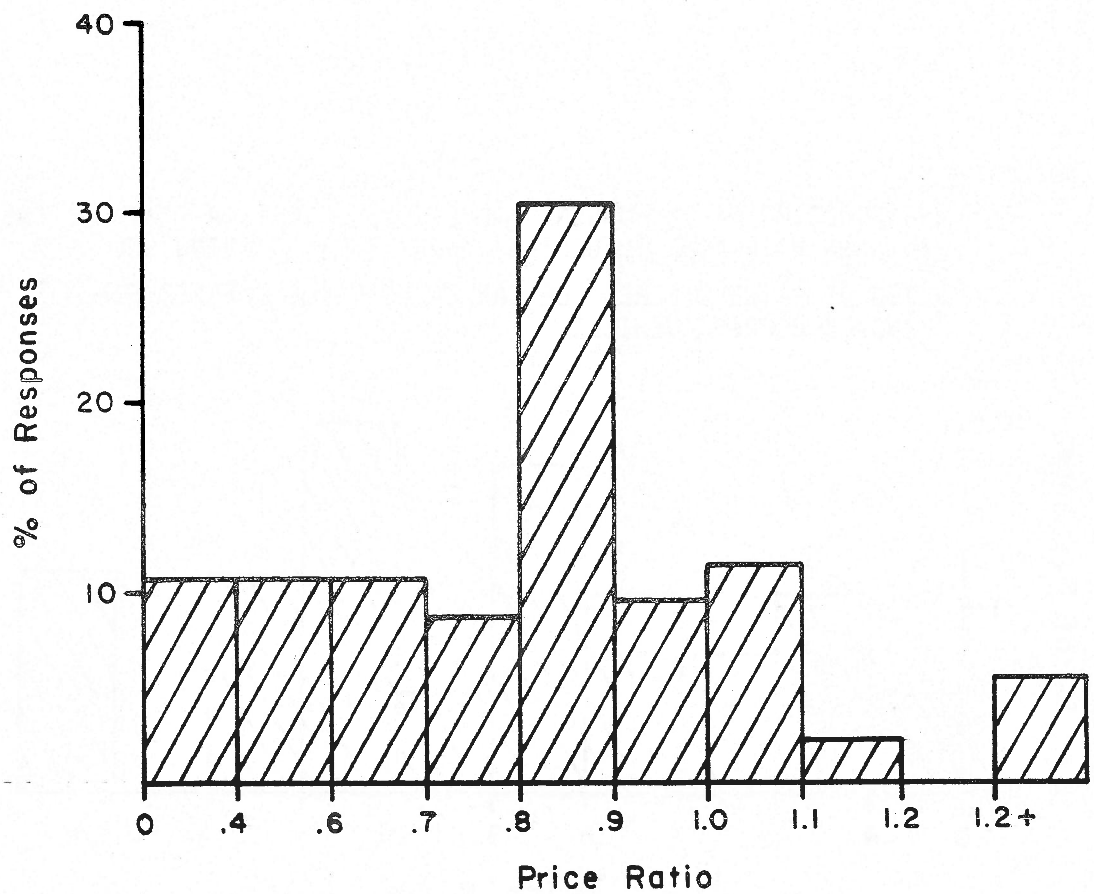


FIGURE 6.4

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 1A (NATURAL GAS/ HYDROGEN WITH HOME REFUELING) UNDER THE RATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 1A TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

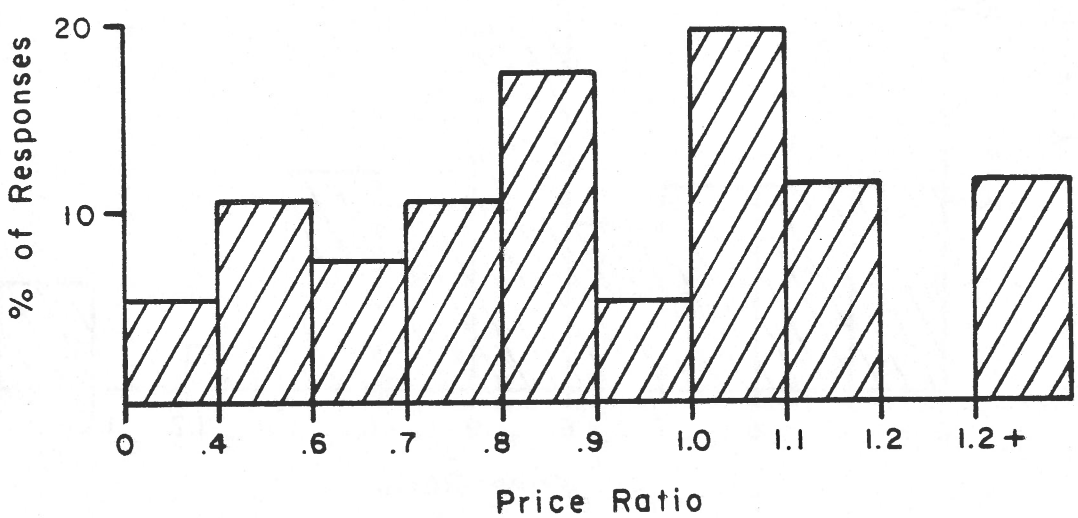


FIGURE 6.5

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 2 (RETROFIT DUAL FUEL HYBRID) UNDER THE NONRATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 2 TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

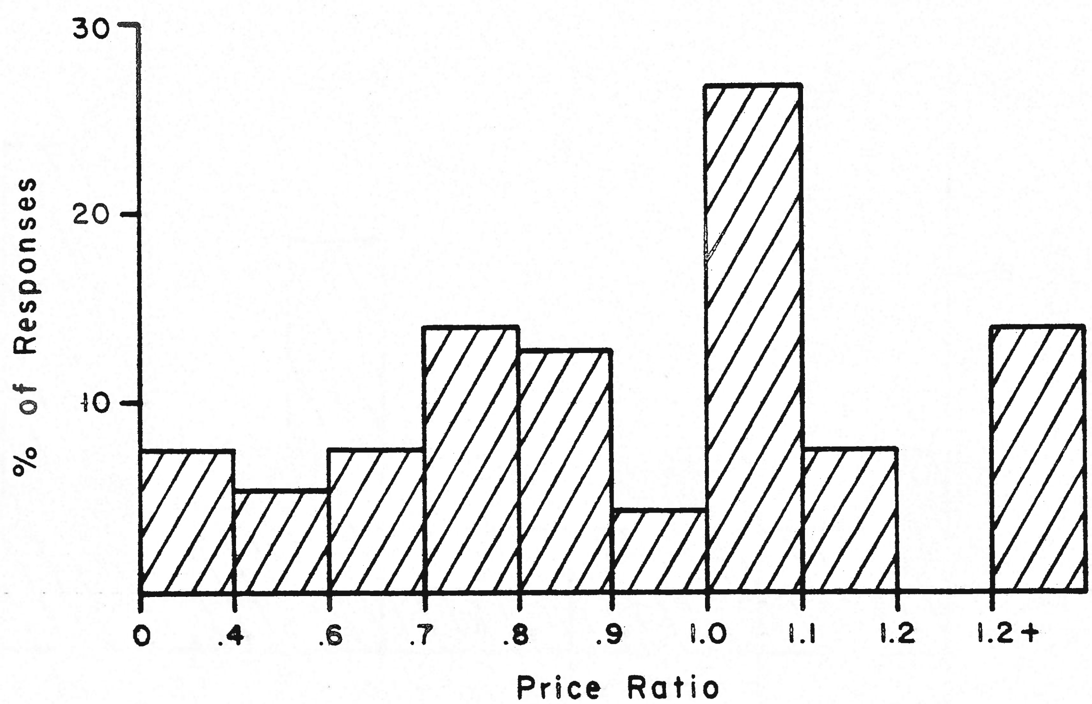


FIGURE 6.6

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 2 (REFROFIT DUAL FUEL HYBRID) UNDER THE RATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 2 TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

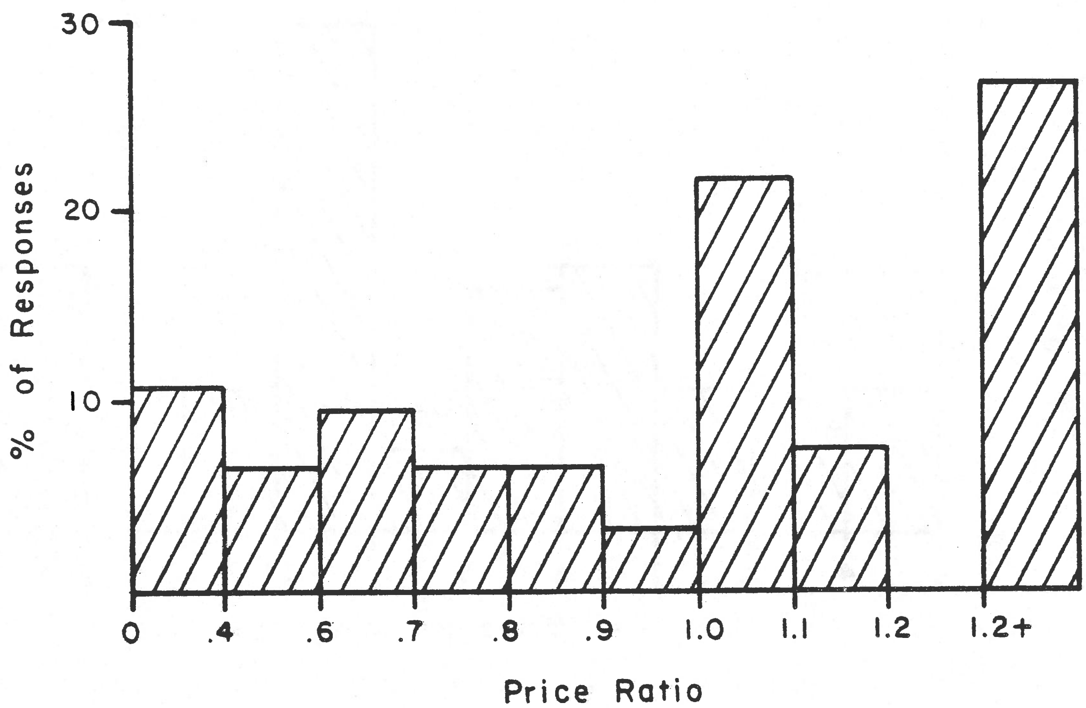


FIGURE 6.7

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 2A (MANUFACTURED DUAL FUEL HYBRID) UNDER THE NONRATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 2A TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

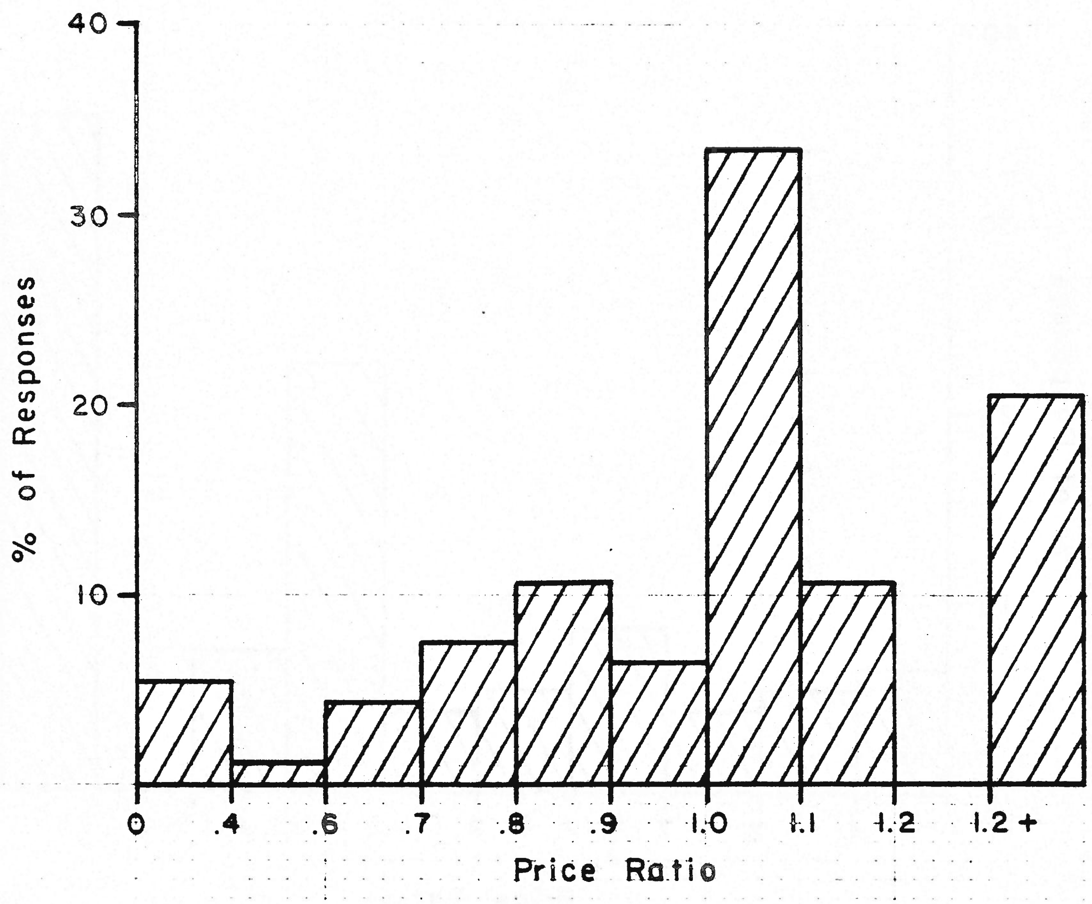
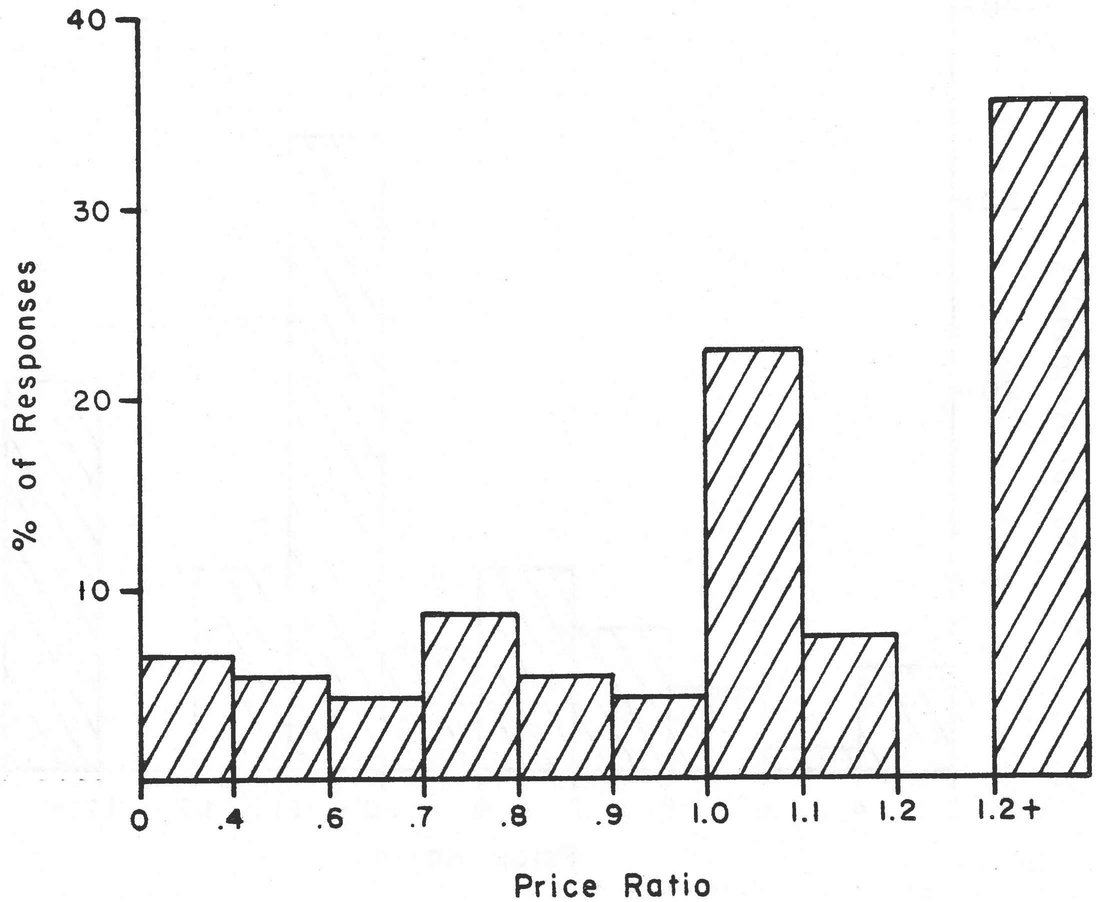


FIGURE 6.8

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 2A (MANUFACTURED DUAL FUEL HYBRID) UNDER THE RATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 2A TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE



DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 3 (ELECTRIC WITH 50 MILE RANGE) UNDER THE NONRATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 3 TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

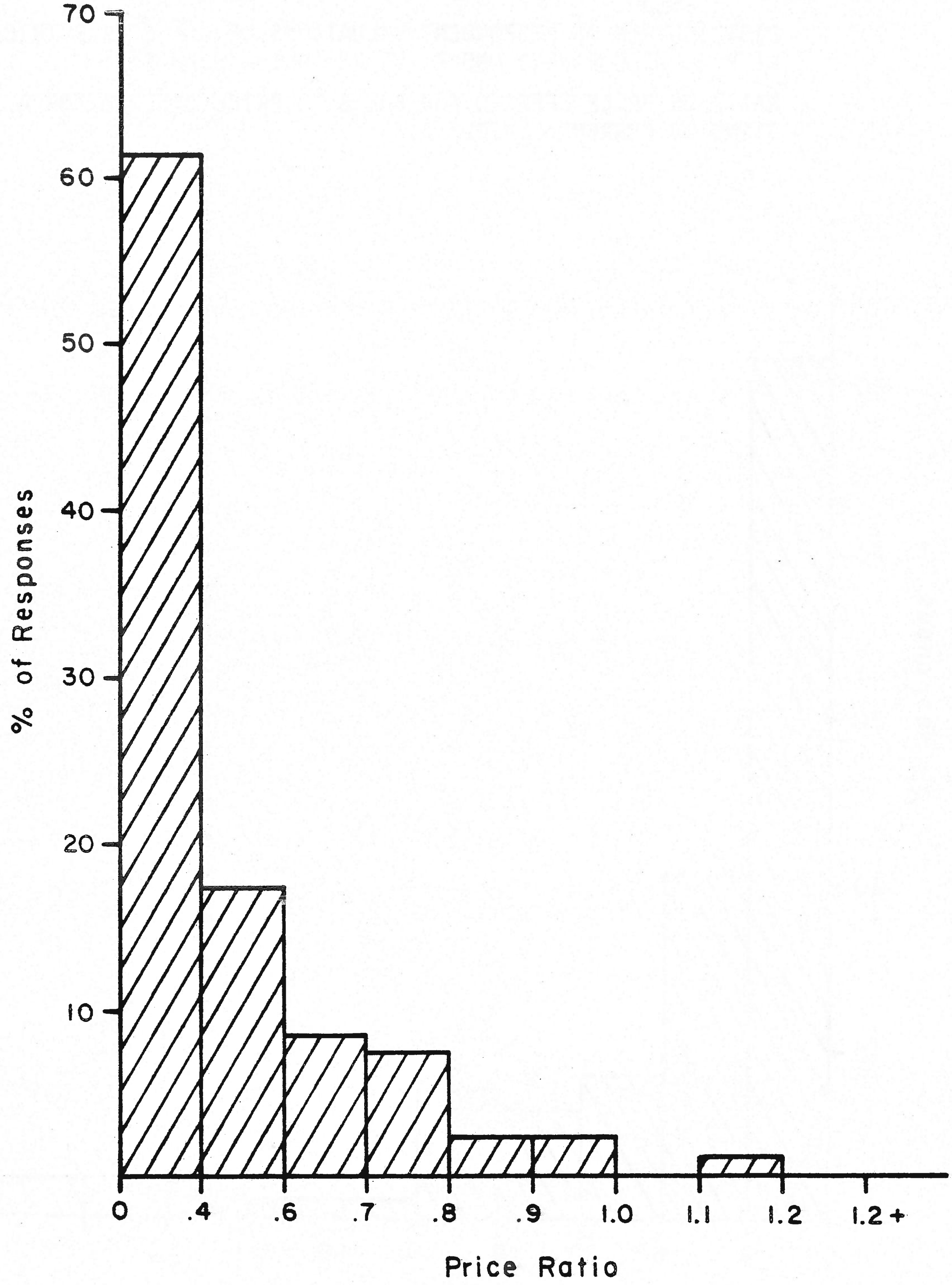


FIGURE 6.9

FIGURE 6.10

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 3 (ELECTRIC WITH 50 MILE RANGE) UNDER THE RATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 3 TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

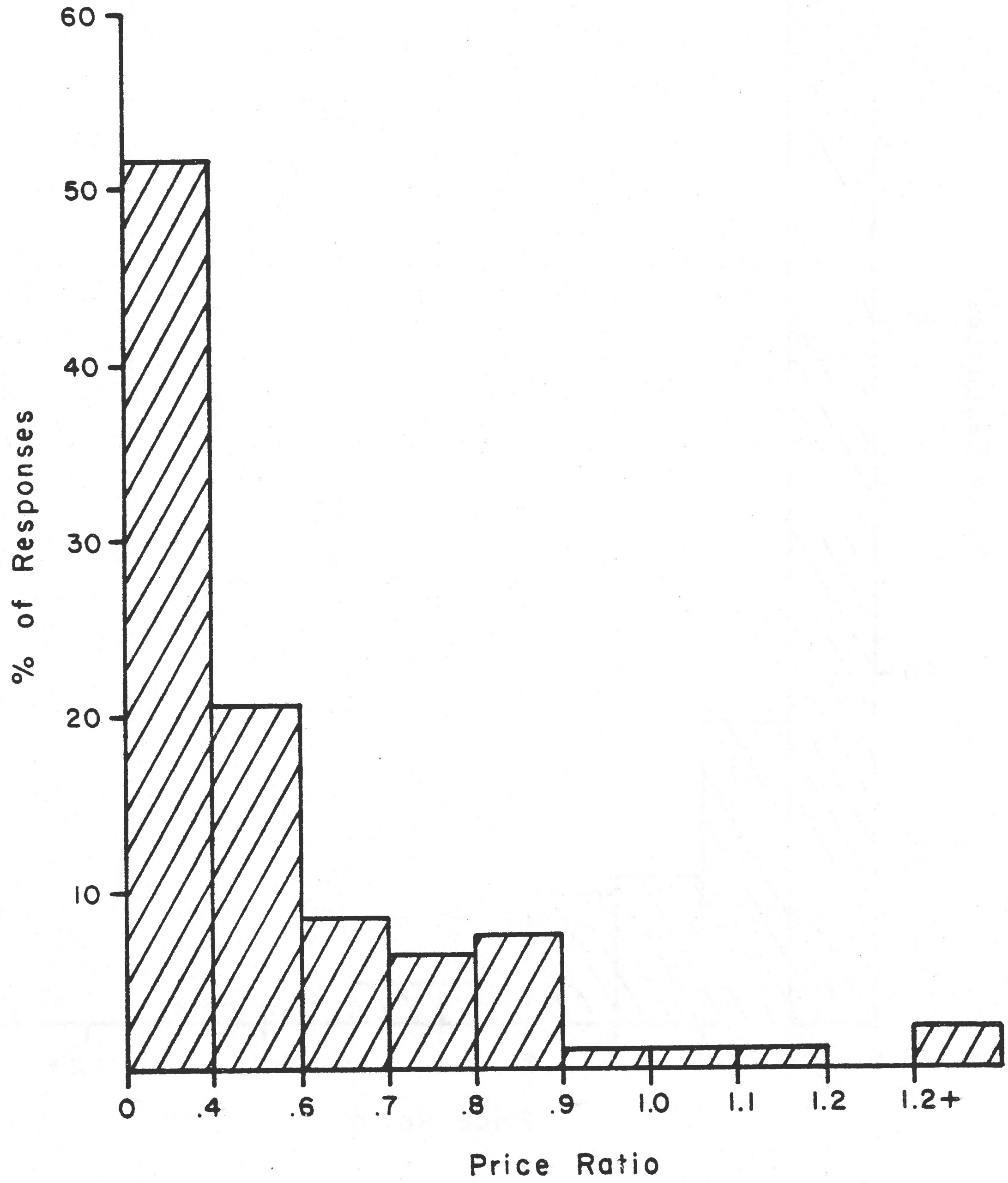


FIGURE 6.11

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 3A (ELECTRIC WITH 100 MILE RANGE) UNDER THE NONRATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 3A TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

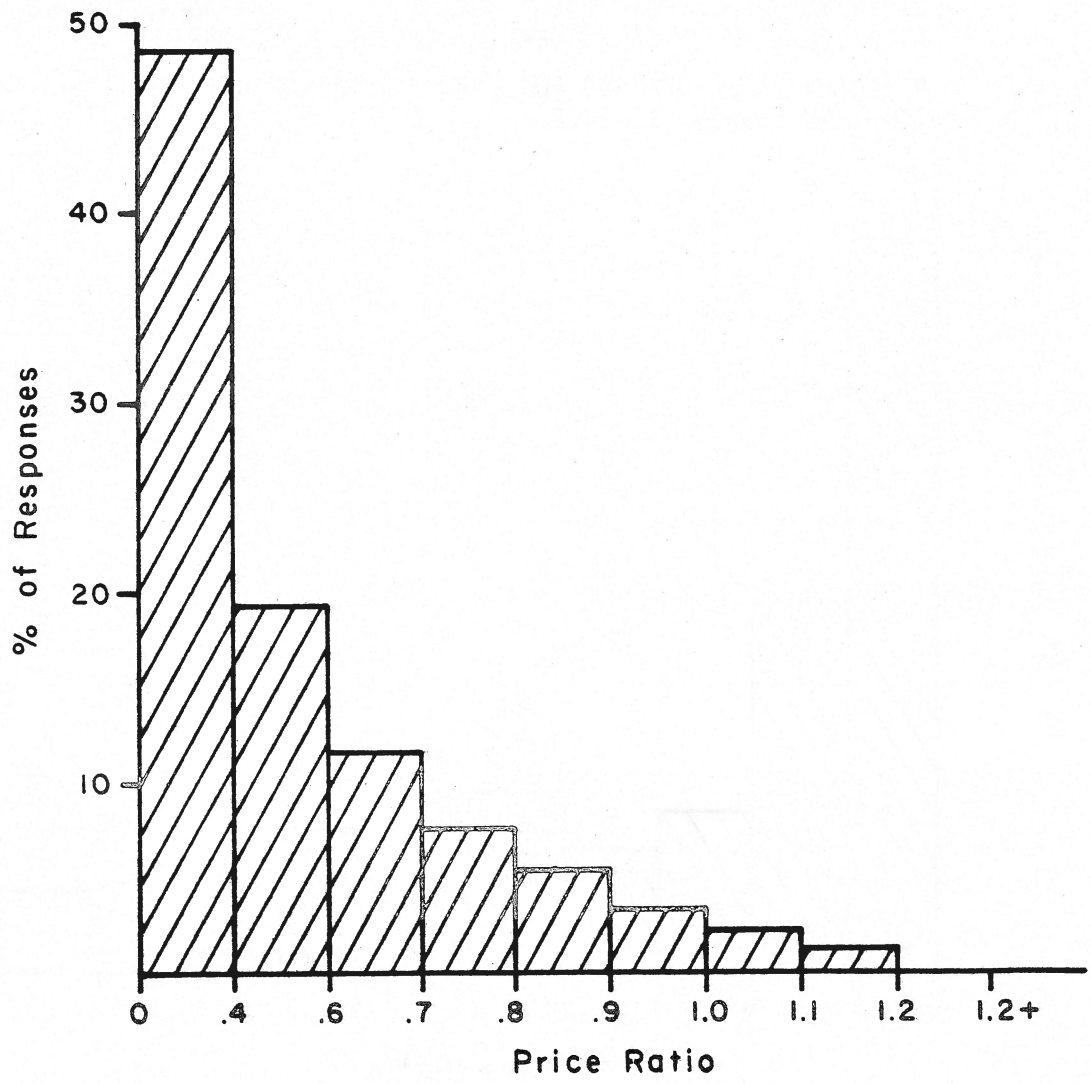


FIGURE 6.12

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 3A (ELECTRIC WITH 100 MILE RANGE) UNDER THE RATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 3A TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

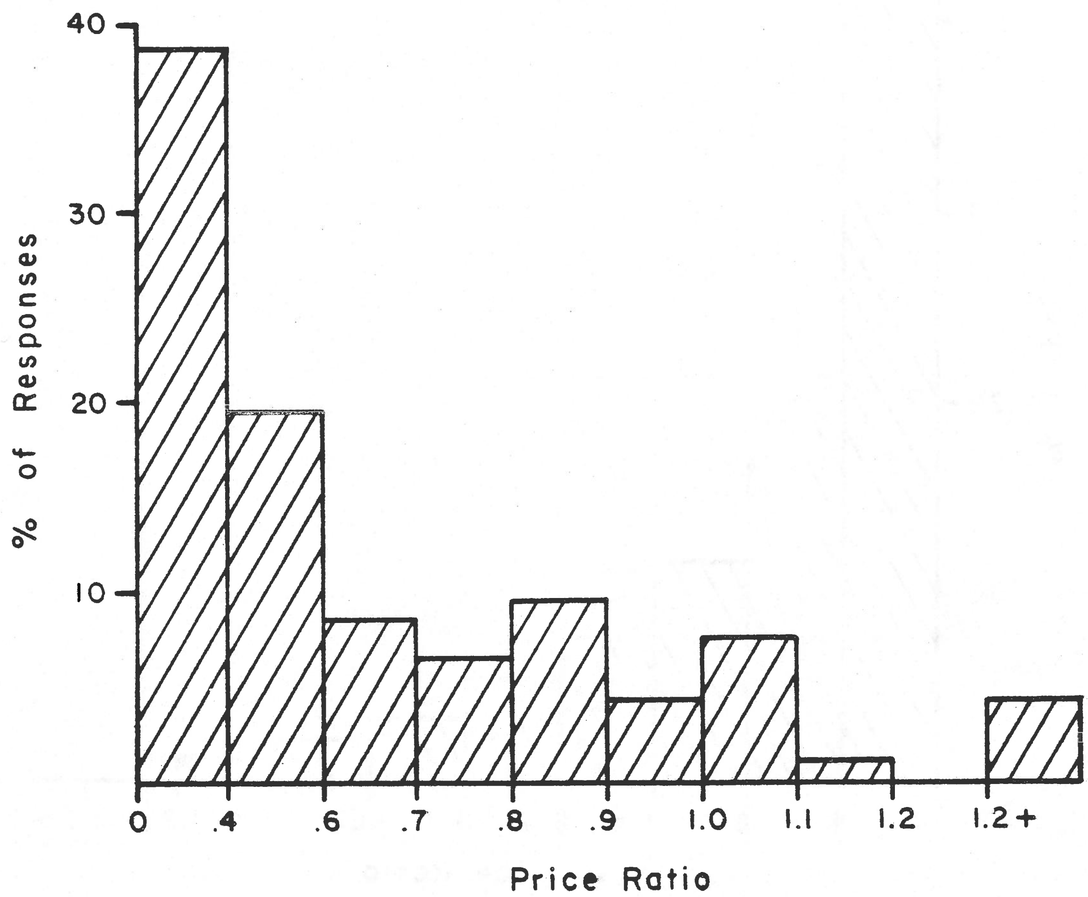


FIGURE 6.13

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 3B (ELECTRIC WITH 350 MILE RANGE) UNDER THE NONRATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 3B TO PRICE OFFERED FOR A STANDARD CURRENT CAR

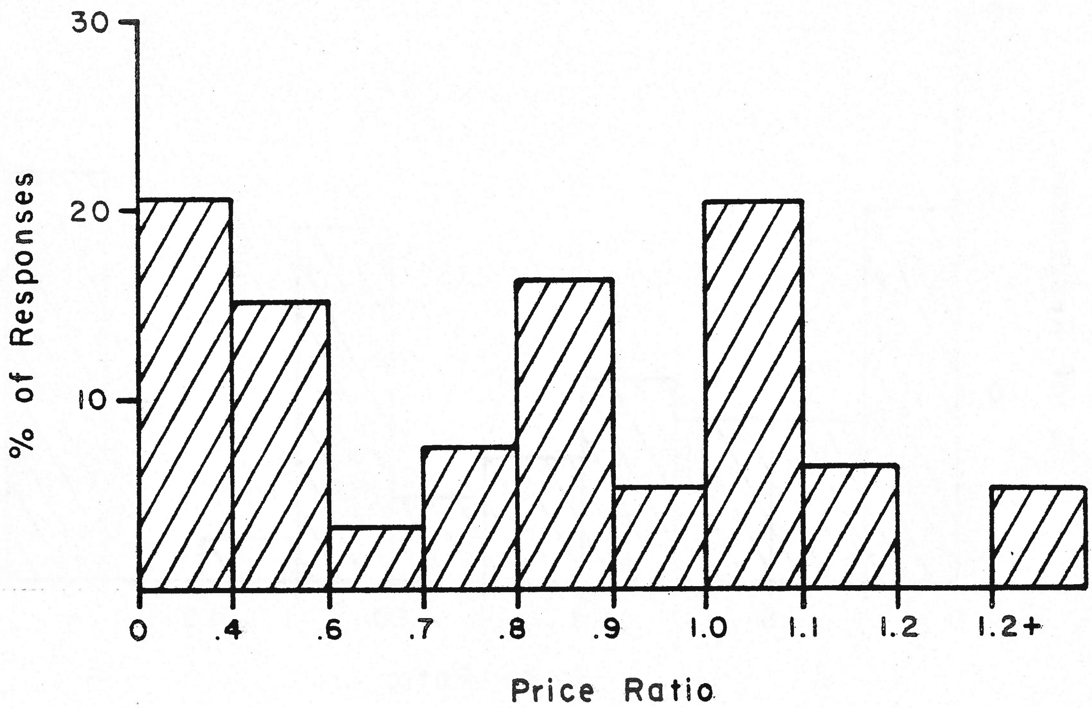
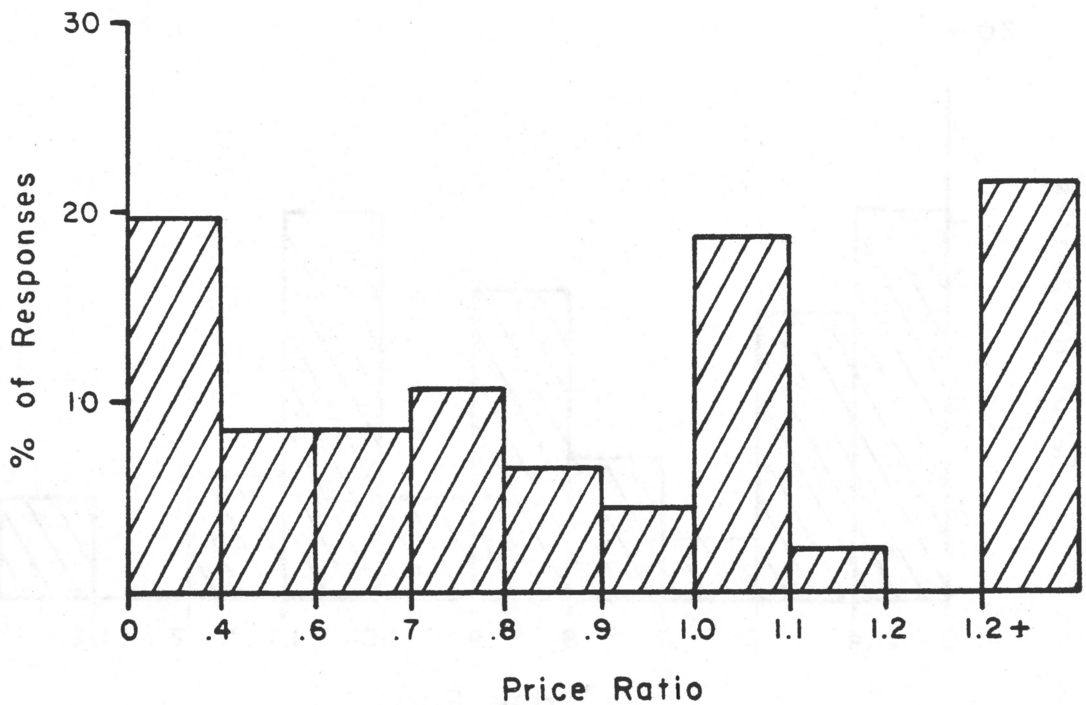


FIGURE 6.14

DISTRIBUTION OF RESPONDENT VALUATIONS OF CAR 3B (ELECTRIC WITH 350 MILE RANGE) UNDER THE RATIONING SCENARIO:

RATIO OF PRICE OFFERED FOR CAR 3B TO PRICE OFFERED FOR A STANDARD CURRENT CAR



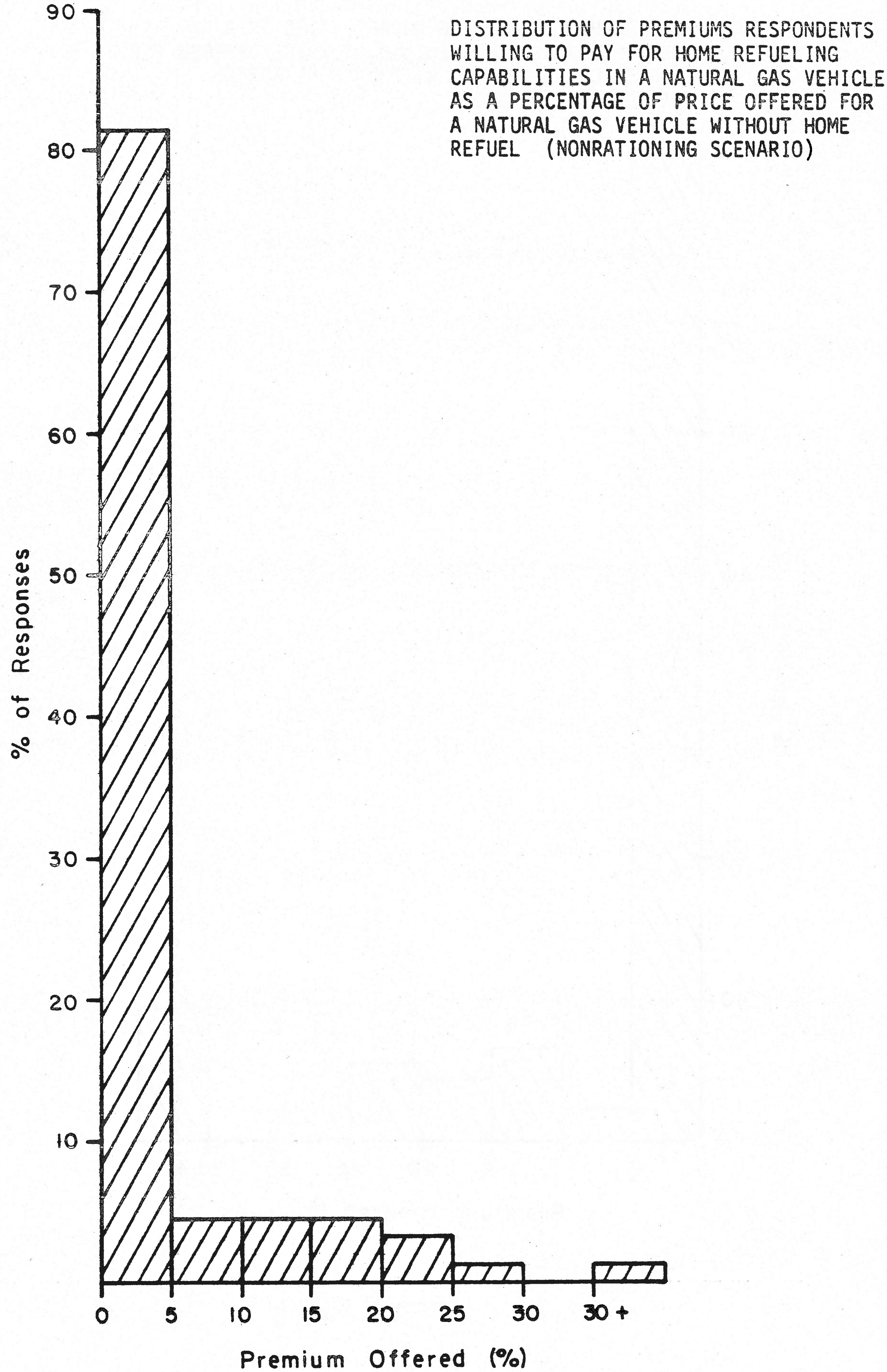

DISTRIBUTION OF PREMIUMS RESPONDENTS WILLING TO PAY FOR HOME REFUELING CAPABILITIES IN A NATURAL GAS VEHICLE AS A PERCENTAGE OF PRICE OFFERED FOR A NATURAL GAS VEHICLE WITHOUT HOME REFUEL (NONRATIONING SCENARIO)
% of Responses
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
30
30 +
Premium Offered (%)

FIGURE 6.15

DISTRIBUTION OF PREMIUMS RESPONDENTS WILLING TO PAY FOR HOME REFUELING CAPABILITIES IN A NATURAL GAS VEHICLE AS A PERCENTAGE OF PRICE OFFERED FOR A NATURAL GAS VEHICLE WITHOUT HOME REFUEL (RATIONING SCENARIO)

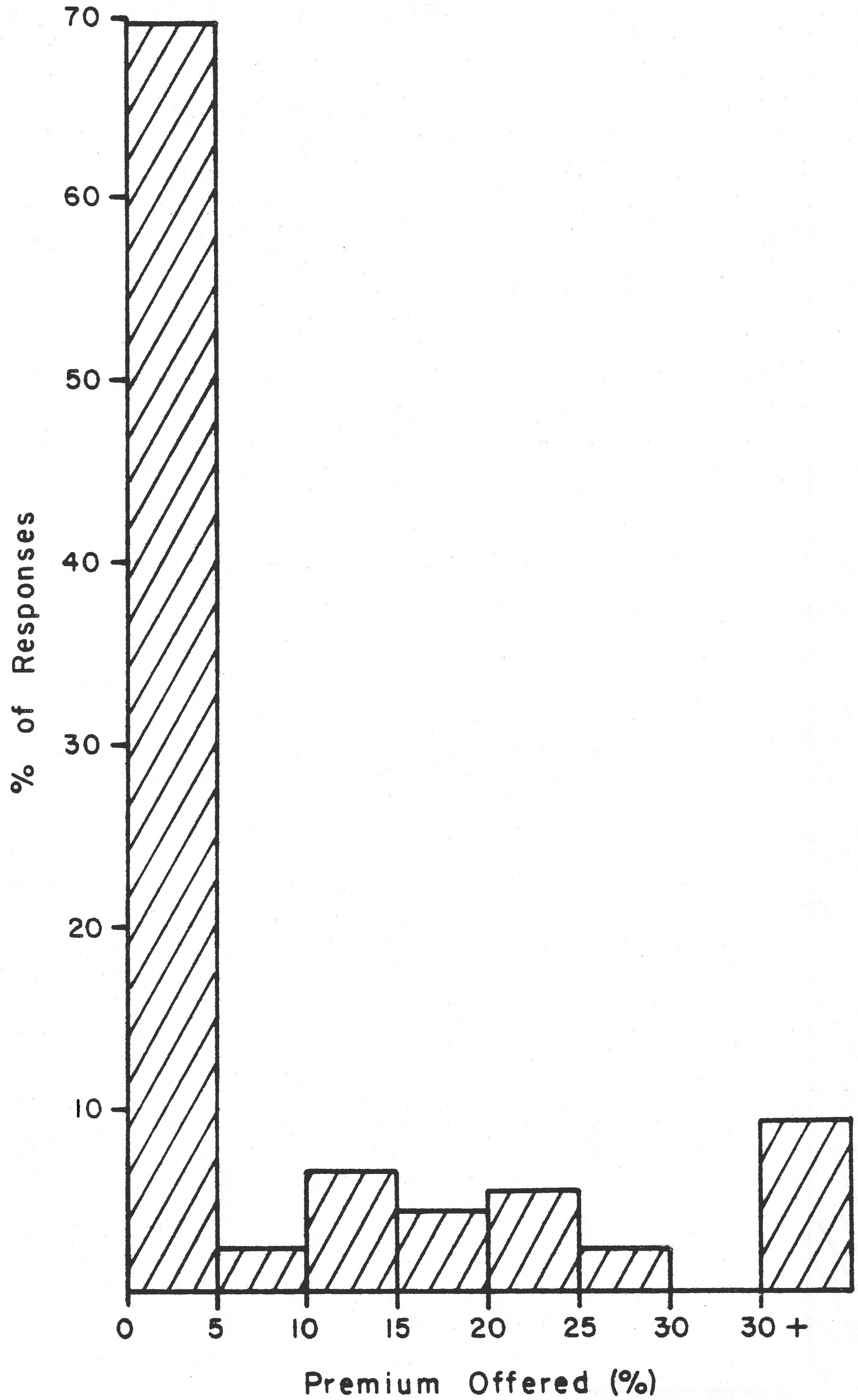


FIGURE 6.16

Figures 6.19 through 6.22 provide comparisons of respondent valuation of the electric vehicle options. Figures 6.19 and 6.20 indicate the premium that respondents would pay for an increase from 50 to 100 miles in range. The distribution of percentage premiums offered here is fairly similar to those offered for manufactured versus retrofit hybrid vehicles, with added range being valued highly by a somewhat larger proportion of respondents under the rationing scenario. The results in Figures 6.21 and 6.22 are particularly interesting. These figures indicate the percentage premium offered for an increase from 50 to 350 miles in the range of an electric vehicle. Not surprisingly over half the respondents offered a premium of 30 percent or more. However, it is interesting that over 30 percent of respondents offered a premium of less than 5 percent for this mileage increase, suggesting that this group's response to electric vehicles is based primarily upon their refueling time rather than range considerations.

A final comparison which can be made is the comparison of the standard current vehicle with an identical vehicle whose operating cost is 2 cents per mile lower. The premium which respondents offer for the reduced operating cost is assumed to be a general reflection of their valuation of operating expenses per mile relative to vehicle purchase price; so that parallel operating cost savings generated by vehicles using alternate fuel types are assumed to be equally valued by the respondent.

The mean premium offered by respondents for a 2 cent per

FIGURE 6.17

DISTRIBUTION OF PREMIUMS RESPONDENTS WILLING TO PAY FOR A MANUFACTURED DUAL FUEL HYBRID VEHICLE WITH FULL TRUNK SPACE AS A PERCENTAGE OF PRICE OFFERED FOR A RETROFIT DUAL FUEL HYBRID VEHICLE (NONRATIONING SCENARIO)

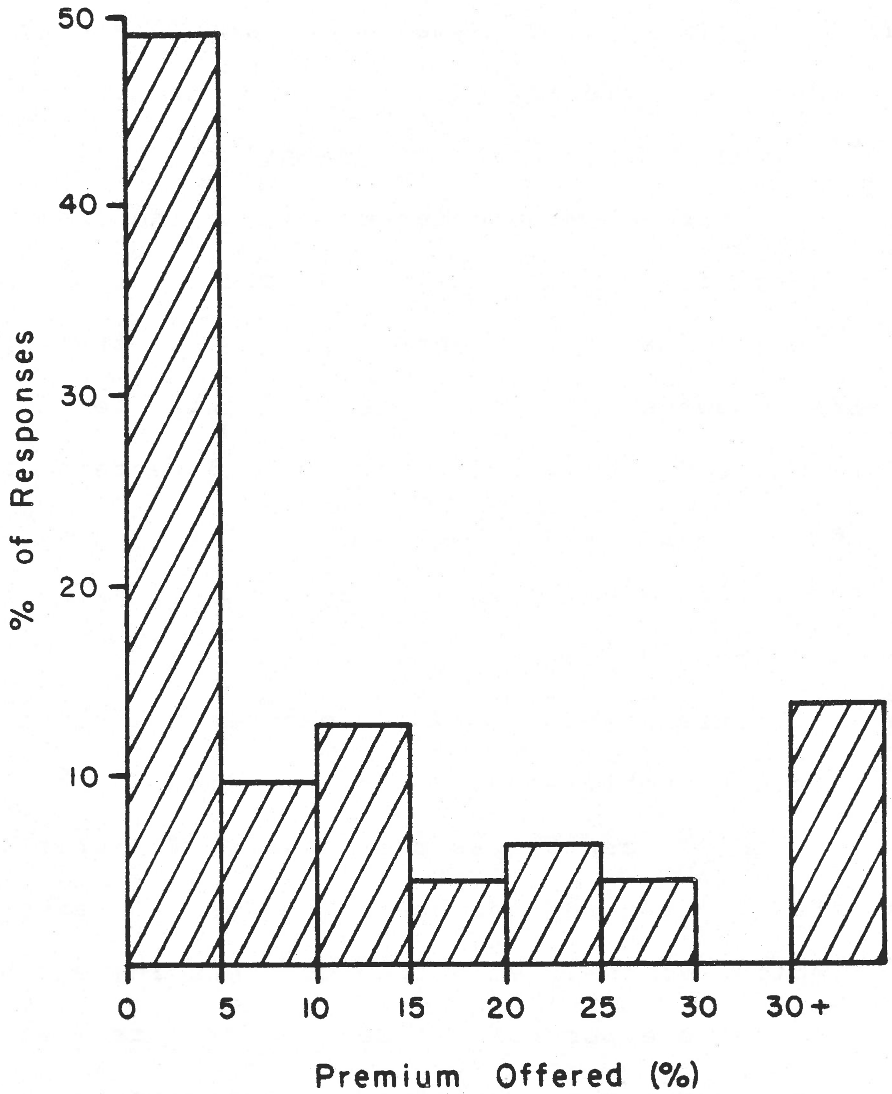


FIGURE 6.18

DISTRIBUTION OF PREMIUMS RESPONDENTS WILLING TO PAY FOR A MANUFACTURED DUAL FUEL HYBRID VEHICLE WITH FULL TRUNK SPACE AS A PERCENTAGE OF PRICE OFFERED FOR A RETROFIT DUAL FUEL HYBRID VEHICLE (RATIONING SCENARIO)

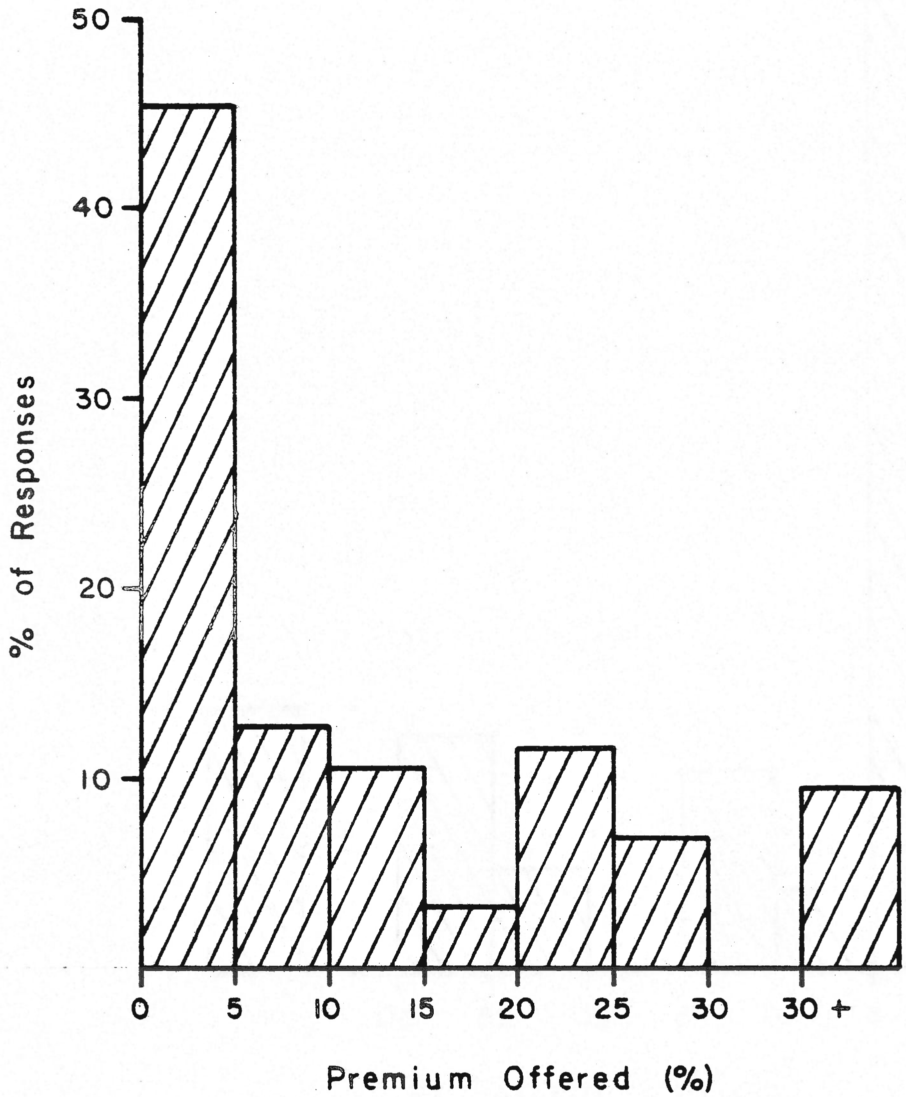


FIGURE 6.19

DISTRIBUTION OF PREMIUMS RESPONDENTS WILLING TO PAY FOR AN INCREASE IN THE RANGE OF AN ELECTRIC VEHICLE FROM 50 TO 100 MILES AS A PERCENTAGE OF THE PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 50 MILE RANGE (NONRATIONING SCENARIO)

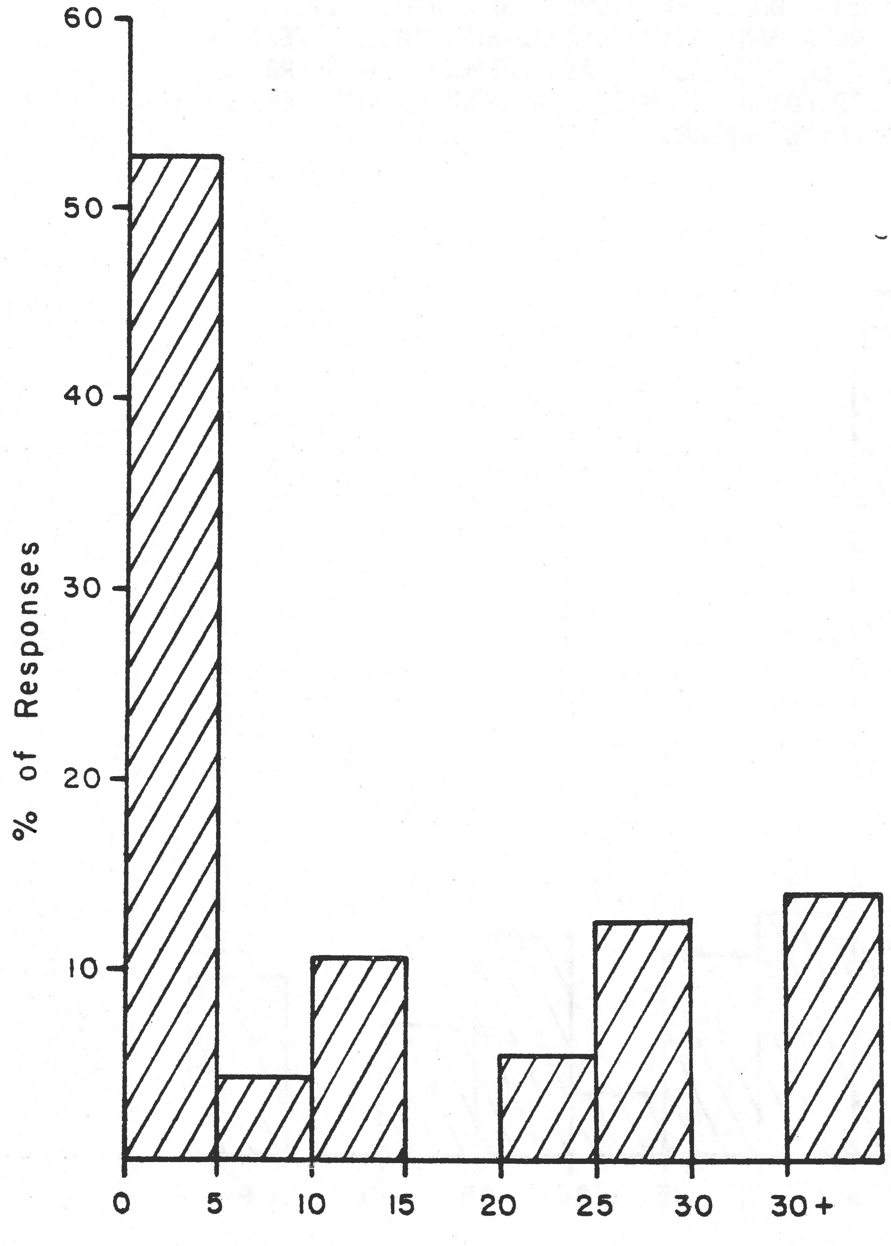


FIGURE 6.20

DISTRIBUTION OF PREMIUMS RESPONDENTS WILLING TO PAY FOR AN INCREASE IN THE RANGE OF AN ELECTRIC VEHICLE FROM 50 TO 100 MILES AS A PERCENTAGE OF THE PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 50 MILE RANGE (RATIONING SCENARIO)

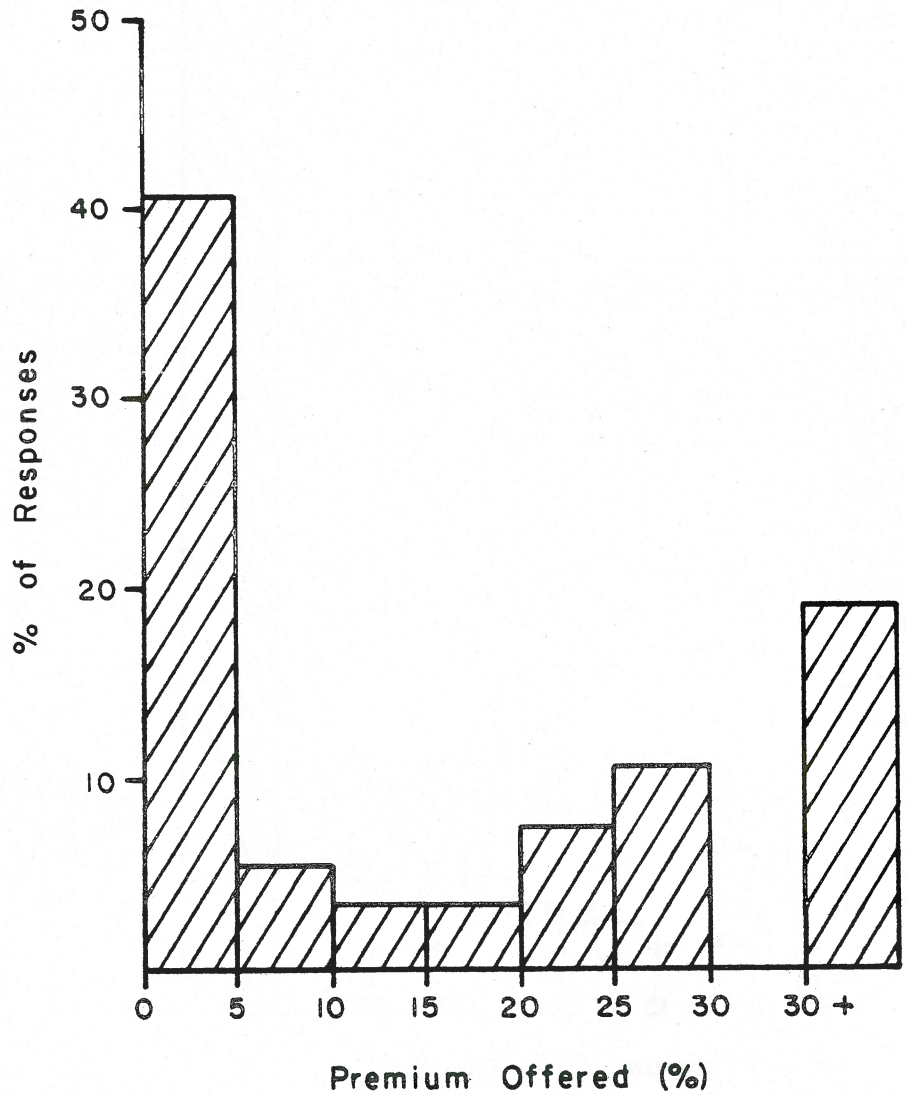
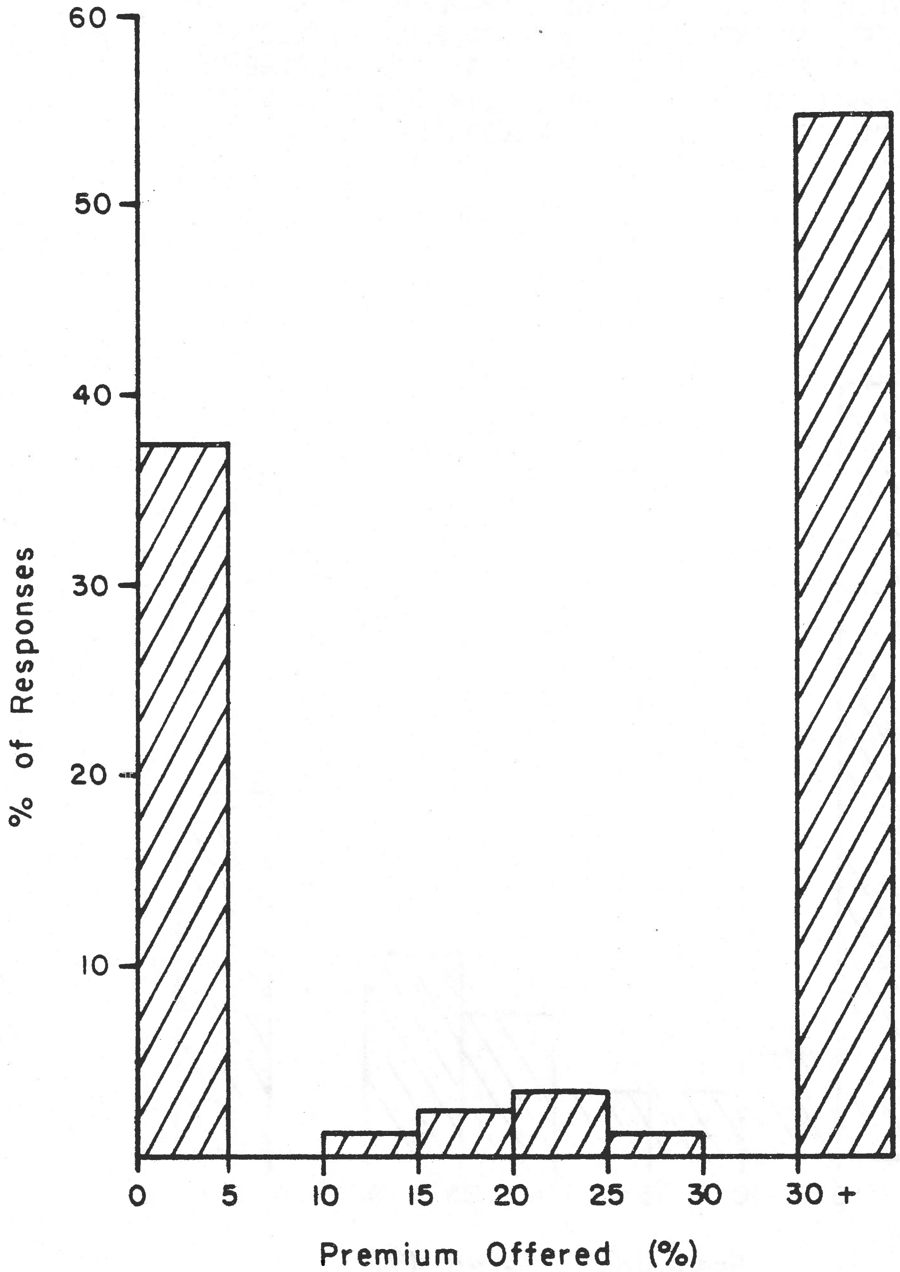


FIGURE 6.21

DISTRIBUTION OF PREMIUMS RESPONDENTS WILLING TO PAY FOR AN INCREASE IN THE RANGE OF AN ELECTRIC VEHICLE FROM 50 TO 350 MILES AS A PERCENTAGE OF THE PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 50 MILE RANGE (NONRATIONING SCENARIO)



DISTRIBUTION OF PREMIUMS RESPONDENTS WILLING TO PAY FOR AN INCREASE IN THE RANGE OF AN ELECTRIC VEHICLE FROM 50 TO 350 MILES AS A PERCENTAGE OF THE PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 50 MILE RANGE (RATIONING SCENARIO)

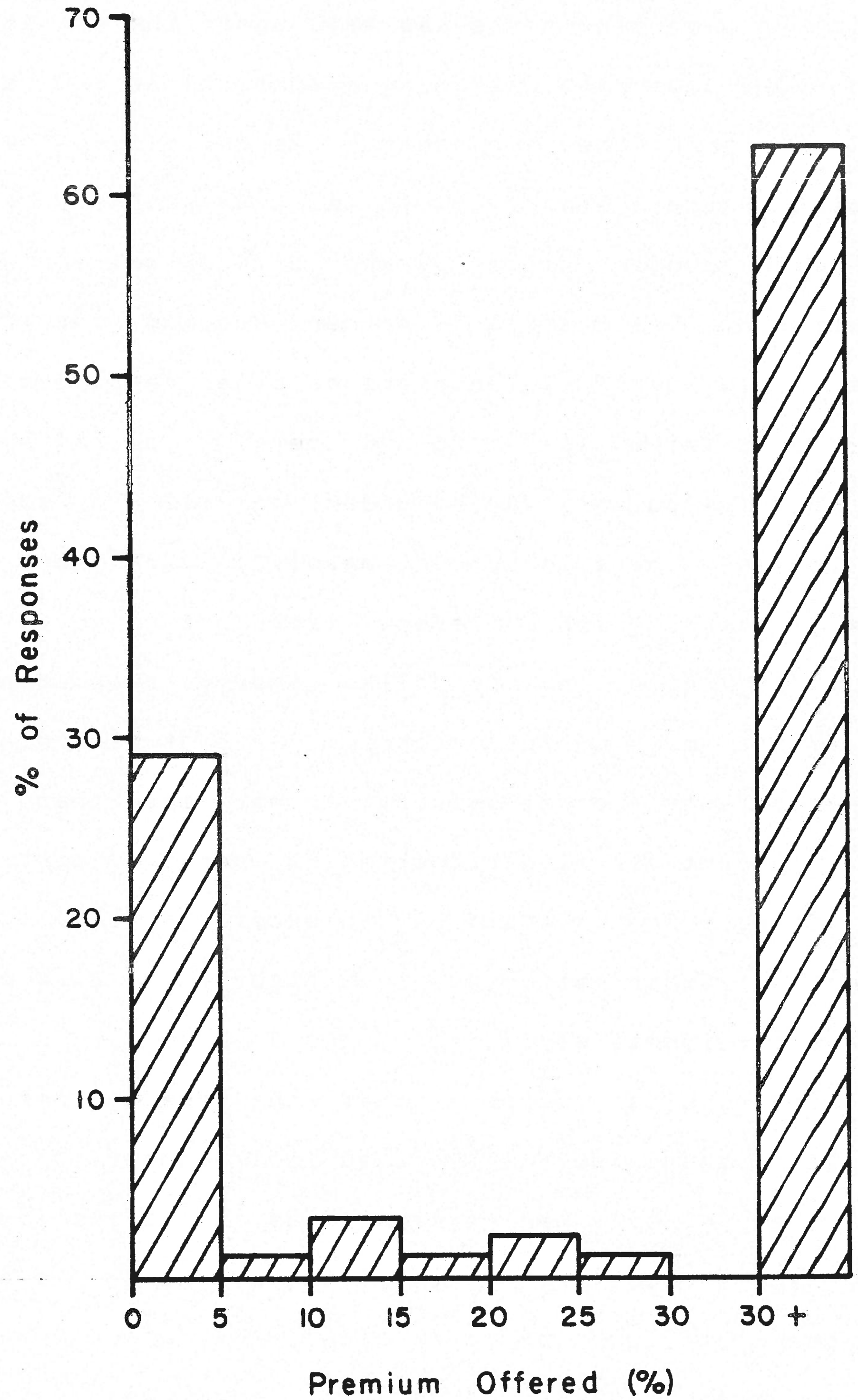


FIGURE 6.22

mile reduction in operating costs was $945 under the nonrationing scenario and $1008 under the rationing scenario. As indicated in Figures 6.23 and 6.24 the respondents' valuations of fuel cost savings varied rather sharply with a substantial proportion (almost 25 percent under rationing and over 30 percent without rationing) offering less than a 5 percent premium for the fuel cost savings, while substantial numbers of other respondents were willing to offer premiums of 20 to 30 percent or more. The responses were particularly varied under the rationing scenario. The variability shown here is not due merely to variations in the price ranges of cars which different respondents expect to buy, but reflects differences in the dollar amounts respondents are willing to pay for improved fuel economy. Without rationing 38.7 percent of respondents are not willing to pay more than a $500 premium for a 2 cent per mile reduction in operating cost, while 26.5 percent of respondents would pay in excess of $1500 for such an improvement. (Under rationing these figures are 34.4 percent and 31.4 percent respectively.)

While these results indicate that the average respondent places a significant value on improved fuel economy, this value appears relatively modest when evaluated as a rational economic decision to trade off current capital outlays in order to avoid a portion of operating cost of over the life of the vehicle. Evaluated in these terms and assuming a new vehicle will be driven 10,000 miles a year for 10 years implied discount rate of the typical respondent is 16 percent.

The Table and Figures presented in this section provide many insights into consumers reactions to various alternate vehicle options. Variability in reactions to each of the vehicles is very great which is not surprising given the low level of familiarity with the technologies and the hypothetical nature of the responses which were elicited. However, it is clear that the dual fuel hybrid vehicles allowing a range of 350 miles when using gasoline fuels were the most preferred type of alternate vehicle. Respondants in general expressed a rather strong ($1000 plus) preference for the manufactured as opposed to the retrofit version of the hybrid vehicle.

The next most preferred alternative was the natural gas (or conceivably hydrogen) vehicle. Respondents were generally willing to pay about three fourths of the price of a standard current car for this type of vehicle without rationing and 80 to 90 percent of the price of a standard current vehicle under rationing. Most respondents were not very interested in the option of acquiring home refueling capabilities for a natural gas vehicle.

Consumer reactions to limited range (50 and 100 mile) electric vehicles were quite negative. Consumer valuation of the electric vehicle with 350 mile range was roughly comparable to that of the natural gas vehicle. Thus it appears that electric vehicles are not good candidates to compete for a significant share of the vehicle market without further major advances in battery technology.

FIGURE 6.23

DISTRIBUTION OF PREMIUMS RESPONDENTS WILLING TO PAY FOR A TWO CENT PER MILE REDUCTION IN VEHICLE OPERATING COSTS AS A PERCENTAGE OF PRICE OFFERED FOR A STANDARD CURRENT VEHICLE (NONRATIONING SCENARIO)

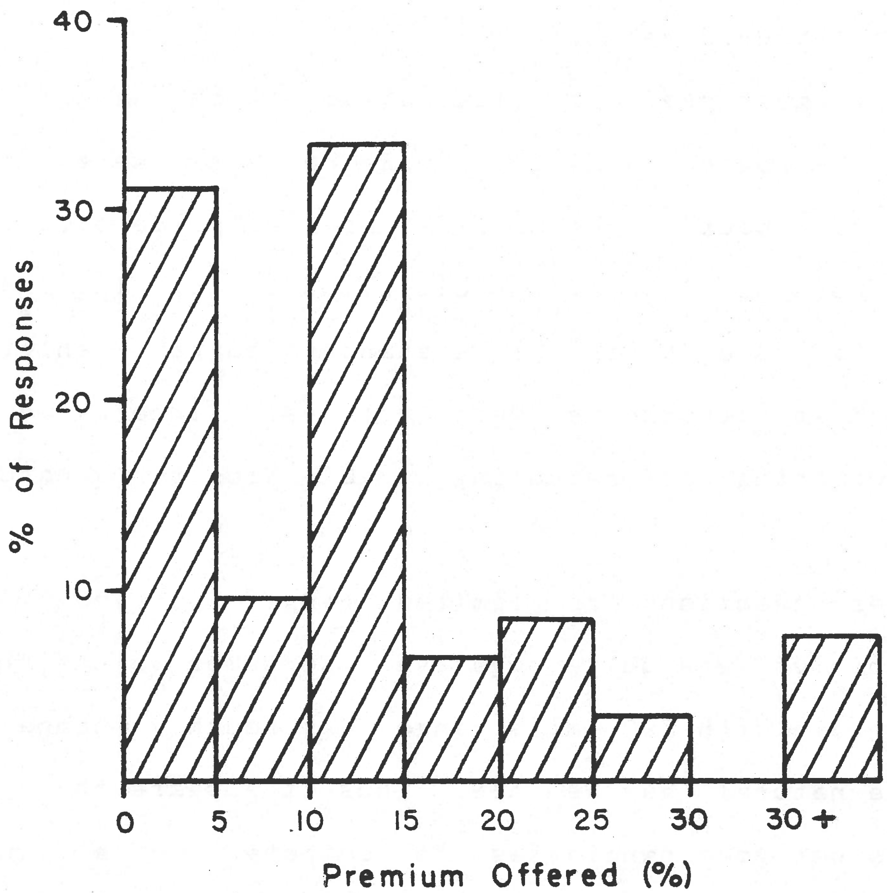
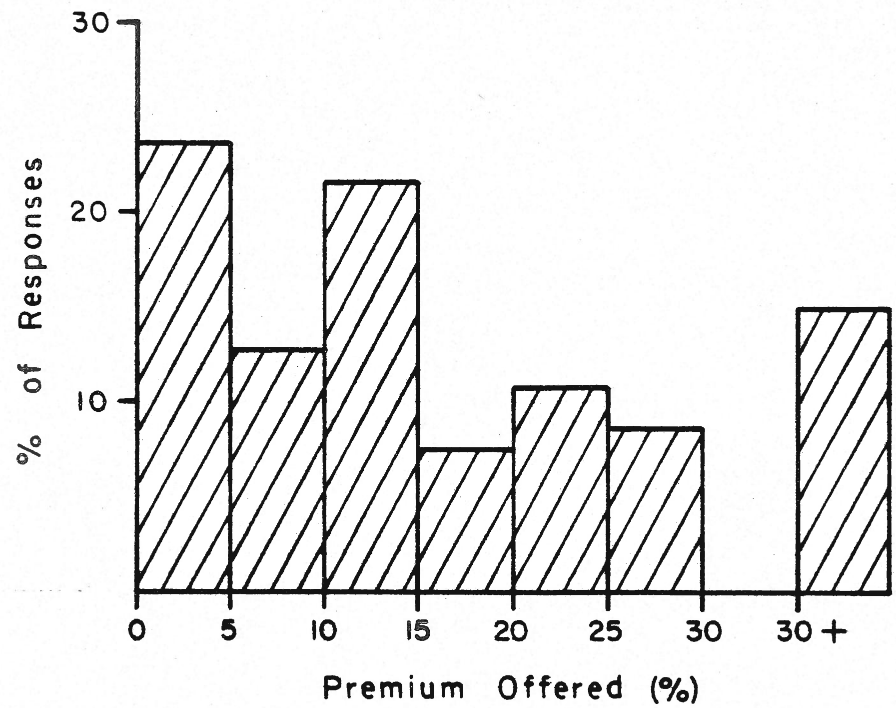


FIGURE 6.24

DISTRIBUTION OF PREMIUMS RESPONDENTS WILLING TO PAY FOR A TWO CENT PER MILE REDUCTION IN VEHICLE OPERATING EXPENSES AS A PERCENTAGE OF PRICE OFFERED FOR A STANDARD CURRENT VEHICLE (RATIONING SCENARIO)



Finally, consumers valuations of improved fuel economy are highly varied. Overall the average premium of about $1000 for a 2 cent per mile saving is substantial, but somewhat modest when viewed as an economic tradeoff between current and future spending.

6.4 ANALYSIS OF VARIANCE RESULTS

Analysis of variance (ANOVA) results relating respondent's relative valuations of each alternate vehicle to a variety of demographic variables are presented below. The ability to explain variations in responses to alternate vehicles is not a central focus of this study. However, to the extent that demographic characteristics such as income and education level systematically affect responses to alternate vehicles it is important that these affects be captured.

Information from survey response forms allows the effects of income, age, education level, number of vehicles, and place of residence on responses to the alternate vehicles to be evaluated. In addition, the effects of rationing on valuations of alternate vehicles can be assessed using ANOVA runs pooled across the rationing and nonrationing scenarios. According to the innovation theory discussed earlier more highly educated and higher income individuals would be expected to respond more favorably than others to a new innovation. On the other hand, the alternate vehicles generally require that the driver make some sacrifice in the convenience of vehicle operation such as more frequent and/or more time consuming refueling. This refueling convenience feature is something of a luxury item which higher income individuals would be less willing to give up. Thus it is not clear what impact income level should be expected to have on responses to alternate vehicles. Similarly, there is no clear hypothesis with regard to the relationship between age and the response to alternate vehicles. Owners of a larger number of vehicles might be expected to respond more favorably than others to alternative vehicles because they have the capability to use an alternate vehicle for commuting while retaining at least one gasoline vehicle for weekend and vacation trips where the limited range of alternate vehicles are a particular disadvantage. Finally, residents of nonmetropolitan areas might be expected to respond less favorably to most alternate vehicles than residents of the state's two metropolitan areas, since range is likely to be a more crucial vehicle feature for residents of rural areas. This limitation would not apply to the hybrid vehicle type, however.

In the analysis presented here the depend variable for each ANOVA is the price offered for an alternate vehicle relative to the price offered for a standard current vehicle. This relative valuation of alternate vehicles is expressed in terms of the ratio of the price offered for an alternate vehicle to that offered for a standard current vehicle. Results are presented for each of the seven alternate vehicle variants for the rationing and nonrationing scenario, as well as, for a pooled run combining the rationing and nonrationing scenario data.

Analysis of variance results are presented in Tables 6.9 through 6.29. For each run the grand mean of the dependent variable (the ratio of the price offered for a particular alternate vehicle relative to that offered for a standard current vehicle) is listed. Also provided is the multiple R square statistic which provides a measure of the percentage of the variance in the dependent variable which is explained by variations in independent variable characteristics. For each of the independent variables the conditional mean of the dependent variable, given that the independent variable is at the level indicated, is listed. For instance, in Table 6.9, the .94 listed for age under 20 indicates that the typical respondent under age 20 offered 94 percent as much for the natural gas vehicle as for a standard current vehicle, assuming the individual is average with respect to all of the other independent variables. In addition to the conditional means, the results of an F-test of the null hypothesis that the independent variable has no effect on the dependent variable are presented for each independent variable. We are entitled to infer that a given independent variable has an effect on the dependent variable only if the null hypothesis can be rejected at the .05 level, that is, if the value listed for significance of F is .05 or lower. Since the sample used was not controlled for independent variable category levels, the number of observations for some independent variable categories is quite small which makes the conditional means for those categories unreliable. Where a conditional mean is based on 10 or fewer observations an asterisk is placed beside the category name to indicate that the observed mean may be unreliable. Exact counts on the number of observations in each independent variable category were presented in Section 6.2 above.

TABLE 6.9

ANALYSIS OF VARIANCE RESULTS (NONRATIONING SCENARIO) FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR A NATURAL GAS/HYDROGEN VEHICLE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.72	Multiple R Squared	0.24

Conditional Means for the Variable Levels Shown

Age		Income	
Under 20*	0.94	Under $15000	1.01
20 - 34	0.66	$15000-$20000	0.92
35 - 49	0.72	$20000-$30000	0.88
50 - 64	0.68	$30000-$50000	0.71
Over 65	0.74	Over $50000	0.56
		No Response*	0.77
Signif. of F	0.56	Signif. of F	0.10

Education Level		# of Vehicles Owned	
High School*	0.68	1	0.58
Some College	0.73	2	0.76
College Degree	0.65	3	0.85
Masters Degree or Above	0.82	4*	0.93
Signif. of F	0.35	Signif. of F	0.05

City of Residence	
Phoenix	0.78
Tucson	0.67
Other	0.52
Signif. of F	0.23

*Indicates Result based on less than 10 cases.

TABLE 6.10

ANALYSIS OF VARIANCE RESULTS (NONRATIONING SCENARIO) FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR A NAT.GAS VEHICLE WITH HOME REFUELING TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.74	Multiple R Squared	0.26

Conditional Means for the Variable Levels Shown

Age		**Income**	
Under 20*	0.91	Under $15000	1.05
20 - 34	0.68	$15000-$20000	1.00
35 - 49	0.75	$20000-$30000	0.93
50 - 64	0.71	$30000-$50000	0.72
Over 65	0.76	Over $50000	0.56
		No Response*	0.80
Signif. of F	0.76	Signif. of F	0.05
Education Level		**# of Vehicles Owned**	
High School*	0.67	1	0.58
Some College	0.76	2	0.79
College Degree	0.65	3	0.88
Masters Degree or Above	0.86	4*	0.93
Signif. of F	0.19	Signif. of F	0.04
City of Residence			
Phoenix	0.79		
Tucson	0.66		
Other	0.59		
Signif. of F	0.29		

*Indicates Result based on less than 10 cases.

TABLE 6.11

ANALYSIS OF VARIANCE RESULTS (NONRATIONING SCENARIO) FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR A RETROFIT HYBRID VEHICLE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.87	Multiple R Squared	0.22

Conditional Means for the Variable Levels Shown

Age		**Income**	
Under 20*	0.85	Under $15000	0.61
20 - 34	0.99	$15000-$20000	0.93
35 - 49	0.80	$20000-$30000	0.97
50 - 64	0.85	$30000-$50000	0.93
Over 65	0.91	Over $50000	0.86
		No Response*	1.06
Signif. of F	0.60	Signif. of F	0.30
Education Level		**# of Vehicles Owned**	
High School*	0.99	1	0.83
Some College	0.89	2	0.89
College Degree	0.80	3	0.87
Masters Degree or Above	0.94	4*	0.96
Signif. of F	0.46	Signif. of F	0.86
City of Residence			
Phoenix	0.86		
Tucson	0.68		
Other	1.17		
Signif. of F	0.05		

*Indicates Result based on less than 10 cases.

TABLE 6.12

ANALYSIS OF VARIANCE RESULTS (NONRATIONING SCENARIO)
FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR A MANUFACTURED HYBRID VEHICLE
TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.97	Multiple R Squared	0.24

Conditional Means for the Variable Levels Shown

Age		Income	
Under 20*	1.10	Under $15000	0.79
20 - 34	1.08	$15000-$20000	1.05
35 - 49	0.90	$20000-$30000	1.03
50 - 64	0.90	$30000-$50000	0.97
Over 65	1.01	Over $50000	0.98
		No Response*	1.07
Signif. of F	0.50	Signif. of F	0.65

Education Level		# of Vehicles Owned	
High School*	1.15	1	0.92
Some College	0.96	2	0.97
College Degree	0.91	3	1.04
Masters Degree or Above	1.07	4*	1.09
Signif. of F	0.21	Signif. of F	0.56

City of Residence	
Phoenix	0.97
Tucson	0.83
Other	1.16
Signif. of F	0.16

*Indicates Result based on less than 10 cases.

TABLE 6.13

ANALYSIS OF VARIANCE RESULTS (NONRATIONING SCENARIO)
FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 50 MILE RANGE
TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.31	Multiple R Squared	0.17

Conditional Means for the Variable Levels Shown

Age		Income	
Under 20*	0.27	Under $15000	0.42
20 - 34	0.22	$15000-$20000	0.57
35 - 49	0.34	$20000-$30000	0.33
50 - 64	0.38	$30000-$50000	0.28
Over 65	0.28	Over $50000	0.25
		No Response*	0.30
Signif. of F	0.76	Signif. of F	0.62

Education Level		# of Vehicles Owned	
High School*	0.55	1	0.26
Some College	0.31	2	0.32
College Degree	0.23	3	0.39
Masters Degree or Above	0.40	4*	0.28
Signif. of F	0.18	Signif. of F	0.72

City of Residence	
Phoenix	0.36
Tucson	0.18
Other	0.24
Signif. of F	0.13

*Indicates Result based on less than 10 cases.

TABLE 6.14

ANALYSIS OF VARIANCE RESULTS (NONRATIONING SCENARIO) FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 100 MILE RANGE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean 0.41

Multiple R Squared 0.21

Conditional Means for the Variable Levels Shown

Age	
Under 20*	0.40
20 - 34	0.30
35 - 49	0.46
50 - 64	0.49
Over 65	0.35
Signif. of F	0.47

Income	
Under $15000	0.58
$15000-$20000	0.69
$20000-$30000	0.45
$30000-$50000	0.36
Over $50000	0.31
No Response*	0.56
Signif. of F	0.27

Education Level	
High School*	0.76
Some College	0.39
College Degree	0.33
Masters Degree or Above	0.53
Signif. of F	0.05

# of Vehicles Owned	
1	0.35
2	0.44
3	0.52
4*	0.32
Signif. of F	0.43

City of Residence	
Phoenix	0.46
Tucson	0.31
Other	0.31
Signif. of F	0.20

*Indicates Result based on less than 10 cases.

TABLE 6.15

ANALYSIS OF VARIANCE RESULTS (NONRATIONING SCENARIO)
FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 350 MILE RANGE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.72	Multiple R Squared	0.34

Conditional Means for the Variable Levels Shown

Age		**Income**	
Under 20*	1.12	Under $15000	0.94
20 - 34	0.50	$15000-$20000	0.98
35 - 49	0.74	$20000-$30000	1.03
50 - 64	0.76	$30000-$50000	0.65
Over 65	0.73	Over $50000	0.53
		No Response*	0.96
Signif. of F	0.05	Signif. of F	0.02
Education Level		**# of Vehicles Owned**	
High School*	1.01	1	0.56
Some College	0.80	2	0.79
College Degree	0.56	3	0.81
Masters Degree or Above	0.80	4*	0.94
Signif. of F	0.07	Signif. of F	0.10
City of Residence			
Phoenix	0.79		
Tucson	0.74		
Other	0.37		
Signif. of F	0.19		

*Indicates Result based on less than 10 cases.

TABLE 6.16

ANALYSIS OF VARIANCE RESULTS (RATIONING SCENARIO) FOR THE DEPENDENT VARIABLE

RATIO OF PRICE OFFERED FOR A NATURAL GAS/HYDROGEN VAHICLE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.82	Multiple R Squared	0.21

Conditional Means for the Variable Levels Shown

Age		Income	
Under 20*	0.93	Under $15000*	0.83
20 - 34	0.76	$15000-$20000	1.04
35 - 49	0.84	$20000-$30000	0.94
50 - 64	0.85	$30000-$50000	0.70
Over 65*	0.97	Over $50000	0.79
Signif. of F	0.74	Signif. of F	0.11

Education Level		# of Vehicles Owned	
High School*	1.09	1	0.95
Some College	0.79	2	0.80
College Degree	0.86	3	0.68
Masters Degree		4*	0.83
or Above	0.84		0.82
Signif. of F	0.83	Signif. of F	0.19

City of Residence	
Phoenix	0.83
Tucson	0.84
Other	0.72
Signif. of F	0.65

*Indicates Result based on less than 10 cases.

TABLE 6.17

ANALYSIS OF VARIANCE RESULTS (RATIONING SCENARIO)
FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR A NAT. GAS VEHICLE WITH HOME REFUELING
TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.90	Multiple R Squared	0.18

Conditional Means for the Variable Levels Shown

Age		Income	
Under 20*	0.97	Under $15000*	1.07
20 - 34	0.83	$15000-$20000	1.12
35 - 49	0.89	$20000-$30000	0.96
50 - 64	1.05	$30000-$50000	0.82
Over 65*	1.04	Over $50000	0.85
Signif. of F	0.60	Signif. of F	0.41

Education Level		# of Vehicles Owned	
High School*	0.95	1	1.04
Some College	0.92	2	0.89
College Degree	0.91	3	0.76
Masters Degree or Above	0.85	4*	0.79
			0.90
Signif. of F	0.93	Signif. of F	0.29

City of Residence	
Phoenix	0.88
Tucson	0.99
Other	0.90
Signif. of F	0.67

*Indicates Result based on less than 10 cases.

TABLE 6.18

ANALYSIS OF VARIANCE FESULTS (RATIONING SCENARIO)
FOR THE DEPENDENT VARIABLE

RATIO OF PRICE OFFERED FOR A RETROFIT HYBRID VEHICLE
TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.97	Multiple R Squared	0.26

Conditional Means for the Variable Levels Shown

Age		**Income**	
Under 20*	1.14	Under $15000*	1.20
20 - 34	1.04	$15000-$20000	1.22
35 - 49	0.84	$20000-$30000	1.11
50 - 64	1.14	$30000-$50000	0.86
Over 65*	0.91	Over $50000	0.86
Signif. of F	0.41	Signif. of F	0.35
Education Level		**# of Vehicles Owned**	
High School*	1.23	1	1.05
Some College	0.85	2	0.87
College Degree	0.97	3	1.14
Masters Degree or Above	1.19	4*	0.94
			0.97
Signif. of F	0.20	Signif. of F	0.35
City of Residence			
Phoenix	0.97		
Tucson	1.16		
Other	0.69		
Signif. of F	0.11		

*Indicates Result based on less than 10 cases.

TABLE 6.19

ANALYSIS OF VARIANCE RESULTS (RATIONING SCENARIO) FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR A MANUFACTURED HYBRID VEHICLE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	1.10	Multiple R Squared	0.23

Conditional Means for the Variable Levels Shown

Age	
Under 20*	1.30
20 - 34	1.22
35 - 49	0.93
50 - 64	1.28
Over 65*	0.98
Signif. of F	0.25

Income	
Under $15000*	1.33
$15000-$20000	1.36
$20000-$30000	1.25
$30000-$50000	0.98
Over $50000	0.99
Signif. of F	0.38

Education Level	
High School*	1.21
Some College	0.99
College Degree	1.06
Masters Degree or Above	1.35
Signif. of F	0.22

# of Vehicles Owned	
1	1.14
2	1.05
3	1.18
4*	1.13
	1.10
Signif. of F	0.88

City of Residence	
Phoenix	1.09
Tucson	1.28
Other	0.93
Signif. of F	0.32

*Indicates Result based on less than 10 cases.

TABLE 6.20

ANALYSIS OF VARIANCE RESULTS (RATIONING SCENARIO) FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 50 MILE RANGE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.38	Multiple R Squared	0.26

Conditional Means for the Variable Levels Shown

Age		Income	
Under 20*	0.57	Under $15000*	0.26
20 - 34	0.27	$15000-$20000	0.33
35 - 49	0.43	$20000-$30000	0.52
50 - 64	0.34	$30000-$50000	0.31
Over 65*	0.66	Over $50000	0.38
Signif. of F	0.22	Signif. of F	0.40

Education Level		# of Vehicles Owned	
High School*	0.87	1	0.54
Some College	0.24	2	0.29
College Degree	0.50	3	0.39
Masters Degree		4*	0.45
or Above	0.52		0.38
Signif. of F	0.05	Signif. of F	0.19

City of Residence	
Phoenix	0.40
Tucson	0.36
Other	0.27
Signif. of F	0.65

*Indicates Result based on less than 10 cases.

TABLE 6.21

ANALYSIS OF VARIANCE RESULTS (RATIONING SCENARIO)
FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 100 MILE RANGE
TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.53	Multiple R Squared	0.23

Conditional Means for the Variable Levels Shown

Age		**Income**	
Under 20*	0.70	Under $15000*	0.24
20 - 34	0.49	$15000-$20000	0.65
35 - 49	0.53	$20000-$30000	0.70
50 - 64	0.48	$30000-$50000	0.46
Over 65*	0.79	Over $50000	0.48
Signif. of F	0.73	Signif. of F	0.22
Education Level		**# of Vehicles Owned**	
High School*	0.87	1	0.70
Some College	0.37	2	0.44
College Degree	0.62	3	0.49
Masters Degree or Above	0.74	4*	0.65
			0.53
Signif. of F	0.07	Signif. of F	0.25
City of Residence			
Phoenix	0.56		
Tucson	0.50		
Other	0.41		
Signif. of F	0.66		

*Indicates Result based on less than 10 cases.

TABLE 6.22

ANALYSIS OF VARIANCE RESULTS (RATIONING SCENARIO) FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 350 MILE RANGE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.84	Multiple R Squared	0.20

Conditional Means for the Variable Levels Shown

Age		Income	
Under 20*	0.89	Under $15000*	0.87
20 - 34	0.86	$15000-$20000	0.92
35 - 49	0.80	$20000-$30000	1.12
50 - 64	0.88	$30000-$50000	0.70
Over 65*	1.04	Over $50000	0.73
Signif. of F	0.95	Signif. of F	0.17

Education Level		# of Vehicles Owned	
High School*	1.14	1	0.95
Some College	0.65	2	0.79
College Degree	0.96	3	0.79
Masters Degree		4*	0.92
or Above	1.08		0.84
Signif. of F	0.09	Signif. of F	0.76

City of Residence	
Phoenix	0.85
Tucson	0.81
Other	0.82
Signif. of F	0.97

*Indicates Result based on less than 10 cases.

TABLE 6.23

ANALYSIS OF VARIANCE RESULTS (COMBINED SCENARIOS)
FOR THE DEPENDENT VARIABLE

RATIO OF PRICE OFFERED FOR A NATURAL GAS/HYDROGEN VEHICLE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.77	Multiple R Squared	0.16

Conditional Means for the Variable Levels Shown

Age		**Income**	
Under 20	0.93	Under $15000	0.90
20 - 34	0.74	$15000-$20000	1.00
35 - 49	0.78	$20000-$30000	0.93
50 - 64	0.74	$30000-$50000	0.71
Over 65	0.76	Over $50000	0.65
		No Response*	0.75
Signif. of F	0.51	Signif. of F	0.01
Education Level		**# of Vehicles Owned**	
High School*	0.95	1	0.75
Some College	0.74	2	0.77
College Degree	0.75	3	0.75
Masters Degree or Above	0.83	4	0.91
Signif. of F	0.43	Signif. of F	0.50
City of Residence		**Rationing Scenario**	
Phoenix	0.80	Yes	0.80
Tucson	0.74	No	0.73
Other	0.65		
Signif. of F	0.17	Signif. of F	0.20

*Indicates result based on less than 10 cases.

TABLE 6.24

ANALYSIS OF VARIANCE RESULTS (COMBINED SCENARIO) FOR THE DEPENDENT VARIABLE

RATIO OF PRICE OFFERED FOR A NAT. GAS VEHICLE WITH HOME REFUELING TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.82	Multiple R Squared	0.16

Conditional Means for the Variable Levels Shown

Age		Income	
Under 20	0.95	Under $15000	1.02
20 - 34	0.80	$15000-$20000	1.06
35 - 49	0.81	$20000-$30000	0.95
50 - 64	0.83	$30000-$50000	0.77
Over 65	0.81	Over $50000	0.69
		No Response*	0.82
Signif. of F	0.82	Signif. of F	0.02

Education Level		# of Vehicles Owned	
High School*	0.90	1	0.78
Some College	0.81	2	0.84
College Degree	0.79	3	0.80
Masters Degree or Above	0.87	4	0.93
Signif. of F	0.75	Signif. of F	0.61

City of Residence		Rationing Scenario	
Phoenix	0.84	Yes	0.88
Tucson	0.80	No	0.75
Other	0.72		
Signif. of F	0.42	Signif. of F	0.03

*Indicates result based on less than 10 cases.

TABLE 6.25

ANALYSIS OF VARIANCE RESULTS (COMBINED SCENARIO) FOR THE DEPENDENT VARIABLE

RATIO OF PRICE OFFERED FOR A RETROFIT HYBRID VEHICLE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean 0.92

Multiple R Squared 0.17

Conditional Means for the Variable Levels Shown

Age	
Under 20	1.09
20 - 34	1.04
35 - 49	0.78
50 - 64	0.95
Over 65	0.96
Signif. of F	0.06

Income	
Under $15000	1.00
$15000-$20000	1.11
$20000-$30000	1.02
$30000-$50000	0.86
Over $50000	0.84
No Response*	1.06
Signif. of F	0.30

Education Level	
High School*	1.00
Some College	0.86
College Degree	0.86
Masters Degree or Above	1.09
Signif. of F	0.04

# of Vehicles Owned	
1	0.93
2	0.88
3	1.04
4	0.91
Signif. of F	0.38

City of Residence	
Phoenix	0.94
Tucson	0.90
Other	0.81
Signif. of F	0.55

Rationing Scenario	
Yes	0.96
No	0.87
Signif. of F	0.19

*Indicates result based on less than 10 cases.

TABLE 6.26

ANALYSIS OF VARIANCE RESULTS (COMBINED SCENARIO) FOR THE DEPENDENT VARIABLE

RATIO OF PRICE OFFERED FOR A MANUFACTURED HYBRID VEHICLE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	1.03	Multiple R Squared	0.18

Conditional Means for the Variable Levels Shown

Age		Income	
Under 20	1.26	Under $15000	1.09
20 - 34	1.17	$15000-$20000	1.23
35 - 49	0.88	$20000-$30000	1.14
50 - 64	1.03	$30000-$50000	0.94
Over 65	1.05	Over $50000	0.98
		No Response*	1.10
Signif. of F	0.03	Signif. of F	0.30

Education Level		# of Vehicles Owned	
High School*	1.17	1	1.02
Some College	0.96	2	1.00
College Degree	0.97	3	1.13
Masters Degree or Above	1.22	4	1.07
Signif. of F	0.02	Signif. of F	0.59

City of Residence		Rationing Scenario	
Phoenix	1.03	Yes	1.09
Tucson	1.08	No	0.97
Other	0.95		
Signif. of F	0.65	Signif. of F	0.11

*Indicates result based on less than 10 cases.

TABLE 6.27

ANALYSIS OF VARIANCE RESULTS (COMBINED SCENARIO)
FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 50 MILE RANGE
TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.35	Multiple R Squared	0.14

Conditional Means for the Variable Levels Shown

Age		**Income**	
Under 20	0.35	Under $15000	0.35
20 - 34	0.27	$15000-$20000	0.47
35 - 49	0.39	$20000-$30000	0.43
50 - 64	0.38	$30000-$50000	0.32
Over 65	0.38	Over $50000	0.31
		No Response*	0.25
Signif. of F	0.60	Signif. of F	0.49
Education Level		**# of Vehicles Owned**	
High School*	0.62	1	0.39
Some College	0.28	2	0.31
College Degree	0.34	3	0.39
Masters Degree or Above	0.47	4	0.33
Signif. of F	0.03	Signif. of F	0.52
City of Residence		**Rationing Scenario**	
Phoenix	0.38	Yes	0.38
Tucson	0.26	No	0.31
Other	0.33		
Signif. of F	0.28	Signif. of F	0.20

*Indicates result based on less than 10 cases.

TABLE 6.28

ANALYSIS OF VARIANCE RESULTS (COMBINED SCENARIO) FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 100 MILE RANGE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.47	Multiple R Squared	0.16

Conditional Means for the Variable Levels Shown

Variable	Mean	Variable	Mean
Age		**Income**	
Under 20	0.51	Under $15000	0.44
20 - 34	0.43	$15000-$20000	0.69
35 - 49	0.49	$20000-$30000	0.57
50 - 64	0.48	$30000-$50000	0.44
Over 65	0.46	Over $50000	0.39
		No Response*	0.55
Signif. of F	0.94	Signif. of F	0.16
Education Level		**# of Vehicles Owned**	
High School*	0.81	1	0.52
Some College	0.38	2	0.43
College Degree	0.46	3	0.50
Masters Degree or Above	0.64	4	0.45
Signif. of F	0.01	Signif. of F	0.61
City of Residence		**Rationing Scenario**	
Phoenix	0.49	Yes	0.53
Tucson	0.41	No	0.41
Other	0.43		
Signif. of F	0.56	Signif. of F	0.06

*Indicates result based on less than 10 cases.

TABLE 6.29

ANALYSIS OF VARIANCE RESULTS (COMBINED SCENARIO) FOR THE DEPENDENT VARIABLE:

RATIO OF PRICE OFFERED FOR AN ELECTRIC VEHICLE WITH 350 MILE RANGE TO PRICE OFFERED FOR A STANDARD CURRENT VEHICLE

Grand Mean	0.78	Multiple R Squared	0.16

Conditional Means for the Variable Levels Shown

Age		Income	
Under 20	0.93	Under $15000	0.78
20 - 34	0.73	$15000-$20000	0.94
35 - 49	0.77	$20000-$30000	1.08
50 - 64	0.81	$30000-$50000	0.72
Over 65	0.81	Over $50000	0.61
		No Response*	0.96
Signif. of F	0.76	Signif. of F	0.01

Education Level		# of Vehicles Owned	
High School*	1.14	1	0.76
Some College	0.69	2	0.76
College Degree	0.76	3	0.80
Masters Degree or Above	0.95	4	0.97
Signif. of F	0.03	Signif. of F	0.59

City of Residence		Rationing Scenario	
Phoenix	0.79	Yes	0.82
Tucson	0.77	No	0.73
Other	0.73	Signif. of F	0.24
Signif. of F	0.89		

*Indicates result based on less than 10 cases.

In evaluating the analysis of variance results we will attempt to draw generalizations across the various models rather than going through each table individually. Clearly the independent variables do not explain a large proportion of the variation in the dependent variable. The proportion of variation explained by the model varied from 14 to 34 percent with just over 20 percent of the variance being explained in the majority of cases. It is also clear that the individual independent variables were rarely shown to have a statistically significant impact on the dependent variable. Only 7 of the 35 independent variables were statistically significant in the nonrationing scenario models. However, this was a considerably stronger result than the 1 significant out of 35 among the rationing scenario models. Combined scenario results showed 10 of 42 independent variables with statistically significant results. This suggests that the explanation for variations in different respondents' reactions to alternate vehicles is more complex than simple variations in demographic variables. The failure to explain most of the variation in responses to alternate vehicles is not unexpected and is not a major difficulty given that explaining the cause of variations in response was not a central thrust of the study. However, the overall weakness of the ANOVA results does make the interpretation of the effects of the various independent variables difficult. Before looking at individual independent variables it is appropriate to indicate that none of these variables showed a consistant and statistically significant effect on the dependent variable across all of the models. Thus all of the relationships discussed in the next few paragraphs should be interpreted as weak indicators of an effect rather than as firmly established relationships.

The age variable proved to be statistically significant in only two of the ANOVA runs. In Table 6.15, the analysis of the 350 mile range car under the nonrationing scenario, respondents between 20 - 34 are seen to be less favorable to this alternate vehicle (conditional mean= .5) while respondents over age 35 all place a similar value of approximately .75 on it. The response of those under 20 has little impact due to the small number of respondents in that category. The other statistically significant result is in Table 6.26, the manufactured hybrid vehicle across the combined scenarios. In this run the respondents between 35 and 50 are seen to value the alternate vehicle less highly than those in both younger and older age groups. In general there is a weak pattern of the 20 to 34 age group responding less favorably than others to electric vehicles across the scenarios and variants of this vehicle type, and there is similarly a weak pattern of 35 to 49 year old responding less favorably than other groups to hybrid vehicles. There is no discernable age pattern in responses to natural gas/hydrogen vehicles.

The respondent's income level is statistically significant in 5 of the 21 specifications and the pattern of response is reasonably stable across the various specifications. Respondents respond less favorably to alternate vehicles as their income rises at least beyond the $30,000 level. For income levels up to $30,000 results vary. In Table 6.9, responses fall as income rises throughout the income range, whereas, in Table 6.15, valuations of the alternate vehicle increase with income up to the $30,000 range.

Education level was the most frequently significant of the independent variables. Results were significant in 7 of the 21 specifications. Ignoring the high school and below category which contains only three observations, there is a rather consistent pattern of a positive relationship between education level and the individuals relative valuation of alternate vehicles. This is consistent with the idea that highly educated people are more likely than others to be innovators.

The number of vehicles owned has a statistically significant impact only in the specifications for natural gas vehicles under the nonrationing scenario. In these two specifications respondents' responses to alternate vehicles become more positive as the number of vehicles owned increases. This pattern is also present although with less strength for other vehicles under the nonrationing scenario, and is consistent with the hypothesis that owners of multiple vehicles can specialize their use of vehicles thus reducing the inconvenience of limited range and long refueling times. No consistent relationship between number of vehicles owned and response to alternate vehicles is apparent under the rationing scenario, and overall the results on this variable are quite weak.

City of residence has a statistically significant impact on responses to an alternate vehicle only for Table 6.11, the retrofit hybrid vehicle under the nonrationing scenario. For this specification the residents of nonmetropolitan areas value the alternate vehicle more highly than do Phoenix area residents who in turn value it more highly than do Tucson area residents. This pattern of responses in not repeated across the specifications, however. In general, nonmetropolitan area residents valued hybrid vehicles more highly and other alternate vehicles less highly than did residents of metropolitan areas. This pattern is consistent with the hypothesis that range is a more crucial factor for nonmetropolitan area residents. There is no consistent pattern in the relative responses of Phoenix versus Tucson area residents.

For the combined scenarios specifications the presence of rationing consistently increases the relative valuation of the alternate vehicle. The difference is statistically significant only for Table 6.24, the natural gas vehicle with home refueling, however.

The ANOVA results presented here indicate that variations in responses to alternate vehicles among individuals with common demographic characteristics are large relative to the systematic variations due to demographic factors. There are no consistently significant relationships between demographic characteristics of respondent and their relative valuations of alternate vehicles.

Income and education level come the closest to providing consistently significant results. Income level appears to be negatively related to the respondent's valuation of alternate vehicles at least beyond the $30,000 level, and education level appears to be positively related to the respondents valuation of alternate vehicles. For the combined scenario specification rationing tends to cause respondents to value alternate vehicles more highly, but the differential is statistically significant for only one of the seven alternate vehicle types. Results for the other independent variables provide no consistent pattern which even approaches being statistically significant.

END NOTES

1. Two of the attributes used in the Arthur D. Little panel survey, air conditioning and type of warranty were dropped. It was felt that air conditioning is a necessary feature for vehicles in most Arizona locations. We decided to deal with the reliability issue by assuming that alternate vehicles must demonstrate reliability comparable to gasoline vehicles in order to successfully penetrate the market.

2. Thus for the nonrationing and rationing scenarios the ANOVA model is specified as:

(1) AVVALj = Boj + B1i · AGEij + B2i · INCij + B3i · EDij + B4i · NOVij + B5i · RESij + Ej

where AVVALj is the respondent's valuation of the j th alternate vehicle, AGEij is the i th age category for the j th alternate vehicle, INCij is the i th income category for the j th alternate vehicle, EDij is the i th education level category for the j th alternate vehicle, NOVij is the i th number of vehicles owned category for the j th alternate vehicle, RESij is the i th place of residence category for the j th alternate vehicle, the Bs are coefficients, and Ej is a random error term. For the specifications which pool the rationing and nonrationing scenario results, the ANOVA model is specified as:

(2) $AVVAL_j = B_{oj}\ B_{1i} \cdot AGE_{ij} + B_{2i} \cdot INC_{ij} + B_{3i} \cdot ED_{ij} + B_{4i} + NOV_{ij} + B_{5i} \cdot RES_{ij} + B_{6i} \cdot RAT_{ij} + E_j,$

where all variables are as described above and RAT_{ij} indicates the presence or absence of rationing ($i = 1$ or $i = 2$) for the j th alternate vehicle. In the tables presented in Section ___ the conditional means listed represent the sum of the coefficient for the specified independent variable category level and the grand mean (B_{oj}).

SECTION 7

ESTIMATES OF ALTERNATELY FUELED VEHICLE MARKET PENETRATION UNDER VARIOUS SUPPLY SCENARIOS

Estimates of the demand for alternatively fueled vehicles can be generated from the consumer demand survey. However, the degree of penetration of these vehicles in the marketplace is the result of the interaction of demand and supply factors. Supply conditions in the fuel and vehicle markets cannot be effectively estimated using the types of statistical analysis employed with the demand side estimates. Decisions made by major auto manufacturers and by major oil producing nations will crucially influence the supply side environment of this market, and such factors do not lend themselves well to statistical analysis. Therefore, supply condition alternatives are presented as a set of scenarios designed to cover the spectrum of supply conditions which have a significant likelihood of occurring.

A forecast rate of penetration of alternately fueled vehicles is generated under each of the alternative supply scenarios by combining the scenario specific supply data with survey demand data to determine, for each survey respondent, whether that respondent would choose a conventional or an alternatively fueled vehicle under the given scenario. Results across the various scenarios will then be reviewed to determine whether or not there is a consistent pattern of response.

7.1 SUPPLY SCENARIOS

Five alternative supply condition scenarios were chosen for the simulations presented here. In all of the scenarios it has been assumed that electric vehicles are not commercially available at viable prices. This assumption was made because of the low value respondents placed on electric vehicles with ranges which are currently achievable, and the uncertainty of the emergence of a battery technology which could overcome this barrier. It appears highly unlikely that electric vehicles will become a viable alternative within a 15 year time horizon. Thus the electric vehicle options were not included in any of the scenario simulations presented here. Further, manufacturer production of alternate vehicles would likely require some minimal scale of operation and the existence of some form of infrastructure for the servicing and repair of alternatively fueled vehicles. Thus it is assumed that a certain level of penetration of retrofit hybrid vehicles is necessary, under any scenario before manufactured alternative vehicles become available. To capture this effect two alternative simulations were run for each scenario; one allowing for all of the natural gas alternative vehicle types and an alternate (the "A" scenario) allowing only for the retrofit hybrid vehicles.

The five scenarios are designed to cover a wide range of potential supply conditions, see Table 7.1. The first three scenarios cover a range of gasoline price alternatives, while scenario 4 assumes governmental incentives for AV purchase and scenario 5 simulates an energy crisis situation with gasoline rationing. Scenario 1, the baseline scenario, assumes that the price difference between gasoline and natural gas remains at approximately the current level and that each of the alternate vehicle types is sold at a competitive price based on the manufacturers expectation of large scale sales. The price differentials listed are based upon evaluation of information provided by suppliers who are either already producing or seriously considering the development of alternatively fueled vehicles as was reported in Section 2. In evaluating fuel cost savings with AVs the hybrid vehicles are assumed to, on average, use 60 percent natural gas and 40 percent gasoline, and this ratio is used under all of the scenarios.

Scenario 2 is the least favorable toward AV development. Under this scenario the price of gasoline is assumed to fall relative to the price of natural gas so that the delivered fuel cost per mile using natural gas is only 1/2 cent less than gasoline. Due to the modest fuel cost incentive for AV adoption it is further assumed that manufacturing of AVs is on a small scale implying higher average production costs and markups for AVs. Each AV type (except the retrofit hybrid) is assumed to be priced $1000 higher under this scenario. The retrofit hybrid vehicle is assumed always to be produced in small scale operations and thus is unaffected by the lack of large scale manufacturers entering the market.

Scenario 3 simulates a situation in which fuel costs provide a strong incentive to adopt AVs. Natural gas is assumed to provide a three cent per mile fuel cost saving when compared to gasoline. This implies a gasoline price of at least two dollars per gallon and perhaps higher since natural gas prices would be expected to rise somewhat as gasoline prices rise. Large scale production of AVs is assumed, so that the AV purchase price differentials of Scenario 1 are again used.

The fourth scenario is designed purely to evaluate the effects of tax incentives on AV purchase. Fuel cost and AV purchase price differentials are assumed to be identical to Scenario 1; however, AV purchasers are not required to pay sales tax on their vehicles. Comparison of Scenario 4 results with those of Scenario 1 should provide an estimate of the impact that tax incentives could have on this market.

Scenario 5 assumes a crisis situation, fuel cost differentials become highly favorable for natural gas vehicles, a three cent per mile saving with AVs. However, it is assumed that the crisis comes without the infrastructure in place to provide large scale AV production, so that the price of AVs rises sharply. All AVs are assumed to be priced $1000 higher than under the baseline scenario. An additional variation in Scenario 5 is that its supply condition projections are combined with rationing scenario demand survey results to produce AV penetration estimates, while all other supply scenarios are used in conjunction with the nonrationing demand survey results.

Scenario 2 is the scenario which is closest to the market conditions currently projected by Dr. Brown of Hudson Institute. It is quite feasible that the cost of delivering natural gas for vehicle use could actually become equal to or even greater than gasoline costs. Rather than develop scenarios for this fuel cost condition, it will simply be assumed that no measurable AV penetration will occur without at least some measure of fuel cost savings.

7.2 THE VEHICLE PURCHASE DECISION

The costs of owning and operating a vehicle can be divided into two major components; the purchase price of the vehicle and the costs of operating the vehicle such as repair and servicing, insurance, and fuel cost. In this analysis all operating costs except fuel costs are assumed to be invariant between gasoline and natural gas vehicles.

The decision of whether to purchase an AV is based on the tradeoff between purchase price and fuel cost considerations. The purchase price of each AV under each scenario is at least somewhat higher than the purchase price of a gasoline powered vehicle, while there is always at least some fuel cost saving associated with owning an AV in all of the scenarios presented. The demander of a vehicle normally factors fuel costs, along with all other vehicle attributes into his or her decision as to how much he or she is willing to pay for the vehicle. In this analysis respondents were forced to separately value fuel cost savings, since they were first asked to place a value on various AVs assuming their fuel economy to be identical to that of a standard current vehicle, and then separately compared two vehicles which were identical in all respects except fuel economy. In virtually all cases AVs were considered less desirable than gasoline vehicles absent fuel cost savings.

Since AVs typically cost more than a standard current vehicle and are valued less highly than a standard current vehicle by most consumers when fuel costs are not considered, an

AV would be purchased only if there are fuel cost savings sufficient (in the mind of the consumer) to overcome this differential. Placing this condition in mathematical terms the i th AV would be purchased by the j th consumer under the k th scenario only if:

$$(1) \quad PAV_{ij} - PDAV_{ik} + FCDAV_{ik} * FSV_{j} > PGV_{j}$$

where PAV_{ij} is the price offered for the i th AV by survey respondent j, $PDAV_{ik}$ is the differential from the price of a standard gasoline vehicle required to purchase the i th AV under the conditions of supply scenario k, $FCDAV_{ik}$ is the fuel cost differential in cents per mile for the i th AV under supply scenario k, FSV_{j} is the value the j th survey respondent places on a one cent per mile fuel cost saving, and PGV_{j} is the price offered for a conventional gasoline vehicle by survey respondent j. In predicting AV penetration a respondent is counted as purchasing an AV under a given scenario if the inequality in equation 1 is in the direction indicated for at least 1 of the available AV types. This analysis is performed for all of the survey respondents, and the results, a set of decisions by individuals to purchase or not to purchase AVs, become the dependent variable in the analysis of the rate of penetration of AVs.

7.3 LOGIT ANALYSIS OF SCENARIO AND SURVEY DATA

The purchase decision described above gives rise to a dichotomous (1 if an AV is chosen, 0 if an AV is not chosen) variable which requires special treatment in statistical analysis. The most commonly used statistical technique for cases where the dependent variable is dichotomous is logit analysis see Theil [1967]. For this study the multinomial logit model of the SPSSX computer package was used to generate logit analyses.

Each individual has either chosen or failed to choose an AV, but what we wish to predict is the probability that an individual with a given set of demographic characteristics would choose an AV. With logit analysis what is actually produced is an estimate of the log of the ratio of the probability of choosing an AV to the probability of failing to choose an AV. The antilog of this result is computed and converted from ratio to percentage terms to produce percentage penetration forecasts.

In logit analysis the log of the odds of a given choice is the dependent variable and its value is assumed to be a linear function of a set of independent variables. In this study demographic variables such as the respondents age, education level, income, and place of residence are the independent variables. These variables were coded in categories in the survey data, however, attempts to run logit analysis utilizing the various categories were unsuccessful due to a failure to obtain convergence of the model parameters. Therefore, categorical data were converted into numeric values by assuming each respondent to be in the center of the category, e.g. a respondent with income between \$15,000 and \$20,000 was said to have an income of \$17,500. Age and number of vehicles were also dropped as variables in the latter case because they were very rarely significant in the analysis of variance results presented earlier. Adjustment to make the results representative of Arizona population was then performed by subtracting the respondents level for each demographic variable from the mean value of the variable in the Arizona population.

The equation used for the logit analysis is as follows:

$$(2) \quad \ln OAV_j = B_0 + B_1 \cdot INC + B_2 \cdot ED + B_3 \cdot TDUM + B_4 NDUM + E_j$$

where $\ln OAV_j$ is the log of the ratio of the odds of individual j choosing an AV to the odds of individual j not choosing an AV, INC is the differential between js income and the mean income of Arizona families in \$1000, ED is j's education minus Arizonans mean education level in years, TDUM is a dummy variable which is one if individual j is from the Tucson area and zero otherwise, and NDUM is a dummy variable which is one if individual j is from a nonmetropolitan county and zero otherwise, the Bs are coefficients to be estimated and E is a random error term. In some instances (particularly where the number of individuals choosing an alternate vehicle was very small) the logit equation failed to converge using the specification of Equation 2. Where this occurred the place of residence dummy variables were dropped from the analysis, and all of the remaining model runs then reached convergence.

Direct interpretation of the logit results is made difficult by the form in which the dependent variable is expressed. The constant coefficient B_0 in fact is not meaningful without conversion out of log form. However, the coefficients on the independent variables do have a meaningful interpretation. A coefficient of zero means that the independent variable had no impact on the odds of choosing an AV, while a positive (negative) coefficient indicates the percentage by which a one unit increase in the independent variable would cause the dependent variable to increase (decrease). Thus, if the B_2 coefficient were .02, and the mean probability of choosing an AV were 50% this would indicate that a $1000 increase in income would cause an increase of .02 times the base of 50 percent in the odds of a person choosing an AV, increasing the probability of AV choice to 51 percent other things remaining the same. In other words, the independent variable coefficients represent the percentage by which the base probability of choosing an AV will be shifted; if the mean probability of choosing an AV were only 10 percent, then the income increase described above would raise the probability of AV choice by only .4 percent to 10.4 percent.

The logit results are presented in Tables 7.2 and 7.3, the Table 7.2 results are for the runs in which all of the natural gas using AVs were assumed to be available, while Table 7.3 presents results for the alternate runs, (Scenarios 1A through