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INSTITUTIONAL FACTORS IN TRANSPORTATION SYSTEMS AND THEIR POTENTIAL FOR BIAS TOWARD VEHICLES OF PARTICULAR CHARACTERISTICS

FINAL REPORT

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Prepared for:

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

DIVISION OF TRANSPORTATION ENERGY CONSERVATION

NOTICE

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Prepared for:

U.S. Energy Research and Development Administration
Division of Transportation Energy Conservation
Washington DC
Attention: Mr. Kenneth F. Barber

FOREWORD

This report is the summary of an investigation into a number of disparate areas which required many different types of expertise. Thus the report is the product of a team effort and the skill, enthusiasm and dedication of the team members is gratefully acknowledged. Those listed as authors helped define the scope of the study, played significant roles in data gathering and analysis and participated in reviewing the findings.

The various institutional analyses were the product of three separate groups which are identified in the attached list. Group Leaders in each team are starred.

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CONTENTS

CONTENTS (CONTINUED)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONTINUED)

LIST OF ILLUSTRATIONS (CONTINUED)

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

EXECUTIVE SUMMARY

In Section 13(a) of the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976 (PL94-413) the Administrator of the Energy Research and Development Administration is directed to "conduct a study to determine the existence of any tax, regulatory, traffic, urban design, rural electrical or other institutional factor which tends or may tend to bias surface transportation systems toward vehicles of particular characteristics." This report presents the findings and conclusions of that study.

The various institutional areas specified in the Act were reviewed and institutional factors that might be sources of bias were identified. These are shown in Table ES-1 where the factors identified are listed in terms of bias source and areas of potential bias impact. In this study an institutional factor was defined as a policy, practice, regulation or infrastructure element that influences vehicle production, ownership or use. Bias was determined by comparing the effect of an institutional factor on an electric or hybrid vehicle with its effect on a comparable, conventional (internal combustion engine equipped) vehicle. If the comparison revealed an inclination favoring one vehicle over another (in terms of production, ownership or use) then a bias existed. Some 60 factors were identified, characterized and evaluated.

Based on the findings of this report, the following conclusions are reached.

- Of the 60 factors analyzed, 33 lead to bias against electric and hybrid vehicles (EHV's), 9 show no bias, 14 cause bias in favor of EHVs and 4 can be argued as a source of bias either for or against EHVs depending on the assumptions made.

- Thirteen bias producing factors are considered to have the potential for major impact. These factors are:

  - safcty laws and standards
  - sales taxes
  - property taxes

TABLE ES-1. MATRIX OF INSTITUTIONAL FACTORS CONSIDERED IN THIS STUDY

AREA OF IMPACT / SOURCE OF POTENTIAL BIAS	TAXES AND REGULATIONS	TRAFFIC CONTROL	URBAN DESIGN	ELECTRICITY SUPPLY	FEDERAL POLICIES AND PROGRAMS	AUTOMOTIVE INDUSTRY STRUCTURE & PRACTICE	MISCELLANEOUS INSTITUTIONAL FACTORS
1. VEHICLE PRODUCTION AND DISTRIBUTION	o FEDERAL MOTOR VEHICLE SAFETY STANDARDS o FEDERAL MOTOR CARRIER SAFETY REGULATIONS o AIR POLLUTION CONTROL LAWS o FEDERAL NOISE STANDARDS o STATE NOISE CONTROL				o AUTOMOTIVE RESEARCH	o ECONOMIES OF SCALE o CAPITAL REQUIREMENTS o IN-PLACE INFRASTRUCTURE o RESEARCH & INNOVATION o PRICING	o OPEC o INTERNATIONAL ENERGY PROGRAM o MATERIAL CARTELS o CAPITAL AVAILABILITY
2. VEHICLE PURCHASE AND OWNERSHIP	o REGISTRATION FEES/ LAWS o SALES TAXES o PROPERTY TAXES o INSURANCE LAWS o INCOME TAX DEDUCTIONS o CUSTOMS AND TARIFFS o RURAL ELECTRIFICATION ACT		o URBAN DENSITY o PARKING AND CHARGING FACILITIES	o UTILITY CAPITAL o UTILITY REGULATIONS	o FLEET PROCUREMENT PROGRAMS o ENERGY RESEARCH		o INSURANCE AVAILABILITY o FINANCING AVAILABILITY o OPEC o INTERNATIONAL ENERGY PROGRAMS
3-A VEHICLE OPERATION-FUEL	o MOTOR FUEL TAXES o EMERGENCY PETROLEUM ALLOCATION o UTILITY TAX o ENERGY POLICY AND CONSERVATION ACT			o UTILITY RATES o ELECTRICITY DISTRIBUTION INFRASTRUCTURE			
3-B MAINTENANCE	o LUBRICATING TAX o TIRE & TUBE TAX o POLLUTION CONTROL LAWS			o BATTERY EXCHANGE			
3-C OPERATING CONDITIONS	o MINIMUM SPEED LAWS	o HIGHWAY TRAFFIC SPEED o HIGHWAY ACCESS RAMPS o TRAFFIC LIGHT TIMING o PREFERENTIAL TRAFFIC LANES o TOLLS AND CONGESTION PRICING o VEHICLE SEGREGATION POLICY	o INTERMODAL PLANNING o ACCESS POLICY o COVERED AUTOMOBILE FACILITIES				

- speed laws
- highway design (grade characteristics)
- electricity infrastructure
- federal research, development and demonstration policy
- automotive industry structure and practices
- oil prices and oil supply shortfalls
- capital availability and markets
- insurance laws and availability
- consumer financing
- Rural Electrification Act

In the above list, 12 cause bias against EHV's and one (the Rural Electrification Act) may lead to bias in favor of EHV's.

● Performance and cost characteristics of near term and intermediate technology EHV's are the basis for many of the biases identified. Any vehicle with similar performance and cost characteristics, irrespective of the propulsion system, would be subject to the same biases.

● Limits on current and intermediate technology are a major source of bias against EHV's. These limits lead to biases in such areas as safety standards, sales and property taxes, speed laws and highway design. Major improvements in technology and cost factors would lead to diminution (or elimination) of these biases.

● There is a serious lack of reliable information (i.e. based on experience) available to institutions about EHV's and their applications. EHV's are essentially new products with the associated uncertainties and risks that automatically elicit caution from established manufacturers, insurers and financial institutions.

● Introduction of EHV's to any large extent will have a significant impact on federal and state revenues derived from automotive transportation.

The following summarizes the major findings of this report, organized in terms of the principal categories of institutional factors:

Taxes and Regulations

- Within the Federal tax code, the gasoline motor fuel tax is clearly biased in favor of EV's, primarily because there is now no "electric fuel" tax comparable to the gasoline motor fuel tax. The resulting differences in yearly federal excise taxes for EV as opposed to conventional vehicle owners are small, however, ranging from $5 to $22.

- All fifty states have vehicle fees and taxes, some of which, by their method of tax base establishment, discriminate accidentally against EHV's. In eleven states and the District of Columbia there are separate registration fee schedules for EV's nearly equally split between favorable and unfavorable provisions. The unfavorable provisions are intended primarily to regain revenues lost by the absence of a fuel tax applicable to EV's. In two states there are restrictions on use which specifically address EV's. In several other states there are requirements that all vehicles be capable of meeting minimum and/or maximum speed laws. This latter group may be accidentally biased against EV's.

- The four states surveyed in depth have sales taxes on initial vehicle purchase, gasoline motor fuel taxes, and registration fees, while two have annual property taxes, and registration fees, (derived on different bases). In all cases, the sales tax is higher for EV's and hybrids due to their correspondingly higher acquisition prices; within comparable vehicle groups tax differences range from approximately $100 to $200. Property taxes are similarly higher for EV's because of their higher acquisition prices. State gasoline taxes, on the other hand, favor electric vehicles to a greater degree than the federal gasoline taxes.

- Federal Motor Vehicle Safety Standards, insofar as they are applied to EV's, create bias against EV's and hybrids. They generally require additional components which, because of the different weight propagation properties of EV's, lead to a much greater total weight increase for EV's than for conventional vehicles.

For example, 45kg (100 pounds) of required components would result in an estimated additional (propagated) weight of 34kg (75 pounds) costing $160 for an EV. The same requirement for a conventional auto would lead to only 20kg (45 pounds) of propagated weight costing some $30.

- Federal air pollution control regulations for mobile pollution sources create a bias in favor of electric vehicles. Exhaust emissions standards require control equipment in conventional cars adding significantly to their purchase price. EV's require no such control equipment. However, if the cost of stationary source (generating plant) pollution control is added to the cost of electricity this bias may be diminished (or eliminated).

Traffic Control

- Based on Los Angeles area freeway data, the acceleration specifications for all study EV's are insuffcent to merge safely into elevated portions of freeways. Their accident involvement rate in such circumstances would be at least 3 times higher than the norm. Up to 58% of the Los Angeles freeway system thus would be dangerous to EV operators. If national data show a similar pattern, a significant bias against EV's is present in ramp design.

- In mixed traffic, ordinary traffic signal timing systems create little or no bias against EV's in terms of intersection capacity. Electric vehicles' slower acceleration characteristics appear to be offset by their smaller size. If EV's ever become a susbstantial portion of the vehicle mix, intersection capacities could be decreased by several percent, but signal timing could be reset to neutralize most of the change in capacity.

- Despite their limited power, most electric vehicles should be capable of adequate performance on high speed roads for brief periods of time. However, 88 km/h (55 mph) represents a maximum to this capability, and could cause problems on highways with grades above 4%.

- At traffic speeds of 105 km/h (65 mph), the 88 km/h (55 mph) maximum speed of intermediate technology electric vehicles will cause significant speed differentials between EV's and non-EV's resulting in accident involvement rates two to three times the norm for vehicles maintaining average speed. Thus, enforcement of speed laws is necessary to prevent a major bias against EV use on highways.

- The two-passenger near term EV has a top speed of 80 km/h (50 mph) and therefore would have an accident involvement rate 3 to 10 times the norm on highways even at average traffic speeds of 88 km/h (55 mph) and grades less than 4%. This design appears unsuitable for use on high speed roads.

Urban Design

- Recent trends toward suburbanization and reduced urban density create biases both for and against EV's. Decreased density encourages multiple-car ownership and facilitates substitution of electric vehicles for secondary autos. However, decreased density also can increase travel requirements beyond EV capabilities. This is particularly important for commercial delivery vehicles, which must travel significantly greater distances in low density areas. On the other hand, existing high density areas appear well suited to electric delivery vans for a variety of commodities.

- The lack of off-street parking facilities for 60% of urban residential structures may create an important bias against EV use since such facilities may be necessary to allow private overnight recharging.

- Commercial off-street parking facilities are significantly biased against small cars. Many parking areas are sized for standard American cars with small car operators forced to pay for large car spaces. It should be noted that this is a bias against all small cars and is only incidentally a bias against EV's. Similarly, on-street parking policies are biased in favor of large (ICE) vehicles.

Federal Policies and Programs

- Due to the Electric and Hybrid Vehicle Research Development, and Demonstration (RD&D) Act (PL94-413) current and planned federal RD&D programs are biased in favor of electric and hybrid vehicles. Pending legislation may lessen or eliminate this bias.

- The present overall energy RD&D emphasis on electricity generation rather than synthetic liquid fuel development creates a bias in favor of electricity as the primary intermediate fuel source and therefore in favor of electric vehicle systems.

- The federal motor vehicle fleet procurement program, in its requirements for minimum initial cost, 19,300 km (12,000 miles) per year usage objective, and lack of comprehensive duty cycle information, has been biased against vehicles such as electrics with high first cost and modest performance capabilities, but potentially low life cycle costs. This historical bias, however, may be eliminated by the Electric and Hybrid Vehicle Act, which requires the introduction of electric and hybrid vehicles in appropriate federal applications at the earliest practical date.

Automotive Industry Structure and Practices

- Economies of scale, large capital requirements, and market demand uncertainties in the U.S. automotive industry create major barriers to entry for new domestic firms and restrict the ability of existing firms to introduce innovative technology. These factors slow the rate of technological change and therefore are biased in the short run towards the status quo.

- Economies of scale also favor vehicles and flexible performance capabilities to meet a variety of applications. Vehicles with major performance limitations (such as current EV's) are at a disadvantage because demand is too small to permit mass production.

- The automobile manufacturer's research and developement programs heavily emphasize refinements and modifications to conventional technology. In several instances, however, manufacturers have reached the introduction stage for radical new technology and appear generally willing to make such introductions when justified economically. There is no clear evidence, therefore, of a long-term structural bias toward vehicles of particular characteristics.

Miscellaneous Factors

- Through its oil price increases, the Organization of Petroleum Exporting Countries has created a significant bias in favor of vehicle technology with reduced petroleum-based fuel consumption, including electric and hybrid vehicles. The possibility of another embargo also creates a bias more directly in favor of electric vehicles, since they are less dependent on petroleum. Because current oil prices are far above marginal costs, however, the possibility also exists for major price reductions.

- In many foreign countries, high gasoline prices and population densities make electric and hybrid vehicles more attractive than in the United States. As a result, Western Europe and Japan have a greater incentive for electric vehicle technology development. Foreign R&D and marketing programs could well stimulate a more rapid introduction of electric vehicles in the U.S. under appropriate circumstances.

- Lack of investment capital creates a bias against the introduction of electric vehicles by new firms. This bias, however, is a consequence of the efficient functioning of capital markets in response to the risks such an investment would represent, and may be partially offset by the loan guarantee provisions of the Electric and Hybrid Vehicle Act. Moreover, existing firms, both within and outside the auto industry, could internally finance the introduction of electric vehicles if such an investment appeared profitable.

- The insurance industry specifies rates for automobile coverage on the basis of vehicle value, purpose of use, place of use, and driver characteristics. Since the method of propulsion is not explictly taken into account, there is no inherent bias for or against electric vehicles. In individual instances, however, where vehicles have not been evaluated by national underwriters, agents may have authority to refuse coverage on the basis of a personal evaluation. Bad publicity regarding the safety of some electric vehicles appears to have caused some such rejections in the past.

- Automobile loans made by banks and financing companies are based much more strongly on the credit worthiness and income of individual purchasers than on vehicle characteristics. But while the financing industry does not appear to be institutionally biased, current uncertainties about the resale value of electric vehicles can cause discriminatory practices by indivudual agents. In particular, loans for electric cars may be offered only to persons with high credit ratings, may require higher than usual down payments, and may require repayment over a shorter term than the average.

1.0 INTRODUCTION

This report is required by Section 13(a) of the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976 (PL94-413). It presents the evaluation of a number of institutional factors related to taxes, regulations, traffic behavior and control, urban characteristics, electrical supply, federal policies and auto industry structure in terms of their potential for the creation of bias in surface transportation systems toward vehicles of particular characteristics.

The scope of the investigation is confined to the areas of interest defined in the Act and is developed by defining specific factors in the existing institutional structure and relating them to their area of impact in the life-cycle of an automotive vehicle. Factors so defined are then analyzed for potential bias in terms suitable to the factor and the area impacted. In general a methodology is used consisting of a five step procedure: (1) conceptual identification of the factor; (2) definition of the potential bias; (3) bias analysis in appropriate, preferably quantitative terms; (4) evaluation of bias implications; (5) recommendations where appropriate.

This report is organized in the following way. Groundwork for the study is provided in Section 2. Definitions for institutional factors, bias, vehicles, markets, and so on are presented. The methodology for bias evaluation is detailed and a set of electric, hybrid and internal combustion engine vehicles are specified in terms of performance characteristics and life cycle costs which provide the data base for some of the analyses which follow. Section 3 discusses potential biases in the Federal tax code, in the state tax codes of four selected states, reviewed in depth, and in the motor vehicle registration and license fees and excise taxes of all 50 states. Also reviewed but in less detail are the customs and tariff regulations, the Federal Motor Vehicle Safety Standards, and pertinent sections of the Energy Policy and Conservation Act, Clean Air Act and Rural Electrification Act.

Section 4 covers potential biases relating to various aspects of vehicle traffic behavior and control. Specific topics include speed limits, freeway access ramps and general roadway gradeability, traffic light times and their relation to intersection capacity, urban transit times, preferential access and lanes policy, vehicle segregation policy, and tolls and congestion pricing.

Section 5 reviews potential biases derived from a number of urban characteristics such as urban density, parking supply, urban growth planning, access policies and intermodal planning.

In Section 6 various factors relating to electricity supply are covered. Among them are electric utility regulation, pricing structure, electricity availability, and electric vehicle recharge options.

Section 7 deals with certain aspects of Federal policy. Topics covered are automotive research, energy research, the Federal fleet purchase program, and the implications of alternative fuels availability.

In Section 8 the automotive industry structure and its major institutional elements are reviewed and their potential for bias is evaluated. Specific topics included are economies of scale, industry infrastructure, rate of technological progress, innovation, and capital availability.

A variety of miscellaneous factors are defined in Section 9, in which a number of institutional elements not conveniently catalogued elsewhere, are considered. In this group are included such diverse items as OPEC and other cartels, availability of financing, insurance availability, and so on.

Finally Section 10 summarizes findings, conclusions and recommendations.

Appendices A through F contain details of methodology and calculations supporting various discussions in the main body of the report and are cross-referenced appropriately.

Appendix G summarizes the written replies received in response to the Department of Transportation's request for public comment on issues relevent to this study.

In the course of this study, the instructions of the Act were taken fairly literally in the sense that the institutional factors were only identified and analyzed for potential bias. No conclusions were drawn as to the ease or difficulty of the introduction of an electric vehicle fleet. Finally, a number of related issues such as consumer incentives and a detailed analysis of safety standards were omitted or touched on only in passing, since they are dealt with specifically in reports required under other sections of the Act.

2.0 SCOPE AND METHODOLOGY

2.1 INTRODUCTION

Institutions evolve to provide a structure within which a society's members can function. The relationship between a society and its institutions is both dynamic and interactive: institutions change in response to new elements of society, while evolving institutions can stimulate structural changes in the society. At any given point in time, however, institutions are likely to reflect the structure and elements of society predominating in the present or the recent past.

In this context, the major societal institutions of the United States clearly reflect a transportation-oriented society in which the internal combustion engine (ICE) vehicle predominates. Institutions appropriate to conventional vehicles, however, may create biases against alternative vehicle systems with significantly different characteristics.

This study presents an analysis of such institutional biases and their influence on U.S. surface transportation systems toward vehicles of particular characteristics. Its primary focus is on biases for or against electric and hybrid vehicles as compared with conventional ICE vehicles. To perform the analysis, an analytical structure and methodology were developed to define and evaluate institutional factors and their potential impact on particular vehicle characteristics.

2.2 SCOPE AND STRUCTURE

The investigation of bias was structured in terms of institutional sources and area of impact. The institutional sources of bias specifically defined by the Act include taxes, regulations, traffic control, urban design, and rural electricity. To these were added federal policy and programs, automotive industry structure and a miscellaneous group most conveniently classified separately. Areas of impact at which bias might occur were classified in terms of the life cycle of automotive vehicles: manufacture and distribution, purchase and ownership, and operation. This analytical structure led to the matrix depicted in Table 2-1.

TABLE 2-1. INSTITUTIONAL FACTORS MATRIX

AREA OF IMPACT \ SOURCE OF POTENTIAL BIAS	TAXES AND REGULATIONS	TRAFFIC CONTROL	URBAN DESIGN	ELECTRICITY SUPPLY	FEDERAL POLICIES AND PROGRAMS	AUTOMOTIVE INDUSTRY STRUCTURE & PRACTICE	MISCELLANEOUS INSTITUTIONAL FACTORS
1. VEHICLE PRODUCTION AND DISTRIBUTION	o FEDERAL MOTOR VEHICLE SAFETY STANDARDS o FEDERAL MOTOR CARRIER SAFETY REGULATIONS o AIR POLLUTION CONTROL LAWS o FEDERAL NOISE STANDARDS o STATE NOISE CONTROL				o AUTOMOTIVE RESEARCH	o ECONOMIES OF SCALE o CAPITAL REQUIREMENTS o IN-PLACE INFRASTRUCTURE o RESEARCH & INNOVATION o PRICING	o OPEC o INTERNATIONAL ENERGY PROGRAM o MATERIAL CARTELS o CAPITAL AVAILABILITY
2. VEHICLE PURCHASE AND OWNERSHIP	o REGISTRATION FEES/LAWS o SALES TAXES o PROPERTY TAXES o INSURANCE LAWS o INCOME TAX DEDUCTIONS o CUSTOMS AND TARIFFS o RURAL ELECTRIFICATION ACT		o URBAN DENSITY o PARKING AND CHARGING FACILITIES	o UTILITY CAPITAL o UTILITY REGULATIONS	o FLEET PROCUREMENT PROGRAMS o ENERGY RESEARCH		o INSURANCE AVAILABILITY o FINANCING AVAILABILITY o OPEC o INTERNATIONAL ENERGY PROGRAMS
3-A VEHICLE OPERATION-FUEL	o MOTOR FUEL TAXES o EMERGENCY PETROLEUM ALLOCATION o UTILITY TAX o ENERGY POLICY AND CONSERVATION ACT			o UTILITY RATES o ELECTRICITY DISTRIBUTION INFRASTRUCTURE			
3-B MAINTENANCE	o LUBRICATING TAX o TIRE & TUBE TAX o POLLUTION CONTROL LAWS			o BATTERY EXCHANGE			
3-C OPERATING CONDITIONS	o MINIMUM SPEED LAWS	o HIGHWAY TRAFFIC SPEED o HIGHWAY ACCESS RAMPS o TRAFFIC LIGHT TIMING o PREFERENTIAL TRAFFIC LANES o TOLLS AND CONGESTION PRICING o VEHICLE SEGREGATION POLICY	o INTERMODAL PLANNING o ACCESS POLICY o COVERED AUTOMOBILE FACILITIES				

The seven institutional sources of bias represent columns, while areas of impact are rows. Some 60 individual factors were classified in the matrix and subjected to analysis.

In order to provide both focus and limits to the study, a set of definitions were developed. These are listed in Table 2-2.

2.3 METHODOLOGY

Preliminary analysis of some of the factors defined in Table 2-1 led to several general observations, out of which analytical criteria were developed. First, factors have either a direct or indirect effect. For example, a sales tax on two vehicles, one of which is more expensive than the other, has a direct effect on the initial cost to the consumer and creates a bias against the more expensive vehicle. In the conceptual framework for this report, therefore, a sales tax is an institutional factor with a direct potential for bias.

Indirect effects, on the other hand, are equally important but more difficult to quantify. For example, the Organization of Petroleum Exporting Countries (OPEC) cartel has a significant impact on the price of crude petroleum stocks, which in turn is reflected in the pump price of gasoline. The latter has an effect on the operating and life cycle cost of an internal combustion engine vehicle and, on a comparative life cycle cost basis, may create a bias for electric vehicles. Furthermore, since the price of crude petroleum stocks is an OPEC decision rather than a decision based on the economic cost of production and distribution, there is considerable possibility for price change in response to a variety of social, economic and political pressures. The existence of the OPEC cartel and the implications of its ultimate, but uncertain, influence on pump prices of gasoline is defined in this study as an indirect effect.

In order to make comparisons more meaningful, quantitative criteria were developed, where possible, to provide a measure of the significance of the bias. This required the specification of a set of electric and hybrid vehicles and a comparable set of internal combustion engine vehicles, operating on gasoline (Tables

TABLE 2-2 DEFINITIONS

(1) Electric Vehicle - a vehicle powered by an electric motor drawing current from rechargeable storage batteries, fuel cells or other portable sources of electric current and which may include a non-electrical source of power designed to charge batteries and components thereof.

(2) Hybrid Vehicle - a vehicle powered by more than one energy source, one of which is electrical, and components thereof. For this study, a hybrid vehicle is defined more narrowly as one propelled by a combination of an electric motor and an internal combustion engine.

(3) Institutional Factor - any policy, practice, regulation or infrastructure element that influences vehicle production, ownership and use. Institutional factors are grouped in terms of mechanism of influence, in accordane with the Act (i.e., tax, regulatory, traffic, urban design, rural electric, and others). Influences on vehicle production, ownership and use excluded by this definition are psychological and sociological factors, climatic and terrain aspects of the operating environment, safety factors, in short, those influences which are subjective, beyond influence or control or are dealt with in other studies.

(4) Bias - a leaning or inclination favoring (or discouraging) the production, ownership or use of an electric vehicle or hybrid vehicle relative to a vehicle equipped with an internal combustion engine as a result of the equal exercise of an institutional factor on the vehicle types being compared. To the greatest extent possible objective criteria are used in assessing bias consequence (e.g., dollar costs of production, ownership and use, functional market size, capital costs, etc). It is recognized, however, that some estimates of bias consequence are of necessity qualitative.

(5) Surface Transportation System - any automotive vehicle defined in terms of particular vehicle characteristics and functional markets.

(6) Vehicle - a passenger or non-passenger automotive device propelled by electricity, hydrocarbon fuel or some hybrid system. This study is limited to urban goods delivery vehicles and private urban/suburban passenger vehicles. Vehicles not included are: forklifts and other commercial special purpose devices for carrying goods or for towing; recreational vehicles; mopeds; buses; and large vans and cargo carriers.

2-3, 2-4). No other propulsion systems or alternative fuels were considered in such detail since it seemed unlikely that any other vehicle systems of sufficiently different characteristics would emerge within the time frame of the Act.

Another general observation was the importance of distinguishing between bias measurement and impact analysis. Given the sales tax example above, if the purchase price of one vehicle is $2000 more than the other and the sales tax is 10% of the purchase price, then a quantitative measure of the bias is the difference in the sales taxes for each ($200). All other things being equal, then, there is a $200 bias against the purchase of the more expensive vehicle.* Impact analysis, however, would attempt to define the significance of a $200 bias in a consumer's determination to buy or not to buy a vehicle $2000 more expensive than anther vehicle and would encounter analytical problems beyond the scope of this report.

Finally, it soon became apparent that comparison of quantitative results among institutional sources of bias led to misleading conclusions and value judgments incompatible with analytical objectivity. Since the institutional factors must be evaluated in different (quantitative) terms, comparison must be qualitative. For example, tax biases were defined in dollars, biases due to speed limits were expressed in terms of greater likelihood of accident involvement, biases due to parking were given as percentage increases or decreases in parking availability, and so on. Comparisons using different units provide little meaningful information, while attempts to reduce the different bases of comparison to some common units are notoriously difficult. Thus, the dollar cost of sales tax bias could not be directly compared with increase (or decrease) in accident involvement rate; assignment of a dollar cost to the increased likelihood of accident involvement, on the other hand, would require the development of a completely new set of assumptions and methodology.

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*It should be noted that the purchase price of a vehicle is not regarded as an institutional factor. It is a consequence of the economics of manufacture, distribution and sale.

TABLE 2-3 CHARACTERISTICS OF ELECTRIC AND ICE VEHICLES OF INTEREST TO THE STUDY

VEHICLE CHARACTERISTIC	ELECTRIC AND HYBRID VEHICLES				INTERNAL COMBUSTION ENGINE (ICE) VEHICLES				
	2 PAX EV Near Term Pb-Acid Battery	4 PAX EV (Intermediate Technology Ni-Zn Battery)	Light Duty Van EV (Intermediate Technology Ni-Zn Battery)	Hybrid (Intermediate Technology Ni-Zn Battery)	Low Performance 4 PAX	Low Performance 2 PAX	CHEVETTE	JEEP VAN	HONDA CVCC
Battery Weight, kg (lbs) EV only	355(781)	298(657)	382(842)	366(806)					
Curb Weight, kg (lbs)	1012(2229)	1193(2628)	1531(3372)	1547(3408)	658(1450)	878(1935)	933(2053)	1171(2500)	814(1745)
Gross Vehicle Weight, kg (lbs)	1192(2622)	1525(3366)	1900(4180)	1879(4138)	826(1820)	1210(2665)	1265(2783)	1538(3388)	1144(2475)
W_B/GVW	0.30	0.20	0.20	0.19					
Driving Cycle	J227 a/C	J227 a/D	J227 a/D	J227 a/D	EPA Combined	EPA Combined	EPA Combined	Post Office	EPA Combined
Acceleration, time to 48 km/hr (30 mi/hr)sec	11	9	11	9	10	8	5		
Top speed km/hr, (mi/hr)	80(50)	90(56)	85(53)	90(56)	112(70)	120(75)	144(90)		
Gradeability, km/hr-% (mi/hr-%)	30/10(19/10)	70/7(44/7)	70/7(44/7)	85/7(53)/7)	29/16(18/16)	85/7(53/7)	27/30(17/30)		
Range, km(mi) for driving Cycle	50(31)	130(81)	130(81)	50/300(30/180)[a]	657(408)	725(450)	690(429)	190(118)	661(413)
Fuel Capacity, liter(gallons)					30(8)	38(10)	49(13)	57(15)	40(10.6)
Electric Energy Consumption, kWh/km	0.212	0.226	0.263	0.284					
Hydrocarbon Fuel Consumption, liters/100 km				8.7	4.6	5.7	7.2	29.7	6.1
Hydrocarbon Fuel Economy (MPG)				27.1	51.	41.	33.	7.9	39.
Engine Displacement, cm^3, (in^3)				36	737(45)	1065(65)	1606(98)	3770(232)	1488(91)
ICE Horsepower				24	30	43	63	90	60
Electric Motor Horsepower									
Retail Price $									
Base Vehicle	4600	2900	3700	4200				3800	3464
Battery	540	1840	2360	2200					
Total	5140	4740	6060	6400	2400	2900	3054	3800	3464
Assumed Vehicle Life, years	12	12	10	12	10	10	10	6	10
Annual Usage km/yr (mi/yr)	10000(6200)	16000(10000)	7000(4300)	16000(10000)	10000(6200)	16000(10000)	16000(10000)	7000(4300)	16000(10000)
Fuel Costs[b], ¢/km (¢/mile)	0.85(1.4)	0.90(1.5)	1.05(1.7)	1.12(1.9)	0.74(1.2)	0.91(1.5)	1.14(1.8)	4.75(7.6)	0.96(1.5)
Life Cycle Costs ¢/km(¢/mile)	13.76(22.1)	10.77(17.2)	30.86(49.4)	13.69(21.8)	9.17(14.7)	8.24(12.7)	8.62(13.8)	33.45(52.8)	8.95(14.3)

a) Range of Hybrid 50 km(30mi) electric, 300 km (180 mi) ICE

b) Cost of Fuel Assumed;
electricity 4¢/kWh
Gasoline 15¢/1 (60¢/gal.)

TABLE 2-4. LIFE CYCLE COST OF OWNERSHIP OF ELECTRIC AND ICE VEHICLES OF INTEREST TO THE STUDY

VEHICLE CHARACTERISTIC	ELECTRIC AND HYBRID VEHICLES				INTERNAL COMBUSTION ENGINE (ICE) VEHICLES				
	2 PAX EV Near Term Pb Acid Battery	4 PAX EV (Intermediate Technology Ni-Zn Battery)	Light Duty Van (Intermediate Technology Ni-Zn Battery)	Hybrid (Intermediate Technology Ni-Zn Battery)	Low Performance 4 PAX	Low Performance 2 PAX	Chevette	Jeep Van	Honda CVCC
Vehicle Life, yrs	12	12	10	12	10	10	10	6	10
Annual Vehicle Utilization, km/yr (mi/yr)	10000(6200)	16000(10000)	7000(4300)	16000(10000)	10000(6200)	16000(10000)	16000(10000)	7000(4300)	16000(10000)
Total Vehicle Travel km(mi)	120000(75000)	192000(120000)	70000(43000)	192000(120000)	100000(62000)	160000(100000)	160000(100000)	42000(26000)	160000(100000)
Battery Life, Cycles	1000	600	600	600	-	-	-	-	-
Battery Life, Years	5	5	5	5	-	-	-	-	-
Batteries/vehicle(over vehicle life)	2.5	2.5	2.0	2.5	-	-	-	-	-
Base Vehicle Price $	4600	2900	3700	4200	2400	2900	3054	3800	3464
Battery Price $	540	1840	2360	2200	-	-	-	-	-
Vehicle Acquisition Price $	5140	4740	6060	6400	2400	2900	3054	3800	3464
LIFE CYCLE OPERATING COSTS, ¢/Km (¢/mile)									
Base Vehicle Depreciation	3.84 (6.2)	1.51 (2.4)	5.29 (8.5)	2.17 (3.5)	2.40 (3.8)	1.83 (2.4)	1.91 (3.1)	9.05 (14.5)	2.17 (3.5)
Battery Depreciation	1.09 (1.7)	2.36 (3.8)	6.74 (10.8)	2.90 (4.6)	-	-	-	-	-
Interest on Base Vehicle (5% Compounded)	3.09 (4.9)	1.22 (1.9)	3.33 (5.3)	1.75 (2.8)	1.50 (2.4)	1.14 (1.8)	1.19 (1.9)	3.08 (4.9)	1.36 (2.2)
Interest on Battery (5% Compounded)	0.30 (0.5)	0.64 (1.0)	1.89 (3.0)	0.79 (1.3)	-	-	-	-	-
Taxes & Fees (3% Vehicle Acquisition Price/Year)	1.54 (2.5)	0.89 (1.4)	2.60 (4.2)	1.21 (1.9)	0.72 (1.2)	0.56 (0.9)	0.56 (0.9)	1.63 (2.6)	0.65 (1.0)
Sub-Total, Capital Sensitive Costs	9.86 (15.8)	6.62 (10.5)	19.85 (31.8)	8.82 (14.1)	4.62 (7.4)	3.52 (5.1)	3.67 (5.9)	13.76 (22.0)	4.18 (6.7)
Repairs and Maintenance	0.80 (1.3)	1.00 (1.6)	1.50 (2.4)	1.40 (2.2)	1.56 (2.5)	1.56 (2.5)	1.56 (2.5)	6.48 (9.7)	1.56 (2.5)
Insurance	1.00 (1.6)	1.00 (1.6)	3.71 (5.9)	1.00 (1.6)	1.00 (1.6)	1.00 (1.6)	1.00 (1.6)	3.71 (5.9)	1.00 (1.6)
Parking Tolls, etc.	1.25 (2.0)	1.25 (2.0)	4.75 (7.6)	1.25 (2.0)	1.25 (2.0)	1.25 (2.0)	1.25 (2.0)	4.75 (7.6)	1.25 (2.0)
Sub-Total Non Fuel Operating Costs	12.91 (20.7)	9.87 (15.7)	29.81 (47.7)	12.47 (19.9)	8.43 (13.5)	7.33 (11.2)	7.48 (12.01)	28.70 (45.2)	7.99 (12.8)
Cost of Fuel Electric @ 4¢/kWh	0.85 (1.4)	0.90 (1.5)	1.05 (1.7)	0.80 (1.3)					
Gasoline 15¢/l @ 60¢/gal				0.42 (0.6)	0.74 (1.2)	0.91 (1.5)	1.14 (1.8)	4.75 (7.6)	0.96 (1.5)
Total Operating Costs	13.76 (22.1)	10.77 (17.2)	30.86 (49.4)	13.69 (21.8)	9.17 (14.7)	8.24 (12.7)	8.62 (13.8)	33.45 (52.8)	8.95 (14.3)

As a result, intercomparison of quantitative results among institutional factors was not attempted in this study.

In summary, then, relevant institutional factors of a direct or indirect nature were identified, the potential bias was identified and defined, a comparative, preferably quantitative measurement was performed, and the significance of the bias consequence was stated. Where appropriate, recommendations were made.

Tables 2-3 and 2-4 are described in more detail in Appendix A. The nine vehicles used in this study are representative of current and likely technology and were arrived at by compromise among the several factors involved. With the exception of the Chevette, the Honda and the Jeep van, the vehicles are synthetic.*

It should be emphasized that many of the analyses and evaluations of bias consequence are traceable to the performance and cost characteristics of the vehicles used in this study (Tables 2-3 and 2-4). These are believed to be realistic estimates over the time frame of the Act. Projections of future technology are, however, notoriously risky. Significant improvements in electric and hybrid vehicle technology would make significant differences in the results of this study.

*At the same time that this study was being conducted, the General Research Corporation, Santa Barbara, CA was developing electric and hybrid vehicle performance and design goal criteria in a parallel effort for the U.S. Energy Research and Development Administration. The performance criteria in Tables 2-3 and 2-4 were developed in conjuction with GRC during the course of their study. The details of the analysis and methodology employed are in the report "Electric and Hybrid Vehicle Performance and Design Goal Determination Study", prepared under Contract EY-76-C-03-1215 by GRC for ERDA and currently being published. Performance criteria for the near term 2-passenger EV in both studies are virtually the same. The design goals for the 4-passenger EV, the light-duty EV van and the hybrid vehicle used in this study are more conservative than those in the GRC study and reflect GRC's working numbers at the time when this report "froze" its EHV values for the institutional factors analyses.

3.0 TAXES AND REGULATIONS

3.1 INTRODUCTION

The study of the institutional factors in the areas of federal and state laws and regulations that may bias surface transportation systems toward vehicles of particular characteristics was conducted by an examination of those sections of the United States Code and of the codes of four focus states (California, Florida, Massachusetts and Michigan) that might relate to motor vehicles. In a general sense these areas include: customs and tariffs; electricity/utilities; fuels; health and safety; motor vehicles; pollution control; streets and highways; taxes and license fees.

Within each of the areas noted, the criteria for determining the presence of bias was to take note of those laws and regulations which:

- explicitly prohibit, limit, or restrict the use of a specific type of vehicle;
- explicitly tax vehicles by form or mode of power;
- explicitly tax vehicles by form of engineering characteristics other than mode of power;
- explicitly prohibit, limit, or restrict the availability of fuel for a particular vehicle;
- explicitly and directly impact the structural and other engineering characteristics of a vehicle;
- direct taxes/excises on fuel;
- direct taxes/excises on vehicle components;
- enable legislation to provide the basis of rules/ regulations that may have the effect of prohibiting, limiting or restricting the use of a specific type of vehicle;
- make provisions which might relate, although tangentially, to the form or mode of vehicle power, its components or source of power;

- provide the basis for discretionary authority to prohibit, limit, or restrict the use of a vehicle.

In assessing the impact of both the federal and state laws and regulations with regard to bias, it was necessary to recognize that a measurement of bias, in both a qualitative and quantitative sense, should be limited to direct effects. An example of this assessment may be noted from the tax laws applicable to petroleum. Depletion allowances on the federal level or severance taxes on the state level on mineral resources were considered as provisions that more directly related to the economic system in defining the cost of a particular product, i.e., motor vehicle fuels or the cost of doing business and not specifically related to vehicles. However, excise taxes on both the federal and state level on such fuels were considered as a direct effect. Similarly, those provisions which were concerned with the siting of electric power plants were considered as indirect and outside the study, whereas a tax on the use of electricity was included in the study.

A further categorization to the assessment and measurement of bias should reflect both legislative intent and administrative objectives inherent in the promulgation of laws and regulations. This became especially apparent in the review of state laws and regulations when there was a specific provision for electric vehicles. Three general categories of bias were therefore identified.

- <u>Intentional Bias</u> - characterized by a law or regulation that made specific note of applicability to electric vehicles.
- <u>Accidental Bias</u> - characterized by a law or regulation which, though not specifically referring to electric vehicles, is applicable to the issue of bias because of the inherent features of vehicles such as mode of power, weight, engineering or performance features.

- <u>Discretionary Bias</u> - characterized by a law or regulation (predominantly those related to streets and highways or public health and safety) which provide a discretionary basis to enforcement officials and which might result in a bias towards vehicles of particular characteristics.

3.2 FEDERAL LAWS AND REGULATIONS

3.2.1 <u>Introduction</u>

With the exception of federal excise taxes and tariffs, all federal laws and regulations having a direct effect on the question of bias towards vehicles of particular characteristics basically address performance features of motor vehicles and reflect a national policy of concern for public health and safety. These include the Clean Air Act (42USC1857 <u>et seq.</u>), the Noise Control Act (42USC4901, <u>et seq</u>.), the National Traffic and Motor Vehicle Safety Act of 1966 (15USC1381, <u>et seq</u>.), and the Motor Vehicle Information and Cost Savings Act (15USC1901, <u>et seq</u>.). It should be noted that most of these laws and regulations have developed within the last fifteen years and only with the regulations pursuant to the National Highway Safety Transportation Act is there any specific mention of electric vehicles so as to constitute intentional bias. All other federal provisions were viewed as resulting in accidental bias.

3.2.2 <u>Taxes</u>

At present, the federal government imposes excise taxes on the sale of gasoline and other petroleum products used to fuel motor vehicles, on motor vehicle lubricating oil and tires and tubes. There are presently no excise taxes applied to the sale of electricity that would be used to charge the batteries of an electric vehicle. This disparity is a bias against internal combustion engine vehicles and in favor of electric vehicles. While motor fuel excise taxes represent a modest cost to the user, they represent a major source of revenue for the federal government.

The replacement of a significant number of ICE vehicles by electric vehicles would result in a reduction of this revenue. In view of the fact that the motor vehicle fuel excise is collected to support and maintain the highway system, it is unlikely that electric vehicles, if marketed in significant numbers, would long remain exempt from an equivalent federal tax.

3.2.2.1 Taxes on Motor Vehicle Fuels - Sections 4081 and 4082 of the Internal Revenue Code (26USC) impose a tax of 1¢ per liter (4¢ per gallon) on gasoline (meaning "all products commonly or commercially known or sold as gasoline which are suitable for use as a motor fuel"). This tax is scheduled to be reduced to 0.4¢ per liter (1 1/2¢ per gallon) on or after October 1, 1979. The definitions section of this excise tax and the structure of the tax create a condition whereby it can be assumed that there is an effective pass-through of this tax to the ultimate consumer.

Section 4041 imposes a tax of 1¢ per liter (4¢ per gallon) on diesel fuel for highway vehicles and 1¢ per liter (4¢ per gallon) on special motor fuels provided that no tax for such fuels has been paid under Sections 4081 and 4082. This tax is scheduled to be reduced to 0.4¢ per liter (1 1/2¢ per gallon) on or after October 1, 1979.

Section 4084 makes reference to Section 6420 for exemption from the excise tax for gasoline used on the farm for farming purposes and to Section 6421 for exemption from the excise tax for gasoline used for certain non-highway purposes or by local transit systems.

Section 6421 provides for a rebate of 0.5¢ per liter (2¢ per gallon) of gasoline excise tax paid multiplied by the percentage that scheduled service commuter fares bear to total passenger fare revenue, provided that such percentage is at least 60 percent for any calendar quarter in which the rebate is claimed. The thrust of this exemption is to foster intra-city transportation systems for commuters. The impact of this provision is to lessen the effect of the excise tax on gasoline for mass transportation vehicles within an urban area.

3.2.2.2 Tax on Lubricating Oils - Section 4091 of the Internal Revenue Code (26USC) imposes a tax of 1.6¢ per liter (6¢ per gallon) on lubricating oils used in highway motor vehicles. This tax results in a minor bias against ICE vehicles.

3.2.2.3 Tax on Tires and Tubes - Sections 4071 and 4072 of the Internal Revenue Code (26USC) impose a tax of 22¢ per kilogram (10¢ per pound) on rubber (which "includes synthetic and substitute rubber") for tires of the type used on highway vehicles. The bias effect of this excise tax is then directly related to surface transportation systems of particular characteristics where those characteristics define a tire size requirement (i.e., weight of the tire exclusive of metal rims or rim bases).

3.2.2.4 Impact of Federal Excise Taxes on the Vehicle User - The cost of federal taxes to the users of the various vehicles of interest to the study are summarized in Table 3-1. As can be noted in Table 3-1, the federal excise taxes have a minor impact on the cost of operating the various vehicles. Most significant is the gasoline tax. In Table 3-1, it was assumed that the cost of lubricating oil excise taxes to an individual owner were 1.7% of the cost of the gasoline tax. This is the ratio of the federal revenue derived from motor oil excise to the federal revenue derived from gasoline and special fuel excises. Tire and tube excise revenue would be slightly larger for electric vehicles than ICE vehicles because of the larger required tire size.

3.2.2.5 Impact of Revenue Derived from Excise Taxes - The various excise taxes mentioned above are a significant source of revenue to the federal government, as outlined in Table 3-2. Most of this is derived from the sale of gasoline or motor fuels.

The presence of a significant number of electric vehicles on the road would have an impact on these revenues. If the equivalent of a million ICE subcompacts were replaced by electric vehicles, federal tax revenue derived from the sale of motor fuel would

TABLE 3-1 IMPACT OF FEDERAL EXCISE TAXES ON VEHICLES OF INTEREST

VEHICLE CLASS		2 PASSENGER AUTOMOBILE		4 PASSENGER AUTOMOBILES					LIGHT DUTY VANS	
VEHICLE		ELECTRIC (near term)	LOW PERF. ICE	ELECTRIC	HYBRID	LOW PERF. ICE	CHEVETTE	HONDA CVCC	ELECTRIC	ICE
Excise Taxes over Vehicle Life										
Gasoline Motor Fuel Tax @ 1¢ per liter (4¢/gallon)	$	-	49.00	-	53.28	97.60	121.20	102.40	-	132.96
Lubricating Oil Tax @ 1.5 ¢ per liter (6¢/gallon)	$		0.83		0.91	1.66	2.06	1.74	-	2.26
Tire & Tube Tax @ 22¢/kg (10¢/lb)	$	16.08	16.08	33.76	39.04	17.40	17.40	16.08	30.96	17.44
Total	$	16.00	65.91	33.76	93.23	116.66	140.66	120.22	30.96	152.66
Federal Excise Taxes per year	$/yr	1.34	6.59	2.81	7.77	11.67	14.07	12.02	3.10	25.44
Federal Excise Taxes per Km.	¢/Km	0.01	0.07	0.02	0.05	0.07	0.09	0.08	0.04	0.36

TABLE 3-2 1975 ESTIMATED REVENUE TO THE FEDERAL GOVERNMENT OF APPLICABLE EXCISE TAXES

TAXES ON:	$ MILLION
Gasoline	3,839.4
Special Fuels	362.6
Motor Fuel - Subtotal	4,202.0
Lubricating Oils	58.9
Tires and Tubes	611.3
Tread Rubber	23.0
Total Revenue from Applicable Excises	4,895.2

Source: U.S. Department of Transportation
Federal Highway Administration
"Highway Statistics, 1975, Sect. 1.
Vehicles, Drivers & Fuels",
Tables FE-7 and FE-8 (June 1976)

decrease by $12 million per year. The total decrease in excise tax revenue would be approximately $11 million per year. If the equivalent of 100,000 ICE vans were replaced by electric vans, federal revenues would decrease by abour $2.3 million per year.

It is doubtful that electric vehicles would reach a significant penetration of the total vehicle fleet before they would become subject to a tax equivalent to the one presently imposed on motor fuels for ICE vehicles.

3.2.2.6 Federal Income Taxes - Another area of bias in the federal tax code occurs in Section 164 (Internal Revenue Code) which provides a deduction against income for state and local taxes paid on personal property and on the sale of gasoline, diesel fuel and other motor fuels. This deduction provision has effect only where there is a difference at the state and local level in the valuations placed on vehicles with different characteristics. Since there are state and local institutional factors that bias the tax assessment value of a vehicle, the deduction provision of Section 164 has the effect of lessening such bias. Similarly, the deduction provision for state and local taxes paid on the sale of gasoline, diesel fuel and other motor fuels also has the effect of lessening the bias associated with such state and local taxes.

There are two additional factors, however, that determine the extent to which any bias would have effect. First, the provisions of Section 164 are only available to taxpayers who itemize deductions on their Federal Income Tax returns. Second, the extent to which such bias is lessened is related to the taxpayer's bracket in the graduated income tax rates. As the adjusted gross income of the taxpayer is increased, the effect of the Section 164 deductions in lessening any state or local bias also increases.

3.2.3 Customs and Tariffs

A review of customs regulations and tariffs revealed no significant bias towards vehicles of particular characteristics other than provisions which incorporate other federal law and regulations. For example, any imported motor vehicle or motor vehicle engine must comply with the Clean Air Act and such vehicles are subject to the Federal Motor Vehicle Safety Standards. Such biases are reviewed elsewhere.

In the specific tariff schedules, there are some distinctions as to motor vehicles or components imported from Canada as contrasted with other countries. Because of the integrated operations of the United States manufacturers in North America, many imports from Canada are duty free. These tariff rates do not suggest a bias towards vehicles of particular characteristics, however, because such rates, varying though they may be, are inherently represented in the cost of the product and have therefore already been reflected in cost estimates used as a baseline in this study (see Appendix A).

3.2.4 Federal Motor Vehicle Safety Standards (FMVSS)

3.2.4.1 Applicability of FMVSS to Electric Vehicles - The applicability of the Federal Motor Vehicle Safety Standards (49CFR571) and Federal Bumper Standards (49CFR581) to electric vehicles appears to be established indirectly. Section 571.5a of Subpart A of the standards refers to matter incorporated by reference as follows:

> "(a) Incorporation. There are hereby incorporated by reference, into this part, all materials referred to in any standard in Subpart B of this part that are not set forth in full in the standard. These materials are thereby made part of this regulation. Materials subject to change are incorporated as they are in effect on the date of adoption of this part, unless the reference to them provides otherwise."

Section 571.124 (Standard No. 124), accelerator control systems, establishes requirements for the return of a vehicle throttle to the idle position when the driver removes the activating force from the accelerator control. Paragraph S4.2 of this standard makes particular reference to electric vehicles as follows:

> "S4.2 In the case of vehicles powered by electric motors, the word "throttle" and "idle" refer to the motor speed controller and motor shutdown, respectively."

Based on the above, all applicable FMVSS should apply equally to electric vehicles at the present time. This situation may change in the future depending on actions that NHTSA may take concerning electric vehicles pursuant to the safety studies required by the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976 (Pl 94-413, Section 13(d)).

3.2.4.2 Nature of the Bias due to the FMVSS - If it is assumed that the existing Federal Motor Vehicle Safety Standards apply equally to all types of motor vehicles, then all applicable safety standards create some bias against electric vehicles relative to ICE vehicles. In general, a manufacturer has to add components, and thus weight, to an automotive vehicle to satisfy the standards. The additional vehicular weight imposed to satisfy these standards is the major source of bias because of the different weight propagation characteristics of ICE and electric vehicles.

As discussed in more detail in Appendix B, an electric vehicle has a weight propagation factor of 1.75 as compared to 1.45 for an ICE vehicle. Furthermore, the propagated weight is much more costly for an electric vehicle than for an ICE vehicle. It was estimated that adding 45 kilograms (100 pounds) of equipment to the model 4-passenger electric vehicle would result in 34 kilograms (75 pounds) of propagated weight which would increase the retail price of this automobile by $160. In comparison, adding the same 45 kilograms (100 pounds) of equipment to an equivalent ICE automobile would result in only 20 kilograms (45 pounds) of propagated weight increasing the retail price of the automobile by $30. These figures do not include the price of the added 45 kg (100 pounds) of equipment itself.

A corollary source of bias in some of the Federal Motor Vehicle Safety Standards is the speed specified in the test procedures. As the prescribed test speed increases, the test becomes more demanding and more equipment is needed on the vehicle to meet the standards. This reinforces the weight propagation bias.

An additional source of bias in some of the Federal Motor Vehicle Safety standards is the prescribed use of test loads that are equal to or proportional to the vehicle weight. An electric vehicle of given characteristics is heavier than a comparable ICE vehicle and will be subjected a more demanding test than the comparable ICE vehicle.

Some of the Federal Motor Vehicle Standards specifically address the crashworthiness of the fuel tank on an ICE vehicle. In the absence of similar specific standards on the crashworthiness of the battery pack on an electric vehicle, these standards represent a bias in favor of electric vehicles.

The Federal Motor Vehicle Safety Standards promulgated under 39CFR571 and 39CFR581 are listed in Table 3-3. In this table, the applicability and nature of the bias of the specific standards for or against electric or ICE vehicles of interest are identified.

3.2.4.3 Quantitative Analysis of FMVSS Bias Against Electric Vehicles due to Weight - Other than a 1974 study by Ford Motor Company (3-1), there appears to be little data in the literature concerning weight penalties imposed on electric vehicles as a result of compliance with the FMVSS. As shown in Table 3-4, that study estimated that converting 1975 model year ICE vehicles to electric vehicles meeting 1976 Federal Safety Standards would require the addition of about 225 kilograms (400 pounds) of safety equipment over the original equipment present on the ICE vehicles. The additional safety equipment represents 13% to 16% of the final vehicle weight.

A difficulty with the Ford data, however, is that the weight changes assigned to the electric vehicles include both modifications to vehicle weights and changing federal standards. For example, the electric vehicle safety weight increases include the additional weight of air bag restraint systems which was not present in the original ICE vehicles. Another difficulty with using the Ford data is that the requirements of the federal standards have changed in the past few years. Nevertheless, the general results of the

TABLE 3-3. SUMMARY OF FEDERAL MOTOR VEHICLE SAFETY STANDARDS

Standard Number	Title	Not Applicable	Applicable No Bias	Applicable Bias Against ICE	Applicable - Bias Against Electric Vehicle		
					Results in Added Weight to Vehicle	Test Method is Function of Vehicle Weight	Test Method Specified Vehicle Speed
101	Control Location, Identification and Illumination		X				
102	Transmission Shift Lever Sequence, Starter Interlock		X				
103	Windshield Defrosting and Defogging Systems				X		
104	Windshield Wiping and Washing Systems				X		
105	Hydraulic Brake Systems				X		
106	Brake Hose	X					
107	Reflecting Surface		X				
108	Lamps, Reflective Devices and Associated Equipment				X		
109	New Pneumatic Tires				X	X	X
110	Tire Selection and Rims				X	X	
111	Rearview Mirrors				X (minor)		
112	Headlamp Concealment Devices	X(if not used)			X (if used)		
113	Hood Latch System				X		
114	Theft Protection				X		
115	Vehicle Identification Number		X				
116	Motor Vehicle Brake Fluid	X					
117	Retreaded Pnuematic Tires				X	X	X

TABLE3-3. SUMMARY OF FEDERAL MOTOR VEHICLE SAFETY STANDARDS

Standard Number	Title	Not Applicable	Applicable No Bias	Applicable Bias Against ICE	Applicable - Bias Against Electric Vehicle		
					Results in Added Weight to Vehicle	Test Method is Function of Vehicle Weight	Test Method Specified Vehicle Speed
118	Power Operated Window Systems	X(if not used)			X(if used)		
119	New Pneumatic Tires for Vehicles other than Passenger Vehicles				X	X	X
120	Tire Selection and Rims for Non-passenger vehicles				X	X	X
121	Air Brake Systems	X					
122	Motorcycle Brake Systems	X					
123	Motorcycle Controls and Displays	X					
124	Accelerator Control Systems				X		
125	Warning Devices	X					
126	Truck Camper Loading	X					
201	Occupant Protection Interior Impact				X		
202	Head Restraints				X		
203	Impact Protection for the Driver from the Steering Control System		X				
204	Steering Control Rearward Displacement		X				
205	Glazing Materials		X				
206	Door Locks and Door Retention				X	X	X
207	Seating Systems		X				
208	Occupant Crash Protection				X		X
209	Seat Belt Assembly				X		

TABLE 3-3. SUMMARY OF FEDERAL MOTOR VEHICLE SAFETY STANDARDS (Cont.)

Standard Number	Title	Not Applicable	Applicable No Bias	Applicable Bias Against ICE	Results in Added Weight to Vehicle	Test Method is Function of Vehicle Weight	Test Method Specified Vehicle Speed
210	Seat Belt Assemblies Anchorages				X		
211	Wheel Nuts, Wheel Disks & Hub Caps		X				
212, 212-76	Windshield Mounting				X		X
213	Child Seating System	X					
214	Side Door Strength				X	X	
215	Exterior Protection				X	X	X
216	Roof Crush Resistance Passenger Cars				X	X	
217	Bus Windows Retention and Release	X					
218	Motorcycle Helmets	X					
219-75	Windshield Zone Intrusion				X	X	X
220	Schoolbus Rollover Protection	X					
221	Schoolbus Body Joint Strength	X					
222	Schoolbus Seating and Crash Protection	X					
301-75	Fuel System Integrity			X			
302	Flammability of Interior Materials		X				
Part 581	Bumper Standard				X	X	X

TABLE 3-4 WEIGHT INCREASES FOR SAFETY

	City Car (Pinto)	Metropolitan Car (Comet)
Curb Weight, I.C. Drive, Kilograms (Pounds)	1,096 (2,436)	1,317 (2,926)
Curb Weight, Electric Drive, Kilograms (Pounds)	1,302 (2,893)	1,407 (3,126)
Difference, Kilograms (Pounds)	206.0 (457)	90.0 (200)
Additional Weight Increase to EV Needed for Safety, Kilograms (Pounds)	242.0 (538)	203.0 (450)
Modified Curb Weight, Kilograms (Pounds)	1,544 (3,431)	1,609 (3,576)
Safety Weight / Modified Curb Weight	0.16	0.13

Source: Electric Vehicle Systems Study
L.R. Foote et al.
Ford Motor Company
Research & Engineering Center
Electric Systems Department
Dearborn, Michigan
1974

Ford study indicate that the weight of equipment and components that are placed on an electric vehicle to satisfy the FMVSS will represent a significant fraction of the weight of the vehicle.

Two further analyses were carried out in this study for purposes of illustration. The relative impacts of the Federal Tire Standards (FMVSS 109, 110, 119, 120) on the various vehicles of interest are discussed in Appendix B. FMVSS 215, Exterior Protection,was analyzed by comparing its impact on a 4-passenger electric vehicle as compared to a 4-passenger Chevette ICE. (Appendix B) These analyses clearly indicate the disproportionate effect that the imposition of additional weight has on electric vehicles.

3.2.4.4 Fuel System Integrity Standards - Bias Against ICE Vehicles - The question of fuel leakage is addressed specifically in Standard 301-75 as well as in Standard 215 and in the Bumper Standard (581.5). Standard 301-75 applies to "passenger cars...(that) use fuel with a boiling point above 0°C (32°F)..." In this context the fuel leakage standards are construed to apply only to vehicles that consume a volatile liquid such as gasoline or methyl alcohol as a fuel. The term fuel does not appear to lend itself to include battery liquids. Therefore, sections of the FMVSS that refer to the integrity of fuel systems and resulting fuel leakage form a bias against vehicles powered by liquid fuels.

3.2.4.5 Battery Crashworthiness - The FMVSS do not explicitly specify the crashworthiness characteristics of batteries that would be used to power electric vehicles. In fact, the term battery appears only once in the FMVSS as part of Standard No. 113 where it is specified that a hood label is required for a battery compartment forward of the windshield.*

*It is to be noted that batteries' electrical systems are considered indirectly to the extent that they are covered in SAE, ASTM and ASI standards which are incorporated by reference in the FMVSS.

Standard 215 and Part 581, however, impose implicit requirements on the crashworthiness of the battery pack used to power an electric vehicle, insofar that these standards specify that:

> "The vehicle's propulsion, suspension, steering or braking systems shall remain in adjustment and shall operate in the normal manner." (49CRF571.215 S5.3.5 and 49CFR581.6(c)5)

The absence of specific battery standards is an issue rather than a bias. At the moment, this issue is being studied by NHTSA. It was one of the topics addressed at NHTSA's public hearing on safety aspects of electric vehicles (July 14, 1977), (3-2).

The meeting focused on the anticipated usage of electric private and commercial vehicles, the appropriateness of current and future safety standards to protect occupants of such vehicles, and safeguards for electric and hybrid vehicles when involved in collisions with conventional vehicles. Specific issues that were addressed include:

(1) Anticipated usage by private individuals of small and intermediate size electric and hybrid automobiles.

(2) Anticipated size and usage by commercial establishments or municipalities of electric and hybrid vehicles such as delivery vans, trucks, and buses.

(3) Appropriateness of existing Federal motor vehicle safety standards for electric and hybrid vehicles.

(4) Development of new Federal motor vehicle safety standards to address safety problems unique to electric and hybrid vehicles. Possible areas of concern are as follows:

(a) Shock hazard from batteries, either in normal use or in a collision environment.

(b) Spillage of electrolyte from batteries during a collision.

(c) Potential for explosion of batteries

(d) Violent movement of batteries during a collision.

(e) Slower acceleration than conventional vehicles, increasing chances of collision during merging into traffic.

(f) Uncontrolled release of energy (e.g., during a collision) from an energy storage device in a hybrid vehicle, such as a hydraulic system or a flywheel.

(5) Application of Federal motor vehicle safety standards to electric and hybrid vehicles based upon their usage and other factors.

A report is expected from NHTSA on the subject.

3.2.5 Federal Motor Carrier Safety Regulations

The Federal Motor Carrier Safety Regulations (49CFR390-397) do not apply to vehicles of interest to the study since these are all lightweight vehicles with a gross vehicle weight of less than 10,000 pounds, except to the extent that (49CFR390.17): a) a vehicle is being used to transport passengers for hire; or b) a vehicle that is being used to transport hazardous materials of a type or quantity that requires the vehicle to be marked or placarded in accordance with 8177.823 of this title.

Section 390.33 further restricts the applicability of the rules with regard to vehicles being used to transport passengers for hire. Regulations 391 to 397 apply only if vehicles and drivers are used beyond a municipality or the commercial zone thereof as defined by the Interstate Commerce Commission. In the State of Hawaii, Regulations 391 to 397 also apply if vehicles and drivers are used wholly within a municipality or the commercial zone thereof.

The Federal Motor Carrier Safety Regulations therefore would apply to vehicles of interest here only if they were used to transport passengers for hire to any extent in the State of Hawaii and on an interurban basis elsewhere. With the exception of certain provisions of Part 393, these regulations are neutral toward particular vehicle characteristics.

Part 393 specifies the parts and accessories necessary for safe operation of motor vehicles which fall under the Act in a fashion similar to the FMVSS. For example, Regulation 393.11, Lamps and Reflectors, Small Buses and Trucks, is a summary of FMVSS 108. It imposes a bias against electric vehicles to the extent that the presence of a specific piece of equipment is required, adding weight to a vehicle.

In terms of this study, the regulations under Section 393 differ from the Federal Motor Vehicle Safety Standards in one aspect. Paragraphs 393.27 to 393.33 inclusive deal with the electrical circuit of a motor vehicle, as summarized in Table 3-5. Since all ICE vehicles on the road are equipped with an electric circuit, these regulations would apply equally to ICE and electric vehicles and would not result in a bias. A bias could exist to the extent that an electric vehicle would require larger overload protective devices or a larger battery cover commensurate with a larger battery and higher voltage. These regulations might become incorporated in a future FMVSS.

3.2.6 Air Pollution Control Laws

3.2.6.1 Introduction - The Clean Air Act (42 U.S.C. 1857 et seq.) authorizes the Administrator of EPA to establish National Standards for air quality, to support local, state and regional authorities in the development of their air pollution prevention and control programs, establish emissions standards for new stationary sources, establish standards for motor vehicle emissions, and regulate automotive fuels and fuel additives.

The Act also authorizes the restriction of the use of, or the banning of, motor vehicles as part of local, state or regional implementation plans developed to control air pollution crises. The issue of whether or not the use of electric vehicles would be curtailed in the implementation of transportation control plans is not clear (see 40 CFR 51 Appendix M). The banning of ICE

TABLE 3-5 FEDERAL MOTOR CARRIER SAFETY REGULATIONS DEALING WITH THE ELECTRIC CIRCUIT OF A MOTOR VEHICLE

SECTION	TITLE
393.27	Wire Specifications
393.28	Wiring to be Protected
393.29	Grounds
393.30	Battery
393.31	Overload Protective Devices
393.32	Detachable Electrical Connections
393.33	Wiring Installations

vehicles, but allowing electric vehicles to operate, results in additional bias against ICE vehicles. If electric vehicles were also to be banned, the Act would then be considered biased against all automotive vehicles.

The issue of the relative impacts of electric and ICE vehicles on air quality is complex if one takes into account the emissions that result from the generation of the electric power needed to propel the electric vehicles. This is further discussed in Appendix C. The merits and logic of including an electric vehicle in a transportation plan depends on how and where the required electric power is generated.

The Clean Air Act results in both direct and indirect biases on the mode of power used to drive a motor vehicle. There is a direct bias against ICE vehicles since the Act specifies the emission of air pollutants from new motor vehicle. To meet these emission standards, ICE vehicles have to be equipped with pollution control equipment that increases their first cost and their life cycle operating costs. This bias against ICE vehicles results in an accidental bias in favor of electric vehicles.

The provisions of the Clean Air Act stipulate the allowable emissions of air pollutants from stationary sources, such as power plants, factories, refineries, mines, etc. These provisions have indirect effects on the operations of both electric and ICE vehicles. To meet the standards, all stationary facilities in the infrastructures of the industries producing and distributing electricity and petroleum have to be equipped with suitable emission control systems. Any bias as to a specific type of automotive vehicle that results from the relative impacts of the Clean Air Act on these stationary facilities is diffuse. The impact of the Clean Air Act on stationary facilities was considered to result in indirect effects as to the mode of vehicle power and for which no measurement of bias was isolated.

3.2.6.2. Clean Air Act as Applied to ICE Automobiles and Light Duty Trucks - The Clean Air Act requires the Administrator of the Environmental Protection Agency (EPA) to establish standards regulating fuels and fuel additives and limiting the emission of air pollutants from new motor vehicles. The Act prohibits the individual states, with the exception of California, which had prior more stringent regulations, from developing such standards of their own which may conflict with the federal regulations.

Fuels may not be sold unless registered with EPA, and sale of certain fuels found to endanger the public health or to impair significantly the functioning of emission control devices may be banned.

The Clean Air Act, as amended in October, 1965, gave the Administrator of the Environmental Protection Agency responsibility for establishing standards for controlling emissions from new motor vehicles. In 1970, the Clean Air Act was again amended to require that carbon monoxide (CO) and hydrocarbons (HC), beginning with model year (MY) 1975, be reduced by at least 90 percent from 1970 levels. The oxides of nitrogen (NO_x) emissions were required to be reduced at least 90 percent from 1971 levels for MY 1976 autos. The statutory standards through 1978 are shown in Table 3-6. Those for 1975 reflect a one-year suspension by the EPA Administrator in 1973, while the 1976 standards reflect the one year deferral in the Energy Supply and Environmental Conservation Act of 1974. New legislation is necessary to change either the compliance dates or the standards. The existing 1977 California standards for passenger automobiles are 0.41 HC/9.0 CO/1.5 NO_x (California Health and Safety Code Section 4300 et seq.)

There are different emission standards for trucks than for automobiles. These apply to commercial vans. Present standards (MY 1977) for light duty trucks are 2.0/20/3.1 (Federal) and 0.9/17/2.0 (California).

TABLE 3-6. CLEAN AIR ACT EMISSIONS STANDARDS - LIGHT DUTY PASSENGER VEHICLES

1970 Statutory	Model Year	HC	CO	NO_x
	1972-74	3.4*	39.0*	3.0*
	1975	1.5	15.0	3.1
	1976	1.5	15.0	3.1
	1977	0.41**	3.4**	2.0
	1978	0.41	3.4	0.4

*1973-74 Test Procedures.
**Suspended until 1978.

The Clean Air standards described above, apply to the first 50,000 miles or five years of the life of automobiles and light duty trucks. EPA was given authority to postpone the deadline for one year, to establish interim standards, and to establish limitations for other classes of mobile sources. As already noted, the EPA Administrator has given two one-year extensions. The statutory standards cannot be delayed again without Congressional action. Such amendments are currently being considered by both the Senate and the House.

The House passed the Dingell-Broyhill Bill (HR 2380). This Bill provides that automobiles manufactured during model years 1978 and 1979 meet the same emissions standards now applicable for model year 1977 (1.5/15/2.0). For model years 1980 and 1981 the standards would be 0.9/9/2.0. For 1982 and subsequent model years, the standards would require 0.41 gpm for hydrocarbons and 3.4 gpm for carbon monoxide, leaving the standard for nitrogen oxides to the administrator of the EPA. The Senate passed a Bill introduced by Senator Baker that also postpones implementation of stricter standards on auto emissions until the 1980 model year. There are significant differences in the House and Senate Bills that will have to be resolved in a conference between the bodies. However, it is very unlikely that 1978 Model Year automobiles will have to meet the existing statutory standards.

The proposed automobile standards will not apply to light duty trucks. The 1977 Federal Standards will apply to model year 1978 light duty trucks. New standards will apply to MY 1979 light duty trucks. The new standards, which will apply to non-passenger automobiles with a GVW of 8500 lbs or less, will be 1.7/18/2.3 (FR 41,250, 56.316 et seq. Dec. 28, 1976).

3.2.6.3 Motor Vehicle Emission Inspections - The Clean Air Act established standards for emissions from new motor vehicles during the first 80,000 km (50,000 mi) or 5 years of use. There has been continuing concern about the degradation of emission control systems with use of a vehicle. Title III of the Motor Vehicle Information and Cost Savings Act (15USC1901, et seq.) requires the Administrator of the National Highway Traffic Safety Administration (NHTSA) to specify standards and procedures for motor vehicle emission inspections by state or state-supervised diagnostic inspection projects, on a demonstration basis.

The consequences of this Act are that owners of ICE vehicles will be required to maintain their pollution control equipment in satisfactory condition over the lifetime of the vehicle.

This Act is preemptive upon all state laws and regulations in this area, with the exception of California, which had promulgated stricter requirements prior to the passenger of the Federal Act (California Bus. and Prof. Code, Section 9889.50, et seq.).

3.2.6.4 Impact of Air Pollution Laws and Regulations on Owners of ICE Vehicles - The air pollution regulations increase the cost of owning and operating ICE vehicles. These additional costs accrue from:

a) added first cost of the vehicle due to the installation of the pollution control equipment;

b) higher fuel costs due to lower fuel economy, and, with standard engine designs (the stratified charge engine of the Honda being the exception), the requirement that a grade of lead-free gasoline be used to prevent catalyst fouling; and

c) higher maintenance costs as a result of the presence of the pollution control equipment.

The cost, fuel economy and economic consequences of various specific auto emission control alternatives were analyzed in a recent inter-agency report. (3-3) In particular, this report considered the additional costs that would accrue to the consumer as a result of the imposition of emission standards stricter than the current Federal emission standards for passenger vehicles of various weight classes. The results presented in the referenced study for a light weight passenger automobile (weighing less than 3000 lbs) are presented in Table 3-7.

To obtain the total impact of the regulation of emissions at any given level, it is necessary to add to the above the costs of meeting the current federal standards (1.5/15/2.0). The value of $125 per car has been proposed as an approximate average of the cost to the consumer of meeting this standard relative to no emission control. (3-4) Based on data presented in the Motor Vehicle Goals Study (3-5), the additional costs of maintaining the necessary control equipment are estimated to be approximately $85. Based on historic fuel consumption data (3-6), the fuel efficiency of 1977 passenger automobiles (U.S. models) is as high as, or higher than, the fuel efficiency of passenger automobiles manufactured in the nineteen sixties that had unregulated emissions. These additional costs were added to the costs presented in Table 3-7 to obtain the total cost of emissions control for various emission levels. The life cycle costs presented in Table 3-7 were obtained by dividing these total costs by the total distance travelled by the vehicles (100,000 mi or 160,000 km) over an assumed 10 year life. Depending on the emission level implemented, the life costs of emission controls for light weight automobiles are estimated

TABLE 3-7. INCREASE IN LIFE CYCLE COSTS OF A LOW WEIGHT (a) AUTOMOBILE RESULTING FROM EMISSION CONTROL REGULATIONS

Emission Levels (gm/mi)	Cost Optimal Case (b) Increase in Life Cycle Costs					Fuel Optimal Case (b) Increase in Life Cycle Costs				
	Depreciation	Interest (d)	Fuel (e)	Maintenance	Total (f)	Depreciation	Interest (d)	Fuel (e)	Maintenance	Total (f)
	¢/Km					¢/Km				
1.5/15/2.0	0.08	0.05	-	0.05	0.18	0.08	0.05	-	0.05	0.18
0.41/9/2.0	0.10	0.06	0.04	0.05	0.25	0.13	0.08	(0.04)	0.06	0.23
0.41/3.4/2.0	0.10	0.06	0.04	0.05	0.25	0.13	0.08	(0.04)	0.06	0.23
0.41/9/1.5	0.13	0.08	0.06	0.06	0.33	0.15	0.09	(0.04)	0.06	0.26
0.41/3.4/1.5	0.14	0.09	0.06	0.06	0.35	0.17	0.11	(0.04)	0.06	0.30
0.41/9/1.0	0.14	0.09	0.08	0.06	0.37	0.17	0.11	(0.04)	0.10	0.34
0.41/3.4/1.0	0.19	0.12	0.08	0.06	0.38	0.22	0.14	(0.04)	0.10	0.42
0.41/9/0.4	0.19	0.12	0-0.16	0.10	0.41-0.57	0.22	0.14	(0-0.04)	0.10	0.42-0.46
0.41/3.4/0.4	0.20	0.13	0-0.16	0.11	0.44-0.60	0.27	0.17	(0-0.04)	0.11	0.51-0.55

a) less than 1361 kg (3000 lbs.)

b) Minimum Cost Design to meet emission levels

c) Maximum fuel economy design to meet emission levels

d) 5% annual compound interest for 10 yrs

e) Assumes 1.2¢/kilometer (2¢/mile) base cost (12.8 km/l with 16¢/liter gasoline) (30 mpg with 60¢/gallon gasoline)

f) Increase over unregulated emissions

to range from about 0.2¢/km to 0.6¢/km. This represents approximately 2 percent to 5 percent of the life cycle costs of operation obtained for various four passenger ICE automobiles considered in the study, which were assumed to have 160,000 km of use over a ten year life.

These costs are presented as a general measure of the bias due to air pollution control laws. Insofar as the costs presented in Table 3-7 are for average light weight automobiles, they do not apply to any specific vehicle considered in the present study. The cost of emission control equipment on the subcompact ICE vehicles considered in the study (which are in the 912 kg ((2000 lb)) weight range) will probably be lower than the values presented in Table 3-7. In particular, these costs do not apply to the Honda Civic CVCC which can meet the 1977 Federal and California standards without the usual exhaust treatment system. Whether the Honda Civic CVCC could meet more stringent emission standards for nitrogen oxide without exhaust treatment system is still to be demonstrated.

3.2.7 Energy Policy and Conservation Act (EPCA)

The question of motor vehicle fuel economy was a major concern in the development of the Energy Policy and Conservation Act (EPCA), which was signed into law on December 22, 1975. In Section 2 of this Act, it is stated that the purposes with respect to transportation are:

1. to grant specific standby authority to the President, subject to Congressional review, to impose rationing, to reduce demand for energy through the implementation of energy conservative plans, and to fulfill obligations of the United States under the international energy program;

2. to conserve energy supplies through energy conservation programs, and, where necessary, the regulation of certain energy uses; and

3. <u>to provide for improved energy efficiency of motor vehicles</u>, major appliances, and certain other consumer products (emphasis added).

The most important provision of the Act, for purposes of this study, sets forth motor vehicle fuel standards. Title III. Part A of the Act - "Improving Automotive Efficiency" - specifies the following weighted fleet average fuel economy standards for passenger automobiles mandated by the Congress.

Model Year	Average Fuel Economy Standard km/l (mpg)
1978	7.7 (18.0)
1979	8.1 (19.0)
1980	8.5 (20.0)
1981	9.4 (22.0)
1982	10.2 (24.0)
1983	11.1 (26.0)
1984	11.5 (27.0)
1985 and thereafter	11.7 (27.5)

The 1981 to 1984 standards are the recent recommendations of the Secretary of Transportation (June 26, 1977 announcement).

The Act also calls for separate fuel economy standards for non-passenger automobiles to be determined by the Secretary. Standards presently proposed for model year 1979 light duty trucks are 6.7 km/l (15.8 mpg) (with the 1979 EPA procedure) which is equivalent to 7.3 km/l (17.2 mpg) (with the current EPA procedure) for Jeep type utility vehicles; 7.3 km/l (17.2 mpg) (with the 1979 EPA procedure) which is equivalent to 7.9 km/l (18.7 mpg)(with the current EPA procedure) for all other non-passenger automobiles with a gross vehicle weight of less than 2722 kg (6000 lbs). (3-7)

The issue of the applicability of the Act to electric vehicles was discussed in a 1976 DOT Report to Congress. (3-8) The thrust of this report was that electric vehicles should be exempted from the provisions of the Act.

To the extent that the Act grants standby authority to the President to ration petroleum fuels, it is biased against ICE vehicles. However, within the context of the study, the Act is otherwise unbiased towards either electric or ICE vehicles. This is a consequence of the choice of ICE vehicles chosen in the study which all exhibit fuel economies greater than those specified in the Act. This provision also applies to the Postal Service vehicle chosen in spite of the very poor fuel economy assumed in the cost calculations. The fuel consumption of 3.4 km/l (7.9 mpg) used reflects the mode of use, and is much lower than the fuel economy determined for this vehicle in the EPA driving cycles which were used to characterize its fuel economy in terms of the Act. In the EPA test, the light weight Post Office vehicle had a combined fuel economy of 8.9 km/l (21 mpg), which exceeds the proposed standards for light duty trucks of this class

3.2.8 Emergency Petroleum Allocation Act of 1973

3.2.8.1 Existing Law - Under present law, the price of domestically produced crude oil is regulated by the FEA in accordance with the "Emergency Petroleum Allocation Act of 1973," as amended. (P.L. 93-59) Under these rules, all domestic oil production other than stripper oil (oil produced from fields where the average daily production is 10 barrels or less) is subject to price controls. There are two types of regulated oil under the existing regulations. "Old oil" is the amount of oil produced on a property up to either 1972 production or 1975 production, whichever is less. "New oil" is oil produced on a property in excess of this amount. Old oil is controlled at a price averaging about $5.17 per barrel, and new oil is controlled at a price averaging about $11.64 per barrel. (The price of any particular barrel of oil may vary by several dollars from these averages depending on the quality of the oil and its location.)

Under the present law, there is an entitlements program which is designed to equalize the cost of crude oil to refineries in the United States, regardless of their actual mix of price-controlled and uncontrolled oil. Those U.S. refineries using more than the national average percentage of price-controlled crude oil must buy entitlements from refineries using less than the national average. This purchase and sale of entitlements among refiners offsets the advantages that would otherwise result for the refiners with access to a disproportionate amount of price-controlled crude oil. The FEA sets the price of entitlements each month based on price differences between controlled and uncontrolled oil. Small refiners receive certain advantages under the entitlements program. Under the Act, the price of refinery products such as aviation gasoline, butane, butene, natural gas liquids, natural gasoline and propane are controlled at various levels, including the refinery, the wholesale distributor and the point of retail sale.

Under present law, these controls are mandatory through May 1979, but the President has the discretionary authority to extend them until September 1981.

The issue of petroleum price regulation is a major part of the President's Energy Program. The law is undergoing review and may be extensively modified in the near future.

3.2.8.2 Bias Due to Mandatory Oil Pricing - As a result of the Act, the price of domestic crude oil has been lower than the world wide price of this commodity since the 1973 crisis. The relative costs of imported and domestic crude oils to U.S. refiners since 1974 are shown in Table 3-8. The composite price paid by refiners for their crude supply is also shown in this Table. This composite price has been from \$2.70 to \$3.65 less per barrel than the landed price of imported oil.

Mandatory oil pricing results in a bias in favor of ICE vehicles in that it results in lower gasoline prices than would exist in its absence. As such, it is biased against electric vehicles. To the extent that petroleum products are used in electric utility plants, the Act results in a secondary bias in favor of electric vehicles. This secondary bias is small in comparison to the primary bias first mentioned.

TABLE 3-8. REFINER ACQUISITION PRICE OF CRUDE PETROLEUM

YEAR	PRICE OF CRUDE OIL $/Bbl DOMESTIC	IMPORTED	COMPOSITE
Jan. 1974	6.72	9.59	7.46
1974 Yearly Average	7.18	12.52	9.07
1975 Yearly Average	8.39	13.93	10.38
1976 Yearly Average	8.84	13.48	10.89
Feb. 1977	9.18	14.50	11.80

Source: Federal Energy Administration
Monthly Energy Review

3.2.8.3 Assessment of Bias - A measure of the bias due to the Act is the difference in the costs of operating the ICE vehicles of interest to the study associated with the lower gasoline prices that result from the price controls.

Table 3-8 presents historic data on the average price of crude oil paid by U.S. refiners in recent years. The U.S. average service station price of gasoline (ex tax) for the same period of time is presented in Table 3-9. As shown in Figure 3-1, there is a good correlation between the average price of gasoline (ex tax) in a given year and the average refinery cost of crude oil in the same year, at least for the past few years. The data can be fitted with a straight line. Extrapolating this straight line to a crude oil price of $13.48, the average price of imported oil in 1976, results in an estimate of 14.9c/l (57.5¢/gallon) for the price of gasoline that would have prevailed in 1976 in the absence of the Act. This price is about 2.6¢/l (10¢/gallon) more than the 1976 average ex tax service station price of gasoline of 12.5¢/l (47.44¢/gallon). Since the Act also restricts the

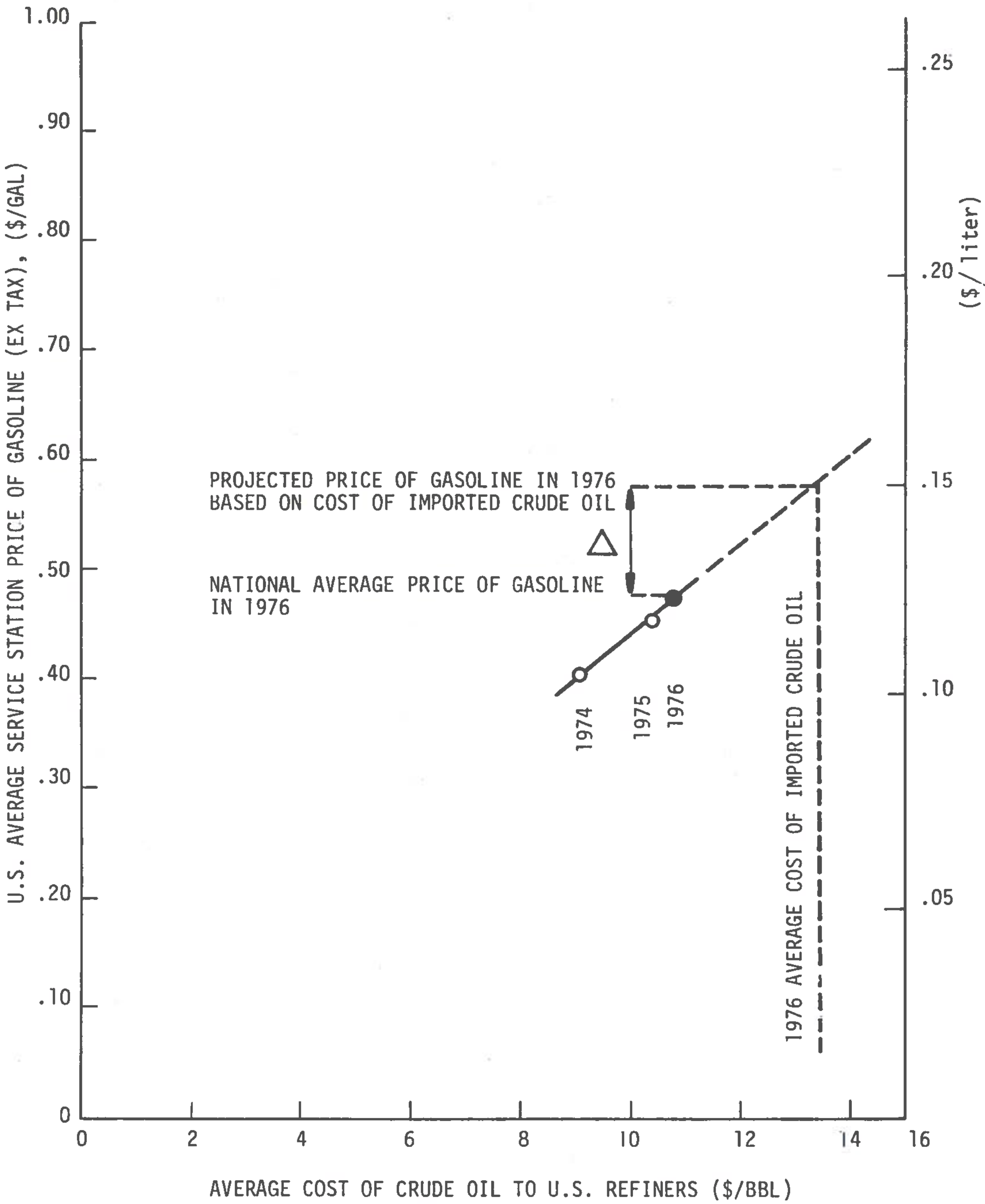

FIGURE 3-1. U.S. AVERAGE RETAIL PRICE OF GASOLINE AS A FUNCTION OF AVERAGE COST OF CRUDE OIL TO U.S. REFINERS

TABLE 3-9. U.S. RETAIL PRICE OF GASOLINE (AVERAGE)

YEAR	U.S. AVERAGE SERVICE STATION PRICE OF GASOLINE EX-TAX ¢/1 (¢/GAL)
1976	12.5 (47.44)
1975	12.0 (45.45)
1974	10.7 (40.41)

Source: National Petroleum News, Factbook Issue, Vol. 69, No.5A (Mid-May 1977)

ability of the refiners, wholesalers and retailers to adjust the prices of their products to accommodate other cost changes, it is quite likely that the actual retail price of gasoline in the absence of the Act would have risen by more than the 2.6¢/1 (10¢/gallon) estimate based on the price of crude oil.

The effect of the price of gasoline on the cost of operating the ICE vehicles of interest to the study is presented in Figure A-2 of Appendix A. A 2.6¢/1 (10¢/gallon) change in the cost of gasoline only has a minor effect on the life cycle costs of operating these vehicles, possibly with the exception of the ICE van.

It is to be pointed out that an assumed price of 15.9¢/1 (60¢/gallon) for gasoline (ex tax) was used in the study. According to Figure 3-1, this price corresponds to an average cost of crude oil of about $14/bbl., which is very close to the current world wide price for crude oil. This assumption has the effect of currently eliminating the bias in favor of ICE vehicles that result from the Act.

3.2.9 Rural Electrification Act

3.2.9.1 Introduction - The Rural Electrification Act of 1936 (7 U.S.C. 901-950(b), as amended, provides for low interest loans by the government for electric and telephone facilities in rural areas. The Act also created the Rural Electrification Administration, presently part of the U.S. Department of Agriculture, as the responsible agency.

Loans pursuant to Section 4 of the Act are made to finance the construction and operation of generating plants, electric transmission and distribution lines or systems to provide initial and continued adequate electric service to persons in rural areas. The loans must be self liquidating within a period not to exceed 35 years, bear interest at 2 percentum per annum and must be reasonably secured in the judgment of the Administrator (of the Rural Electrification Administration). They may be made to persons, corporations, public bodies, and to cooperative non-profit, or limited dividend associations. Preference is to be given to public bodies and to cooperative non profit, or limited dividend associations.

Loans pursuant to Section 5 of the Act are made to the borrowers of funds loaned under Section 4 of the Act for financing the wiring of persons in rural areas and for purchase and installation of electrical and plumbing appliances and equipment, including machinery. The loans are required to be repaid, over a period of not more than five years, and bear interest at two percentum per annum. (Section Sec 3(2) of Title 8). The funds made available to REA borrowers under these loans are reloaned to their consumers.

On May 11, 1973, the Act was amended to establish a revolving fund for insured and guaranteed loans made under Sections 4.5 and 201 (telephone bank loans) under Title III (87 Stat 65, 7 U.S.C. 931-940). Section 305 of the Act, as amended May 11, 1973, authorizes insured loans to be made by the Administrator for the purposes authorized by Sections 4, 5 and 201 of the Act, and though serviced by the Administrator are sold by a Contract of insurance by the Administrator. The standard interest rate on the loans made by the Administrator under this Section is 5 percent, but a special 2 percent rate is applicable on the basis of certain consumer or subscriber density, average earnings per mile, extenuating circumstances or extreme hardship.

3.2.9.2 Resulting Bias - The Rural Electrification Act can be interpreted as resulting in both a direct bias and an indirect bias in favor of electric vehicles. The direct bias evolves out of the provisions of Section 5 that makes available low interest loans for the financing of the purchase of electrical equipment, including machinery, by persons in rural areas. Electric vehicles could be considered to be electrical machinery under the terms of the Act, so that purchasers of electric vehicles in rural areas could qualify for REA loans. Since these loans bear an interest rate that is less than the rate of inflation of about 5 percent to 6 percent per year (3-9), the granting of these loans represent a form of government subsidy. The two percent special rate of interest, payable in current dollars, in equivalent to a 3 percent negative interest rate, or subsidy, in constant dollars. Since a significant part of the life cycle costs of electric vehicles are associated with the capital cost of ownership, the ability to purchase the vehicles with low interest rate loans would make them more competitive economically, in terms of the purchase, with ICE vehicles that would be financed in the normal manner.

The Act also results in an indirect bias in that the cost of electricity to the user is lower than it would have otherwise been if normal financing methods were used. This was designed to offset the higher costs of providing services in rural areas of low population density.

3.2.9.3 Applicability of Section 5 to Electric Vehicles - Through Sept. 30, 1976, a cumulative total of $47.4 million have been made available under the Act for the financing of consumer facilities. This represents 0.3 percent of the total funds that have been made available under the Act since its inception. However, lending activity under Section 5 has diminished in the past few years, with the last loan having been made in 1969.

According to the REA (3-10), a cooperative would typically borrow sums of the order of $25,000, which would then be reloaned to consumers. A consumer typically borrowed sums of about $500 - $600 from the cooperative, at essentially the same interest rate (other than a small service fee of ¼% to ½%) as that charged by the REA. The magnitude of the loan to a consumer is established by the cooperative who remains responsible to the government for the reimbursement of the loan. In addition to electrifying a farmstead, loans under Section 5 have been for purposes of rural development which are not directly related to farming. The electrification of manufacturing plants, sawmills and the installation of an electrically operated ski lift have been financed by such loans. To date, all Section 5 loans have been made for stationary applications. There have been no requests for such loans to finance the purchase of electric vehicles, which could be construed to be mobile electrical equipment or machinery.

The wording of the Act would not prevent such loans from being made. However, there is also no precedent for such loans. If a loan application for the financing of an electric vehicle were made in the future under Section 5, the granting of the loan would depend on the judgment of the Administrator of the REA at the time of the application. If such loans were granted, they would most probably be made at the standard interest rate of 5%, unless it was deemed by the Administrator that the purchase of electric vehicles was in the National interest, and as such resulted in extenuating circumstances that would allow the special interest rate of 2% to apply to loans made for their purchase.

3.2.9.4 Assessment of Bias - Of the various electric and hybrid vehicles considered in the study, the electric van is the most suited to the needs of the farmer (see Appendix D). A measure of the bias towards electric vehicles resulting from Section 5 of the Rural Electrification Act is the reduction in life cycle costs of operating an electric van financed with an REA load as compared to one purchased outright. This comparison is made in Table 3-10. Financing the initial purchase of an electric van (base vehicle and battery) with a 5 year REA loan reduces the net present value of the life cycle cost of ownership by 8 percent to 12 percent, approximately $800 to $1200, as compared to purchasing the electric van outright.

TABLE 3-10. POTENTIAL IMPACT OF REA LOW INTEREST LOANS ON COST OF OPERATING AN ELECTRIC VAN

VEHICLE	ICE VAN	ELECTRIC VAN		
Method of Vehicle Purchase	CASH PAYMENT	CASH PAYMENT	5% REA LOAN	2% REA LOAN[a]
Net Present Value[b] of Costs of				
Base Vehicle Purchase ($)	3800	3700	3204	2748
Initial Battery Purchase ($)	-	2360	2044	1880
Subtotal ($)	3800	6060	5248	4828
Life Cycle Costs of Ownership[c] ($)	11375	10231	9414	9000
Life cycle costs per kilometer, (¢/km)	27.08	24.36	22.43	21.43

[a] No down payment, 5 year loan.

[b] In constant dollars assuming a 5% discount rate and a 5% annual inflation rate.

[c] Assuming 42000 km and 6 years of use.

As discussed in Appendix A, an electric van has a slight competitive advantage over an ICE van when the vehicles are purchased in a similar manner. Being able to finance an electric van with a low interest REA loan would increase the cost advantage an a electric would have over an ICE van purchased in the normal and more expensive manner. As also shown in Table 3-10, an electric van purchased with an REA loan would be from 17 percent to 21 percent, depending on the interest rate, less costly to operate than an ICE van purchased on a cash basis. This is a significant difference.

Details of the calculations supporting Table 3-10 are presented in Appendix A.

3.3 STATE LAWS AND REGULATIONS

3.3.1 Introduction

Through an historical view of state motor vehicle laws it is possible to recognize some separate though interrelated purposes to these laws. Laws concerned with motor vehicle license fees and taxes were first applied to help pay for increased governmental administrative expenses associated with the registration of vehicles. Subsequently the need for increased revenues to build roads and highways were recognized. These factors led to the introduction of weight-based fees for commercial and other vehicles and the motor fuel excise tax.

Since the 1950's, legislatures have recognized that the significant revenue opportunities associated with motor vehicles may be applied to other governmental costs and programs, not merely to those specifically related to the predominant role of the motor vehicle in the society. Sales tax revenues helped to relieve overall expense burdens and annual excise taxes in lieu of ad valorem property taxes helped to fund revenue sharing concepts between the state and local communities or counties.

Only in the last fifteen to twenty years has the structure of state laws reflected a serious concern for the engineering and performance criteria of motor vehicles and their effect on the health and safety of people and property. Coincident with these trends in motor vehicle legislation, provisions as to the regulation of traffic, with a due regard for safety in the use of streets and highways, resulted in enactments designed to provide for smooth traffic flow.

There have always been statutory provisions which placed a motorist under the somewhat ambiguous obligation of seeing that the operation of his vehicle was reasonable and prudent given conditions of the road, the vehicle, other traffic, etc. These laws and others providing for public safety and convenience give broad discretionary powers to traffic and safety enforcement personnel.

There are very few state provisions resulting in an intentional bias towards electric vehicles. Electric vehicles represent so small a fraction of the vehicles now travelling on the streets and highways that legislatures have yet to consider, in any substantive sense, what policies should be formulated concerning their use.

It might be anticipated, however, that new laws and regulations resulting from the presence of more electric vehicles will in fact be biased against such vehicles. The introduction of the motor vehicle, while providing improved transportation, saw restrictive provisions that reflected the prevailing interests of the public. As an example, a local ordinance in Lake County, California in the early 1900's provided that whenever a motorist saw a horse approaching, he was required to pull over to the side of the road and shut off the engine. When the horse was well past, the motorist was permitted to crank his engine and proceed. (3-11) Today, there are few streets or highways that would even permit the horse or horse-drawn vehicle on the road. Similarly, one may expect that new legislation and regulations may be biased against electric vehicles unless their performance is compatible with the prevailing mode of vehicle transportation.

3.3.2 Registration and Licensing Fees and Taxes

Since almost all state provisions regarding electric vehicles specifically relate to fees and taxes, an investigation of the vehicle fees and taxes of all fifty states was conducted. Where there were specific provisions enumerating an electric vehicle in any state, a review was conducted of their statutory history and telephone interviews were held with state administrative officers to ascertain other actions that may have been taken in recognition of the electric vehicle. This was especially important in those states other than the four which had previously been selected for detailed study.

Motor vehicle registration and license fees are present in all fifty states. While the pattern of the fees is not uniform, their underlying nature is to provide revenues to meet the administrative expenses of motor vehicle departments. Additionally, they are imposed for the privilege of operating vehicles upon the public highways and a part of the revenues are allocated to funds used for highway construction and maintenance. In some states, depending upon the constitutional powers and the specific statutory enactment of the fee or tax, some of the revenue is allocated to other transportation needs such as rapid transit systems.

Table 3-11 and the accompanying notes of Appendix B summarize a review of the registration and license fees and taxes of all fifty states and indicate those situations where the structure of the fees and taxes can be identified as having intentional or accidental bias towards vehicles of particular characteristics. (See also Appendix B.)

Wherever there exists a fee or tax determined by either a schedule of vehicle weight for weights less than 6000 pounds or by some measure of value of the vehicle (purchase price, fair market value or some schedule of values), it is indicated by "●" in Table 3-11 regardless of whether or not the vehicles are characterized by mode of power. This has been previously described as

TABLE 3-11. STATE MOTOR VEHICLE FEES AND TAXES

	REGISTRATION		SPECIAL FEES			SPECIAL TAXES			OTHER
	PASSENGER VEHICLES	TRUCKS AND BUSES	COMMERCIAL VEHICLES	COMMON CARRIERS	CARRIERS MILEAGE	EXCISE AND LICENSE TAX	SALES AND USE TAX	TITLING EXCISE TAX	MISC.
Alabama				●					
Alaska									
Arizona						●			
Arkansas	●								
California			X			●	●		
Colorado	●	●	●			●			
Connecticut	X	X							
Delaware				●					
District of Columbia	X	X						●	
Florida	●	●		●					
Georgia	●	●							
Hawaii									●
Idaho									
Illinois	X								
Indiana						●			
Iowa	X								
Kansas	X	X					●		
Kentucky									
Louisiana									
Maine						●			
Maryland	●	●	●	●				●	
Massachusetts		X		X		●			
Michigan	●	●	●						
Minnesota	●	●				●	●		
Mississippi	●	●				●			
Missouri									
Montana	X						●		
Nebraska									
Nevada		●				●			
New Hampshire	●	●				●			
New Jersey	●								

●Fee or tax determined either by (a) a schedule of vehicle weight for weights less than 6000 lbs; or (b) some measure of value of the vehicle.

XFee or tax specifically related to electric vehicles.

TABLE 3-11. STATE MOTOR VEHICLE FEES AND TAXES (cont'd)

	REGISTRATION		SPECIAL FEES			SPECIAL TAXES			OTHER
	PASSENGER VEHICLES	TRUCKS AND BUSES	COMMERCIAL VEHICLES	COMMON CARRIERS	CARRIERS MILEAGE	EXCISE AND LICENSE TAX	SALES AND USE TAX	TITLING EXCISE TAX	MISC.
New Mexico	●							●	
New York	X	X	X						
North Carolina									
North Dakota	●	●						●	
Ohio		●							
Oklahoma	●					●			
Oregon	X	X	X		●				
Pennsylvania									
Rhode Island	●	●	●						
South Carolina	●			●					
South Dakota	●	●		●		●			
Tennessee									
Texas	●	●					●		
Utah									
Vermont		●					●		
Virginia	●	●	●				●		
Washington		X	●			●			
West Virginia	●	●	●	●				●	
Wisconsin		●							
Wyoming	●	●		●	●				

● Fee or tax determined either by (a) a schedule of vehicle weight for weights less than 6000 lbs; or (b) some measure of value of the vehicle.

X Fee or tax specifically related to electric vehicles.

accidental bias. In those states where the fee or tax is specifically related to electric vehicles (intentional bias), this is indicated by "X" in Table 3-11.

The review of the statutory history and follow-up telephone interviews in those states in which there was a provision specifically enumerating electric vehicles in regard to license fees and taxes indicated:

a) California

  a) An additional registration fee for electric passenger vehicles was repealed in 1970 to remove the bias against such vehicles.

  b) The registration fees for commercial vehicles which are based on both weight and mode of power have been retained.

  c) Members of the registration department and of the motor vehicle department were unaware of any regulations or practices that are specifically related to electric-powered vehicles other than the fees for commercial vehicles.

b) Connecticut

  a) The registration fee for all electric vehicles is less than the registration fee for comparable vehicles with another mode of power. While the actual amount of these fees has changed periodically, the differential in favor of electric vehicles has existed since at least 1951.

  b) There are no specific provisions or restrictions as to the use of electric vehicles other than minimum speed laws.

c) District of Columbia

  a) The registration fees for passenger vehicles and trucks using other than a taxable fuel is presently double that for such vehicles using a taxable fuel. The applicability of these fees to electric vehicles is drawn from the definitions section of the code. While this bias against electric vehicles dates back to 1960, the telephone interview indicated that, in order to encourage the use of electric vehicles, the differential fee schedule will be eliminated as of October 1, 1977.

b) There are currently no use restrictions as to electric vehicles.

c) Registry information indicated that there were two electric vehicles registered in the District at present.

d) Idaho

a) While there is a special fee for vehicles propelled by special fuels in lieu of the motor vehicle fuels tax, special fuels means "all combustible gases and liquids" and does not cover electric vehicles.

b) Members of the registry indicated that there are several electric vehicles registered, that there are no use restrictions as to such vehicles, and that there are no special registration fees.

e) Illinois

a) The provision for lower registration fees for electric passenger vehicles is at least twenty years old.

b) All vehicles with a maximum speed capability of 45 miles per hour are issued restricted area license plates.

c) There are currently 93 electric vehicles registered in Illinois, and these have all been assigned restricted area plates.

f) Iowa

a) Registration fees specifically related to electric vehicles have been part of the code provisions for more than thirty years.

b) No restrictions as to use or any information as to the number of electric vehicles registered were identified through the telephone interview.

g) Kansas

a) The registration fee for electric vehicles other than those intended for the purpose of transporting merchandise or persons for hire is approximately one-half the rate for vehicles with another mode of power.

b) Electric vehicles are not issued any special plates, there are no restrictions as to use and no information was available as to the number of such registered vehicles.

h) Massachusetts

a) The differential fees applicable to electric trucks, taxicabs, and buses dates back over twenty years.

b) No information as to number of electric vehicles registered or restrictions as to use was available from the telephone interview.

i) Montana

a) The specific registration fee for electric passenger vehicles is over twenty years old.

b) No information was available through the telephone interview as to the number of electric passenger vehicles registered and there are no provisions restricting the use of such vehicles.

j) New York

a) In addition to confirming the different registration schedules for electric vehicles in lieu of gas taxes, the telephone interview indicated that many electric vehicles can only be registered as limited use automobiles.

b) Limited use automobiles are defined as vehicles with capability of 27.4 km/hr (17 miles per hour) minimum speed and a 64.4 km/hr (40 miles per hour) maximum speed. Limited use vehicles can only be operated in areas specifically designated (principally around New York City) by the Commissioner of Motor Vehicles. Even in those areas, limited use vehicles cannot be operated on controlled access highways.

c) The limited use description is not applicable to special purpose vehicles such as an electric garbage truck.

d) Prior to 1976, vehicles which could not proceed at speeds greater than 64.4 km/hr (40 miles per hour) were not issued registrations and the provision for limited use registrations primarily results from the introduction of mopeds.

e) No information was available through the telephone interview as to the number of electric vehicles presently registered in the State. Such information could be generated by appropriate programming of the registration computer tapes.

k) <u>Oregon</u>

a) The higher registration fee for electric powered vehicles is at least twenty years old.

b) No information was available on the number of electric vehicles registered and there was no indication of any restrictions as to use.

l) <u>Washington</u>

a) The slightly greater registration fee for electric trucks is at least ten years old.

b) There are no restrictions as to use of electric vehicles.

c) No information on number of electric vehicles registered was available through the telephone interview.

Thus, in most states, license or registration fees are neutral with respect to electric vehicles. In 11 states and the District of Columbia special provisions have been applied pertaining largely to form of fuel. Bias with respect to electric vehicles in these states is nearly equally split between favorable and unfavorable provisions. The unfavorable provisions are intended primarily to regain revenues lost by the absence of a fuel tax applicable to EVs.

3.3.3 Excise Taxes on Petroleum Fuels

3.3.3.1 Introduction - A motor fuel gallonage tax is imposed by every state in the Union, and by the District of Columbia. These state taxes are all higher than the federal tax discussed above, ranging from 1.3¢ per liter (5¢ per gallon) in Texas to 2.9¢ per liter (11¢ per gallon) in Connecticut.

A summary of the tax rate on a gallon of gasoline in each state and the District of Columbia, together with the impact of gasoline tax revenues is presented in Table 3-12. Excise taxes for gasoline sold for highway fuel in the four focus states of the study are:

California	1.8¢ per liter (7¢ per gallon)
Florida	2.4¢ per liter (9¢ per gallon)
Massachusetts	2.2¢ per liter (8.5¢ per gallon)
Michigan	2.1¢ per liter (8¢ per gallon)

Other petroleum fuels, such as diesel fuel, liquefied petroleum gas (LPG), liquefied natural gas (LNG) or compressed natural gas (CNG) are similarly taxed if they are to be used to propel highway vehicles. In Florida and Massachusetts, the excise tax on alternate fuels is the same as on gasoline. In Michigan, the special fuel tax is the same as gasoline, but it is only 1.8¢ per liter (7¢ per gallon) on diesel fuel. In California, the diesel fuel tax is the same as the gasoline tax, whereas special fuels are taxed at 2.1¢ per cubic meter (6¢ per hundred cubic feet).

TABLE 3-12. STATE FUEL EXCISE TAXES AND THEIR REVENUE EFFECT

State	State Gasoline Tax as of 12/76 ¢/1(¢/gal)	State Revenue From Motor Fuel Tax in 1975 (Million $)	Total State Tax Revenue in 1975 (Million $)	Motor Fuel Taxes as % of Total State Taxes
Alabama	1.8 (7)	148.6	1,111.3	13.4
Alaska	2.1 (8)	18.0	203.5	8.8
Arizona	2.1 (8)	101.6	938.4	10.8
Arkansas	2.2 (8.5)	108.6	652.6	16.6
California	1.8 (7)	743.7	9,564.6	7.8
Colorado	1.8 (7)	91.3	866.4	10.5
Connecticut	2.9 (11)	138.5	1,058.9	13.1
Delaware	2.4 (9)	29.7	336.3	8.8
District of Columbia	2.6 (10)	4.8		
Florida	2.1 (8)	362.5	2,791.2	13.0
Georgia	2.0 (7.5)	228.2	1,547.8	14.7
Hawaii	2.2 (8.5)	21.2	575.5	3.7
Idaho	2.5 (9.5)	37.1	298.1	12.4
Illinois	2.0 (7.5)	374.4	4,409.5	8.5
Indiana	2.1 (8)	242.8	1,854.0	13.1
Iowa	1.8 (7)	118.9	1,062.0	11.2
Kansas	1.8 (7)	94.3	769.0	12.3
Kentucky	2.4 (9)	168.7	1,283.7	13.1
Louisiana	2.1 (8)	153.4	1,528.7	10.0
Maine	2.4 (9)	50.6	369.0	13.7
Maryland	2.4 (9)	176.9	1,730.7	10.2
Massachusetts	2.2 (8.5)	179.9	2,218.5	8.0
Michigan	2.4 (9)	397.3	3,486.0	11.4
Minnesota	2.4 (9)	144.0	2,022.2	7.1
Mississippi	2.4 (9)	127.4	797.4	16.0
Missouri	1.8 (7)	178.8	1,303.0	13.7
Montana	2.0 (7.75)	36.5	232.7	15.7
Nebraska	2.2 (8.5)	81.1	424.8	19.1
Nevada	1.6 (6)	25.8	266.8	9.7
New Hampshire	2.4 (9)	36.1	172.4	20.9
New Jersey	2.1 (8)	273.6	2,100.9	13.0
New Mexico	1.8 (7)	57.7	519.6	11.1
New York	2.1 (8)	509.8	8,939.2	5.7
North Carolina	2.4 (9)	265.7	1,900.4	14.0
North Dakota	1.8 (7)	27.0	263.6	10.2
Ohio	1.8 (7)	371.4	3,039.2	12.2
Oklahoma	1.7 (6.58)	111.3	883.7	12.6
Oregon	1.8 (7)	81.7	793.0	10.3
Pennsylvania	2.4 (9)	455.4	4,733.4	9.6
Rhode Island	2.6 (10)	31.8	349.8	9.1
South Carolina	2.1 (8)	127.9	965.6	13.2

TABLE 3-12. STATE FUEL EXCISE TAXES AND THEIR REVENUE EFFECT (cont'd)

State	State Gasoline Tax as of 12/76 ¢/l (¢/gal)	State Revenue from Motor Fuel Tax in 1975 (Million $)	Total State Tax Revenue in 1975 (Million $)	Motor Fuel Taxes as % of Total State Taxes
South Dakota	2.1 (8)	29.9	171.1	17.5
Tennessee	1.8 (7)	173.1	1,140.6	15.2
Texas	1.3 (5)	395.2	3,636.6	10.9
Utah	1.8 (7)	48.4	398.8	12.1
Vermont	2.4 (9)	21.7	187.0	11.6
Virginia	2.4 (9)	246.8	1,662.7	14.8
Washington	2.4 (9)	161.5	1,554.1	10.4
West Virginia	2.2 (8.5)	73.0	740.6	9.7
Wisconsin	1.8 (7)	165.1	2,140.8	7.7
Wyoming	2.1 (8)	20.5	154.3	13.3
Grand Total U.S.		8,255.6	80,141.3	10.3

Sources:

State Gasoline Taxes: 1976 Federal Income Tax Forms, Form 1040
Department of the Treasury, Internal Revenue Service

1975 Tax Revenue: Motor Vehicle Facts & Figures '76, page 96
Motor Vehicle Manufacturers Association
of the United States Inc., Detroit, Mich.

In California, the owner of a vehicle that uses petroleum gas has the option of paying an annual flat rate tax in lieu of a gallonage tax. This tax is \$36 if the vehicle weight is 1814 kilograms (4000 pounds) or less, \$72 if it is over 1814 kilograms (4000 pounds) but less than 3629 kilograms (8001 pounds) and \$168 for vehicles weighing more than 5443 kilograms (12,000 pounds.)

3.3.3.2 Impact of Motor Fuel Taxes on the Vehicle User - The existence of excise taxes on petroleum products that are used to fuel ICE vehicles, and the absence of similar taxes on the electric energy that would be used to drive electric vehicles, represents a direct bias in favor of electric vehicles. The cost of these taxes to the user will depend on the fuel economy of the ICE vehicle being driven and on the location of the vehicle. The annual costs of motor fuel excise taxes (including federal excise taxes) to users of the four ICE vehicles of interest to the study are summarized in Table 3-13. Table 3-13 is based on estimates presented in Appendix A. At the present rate of 1¢ per liter (4¢ per gallon), federal motor fuel excise taxes result in a cost to users of ICE vehicles that ranges from about \$5 per year for the low performance 2-passenger vehicle to about \$22 per year for the ICE delivery van. If the federal tax is decreased as scheduled to .4¢ per liter (1.5¢ per gallon) in 1979, these costs will decrease to about \$2 to \$8 on an annual basis. State motor fuel excise taxes result in an annual cost that ranges from \$6 to \$60 per year depending on the vehicle and the rate of excise. The total cost to the user of the combined federal and state excises range from \$11 to \$82 per year depending on the vehicle and location.

On a life cycle basis, the added costs of motor fuel excise taxes range from 0.11¢/km to 0.18¢/km for the ICE van. As a percentage of total life cycle costs, exclusive of taxes and fees, motor fuel excise taxes represent from 1.3% to 3.7% of these costs.

3.3.3 Impact on Revenue Derived from Motor Fuel Taxes - Motor vehicle fuel excise taxes are a major source of revenue to both

TABLE 3-13. COSTS OF MOTOR FUEL EXCISE TAXES TO ICE VEHICLE USERS

	2 PAX LP ICE	4 PAX LP ICE	CHEVETTE	ICE VAN	HONDA CVCC
Annual Vehicle Utilization, km(mi)	10000(6200)	16000(10000)	16000(10000)	7000(4300)	16000 (10000)
Fuel Economy, km/liter (mpg)	21.7 (51)	17.4 (41)	14.0 (33)	3.4 (7.9)	16.6 (39)
Annual Fuel Consumption, liters (gallons)	462 (122)	924 (244)	1147 (303)	2059 (544)	969 (256)
Annual Federal Tax Revenue @ 1¢/liter (4¢/gallon) $	4.88	9.76	12.12	21.76	10.26
Range Annual State Tax Revenue (Excise)					
@ 1.3¢/liter (5¢/gallon) $	6.10	12.20	15.15	27.20	12.82
@ 2.9¢/liter (11¢/gallon) $	13.42	26.84	33.33	59.84	28.21
Range of Costs of Combined Excises to user $	11-18	22-37	27-45	49-82	23-38
Life Cycle Range of Costs of Combined Excises to user, ¢/km	0.11-0.18	0.14-0.23	0.17-0.30	0.70-1.17	0.14-0.24
Life Cycle Costs Exclusive of Taxes and Fees, ¢/km	8.45	7.69	8.05	31.82	8.30
Combined Excises as Percent Life Cycle Costs	1.3-2.1	1.8-3.0	2.1-3.7	2.2-3.7	1.7-2.9

the federal and state governments. In 1975, state taxes totalled $8.354 billion, nearly twice as much as federal revenues from such taxes. Motor vehicle fuel gallonage taxes ranged from 3.7% (Hawaii) to 20.9% (New Hampshire) of total state tax revenue. On a national average, 10.3% of state tax revenues were derived from the sale of motor vehicle fuels.

The presence of a significant number of electric vehicles on the road would have an impact on these revenues. If the equivalent of a million ICE subcompacts were replaced by electric vehicles, state tax revenue would decrease by approximately $24 million per year. If the equivalent of 100,000 ICE vans were replaced by electric vans, state revenue would decrease by about $4.3 million per year.

It is doubtful that electric vehicles would reach a significant penetration of the total vehicle fleet before they would become subject to a tax equivalent to the one presently imposed on petroleum fuels for ICE vehicles. Such an annual tax might be similar to the existing single payment California tax on natural gas derived fuels.

3.3.4 Sales Taxes

3.3.4.1 Introduction - Sales taxes are imposed at one rate on a broad range of items sold at retail. They are generally proportional to the retail value of the item being sold, and thus may be viewed as resulting in a bias against the more expensive of two otherwise comparable items. For example, if a 5% sales tax is imposed, the difference due to sales tax in the total price to the consumer in two items that have nominal retail pretax prices of $3000 and $4000 respectively will be $50. Sales taxes, therefore, represent a bias against electric vehicles because of the inherently higher retail price of electric compared to equivalent ICE vehicles.

3.3.4.2 Sales Taxes in the Four Focus States - The sales taxes present in each of the focus states are in addition to other taxes and license fees which might also be related to the value of the vehicle. The range of the sales tax for the focus states is 4 to 6%, with Florida and Michigan at 4%, Massachusetts at 5% and California at 6%, derived from a base rate of 4-3/4% with provisions for added taxes by cities of 1% and by counties of 1-1/4%.

3.3.4.3 Impact of Sales Taxes on Vehicle User

3.3.4.3.1 First Costs - The principal impact of sales taxes on the ownership of a motor vehicle is associated with its acquisition cost. The incremental acquisition cost due to sales taxes for the various vehicles of interest to the study are presented as a function of the tax rate in Figure 3-2. The difference in sales taxes imposed on electric vehicles compared to the sales taxes on functionally comparable ICE vehicles is a measurable bias. This difference is plotted as a function of the tax rate for the various classes of vehicles of interest to the study in Figure 3-3.

3.3.4.3.2 Life Cycle Costs - For purposes of this discussion, it will be assumed that sales taxes are applicable to the sale of goods and materials at retail, other than fuel. It will be assumed that services will not be subject to sales taxes. Referring to Appendix A, sales taxes were applied on the initial sales price of the vehicle and on the sales price of parts and materials needed to maintain and repair the vehicle. In the case of electric vehicles, batteries are subject to sales taxes.

In terms of life cycle costs, the imposition of sales taxes will increase all the capital related costs, except taxes and fees, and the non-labor element of repair and maintenance costs. It was assumed that maintenance parts and materials represented 63% of all maintenance costs. This assumption is based on maintenance costs for 4-passenger motor vehicles that were published in the Motor Vehicle Goals Study. (3-12) It is not known whether these maintenance cost values already include sales taxes. For purposes of these calculations, it was assumed that these costs do not include sales taxes. Any error due to this assumption will be smaller than the uncertainty in the base data. Sales

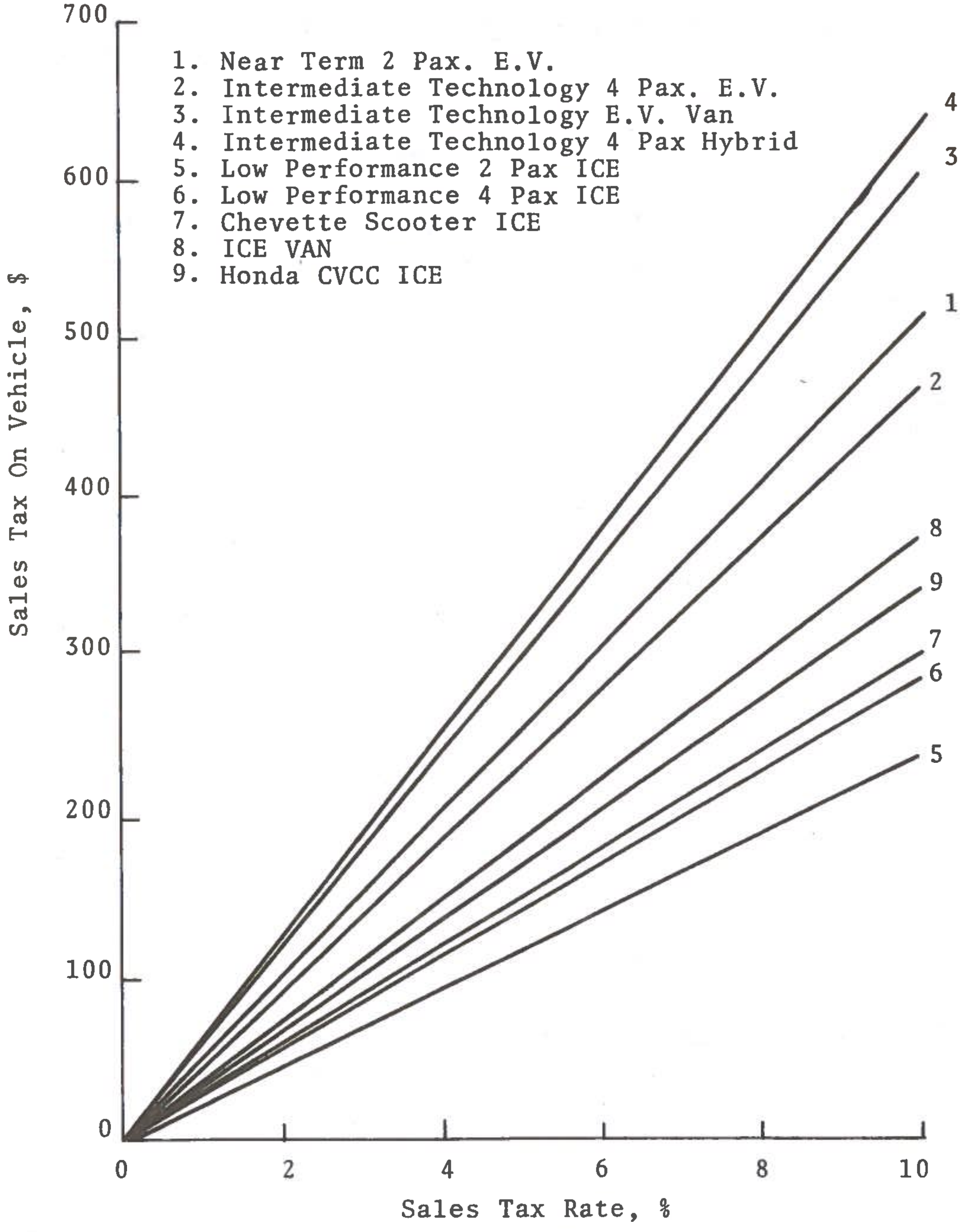

FIGURE 3-2 SALES TAXES IMPOSED ON PURCHASE OF VEHICLES

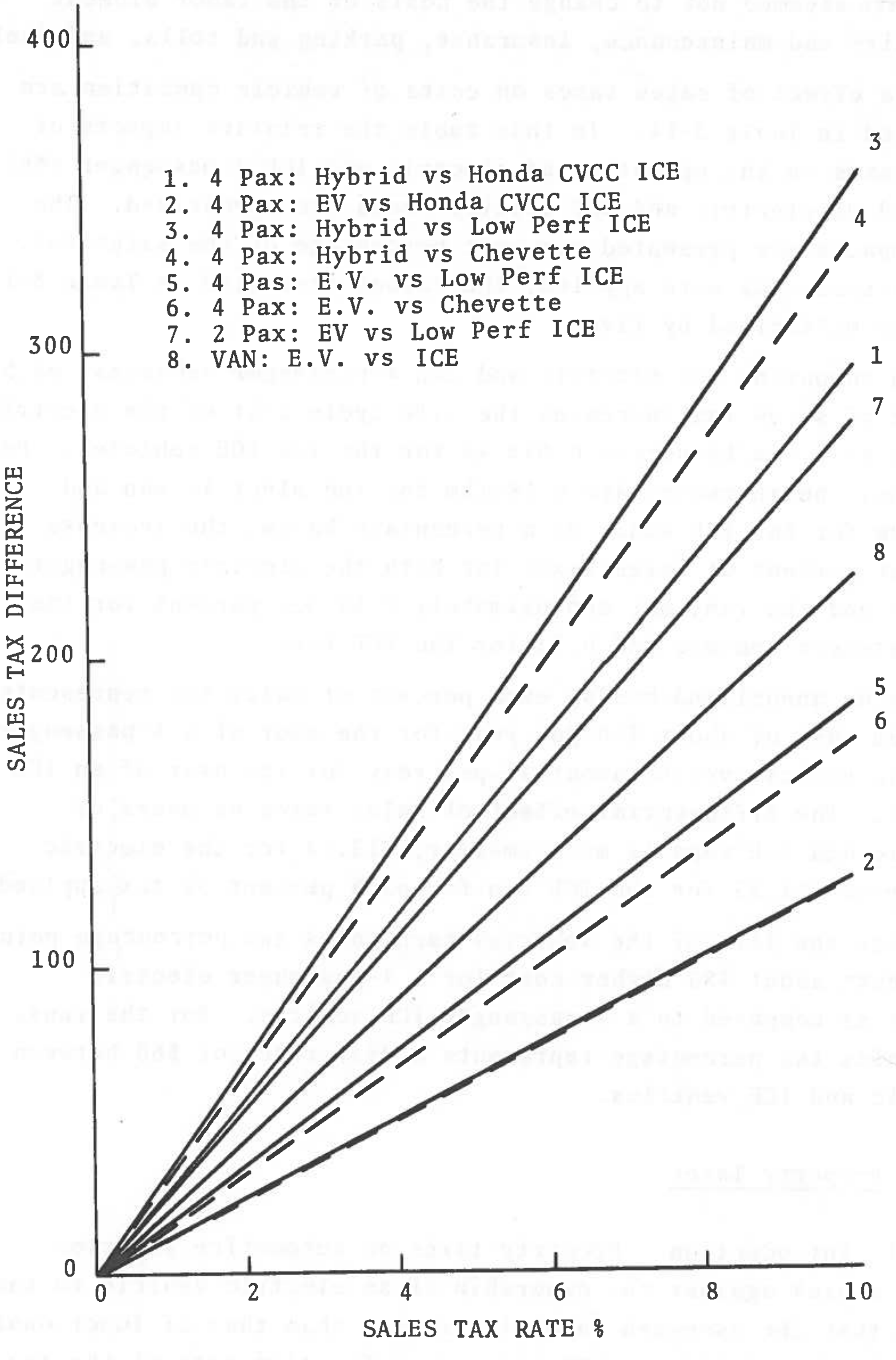

FIGURE 3-3 BIAS RESULTING FROM SALES TAXES ON VEHICLE PURCHASE

taxes were assumed not to change the costs of the labor element of repairs and maintenance, insurance, parking and tolls, and fuel.

The effect of sales taxes on costs of vehicle operation are presented in Table 3-14. In this table the relative impacts of sales taxes on the operation of electric and ICE 4-passenger vehicles and of electric and ICE delivery vans are summarized. The cost impacts are presented per unit percentage of the sales tax. If a 5% sales tax were applied, the values presented in Table 3-14 would be multiplied by five.

In comparing the electric and ICE 4-passenger vehicles, each percent of sales tax increases the life cycle cost of the electric vehicle by 0.06¢/km versus 0.04¢/km for the two ICE vehicles. For the vans, the increases are 0.18¢/km for the electric van and 0.16¢/km for the ICE van. On a percentage basis, the increase is 0.6% per percent of sales taxes for both the electric passenger vehicle and the van, but approximately 0.5% per percent for the ICE passenger vehicle and 0.3% for the ICE van.

On an annualized basis, each percent of sales tax represents an added cost of about $10 per year for the user of a 4-passenger electric vehicle versus about $6 per year for the user of an ICE vehicle. The differential effect of sales taxes on users of electric and ICE vans is much smaller, $12.74 for the electric van versus $11.35 for the ICE van for each percent of tax applied.

Over the life of the vehicles each sales tax percentage point represents about $80 higher cost for a 4-passenger electric vehicle as compared to a 4-passenger ICE vehicle. For the vans, each sales tax percentage represents a difference of $60 between electric and ICE vehicles.

3.3.5 Property Taxes

3.3.5.1 Introduction - Property taxes on automotive vehicles impose a bias against the ownership of an electric vehicle to the extent that the assessed value is greater than that of functionally comparable ICE vehicles. The bias is a function both of the tax rate and of the assessed value of the vehicles over time. An evaluation schedule that results in a lower vehicle assessment

TABLE 3-14 EFFECT OF SALES TAXES AND COSTS OF VEHICLE OPERATION

VEHICLES	4 PASSENGER AUTOMOBILES					2 PASSENGER AUTOMOBILE		DELIVERY VAN	
	ELECTRIC	HYBRID	ICE LOW PERFORMANCE	CHEVETTE ICE	HONDACVCC ICE	ELECTRIC	ICE LOW PERFORMANCE	ELECTRIC	ICE
	LIFE CYCLE COSTS, CENTS/KM								
REFERENCE TOTAL COSTS	10.77	13.69	8.24	8.62	8.95	13.76	9.17	30.86	49.4
Capital Sensitive Costs, (Not Including Taxes & Fees)	5.73	7.61	2.98	3.10	3.53	8.32	3.90	17.25	12.13
Maintenance Materials*	0.63	0.88	0.98	0.98	0.98	0.50	0.98	0.95	4.08
Total of Costs Sensitive to Sales Taxes	6.36	8.49	3.95	4.08	4.51	8.82	4.88	18.20	16.21
Increase in Life Cycle Costs per % Sales Tax Imposed	0.06	0.09	0.04	0.04	0.05	0.09	0.05	0.18	0.16
Percent Increase in Life Cycle Costs per % Sales Tax Imposed	0.6	0.6	0.5	0.5	0.5	0.64	0.53	0.6	0.3
Increase in Annual Ownership Costs per % of Sales Tax Imposed, $	10.18	13.59	6.32	6.53	7.22	8.82	4.88	12.74	11.35

*Maintenance Materials: 63% Repairs & Maintenance Costs.

than its fair market value would tend to mitigate the extent of the bias against a more costly class of vehicles.

3.3.5.2 Property Taxes in the Four Focus States - Property taxes applicable to motor vehicles were noted only in California and Massachusetts. These taxes are in addition to any other fees or taxes imposed on sale, registration or licensing. The specific structure of the tax in each of the two states is discussed following a presentation of the measurement of the fair market value of automobiles, the base to which a property tax rate is applied.

3.3.5.3 Fair Market Value of Automobiles - In some states, the automobile is taxed on the basis of its nominal fair market value. This value is obtained from car value books published on a quarterly basis by national vehicle dealer groups (3-13) for various regions of the country. The published car values are determined by a canvass of selling prices of vehicles in each geographic area. The listed value of an automobile is a complex function of its age, size, class, make, and options as well as on the demand for new and used automobiles in general. For a particular vehicle the listed value is only a general indication of its market value since the latter also depends on the mileage and the physical and mechanical condition of the vehicle.

In order to measure the bias for or against electric vehicles in those jurisdictions that base taxation on fair market value, it was necessary to develop estimated depreciation schedules for the various vehicles of interest to the study. The derivation of these schedules is discussed in Appendix B.

3.3.5.4 Bias Due to California Property Taxes - California imposes an annual property tax on motor vehicles equal to 2% of the market value of the vehicle. The market value of a vehicle for assessment purposes is defined by the schedule presented in Table 3-15. According to this schedule, the assessed value is a decreasing percentage of the original list price of the vehicle with increasing age of the vehicle, up to the ninth year and succeeding years. The

TABLE 3-15 DEPRECIATION SHEDULE USED BY CALIFORNIA TO ASSESS VALUES OF AUTOMOTIVE VEHICLES

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Annual Assessed Value, as Percent of Initial List Price	85	70	55	40	30	25	15	10	5	5	5	5
Assumed Vehicle Life	1	2	3	4	5	6	7	8	9	10	11	12
Average Annual Assessed Value over Life of Vehicle, as Percent of Initial List Price	85	77.5	70	62.5	56.0	50.8	45.7	41.3	37.2	34.0	31.4	29.2

TABLE 3-16. IMPACT OF CALIFORNIA PROPERTY TAX ON VEHICLES OF INTEREST

(Tax Rate: 2% of Market Value Based on Schedule)

		2 PASSENGER VEHICLE		4 PASSENGER VEHICLE					LIGHT DUTY VAN	
		Electric (Near Term)	Low Perf ICE	Electric	Hybrid	Low Perf ICE	Chevette	Honda CVCC	Electric	ICE
Useful Life, yrs		12	10	12	12	10	10	10	10	6
Annual Usage, Km/yr		10,000	10,000	16,000	16,000	16,000	16,000	16,000	7,000	7,000
Vehicle Acquisition Price,	$	5,140	2,400	4,740	6,400	2,900	3,054	3,464	6,060	3,800
Average Assessed Value over Vehicle Life	$	1,499	816	1,383	1,867	986	1,038	1,178	2,060	1,930
Average Annual Tax Based on 2% of Average Assessed Value of Vehicle	$	29.98	16.32	27.65	37.33	19.72	20.77	23.56	41.21	38.61
Total Property Taxes Paid over Vehicle Life	$	359.80	163.20	331.80	448.00	197.20	207.70	235.60	412.10	231.65
Average Cost of Property Tax per Distance of Travel Use	¢/Km	0.30	0.16	0.17	0.23	0.12	0.13	0.15	0.59	0.55
Vehicle Life Cycle Costs, Exclusive of Taxes and Fees	¢/Km	12.22	8.45	9.88	12.48	7.69	8.05	8.30	28.26	31.82
Annual Property Tax as Percent of Vehicle Life Cycle Costs, Exclusive of Taxes and Fees		2.5	1.9	1.7	1.9	1.6	1.6	1.8	2.1	1.7

tax schedule results in a lower assessment than one based on the nominal market value of the vehicles of interest, except for very old vehicles which have a very low actual or assessed value, and, therefore, for which the absolute value of the tax is very small.

The effects of these property taxes on vehicles of interest to the study are presented in Table 3-16. California property taxes result in a bias against electric vehicles. Depending on the particular type of vehicle, an electric owner will pay from about \$3 per year to \$18 per year more in average property taxes over the life of the vehicle than the owner of the equivalent ICE vehicle. On a life cycle basis, the difference ranges from 0.02¢/km (4-passenger electric vehicle vs. Honda CVCC) to 0.14¢/km (2-passenger near term electric vehicle vs. 2-passenger low performance ICE vehicle).

3.3.5.5 Bias Due to Massachusetts Property Taxes - Massachusetts imposes an annual property tax on motor vehicles of \$66 per \$1000 evaluation. The evaluated value of a vehicle is not to exceed 50% of the list price in the year preceding the designated year of manufacture, 90% of the list price in the year of manufacture, and scaled down to 10% in the fifth and succeeding years, as shown in Table 3-17. The tax schedule results in a lower assessment than one based on the nominal market value of the vehicles, except for vehicles of ten years or more. The tax structure is most favorable for vehicles approximately two to seven years old.

The effects of these property taxes on vehicles of interest to the study are presented in Table 3-18. As demonstrated by the numbers presented in Table 3-18, Massachusetts property taxes result in a bias against electric vehicles. Depending on the particular type of vehicle, an electric vehicle owner will pay from about \$12 per year to \$50 per year more in average property taxes over the life of the vehicle than the owner of the equivalent ICE vehicle. On a life cycle cost per kilometer basis, the difference ranges from 0.09¢/km (4-passenger electric vehicle vs. Honda CVCC) to 0.39¢/km (2-passenger near term electric vehicle vs. 2-passenger low performance ICE vehicle).

TABLE 3-17 DEPRECIATION SCHEDULE USED BY MASSACHUSETTS TO ASSESS VALUE OF AUTOMOTIVE VEHICLES

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Annual Assessed Values, as Percent of Initial List Price	90.0	60.0	40.0	25.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Assumed VEHICLE LIFE, yrs	1	2	3	4	5	6	7	8	9	10	11	12
Average Annual Assessed Value Over Life of Vehicle, as Percent of Initial List Price	90.0	75.0	63.3	53.8	45.0	39.2	35.0	31.9	29.4	27.5	25.9	24.6

TABLE 3-18 IMPACT OF MASSACHUSETTS PROPERTY TAX ON VEHICLES OF INTEREST
(Tax Rate: $66.00 Per $1000 Evaluation)

		2 PASSENGER VEHICLES		4 PASSENGER VEHICLES					LIGHT DUTY VANS	
		Electric (Near Term)	Low Perf ICE	Electric	Hybrid	Low Perf ICE	Chevette	Honda	Electric	ICE
Useful Life, Years		12	10	12	12	10	10	10	10	6
Annual Usage, Km/yr		10,000	10,000	16,000	16,000	16,000	16,000	16,000	7,000	7,000
Vehicle Acquisition Price	$	5,140	2,400	4,740	6,400	2,700	3,054	3,464	6,060	3,800
Average Assessed Value of Vehicle over Vehicle Life	$	1,264	660	1,166	1,574	798	840	953	1,667	1,490
Average Annual Tax Based on Tax Rate of $66.00/$1000 Evaluation	$	83.42	43.56	76.96	103.88	52.67	55.44	62.90	110.02	98.34
Total Property Taxes Paid Over Vehicle Life	$	1,001.09	435.60	923.47	1,246.61	526.68	554.40	629.00	1,100.22	590.04
Average Cost of Property Tax per Distance of Travel Use	¢/Km	0.83	0.44	0.48	0.65	0.33	0.35	0.39	1.57	1.41
Vehicle Life Cycle Costs, Exclusive of Taxes and Fees	¢/Km	12.22	8.45	9.88	12.48	7.69	8.05	8.30	28.26	31.82
Annual Property Tax as Percent of Vehicle Life Cycle Costs, Exclusive of Taxes and Fees		6.8	5.2	4.9	5.2	4.3	4.3	4.7	5.6	4.4

The average annual property tax on an ICE van is approximately 90% of the corresponding tax on an electric van, even though the initial list price of the ICE van is only about 60% of the list price of the electric van. This is a result of the assumed relatively short life of six years for the ICE van as compared to a ten year life for the electric van. The owner of an ICE van obtains the benefit of the minimum 10% assessment for only two years, whereas the owner of an electric vehicle benefits for six years.

3.3.6 Utility Taxes

Most states have provisions for taxing utilities which generate electricity. The potential impact of these taxes was considered to be an indirect bias in that such taxes would have already been reflected in the cost per unit of electricity. However, the structure of the tax in California (and, on the basis of a very limited search, in Idaho, South Carolina and Vermont) warrants some comment.

The California tax is a user's surcharge at the rate of 1/10 of a mill per kilowatt-hour (½ of a mill per kilowatt-hour in the other referenced states). This type of tax could easily be extended to electric vehicles and might be considered as the basis of the substitute for foregone motor vehicle fuel excise taxes on the state level.

3.3.7 Noise Control

The control of noise from motor vehicle operations has been legislated on both the federal, state and local levels. The federal regulations are not applicable to the vehicles considered in this study in that they are applicable only to interstate vehicles over 4536 kg. (10,000 pounds). While noise control regulations are viewed as primarily affecting ICE vehicles and the requirements are easily met with the addition of mufflers, etc., a summary of noise regulation as compiled by the Bureau of National Affairs, Inc. Noise Regulation Reporter is contained in Appendix B.

3.3.8 Other Provisions

3.3.8.1 Introduction - Within the four focus states numerous provisions of law and regulation were noted that might result in a bias. Most of these provisions were in the area of speed laws, in particular minimum speed laws, which are discussed in Chapter V. In this section, examples of these laws or regulations from the four focus states are presented to illustrate their nature.

3.3.8.2 Minimum Speed Laws - Typical examples of minimum speed laws, some of which include discretionary provisions, are:

a) "No person shall drive upon a highway at such a slow speed as to impede or block the normal and reasonable movement of traffic,...Whenever the Department of Transportation determines on the basis of an engineering and traffic survey that slow speeds on any part of a state highway consistently impede the normal and reasonable movement of traffic, the department may determine and declare a minimum speed limit below which no person shall drive a vehicle..."

Cal. Vehicle Code Section 22400

b) "On all streets or highways, the maximum speed limits for all vehicles shall be 30 miles (48 km) per hour in business or residential districts, and 55 miles (88 km) per hour at any time at all other locations. The minimum speed limit on all highways which comprise a part of the national system of interstate and defense highways and have not less than four lanes shall be 40 miles (64 km) per hour."

Florida Code Section 316.183

c) "On limited access facilities it shall be unlawful for any person...to operate upon an expressway any vehicle which by its design or condition is incompatible with the safe and expedient movement of traffic..."

Florida Code Section 339.30

d) "No person shall operate a vehicle on the Turnpike roadway at a rate of speed less than 40 mph (64 km) except on a creeper, acceleration or deceleration lane or where lesser speed is posted on such roadway."

20 Mass. Rules and Regulations
Part 3

3.3.8.3 Discretionary Provisions - In all the jurisdictions considered, there are provisions pursuant to the police power, for discretionary rulings, by an administrative officer, to limit or restrict, in the interest of public health and safety, the use of any particular vehicle. Examples of such provisions are:

a) "The Department (of public works) for purpose of promoting public safety upon limited access and express state highways, may from time to time make, alter, rescind or add to regulations to exclude, govern and restrict the use of such state highways by horse-drawn vehicles, bicycles, pedestrians, and vehicles determined by the department, because of their type or because of materials or products being transported, as unsafe for limited access and express state highways, bridges, tunnels or overhead highway structures, which regulations may provide penalties for the violation thereof..."

Mass. Gen. Laws ch. 85, sec. 2B

b) "...the department (of public works) for purposes of public safety and convenience may from time to time by regulations exclude persons and vehicles from state highways or portions thereof for such periods as it may deem necessary..."

Mass. Gen. Laws ch. 85, sec.2E

c) "If the registrar shall determine at any time, that, for any reason, a motor vehicle or trailer is unsafe or improperly equipped or otherwise unfit to be operated, he may refuse to register such motor vehicle or trailer or if it is already registered, may suspend or revoke its registration."

Cal. vehicle Code Section 2804

d) "A member of the California Highway Patrol upon reasonable belief that any vehicle is being operated in violation of any provisions of this code or is in such unsafe condition as to endanger any person may require the driver of the vehicle to stop and submit to an inspection of the vehicle, its equipment..."

Cal. vehicle Code Section 2804

3.3.8.4 Miscellaneous Provisions

"For motor vehicle insurance rates, appropriate reductions in premium charges shall be applied to vehicles that are less damageable than others due to safety features incorporated into such vehicles."

Mass. Gen. Laws ch. 175E, sec. 4

3.3.8.5 Electric Vehicle Charging

It was noted that the Massachusetts Electrical Code provides for the charging of electrical vehicles under Section 511-8. This regulation stipulated that the "ampacity" (sic) of the cords and connectors be adequate for the charging current. The wording of this regulation is such as not to result in any bias.

CHAPTER 3 - REFERENCES

3-1 L.R. Foote, et al, "Electric Vehicle Study" Ford Motor Company, Research and Engineering Center, Electric Systems Department, Deerborn MI 1974.

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3-3 "An Analysis of Alternative Motor Vehicle Emission Standards" U.S. Dept. of Transportation, U.S. Environmental Protection Agency, U.S. Federal Energy Administration, May 19, 1977.

3-4 Automobile Emission Control: The Current Status and Development Trends as of March 1976; A Report to the Administrator, U.S. Environmental Protection Agency, U.S. Environmental Protection Agency Office of Mobile Source Air Pollution Control, Ann Arbor MI (April 1976).

3-5 The Report by the Federal Task Force on Motor Vehicle Goals Beyond 1980, Vol. 2, Task Force Report, Draft, September 2, 1976, P. 6D-1.

3-6 J.D. Murrell et al., "Light Duty Automotive Fuel Energy-Trends through 1977", SAE Paper 760795.

3-7 Federal Register, Vol. 42, No. 49, p. 13807 (March 14, 1977).

3-8 S.F. Powel and N. Rosenberg, "The Advisability of Regulating Electric Vehicles for Energy Conservation" Report No. DOT-TSC-OST-76-36, August 1976.

3-9 New York Times, page D-1, D-12, June 17, 1977.

3-10 D. Runyon, Rural Electrification Administration, Personal Communication, June 26, 1977.

3-11 R.H. Nida, "California Motor Vehicle Regulation," California Motor Vehicle Code, p. LXIII, (1976).

3-12 The Report by the Federal Task Force on Motor Vehicle Goals Beyond 1980, Vol. 2. Task Force Report, Draft September 2, 1976. Chapter 6, Table 6-9.

3-13 Car and Truck Appraisals. American Auto Appraisal, P.O. Box 930, Royal Oak ME 48068, April-May-June 1977 Issue.

4.0 TRAFFIC CONTROL PRACTICES

4.1 INTRODUCTION

The traffic control practices commonly used on U.S. streets and highways have evolved to match the characteristics of conventional ICE-powered vehicles. If electric and hybrid vehicles have substantially different characteristics, traffic control practices may create significant biases against their purchase and use.

This chapter examines the major traffic control practices and identifies the biases they could create against electric and hybrid vehicles. Table 4-1 lists the practices considered and the specific vehicle characteristics through which bias might arise.

TABLE 4-1. POTENTIAL TRAFFIC CONTROL BIASES RELATED TO CHARACTERISTIC DIFFERENCES OF STUDY VEHICLES

Potential Bias	Acceleration	Max. Speed Gradeability	Size	Noise/Air Pollution
1. Highway Traffic				
a. Speed Laws	X	X		
b. Access Ramps	X	X		
2. Traffic Light Timing				
a. Fixed-Time	X		X	
b. Demand Actuated	X		X	
c. Travel Time	X		X	
3. Preferential Lanes, Carpools			X	
4. Vehicle Segregation Policy			X	
5. Tolls and Congestion Pricing			X	X

4.2 SPEED LAWS

Electric vehicles have generally been designed to be slower than ICE vehicles. As a result, minimum requirements have been established (See Table 2-3) for maximum speed to assure reasonable speed compatibility with surrounding traffic. These maximum speeds are for level road operation and speed will diminish whenever significant upgrades are encountered. Thus the magnitude of allowable speed and variations in road grade constitute potential biases against electric vehicles.

Gradeability criteria for electric vehicles have been established to assure that some minimum performance is maintained. The gradeability standard is stated in terms of a minimum sustained speed on a stated grade. For the four study vehicles, the following standards were established.

	Maximum Speed	Gradeability
Hybrid	90 km/h (56 mph)	85 km/h (53 mph) on 6%
4-Passenger EV	90 km/h (56 mph)	71 km/h (44 mph) on 7%
Commercial EV	85 km/h (53 mph)	71 km/h (44 mph) on 7%
2-Passenger EV	80 km/h (50 mph)	30 km/h (18.5 mph) on 10%

To measure the bias, gradeability curves for each of the study vehicles were established to see how sustained speed is related to road grade. This was accomplished by first establishing the power requirements to meet the gradeability specification for each of the study vehicles (See Appendix E). Using these specific power requirements, curves for velocity and grade were derived. Results are shown in Figure 4-1. The calculation assumes that the EV motor has been sized for maximum speed and gradeability. Figure 4-1 shows that gradeability is a more stringent requirement than maximum speed for all the vehicles.

The gradeability specification is a minimum acceptable requirement. If another specification, such as acceleration, requires more power and if that same power is available for hill climbing, then the curves based on a minimum gradeability specification will understate the capability of the vehicles. For completeness, curves

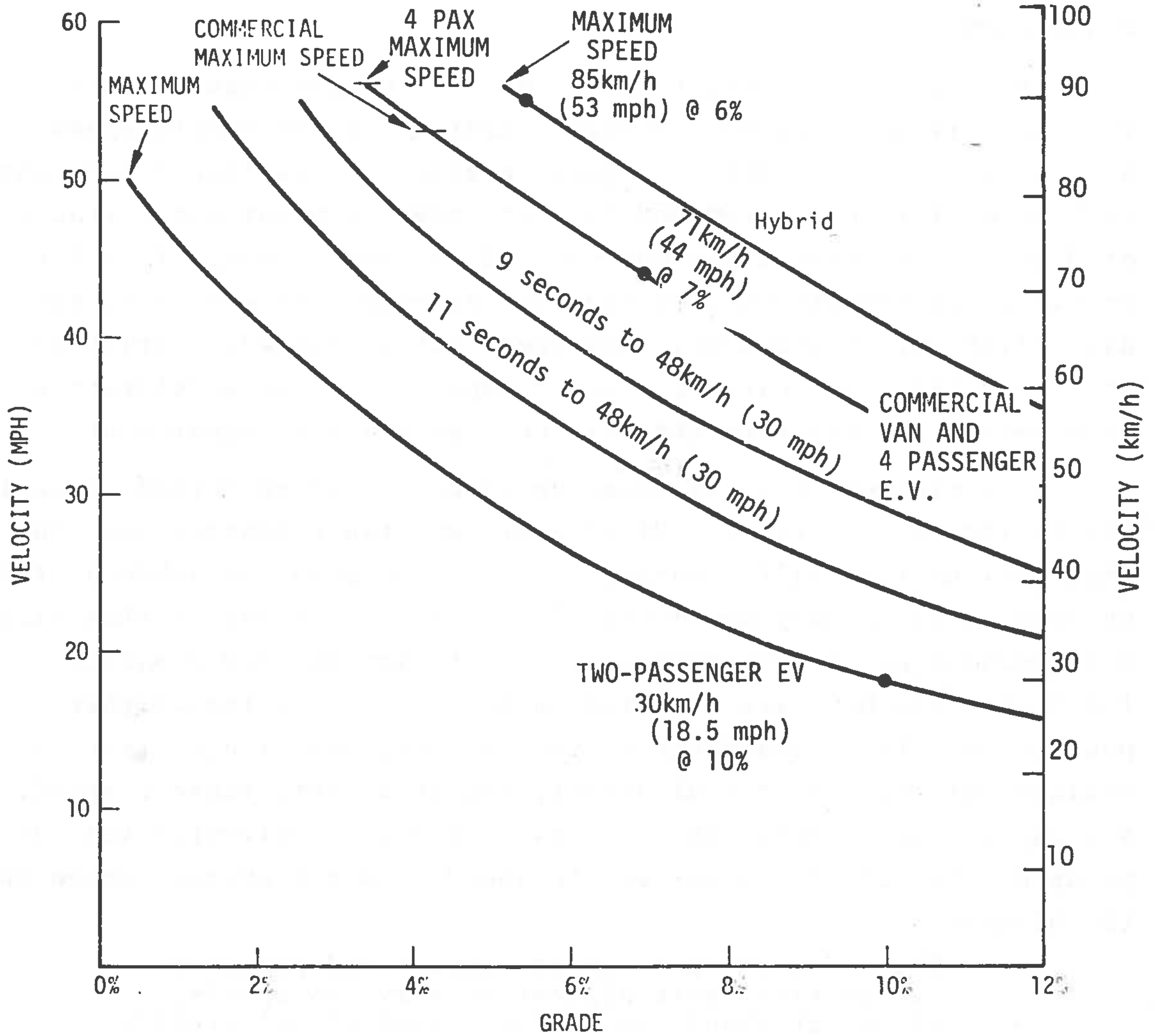

FIGURE 4-1. GRADEABILITY FOR DIFFERENT VEHICLE CHARACTERISTICS

were also calculated for each of the study acceleration specifications: 11 seconds to 48 km/hr (30 mph) for the commercial and two-passenger EV, and 9 seconds to 48 km/hr (30 mph) for the hybrid* and four-passenger EV.** While the two-passenger electric vehicle appears to have extra power for acceleration, the other vehicles have less, and the gradeability criteria establish the power requirement.

It is clear from Figure 4-1 that the two-passenger electric vehicle will have serious problems maintaining reasonable speeds on grades. For the other vehicles, grades of less than 4 per cent will be of little problem and loss of speed is minor until grades of 6 percent or more are required. If the power implicit in the acceleration requirement for the two-passenger car were used for hill-climbing, it would help somewhat, but speeds would still be low. For the other cars, the power implicit in the acceleration requirement is less than that of the gradeability requirement.

At a minimum, loss of speed on grades is inconvenient, resulting in longer trip times. Of greater importance however, are the implications for traffic safety. In 1964 Solomon published a study on main rural highway accidents.(4-1) Two conclusions in that study are fundamental to this analysis. First, low powered vehicles [<820 kw (<110 hp)] are involved in more accidents than higher powered vehicles, regardless of vehicle age, driver age, type of vehicle, military status of driver, sex of driver, vehicle speed, and day or night operation. Second, accident involvement rate depends on the difference in vehicle speed from the average speed on the highway:

> "The accident-involvement, injury and property damage rates were highest at very low speeds, lowest at about the average speed of all traffic and increased at the very high speeds, particularly at night. Thus, the greater the variation in speed of any vehicle from the average speed of all traffic, the greater its chance of being involved in an accident." (4-2)

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*The hybrid gradeability specification has a power requirement sufficient for an acceleration specification of 64 km/h (40 mph) in 10 seconds.

**The specific power for these two curves were 0.0073 [48 km/h (30 mph) in 11 seconds], and 0.0089. This was calculated from Ford data which rates a 48 km/h (30 mph) in 10 seconds vehicle at 0.013 kw/kg (0.008 hp/lb).

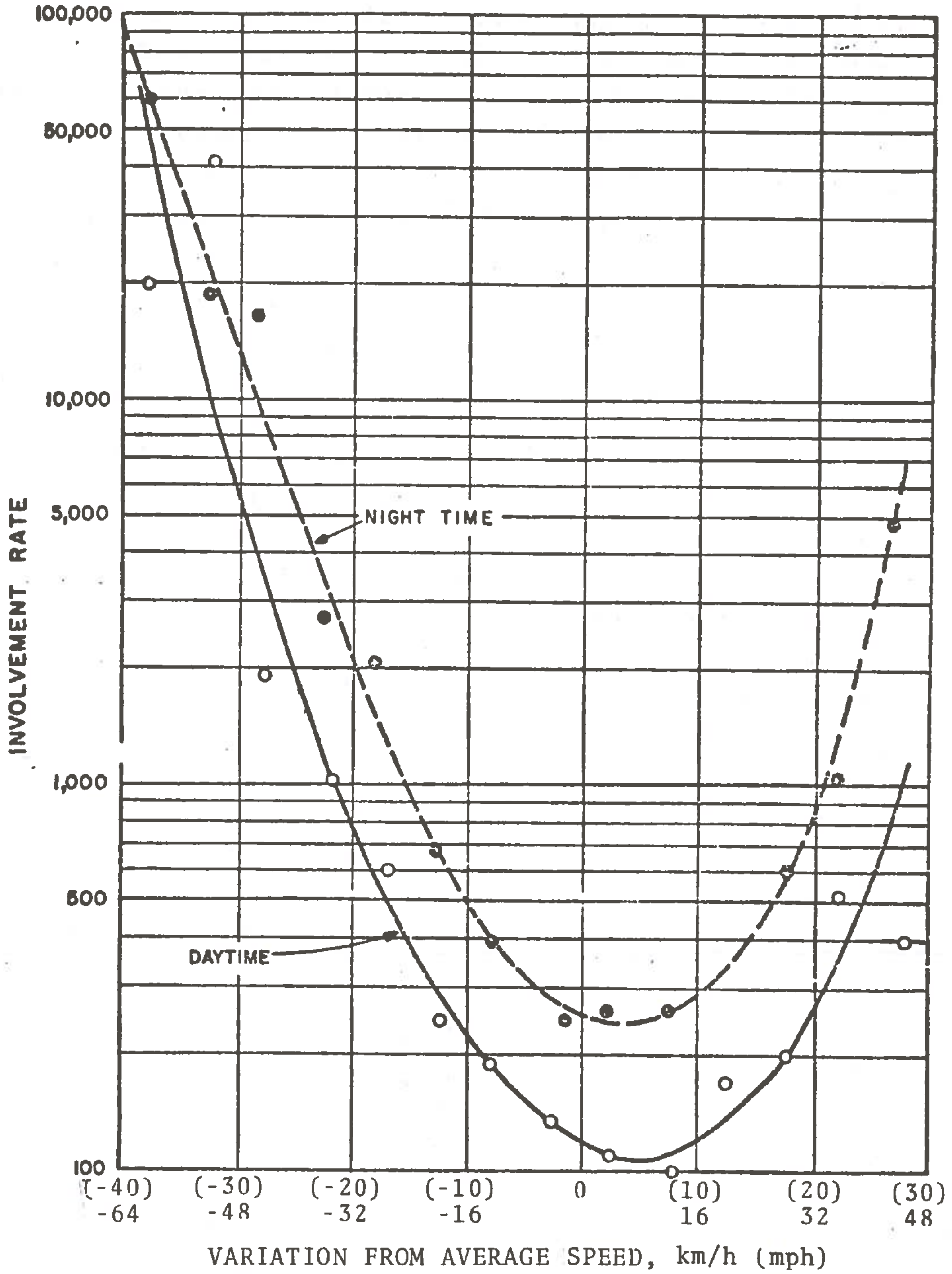
This result appears to be fundamental to traffic safety. When data were adjusted for average speed of all traffic, the relationship between involvement rate and speed difference was shown to be essentially independent of the average speed. This result is shown in Figure 4-2. Accident severity increases with speed, but speed <u>difference</u> is the primary causative variable of involvement rate.

To see how these findings affect the vehicle types in this study, speed differences were calculated for the different grades in Figure 4-1. Eighty-eight km/h (55 mph) was assumed to be the average traffic speed and daytime involvement rates were plotted. Results are shown in Figure 4-3. For simplicity of presentation a 88 km/h (55 mph) top speed for the four-passenger and commercial electric vehicles was assumed. The figure clearly indicates that the two-passenger electric vehicle should avoid all high-speed operations. For the other vehicles (using the gradeability criteria), accident rates do not begin to climb until the 4 per cent to 6 per cent grade range. Using the acceleration criteria, involvement rates will start to rise before the 4 per cent grade is attained for all vehicles.

The significance of the bias depends upon the distribution of grades in urban areas. Park and Crout made an estimate of road grades across the U.S., using primarily New York State data and calculating a distribution of urban and rural grades by terrain type.[4-3] This was extrapolated to other areas of the country, adjusted for terrain. Results were cross-checked with available California data.

It was estimated for the U.S. as a whole that 63.7 per cent of urban highways are less than 3 per cent, 32 per cent between 4 per cent and 6 per cent, 3.9 per cent between 7 per cent and 9 per cent, and 0.3 per cent greater than 9 per cent. Average involvement rates for these categories were estimated from each of the curves in Figure 4-3.* Results are shown in Table 4-2. A total involvement

*Curve values at 1/2 per cent, 1-1/2 per cent, and 2-1/2 per cent were averaged for the 0 per cent - 3 per cent category; 3-1/2 per cent, 4-1/2 per cent, and 5-1/2 per cent averaged for the 4 per cent - 6 per cent category, etc.



Source: Solomon, David, <u>Accidents on Main Rural Highways Related to Speed, Driver and Vehicle</u>, U.S. Department of Commerce, Washington, July 1964.

FIGURE 4-2. INVOLVEMENT RATE BY VARIATION FROM AVERAGE SPEED - DAY AND NIGHT

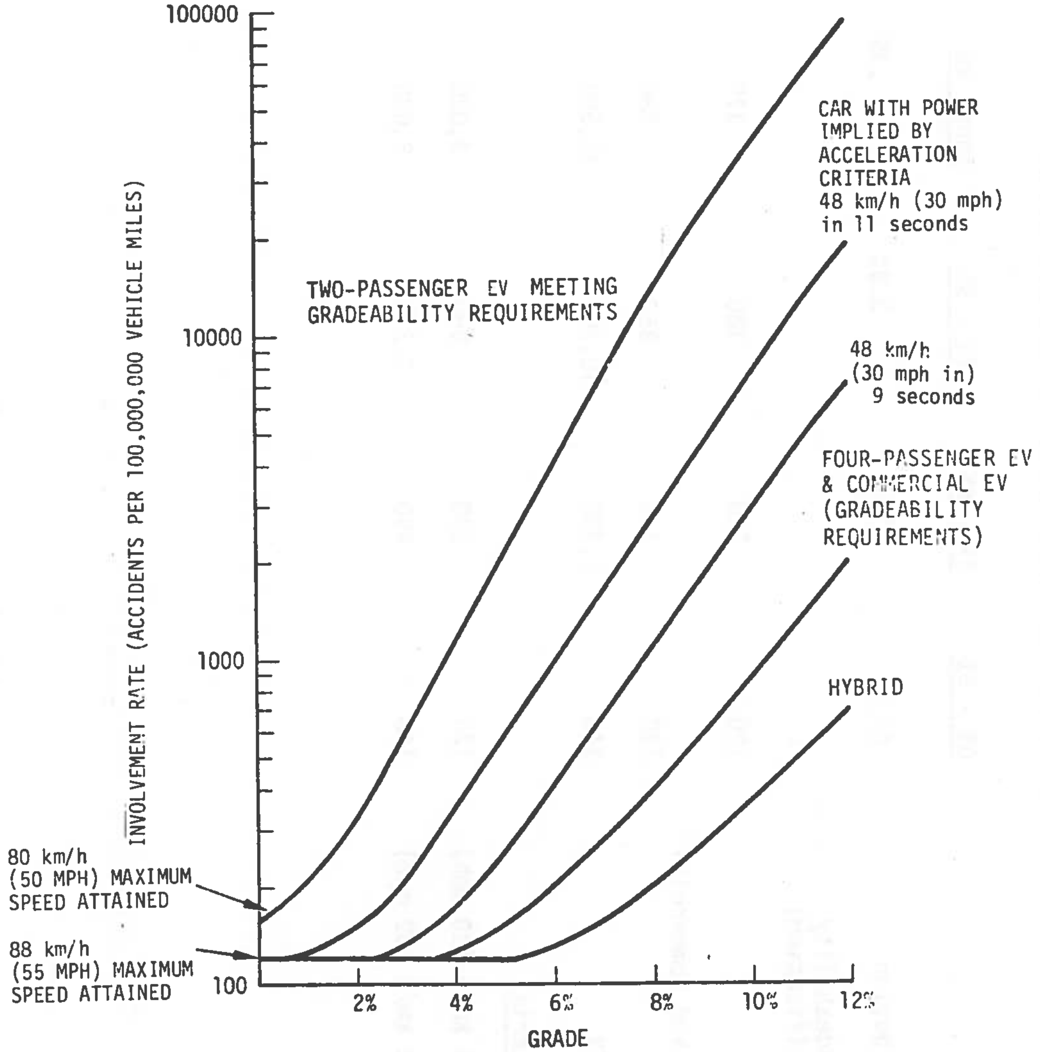


FIGURE 4-3. ACCIDENT INVOLVEMENT RATES FOR STUDY VEHICLES ASSUMING 88 km/h (55 mph) AVERAGE TRAFFIC SPEED AND DAYLIGHT OPERATIONS

TABLE 4-2. URBAN HIGHWAY AVERAGE ACCIDENT INVOLVEMENT RATE, 88 km/h (55 mph) AVERAGE TRAFFIC SPEED

	0% - 3%	4% - 6%	7% - 9%	Above 9%	Total	Ratio
Urban Road Distribution	63.7%	32%	3.9%	.3%	100%	
Vehicle Type (Gradeability Specification)						
Hybrid	120	120	180	370	120	1
Four-passenger and commercial van	120	140	350	880	140	1.2
Two-passenger EV	340	1,700	10,700	36,500	1,300	10.8
Acceleration Criteria						
9 seconds to 48 km/h (30 mph)	120	230	960	3,020	200	1.7
11 seconds to 48 km/h (30 mph)	140	490	2,350	8,000	360	3

rate was then calculated using the grade distribution of Park and Crout. Finally, this average was divided by the involvement rate for vehicles traveling the average speed of all vehicles [75 accidents per one hundred million vehicle kilometers (120 accidents per one hundred million vehicle miles)]. This ratio shows how the involvement rate has increased over the minimum possible due to reduced power available to the vehicle.

All vehicles except the two-passenger EV perform sufficiently well to be able to handle most urban grades (provided the gradeability criteria are used). If acceleration criteria are used then involvement rate rises 70 per cent for the four-passenger vehicle and hybrid [9 seconds to 48 km/h (30 mph)]. For the commercial EV on the other hand, the acceleration specification is the same as the commercial EV and therefore important to vehicle safety. If the two-passenger EV gradeability specification is used to select the vehicle power requirements, involvement rate will be 10.8 times the baseline.

In general, the electric vehicles perform fairly well, but these results assume an average traffic speed of 88 km/h (55 mph. A recent GAO study on the other hand, stated that "at least 75 per cent of the Nation's motorists are driving eight or more kilometers (5 or more miles) per hour faster than the 88 km/h (55 mph) speed limit."(4-4) Hence, non-enforcement of speed laws magnifies the problem.

To test the sensitivity of the preceding results to average speed, daytime involvements were recalculated for each vehicle type assuming 104 km/h (65 mph) as the average speed. Figures 4-4 through 4-8 show the results. As can be seen, a considerable shift in involvement rate occurs and even the hybrid vehicle shows higher involvement rates below the 6 per cent grade, primarily due to the 88 km/h (55 mph) maximum sustained speed specification.

Average involvement rates for urban highways were then calculated for 104 km/h (65 mph) (average traffic speed) contrasted to the 88 km/h (55 mph) results (Table 4-3). Involvement rates are 2.1 times the 88 km/h (55 mph) results for the hybrid vehicle.

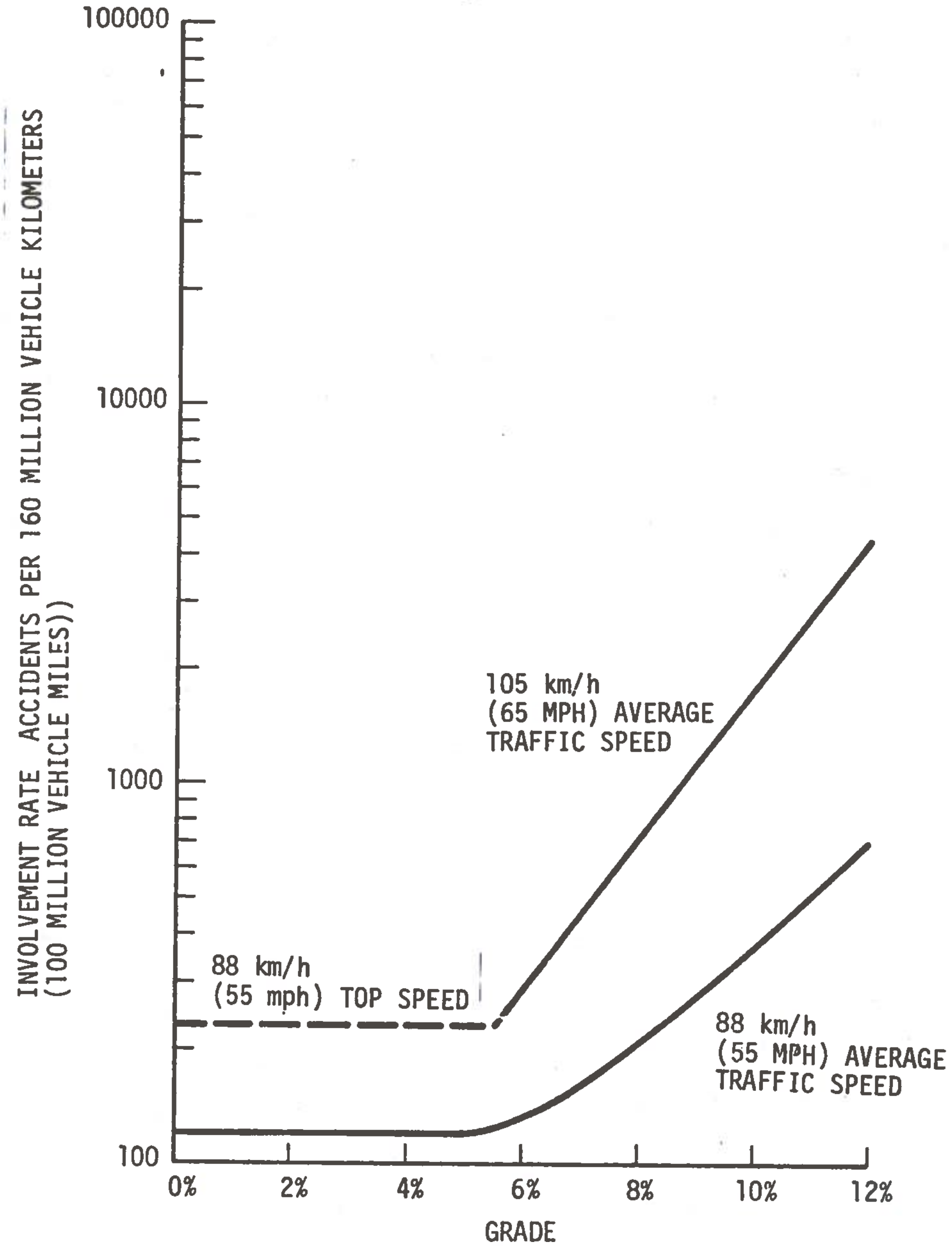


FIGURE 4-4. ACCIDENT INVOLVEMENT RATE FOR HYBRID VEHICLE USING GRADEABILITY SPECIFICATION - 85 km/h AT 6 PER CENT GRADE

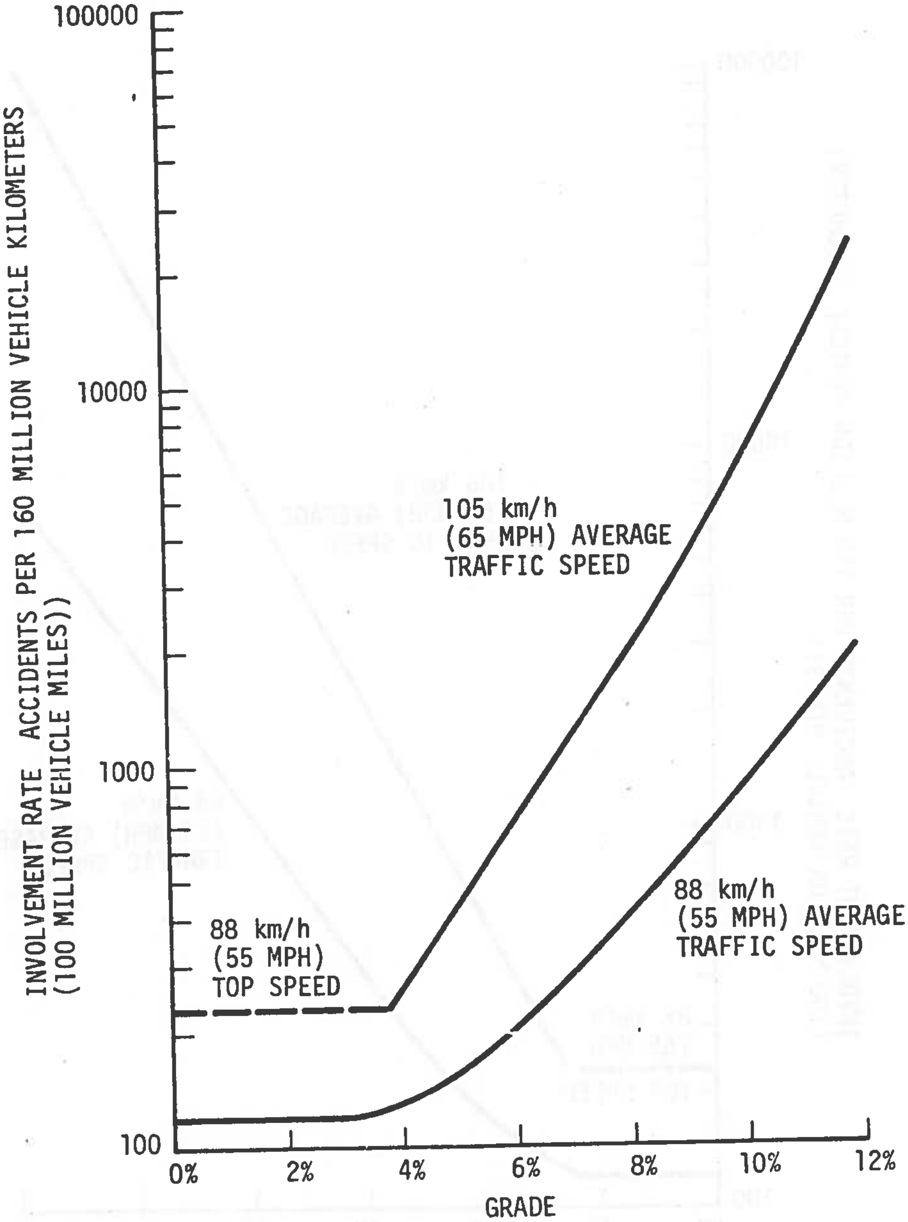


FIGURE 4-5. ACCIDENT INVOLVEMENT RATE FOR FOUR-PASSENGER AND COMMERCIAL ELECTRIC VEHICLES USING GRADEABILITY SPECIFICATION - 70 km/h AT 7 PER CENT GRADE

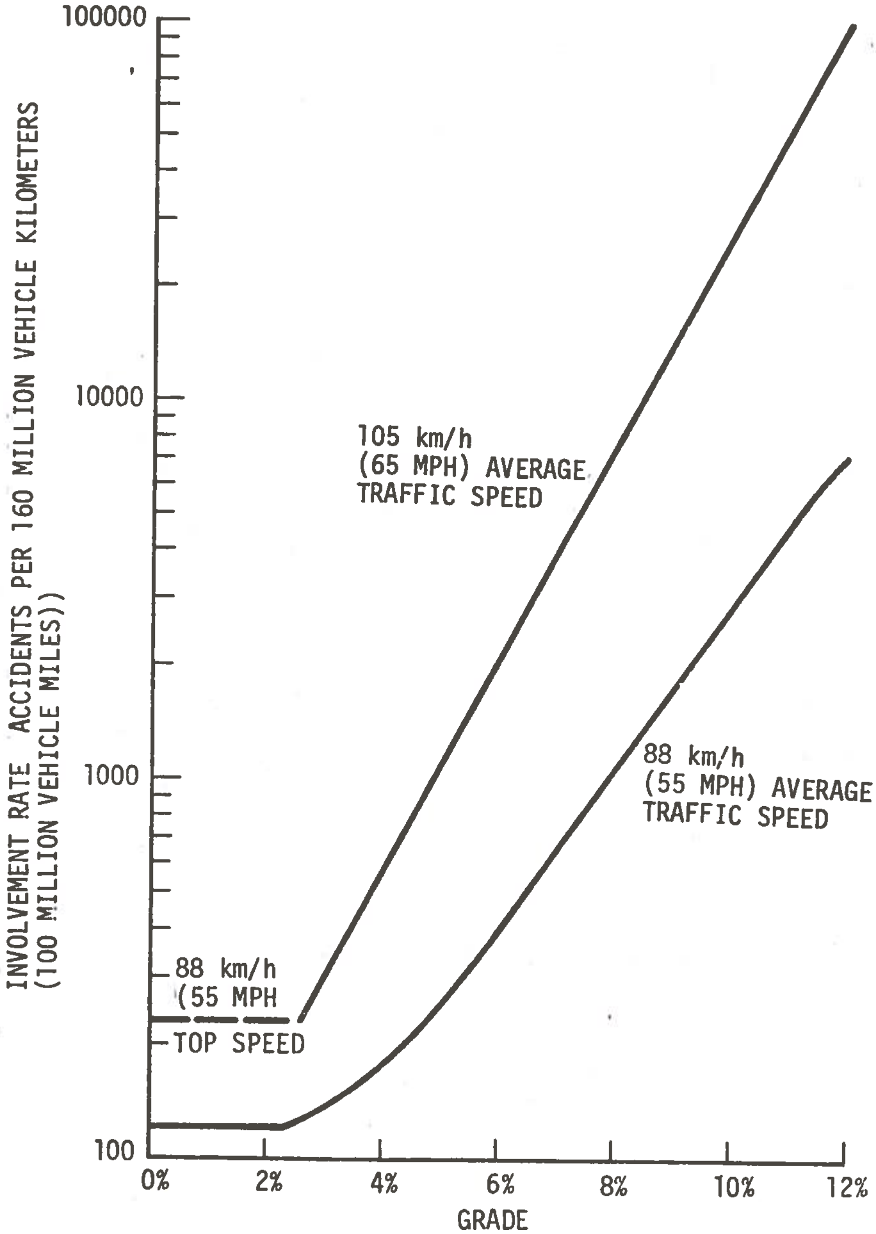


FIGURE 4-6. ACCIDENT INVOLVEMENT RATE FOR FOUR-PASSENGER ELECTRIC VEHICLE USING ACCELERATION SPECIFICATION - 48 km/h IN 9 SECONDS

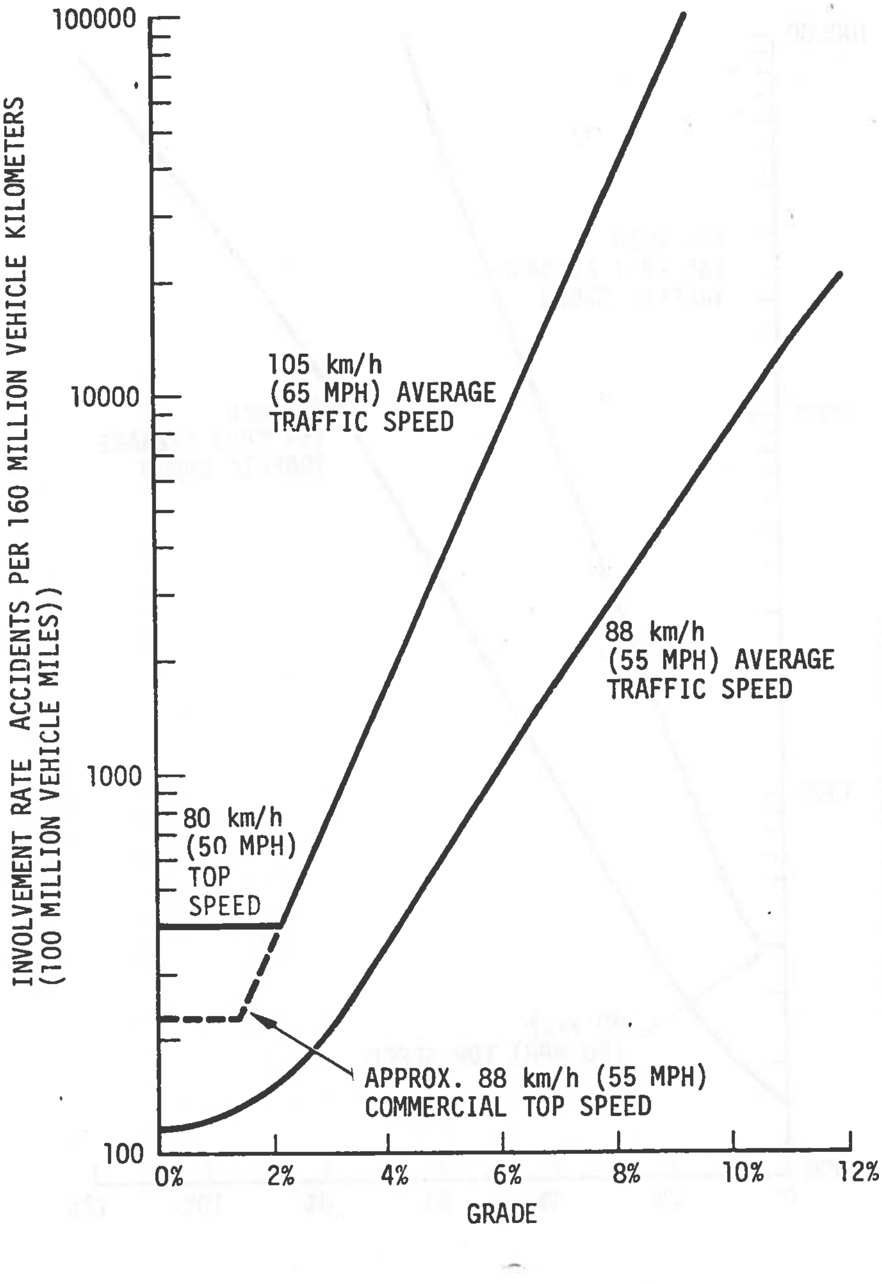


FIGURE 4-7. ACCIDENT INVOLVEMENT RATE FOR TWO-PASSENGER AND COMMERCIAL ELECTRIC VEHICLES USING ACCELERATION SPECIFICATION - 40 km/h IN 11 SECONDS

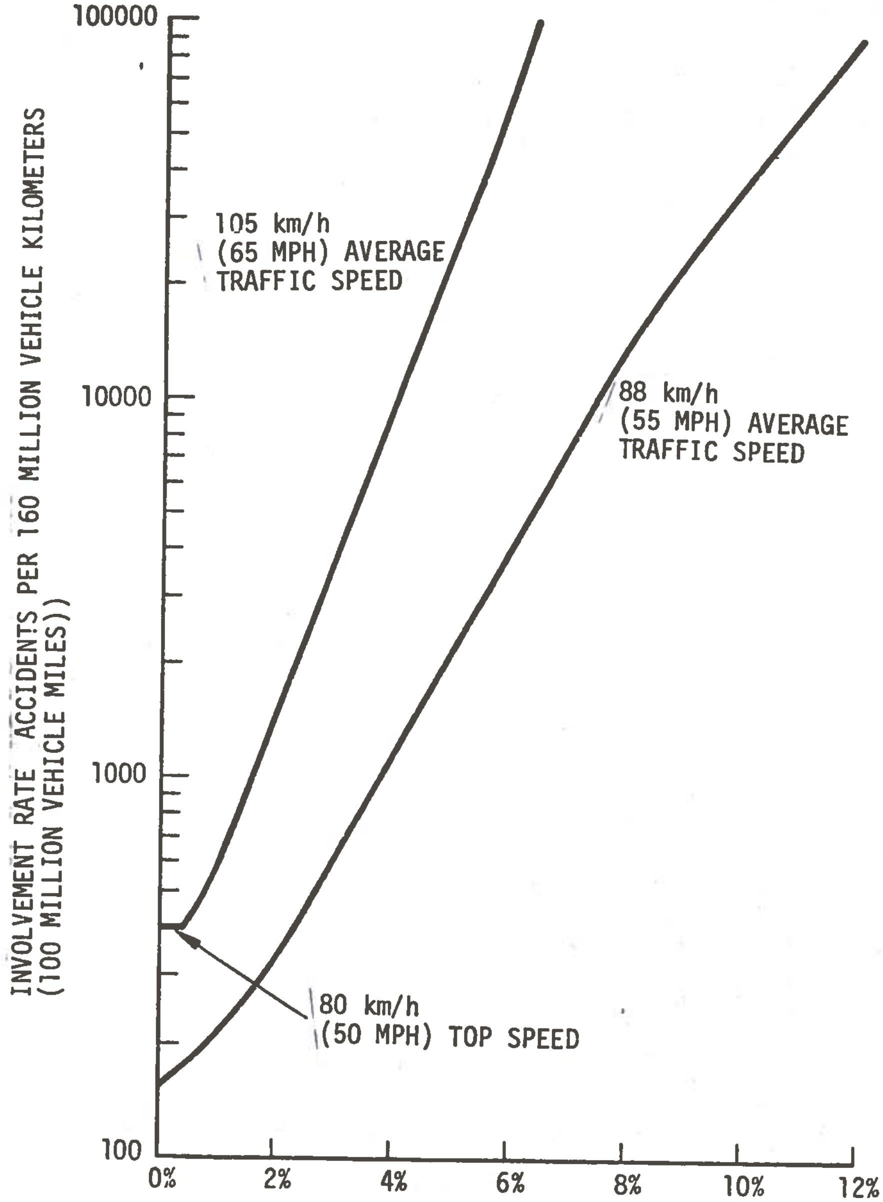


FIGURE 4-8. ACCIDENT INVOLVEMENT RATE FOR TWO-PASSENGER ELECTRIC VEHICLE USING GRADEABILITY CRITERION - 30 km/h AT 10 PER CENT GRADE

TABLE 4-3. ACCIDENT INVOLVEMENT RATE - URBAN HIGHWAYS (NON-ENFORCEMENT OF MAXIMUM SPEED)

	Involvement Rate		
Vehicle	88 km/h (55 mph) Average Speed	105 km/h (65 mph) Average Speed	Non-Enforcement Ratio
Hybrid	120	250	2.1
Four-Passenger and Commercial Van	140	350	2.5
9 Seconds to 30 mph	200	770	3.8
11 Seconds to 30 mph	360	2,600	7.2
Two-Passenger EV	1,300	11,100	8.5

This ratio increases to 8.5 times for the two-passenger EV. The combined effect makes this vehicle over 90 times as likely to be in an accident as a vehicle capable of traveling the average speed across all grades.

In conclusion, with the exception of the two-passenger and hybrid designs, electric vehicles should not be at a significant disadvantage to ICE vehicles provided the 88 km/h (55 mph) speed limit is enforced. Should non-enforcement continue, these vehicles will begin to show declining speed performance at 4 per cent - 6 per cent grades which will imply involvement rates of 2 to 3 times over those of vehicles that can maintain 105 km/h (65 mph) speeds. The two-passenger electric vehicles are definitely underpowered even if acceleration criteria are used in place of the more stringent gradeability criteria. Accident involvement rates will be three to ten times higher for average traffic speeds of 88 km/h (55 mph). If speed law non-enforcement continues, involvement rates will be 22 to 90 times larger than for vehicles able to maintain 105 km/h (65 mph). The two-passenger EV is simply not suitable for high-speed roads.

4.3 ACCELERATION RAMPS

A related area of special concern for electric vehicles is their ability to traverse acceleration ramps onto urban freeways and enter the traffic flow at a speed close to the prevailing freeway traffic. This potential bias differs from gradeability in that acceleration is the key specification.

Up-hill on-ramps onto elevated portions of the freeway are the entry points that will cause difficulty to vehicles with low acceleration capability. Down-hill on-ramps onto depressed freeway segments will aid in acceleration while at-grade freeway segments will be covered by the basic acceleration specification alone.

The Highway Design Manual lists twelve basic local street interchanges.[4-5] They fall into three main categories; diamond, cloverleaf, and trumpet. All except the diamond design include turning movements which are more demanding in acceleration requirements, but also allow for an initial velocity onto the ramp. The diamond design requires little in turning movements, but generally requires a turn onto the ramp or a passage through a controlled intersection. Hence, velocity can be assumed to be zero at the start of the ramp.

The diamond ramp was selected for analysis because it is widely used, requires a near zero starting velocity (restrictive), and little turning movement (less restrictive). This configuration, therefore, represented a typical requirement for the electric vehicle, and avoided a requirement to estimate entering velocity.

Although ramp designs also vary even within basic types, they can be broken down into three sections; approach, climb (for elevated) and merge. These are shown in Figure 4-9. For this analysis, the three sections were combined into an average grade as shown by the dashed line. Thus, the grade used in this analysis was less than the grade of the climb portion of the ramp making these results conservative.

An equation was developed (Appendix F) which estimated the length of the ramp required to enter the freeway at a minimum velocity as a function of average grade and vehicle acceleration

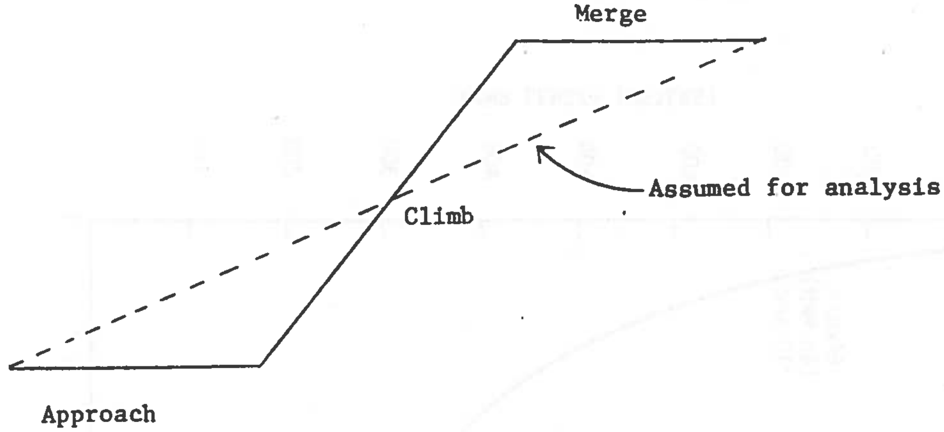


FIGURE 4-9. ON-RAMP TO ELEVATED SEGMENT

characteristics. Using this equation, ramp length requirements for various grades were calculated for selected acceleration characteristics including those in the study vehicles. A 64 km/h (40-mph) entry speed onto the freeway was assumed to be the minimum requirement. Results are shown in Figure 4-10.

The majority of on-ramps onto elevated freeway segments have a 4% - 6% average grade and are 210-300 meters (700-1000 feet) long,* as shown in Figure 4-10. It is clear that all of the study vehicles have acceleration characteristics incapable of negotiating these typical ramps and entering the freeway at 64 km/h (40 mph). A vehicle with acceleration characteristics of 64 km/h (40 mph) in 10 seconds appears to be the minimum requirement. It is important to note how far removed from the requirements of the typical elevated segment on-ramp the study vehilces are. For the typical ramp lengths, the study vehicles are barely able to negotiate at-grade (0 per cent) ramps. Even a 1 per cent ramp is beyond the 300 meters (1000 fect) range for the two-passenger electric car and the van.

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*Gratitude is expressed to Mr. Philip Ching and Mr. Parker Hall of CALTRANS who provided this information

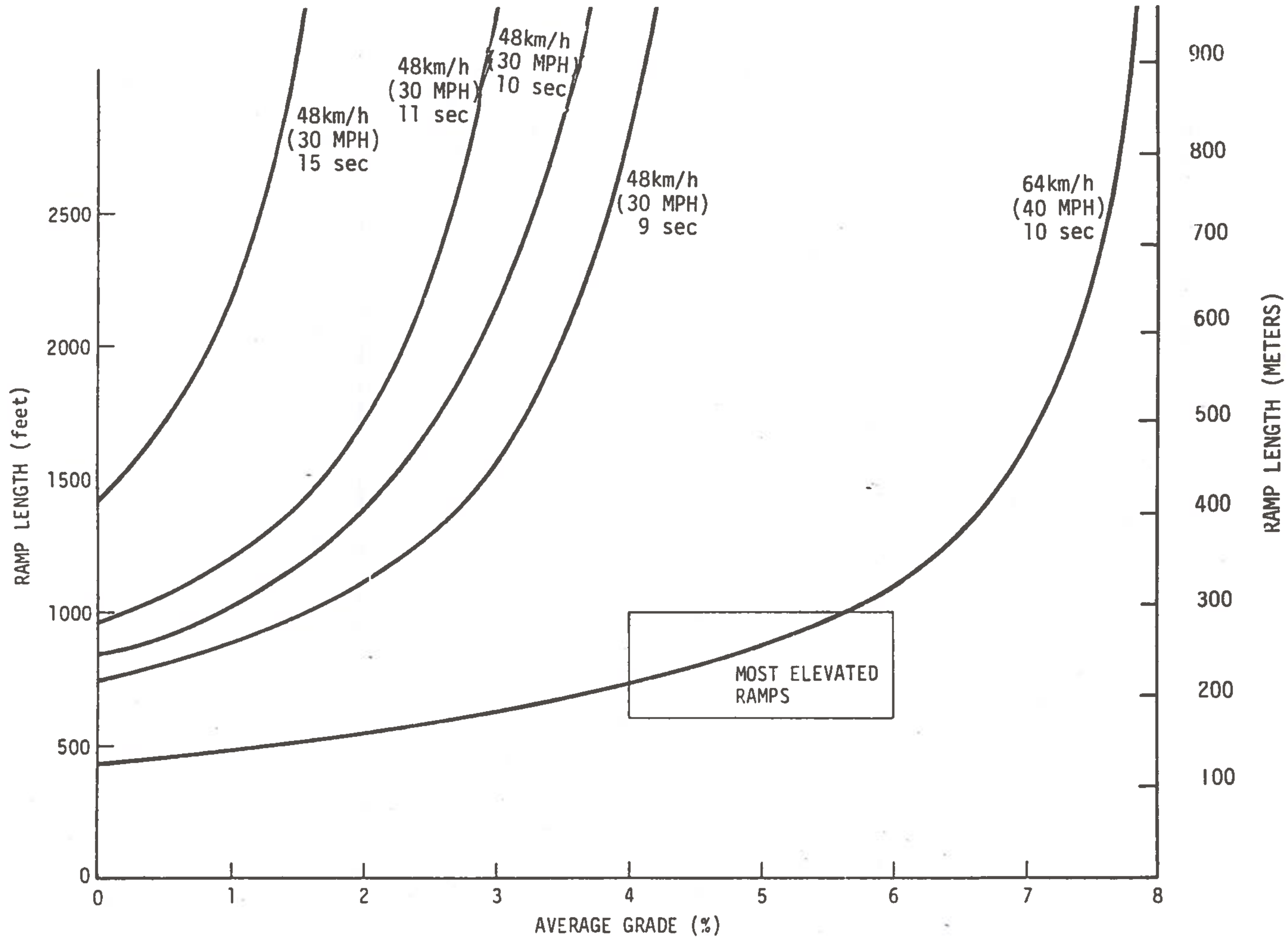


FIGURE 4-10. REQUIRED RAMP LENGTH TO ENTER AT 64km/h (40 mph) (AERODYNAMIC DRAG EXCLUDED)

The 64 km/h (40 mph) entrance velocity requirement appears to be a minimum. If traffic is moving at 88 km/h (55 mph) the accident involvement rate will be three times higher than when merging at 88 km/h (55 mph). If traffic is moving at 105 km/h (65 mph), involvement rate is fourteen times higher. Thus, speed law enforcement is still vital in establishing the magnitude of the bias. Unfortunately, no study vehicles can achieve a 64 km/h (40 mph) entrance speed. Entry speeds of 45 km/h (28 mph) and 39 km/h (24 mph) will be more typical. Even with improved acceleration -- 40 mph in 10 seconds -- accident involvement rates would be 3 to 14 times higher than an at-traffic speed merge as stated above. Table 4-4 quantifies these findings.

TABLE 4-4. VELOCITY AT MERGE FOR A 5%, 240-METER (800-FOOT) ELEVATED FREEWAY SEGMENT ON-RAMP

Acceleration	Speed Merge km/h (mph)	Involvement Rate at Avg. Freeway Speed 88 km/h (55 mph)	104 km/h (65 mph)	Ratio to 120 Involvement Rate Avg. Freeway Speed* 88 km/h (55 mph)	105 km/h (65 mph)
64 km/h (40 mph) in 10 secs	64 (40)	300	1,700	3	14
48 km/h (30 mph) in 9 secs	45 (28)	3,000	50,000	25	420
48 km/h (30 mph) in 11 secs	39 (24)	6,000	1000,000	50	840

*Ratio of involvement rate to that of vehicle merging at average freeway speed.

These limitations would still not be too severe if elevated freeway segments were atypical and by driving a mile or two out of the way, the driver could find a depressed or an at-grade portion of the freeway. Analyses of interchanges in Los Angeles and Sacramento, however, indicate that as many as 58 per cent of the ramps in Los Angeles and 36 per cent of those in Sacramento are at intersections where the freeway overcrosses the road.

If the elevated segment on-ramps were equally spaced, this high frequency would still not be a problem. Even in Los Angeles, almost every other ramp could be at-grade or depressed. This is not the case; freeways were built in segments and long sections are elevated. For Los Angeles, the number of freeway segments

TABLE 4-5. DISTRIBUTION OF LOS ANGELES FREEWAY SEGMENTS GREATER THAN 3.2 KM (2 MILES) WITHOUT UNDERCROSSINGS

	KILOMETERS (MILES)										
Length	5 (3)	6 (4)	8 (5)	10 (6)	11 7	13 (8)	14 (9)	16 (10)	18 (11)	24 (15)	26 (16)
Number	6	6	6	4	1	4	4	1	1	1	1

where the freeway overcrosses the surface streets for 5 km (3 miles) or longer is given in Table 4-5. In Sacramento the problem is not as severe, largely because the city is smaller. However, elevated sections are concentrated in the downtown area and extended surface street trips would be required to find a safe entry point. These two cities should represent a typical range of conditions for most urban areas.

In conclusion, the electric and hybrid vehicles specified for this study are underpowered for safely entering elevated sections of freeways. As a result, substantial portions of city freeway systems will be denied to EV operators. While a minimum acceleration specification of 64 km/h (40 mph) in 10 seconds would help to alleviate the problem, the resulting freeway merge at 64 km/h (40 mph) would still imply an accident involvement rate three times higher than that of a 88 km/h (55 mph) merge. If speed laws are not enforced and average freeway speed rates are 105 km/h (65 mph), accident involvement would be 14 times the baseline, even for the 64 km/h (40 mph) merge.

4.4 TRAFFIC LIGHT TIMING

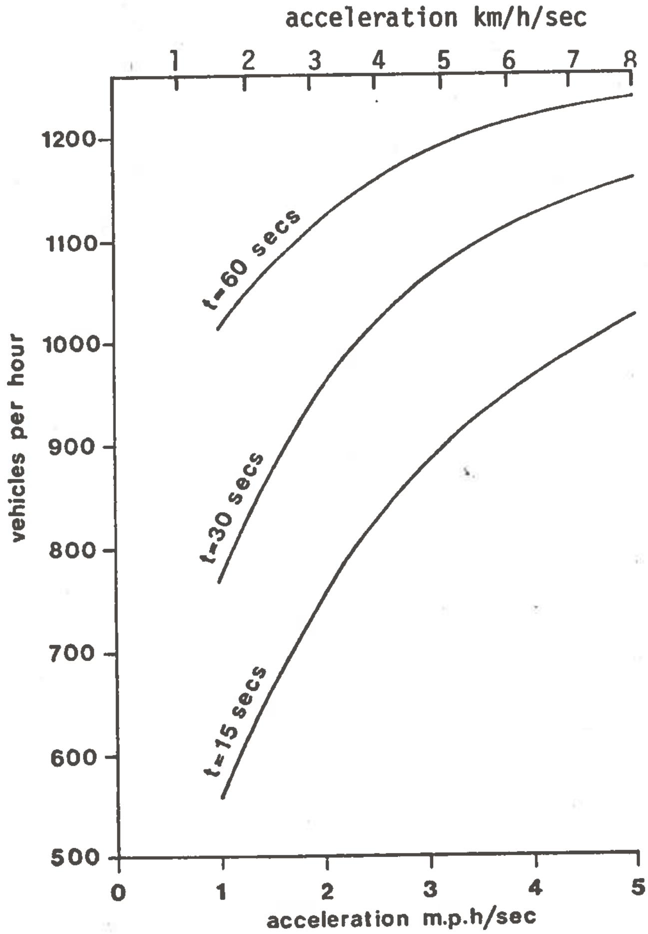
With respect to street performance and movement through intersections, a potential bias exists against electric vehicles because of their slower acceleration. Capacity constraints on city streets ordinarily exist at intersections rather than at midblock segments because traffic flow is interrupted at intersections to allow for the passage of cross traffic. Congestion at intersections increases with increased traffic demand and decreases with improved intersection performance. Signalized intersection performance is a function of street characteristics, traffic signal timing, and vehicle acceleration. Three potential elements of bias are examined in this section: (1) fixed-time traffic signals, (2) demand-actuated (vehicle-actuated) traffic signals, and (3) travel-time across a city through a series of traffic signals.

4.4.1 Fixed-Time Signals

A queue of waiting cars frequently has a fixed time in which to move through an intersection. Electric cars would be penalized in this situation if their reduced acceleration capabilities restricted their movement. A measure of this potential bias is the likely reduction in vehicle capacity through intersections as a consequence of electric vehicles in the traffic flow.

The possible effect of acceleration on capacity has been theoretically derived in a British report, reproduced as Figure 4-11.[4-6] The figure suggests that capacity is directly related to acceleration and shows that signal timing can dampen the effects of slower acceleration. For reference, electric vehicles in this study have an acceleration rate of about 4.3 to 5.3 km (2.7 to 3.3 miles) per hour per second (for the 48 km/h (30 mph) in 11 seconds, and 48 km/h (30 mph) in 9 seconds vehicles respectively). In contrast, many ICE vehicles can accelerate at 8 km (5 miles) per hour per second.

Once the timing has been set, the capacity of a fixed-time signal is approximately proportional to the saturation flows of the traffic on each intersection approach. Saturation flow, the average maximum rate of departure of vehicles stopped at a traffic



Source: Cars for Cities, Ministry of Transport
Her Majesty's Stationary Office
London, 1967

FIGURE 4-11. SIMPLIFIED THEORETICAL EFFECT OF ACCELERATION AT A TRAFFIC LIGHT CONTROLLED JUNCTION (t = GREEN PHASE FOR AN INTERSECTION APPROACH) signal, is a function of the characteristics of the intersection approach, such as width and steepness, as well as the performance characteristics of the vehicles in the traffic stream, such as acceleration. Acceleration affects headways between vehicles. Average saturation headway - the number of seconds between vehicles leaving the stop line - is inversely proportional to saturation flows in vehicles per hour.

The ratio of the average headway of a class of vehicles to the average headway of a passenger car is called the passenger car equivalent measured in through car units (t.c.u.) or passenger car units (p.c.u.).

Passenger car equivalents shown in Table 4-6 were determined by research in the United Kingdom by Webster[4-7] and in Australia by Miller.[4-8] The findings of both researchers are in agreement and are in general use for estimating the capacities of mixed traffic streams. Tests by Miller indicate that the position of commercial vehicles in a queue of traffic is of no consequence, i.e., capacity is influenced only by the percentage of various classes of vehicles and not by their sequence in the traffic stream.[4-9]

TABLE 4-6. PASSENGER CAR EQUIVALENTS BY TYPE VEHICLE

	Type of Vehicle	Passenger Car Equivalent
Webster:	1 Tram	2-1/2
	1 Bus	2-1/4
	1 Heavy or Medium Goods Vehicle	1-3/4
	1 Car	1
	1 Light Goods Vehicle	1
	1 Moped, Motorcycle, or Scooter	1/3
	1 Pedal Cycle	1/5
Miller:	1 Commercial Vehicle	2
	1 Car	1

Intuitively, from Webster's list of vehicle equivalents, one would expect that electric cars would fall into the range of slower accelerating trucks. Unfortunately, as far as can be determined, the vehicle equivalence of electric cars has not been tested. There is evidence, however, of essentially no difference between the headways of the larger, more powerful American cars and the smaller, less powerful Fiats.[4-10] Apparently, the effect of low acceleration is offset by small size. Thus, one expert has concluded that electric cars should have a vehicle equivalence of one.[4-11]

This conclusion might appear to contradict the findings in Figure 4-11. However, those curves were based on tested vehicles identical except for acceleration. Thus, Figure 4-11 shows the capacity/acceleration trade-off for vehicles of equal size. The tested vehicles had accelerations of about 5.6 and 8.0 km/h (3.5 and 5.0 mph) per second, and the higher acceleration alone increased capacity by 5% to 10% among the study vehicles. Results using the acceleration characteristics of the electric vehicles in this study [4.3 - 5.3 km/h/sec (2.7 - 3.3 mph/sec)] and the most efficient signal timing curve for heavier traffic flows indicate that capacity would be reduced 5% to 15% below that of a 8 km/h/sec (5 mph/sec) ICE compact car. This would suggest a vehicle equivalent of about 0.9 p.c.u. for more powerful ICE vehicles of the same size as electric vehicles.

In traffic of the present city environment, therefore, electric cars would appear to have no significant effect on the capacity of the fixed-time traffic signals. In an all small-car city, capacity at fixed-time traffic signals could be reduced by as much as 5% to 15% below the intersection capacity compared with gasoline powered vehicles of the same size. For a mixture of small ICE and electric vehicles, capacity would be reduced proportionately to the percentage of electric vehicles in the traffic stream. For example, if half of the vehicles were electric powered and half of the vehicles were ICE of equal size, capacity would be reduced by 2-1/2% to 7-1/2%. Thus even in the all small-car world, capacity reductions would be minor.

4.4.2 Demand-Actuated Traffic Signals

The same reasoning appears to apply for demand-actuated traffic signals. At such signals, the green periods which serve each traffic movement are varied according to detected traffic. Vehicle-actuated traffic signal controllers extend the green periods for long queues of traffic and shorten them for lighter traffic.

When traffic demand equals or exceeds capacity, vehicle detections extend signal timing to its preset maximum, causing the signal to operate as a fixed-time traffic signal. Therefore, all of the comments regarding capacity for fixed-time traffic signal controllers also apply to vehicle-actuated signals during congested periods. A bias against electric cars related to intersection capacity at vehicle-actuated traffic signals does not appear to exist.

At traffic demands below capacity and at capacity situations when the maximum green period on one or more stages is so long that the maximum flow is not reached, the signals switch stages when a time gap is detected in traffic being served. The gap may be a constant vehicle interval or it may be a reducible gap which becomes shorter for longer waiting times of opposing traffic.

The gap corresponds to time headways between vehicles. If vehicles of larger than average headways were in the traffic stream and the vehicle actuated signals were not timed to accommodate them, then one or more vehicles occasionally might be caught by a red light, thus increasing delay. Since the time headway of electric cars is presumed nearly equal to that of ICEs, a gap problem is not likely to exist. A delay bias against electric cars at intersections controlled by vehicle actuated controllers would therefore be nonexistent during subcapacity situations.

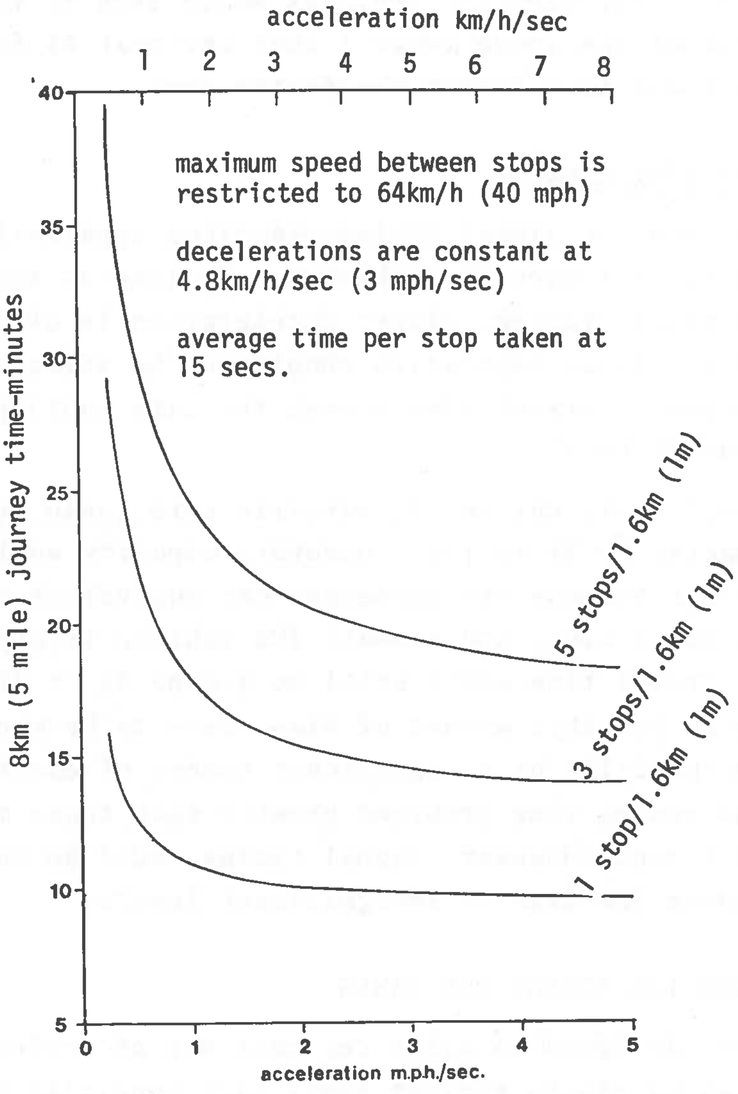
In an all small car city, if vehicle actuated controllers were set for ICEs of the same size as electric vehicles, and a substantial number of electric vehicles were later introduced into the traffic stream without resetting the signals, there could be a small increase (not more than 5% to 15%) in the rare occurrence of queued traffic not clearing the green light. Since vehicles are rarely trapped at vehicle actuated signals at subcapacity conditions, even a 15% increase in the number of instances would be barely noticable.

4.4.3 Travel Time Impacts

Although capacities at intersections will remain unchanged by electric vehicles, slower midblock acceleration may cause more frequent missing of a signal in a series of signals. Consequently, travel time through cities would be increased.

Figure 4-12 (extracted from Reference 4-7) shows the theoretical effect of journey times under start-stop conditions. Electric vehicles having an acceleration of 4.3 to 5.3 km (2.7 to 3.3 miles) per hour per second would fall into the nearly horizontal portions of the three curves. Based on these graphs, an electric car capable of 4.3 km (2.7 miles) per hour per second acceleration would require 4% to 9% more time to traverse a five mile section of city streets than an ICE of 8.0 km (5.0 miles) per hour per second acceleration. Assuming 15 seconds per stop, a maximum speed of 64 km/h (40 miles) per hour, and a deceleration of 4.8 km (3.0 miles) per hour per second, the electric car would require 9% more journey time if there were five stops per 1.6 km (per mile), 6% more journey time if there were three stops per 1.6 km (per mile), and 4% more journey time if there were one stop per 1.6 km (per mile). For an electric car of 5.3 km/h (3.3 mph) acceleration, the through city journey times would increase by 7% for five stops per mile, 4% for three stops per mile, and 3% for one stop per mile.

These estimates appear reasonable for electric vehicles traveling independently of other traffic or for vehicles all of the same size. For electric vehicles in mixed traffic and slowed by other traffic, the upper limit of acceleration would be less important, and the percentage differences in journey times between electric cars and ICEs would be less pronounced.



Source: <u>Cars for Cities</u>, Ministry of Transport
Her Majesty's Stationary Office,
London, 1967

FIGURE 4-12. SIMPLIFIED THEORETICAL EFFECT OF ACCELERATION ON JOURNEY TIMES UNDER STOP/START CONDITIONS

Further, if a substantial number of slower accelerating electric cars were to pass through a series of coordinated traffic signals, the signal timing could be adjusted to accommodate them. This would have the effect of reducing the number of stops per mile and the length of each stop. Hence, the percentage increase in journey time for electric vehicles would tend to fall toward the lower end of the above range - that is, near 4% for the slower electric cars and near 3% for the faster ones.

4.4.4 Concluding Remarks

Current traffic signal timing practices apparently create little bias against electric vehicles. As long as the electric car operates in mixed traffic, slower acceleration is offset by smaller size and intersection capacities should not be affected. Furthermore, increases in travel time across the city would probably be small, around 3% to 4%.

In an all small car world, electric cars could decrease intersection capacity by 5% to 15%. However, capacity would be greater than now exists because the passenger car equivalent of electric vehicles is one p.c.u., and a small ICE vehicle is approximately 0.9 p.c.u. Travel time could still be around 3% to 4% longer for electric cars, but this amount of bias seems to be minor. Finally with the introduction of a significant number of electric vehicles, capacity and travel time problems greater than those mentioned above could arise. However, signal timing could be reset in this event to reduce the bias to insignificant levels.

4.5 PREFERENTIAL ACCESS AND LANES

Policies designed to allow car pool use of preferential lanes or access can be biased against small cars generally and electric vehicles in particular. Preferential lanes on commuter routes and preferential access have become an accepted alternative to expansion of existing roadways by transportation planners. While preferential lanes and access are similar, in that they provide preferential treatment to a class of vehicles, their rules for preferential treatment vary even when used on the same route. Preferential access provides special treatment for a class of vehicles at a roadway entrance ramp. The following analysis will primarily discuss preferential lanes with comments pointing out the differences in preferential access rules.

The major objectives of the preferential concept are to move more people with fewer vehicles in an effort to improve traffic flow in peak demand periods, to improve air quality, and to conserve energy. In order to accomplish these objectives, the emphasis has been to encourage commuters to switch to high-occupancy vehicles. The indirect effect is to discourage the use of small cars and to encourage the use of fewer large cars.

Rules for preferential lane use were examined to determine if a bias in favor of car propulsion or size was evident. Through a literature search, no rules were found for preferential lane or access lane use that would single out electric cars as opposed to ICE cars except for size. In fact, the sole criterion for use of preferential lanes, because they are designed to encourage higher occupancy rates, is the number of occupants per car.

These rules tend to discourage electric cars. The number of occupants per car for a car pool as defined by the Environmental Protection Agency (EPA) is three and since EPA has also required all governmental entities, states, cities, and counties within the impacted air quality control regions to establish bus/car pool lanes, it is assumed that the accepted criterion is three occupants per car.*

*Preferential access policies tend to be more liberal and subject to to more variation. In the case of the Santa Monica Freeway Diamond Lane Project in the Los Angeles area, preferential access policy was set at two or more occupants per vehicle at some entrance ramps while others indiscriminately metered vehicles onto the freeway. But, as in the case of preferential lanes, there appear to be no policies that would favor one type of car over another except for the number of occupants which affects the car size.

In the case of two-passenger electric cars, the resulting bias amounts to a prohibition. The bias against the four passenger electric car depends on how many commuters will be willing to commute in a three-passenger or more car pool occupying a four-passenger electric car which is roughly the size of a subcompact ICE vehicle.

Data are limited on the size of automobiles used in car pools, but the Hollywood Freeway survey in November 1973 did determine the distribution of automobile size in existing car pools.(4-12) This survey found "no significant differences ... in the types of cars driven by car pools and non-poolers." The data are reproduced in Table 4-7. However, it is important to note that the definition of car pool used in this study is two or more occupants so the similarity of vehicle type does not necessarily apply to the EPA car pool definition. Furthermore, two occupant car pools are not biased against particular vehicle sizes. So one would expect a similar distribution of vehicle types.

TABLE 4-7. TYPE OF CAR USUALLY DRIVEN TO WORK

	Total (Percent)	Pool (Percent)	Non-Pool (Percent)
Luxury	7	7	8
Standard	29	26	29
Compact	20	18	20
Subcompact/Economy	25	29	25
Sports Car	3	3	3
Station Wagon	2	2	2
Other	12	16	12

Source: Alan M. Voorhees and Associates, Inc., A Study of Techniques to Increase Commuter Vehicle Occupancy on the Hollywood Freeway, prepared for the California Dept. of Transportation, Nov. 1973, p. 77.

Several surveys provided the distribution of car pools by the number of occupants. Two of these survey distributions are shown in Tables 4-8 and 4-9. They clearly indicate the importance of two-occupant car pools.

TABLE 4-8. NUMBER OF PERSONS IN CAR POOL, SACRAMENTO (INCLUDES DRIVER)

Number of Persons in Car Pool	Percent of Car Pools
Two	35.5
Three	22.5
Four	26
Five or more	16

Source: Derby, Jack and Baetge, Jim, Sacramento Ridesharing Project. Second Interim Report, California Dept. of Transportation, Office of Ridesharing, Sacramento, March 1977. p. 24.

TABLE 4-9. NUMBER OF PERSONS IN CAR POOL, SAN DIEGO (INCLUDES DRIVER)

Number of Persons in Car Pool	Percent of Car Pool
Two	62
Three	23
Four	12
Five or more	3

Source: Kaplan, Oscar J, San Diego Transportation Survey, prepared for Comprehensive Planning Organization, San Diego, CA Feb 8, 1976, p. 2.

In summary, the bias against the two-passenger electric vehicle is one of prohibition due to EPA's definition of a car pool as having three or more occupants, while bias against the four-passenger electric vehicle is one of discomfort and has not been quantified. Table 4-7 clearly indicates that a two-occupant definition for car pools would remove any bias against vehicle size. Tables 4-8 and 4-9 show that the two-occupant car pool is a significant percentage of the car pool population. Similar conclusions are applicable to preferential access.

4.6 STREET SIZE AND VEHICLE SEGREGATION POLICY

Urban streets have been sized for large vehicles. Small car operators, including electric vehicle drivers, must pay for large car privileges in the form of congestion. The implications of this bias can be quantified in terms of street capacity increases for all small car operation.

According to British studies, the increased capacity will be largely due to reduction in vehicle width rather than vehicle length.(4-13) Reduction in vehicle width can be translated into reduced lane width. In some cases this will allow the addition of a traffic lane and therefore an increase in street capacity. Since street capacity between intersections is essentially proportional to the number of lanes, the increase can be as much as 50% (by making three lane one-way streets out of two lane streets). Futhermore, intersection capacity will also be increased by the number of lanes.

Reduction in vehicle length on the other hand does not have the same potential. As pointed out in Section 4.4, capacity restraints on city streets ordinarily exist at intersections. This capacity is affected by traffic demand (number of vehicles per lane) and intersection signal performance. Reducing vehicle size will offset slower acceleration performance of electric vehicles and leave intersection signal performance about the same, so that intersection capacity and street capacity will not be affected.

For small ICE vehicles which retain high acceleration performance, mid-block capacity increases due to length reduction will still be less than 10%. This assertion is based upon a British study of headway requirements related to vehicle size. According to the British survey, small vehicles will have 10% smaller headways (the distance between the front end of the car and the front end of the car immediately following).(4-14) The headway reduction decreases as speed increases.* Furthermore, if mid-block street capacity were increased, volume per lane would be increased and

*The study results included a 17% reduction in headway for vehicles traveling 16 km/h (10 mph) and a 7% reduction in headway for vehicles traveling 72 km/h (45 mph.) Study results are based on comparing 10 foot long cars to 14 foot long cars. The percentage reduction in lengths is similar to vehicles in this study [510 cm (170 inches) to 675 cm (225 inches)].

saturation flow would be achieved earlier. Thus intersection capacity would limit any mid-block capacity gains.

For all practical purposes, therefore, capacity increases would be the result of additional lanes. The following traffic lane widths and parking lane widths are recommended by the Association of State Highway Officials.[4-15] For traffic lanes on arterial roads, 3.6-meter (12-foot) widths are ideal with 3.3-meter (11-foot) minimum. For parking lanes they recommend that they be the same size as traffic lanes so that they can be converted to traffic lanes if required by restricted parking. At a minimum they should be 3-meters (10-feet) wide providing 2.1-meters (7-feet) to the vehicle and a 0.9-meter (3-foot) clearance from traffic lane.* Using the Santa Barbara values, potential capacity changes can be examined by assuming that parking lanes as well as current driving lanes are employed.

On streets designed for large cars, deletion of one parking lane would provide 2¼ meters (7.5 feet) for an additional travel lane. This will not meet the average lane requirement however, and no advantages would occur. When two parking lanes are deleted, 45 meters (15 feet) of roadway is made available. This is more than enough for the addition of one lane, but not sufficient for the addition of two lanes. Thus, deleting both parking lanes can only add one additional lane of traffic.

If the existing street capacity is used for small cars, however, quite a different picture emerges. First each lane can be one foot narrower as the vehicles in our study are 0.3 meter (one foot) narrower. Thus the two-lane road will have 1.2-meters (4-feet) of extra width (two travel and two parking lanes) and the four lane road will have 1.8 meters (6 feet) of extra width.

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*In a survey of Santa Barbara roads the following average values were found: traffic lanes 3.6 m (12 feet) average; interior traffic lanes 3 m (10 feet); exterior (next to parking or curb) lanes 4.2 m (14 feet); parking lanes 2.1-2.4 m (7-8 feet); two lane road curb-to-curb width 12 m (40 feet); four-lane road curb-curb width 19.2 m (164 feet).

Second, additional lanes will only require 2.7 m (9 feet) (as they are interior lanes). Using these two assumptions we have the following:

1. No new lanes can be added without giving up a parking lane.
2. If one parking lane [2 meters (6-1/2 feet)] is deleted, 3.2 additional meters (10-1/2 feet) are available on the two-lane road and 3-3/4 meters (12-1/2 feet) on the four lane. Clearly one lane of traffic can be added in each case.
3. If two parking lanes are deleted then 5 additional meters (17 additional feet) are available for the two-lane road and 5.7 meters (19 feet) are available for the four-lane road. Two lanes can be added to the four lane road.

Results of the analysis are shown in Table 4-10. For the road widths selected, small car streets offer significantly better peak-hour capacities and off-peak, on-street parking availability. Peak hour congestion is a problem in most urban areas. Where the traffic demand is high, restricted parking has already been implemented. Clearly, capacity could be further increased in these areas by providing small car streets. In addition, on-street, off-peak parking can be increased.

4.7 TOLLS AND CONGESTION PRICING

Historically tolls have been collected at bridges, tunnels, and toll roads to pay for the capital cost of these improvements, their annual operation and maintenance cost, and in some cases, as a general revenue source. Congestion pricing is a relatively new concept in which a higher price is imposed for the use of transportation systems during peak periods as opposed to off-peak periods. Like preferential lanes, congestion pricing of tolls can create biases against small cars if it is based on minimum occupancy standards.

TABLE 4-10. STREET CAPACITY FOR SMALL AND LARGE CARS

	Existing Roadway							
	2 Lane 13 meter (43 Feet) (Curb to Curb Width)				4 Lane 19 meter (63 Feet) (Curb to Curb Width)			
	Peak Hour		Off-Peak		Peak Hour		Off-Peak	
	Parking Lane	Travel Lane	Parking Lane	Travel Lane	Parking Lane	Travel Lane	Parking Lane	Travel Lane
Large Cars								
	2	2	2	2	2	4	2	4
	1	No Change			1		No Change	
	0	3	1	2	0	5	1	4
Small Cars								
	2	2	2	2	2	4	2	4
	1	3	2	2	1	5	2	4
	0	Same as 1 parking lane			0	6	2	4
Marginal								
	0	4	2	2				

Congestion pricing of tolls can be used to encourage car pooling by imposing a higher price on travel by low-occupancy vehicles. Preferential lanes discussed in Section 4.5 are a non-monetary form of congestion pricing. The low-occupant vehicle passengers pay for travel on a roadway having preferential lanes in terms of longer travel time.

An extension to the congestion pricing concept is to apply it to congestion areas or zones, such as a central business district. Entry into the congestion zone is prohibited during peak hours without a supplementary license. Colleges and universities and large employers have employed supplementary licensing to discourage through traffic and reduce parking requirements. The Urban Mass Transportation Administration (UMTA) currently is planning a congestion pricing demonstration program based on supplementary licensing and other congestion pricing policies. Eleven cities are currently being solicited by UMTA as possible sites for the demonstration program. A proposed supplementary licensing ordinance was rejected by the Berkeley, California city council in December 1976.

Prevailing tolls and congestion pricing are not dependent on vehicle characteristics other than size. Their use to promote car pooling of 3 or more occupants will be biased against small (including electric) vehicles.

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5.0 URBAN DESIGN

5.1 INTRODUCTION

The evolution of urban design in the United States has been drastically shaped by automobiles. Many aspects of the urban environment are a consequence of, or are tailored specifically to, conventional ICE vehicles. Such strong interrelationships can create biases against vehicles with differing characteristics, including electric and hybrid vehicles.

This chapter examines major elements of urban design that create potential biases and relates these potential biases to the alternative characteristics of conventional and electric vehicle technology. Table 5-1 displays the relevant institutional factors and vehicle characteristics.

5.2 URBAN DENSITY

Urban density varies from city to city in the U.S. and from area to area within each city. In general, the greater the density the more employment, shopping, and residential opportunities are brought into close proximity. The closeness of these opportunities affects the potential for electric car ownership.

In the early decades of the twentieth century, public transit played a central role in opening up the urban fringes. In the 1950's, however, pent-up demand for housing and cars, accommodated by road building programs, housing availability and cheap energy, led to the rapid growth of the suburbs surrounding the older urban areas and, in fact, to the creation of new urban areas. This largely residential growth was followed closely by commercial development. Land uses in newly urbanized areas were kept separate mostly through zoning, and many of the industrial employment areas were left behind.

Consequences of this new low density development included: (1) an increase in multi-car families, (2) an increase in home-to-work trip lengths, and (3) an increase in required trip lengths for commercial vehicles. Thus, this trend has created biases both

TABLE 5-1. POTENTIAL URBAN DESIGN BIASES RELATED TO CHARACTERISTIC DIFFERENCES OF ELECTRIC VEHICLES

Potential Bias	Refueling Capability: Recharge Site	Refueling Capability: Multi-Vehicle Household Requirement	Range Limits	Size	Noise Air/ Pollution
(1) Urban Density and Urban Growth Planning	X	X	X		
(2) Intermodal Planning		X	X		
(3) Access Policies					X
(4) Parking Supply					
a. Commercial				X	
b. On-Street				X	
c. Residential				X	
(5) Covered/Uncovered Auto Facilities					X

favoring and opposing electric vheicles.

5.2.1 Car Ownership

The relationship between car ownership and urban density has been observed for some time. Levenson and Wynn developed the graph shown in Figure 5-1 from 1960 census data which clearly shows the decline in car ownership per household as urban density increases.(5-1) Lansing performed further analyses indicating that multi-car ownership increases for all income levels as density decreases (Fig. 5-2 and Table 5-2).(5-2)

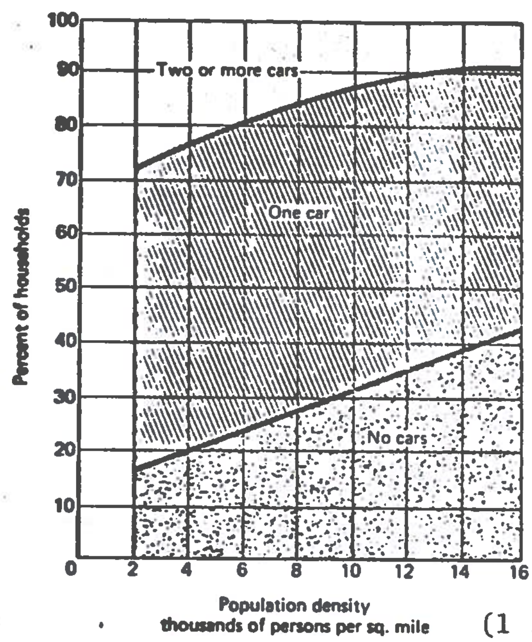
More recent data from the Bureau of the Census "Current Population Reports Series P-65," shows that the relationship between multi-car households and population density continues to hold.(5-3) This is shown in Table 5-3.

By encouraging multiple car ownership in households, the suburbanization trends of the past several decades have contributed to a situation in which electric vehicles can more easily replace conventional automobiles. Secondary cars are often used for less demanding local trips, thus matching electric vehicle capabilities. The more demanding travel requirements of the household, on the other hand, can still be served by a conventional automobile.

This tendency cannot be clearly identified as a bias, however, because suburbanization also increases the lengths of trips in most instances. This second aspect of urban density is discussed below.

5.2.2 Trip Length

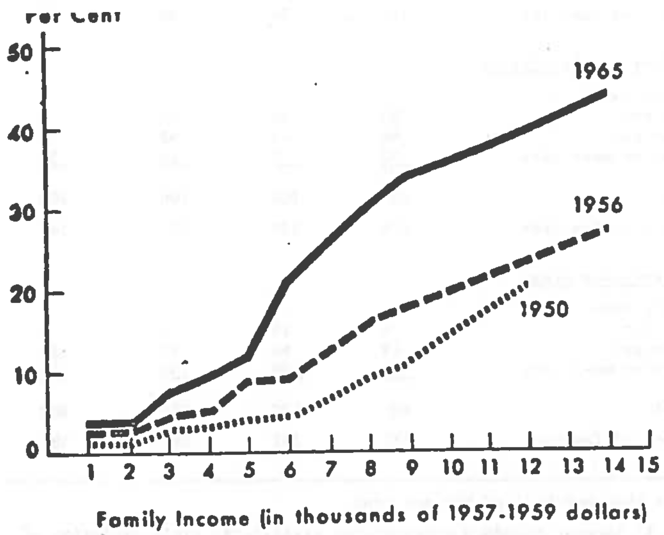
The relationship between trip length and urban density is not as well understood as that between car ownership and density. National Transportation Study data relating average trip length (miles) and density for sixteen of the twenty-four largest urban



(1 sq. mile = 2.59 km^2)

Source: Transportation and Traffic Engineering Handbook, Institute of Traffic Engineers, 1976, Prentice-Hall, Inc., Englewood Cliffs, NJ.

FIGURE 5-1. CAR OWNERSHIP AND POPULATION DENSITY



Source: J.B. Lansing, Automobile Ownership and Residential Density, University of Michigan, June 1967.

FIGURE 5-2. SPENDING UNITS OWNING TWO OR MORE AUTOS IN 1950, 1956, AND 1965 BY FAMILY INCOME (ENTIRE U.S.)

TABLE 5-2. AUTOMOBILE OWNERSHIP BY FAMILY INCOME AND TYPE OF AREA

Old Central Cities of 11 Largest SMSAs[a]	All	Under $4000	$4000 -7499	$7500 or more
Family owns:				
No car	54	85	46	14
One car	38	15	46	67
Two or more cars	8	*	8	19
Total	100	100	100	100
Number of families	117	53	28	36
New Central Cities of 11 Largest SMSAs[a]				
Family owns:				
No car	16	42	19	2
One car	62	58	76	53
Two or more cars	22	*	5	45
Total	100	100	100	100
Number of families	111	24	38	49
Smaller Central Cities				
Family owns:				
No car	20	52	12	3
One car	48	41	62	38
Two or more cars	32	7	26	59
Total	100	100	100	100
Number of families	474	130	177	167
All Suburban Areas				
Family owns:				
No car	4	16	3	1
One car	49	64	59	38
Two or more cars	47	20	38	61
Total	100	100	100	100
Number of families	772	101	287	384

*Less than one-half of one per cent.

[a] The 11 largest standard metropolitan statistical areas exclusive of the New York area have been divided into "old" and "new". The "old" cities are: Baltimore, Boston, Chicago, Saint Louis and Philidelphia. All had a population of over 500,000 as of 1900. The "new" cities are: Cleveland, Detroit, Los Angeles, Pittsburgh, San Francisco and Washington D.C.

Source: J.B. Lansing, Automobile Ownership and Residential Density, University of Michigan, June 1967.

TABLE 5-3 PERCENT OF MULTI-CAR HOUSEHOLDS BY PLACE OF RESIDENCE

	1960	1967	1970	1972
Metropolitan Areas	13.6	24.2	30.5	30.4
Central Cities	9.7	18.9	21.7	21.0
Suburban Rings	21.3	32.0	38.4	38.7
Non-Metropolitan Areas	18.7	26.3	27.0	29.8
All Areas	16.4	25.1	29.3	30.2

areas is shown in Fig. 5-3.* A downward trend can be seen; however, it is also clear that something other than urban density is affecting trip length.

The most influential factor appears to be the character and size of subregions within an urban area. Studies by Voorhees indicate that short trips are more common where subregions are densely populated and close together.(5-4) Furthermore, the proper mix of shopping, residential, and employment opportunities within subregions will minimize external trip requirements. The approximate minimum size for a subregion to offer the appropriate mix of opportunities is a population of 100,000.

To the extent that trip lengths are beyond the electric vehicle range, low density urban design is biased against electric vehicles. Since the electric vehicle bias depends both on density and location of subregions, it is impossible to estimate specific population densities when bias occurs. However, some general rules-of-thumb based on the electric vehicle range are possible.

*Data were available for only 16 of the 24 urban areas having a population over one million. Boundaries of excluded urban areas crossed state lines and data were therefore not presented.

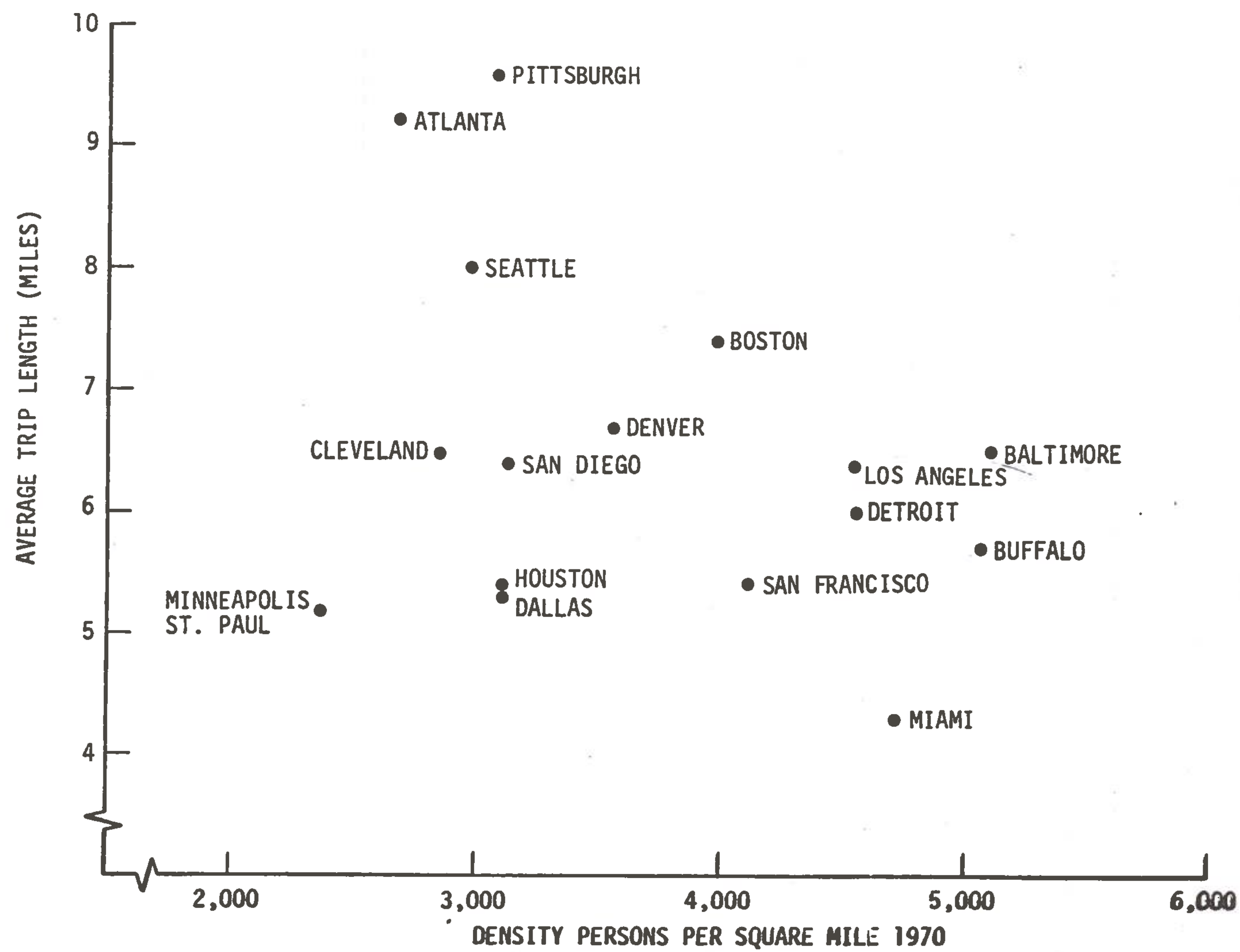


FIGURE 5-3. AVERAGE TRIP LENGTH FOR SIXTEEN URBAN AREAS

Fox showed the following data for two and three car households: (5-5)

Average Number of Vehicles/Household	Daily Automobile Trips/Household	Daily Vehicle Kilometers (Miles) of Travel/Household
2	6.3	94.3 (58.6)
3.05 (or more)	8.5	132 (82.1)

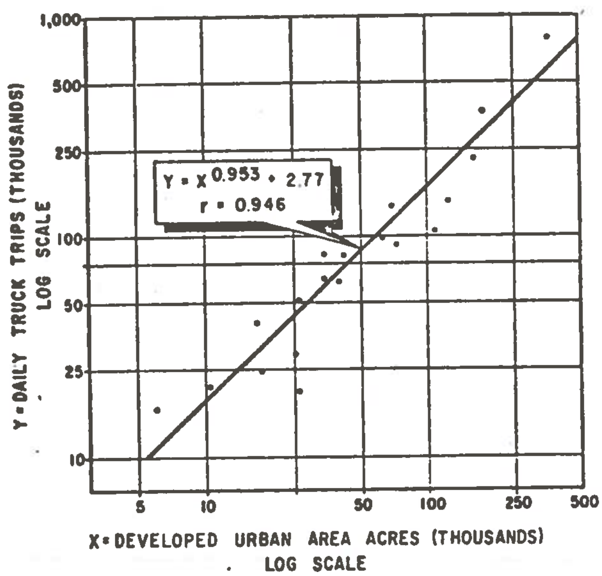
The average trips per household per car was about three. For a two-passenger electric vehicle with a 48 km. (30-mile) range, the subregion radius should not be more than 8 km. (five miles), allowing for three round trips. Thus the subregion should be less than 202.8 km (78 square miles), and density no smaller than 502 persons per square km. (1300 persons per square mile) (to attain 100,000 people in the subregion). Distance between the subregion and external employment should not be greater than 24 km (15 miles).

For the four-passenger electric vehicle with a 128 km (80-mile) range the radius of the subregion should be less than 20.8 km (13 miles), implying a population density of 78 per square km (200 per square mile). Distance between the subregions and external employment should not be greater than 64 km (40 miles).

Unfortunately, the extent to which current urban areas in the U.S. match such size and density requirements is a topic beyond the scope of this study. Thus the net bias inherent in historical patterns of suburbanization is not evident. It is clear, however, that suburban growth need not penalize and can, in fact, stimulate demand for electric vehicles if it is planned with such a goal in mind.

5.2.3 Commercial Uses

Commercial trips tend to increase as the urban area increases and the population density decreases. This trend was noted by Smith and reproduced here in Figure 5-4. (5-6) Since a trip is defined as any part of a truck route with a beginning and an end, the results cannot be directly translated into journey length (distance traveled before return to home base), which has a number of stops and hence trips. However, it does show the increase in truck activity with lower density operations.



1 Acre ≈ .004 Km²

Source: Wilbur Smith & Associates, Motor Trucks in the Metropolis, August 1969, New Haven, Connecticut.

FIGURE 5-4. RELATIONSHIP OF DAILY URBAN TRUCK TRIPS AND DEVELOPED URBAN LAND AREA

As density decreases, commercial centers are moved further apart since their spacing is based upon population. Therefore with a decline in density, journey length and truck activity (trips) will increase.

According to Kearney, a journey's time can be divided into four parts; terminal time, when products to be delivered are loaded on the trucks (or products bound for line-haul segments are unloaded); stem time spent driving to the zone of operation; zone time spent driving between stops in the zone of operation; and at-stop-time unloading (or loading) at retail (or home) sites.[5-7] Equating zones to the subregions of the previous discussion, some idea of how the closeness of subregions affects journey mileage can be obtained from examining typical journey lengths.

The referenced study made use of Kearney proprietary data for 243 urban areas representing 58% of the U.S. pick-up and delivery operations. Of the 1,333,487 vehicles in the study, only 627,047 were in the light-vehicle range. These were evaluated as to their electric vehicle potential; 473,590 (76%) were viewed as potential electric vehicle candidates. Others were excluded due to excessive daily journey length or excessive payload weight.

Of these, the following were viewed as marginal due to daily mileage requirements, with no typical intermittant returns to make battery swapping possible: surface parcel service (43,058); appliance service (32,941); milk from retail (21,192); beverages (1,920); and apparel (13,667). These commodities had typical daily journeys of 96 km (60 miles) or more implying that many would be in excess of 128 km (80 miles) and be beyond the commercial electric vehicle range. These uses were therefore deemed marginal as fleet operators would probably not wish to mix ICE and electric vehicles. Exclusion of the group would decrease electric vehicle potential to 58% of the total in the weight class.

Of those excluded, laundry (39,611) and bakery products (13,039) were excluded due to daily journeys in excess of 128 km (80 miles). Air freight (18,176), milk to retail (49,725), and paper products (24,801) were excluded due to payload weights exceeding 454 kg (1000 lbs) and tobacco products (8105) were excluded due to payload size. Thus, range excluded an additional 52,650 vehicles (8% of the total) while the remaining 100,807 vehicles (16% of the total) were deleted for other reasons.

Typical journey lengths by commodity are shown in Table 5-4. A number of the commodity groups have long stem distances. These include laundry, surface parcel post, air freight, appliance service, milk, and apparel. Shortening the stem length by higher density operation can bring all of the marginal distance operations within assured range of 96 km (60 miles) or less. In addition, laundry and bakery can be brought within marginal range of 96 km. to 128 km. (60-80 miles). Thus, the bias against electric vehicle pick-up and delivery operations from long journey lengths is largely eliminated under appropriate density conditions.

5.2.4 Urban Design Policies

Today's urban form has evolved largely from private initiative, spurred by government road building and housing financing. These government programs have been created to accommodate expressed demand; the transportation consequences were not the central issue. As Krzyczkowski points out, "minimizing travel is not a recognized planning criterion in the U.S." [5-8] Further, zoning laws encouraging separation of uses has permitted the "garden city" to be realized with residential uses separated from employment.

The result has been a lowering of urban density, with concommitant increases in multiple car ownership and auto travel. These increases tend to offset each other in their influence on electric vehicles. Multi-car ownership, which improves EV applicability, is stimulated by the increased travel requirements implicit in low urban density, requirements which, at some point, discourage the use of EV's. For commercial vehicles, decreasing density is clearly a bias against EV's but the limited data available suggest that electric vehicles are still applicable in nearly 60 percent of current light duty pick-up and delivery operations.

TABLE 5-4. TYPICAL DAILY MILEAGE; COMMODITIES TRANSPORTED BY SMALLER VEHICLES.

Commodity	USE: Truck to Retail	USE: Truck from Retail	USE: Both	JOURNEY LENGTH, km. (miles): Stem	Zone	Total	Multi-Journey
Laundry		X		61 (38)	90 (56)	150 (94)	
Mail			X	30 (19)	69 (43)	99 (62)	X
Telephone		X		29 (18)	48 (30)	77 (48)	
Surface Parcel Service			X	64 (40)	50 (31)	114 (71)	
Air Freight			X	70 (44)	59 (37)	130 (81)	
Vending		X		37 (23)	40 (25)	77 (48)	
Appliance Service		X		48 (30)	72 (45)	120 (75)	
Milk, Ice Cream, & Other Dairy	X			62 (39)	69 (43)	131 (82)	
		X		48 (30)	61 (38)	109 (68)	
Bakery Products	X			32 (20)	112 (70)	144 (90)	
		X		32 (20)	112 (70)	144 (90)	
Beer		X		32 (20)	80 (50)	112 (70)	
Wine & Brandy		X		32 (20)	80 (50)	112 (70)	
Liquor		X		32 (20)	80 (50)	112 (70)	
Tobacco Products	X			38 (24)	77 (48)	115 (72)	
Apparel		X		56 (35)	70 (44)	126 (79)	
Paper Products		X		16 (10)	69 (43)	85 (53)	
Newspapers	X			29 (18)	102 (64)	131 (82)	X
Electricity		X		32 (20)	38 (24)	70 (44)	

Source: A.T. Kearney, Inc., Urban Goods Movement Demonstration Project Design; Final Report on Phase I and II, PB-249319, NTIS, December 1975 and Appendix C. Distribution - Logistics Analysis and Findings, NTIS, PB-249321, November 1975.

Future urban growth policies could support EV use more consistently by encouraging development in relatively small subregions with good access to an appropriate mix of activities. The use of EV's, however, can only be viewed as a minor factor in planning for urban growth.

5.3 INTERMODAL PLANNING

Intermodal planning received widespread attention in the early 1970's and especially since the gasoline shortage in the winter of 1973-1974. Intermodal transportation involves the use of some form of private conveyance to a staging area where a transfer is made to some form of line-haul, private, or public transportation. The initial part of the intermodal transit trip can involve any of the following: drive-alone to the staging area (Park and Ride), drop-off (Kiss 'N Ride), walk, car pool, or other modes, such as bicycle, motorcycle, etc. The line-haul portion of the trip is made in a high occupancy vehicle (HOV), such as a bus or fixed-rail public transit system or private HOV, such as car pool, or van pool. The distribution portion of the transit trip within the CBD is ignored since the discharge point is usually very close to the destination point even though a transfer may be involved from an HOV to a local transit system.

Long home-to-work trips, of course, are biased against electric vehicles. The bias can be diminished by encouraging park-and-ride opportunities. Through proper intermodal planning, all vehicle types can negotiate the short connection trip to public transit, private car, or van pooling. However, a bias against electric vehicles will persist if multicar families are encouraged to become single car families by using drop-off to connect with the intermodal opportunities.

The initial portion of the transit trip, from home to pick-up point, is of primary interest in this study because substituting this short trip for the total trip will remove the long home-to-work trip bias against electric vehicles. The line-haul portion is also discussed in the following analysis to the extent that it affects the initial trip mode. Hybrid vehicles are not range-limited and intermodal policies will not help commercial electric vehicles. Hence, the bias evaluated pertains to the 2- and 4-passenger electric vehicles.

5.3.1 Public Transit

Due to a lack of nationwide data on the mode of travel to transit stations, data from two California transit systems were used: Southern California Rapid Transit District (San Bernardino Freeway-Express Busway) and Bay Area Rapid Transit District (BART) to estimate ICE vehicles that could be replaced by electric vehicles.

The San Bernardino Freeway Express Busway provides rapid transit opportunities to automobile commuters.[5-9] This 17.6 km. (11-mile) exclusive lane busway was built partly in the median strip and alongside the freeway. The overall system includes off-line stations, park-ride lots, bi-directional bus lanes, feeder bus lines, and a downtown reserved (contraflow) lane, making it one of the most complete facilities of its kind. A number of suburban communities are provided with direct service through buses that enter and leave the busway at several points along the busway. The El Monte Terminal has the largest park-and-ride facility and most riders enter the system through this terminal.

The majority of busway users come from multi-car families. Table 5-5 lists the distribution of automobiles owned by bus riders and the travel mode to the busway. 67 percent of the busway users have more than one automobile per household and 74 percent drive their car to the system and park.

The El Monte station is 17.6 km. (11 miles) from the Los Angeles CBD. For commuters who formerly drove their car to CBD this cuts off up to 17.6 km. (11 miles) from their home-to-work auto travel. This effectively extends the range of the two-passenger electric car's oneway driving distance from 24 km. (15 miles) to as much as 42 km. (26 miles) and the four-passenger electric from 64 km. (40 miles) to 82 km. (51 miles).

TABLE 5-5. SAN BERNARDINO BUSWAY NUMBER OF AUTOMOBILES IN HOUSEHOLD.

(Busway data collected in November & December 1975)

Number of Automobiles/ Household	Percent of Busriders
0	3
1	29
2	54
3 or more	13
Unknown	1
	100

Base = 1,529

MODE OF TRAVEL TO PARK N' RIDE

Mode	Percent of Busriders
Drive Own Car and Park	74
Passenger Driven to Lot*	17
Take Another Bus	4
Walk	4
Other	1
	100

Base = 1,529

Source: Bigelow-Crain Associates, Second Year Report San Bernardino Freeway Express Busway Evaluation, prepared for the Southern California Association of Governments, September 1975.

*According to Bigelow-Crain Associates, "Visual evidence suggests that this group is more likely to be kiss-ride than carpools").

Comparison with NPTS data for incorporated areas of 1 million or more indicates that this will increase the percent of home-to-work for which the two-passenger electric car is not distance-limited from 80.4 percent to approximately 92 percent.[5-10] A similar comparison for the four-passenger car indicates that it is currently applicable to 97.9 percent of the home-to-work trips. Removing 17.6 km (11 miles) from the home-to-work trip extends its range to 82 km. (51 miles) which picks up an additional (approximately) 0.8 percent of the home-to-work trips.

The Bay Area Rapid Transit District (BART) system is a modern fixed rail transit system that provides transportation from suburban communities to the major CBD's in the San Francisco Bay area.[5-11] While the system facilities involve technologies that are very different from the San Bernardino Busway, the two systems are very similar in the service they provide. BART, like the Busway, has park-and-ride lots at the arterial line terminals. Also, like the Busway, the BART parking lots are full, according to data from the Concord feeder line (the line with highest ridership).

Access mode to the BART system is shown in Table 5-6 along with the distribution of automobiles per household. More BART riders travel by bus or walk to the terminals than Busway riders. Automobiles account for 49.2 percent of the access mode on the BART system, whereas, they account for 91 percent on the Busway.

Trip lengths to the CBDs are shortened as shown in Figure 5-5.[5-12] For simplicity we have shown only the distribution of trips on the Concord line. Mileages are from the terminal to the BART link point at mile post 0.0 in the Oakland CBD. Trips to San Francisco are 12 km. (7-1/2 miles) longer. This illustrates the distribution of home-to-work trips that are shortened through use of this system.

5.3.2 Car Pools

The gasoline shortage of 1973-1974 provided a new emphasis on increasing the occupancy rate of commuter vehicles. Car pools

TABLE 5-6. ACCESS MODE TO BART

Mode	Percent
Drive Alone	27.9
Dropped Off	15.5
Carpool	5.8
Bus	20
Walk	29.5
Other	1.5

Automobiles/household	
Less than 2	43
2 or more	57

Source: Bay Area Rapid Transit District, Marketing Planning Implications Developed from Recent Research Findings, presentation before the Public information Committee of the Bay Area Rapid Transit District, Oakland, California, November 1976.

Source: Bay Area Rapid Transit District, Marketing Planning Implications Developed from Recent Research Findings, presentation before the Public Information Committee of the Bay Area Rapid Transit District, Oakland, California, November 1976.

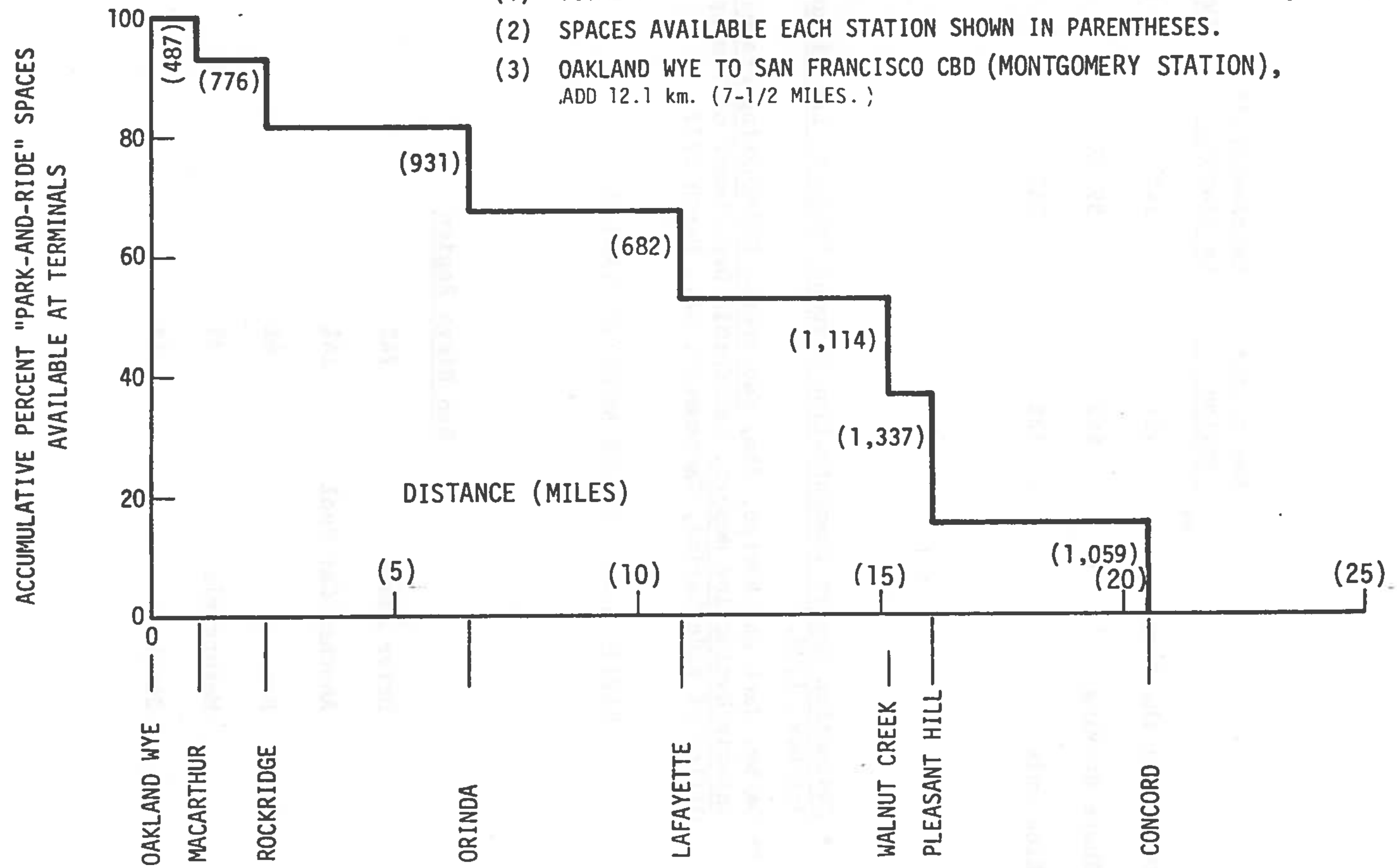


FIGURE 5-5. MILES FROM OAKLAND CBD TO END OF CONCORD LINE

TABLE 5-7. CAR POOL DRIVING ARRANGEMENT

	San Diego* Region	Sacramento,** California	Average
Drive All the Time	12%	14%	13%
Share Driving	56%	59.5%	58%
Ride Only	32%	26%	29%

Sources: * Evaluation Report Demonstration Carpool Project, San Diego Region, October, 1976.

** Derby, Jack and Baetge, Jim, Sacramento Ridesharing Project, Second Interim Evaluation Report, California Department of Transportation, Office of Ridesharing, Sacramento, CA., March 1977.

TABLE 5-8. PRIOR MODE OF TRAVEL

	San Diego Region
Drive Alone	74%
Another Car Pool	14%
Bus	6%
Motorcycle	2%
Other	4%

Source: Evaluation Report, Demonstration Carpool Project, San Diego Region.

are one way to decrease the number of commuter vehicle-trips. However, most car pool arrangements are for sharing the driving burden. If a car pool member shares driving, there is a reduction in the number of trips, but no reduction in the required trip length.

Several recent car pool evaluations in California provide data which show how few car pool riders do not share driving. The following driving arrangements of car pools and the mode of travel prior to joining a car pool were reproduced from Sacramento and San Diego studies and are shown as Tables 5-7 and 5-8.

From the San Diego data in Table 5-7, there appears to be a large fraction (32 percent) of the car pool riders who do not share driving (Ride Only), and, as such, might be candidates for electric cars. But when this data is compared with the prior mode of travel, Table 5-8, it appears that the ride-only group came from a prior mode group that had already shifted from driving alone. It was calculated that only 6 percent of the cars left at home experienced a reduction in trip length: Ride-only (32%) minus those whose prior mode of travel was another car pool (14%), bus (6%), motorcycle (2%), and other (4%).

The Sacramento evaluation also surveyed car pool joiners as to the use made by other family members of the car left at home. On the average, 16.3 percent of those surveyed indicated that the car left at home was driven by others an average of 13.3 km. (8.3 miles) per week.[5-13] If it is assumed that the 16.3 percent of the cars left at home would not be given up because they provide another member of the household with mobility, then approximately 1 percent of those joining car pools are candidates for replacement by electric vehicles. It was assumed that those cars left at home and not driven may be eliminated and therefore would not be good candidates for replacement by electric vehicles.

While this result is by no means conclusive, it is indicative of what could be expected. Public policy favoring car pools could be significant in eliminating driver-only, home-to-work trips, but the same policy would have minimal effect on reducing the bias against electric cars. Although the individual is required to drive the trip less frequently, trip length is not reduced.

5.3.3 Van Pools

Van pools are a relatively new concept in intermodal planning. The first major use of van pool was undertaken by the 3M Company at its St. Paul, Minnesota plant in April 1973.(5-14) The program was such a success that the six-van pilot operation was expanded to include 57 vans as of May 1974. Since the success of the 3M pilot program, many other van pools have been initiated. Many of these van pool programs are documented in two recent government reports.(5-15, 5-16)

Van pools have similarities to both car pools and public transit systems. Passengers may be picked up at home like car pools and/or at park-and-ride lots along major routes.

As in the analysis of car pools, data on van pools is limited. Van pools differ from car pools primarily in that for van pools the home-to-work trip is not provided through alternating use of private cars. By eliminating the private car home-to-work trip, the electric car could accomodate all private car trips except occasional long excursions and vacation trips.

Data from a California Department of Transportation van pool experiment indicates that some van pool riders will be inclined to give up second cars, while the majority (69 percent) intend to keep their second car.(5-17) Similar results were reported by 3M following their pilot program.(5-18) Out of 57 3M Company van pool participants, 77 percent intend to keep their second car. Thus, van pools appear to effectively remove the bias against electric vehicles arising from long home-to-work trips.

5.4 ACCESS POLICIES

In a number of European cities, and to some extent in U.S. cities, automobile use has been severly limited. These limitations range from total bans, represented by auto-free zones, to limited bans, in which restricted streets or other devices are used to discourage automobile movement.

U.S. experience in planning and implementing auto-free zones is somewhat less than that of Europe. This is not surprising, since European cities have poorer road networks in general and therefore face more severe congestion problems, especially in their CBD's. As a result such cities as Essen and Munich, Germany, have auto-free zones in their CBD areas. Former streets have been turned over to pedestrians with traffic routed around the auto-free zone; parking has been limited and public transit improved for access to and from the CBD.[5-19]

Other European cities have adopted restriction policies. Bremen, Germany, and Gothenburg, Sweden, have successfully used a cell concept in which the city center is divided into sectors, with limited auto access to each sector from the perimeter and movement between sectors prohibited.[5-20, 5-21] Traffic movements have been diverted around the central area, with noticeable traffic reductions within the sectors.

Examples of auto-free zones in residential areas are more limited. They include Welfare Island, New York,[5-22] and Port Gumaud, France.[5-23] In both cases shopping opportunities are close to residential areas with easy public transit or walking access. Automobiles are restricted to perimeter parking. These high-density applications would tend to encourage one car families, thereby discouraging electric vehicle use.

Auto-free or limited movement concepts for lower density residential areas that may have more applicability to electric vehicles are suggested by Garrison.[5-24] Without altering the urban form and thereby encouraging a reduction in auto ownership, auto travel is discouraged or prohibited. Less ambitious programs of diverting auto traffic have been successfully implemented by Berkeley, CA, Portland, OR, Seattle, WA, and Isla Vista, CA.[5-25]

Most limited access policies presently in use are biased against all automobiles equally. They have been imposed largely for congestion in CBD's, and properly preclude all vehicle types equally. Exclusion of electric vehicles may be unnecessary, however, if air quality and noise are the primary reasons for limiting access. Such policies are biased inappropriately against electric cars if they do not allow their use while excluding ICE vehicles. This is a particularly important issue for the U.S., where air quality is a major goal of limiting access.

5.5 PARKING SUPPLY*

Parking and roadways have been designed for the standard size American car. In effect, small car owners are required to pay for space they do not use. In the case of parking, the charge is significant both in terms of cost and convenience. In commercial parking areas, the cost is represented by too high a parking fee in lots and garages, or too much land devoted to parking in shopping centers and hence too little in sales areas. For on-street parking, the cost is inconvenience, not being able to find a parking place, or in parking fees for off-street parking when a less expensive or potentially free on-street space might have been available. In residential areas, space can still be a problem if the street is a primary parking place. However, the main problem in residential areas is providing a convenient, readily available site for EV recharge.

5.5.1 Commercial Parking

Commercial parking facilities have been sized for large domestic cars. Stall size requirements vary little in local city ordinances. Table 5-9 gives the distribution of stall width and

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* The discussion involving parking supply revolves around the dimensions of vehicles rather than types of propulsion systems, but since the electric and hybrid vehicles defined in this study are small, the potential biases are relevant.

length requirements of 139 cities.*[(5-26)] Clearly, a 2.7 meter (9-foot) by 6.1 m (20-foot) stall size is preferred among those responding. The Community Builder's Handbook confirms these stall requirements for 90° parking.[(5-27)]

Stall sizes do not take into account lanes, ramps, walkways, landscaping, paybooths, etc. The size of these requirements vary by angle of parking. For example, 90° parking generally requires two-way movement in the aisles (needed for turning as well as movement) while 60° parking can use one-way movement in the aisles.

Using a 90° parking scheme, aisle and stall requirements for compact and sub-compact cars were calculated and compared with current unit parking** allocations based on standard size ICE cars. For both subcompacts and compacts, the aisle width is reduced by 0.61m (two feet), due to the smaller car width. This is a conservative reduction as no credit is given for reduced turning radius. Resulting area requirements for aisle and stall are 18.6 m^2 (199.5 square feet) and 17.3 m^2 (185.5) square feet for compacts and subcompacts, respectively, representing reductions of 8.6 m^2 and 9.9 m^2 (93 and 107 square feet), respectively. These calculations are summarized in Table 5-11).

If this reduction is now compared to the total parking requirements averaging 37.2 m^2 (400 sq. ft.) per car in lots and, 32.5 m^2 (350 sq. ft.) in garages, the percentage reductions shown in Table 5-12 are achieved. No reductions have been assumed for aisle turn arounds, landscaping, walkways, etc. Also shown is vehicle size reduction for comparison.

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*This survey will be referenced several times. Published in 1972, it shows the requirements in ordinances from 216 cities geographically distributed as shown in Table 5-10. All but two cities responding have parking regulations in their ordinances. Although the survey cannot address the non-respondents, which may have no requirements, it is representative of cities that include traffic and parking ordinances.

**Unit parking includes two stalls and the aisle in between.

TABLE 5-9. STALL WIDTH AND LENGTH REQUIREMENTS

Width, Meters (Feet)	Percent of Returns
2.44 (8'0")	15
2.59 (8'6")	17
2.74 (9'0")	50
2.90 (9'6")	3
3.05 (10'0")	10
Varying by Land Use	5
Total	100

Length, Meters (feet)	Percent of Returns
5.49 (18'0")	23
5.79 (19'0")	16
6.10 (20'0")	51
TOTAL	100

Source: G.E. Kanaan, and D.K. Witheford, Zoning, Parking and Traffic, 1972, Eno Foundation for Transportation, Inc.

TABLE 5-10. ZONING QUESTIONNAIRE DISTRIBUTION AND RETURN

Region	Total Questionnaire Sent	Number of Returns by City Population Size (M - 1000 residents) 25-50M	50-100M	Over 100M	All Cities	Percent Returned
Northeast	109	9	25	16	50	46
Southeast	68	10	21	9	40	59
Midwest	114	12	31	13	56	49
Mtn. & Plains	23	6	7	3	16	70
Southwest	29	1	8	5	14	48
West Coast	55	9	21	10	40	73
Total Returned		47	113	56	216	
Total Sent	398	100	200	98	398	
Percent Returned		47	57	58	54	

Source: G.E. Kanaan, and D.K. Witheford, Zoning, Parking and Traffic, 1972, Eno Foundation for Transportation, Inc.

TABLE 5-11. PARKING REQUIREMENTS FOR THREE CLASSES OF VEHICLES

	Dimensions, m (in) Width	Length	Area Requirements, m^2 (ft^2) Unit Parking	Stall	Vehicle
Standard	2.0 (80)	5.72(225)	27.2(293)	16.7(180)	11.6(125)
Compact	1.8 (71)	4.83(190)	18.6(200)	11.1(119)	8.7(93.7)
Subcompact (electric)	1.7 (68)	4.32(170)	17.3(186)	9.8(105)	7.5(80.3)
Reduction over Standard					
Compact	0.23(9)	0.88(35)	8.6(93)	5.7(61)	2.9(31.3)
Subcompact (electric)	0.30(12)	1.38(55)	9.9(107)	7.0(75)	4.2(44.7

TABLE 5-12. PERCENTAGE REDUCTION IN PARKING REQUIREMENTS FOR SMALLER CARS

Type	Type Parking: Lot, 37.2 m^2 (400 sq. ft.)	Type Parking: Garage, 32.5 m^2 (350 sq. ft.)	Vehicle Size
Compact	23%	27%	25%
Subcompact (electric)	27%	31%	36%

Thus, it appears that if parking garages and lots were converted to compact and subcompact parking, more cars could be parked in the same facilities. A parking capacity increase of a maximum of 37% in lots and 45% in garages could be achieved if only subcompact size (electric) cars were allowed.* For compact cars, capacity would be increased 30% and 37% respectively.

This increased capacity could be passed on to the public by a reduction in parking fees. Estimates of current parking charges and potential savings from such conversions are shown in Tables 5-13 and 5-14. The estimates assume that operating costs will not increase with the added capacity (i.e., operating costs are related to structure size more than volume).

These annual cost savings can be passed directly on to the parker, in cases of leased parking. For others, they can be passed on proportional to the turnover rate. For example, in 18 selected municipal garages, the rate of parkers per year per space was 500 for self-parking and 550 for attendent parking.[5-28] Using an average of 525, the savings in parking fee per parker for a subcompact (electric) car in a medium CBD garage would be 40¢ to 67¢.

*To make sure that the 90° parking angle assumption had not distorted the results, a 60° case was calculated for electric cars. A 106 square foot reduction (instead of 107) in unit parking requirements was calculated.

TABLE 5-13. ANNUAL COST PER PARKING SPACE (Dollars)

Type of Facility	Source and Interest Rate: 6% Meyer-Kain-Wohl	6% Smith & Assoc.	12% Meyer-Kain-Wohl	12% Smith & Assoc.
(1) Lot - Fringe	$201	$228	$278	$320
(2) Lot - Low CBD	388	430	651	723
(3) Garage - Low CBD	558	508	838	770
(4) Garage - Medium CBD	705	668	1131	1084
(5) Garage - High CBD	885	861	1491	1473

Source: T.E. Keeler, L.A. Merewitz, P.M.J. Fisher, Full Costs of Urban Transport, Part III; Automobile Costs and Final Intermodal Cost Comparisons. University of California, July 1975.

TABLE 5-14. POTENTIAL ANNUAL PER SPACE SAVINGS FOR SMALL CAR PARKING

	Compact		Subcompact (electric)	
	Capacity Increase	Annual Savings	Capacity Increase	Annual Savings
Lot - Fringe	30%	$46-$74	37%	$54-$86
Lot - Low CBD	30%	$89-$166	37%	$105-$195
Garage - Low CBD	37%	$137-$226	45%	$157-$260
Garage - Medium CBD	37%	$180-305	45%	$207-$351
Garage - High CBD	37%	$232-$378	45%	$267-$462

For situations where parking is not paid for by fees, e.g., shopping centers, land devoted to parking could be used instead for additional building coverage with reduced land costs per square foot of building. To measure the potential savings, the Urban Land Institute's suggested parking index of 5.9 spaces per 100 m^2 (5.5 spaces per 1,000 sq. ft.) of gross leasable area was used.(5-29) The standard implies a parking ratio of 2.2 units of parking area per unit of leasable area. If the subcompact electric car is used, the parking ratio becomes 1.6. The implied reduction in land area requirements of the shopping center can then be calculated as:

$$(1 + 1.6) / (1 + 2.2) = 0.81,$$

that is, the same shopping center with subcompact parking would have required 81% of the net land area.

Both the parking index and the size of the standard parking space will affect the results as well as whether a compact or subcompact car is used. Combinations of these parameters are plotted in Figure 5-6. As the space for the standard car decreases from 37.2 m^2 to 32.5 m^2 (400 to 350 $ft.^2$), greater savings in net land area are possible from providing subcompact (electric) car parking. Also, as the parking index increases, potential savings increase, although the effect is diminishing. Over the shopping center index range of 5.5 to 7.5, shopping centers can be reduced to 82-1/2% to 84-1/2% of the original size by providing parking for compacts and 80% to 81-1/2% for subcompacts if 37.2 m^2 (400 square feet) per car has been provided for the standard car. The ratio is 78% to 80% if 32.5 m^2 (350 square feet) is used.

In summary, present commercial parking favors larger cars. If some paid parking were sized for small (electric) cars and the savings passed on in lower parking fees, the implicit bias against the use of subcompact (electric) cars would be removed. Shopping centers could be smaller (by about 20%) or offer more store space or open space if parking were sized for subcompacts (electric vehicles). How these savings could be passed on to the vehicles' owners is not clear.

Finally, it should be noted that increased availability of parking and its associated rise in vehicle density may not be desirable from the viewpoint of the urban planner. The current emphasis appears to be toward increasing utilization of urban mass transit and discouraging the private vehicle in the central business district. Removal of the parking bias against small (electric) cars might lead to a significant societal penalty in terms of increased vehicle congestion in the urban setting.

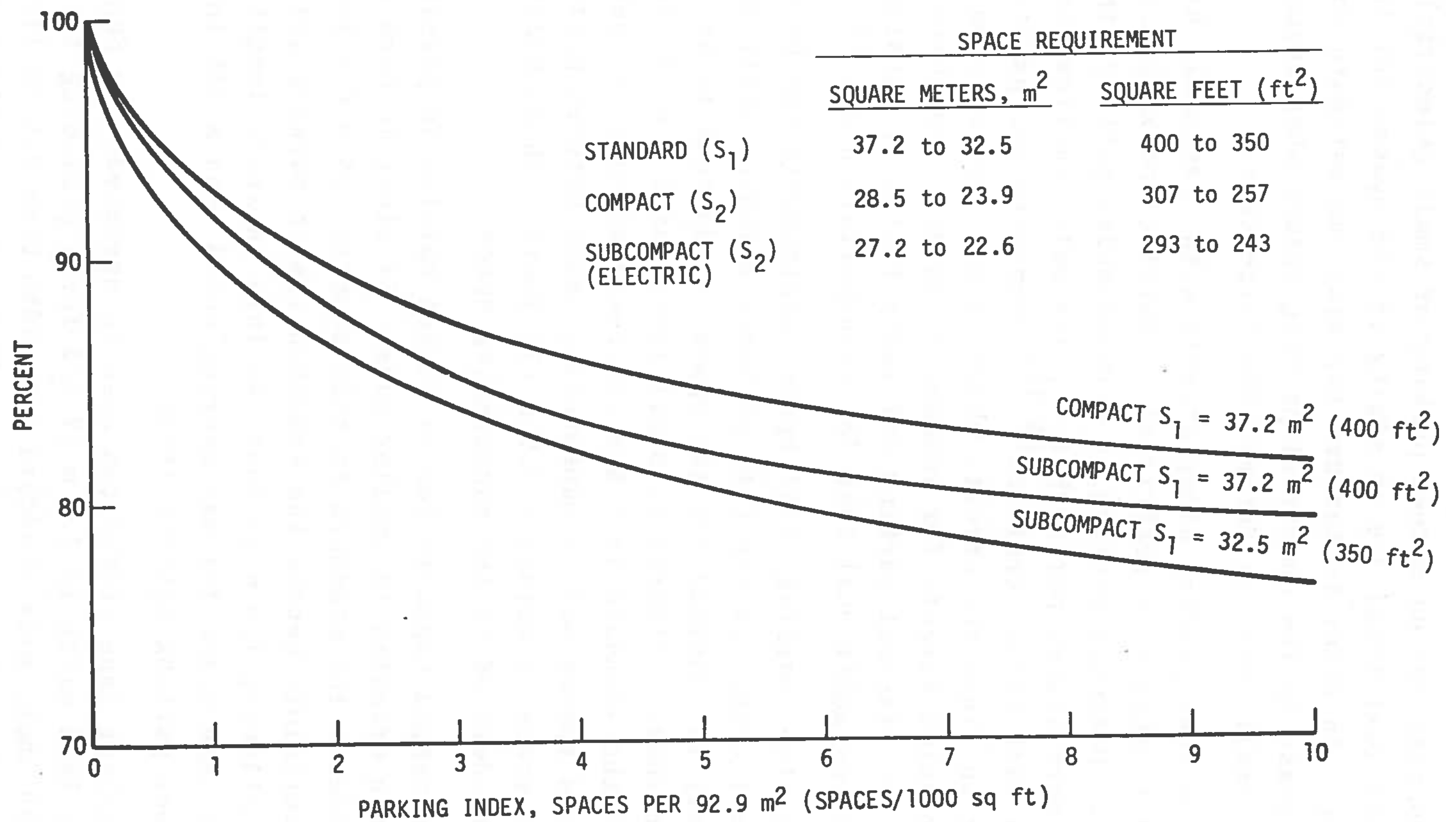


FIGURE 5-6. PERCENT OF LAND NEEDED TO ACCOMMODATE SHOPPING CENTER WITH SMALL CAR PARKING

5.5.2 On-Street Parking

Capacity for on-street parking of small (electric) cars has also been restricted due to sizing of the spaces for large vehicles. In order to measure the bias, an estimate was made of the increase in the number of parking spaces when space size is set for small vehicles rather than large cars.

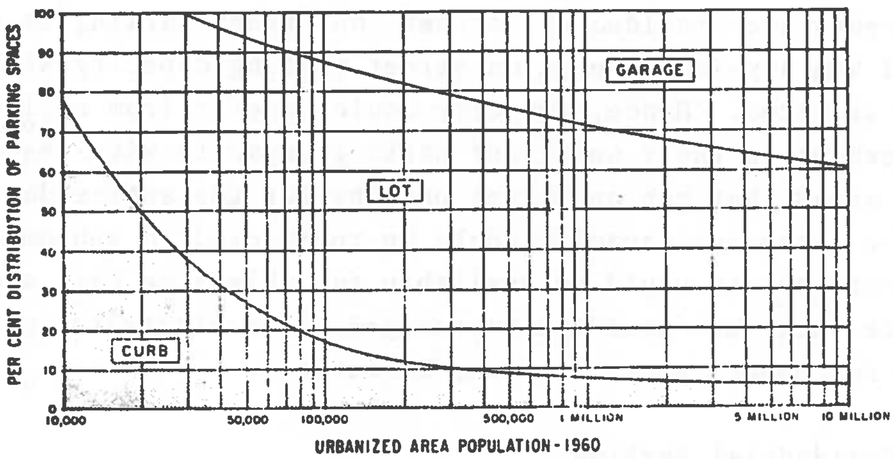
On-street parking along streets with reasonably high traffic volumes is generally restricted to parallel parking (if allowed at all). Diagonal parking or perpendicular parking, though providing more spaces per curb foot, are only practical on wide streets with little traffic.[5-30] Non-parallel parking requires backing out into the street, which is not desirable on narrow well-traveled streets for reasons of safety. Furthermore, removal of diagonal parking and substitution of parallel parking can add one additional lane for transportation use.[5-31]

Parallel parking stall space requirements can be arranged in different ways. In the City of Santa Barbara, stall length of 6.1 m (20 feet) is required oif the space is adjacent to an intersection or a driveway. Otherwise, stall length is 7.3 m (24 feet), In England the standard is 5.5 m (18 feet) of curb per vehicle arranged in paired spaces with a maneuvering space between pairs.[5-32] Each parking space is actually 4.9 m (16 feet) with an additional 1.2 m (4 feet) devoted to the maneuvering space.

Increased capacity for on-street parking is possible if stall sizes are oriented to smaller cars. If electric cars (subcompact size) became the standard in this country 4.6 m (15 foot) stalls could certainly become the standard (as in parking garages and lots), allowing 1.5 m (5 foot) savings in stall length. Providing the same space for maneuvering would mean a 33% increase in on-street parking possibilities.

Parking lane widths can also be narrowed. In Santa Barbara, parking lane width is 2.3 m (7-1/2 feet) providing for the 20 m (80 inch) wide standard car width plus 2.5 cm (10 inches) for distance from the curb, opening doors, etc. Parking width could be reduced to 2.0 m (6-1/2 feet) and still accommodate the 1.72 m (68 inch) wide subcompact car.

The significance of the bias depends on whether additional spaces would be utilized. Clearly, adding on-street parking opportunities in under-utilized on-street parking areas would not be meaningful. The percentage of on-street parking spaces to total parking spaces declines as city density increases and the streets are incapable of handling the increased parking demand or on-street parking is restricted to increase street capacity. Off-street parking opportunities are provided in lots and garages with the latter becoming significant in larger cities, as shown in Fig. 5-7.



Source: Wilbur Smith and Associates, Parking in the City Center, May 1965, New Haven, Connecticut.

FIGURE 5-7. DISTRIBUTION OF CENTRAL BUSINESS DISTRICT PARKING SPACE BY TYPE OF FACILITY

Demands for CBD parking have continued to increase as Table 5-15 demonstrates. Thus, areas with saturated on-street parking have continued to increase.

TABLE 5-15. TRENDS IN CBD CURB PARKING

City Population	Percent of All CBD Parking on Street 1956	1968	Change
50,000-100,000	59	35	-24
100,000-250,000	45	27	-18
250,000-500,000	28	20	- 8
500,000-1,000,000	22	14	- 8
1,000,000 and Over	14	14	- 0

Based on: Table 5 in R.W. Stout, "Trends in CBD Parking Characteristics, 1956 to 1968," Highway Research Record Number 317, (Washington, D.C., Highway Research Board: 1970) p. 43.

In effect, whenever a significant portion of the parking requirements are provided off-street, on-street parking is fully utilized and any increase in on-street parking capacity will be quickly utilized. Hence, any city could benefit from an increase of 33 percent in their on-street parking capacity with the exception of areas that ban on-street parking for the entire day. Since the increased capacity would be restricted to subcompact car users, more spaces would be available for this size car, and therefore their use would be encouraged. The electrics, which will be subcompact size, would be encouraged.

5.5.3 Residential Parking

The above conclusions apply to residential areas as well. However, the primary concern in residential areas will be the provision of safe and convenient places for electric battery recharge, since the primary source of electricity for recharging will be at home and the recharge will take place overnight (see Chapter 6). Households lacking such facilities will be discouraged from owning EV's. Where urban design practice has not required off-street parking or where present zoning does not require such facilities, electric vehicle ownership will thus be discouraged.

To measure this bias, an estimate of the percentage of households having off-street parking, preferably covered, was made. Data on the availability of off-street parking is sketchy, but the FHA does maintain data on off-street covered parking for single family structures.(5-33)

As shown in Table 5-16 covered off-street parking availability is generally high (above 70 percent). However, five cities have around 50 percent or less with Baltimore and Washington, D.C. leading the list of those not providing covered parking. Only 19 percent of the FHA units in Washington, D.C. and Baltimore have covered parking. In such cities the bias against electric cars will be severe.

Multi-family residences are not covered in the data. Multi-family structures, however, are less likely to have a high percentage of off-street covered parking that can easily be equipped for recharging. The exclusion of this group of residences understates the bias against electric cars, since only 53.4 percent of the households in the 24 urban areas listed live in single-family structures.

Many cities require off-street parking through local zoning ordinances. Table 5-17 summarizes ordinance requirements organized by type of residential unit. The number of spaces required is surprisingly low. Although builders can provide more parking spaces than required in zoning ordinances, they rarely do in the current housing market. Therefore, the relatively small number of required spaces may deter multi-car ownerships, particularly in multiple family dwellings where other off-street parking opportunities are likely to be unavailable. Thus the existing zoning provisions do not appear to totally alleviate the bias against EV's.

In summary, a lack of off-street residential parking creates a bias against electric vehicles for many households. The problem is acute in some cities, although the number of residences with appropriate parking is still much higher than the anticipated demand for EV's. Zoning ordinances requiring off-street parking for new residences could help alleviate this bias, but the number

TABLE 5-16. 1970 HOUSEHOLDS LIVING IN SINGLE FAMILY STRUCTURES WITH GARAGE OR CARPORT, LARGE URBAN AREAS

City	Households 1970 Census (000s)	% Single Family Structures Ref.[5-31]	% of Single Family Structures With Garage or Carport - FHA Data Ref.[5-32]	% Households Which Live in Single Family Structures With Garages or Carports	Number of Households Living in Single Family Structures With Garages or Carports (000s)
New York	5,477	33.2	73	24.2	1,327
Los Angeles	2,954	61.7	97	59.8	1,766
Chicago	2,210	44.4	70	31.0	687
Philadelphia	1,302	71.8	52	37.3	486
San Francisco	1,093	57.0	95	54.2	592
Detroit	1,254	69.8	72	50.3	630
Boston	866	41.6	41	17.1	147
Washington, D.C.	832	50.5	19	9.6	79
Cleveland	645	57.3	84	48.1	310
St. Louis	630	51.8	74	45.7	289
Pittsburg	615	68.1	67	45.6	280
Baltimore	512	67.6	19	12.8	66
Minneapolis-St. Paul	545	61.9	85	52.6	285
Houston	567	71.2	95	67.6	385
Seattle	448	68.3	87	59.4	265
Atlanta	384	60.6	72	43.6	166
Miami	436	55.9	51	28.5	124
Cincinnati	373	54.8	66	36.2	135
San Diego	398	66.2	91	60.2	241
Milwaukee	403	51.8	82	42.4	171
Kansas City	386	70.1	83	58.2	224
Buffalo	356	49.0	76	37.2	132
Denver	349	67.1	70	47.0	163
Dallas	456	67.7	89	60.3	275
TOTAL AVERAGE	23,491	53.4	73.6	39.3	9,225

TABLE 5-17. ZONING ORDINANCES OF OFF-STREET PARKING REQUIREMENTS FOR RESIDENTIAL LAND USES (SURVEY OF 207 CITIES)

	Building Type															
	Single Family Dwelling	Duplexes	Multiple Family Dwellings	Dormitories, Sororities and Fraternities			Hotels		Motels		Clubs and Lodges		Trailer Courts	Apartment Hotels and Rooming Houses		
Requirement	Spaces/ Dwelling Unit	Spaces/ Dwelling Unit	Spaces/ Dwelling Unit	Spaces/ Room	Spaces/ Occupant	Spaces/ Bed	Spaces/ Bedroom	Spaces/ Unit	Spaces/ Bedroom	Spaces/ Unit	Spaces/ 100 Sq. Ft. GFA	Spaces/ Member	Spaces/ Unit	Spaces/ Dwelling Unit	Spaces/ Room
Minimum	0.50	0.50	0.50	0.16	0.07	0.08	0.16	0.25	0.25	0.25	0.10	0.07	1.00	0.25	0.20
Maximum	3.00	2.00	2.00	1.00	1.00	1.00	2.00	1.33	1.25	1.33	3.00	1.00	2.00	1.50	1.00
Modal	1.00	1.00	1.00	0.50	0.33	0.50	1.00	1.00	1.00	1.00	0.50	0.20	1.00	1.00	0.50
Mean	1.28	1.26	1.20	0.56	0.44	0.36	0.64	0.97	0.90	1.00	0.71	0.23	1.25	0.94	0.62
Number of Cities:															
Using Above Basis	183	163	163	39	29	26	82	44	53	94	37	28	62	71	58
Using Other Basis	16	8	17	54			48		32		65		9	53	
With No Requirement	8	36	27	59			33		28		77		136	25	

Source: G.E. Kanaan, and D.K. Witheford, Zoning, Parking and Traffic, 1972, Eno Foundation for Transportation, Inc.

of spaces required is often too small to encourage multi-car ownership and hence EV's.

5.6 COVERED/UNCOVERED AUTO FACILITIES

Electric vehicles will not emit the kinds of pollutants (HC, CO, NO_x, etc) during operation that are typical of ICE vehicles. Thus, ventilation equipment required for ICE vehicle operation in below ground or covered facilities will not be required. This lack of need for ventilation in new facilities is biased in favor or EV's.

In general, parking studies have not specifically identified the cost of ventilation equipment. Thus, it is assumed that their cost is minimal. To verify this assertion, we contacted the Port of New York and New Jersey Port Authority. They provided investment and operating cost estimates for ventilation of the enclosed parking garage located in the World Trade Center. Investment cost was $125,000 for 1000 parking spaces with annual operating costs at $4750 for 1000 parking spaces. The investment cost was amortized at $10,750 over twenty years using 7 percent interest.

Thus investment and operating costs for ventilation equipment were $10.75/space and $4.75/space per year, respectively. The total annual cost is $15.50/space per year.

The cost of ventilation equipment is relatively small. It is less than 2 percent of the high CBD garage costs of Table 5-13 (approximately $870/stall/year). Thus savings would be minor if ventilation requirements were removed by restricting the garage to electric vehicles.

SECTION 5
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6.0 POTENTIAL BIAS IN ELECTRICITY SUPPLY

6.1 INTRODUCTION

Current and future electricity supply characteristics could have a major impact on the production and use of electric and hybrid vehicles in the United States. Of foremost importance is the electric utility industry and its ability to supply electricity to surface transportation users at a price competitive with conventional fuels. The issue also encompasses the problem of supplying electricity for transportation use through some appropriate infrastructure and its implications for potential EV markets.

6.2 ELECTRIC UTILITY INDUSTRY

The electric utility industry is currently in the midst of a difficult transition from a period of rapidly increasing demand and falling prices to one of escalating prices and uncertain demand. The historical growth rate of electricity was about 7 per cent prior to the 1973 oil embargo and subsequent price escalation of electricity in 1974. In 1974, electricity consumption declined by 0.14 per cent, while in 1975, consumption increased by only 2 per cent over 1974. In 1976, however, preliminary estimates are that electricity consumption increased by 6.2 per cent, close to its historical growth rate. (6-1)

The industry has problems in fossil fuel availability and costs, estimating growth in demand and planning for capacity additions. Capital requirements for growth are enormous, and cash inflows do not begin until plants go into service. Obtaining permits for major generation and transmission sites is becoming increasingly difficult and time consuming. Local environmental and other action oriented groups are strongly resisting additional plant construction at local Public Service Commission hearings or by contesting decisions in court.

Such problems create uncertainties about the future supply and cost of electricity and how they will impact electric and hybrid vehicles as opposed to vehicles consuming other fuels. Three major characteristics of the industry create rather clear potential biases with respect to electric and hybrid vehicles: capital intensity, extreme regulation, and pricing practices. These characteristics and their impacts are examined below.

6.2.1 Capital Intensity

The electric utility industry is the most capital intensive in the nation, requiring $4.18 of investment capital for every dollar in annual sales as compared with $2.13 for the gas industry, $1.15 for oil, $0.86 for steel, and $0.57 for the automobile industry. (6-2)

As peak demand for power (kilowatts of capacity) has been growing faster than overall demand for electrical energy, load factors have steadily deteriorated over time, from 65.5 per cent in 1970 to 61.0 per cent in 1975. This trend ultimately increases capital intensity as more plants remain idle for significant periods of time.

As a result of capital intensiveness, the fixed charges paid to finance the required investment play an important part in determining the ultimate price electric utilities must charge for their product.* (6-3) Other fixed charges such as depreciation and property taxes also weigh heavily in the total cost of delivered electricity.

A further result of capital intensiveness is that electric utilities must finance a large part of their growth through the continuous sale of additional securities. The return on common equity that a utility must earn to finance its growth depends on the equity's yield and upon investors' estimates of the growth

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*In 1974, interest and preferred dividends amounted to 12.3 per cent of gross revenues, taxes other than income amounted to 8.3 per cent, and depreciation amounted to 8.2 per cent.

rate of dividends per share. This growth rate in turn depends on the fraction of earnings not paid out to investors, the actual return on equity, and proceeds from the sale of additional equity.

In the face of continuing needs for external financing, utilities' return on equity becomes crucial. If it is insufficient to keep the price of common stock at book value, continued sales of common stock will only reduce per share earnings and make it more difficult to raise adequate funds. Table 6-1 shows the minimum earnings that could be expected to provide a market value to book value ratio of one. Historically, the industry has performed very well in this respect. During the past few years, however, while many individual utilities continued to provide excellent rates of return, the industry average began to show significant deficits.

Until 1974, a rate increase of less than 4 per cent would have proved sufficient to cover the earnings shortfall assuming that about 40 per cent of a rate increase could be expected to go for income taxes. In 1974, the shortfall widened appreciably and it would now take a rate increase of about 20% to restore after tax earnings.

The stock market has reflected this relationship in the evaluation of electric utility equities. In 1966, when actual returns had been exceeding required returns for a long period, market value averaged 2.05 times book value for the stocks. This ratio declined through 1974 and reached its nadir in the wake of the announcement by Con Edison that it would pass its dividend. The market dropped to an average of 0.67 times book value. Subsequently, the market recovered as the 1974 energy crisis atmosphere passed; interest rates declined and utility earnings rose slightly. By June, 1975 the average market to book ratio had risen to 0.89, but was still well below 1.0. The ratio must rise at least slightly above one if the companies are to be able to continue to raise the amounts of equity needed in coming years.

TABLE 6-1. REQUIRED AFTER TAX RETURNS VERSUS ACTUAL RETURNS
(millions of dollars)

Year	Required Returns to Capital	Actual Returns to Capital	Actual Minus Required	Per Cent Difference
1974	$11,092	$9,755	(1,337)	(12.1)
1973	9,027	8,493	(535)	(5.9)
1972	8,027	7,404	(623)	(7.8)
1971	6,614	6,424	(190)	(2.9)
1970	6,268	5,603	(665)	(10.6)
1969	5,140	4,953	(187)	(3.6)
1968	4,455	4,454	(1)	--
1967	3,992	4,137	145	3.6
1966	3,566	3,821	254	7.1

Source: Edison Electric Institute

In order to finance their capital needs, utilities have been forced to rely increasingly on external funds. As the cost of utility plants has increased, utility construction expenditures have grown even more rapidly. The past growth rate of the industry dictated a doubling of capacity every decade; construction expenditures, however, quadrupled in the nine years from 1965 to 1974. Long-term financing by electric utilities increased over eight times from 1964-1975 to meet investment requirements. The ratio of total investment financed externally increased from 45 per cent in 1965 to 92 per cent in 1974. During 1975, financial conditions within the industry improved, bringing external financing down to 82 per cent. The sale of debt by utilities is now severely limited by the decline in interest coverage ratios--generally the ratio of income before interest and income taxes to pro forma interest payments. In most states this legal limit is 2:1 which many utilities have reached or are rapidly approaching. In 1966, the average coverage ratio was as high as 5.3:1. Yet, by 1970 it had declined to 3.4:1 and by 1974 to 2.1:1. Thus, many utilities are barred from acquiring additional capital through the issuance of debt.

This increasing reliance on the financial markets, coupled with the continuing trend of rising plant costs may make it difficult for utilities to raise the necessary capital without continued improvement in both the industry and financial markets.

Consequently, extreme capital intensity makes it difficult for electric utilities to expand without significant price increases. And either capacity shortfalls or price increases are biased against electric vehicles, since they would limit the availability and competitiveness of electricity as an automotive fuel.

The significance of potential capacity shortfalls as a bias appears limited. Use of substantial numbers of electric vehicles would have little impact on national electricity consumption; 10 million electric vehicles in service in 1995 would add no more than two per cent to the total forecast demand in that year. (6-4) Electricity price increases are a more serious bias, since fuel cost is an important area in which electric vehicles can offer real savings to drivers in some applications. In average driving conditions, however, fuel costs are such a small fraction of overall vehicle life-cycle costs that major increases in electricity prices would have little tangible impact.

6.2.2 U.S. Government Regulation

The electric utility industry is perhaps the most regulated of all U.S. industries. Federal, state and local agencies are a part of the regulatory process which ultimately determines the supply of electricity, the electricity rate structure, and to a lesser extent, the capital and operating costs of electricity generation. (6-5)

The large number of regulatory groups spread over three tiers of government create inevitable lags in the process of bringing electric generating capacity on line. Nowhere is this more clearly demonstrated than in the licensing schedule for nuclear generators, shown in Figure 6-1. The period from initial utility plans for a nuclear plant to initiation of commercial operation is now some 10 years, and often longer when special problems are encountered. Of the total base capital costs for nuclear power, as shown in Figure 6-2, some 49 per cent can be attributed to delays in construction brought about primarily by regulation.

Thus, government regulation of electric utilities creates biases against electric vehicles by retarding generating capacity expansion and by increasing the costs of new capacity. Regulation contributes to and reinforces the high capital requirements of the industry, and greatly increases uncertainty in planning capacity expansions, since demand must be anticipated many years into the future. Here again, however, the significance of the bias for electric vehicle use appears slight.

UTILITY ACTIONS	TIME-MONTHS	GOVERNMENT ACTIONS
	-3	JUSTICE DEPARTMENT ISSUED ADVISORY LETTER (MAY REQUIRE HEARINGS)
FILE ANTITRUST INFORMATION WITH JUSTICE DEPARTMENT	-9	
SELECT NSS AND AE*	-8	*NSS - Nuclear Steam Supplier AE - Architect and Engineer
FILE NORMAL ANTITRUST NOTICE WITH NRC	-11	
NOTIFY NRC STAFF OF INTENTIONS	-13	
FILE NOTICE TO SURROUNDING UTILITIES OF INTENTION TO CONSTRUCT A NUCLEAR PLANT (ANTITRUST NOTICE)	-14	
SELECT PLANT LOCATION, ACQUIRE LAND	-18	
CONTINUING PUBLIC ACCEPTANCE PROGRAM		

Source: J. R. Tomoto, Florida Power and Light Co.

FIGURE 6-1a. PREAPPLICATION PHASE OF REACTOR LICENSING

UTILITY ACTIONS	TIME-MONTHS	GOVERNMENT ACTIONS
	13	DRL STAFF PREPARES SAFETY EVALUATION TO NRC ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)
	13	NRC PREPARES ENVIRONMENTAL IMPACT STATEMENT
RESPONSE TO SECOND ROUND-QUESTIONS SUBMITTED	9	
	6	SECOND ROUND SAFETY AND ENVIRONMENTAL QUESTIONS ISSUED
RESPONSE TO FIRST ROUND QUESTIONS	4	
	3	SAFETY AND ENVIRONMENTAL QUESTIONS ISSUED TO UTILITY (FIRST ROUND)
	1	NRC DIVISION OF REACTOR LICENSING (DRL) DISTRIBUTES COPIES TO PUBLIC DOCUMENT ROOM, ACRS, STATE AND LOCAL OFFICES, STAFF STARTS REVIEW
FILE DRAFT ENVIRONMENTAL STATEMENT WITH NRL	0	
UTILITY SUBMITS A FORMAL APPLICATION DESCRIBING THE DESIGN, LOCATION AND SAFEGUARDS TO BE PROVIDED FOR THE PROPOSED PLANT (PSAR)	0	

Source: J. R. Tomoto, Florida Power and Light Co.

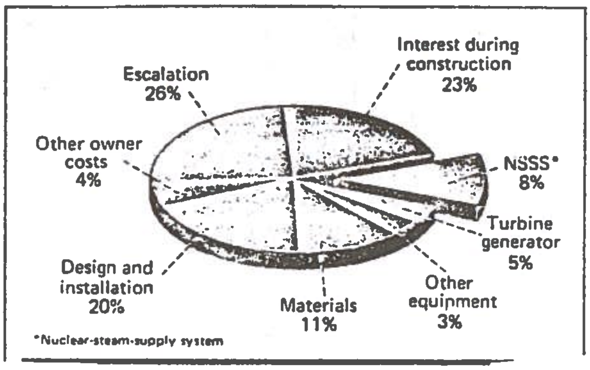
FIGURE 6-1b. APPLICATION PHASE OF REACTOR LICENSING

UTILITY ACTIONS	TIME-MONTHS	GOVERNMENT ACTIONS
		ROUTINE AND UNANNOUNCED INSPECTIONS BY NRC OFFICE OF INSPECTIONS AND ENFORCEMENT
PLANT COMMERCIAL OPERATION	96	
	90	ISSUANCE OF OPERATING LICENSE BY NRC COMMISSIONERS
	84	REVIEW BY ACRS AND ASLB
UTILITY FILES FSAR AND APPLICATION FOR AN OPERATING LICENSE	82	
	34	INSPECTION BY NCR OFFICE OF INSPECTION AND ENFORCEMENT
	33	CONSTRUCTION PERMIT ISSUED
	30	REVIEW OF ASLB RULING BY NRC COMMISSIONERS
	29	ASLB RULES FOR OR AGAINST APPLICATION
	16	PUBLIC HEARING NEAR PROPOSED SITE CONDUCTED BY ATOMIC SAFETY AND LICENSING BOARD (ASLB) ON SAFETY AND ENVIRONMENTAL IMPACT
	16	NRC ISSUED LWA 1 AND/OR 3
FILE FOR LIMITED WORK AUTHORIZATION	15	SUPPLEMENT TO SER ISSUED BY STAFF
	14	ACRS HEARINGS AND LETTER OF FINDING

*LWA - Limited Work Authorization
**FSAR - Final Safety Analysis Report

Source: J. R. Tomoto, Florida Power and Light Co.

FIGURE 6-1c. APPLICATION PHASE ON REACTOR LICENSING



Source: R.E. Balzhiser, "Energy Options for the Year 2000" Chemical Engineering, January 3, 1977, p. 79.

FIGURE 6-2. BASE CAPITAL COSTS FOR NUCLEAR POWER

6.2.3 Electricity Rates and Pricing Policies

Electricity pricing directly affects the cost of operating electric vehicles. Wall plug electricity consumed by electric vehicles considered in this study is as follows:*

two-passenger EV	0.212 kWh/km
four-passenger EV	0.226 kWh/km
light van EV	0.263 kWh/km
hybrid	0.284 kWh/km

For illustrative purposes, an average consumption of 0.220 kWh/km (high proportion of two-passenger vehicles) is assumed throughout this section.

Electricity rates exhibit considerable variation in different regions of the country, ranging from $36.64 for 500 kWh monthly service by Consolidated Edison of New York to $5.42 for 500 kWh

*Source: Table 2-3.

monthly service by Seattle (Washington) Department of Lighting. The national average residential rates for 500 kWh service was \$19.26.* Overlaid on these regional variations are experimental time-of-day pricing programs with extremes in pricing of from \$.01 to \$.16 per kWh depending on time of day.

Electricity cost at January 1976 rates for 10,000-km annual travel would cost \$84.70 at the national average rates, \$23.85 in Seattle, and \$160.51 in New York City.

The highest average bills are found in the New England and the Middle Atlantic regions, while the East South Central region shows the lowest average bills. Table 6-2a shows weighted average residential bills as of January 1976 by region.

State average residential bills for 500 kWh of service in January 1976 ranged from a low of \$7.58 in Oregon to a high of \$25.98 in New Jersey, compared to the national average of \$19.26. The distribution of state average monthly bills for 500 kWh is shown in Table 6-2b.

Privately-owned utility rates are higher on the average than are publicly-owned utilities. Table 6-3 shows the rate for the highest, lowest, and averages of the ten highest and lowest rates for private and public utility companies serving communities of 50,000 population and more.

These extreme variations in electricity prices create biases both for and against electric vehicles depending upon location in the country. Low rates in the Pacific and South Central portions of the country, for example, could stimulate regional demand for electric vehicles, while high rates in the New England and Middle Atlantic areas could retard EV applications there. On balance, the bias against EVs is likely to be more significant, since high electricity prices occur in densely populated urban portions of the country where the applicability of and demand for EVs would otherwise be greatest.

*All rates as of January 1, 1976.

TABLE 6-2a. WEIGHTED AVERAGE BILLS FOR RESIDENTIAL SERVICE BY GEOGRAPHIC REGIONS - JANUARY 1, 1976

Geographic Division	500 kWh	750 kWh	1,000 kWh
New England	$22.19	$31.26	$40.96
Middle Atlantic	26.42	36.65	48.59
East North Central	16.91	23.89	31.49
West North Central	17.36	24.47	31.42
South Atlantic	19.58	27.09	34.52
East South Central	15.36	20.58	25.80
West South Central	15.43	21.31	27.66
Mountain	17.20	23.42	29.78
Pacific	16.91	23.45	30.04
Noncontiguous	22.17	30.32	38.55
U.S. Average	19.26	26.78	34.85

Source: FPC, Typical Electric Bills 1976.

TABLE 6-2b. STATE AVERAGE RESIDENTIAL MONTHLY BILLS FOR 500 kWh - January 1, 1976

Number of States	Monthly Bill
13	Under $15.45
12	$15.45 to $17.52
13	$17.53 to $20.50
12	Over $20.50

Source: FPC, Typical Electric Bills, 1976.

TABLE 6-3. RESIDENTIAL UTILITY BILLS FOR 500 kWh - January 1976
PUBLICLY AND PRIVATELY-OWNED UTILITIES SERVING COMMUNITIES OF 50,000+

<u>Privately-Owned</u>	
Highest	
Consolidated Edison Co. of New York, Inc.	$36.64
Average of Ten Highest Utilities	26.01
Lowest	
Southwestern Electric Power Company	$ 8.36
Average of Ten Lowest Utilities	11.04
<u>Publicly Owned</u>	
Highest	
Austin (Texas) Electric Dept., City of	$25.44
Average of Ten Highest Utilities	22.20
Lowest	
Seattle (Wash.) Dept. of Lighting	$ 5.42
Average of Ten Lowest Utilities	8.17

Source: <u>FPC, Typical Electric Bills, 1976</u>.

In addition to geographic variations in price, the pricing policies employed by electric utilities will have major impacts on demand for EVs. Utility rates traditionally have been rooted in the cost of service. These costs are classified into three groups: energy, demand, and customer. Energy costs are those which vary with the level of electrical production. Demand costs are fixed costs which result from the maximum rate of electricity use. The major portion of demand costs is the capital investment in generation, transmission, and distribution capacity. Customer costs are costs directly attributable to connecting and maintaining customer service, such as metering, billing, etc.*

In traditional billing, these total allowable expenses are allocated to customer classes; residential, commercial, industrial, etc. Rate structures are then developed to recover allocated costs from each customer class. No unique rate structure is dictated by this cost allocation system. Allocated costs to a customer class could be recovered by means of declining, flat, or inverted block rate structures. Historically, declining block rate policy was considered to be the appropriate form for electrical pricing: it explicity recognized the decreasing marginal costs of generation as plant capacity factors decreased.

Beginning about 1970, however, the economics of electricity supply reversed and costs accelerated rapidly. Construction costs for new capacity have risen markedly, fuel costs of all types have increased, and environmental and regulatory costs have also risen--increased pollution abatement and siting costs as well as

*In 1974, utility plant investment costs were distributed as follows: production - 53 per cent, transmission - 22 per cent, distribution - 41 per cent. Operation and maintenance expenses (including fuel), which were 60 per cent of revenues, were distributed as follows: production - 77 per cent, transmission - 2 per cent, distribution - 7 per cent, customer - 1 per cent, sales and G&A - 9 per cent.

delays and uncertainties in plant construction. The secular deterioration in load factors (relationship between peak and average demand) has also caused new plant construction to be undertaken at a more rapid rate than required for average energy production. Poor load factors mean that much of the capacity which is required to service peak periods will be idle during off-peak periods.

The general erosion of national load factors has necessitated expensive capacity additions whose costs have not been recouped by energy sales due in part to declining block rates. This had led to a recognition that on-peak electricity costs more to produce (in terms both of marginal energy and of marginal capacity costs) than off-peak service. Rate structures which charge the same for on-peak as off-peak have been construed as a subsidization of on-peak consumption by off-peak users. This concern received regulatory approval in a landmark rate reform in the Wisconsin Public Service Commission decision in the matter of the Madison Gas and Electric Company's rate increase in August 1974. This decision established marginal cost, as represented by long-run incremental costs, as the "most effective way to obtain an efficient allocation of resources and to prevent wasteful use of electric energy. Full peak-load pricing must, for large customers, be implemented without delay." (6-6)

The Federal Energy Administration initiated an Electric Utility Demonstration program in November 1974 which now includes 16 separate projects. (6-7) The Electric Utility Rate Demonstration Program is designed to fulfill three major objectives: (a) to provide national leadership in developing, assessing and implementing innovative rates, load management and conservation practices; (b) to provide assistance to state and local government agencies to conduct demonstration programs; and (c) to coordinate, analyze and disseminate program findings to all interested parties.

A number of significant findings are beginning to emerge from the five residential rate programs now reporting data to FEA.* Key results how that: (1) there appears to be significant kilowatt-hour consumption price elasticity at all hours of the day, including peak, shoulder and off-peak periods; and (2) that shoulder elasticities appear to be significantly above either peak or off-peak elasticities. Results were based on two kinds of analysis, one relying on complex econometric modeling tools, the other on less sophisticated analytical techniques.

These findings suggest that peak load pricing can succeed in shifting demand from traditional peak periods to off-peak periods. However, they are too tentative to allow major conclusions regarding the net effect of peak pricing on average electricity costs or on utility finances.

Nevertheless, the initiation of peak pricing, to the extent that it occurs in coming years, will create a bias in favor of electric vehicles. By recharging at home during off-peak evening and morning hours, electric vehicle owners could purchase motive power at a cost far below the average price of electricity. Figure 6-3 indicates potential savings due to reduced off-peak prices relative to the national average and highest residential electricity rates. It should also be noted that declining block

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*Several caveats to interpretation of these results should be noted. First, only 5 of 16 programs have submitted data to FEA at this point, and of these, the data collection portion of the programs are generally only partially completed. Second, although the data provided FEA has been validated for accuracy, some possibility of "bad" data in raw data tapes may remain. Finally, the lack of uniformity in the experimental design of programs now reporting data to FEA hinders the comparison of data from separate programs at this time--an analytical tool that promises to provide significantly more powerful insights than separate examination of each demonstration program.

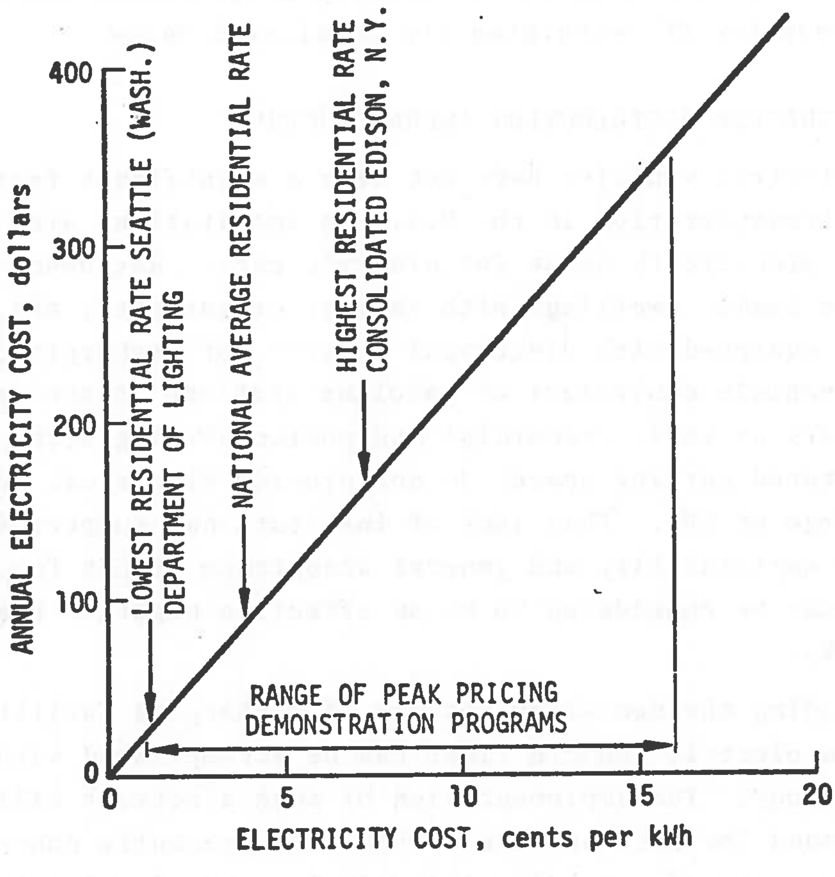


FIGURE 6-3. ANNUAL EV ELECTRICITY COST (10,000 km, 0.220 kWh/km)

rates, to the extent that they encourage any new electricity use, create a bias in favor of electric vehicles. The marginal costs to EV owners for electricity to power their vehicles is far less under a declining rate structure than under straight line or inverted rate structures.

The above biases in favor of electric vehicles, however, are strongly related to the issue of how electric vehicles will be recharged. The question of electricity distribution and its implications for EV recharging are considered below.

6.3 ELECTRICITY DISTRIBUTION INFRASTRUCTURE

As electric vehicles have not been a significant factor in personal transportation in the U.S., no institutions are in place to supply electricity needs for electric cars. Residences, except for single family dwellings with garages or carports, are not typically equipped with electrical outlets for recharging EVs. The electric vehicle equivalent of gasoline stations is non-existent. Parking lots at work, commercial and public parking lots, or on-street metered parking spaces do not provide electrical outlets for recharge of EVs. This lack of institutional support for EVs may deter marketability and general acceptance of EVs for personal use, and may be considered to be an effective negative bias against EVs.

Providing the necessary network of recharging facilities to support an electric vehicle fleet can be accomplished with existing technology. The implementation of such a network will depend on the demand for such services (which are presently non-existent) and on the costs of providing individual recharging facilities. A number of the leading institutions active in the electric vehicle field were contacted in the course of this study in order to obtain relevant information as to concepts and costs of providing such an infrastructure. While the existence of the problem is recognized, there is little research activity in the area. This absence of present effort may be due to the fact that providing an infrastructure is not a problem of technology, but an engineering problem that may be best solved when an actual need arises. Indeed, the U.S. Postal Service which had to build a number of recharging facilities to support its recently acquired fleet of electric vehicles was the only institution able to provide cost information. Furthermore, as will be discussed in a subsequent section, these costs varied widely and were highly dependent on the local situation.

6.3.1 Electric Vehicle Power Requirements

Electric power requirements are considered within the context of the electric vehicles considered in the study. The amount of electricity needed to completely recharge the batteries of the electric vehicles considered in the study is presented in Table 6-4. These values are obtained by multiplying the electric consumption in kWh/km by the range of the vehicles. Depending on the vehicle, approximately 10 kWh to 35 kWh will be required to completely recharge the battery.

The required power will depend upon the time available for recharge. As shown in Figure 6-4, the required power decreases as the time available for recharging the vehicles increases. The lines drawn for each vehicle in this figure assumes a constant rate of charge with time, and a constant charging efficiency with charging rate, neither of which really occur. Since batteries are normally recharged at a declining rate, the actual time needed to recharge a battery may be 25% to 50% longer than the time indicated in Figure 6-4. As charging efficiencies decrease at high charging rates, rapid recharge will require significantly more power than indicated. Figure 6-4 however is useful, to a first approximation, as a method of comparing the electric power requirement of electric vehicles to those of other electrical consumer goods and of standard domestic electric circuits.

Typical electric consumer service to private homes ranges from 7.2 kW (120V, 60 amp, single phase AC) for older single family homes to 48 kW (240V, 200 amp, single phase AC) for modern, electric homes that have a full complement of electric appliances. Electric service within a household is usually

TABLE 6-4. ELECTRICAL ENERGY NEEDED TO RECHARGE EVs OF INTEREST

Electric Vehicle	Nominal Range (electric, (km)	Electric Energy Consumption kWh/km	Maximum Electric Energy For Recharging kWh/vehicle
2 PAX NEAR TERM	50	0.212	10.6
4 PAX INTERMEDIATE	130	0.226	29.4
4 PAX HYBRID	50	0.284	14.2
LIGHT DUTY VAN	130	0.263	34.2

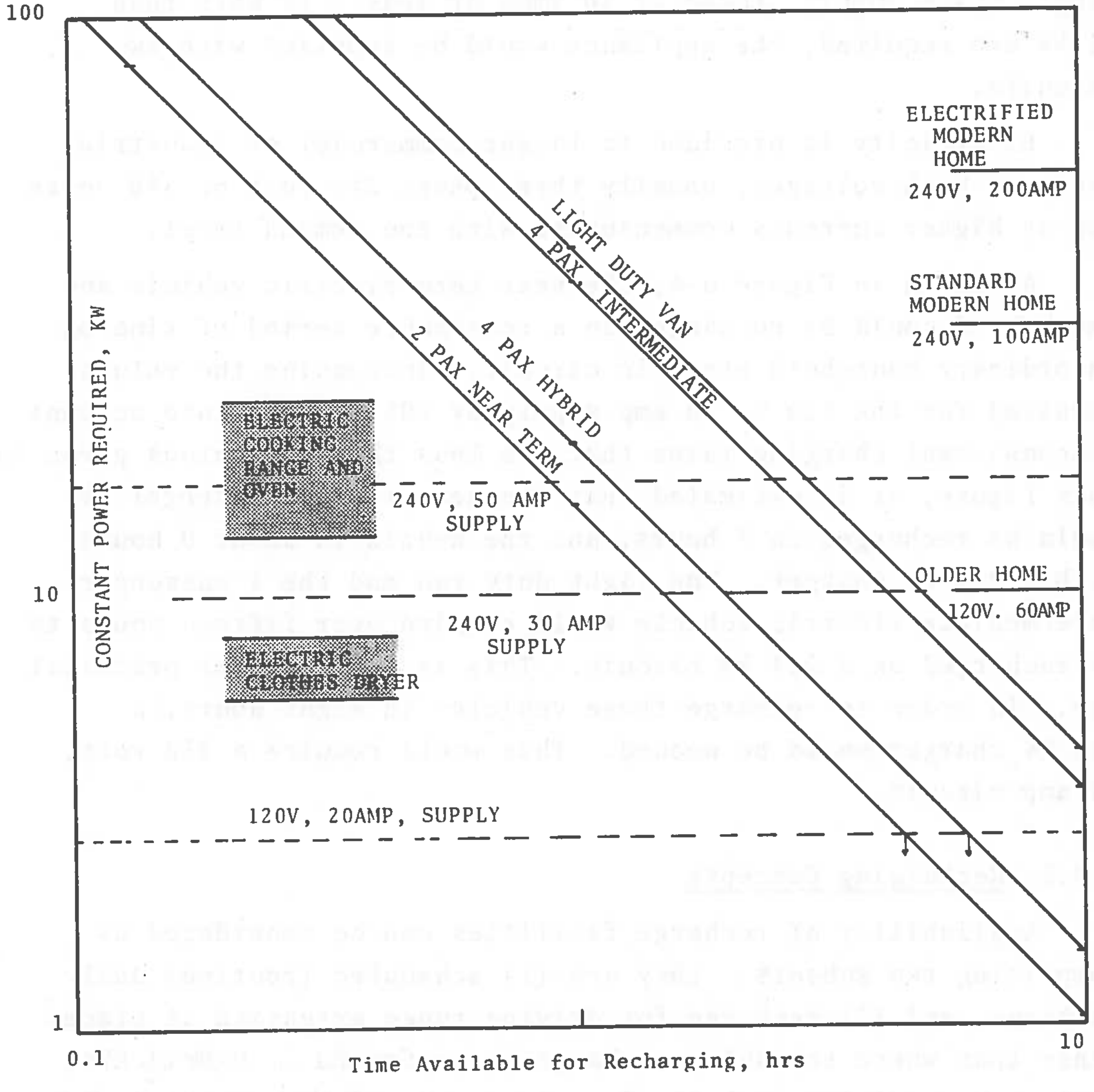


FIGURE 6-4. TYPICAL HOME ELECTRICITY SYSTEMS AND CHARGING CHARACTERISTICS OF EHV BATTERIES

provided at 120V, at currents of 20 amps or less. Such circuits can not be used to serve heavy duty electric appliances. Typical of these appliances would be an electric clothes dryer, that draws 4.5 kW to 6.0 kW, or an electric kitchen range, that can draw from about 9.5 kW to 18 kW. These normally require a 240V, single phase supply, fused at 50 amps or less. If more than 12 kW are required, the appliance would be supplied with two circuits.

Electricity is provided to larger commercial or industrial users at high voltages, usually three phase 240 volt or 480 volts and at higher currents commensurate with the demand level.

As shown in Figure 6-4, the near term electric vehicle and the hybrid could be recharged in a reasonable period of time on an ordinary household electric circuit. Increasing the values obtained for the 120 V, 20 amp supply by 50% to take into account nonconsistent charging rates that are less than the values given in this figure, it is estimated that the near term 2 passenger EV could be recharged in 7 hours, and the hybrid in about 9 hours with a 2.4 kW charger. The light duty van and the 4 passenger intermediate electric vehicle would require over fifteen hours to be recharged on a 2.4 kW circuit. This is too long for practical use. In order to recharge these vehicles in eight hours, a 7.2 kW charger would be needed. This would require a 250 volt, 30 amp circuit.

6.3.2 Recharging Concepts

Availability of recharge facilities can be considered as comprising two subsets: they are (1) scheduled (routine) daily recharge, and (2) recharge for driving range extension at places other than where scheduled recharge is performed . Hybrid EVs, while not requiring recharge for range extension, require routine recharging; pure EVs require routine recharging and are candidates for recharging for range extension as well.

Scheduled recharging may be accomplished with captive, privately owned facilities, or in facilities designed to service the general public. Recharging for driving range extension will require facilities open to the public.

In the case of privately owned vehicles, it is possible to conceive of privately owned facilities installed at the domicile or at the place of work of the vehicle owner. Vehicles in commercial fleets would be recharged at their dispatching garages. Privately owned facilities could either be single, or multivehicle recharging facilities depending upon the particular situation.

Recharging facilities designed to service the public undoubtedly would be designed to service a number of vehicles. A number of concepts can be envisioned. These include:

a. Custom Recharging Service: The owner of an electric vehicle drops the vehicle at the facility where it is recharged in his absence. This sort of facility would be the electric equivalent of a manned gasoline station. There would be one major difference in that pumping gasoline into the tank of an ICE vehicle is accomplished in a matter of minutes while recharging of an electric vehicle requires a number of hours, unless rapid recharge capabilities were developed.

b. Self Service Recharging: A public garage or parking area is equipped with a number of electric sockets accessible to the public, that can be activated by the insertion of coins or a credit card. Upon parking an electric vehicle, the owner plugs the vehicle into the socket, activates it, and draws electricity to recharge the vehicle. This concept is a derivative of the use of electrified parking meters that now exist in certain cities of the northern United States and Canada where the winters are very cold. In these regions, it is not uncommon to install an auxiliary electric engine heater on the vehicle to keep the engine warm while the vehicle is parked outdoors. These heaters have typical power ratings of 500 watts to 1500 watts (6-8); keeping the engine warm in sub-zero degree weather results in more rapid and easier starting of the vehicle. These heaters are usually connected to a private outlet. The existence of electrified public parking meters was most probably a response to an apparent public need.

c. Battery Exchange: This mode of recharging envisions the exchange of a discharged battery for a fully charged battery at a suitable facility. This approach has been considered as a possible alternative that would allow rapid "refueling" of an electric vehicle. The discharged battery would be recharged in the normal time and then placed on another vehicle.

6.3.3 Private Facilities - Recharge at Home

The primary source of electricity considered for recharging EVs for personal use has been overnight at-home recharging. This mode of operation would offer advantages to the vehicle owner and to the utility.

From the owner's viewpoint, overnight slow charging would be least costly, most convenient, and would tend to enhance battery life in comparison to rapid recharge. Additionally, the peak kW demand would be sufficiently modest that adequate meter capacity would be in place. From the utility viewpoint, overnight recharging would draw power at off-peak hours, thereby contributing to load leveling. The utility would also perceive EV recharging as a new load, similar in magnitude to an electric dryer or range depending on the vehicle. This load, however, is one that could be managed by a time clock or central utility control to preclude large numbers of EVs from recharging at peak times.

Overnight recharging at a private home facility, however, would be precluded for those without access to off-street parking with an electrical outlet available. Type of available housing will thus play a major role in the market penetration of electric cars for personal use if the home is the principal recharge place. While range limitations for pure EVs may preclude their use as secondary vehicles for persons who routinely travel distances in excess of EV range, the ability (or lack thereof) to recharge at home is viewed as a broader limitation to EV ownership. Studies of market potential for EVs have considered that multi-car families residing in single-family dwellings with garages, carports, or off-street parking areas were the primary market.[6-9, 6-10]

Families living in multiresidence dwellings would find it more difficult to install a captive outlet for electric vehicle recharging, even if the building has suitable off-street parking. The landlord's permission would be required, which may or may not be granted. Even if the landlord has no objection to the recharging of one EV on the premises, he may require that a separately metered electric outlet be installed. Since this outlet would be accessible to others than the owner of the EV, a key switch may be necessary. The installation of such facilities could prove to be prohibitively expensive and might deter a non-house owner from purchasing an electric vehicle unless recharging facilities open to the public were available. This criterion alone would exclude persons living in 61 per cent of the housing in the twenty-four largest urban areas as shown in Table 5-16.

6.3.4 Public Rapid Recharge/Battery Exchange Services

Public recharge or battery exchange services are an alternative to routine recharge at home and might supplement the inherent range limitations of pure EVs, which are usually considered as substitutes for ICE vehicles for secondary use in multi-car households, not as primary vehicles. Hybrid vehicles are not range limited and would not require rapid recharge or battery exchange for range extension.

The potential demand for battery exchange services on a routine basis would be families owning EVs and living in dwellings other than single-family units with garages or carports.

Based upon analysis of the Los Angeles and Washington, D.C. urban areas, about 33 per cent to 42 per cent of total household units are multicar owners for whom the EV could be a candidate replacement for other than the primary vehicle.

The Los Angeles and Washington, D.C. urban areas were examined to show the effect of housing patterns on the availability of home overnight recharge facilities. While the Los Angeles area is characterized by a high proportion of single-family housing with garages or carports, the Washington, D.C. area has one of the lowest ratios of housing units that are single-family with garages or carports in the U.S. Table 6-5 shows urban projections of housing and automobiles for 1970 and projections for 1980 and 1990.

From the data shown in Table 6-5, the potential market penetration of electric vehicles as secondary cars as a function of housing characteristics may be inferred. The data are shown in Table 6-6. Limiting EVs to single-family dwellings with garages or carports would seriously constrain their application in the Washington, D.C. area in comparison to the Los Angeles area. These two cities represent the extremes of the 24 largest urban areas in terms of the proportion of housing represented by single-family units with garages and carports. On average for these areas, only 39 per cent of all housing units had the facilities appropriate for EV recharging. While this constitutes a bias against widespread use of electric vehicles, its significance is uncertain since technological and cost constraints will probably limit EV applications to an even smaller share of the automotive market in the foreseeable future.

The demand for recharge or battery exchange service for range extension is critically dependent on the range capability of the EV. Studies (6-9, 6-10) have shown that for secondary vehicle travel a range of 50 km will satisfy approximately 83 per cent of average daily travel. Increasing range capability to 130 km will satisfy almost 99 per cent of average daily driving needs.

TABLE 6-5. POTENTIAL ELECTRIC CAR PENETRATION BY HOUSING TYPE
(1000's)

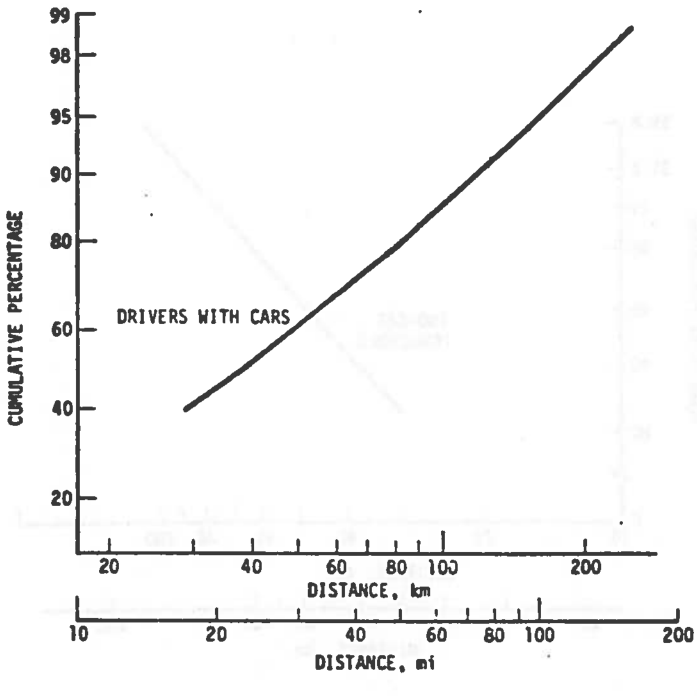
	Los Angeles Area			Washington, D.C. Area		
	1970	1980	1990	1970	1980	1990
Total Automobiles	4,726	5,774	6,751	1,131	1,643	1,987
EV Secondary Car Market - All Housing Units* (Number and Per cent)	1,566(33)	1,984(34)	2,240(36)	432(38)	653(40)	834(42)
Multiple-Family Units	600(13)	760(13)	934(14)	214(19)	323(20)	413(21)
Single-Family Units	966(20)	1,224(21)	1,506(22)	218(19)	330(20)	421(21)
Single-Family Units with Garage/Carport	936(20)	1,188(21)	1,461(22)	41(4)	62(4)	80(4)

*Washington, D.C. shows a higher percentage of total cars which could be replaced than does Los Angeles because only one auto in a multi-auto household was considered as an EV replacement candidate, and Los Angeles has a higher proportion of 3+ automobile households than does Washington, D.C.

TABLE 6-6. POTENTIAL DEMAND FOR DAILY BATTERY EXCHANGE/RECHARGE
(EV AS SECONDARY CAR)

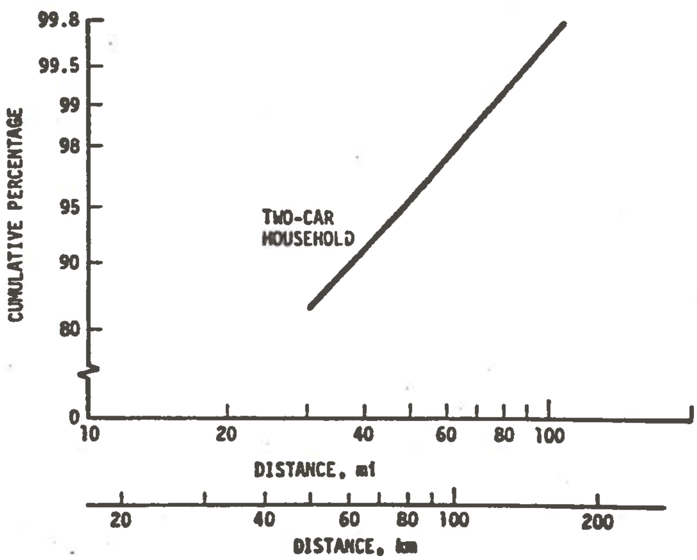
	Year	Range (km)	No. of EVs & Market Penetration*		Daily Demand for Exchange/Recharge With at Home Overnight Recharge: Total	Per 100 km^2	Per 400 km^2	Per 1,000 km^2
Los Angeles	1980	50	1,188,000	100%	201,960	3,737	14,949	37,372
			188,800	10%	20,196	373	1,495	3,737
	1990	130	1,461,000	100%	11,688	175	700	1,749
			146,100	10%	1,169	17	70	175
Washington, D.C.	1980	50	62,000	100%	10,540	428	1,712	4,281
			6,200	10%	1,054	43	171	428
	1990	130	80,000	100%	640	18	71	177
			8,000	10%	64	2	7	18

*Secondary vehicles at single-family dwellings with garages or carports.



Source: Adapted from EPA-460/3-74-020-C, Impact of Electric Cars in the Los Angeles Region, GRC, October 1974.

FIGURE 6-5. DISTRIBUTION OF DAILY DRIVING DISTANCE IN THE LOS ANGELES REGION - ALL DRIVERS



Source: Adapted from EPA-460/3-74-020-C Impact of Electric Cars in the Los Angeles Region, GRC, October 1974.

FIGURE 6-6. DISTRIBUTION OF DAILY DRIVING DISTANCE IN LOS ANGELES REGION, SECONDARY DRIVERS WITH CARS

Driving distributions for primary and secondary cars are shown in Figures 6-5 and 6-6. Table 6-6 shows the effects of EV range on the potential daily demand for recharge/exchange services for two market penetration levels of 1980 and 1990 performancé EVs. What is striking in the table is that a range extension from 50 km to 130 km would result in an approximately twenty-fold decline in the requirements for battery exchange or quick charge for range extension.

Quick charging (less than eight hours) for a depleted battery requiring 10-40 kWh would require charging currents in excess of 50 amp with 240 volt charging. Simultaneous rapid recharging of vehicles could result in power requirements of several hundred kilowatts. The cost to the customer for rapid recharging if done in an attended gasoline service station atmosphere would no doubt be considerably more than at-home overnight recharging, since in addition to the cost of electricty there would also be a charge to cover costs of labor and equipment.

Routine battery exchange in lieu of overnight recharge is likely to be the most costly and least convenient alternative. A battery exchange involving a fork-lift truck or other similar device would be at least as time consuming as purchasing a tank full of gasoline. For electric vehicles, this operation would be required on a daily or every-other-day cycle. Routine battery exchange would also dictate that batteries be leased or that the vehicle owner purchase a spare battery for recharging by the exchange service. In either circumstance, two batteries per vehicle for a short-range car requiring a daily exchange would be required. For longer range vehicles requiring an exchange every second or third day, battery leasing would seem to be preferable. With leasing, the battery/vehicle ratio could decline to about 1.5:1, which should result in lower cost to the owner than buying two battery sets while allowing adequate return on investment for the exchange operator.*

*Overnight recharge, rather than rapid, daytime recharge is assumed. This would allow use of off-peak power and conserve battery life in comparison to daytime rapid recharge.

In addition to energy charges and capital recovery charges for leasing batteries, a labor charge for exchanging the battery pack would also be indicated. A 50 cents to $1.00 labor charge per battery exchange would result in annual costs of $125 to $250 per year in addition to lease and energy costs. The potential buyer of an electric vehicle might easily be persuaded to pay this amount as a one-time cost to obtain a recharge outlet at a multi-family dwelling which already provides off-street parking but is not equipped with electrical service. Alternatively, the prospective buyer might be attracted to coin operated overnight recharge outlets in conjunction with a parking space, if such were available. Either the one-time "purchase" of an electrical outlet in a parking lot or garage, or the use of coin operated outlets for overnight recharging appears to be less costly and more convenient than routine battery exchange.

The battery exchange/rapid recharge service operator therefore, is likely to operate in only a small niche in the market place. Single-family households with garages or carports will prefer to charge at-home and for the 1980, 50 km (31 mile) range car, even 60 amp, 120 volt service to the home would be adequate for overnight recharge. Without overnight recharge facilities, the labor, capital, and inconvenience costs of battery exchange might be sufficient to deter purchase of an EV, to make a one-time purchase/lease of an overnight outlet, or to vigorously encourage the installation of coin operated outlets by apartment owners or utilities. The prospects of a hybrid vehicle or substantially improved batteries which would eliminate the requirement for rapid recharge or battery exchange for range extension might also be deterrents to investment in recharge or exchange stations.

6.3.5 Cost of Recharging Facilities

The cost of recharging facilities will vary widely and will depend on factors such as:

1. The number of recharging stations involved
2. The characteristics and availability of electricity already on site.

3. The characteristics of the electric vehicles

4. The time available for recharging

5. Site characteristics -

   -indoor or outdoor facilities

   - new or existing construction

   - need for explosion proof fixtures

The cost of installing a recharging facility will be significantly less for the owner of a single family home already supplied with 240 V, 200 amp service who wants to recharge a single electric vehicle on an overnight basis than it would be for someone who waited to install a 10 bay recharging facility at a site where electricity is not directly available.

If there is ample service at the site, the cost of installing the recharge station is minimal: It entails running a line from the master panel to the designated recharging area. In a private home, this would be typically from the basement to the garage or carport. The cost would be comparable to the cost of installing the circuit for an electric dryer, or, more likely, for an electric range. Based on the data in Table 6-7, the installation would cost from about $45 to $150 depending on whether or not metallic conduits and weather proof receptacles were used. This unit does not include any provision for a battery charger, which would have to be provided if the vehicle has no on-board charger, Providing a 5.0 kw to 7.5 kW battery charger (as would be required for the light duty van or intermediate 4 passenger electric vehicle) would cost an additional $400 to $600, based on an assumed charger cost of $80/kW.

If there is inadequate electric service at the site, the cost of bringing this service to the site will increase the costs significantly. Bringing in 200 amp/240 volt single phase service and installing a new panel will cost an additional $500 to $750. This would provide 48 kW of power which would be sufficient to charge as many as six to ten vehicles simultaneously.

TABLE 6-7. REPRESENTATIVE 1977 COSTS OF INSTALLING RESIDENTIAL WIRING

JOB	ESTIMATED COST FOR AVERAGE RUNS USING NON-METALLIC SHEATHED CABLE ($)
Average Light Fixture	20
Dryer Circuit	45
Range Circuit	65
Service and Panel, 100 amp	250
Service and Panel, 200 amp	450
Weatherproof Receptacle with Ground Fault C.B. at Panel	75

For BX Cable, add	8%
For EMT Conduit, add	55%
For Aluminum Conduit, add	70%
For Galvanized Steel Conduit, add	90%
For Custom Residential, add	20%

Source:

Building Construction Cost Data 1977

35th Edition

Robert Shaw Meens Company, Inc.

Duxbury, MA 1976

This problem would be presented to the potential owner of an electric vehicle who lives in a multistory apartment building, if the landlord while allowing an electric vehicle to be garaged and recharged in the building (an issue in itself) would require that a separate service be brought into the building to service the electric vehicle. If this cost cannot be distributed over a number of vehicles, it could be an effective barrier to vehicle ownership by residents of multistory apartment buildings provided with off-street parking facilities. For residents of multistory apartment buildings in densely populated urban areas tht have no off-street parking facilities, recharging facilities open to the public would be required. Their absence would be an effective means of prohibiting electric vehicle ownership to this population group.

The cost of installing a multi-vehicle recharging facility is expected to be more expensive on a project basis than a single vehicle facility, but less expensive on a per vehicle basis. The specific costs will, however, vary widely with circumstances. Here again, adaptation of existing facilities with adequate service already installed will be significantly less expensive than installing a grass roots facility.

This has proven to be the experience of the U.S. Postal Service. (6-11) The USPS recently purchased an experimental fleet of 350 AM General Electric Jeeps for evaluation. While the majority of these vehicles (295 vehicles) are being used in San Bernadino, California, the balance of the vehicles have been apportioned in fleets of five or ten vehicles to seven different locations throughout the country. Recharging facilities have had to be provided at each of these locations. The cost of installing these facilities have varied from a nominal amount ($25/vehicle) under the best conditions, to as much as $500/vehicle, when electric utilities had to be provided. These costs do not include the actual battery chargers which were procured with the electric vehicles. The lower costs were incurred where there was ample power already available at the site and where the required lines only had to be hooked to the existing service box and could be surface mounted. The higher costs were incurred where new service had to be brought in and where excavation or building modifications were required to lay in the wiring.

A multivehicle recharging facility can expect to have a high electric power demand. The operator of a multi-station recharging faicilty would most probably be charged on the basis of both peak demand (kW) and energy consumption (kWh). To offset high demand charges, a mutivehicle recharging facility will tend to schedule its operations on as uniform a basis as possible (essentially around-the-clock charging), all other conditions being the same. The recharging of electric vehicles in this manner may exacerbate existing daytime peak load demands for electricity. This would run contrary to the general premise that electric vehicles would normally be recharged at night and thus alleviate load management problems presently besetting electric utility companies.

No information has been developed to date on the costs of coin operated public recharging facilities. While analogous in concept to the electrified parking meters used to energize engine heaters, coin operated electric vehicle recharging facilities would be required to handle much larger electric power loads, 5 kW to 7.5 kW than the 1.5 kW or less used for vehicle heaters. In order for vehicle recharging facilities to be of general utility, the charging characteristics of electric vehicles would have to be standardized. The characterisitics of any automated recharging facility would vary significantly depending on whether an AC output (for vehicles with on-board chargers) or a DC output (for vehicles without on-board chargers) was required.

6.3.6 Summary, Electricity Distribution Infrastructure

The lack of a recharging infrastructure creates a clear bias against the use of electric vehicles. It implies that EV owners must rely on private facilities, presumably recharging overnight, and thus restricting their daily driving capability to the single-charge range of the vehicle.

This bias is mitigated somewhat by the availability of adequate electric power to provide for individual recharging needs at single-family homes with off-street parking. Such homes represent only some 40 per cent of the urban housing stock, however, so that many households will have difficulty in recharging overnight.

In the longer term, rapid recharging or battery exchange stations might provide services for range extension and non-home recharging. There appears to be no institutional bias against such stations, and the necessary technology is available. Unlike gasoline, however, electricity is available at home, and even residents of multi-family housing are likely to find it less expensive to invest in their own recharge facilities than to use commercial recharge stations. Demand may never be sufficient, therefore, to support the widespread establishment of a decentralized commercial recharging network.

This whole issue has not received as much attention as the development of the electric vehicle. It deserves more careful study since major investments would ultimately be required to implement an operational network of recharging stations. While it is true that such a network can not be justified without a fleet of electric vehicles, the desired fleet of electric vehicles can not hope to exist, much less grow, without the infrastructure.

CHAPTER 6 REFERENCES

6-1. Edison Electric Institute, 1976 Electric Power Post Summer Survey, October 1976.

6-2. Technical Advisory Committee to the Federal Power Commission on the Financial Problems of Electric Utilities, December 1975.

6-3. Federal Power Commission, Statistics of Privately Owned Electric Utilities in the United States, 1974.

6-4. W. Flueckiger, General Research Corp, personal communication. Using a forecast of 5.4%/yr growth in electricity demand for the years 1975-1985 (FEA "National Energy Outlook") the projected 1995 demand for electricity is 4965 billion kWh/yr. Assuming a very high average energy requirement for the 1995 EV fleet of 0.7 kWh/km and an average use of 10000 km/vehicle/yr, the total energy requirement for 10 million EV's is 70 billion kWh/yr, a 1.4% increase in total forecast demand for 1995. Using a vehicle requirement of 0.25 kWh/km and average distance traveled of 16,000 km/yr a 0.8% increase in 1995 projected total demand is obtained. These projections represent national averages and significant regional and local variations may be expected to occur

6-5. The major regulatory activities are as follows:

Federal Level

Nuclear Regulatory Comission - Responsible for licensing and regulating of nuclear fuel facilities. NRC has licensing authority for nuclear fuel facilities, reactor safety, materials safeguards, and regulatory procedures.

Federal Power Commission - FPC regulates the price of interstate wholesale sales of electricity. Additionally, FPC regulates the price and end use of natural gas in interstate commerce. FPC also exercises jurisdiction over certain entities of power activities.

Federal Energy Administration - FEA regulates the price of domestic crude oil and some refined products, and controls use of petroleum products for use as boiler fuel.

Environmental Protection Agency - EPA develops and enforces standards for clean air and water, controls pollution from pesticides, toxic substances, and noise. EPA also approves state pollution abatement plans and rules on environmental impact statements.

Mining Enforcement and Safety Administration, Department of the Interior - Enforces all mine safety regulations, including air quality and equipment standards.

Occupational Safety and Health Administration, Department of Health, Education and Welfare - Responsible for regulating safety and health conditions in all work places, except those run by governments.

State Agencies

Public Utility or Service Commissions - PUC's approve electricity rates, regulate earnings, making siting determinations for generation and transmission facilities, recommend state policies and actions determining energy use.

Other State Agencies - Some states (e.g., California) have environmental offices and water resource boards which are instrumental in approving power plant siting.

Local Agencies

City and county instrumentalities affect siting by means of zoning, comments on environmental impact reports, etc. Hearings and public opinion at local levels can filter upwards to State and Federal levels to affect policy decisions not subject to strictly local control.

6-6. Public Service Commission of Wisconsin, Decision in Case 2-U-7423, August 8, 1974.

6-7. Federal Energy Administration, Electric Utility Rate Demonstration Program, Initial Results, February 14, 1977.

6-8. Sears Roebuck Winter Catalogue, 1977, p. 754.

6-9. US Environmental Protection Agency, Impact of Future Use of Electric Cars in the Los Angeles Region, EPA 460/3-74-020, October 1974.

6-10. US Energy Research and Development Administration, Impact of Future Use of Electric Cars in the St. Louis and Philadelphia Regions, TEC 75/006, September 1975.

6-11. R. Bowman, Office of Fleet Management, U.S. Postal Service, Washington, D.C., personal communication, June 30, 1977.

7.0 FEDERAL POLICIES AND PROGRAMS

7.1 INTRODUCTION

In addition to its regulatory and taxation activities, the federal government can influence transportation vehicle characteristics through a variety of policies and programs. The following chapter identifies potential biases in the most important of such largely non-regulatory programs, including energy research, development, and demonstration; motor vehicle fleet procurement; and special low-emissions vehicle procurement.

7.2 ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION

Energy-related federal research, development, and demonstration (RD&D) programs represent a clear source of potential bias for or against future surface transportation vehicles of particular characteristics. Such programs can strongly influence the types of vehicle technology available for future applications, as well as the forms in which energy is available for vehicular use. However, while federal RD&D is a relevant institutional factor, identification of any "bias" in its emphasis or magnitude is a highly complex and largely qualitative problem. A definitive analysis is beyond the scope of this study.

Some perspective can be gained, nevertheless, by reviewing the institution of federal RD&D in terms of its goals and assumptions. Current programs can then be evaluated against this perspective and tentative conclusions reached concerning potential biases for or against particular classes of vehicles.

7.2.1 Federal Energy RD&D: Goals and Assumptions

It has long been assumed in the United States that development and commercial introduction of new technology is best left to private industry. This assumption has, with the passage of time, become a well-established tradition. However, events of the last several years have raised serious questions about this tradition as applied to energy sources and technology (7-1). Starting in 1974, a series of legislative actions strengthened and encouraged the major energy RD&D programs that are at present coordinated by the Energy Research and Development Administration (ERDA) (7-2).

Although federal RD&D can have several objectives (7-3), the current energy-related programs are aimed primarily at providing new technology for commercial applications. Funding is spread among basic research to identify new technological options, applied research and development to explore the viability of previously identified options, and demonstration projects to determine the cost and benefits of options on a commercial scale and speed their wide-spread application.

The basic goal of these programs is to maximize the returns to society of "investments" in RD&D. (7-4) This implies that support for a given technological option should be based on the anticipated benefits and costs it will provide in future use, taking into account the risks that: (a) technical development will fail, and (b) that the option will not achieve widespread application.

"Benefits" in this context are usually stated in monetary terms on the assumption that prices reflect the true value to society of the resources in question. However, many goods, for example, clean air, national security, and personal mobility, are difficult to quantify in monetary terms. Furthermore, there is substantial controversy (7-5) as to how accurately current energy prices reflect social values. The problem of assessing energy RD&D options is accordingly difficult.

It is important to recognize, neverthless, that decreased consumption of one resource -- petroleum, for example -- will not provide benefits in the limited sense defined above if consumption of other valuable resources increases to an off-setting degree. The difficulty is in determining appropriate trade-offs between scarce resources; and market prices, although imperfect, are still the most widely used index of value.

A wide variety of procedures has been proposed for evaluating alternative RD&D programs to determine appropriate funding levels. (7-6)

While substantial differences occur in their approach to the problem, a common if sometimes implicit theme is the net present value of each alternative. In principle, the appropriate level of support for a given option can be calculated by forecasting its period of commercial application and net benefits over this period, discounting these benefits back to their net present value, and adjusting this value for risks. Funding for the option, in theory, can equal the risk-adjusted net present value while still providing for a positive rate of return.

Application of this approach, of course, is fraught with difficulties. Energy technology options tend to be interactive, their ultimate costs are difficult to estimate, their external (non-energy) costs and benefits are uncertain, and their market penetration is difficult to forecast. In addition, as mentioned above, such financial calculations do not always account for extra-financial problems. There are good reasons to believe (7-7), for example, that the value of petroleum to society is well above its market price. Analysis of petroleum-saving technology based on market price, therefore, might yield a negative present value despite large potential benefits to society. Calculations based on an assumed "social value" of petroleum, on the other hand, might ignore the difficulty of ensuring commercial application at depressed market prices.

Further, federal RD&D is a dynamic process, in which programs and funding levels evolve to meet new priorities. The programs at any given time may not fully reflect the current perceptions of alternative technologies and their anticipated benefits because of lags in the planning and funding process.

Nevertheless, the principles themselves provide sound qualitative criteria for evaluating RD&D programs. The basic determinant of support should be the expected benefits of a technological option, including its overall impact on resource consumption. The longer the time before commercial application, however, the smaller the amount of current support that is warranted. And, of course, the options with a high risk of failure deserve less support, all other things being equal.

The principles also help to establish what "bias" might occur in federal RD&D. While different levels of support for alternative technological options may constitute a bias in the fundamental sense of a leaning or inclination, this may be economically or socially appropriate to the situation. Where relative funding levels do not reflect the anticipated benefits of alternatives, taking into account the criteria enumerated above, however, the bias may become prejudicial. Current federal RD&D programs can be assessed with this perspective.

7.2.2 Current Federal RD&D Programs

Current ERDA energy RD&D programs are summarized in Table 7-1.* They span a broad range of basic energy sources, power conversion methods, and end-uses. The conservation program includes direct research on transportation vehicles, while the remaining programs influence the forms of fuel available to the transportation sector. The question of bias towards vehicles of particular characteristics may therefore be subdivided into two elements:

- direct bias in automotive RD&D
- indirect bias in RD&D on alternative energy sources and fuel types.

7.2.3 Bias in Automotive RD&D

The automotive sector -- passenger automobiles, light duty trucks, and commercial vehicles -- represents a prime target for RD&D because of its significance in energy consumption. With more than 100 million such vehicles traveling some one trillion miles annually, even very small improvements in fuel economy have significant social benefits.

*It should be noted that while the ERDA program is the one most directly related to the subject of this report, there are a number of other programs in other agencies of the Federal Government which are indirectly related (DOD, FEA, DOT, etc.). These programs have not been specifically included in the discussion which follows and therefore represent a potential uncertainty in certain aspects of the argument.

TABLE 7-1. CURRENT ERDA ENERGY RD&D PROGRAMS
(Millions of Dollars)

Program	Budget Outlay $ (millions) 1977*	Budget Outlay $ (millions) 1978 Request*
Conservation:		
Electric Energy Systems	20.7	34.0
Energy Storage	27.5	41.0
Industrial Energy Conservation	12.4	18.6
Buildings and Community Systems	22.6	43.0
Transportation Energy Conservation	24.0	56.0
Improved Conversion Efficiency	12.7	45.6
Energy Extension Service	5.0	6.0
Total Conservation	124.9	244.2
Fossil Energy:		
Coal	388.3	420.5
Petroleum and Natural Gas	36.6	63.4
Oil Shale *In Situ*	20.5	35.1
Total Fossil Energy	445.4	519.0
Solar Heating and Cooling	61.0	86.0
Solar Electric and Other	122.0	164.0
Geothermal Energy	49.0	68.0
Fusion Power Development	322.0	392.0
Fast Breeder Reactor	595.0	651.0
Nuclear Fuel Cycle and Safeguards	336.0	486.0
Other Fission	122.0	137.0
Total	2,177	2,747

*Fiscal year funding.

Source: U.S. Energy Research and Development Administration, "Revised FY 1978 Budget to Congress: Narrative Highlights", February 1977.

Historically, the government has left automotive RD&D to private industry. In the late 1960's, however, increased concerns about exhaust emissions created a new outlook on choosing optimum automotive powerplants. Senate hearings (7-8) in 1967 and 1968 generated enthusiasm for alternatives like electric and steam systems. In 1970, the Advanced Automotive Power Systems (AAPS) program was established to support research on alternatives to the ICE; originally, administered by the National Air Pollution Control Administration, it was shifted to the Environmental Protection Agency in late 1970 and to ERDA in 1975. (7-9)

In Table 7-2, the automotive industry's total R&D expenditures are listed while Table 7-3 lists R&D expenditures on alternative automotive power plants by the leading manufacturers and by the AAPS Program from 1971-1975. While the manufacturers' research and development expenditures averaged nearly a billion dollars annually during this period, efforts on alternative power plants represented only a few percent of the total. Emission control technology apparently received several hundred million dollars annually (7-10), while the balance was spread among evolutionary improvements to the conventional ICE vehicle. The federal program was quite modest even in comparison to industry expenditures on alternative power plants alone.

In September, 1976, however, the Electric and Hybrid Vehicle Research Development and Demonstration Act was signed into law. The Act authorizes major funding -- $160 million over five years -- for RD&D on these specific vehicle systems. Legislation to support R&D on other alternative power plants failed to achieve Congressional approval later that year (7-11), but is now under review and could be passed later this year. (7-12)

Electric and hybrid vehicle RD&D therefore dominates the current federal automotive program. This emphasis clearly creates a bias in the basic sense of an inclination toward electric vehicle systems. On the other hand, such an emphasis could originate in the anticipated social benefits of electric vehicles relative to alternative systems. While a detailed technical analysis is not

TABLE 7-2. AUTOMOTIVE INDUSTRY R&D EXPENDITURES
(millions of dollars)

	Corporation				
Year	General Motors	Ford	Chrysler	American Motors	Total
1975	544	282	84	28	938
1974	560	376	111	31	1,078
1973	533	392	121	31	1,077
1972	452	301	98	21	872
1971	492	246	80	18	836

Source: "Data and Analysis for the 1981 Through 1984 Passanger Automobile Fuel Economy Standards" Feb. 28, 1977, Document 4 "Financial Analysis of the U.S. Auto Manufacturers, DOT-NHTSA Document.

TABLE 7-3. GOVERNMENT AND INDUSTRY EXPENDITURES FOR R&D ON ALTERNATIVE AUTOMOTIVE POWER PLANTS
(millions of dollars)

	Year					
Industry:	1970	1971	1972	1973	1974	1975
GM	11.3	18.9	20.8	23.7	22.4	22.5
Ford	8.0	13.0	20.3	26.5	NR	NR
Chrysler	0.1	0.3	0.8	3.9	6.0	NR
Industry Total	19.4	32.2	4.19	54.1	53+	NR
AAPS Programs*	2.2	4.3	9.1	9.8	12.3	7.0
Combined Total	21.6	36.5	51.0	63.9	65+	-

*Fiscal Year

NR = Not revealed.

Source: J.B. Heywood, Et. Al., The Role for Federal R&D on Alternative Automotive Power Systems, MIT Energy Laboratory Report No. MIT-EL-74-013, November 1974.

possible here, a brief summary of electric vehicle characteristics relative to those of alternatives will help clarify the issue.

The uniqueness of electric vehicles lies in their independence from liquid fuels; Section II of the Act refers several times to the petroleum savings their introduction would foster. Because most electricity in the U.S. is generated with non-petroleum fuels, the introduction of electric vehicles could cause a major reduction in petroleum consumption. Such a reduction would be beneficial to society, however, only if electric vehicle use did not cause increased consumption of other resources -- for example, coal, battery materials, etc. -- to counter petroleum savings.

As Chapter 2 indicated, life cycle cost estimates based on current prices strongly suggest that electric vehicles are not an attractive substitute for the <u>average</u> conventional passenger automobile. This implies, based on current market prices, that their petroleum savings are more than offset by increased consumption of other resources. Gasoline would have to be substantially more valuable to society -- perhaps a dollar per gallon more than current prices -- for electric vehicles to provide net benefits in the average situation. (7-13)

Some atypical vehicle owners, on the other hand, in particular those with modest, well-defined and relatively invariant driving cycles dominated by short stop-and-go trips, should gain real savings by switching to electric vehicles, even at current gasoline prices. Electric commercial delivery vehicles, for example, could cost several cents per mile less to operate than current ICE vehicles. Similarly, an unknown fraction of the passenger automobile fleet is driven over cycles for which electric vehicles should offer net cost savings.

It is in these atypical applications, rather than replacement of average automotive vehicles, that electric vehicle RD&D finds its economic justification. Even if electric vehicles were introduced a decade from now, replacing only a few hundred thousand vehicles (far less than one percent of the fleet), and saving a modest amount per mile of driving, the present value of their future benefits could easily exceed $100 million. (7-14) At higher gasoline prices relative to electricity prices, this amount would be even larger.

Moreover, electric vehicles offer potential political and environmental benefits that are difficult to quantify in economic terms. By lowering petroleum consumption, the use of electric vehicles would reduce our dependence on foreign oil, improving our balance of trade and increasing national security. Their use might also help to improve air quality in urban areas if more stringent emission standards are required or if emission control for conventional vehicles is insufficient to achieve air quality goals. Electric vehicles are much quieter than current ICE vehicles and could help to control noise pollution. Lastly, development of electric vehicle technology and encouragement of a viable supply industry would provide insurance against major disruptions in liquid fuel supplies or prices.

The currently planned expenditures for electric and hybrid vehicle RD&D -- some $160 million over five years -- therefore represent a reasonable gamble. Major reservations have been expressed, however, concerning the emphasis of the program on short-term demonstration rather than longer-term technology development (7-15, 7-16). The merits of the approach are difficult to assess. Short-term demonstration could speed up the introduction of electric vehicles and the realization of their benefits. On the other hand, support for demonstration reduces the funds for research to improve electric vehicle technology; both the magnitude of the potential benefits and their long-term realization may thus be reduced.

One expert testified:

> The electric vehicle bill as now worded would do a disservice to the advancement of electric propulsion. The time scale is much too short, the early emphasis on large scale procurement is inappropriate, and the importance of sustained research and development is not recognized. Getting more electric cars on the road without advancing the technology will only produce expensive and discouraging results. (7-15)

Thus, there is at least the possibility that the Act, in its orientation toward short-term demonstration, may create a bias against electric and hybrid vehicles in the long term.

In addition to electric and hybrid vehicles, there are several alternative heat engine systems that are candidates for federal support. These systems have received the majority of funding under the AAPS program, but still require major developmental efforts before their actual competitiveness relative to the ICE and electric systems can be determined. The principal alternatives are the Stirling cycle, Rankine cycle, and gas turbine engines.

Several major studies in the past few years have performed detailed analysis of potential performance and cost characteristics of these systems. (7-17, 7-18, 7-19) They may offer lower exhaust emissions, higher fuel economy, and less sensitivity to fuel properties than the ICE. While their initial prices are projected to remain above those of conventional vehicles, they could significantly reduce life cycle costs.

Federal RD&D on such alternative power plants, therefore, appears to be a viable policy option. Based on current performance and cost projections, they offer the same or greater magnitude of social benefits as electric vehicles. While such heat engines would continue reliance in the surface transportation sector on liquid fuels, synthetic fuels may ultimately prove to be a more attractive energy source than electricity in many transportation applications.

In conclusion, the current federal RD&D program on automotive technology is biased in favor of electric vehicles. The bias is not related to the level of funding, which appears justifiable, but rather to the exclusion of liquid-fuel alternatives from similar support. However, proposed legislation now under review by Congress could eliminate this bias (i.e., the Automotive Transport Research and Development Act of 1977, Title 3 of HR6796).

7.2.4 Bias in RD&D on Alternative Energy Sources

Federal programs on alternative sources of energy are divided among nuclear technology, coal, solar power, geothermal energy, and oil shale. These programs have only an indirect influence on surface transportation system characteristics. They will, however, play a major role in determining one vital vehicle attribute: type of fuel consumed. The types of fuel available to the transportation sector in the future will, in turn, strongly influence other vehicle characteristics like power plant.

The issue, therefore, involves not only the primary energy sources to be developed, but also the intermediate forms into which they will be transformed for end use. In particular, emphasis on electricity generation from non-liquid feedstocks could stimulate electric vehicle use as petroleum grows scarce, while aggressive development of synthetic liquid fuels would favor non-electric vehicles.

Table 7-4 displays current budget outlays by category of primary energy source supporting the three principal intermediate forms of fuel: electricity, gaseous fuels, and liquid fuels. Support for electricity generation comprises research on coal combustion, including emissions control, solar and geothermal generating technology, and nuclear technology. These programs total to some 1.7 billion dollars, an amount some 18 times larger than the funding level for synthetic liquid fuels development. Moreover, coal gasification programs, in addition to supporting industrial, commercial, and household end uses also support electricity generation, particularly for peak load plants.

In the fundamental sense of relative emphasis, therefore, current federal RD&D on alternative energy sources is biased in favor of electricity as an intermediate fuel source and thus in favor of electric vehicles as end users in the transportation sector. The economic, environmental, and political bases for such an inclination, are however, enormously complex and far beyond the scope of this study to address. The major issues can only be summarized briefly.

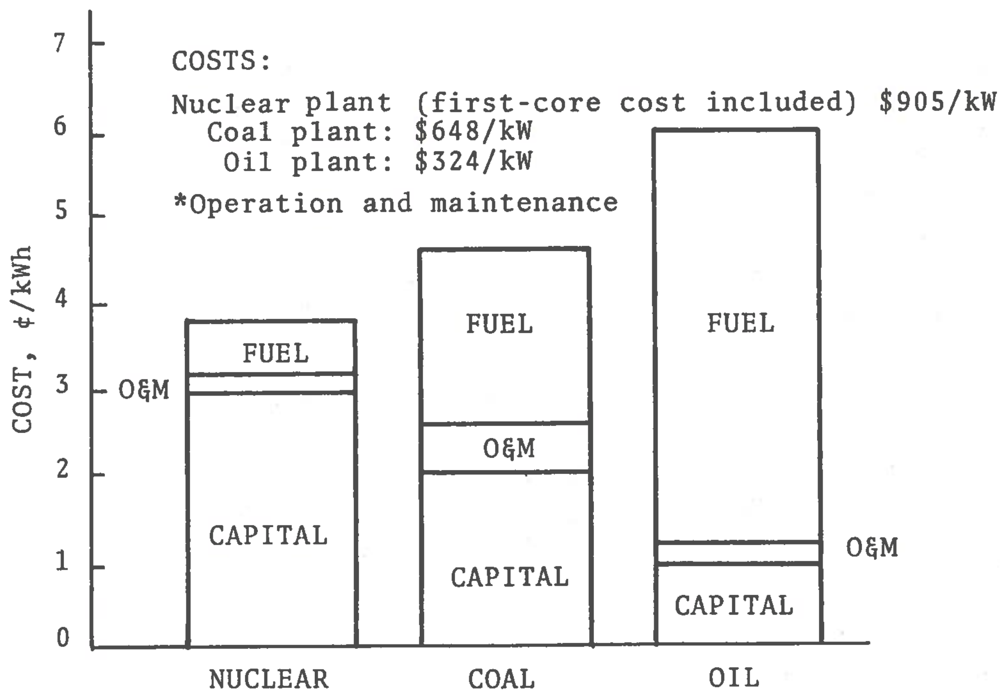
Electricity generation currently accounts for some 25 percent of U.S. primary energy consumption. That fraction has been growing

TABLE 7-4. CURRENT EMPHASIS IN ERDA RD&D ON ALTERNATIVE ENERGY SOURCES
(millions of dollars)

Electricity Generation		Synthetic Gaseous Fuels		Synthetic Liquid Fuels	
Program	Funding*	Program	Funding*	Program	Funding*
Coal Combustion	209.8	Coal Gasification	106.0	Coal Liquefaction	79.5
Solar Electric	76.0			Oil Shale	15.8
Geothermal	55.7			Total	95.3
Fusion	304.5				
Fission	789.3				
Nuclear Fuel Cycle	305.8				
Total	1,741.1				

*Fiscal year 1977 budget outlay.

Source: Derived from U.S. Energy Research and Development Administration, "Revised FY1978 Budget to Congress: Narrative Highlights," February, 1977



Source: Energy Research and Development Administration, Comparing New Technologies for the Electric Utilities, ERDA 76-141, December 1976

FIGURE 7-1 POWER COSTS OF ENERGY-GENERATION TYPES rapidly, however, and is expected to reach 50 percent by the year 2000 with no special stimulus by government action. (7-20)

More important, electricity generation represents an energy consuming sector in which the switch from petroleum and natural gas to other primary energy sources can offer real cost savings in the short term, even at current prices. Recent estimates, as shown in Figure 8-1, suggest that coal-fired or nuclear base load plants can produce electricity for one to two cents less per kilowatt-hour than new oil-fired plants. Since over half of U.S. electricity is still generated from petroleum and natural gas, conversion of power plants to alternative fuels offers enormous short-term benefits.

In addition, some of the nation's abundant primary energy sources can achieve widespread use only with electricity as the intermediate fuel. This is clearly true of fusion and fission, because the technology requires or will require large scale, capital intensive operations. Similarly, solar and geothermal energy, while they can be used in some decentralized thermal applications, would require an intermediate power supply like electricity for end uses such as transportation.

Liquid fuel programs, appear to be less well-funded in the current budget. Liquid fuels currently represent some 40 percent of primary energy consumption in the U.S.. Development of synthetic liquid fuels would greatly reduce disruptions to capital stocks as natural fuel sources become scarce. While the estimated price of synthetic liquid fuels is now some $20-$25 per barrel of petroleum equivalent (7-21), this estimate is based on first generation technology dating back to World War II. ERDA's Program Plan (7-22) includes the objective of developing and demonstrating second- and third-generation technology in the late 1980s, but the relative level of funding for coal liquefaction and oil shale extraction implies that these efforts currently have a lower priority than new electricity generation technology.

It is important to recognize, however, that the program expenditures discussed above represent no more than a static snapshot of a still-evolving national energy program that appears likely to continue for many years. The various RD&D efforts are in different states of maturity. Some, like the nuclear programs, are now undergoing costly one-time-only test facility construction, while in others, expenditures focus on less costly laboratory and pre-demonstration research.

The dominance of support for electricity generation RD&D, therefore, is not clearly inconsistent with anticipated societal benefits as currently perceived. Furthermore, electric vehicle RD&D is a rational extension of the overall energy research program to provide end use characteristics compatible with forms of available energy likely to prevail in the future. It should be recognized, however, that liquid-fuel consuming vehicles are likely to remain a substantial fraction of the motor vehicle fleet even at oil or synthetic fuel prices of $20-$25 per barrel. For the transportation sector, at least, RD&D on synthetic liquid fuels may well become increasingly important in the future.

7.2.5 Summary

Current federal energy research, development, and demonstration programs may be biased in favor of electric and hybrid vehicles. This is true both in direct automotive RD&D, where electric vehicle systems are receiving far more effort than other, potentially equally attractive alternatives, and in programs on alternative energy sources, where electricity generation is emphasized over synthetic liquid fuel activities.

An alternative or complementary policy option would be to develop and demonstrate second- and third-generation synthetic fuel production technology more aggressively, while also pursuing alternative advanced heat engines to help off-set the likelihood of higher prices of synthetic fuels. In the transportation sector, where a quarter of our total energy and more than half our petroleum is consumed, the relative merits of electricity versus synthetic liquid fuels as long term motive power sources remain to be determined.

Despite many previous studies of alternative automotive technology and fuels, no comprehensive and consistent integration of their findings is available. There is a pressing need for such an analysis to match primary energy sources and potential intermediate fuels with technological options on the basis of their likely availability and costs. This analysis is necessary to ensure that automotive RD&D is balanced and consistent with the overall energy program, as well as to ensure that the optimum forms of fuel for the transportation sector receive appropriate RD&D support.

7.3 FEDERAL FLEET PROCUREMENT PROGRAM

The U.S. government owns and operates the largest single fleet of motor vehicles in the world. Distributed domestically and abroad among dozens of departments and agencies, this fleet comprised some 420 thousand vehicles in 1975. (7-23) Of these, nearly three-quarters were passenger automobiles and light trucks.

The General Services Administration coordinates government fleet procurement and operation activities. It evaluates agency requests for replacement vehicles, solicits competitive bids for aggregate fleet purchases, distributes vehicles according to need, and monitors the operation and cost characteristics of the fleet. The GSA's activities in this area are closely regulated. (7-24)

In its historical practices, the federal fleet procurement program appears to have created biases toward specific vehicle characteristics in several important ways. Most significant perhaps is the emphasis on minimum initial cost in selecting successful bids. (7-25) The fundamental approach has been to select bids offering vehicles meeting rather general specifications at the lowest cost to the government. It largely ignores overall life-cycle cost, the most appropriate basis of comparison. The procurement process, therefore, has been biased against vehicles with high initial costs but which offer counter-balancing savings through superior durability, lower maintenance requirements, or better fuel economy. Electric and hybrid vehicles can offer such savings in some applications.

A second, less explicit bias arises from the current lack of detailed information on the duty cycles of federal fleet vehicles used by different government agencies. Such data are necessary to evaluate the applicability of vehicles with alternative characteristics to some segments of the fleet. With some exceptions, there has been no concerted effort to study the costs and benefits of replacing conventional vehicles with innovative alternatives.

The government's usage objectives also tend to penalize vehicles with limited performance but longer than average useful lifetimes and lower than average operating costs. The usage objective is 3,000 miles per quarter or 12,000 miles per year (7-26); federal agencies requesting vehicles must show that the usage objective can be met. In addition, the GSA rotates vehicles among users to achieve the above goals.

Both practices run counter to electric vehicle introduction. With a maximum daily range of 30-50 miles, electric vehicles would be hard pressed to achieve the usage objective; indeed they are most economical in even more limited duty cycles. Yet over a long period of time they can offer overall cost savings. Electric vehicles, however, must be carefully matched to driving requirements to achieve savings, so rotation among different user groups might prove difficult or impossible.

Lastly, the federal replacement criteria allow vehicles to be retired from government service after 6 years or 60,000 miles. (7-27) To the extent that these criteria encourage early replacement, they would penalize electric and other vehicles with superior durability and low maintenance requirements. By early resale, particularly in an uncertain market, the government could lose the principal benefits such vehicles have to offer.

These historical biases should be eliminated in the future. Section 11 of the Electric and Hybrid Vehicle Research, Development, and Demonstration Act directs the heads of federal agencies to carry out a study of the practicability of using electric and hybrid vehicles, and to arrange for the introduction of such vehicles into their fleets as soon as possible. The U.S. Postal Service is already conducting pioneering studies of electric vehicle performance and cost, with several hundred vehicles now in operation and a new buy of 750 more planned for this summer.

Section 11 also authorizes the Administrator of ERDA to pay other agencies the incremental costs of operating electric and hybrid vehicles as compared with conventional vehicles. If such compensation did occur, it would constitute, in a strict sense, a bias in favor of electric and hybrid vehicles, since it would encourage the use of such vehicles despite a lack of economic justification. This authorization, however, supports the Act's demonstration program, the objectives of which go far beyond the simple economics of electric and hybrid vehicles.

7.4 LOW-EMISSION VEHICLE PROCUREMENT PROGRAMS

The Clean Air Act authorizes EPA and other federal agencies to procure low-emission vehicles for testing and agency use despite non-competitive costs or performance. (7-28) The resulting programs thus are clearly biased in favor of low-emission vehicles like electrics and hybrids.

The programs, however, have had little real impact. EPA has spent only $25,000 out of its $20 million budget for low emission vehicle demonstration. Similarly only two applications have been made for agency procurement and use. Both were for electric vehicles whose performance was unacceptable to the agencies involved. (7-29)

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7-1. See, for example, J.H. Holloman, et. al., Energy Research and Development, A Report to the Energy Policy Project of the Ford Foundation, Ballinger Publishing Company, Cambridge, Mass., 1975.

7-2. The principal enabling legislation was the Energy Reorganization Act of 1974, P.L. 93-438, approved October 11, 1974.

7-3. See L.H. Linden, et. al., Federal Support for the Development of Alternative Automotive Power Systems (MIT Energy Laboratory Working Paper No. MIT-EL-76-001WD, Cambridge, Mass., March, 1976), for an excellent discussion of this topic.

7-4. P.L Mullins, "Capital Budgeting for Research and Development," Management Services, May 1969.

7-5. See Policy Study Group "Government Support for the Commercialization of New Energy Technologies," MIT Energy Laboratory, Report No. MIT-EL-76-009, November 1976.

7-6. Linden, et. al., op. cit., pp. 80-85.

7-7. Policy Study Group, op. cit., pp. 80-85.

7-8. "Electric Vehicles and Other Alternatives to the Internal Combustion Engine," Joint Hearings Before the Committee on Commerce and the Subcommittee on Air and Water Pollution of the Committee on Public Works, U.S. Senate, March 14-17 and April 10, 1967.

7-9. R.M. Nixon, "Message to Congress on the Environment, February 10, 1970.

7-10. J.B. Heywood, et. al., The Role for Federal R&D in Alternative Automotive Power Systems, MIT Energy Laboratory Report No. MIT-EL-74-013, November 1974.

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7-11. H.R. 13655, "Automotive Transport Research and Development Act of 1976."

7-12. "The Automotive Transport Research and Development Act of 1977," Title 3 of HR 6796

7-13. Using the four-passenger vehicle specifications of this study (see Appendix A), gasoline prices would have to rise nearly three-fold (to $1.80 per gallon) for electric vehicles to be cost competitive on a life cycle basis.

7-14. Assume, for example, that as a result of federal R&D, electric vehicles replace some 10 percent of the commercial fleet of 2.5 million delivery vans during the period 1985-2005. If these vehicles are driven 16,000 km per year at a cost savings of 2¢ per kilometer, then annual benefits during the period would be some $80 million. The present value in 1977 of this stream of benefits is well in excess of $200 million.

7-15. See, for example, Richard Thornton's testimony in "Hearings on the Electric Vehicle Research, Development, and Demonstration Act of 1975," before the Subcommittee on Energy Research, Development, and Demonstration of the Committee on Science and Technology, U.S. House of Representatives, June 3-6, 1975.

7-16. Goodson, R.E., "Analysis of the Opportunities and Risks Associated with the Implementation of the Electric and Hybrid Vehicle Research Development, and Demonstration Act of 1976 (PL94-413)." Interim Report dated July 1977, prepared by the Institute for Interdisciplinary Engineering Studies of Purdue University, West Lafayette, Indiana under ERDA Contract No. EC-77-5-02-4250.

7-17. Jet Propulsion Laboratory, Should We Have a New Engine? California Institute of Technology, Report No. JPL SP 43-17, August 1975.

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7-21. R.E. Balzhiser, "Energy Options to the Year 2000," Chemical Engineering, January 3, 1977, pp. 73-90.

7-22. A National Plan for Energy Research, Development, and Demonstration: Creating Energy Choices for the Future, ERDA 76-1, 1976.

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7-24. Code of Federal Regulations, No. 41, Chapters 10-17.

7-25. Ibid.

7-26. Ibid.

7-27. Ibid.

7-28. The Clean Air Act Amendments of 1970, P.L. 91-604, signed Dec. 31, 1970.

7-29. Heywood, et. al., op. cit., p. A-19.

8.0 THE AUTOMOTIVE INDUSTRY

8.1 INTRODUCTION

The U.S. automotive industry is the principal economic institution within which the characteristics of surface transportation vehicles in the U.S. are determined. The industry's structure and practices are a clear potential source of bias for or against vehicles of particular characteristics. Bias in this instance is largely a matter of the industry's alleged "resistance" to innovation and the barriers preventing innovation by either existing auto companies or new firms.

Such a question probably would not arise if the automotive industry conformed more closely to economists' ideal of perfect competition. In that case, market forces would lead manufacturers to supply the optimum quantity of each type of vehicle. However, the auto industry is far from the perfectly competitive ideal.(8-1) The Big Four -- General Motors, Ford, Chrysler, and American Motors -- manufacture virtually all cars made in the U.S. and capture some 80 percent of all domestic sales. As a result, they have considerably more market leverage than perfectly competitive firms.

This degree of market concentration is largely the result of intrinsic structural elements of the industry. These structural elements in turn lead to operating practices characteristic of highly concentrated industries that can influence innovation and the features of the vehicles produced. The following discussion examines potential biases arising from these elements of industry structure and practices.

8.2 KEY ELEMENTS OF INDUSTRY STRUCTURE

The U.S. auto industry is enormously complex; many studies (8-2) have been devoted exclusively to characterizing its structure. A few elements of the industry's structure, however, are highly relevant to the issues of innovation and bias.

8.2.1 Economies of Scale

The principal reason for extreme concentration in the automobile industry is the significant reduction in unit costs with high production volume. Economies of scale have gradually brought about a reduction in the number of independent firms from more than a dozen in the early 1900's to the current four. White (8-3) estimated that full economies of scale could be reached at annual production volumes of 250,000-400,000 vehicles. More recent data indicate that unit cost reductions may continue at substantially higher volumes. (8-4)

Such economies of scale have important implications for vehicle characteristics. First, they dictate a minimum size at which firms can be cost competitive -- in this case, that size requires a production capacity of several hundred thousand vehicles per year. Consequently, the limited number of firms that can succeed have, in theory, the power to determine production levels, prices, and vehicle characteristics in partial conflict with consumer preferences. With sufficient market power, firms could refrain from producing vehicles that consumers would prefer, but which would lower profits.

Besides encouraging industry concentration, economies of scale stimulate manufacturers to limit market segmentation. Each manufacturer produces large quantities of components that can be placed in a variety of models under different nameplates to achieve economies of scale. Despite more than 100 models marketed under a dozen nameplates, true market segmentation is limited to some half dozen classes of vehicles differentiated primarily by size. As a result, consumers who might prefer more specialized vehicle characteristics may have to satisfy themselves with mass-produced alternatives.

These tendencies create a bias in favor of vehicles with highly flexible performance capabilities and interchangable components. New technologies and designs that can be integrated with conventional production facilities and utilize existing components are preferable. Electric and hybrid vehicles, in contrast, have a narrow range of performance capabilities and require many specialized components and design features. Thus the economies of scale and mass production characteristic of the industry create an inclination against electric and hybrid vehicles.

8.2.2 Capital Requirements

The manufacturing facilities necessary for mass production impose enormous capital requirements on firms competing or hoping to compete in the automotive industry. The Big Four annually invest some 3 to 4 billion dollars in new plants and facilities (8-5); the majority of these expenditures are financed internally. White (8-6) estimated, in the late 1960's, that a new entrant in the industry would require one billion dollars of venture capital to approximate the economies of scale of existing firms. Today that requirement is probably closer to 2 billion dollars.(8-7) Even very large firms have major difficulties in raising such amounts.

These requirements can discourage not only the establishment of new firms in the industry, but also the ability of existing firms to fund innovative new technology substantially altering vehicle characteristics. Capital requirements themselves, however, do not appear to create a bias toward specific vehicle characteristics. Rather, they help insure that changes in vehicle characteristics will occur only gradually and, because huge sums are at risk, that new technology must offer clear market superiority and high return on investment. These impacts are discussed further in later sections.

8.2.3 In-Place Infrastructure

Since World War II, the automotive industry has established or attracted a massive infrastructure in support of its operations. The principal elements of this infrastructure include:

- o sales and service dealerships
- o financing networks
- o supply industries for automotive parts and components
- o resale markets for used vehicles

The primary impact of this in-place infrastructure is to make it more convenient and less expensive to own and operate conventional vehicles rather than alternatives like electric or hybrid vehicles. In a basic sense, therefore, the infrastructure creates an inclination towards vehicles of conventional characteristics. There is little indication, however, that this inclination is intrinsic to the structure of the auto industry.

The current automotive infrastructure has grown gradually, in response to the growing use of automobiles. If demand for and use of electric vehicles were to grow, most elements of the infrastructure could be expected to match that growth. On the whole, however, demand for electric vehicles is too diffuse and small to make such activities economically viable on a highly decentralized basis.(8-8)

Other complementary facilities are technologically inhibited and require more innovation than the adaptation of conventional services to suit electric vehicle needs. For example, electric vehicle refueling stations comparable to gasoline stations are technologically infeasible since battery recharging requires several hours to complete. One alternative that has been considered is a network of battery swap stations. This is currently impractical because of the high cost of the battery packs and the low density of electric vehicles in any one location. Some methods of recharging while the vehicle is parked during the work day would be less expensive but is limited by the capacity to generate additional electricity during peak hours.

Finally, some infrastructure elements are already largely in place. This is particularly true of the components supply industry; batteries, electric motors, and controller systems are currently produced in large volumes. At present, however, electric vehicle manufacturers lack the market power to stimulate custom design of components for vehicular use or to achieve the economies of mass purchases. The component manufacturers themselves, on the other hand, appear to be undertaking development efforts in support of electric vehicle systems. (8-9)

On balance, the in-place infrastructure favors the sales and operation of conventional vehicles. However, many infrastructure elements are consistent with or could easily be adapted to electric vehicle services. A shift in preferences toward electric or other non-conventional vehicles could be expected to elicit an appropriate supporting infrastructure. The first elements of such an infrastructure have already appeared, although the level of activity is low.

8.2.4 Demand Variations

Demand for new automobiles has exhibited marked variations over time. As Figure 8-1 indicates, new car sales, while clearly trending upwards, can fluctuate widely from year to year. While sales have been 8 to 10 million vehicles per year in recent years, actual growth in the motor vehicle fleet has amounted to only 2 to 3 million vehicles annually. The balance of the new cars sold were replacements for used vehicles that remained in the fleet. Most potential new car buyers, therefore, can postpone their purchases with little resulting hardship in times of recession, rising prices, or perceived quality reductions. Consequently, manufacturers face extreme and largely unpredictable fluctuations in revenues.

For potential new entrants, demand-related risks have major negative implications. Extra working capital would be required to weather possible down-turns from anticipated sales. In addition, profit expectations would have to include a risk premium to attract financing. As a result, demand fluctuations intensify the barriers to entry brought about by economies of scale and capital requirements.

Variations in demand also strongly affect the practices of existing firms. In particular, they foster conservatism toward drastic product changes and stimulate frequent cosmetic styling modifications to attract replacement sales. These impacts are discussed more fully below.

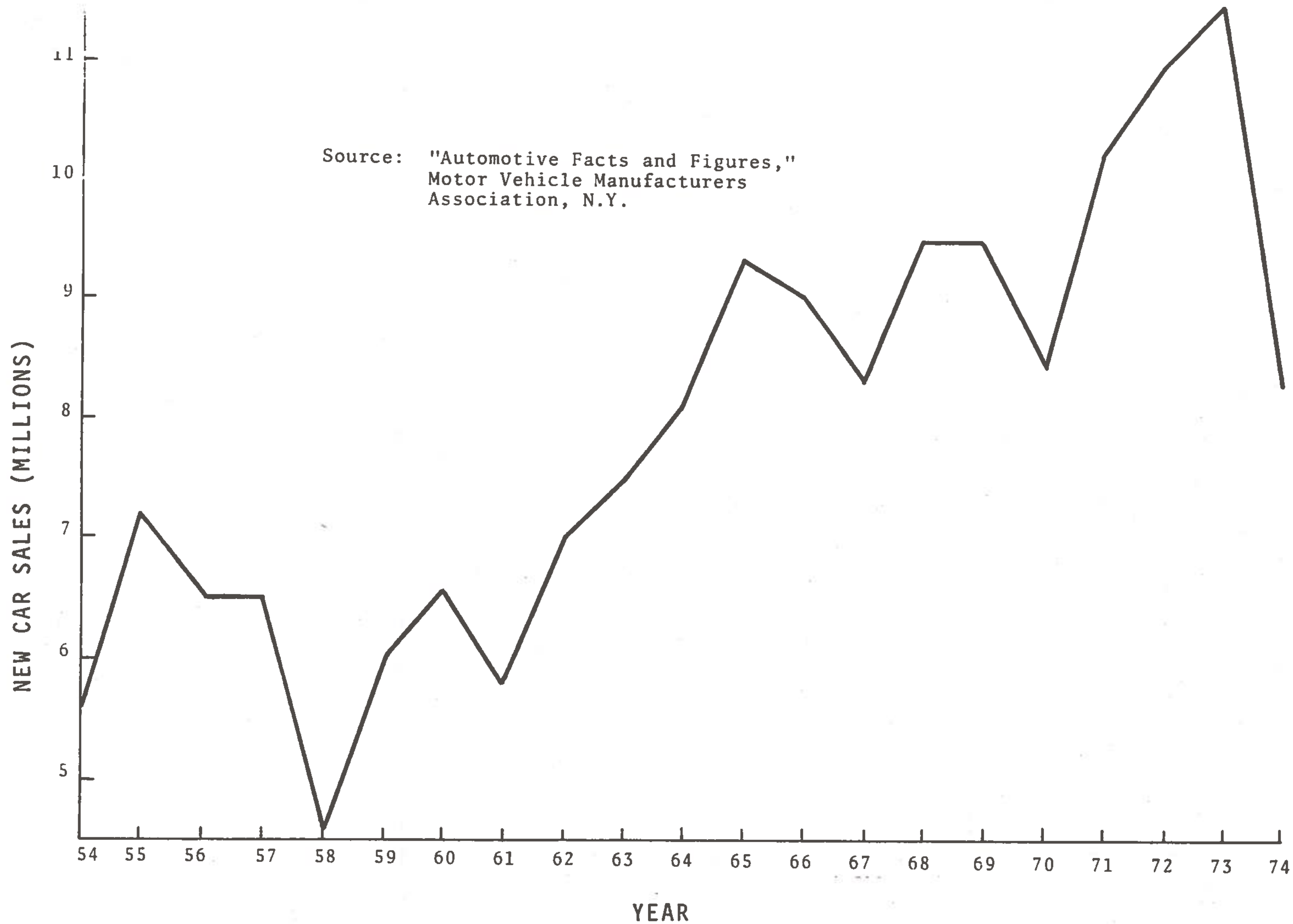


FIGURE 8-1 ANNUAL NEW CAR SALES

8.2.5 Summary: Overall Barriers to Entry

It is widely agreed that the combination of structural elements discussed above creates formidable barriers to entry in the U.S. automotive industry. A single large investment of this type is inherently risky. Further, a new auto manufacturer of the scale necessary to achieve reasonable economies would require a domestic market penetration on the order of 5 to 10 percent to be profitable. To obtain such a sizeable market share, the new entrant would have to offer vehicles superior in some respect valued by consumers. New products, however, whether differing in design or technology, carry the added risk of failure to achieve market acceptance. The industry has therefore been marked by the absence of large-scale new entrants for some 30 years, at least within the U.S., although foreign imports have added competition.

At the other end of the spectrum, however, are entrepreneurs willing to enter the industry at low levels of production with concomitantly small investments. This is the niche into which present electric vehicle manufacturers fall. At current production levels, the costs of these vehicles are inevitably higher than they would be in mass production. Capital requirements to reach mass production, however, could be considered a constraint to electric vehicle manufacturers only if the market for their vehicles could support mass production. Such mass markets for electric vehicles have not yet been identified (8-10), and, as a consequence, the necessary investments do not appear warranted. Indeed, several current electric vehicle manufacturers are related to, or subsidiaries of, large corporations that could raise additional capital if it were merited. (8-11) As in the general case, however, electric vehicles would have to demonstrate some market superiority to attract the investment.

It is possible that a tangibly superior vehicle, clearly protected by patents, could attract the required capital for a new entrant outside the existing industry. There is no clear reason, however, why such an external financing scheme would be more attractive to the entreprenueur than licensing or royalty agreements with current manufacturers. The latter approach precludes the severe capital requirements of independent entry while still fostering technological change. Historically, auto manufacturers have been willing to enter such agreements for a variety of new components ranging from power steering to rotary engines. (8-12)

Thus the auto industry appears to be structurally biased against electric and hybrid vehicles only insofar as it refrains from producing special purpose vehicles in relatively small quantities. As noted earlier, this is a consequence of economies of scale which encourage mass production, the special production requirements of electric vehicles, and the perceived lack of demand to support mass production of electric vehicles.

8.3 SIGNIFICANT INDUSTRY PRACTICES

In addition to -- and partially because of -- its major structural elements, the automotive industry has consistently engaged in practices that might tend to bias production towards vehicles of particular characteristics. Of greatest concern is the alleged resistance to innovation and the slowness with which new technology is introduced.

8.3.1 Corporate Research and Technological Innovation

The effect of industrial concentration on technological change has been widely debated with no apparent consensus emerging. (8-13) While large and profitable corporations have more resources for research and development, they are frequently accused of avoiding real innovation. (8-14) The automotive industry has been one focus of criticism, with some analysts claiming that the industry is overly slow to introduce innovative new products. (8-15) Electric vehicles have been specifically identified as an innovative product ignored by the industry. (8-16)

There is no question that the process of technological change in the auto industry is gradual. It involves a sequence of steps, including:

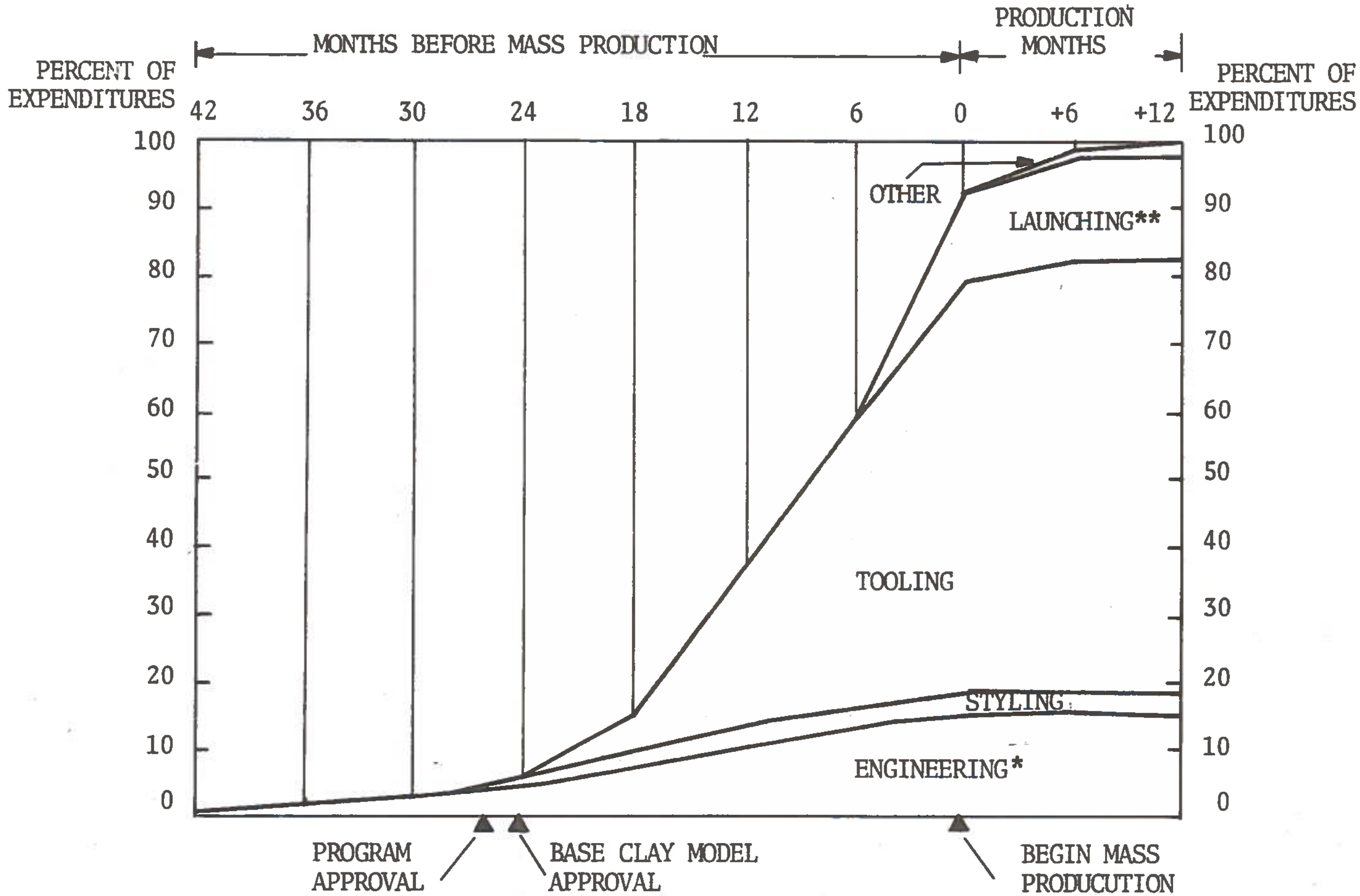
- basic research
- applied research

- exploratory development
- final product development
- introduction.

The basic and applied research steps are intended, in essence, to develop technology alternatives and determine those worthy of further study. Exploratory development then proceeds to gain actual operating data on performance and cost. The final product development stage includes fleet testing, final engineering specifications, and detailed cost estimation. Finally, introduction requires the acquisition of appropriate tooling and actual production for marketing. Each of these steps requires a go-ahead decision and costs are heavily skewed toward the final stages (Figure 8-2). The entire process can take many years; most significant advances -- the automatic transmission, power steering, etc. -- achieved widespread introduction some 10 to 20 years after their basic concepts had been worked out. Development and introduction alone require a minimum of 3-1/2 to 5 years. (8-17)

The slow pace of this process clearly creates a short-term bias against new automotive technology of any kind. Major changes, no matter how advantageous, take years to implement. Electric and hybrid vehicles, since they require major design changes and subsequent tooling, fall into this category.

Thus the historical rate of innovation seems to be an intrinsic outgrowth of the auto industry structure rather than conscious resistance on the part of corporations. Demand for better technology, which usually carries a higher price tag, is uncertain. Major new developments, for example, fuel injection and air suspension, were failures when first introduced (8-18). More important, major technological change requires substantial front-end investment and therefore carries a high risk. Ironically, this is a consequence of the industry's greatest innovation, mass production technology. Most automotive manufacturing and assembly operations are highly automated to achieve minimum costs (8-19), and are therefore heavily capital intensive. The required investments must be amortized over long periods -- 15 to 20 years for major structural component



*INCLUDES COSTS INCURRED FOR ENGINEERING WORK ON PRODUCTION VEHICLES AND SERVICE PARTS

**INCLUDES COSTS INCURRED IN MANUFACTURING PHASE, TO SHUT DOWN AND CHANGE OVER PLANTS AND INCREASE PRODUCTION TO NORMAL VOLUMES.

Source: Automotive Manufacturing and Maintenance, Panel Report, Interagency Task Force on Motor Vehicle Goals Beyond 1980, March 1976

FIGURE 8-2. PASSENGER CAR LINE PRE-PRODUCTION PROGRAM-ESTIMATED PRODUCT EXPENDITURES BY PHASE production facilities. (8-20) Superficial changes in vehicle appearance, on the other hand, require relatively modest investments that can be amortized over a few years.

The decision to introduce major innovations is, therefore, one the industry makes with great caution, after long study, and, if possible, in conjunction with the phasing out of fully depreciated facilities. The process is gradual because of the risks involved, and the risks are there largely because the industry has sought cost minimization through automation.

In the long-term, there is no evidence that the industry's product development activities favor particular vehicle characteristics. While the ICE-powered automobile has been the basic product for some 50 years, reliance on this technology was itself dictated by vigorous competition with steam- and electric-powered cars early in this century. And while the basic product has remained the same, the vehicle of today is far superior in performance, handling, and amenities than the automobiles produced 50 years ago. (8-21)

The manufacturers, moreover, have remained active in exploring technological alternatives, many of which do not reach the introduction stage. General Motors, for example, reportedly spent more than $100 million on rotary engine development (8-22) before indefinitely postponing (in 1974) its large scale introduction. Similarly, Chrysler undertook a major development program for the gas turbine engine which, after a highly publicized consumer test program (8-23), was suspended for a variety of technical and economic reasons. Ford is now performing extensive engineering studies of the Stirling engine in cooperation with Phillips Research Laboratories of the Netherlands. (8-24)

Another key stimulus to technological development is the action of foreign firms in the U.S. market. Foreign manufacturers have long shown their willingness to exploit market segments and new technology previously ignored by Detroit. In the case of small subcompact or "mini" cars, this willingness has led to significant market penetration as well as direct competitive response by domestic firms. More recently, the commercial introduction of the rotary and pre-chamber stratified charge engines by Japanese firms was accompanied by vigorous domestic investigations to ascertain the nature and degree of the technological threat.

With regard to electric vehicles specifically, General Motors has been active for more than a decade. GM built a series of prototypes for study in the 1960's and has been active in battery development since 1959. (8-25) More recently the GM Engineering Staff has performed comparisons of electric and conventional vehicles in several driving patterns and judged the ICE to be superior in overall performance. (8-26)

Ford also has a long-standing program involving electric vehicle technology. Ford built prototypes in 1967 and 1970 for performance testing. The company has continued with computer simulations and design studies matching electric vehicle characteristics to various markets. (8-27) Ford's Scientific Research Staff, in addition, developed the sodium-sulfur cell, a potential high energy density battery for electric vehicles.

Thus the absence of mass-produced alternatives to the ICE is not evidence of a bias in the industry's product development efforts. Rather, major R&D programs on several alternatives including electric vehicles have culminated in the conclusion that fundamental technical problems obstructed their commercial viability. While short term introduction of new technology is largely ruled out, the history of evolutionary changes in components suggests that the industry is quite willing to offer new features when consumers will support them in the market place.

8.3.2 Pricing Practices and Profitability

The automobile industry is a clear instance of oligopoly, in which a few firms control a large fraction of the market. The manufacturers therefore have a greater flexibility in determining production volumes and price levels than they would under perfect competition. Two consequences are target return pricing and higher than average profit expectations.

Under target return pricing, price is set in relation to total costs at such a level to provide a profit margin on the product that will yield a pre-determined "target" rate of return on investment. As early as 1924, a vice president of General Motors advocated this approach:

> An acceptable theory of pricing must be to gain over a protracted period of time a margin of profit which represents the highest attainable return commensurate with capital turnover ... with adequate regard to the economic consequences of fluctuating volume. (8-28)

He suggested a target of 20 percent return on capital with the assumption of plants operating at 80 percent of capacity.

As the data in Table 8-1 indicate, General Motors has been quite successful with this pricing policy. While major fluctuations have occurred, GM's average after-tax rate of return closely approximates the target.

Obviously this policy would fail if General Motor's competitors were to undercut target return price levels. In Congressional hearings, however, former presidents of Ford and Chrysler indicated that their companies have no target return and price according to competitive pressures. (8-29) Such assertions are consistent with the widely held belief that General Motors is the industry price leader (8-30), with whose actions competitors closely conform.

Although overall industry profit levels as shown in Table 8-1, are above the norm for all U.S. manufacturers in 8 out of 12 years, they also exhibit much more variation. On the average* while GM's profits are significantly above the level for all manufacturers, the auto industry as a whole has a slightly lower average profitability.

GM's target return pricing and higher than average profit expectations serve to reinforce the company's reluctance to produce limited quantities of individual models. Small production volumes imply not only a higher fixed cost per vehicle but a larger profit

*The average used refers to the harmonic mean since profits are expressed as a rate of return on net worth.

TABLE 8-1. RATE OF RETURN AFTER TAXES ON STOCKHOLDERS' INVESTMENTS

Year	General Motors	Auto Industry	All Manufacturers
1953	19.7		
1954	24.5		
1955	30.5		
1956	18.9		
1957	17.1		
1958	12.6		
1959	16.6		
1960	16.9		
1961	14.9		
1962	21.3		
1963	23.0		
1964	23.5		
1965	26.8	21.0	13.0
1966	21.2	16.8	13.4
1967	18.1	11.6	11.7
1968	18.2	15.7	12.1
1969		13.2	11.5
1970		6.0	9.3
1971		14.2	9.7
1972		16.1	10.6
1973		16.4	12.8
1974		5.9	14.9
1975		5.8	11.5
1976		22.2	14.5

Source: John M. Blair, Economic Concentration, Harcourt, Brace, Jovanovich, Inc., New York, 1972.

margin to achieve any given rate of return. Since electric and hybrid vehicles represent a small market segment, these practices do create a bias against their introduction, at least for the largest firm. Here again, however, the absence of demand rather than the industry itself is the central parameter controlling the situation.

8.3.3 Competitive Practices

Congressional studies (8-31) have indicated that price competition plays a relatively minor role in the auto industry. Comparisons of price levels for different models in the same market class revealed modest variations after correction for standard equipment differences. Consequently, the most vigorous forms of competition are product differentiation and advertising.

A considerable portion of this product differentiation involves essentially superficial differences in vehicle appearance through frequent, largely cosmetic changes in vehicle design. By diverting resources from more substantive new product development efforts, these practices may constrain major innovation and thus create a bias against new technologies like electric and hybrid vehicles.

However, these minor model changes are much less costly (because they can be amortized more quickly) than major innovations and involve less risk in terms of consumer acceptance. It is therefore impossible to ascertain the degree of bias in the allocation of R&D resources due to product differentiation.

Product differentiation and advertising do add to the barriers to entry previously examined. The smaller scale production, required for the lower level of demand for electric vehicles, would inhibit competition in the form of frequent model changes. Performance and utility play some role in advertising, but much of the industry's advertising promotes the identification of brand names with quality. (8-32) To the extent that advertising expenses have a cumulative effect on consumers, new entrants are at a disadvantage until their reputations can be established.

On the whole, therefore, the emphasis on non-price competition in the auto industry has been a barrier to entry and as such constitutes a bias against alternative vehicles. Existing firms, however, do not face this bias in choosing auto technology.

8.3.4 Summary and Conclusions

Because of its extreme concentration and oligopolistic practices, the U.S. automotive industry is biased to some degree toward conventional vehicles. But while the industry's basic product, the ICE-powered automobile, has remained largely constant for 50 years, substantial improvements in its quality have been achieved.

The industry's economics of scale, capital requirements, and market vagaries create formidable barriers to entry for new domestic competitors offering alternative vehicle characteristics or technology. In the final analysis, however, the greatest impediment is the inherent riskiness of new product acceptance. Furthermore, foreign competitors serve as an important catalyst of technological change in the absence of domestic entrants. Domestic firms have repeatedly shown the willingness and ability to successfully respond to foreign technological advancements.

Product change in the industry is undeniably gradual. This rate of change is largely the result of capital intensive operations, requiring massive investments to introduce major new components. Such investments are made only after reasonable prospects for market acceptance have been established. Once made, they must be amortized over long periods to achieve capital recovery and profit.

Despite the small number of firms, there is ample competition in the industry to stimulate technological change. The higher than average profit expectations of the leading manufacturers, however, may cause them to ignore small potential markets offering only "normal" profits.

The most serious potential industry bias against electric vehicles arises from a combination of factors. These vehicles appear to represent a limited market without the profitability necessary to attract the major manufacturers. New domestic entrants specializing in electric or hybrid vehicle production, however, could not match the low costs that the major firms would achieve if interested. Thus, new entrants will be discouraged by the prospect of potential competition with the Big Four. As a consequence, very small numbers of electric vehicles may be produced despite significantly higher demand -- perhaps in the tens of thousands of annual sales -- at prices that could be achieved with reasonable profits by normal industry standards.

Whether or not this hypothetical bias will have a real effect is questionable. There is considerable interest today in producing limited quantities of electric vehicles both by new firms and by existing specialty vehicle manufacturers. (8-33) Further, foreign firms might meet the electric vehicle demand even more efficiently than the domestic industry (See Chapter 9). From a policy viewpoint, therefore, the problem does not appear to be significant.

CHAPTER 8 REFERENCES

8-1. The Subcommittee on Antitrust and Monopoly of the Judiciary Committee in the U.S. Senate compiled some 44 volumes of testimony and reports in Hearings on economic concentration and administered prices between 1957 and 1971. The Hearings provide a wealth of information on economic concentration and its effects in many industries, including the auto industry.

8-2. Perhaps the best recent study is L.J. White, The Automobile Industry Since 1945, Harvard University Press, Cambridge, Mass, 1971.

8-3. L.J. White, The Automobile Industry Since 1945, Harvard University Press, Cambridge, Mass, 1971.

8-4. Automotive Manufacturing and Maintenance, Panel Report, Interagency Task Force on Motor Vehicle Goals Beyond 1980, March 1976.

8-5. Report of the Federal Task Force on Motor Vehicle Goals Beyond 1980, (Draft), July 1976.

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8-7. Report of the Federal Task Force on Motor Vehicle Goals Beyond 1980.

8-8. See Advisability of Regulating Electric Vehicles for Energy Conservation Report to Congress and the President prepared by the U.S. Department of Transportation, August 1976.

8-9. Gould and ESB, Inc., are good (but certainly not the only) examples of such manufacturers. Both have made significant efforts to develop components and prototypes for electric vehicles.

8-10. Advisability of Regulating Electric Vehicles for Energy Conservation

8-11. AM General Corporation, Chloride, Inc., and Exxon Enterprises are good examples.

8-12. See E. Starkman, et. al., testimony before the Subcommittee on Space Science and Applications of the Committee on Science and Astronautics, U.S. House of Representatives, June 11, 12, 13, and 18, 1974 for a discussion of this approach in the rotary engine case.

8-13. John M. Blair, Economic Concentration, Harcourt, Brace, Jovanovich, Inc., New York, 1972, contains a lengthy analysis of this issue.

8-14. See, for example John Jenkes, et. al., The Sources of Invention, MacMillan, 1958; revised edition, 1969.

8-15. Blair, Economic Concentration.

8-16. Ibid.

8-17. Automotive Manufacturing and Maintenance.

8-18. White, The Automobile Industry.

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8-22. General Motors Corp., "Application for Suspension of the 1976 Motor Vehicle Emission Standards," May 1973.

8-23. "History of the Chrysler Corporation Gas Turbine Vehicles," Chrysler Corporation, January, 1964; revised July, 1974.

8-24. D. Jensen, et. al., testimony before the Subcommittee on Space Science and Applications, op. cit.

8-25. H.F. Barr, testimony in "Electric Vehicles and Other Alternatives to the Internal Combustion Engine," op. cit.

8-26. D.C. Sheridan, J.J. Bush and W.R. Kuziak, "A Study of the Energy Utilization of Gasoline and Battery-Electric Powered Special Purpose Vehicles," SAE 760119, presented February 1976.

8-27. L.E. Unnewehr, et. al., "How Ford Evaluates Three Types of Electric Vehicles," Automotive Engineering, Vol. 82, No. 6, June 1974.

8-28. D. Brown, "Pricing Policy in Relation to Financial Control," Management and Administration, Feb., Mar., April, 1924, 283-86, 417-22.

8-29. Blair, Economic Concentration.

8-30. See Blair, op. cit., pp. 503 for this assertion.

8-31. See "Hearings on Economic Concentration and Administered Pricing: Automobiles" held before the Senate Subcommittee on Antitrust and Monopoly, Committee on the Judiciary, 1957-1971.

8-32. Blair, op. cit., notes that "...among consumer goods industries the critical factor associated with increasing concentration is not whether products are differentiated but whether they are promoted extensively through TV advertising," (p. 527).

8-33. AM General, a subsidiary of AMC, is one such specialty vehicle manufacturer with extensive interest and experience in EV production.

9.0 MISCELLANEOUS INSTITUTIONAL FACTORS

9.1 INTRODUCTION

The preceding chapters have evaluated major categories of institutional factors that might influence transportation vehicle characteristics. There is, in addition, a long list of potentially influential institutions that defy similar categorization. While most such miscellaneous factors appear to have little current or future importance, several have been mentioned as potentially significant in previous testimony or literature on the subject, and therefore are discussed below.

9.2 ORGANIZATION OF PETROLEUM EXPORTING COUNTRIES

The Organization of Petroleum Exporting Countires -- OPEC -- is the most obvious and important international institution affecting transportation system characteristics. While OPEC'S basic influence is simple, the cartel's long-range real impact is more complex and difficult to anticipate.

9.2.1 Cartel-Set Oil Prices

With limited exceptions, OPEC has set "world" petroleum prices since 1973. The current price level for standard crude is $12 to $13 per barrel; in contrast the free market value of petroleum is estimated to be around $2 per barrel in 1976 dollars. (9-1) The cartel-set price is therefore some 6 or 7 times the marginal production cost, with concommittant monopoly profits to OPEC members.

For transportation systems, the clear result of cartel pricing is a bias toward more fuel efficient vehicles and vehicles that do not consume petroleum products. Electric and hybrid vehicles fall into these categories; much of the current interest in electric vehicles can be traced directly to the sudden increase in OPEC determined oil prices.

Yet the real impact of this bias is highly uncertain. OPEC, like any international cartel, is subject to political pressures and internal instability. Many observers believe that OPEC cannot maintain strict control of prices and production in the long term. (9-2) Furthermore, OPEC can cut prices in selected markets to destroy competing suppliers or to eliminate growth of non-oil based technology. The possibility of oil price reductions, whether through OPEC action or OPEC dissolution, poses a serious risk to non-petroleum based technology dependent on current energy price differentials.

Thus, in the near term at least, the impact of OPEC prices on non-conventional vehicle technology is likely to be less than that warranted by current price differentials. In the longer term, it is widely believed that the supply of oil will be characterized by real scarcity. As existing reserves are replaced at a much higher cost, the competitive floor price will rise to or above the current cartel-set level. Long-term anticipations of energy price differentials, therefore, have a firmer base than OPEC actions, and potential investors in non-petroleum technology face a more nearly normal commercial risk. At the same time, rising competitive price levels for oil will make emphasis on alternative technology justified in the formal economic sense.

9.2.2. Potential Supply Shortfalls

A perceived threat of new supply shortfalls, for example, through another OPEC embargo, would be a much more powerful stimulus to the introduction of alternative vehicles than current oil price levels. Consumers can and have adjusted to higher oil prices by driving less, purchasing more fuel efficient vehicles, or simply by paying more. When oil is unavailable at any price, however, or rationed formally or informally, more serious personal and business disruptions occur.

Such a threat will exist so long as OPEC maintains its high level of control on petroleum production and distribution. At the present time, nevertheless, the probability of another embargo seems low. Certainly the public perception of this threat is minimal. Consequently, it cannot be said to influence significantly the characteristics of surface transportation vehicles now in production. If a new, extended embargo did occur, however, it would create a powerful bias in favor of electric and other non-petroleum powered vehicles.

9.3 OTHER MINERAL CARTELS

OPEC's activities, particularly the oil embargo, have also stimulated major concern and a series of studies (9-3,9-4) on potential supply restrictions or price increases of other critical or strategic minerals. Such actions, by new cartels or individual nations, could also influence vehicle characteristics in the U.S.

By broad consensus, the most critical materials for the U.S. in this context are aluminum, chromium, cobalt, manganese, and nickel. (9-5) Of these, chromium, nickel, and aluminum are most significant for motor vehicle production. Chromium and nickel play a major role in steel production (although they are used primarily in stainless steel) and chrome trim is a major cosmetic in the auto industry: price increases or shortfalls could stimulate substitution of alternative materials for certain steel products and for chrome trim. Aluminum, even though critical, is one such substitute. Price increases for aluminum could shift automotive demand toward plastics and fiberglass.

It is difficult to evaluate in a general sense how potential mineral supply restrictions might influence the attractiveness of alternative vehicle systems. No clear bias seems to be likely. Specific implications for electric vehicles are easier to quantify. As Table 9-1 indicates, the maximum plausible production of alternative electric vehicle designs during the next decade would scarely affect the consumption of major critical materials. Perhaps the most significant potential impacts are in nickel and lithium consumption. The primary U.S. supplier of nickel, however, is Canada; further, recovery of nickel from deep ocean mining may make the U.S. self sufficient in the next few decades. Similarly,

TABLE 9-1. RELIANCE OF ELECTRIC VEHICLE PRODUCTION ON CRITICAL MATERIALS

		Metal Use[1] per Battery kg (lbs.)	Maximum Use[2] in Electric Vehicle Production (10^3 metric tpy)	Electric Vehicle[3] Use as % of 1974 U..S. Consumption	Net[4] Import Reliance (%)	Principal Foreign[4] Sources of Supply
Lead-Acid	Lead (Pb)	388 (855)	38.9	3.1	4	Canada, Peru
	Antimony (Sn)	11 (24)	1.1	6.0	56	South Africa
Nickel-Zinc	Nickel	169 (362)	16.6	11.7	71	Canada
	Zinc	119 (262)	12.0	1.1	64	Canada
	Copper	5 (11)	0.5	-	0	-
Lithimum-Iron Sulfide	Aluminum (Al)	46 (101)	4.6	0.1	85	Jamaica, Surinam
	Lithium (Li)	19 (41)	1.9	123.0	0	-
	Molybdenum (Mo)	29 (63)	2.9	6.9	0	-

1. American Metal Market, p.5 (123), June 27, 1977

2. Assumes production of 100,000 4-passenger electric cars per year

3. Mining Annual Review, Mining Journal, June 1975.

4. C. Rampacek, "The Impact of R&D on the Utilization of Low Grade Resources," Chemical Engineering Progress, February 1977.

the U.S. has huge reserves of lithium that could easily meet demand increases brought about by electric vehicle production (See Table 9-1).

On the whole, potential material supply restrictions should create no significant bias in favor of particular motor vehicle characteristics. While such restrictions could lead to substitute materials in vehicle construction, they do not appear likely to influence the selection of power plants or fuel sources.

9.4 FOREIGN ENERGY PROGRAMS

Many technologically advanced foreign nations -- most notably, the Western European countries and Japan -- are substantially more dependent on imported petroleum than the United States. As a result, they have been exploring alternative transport systems with greater intensity for a longer period than the U.S. Electric vehicle R&D in particular has received major government support in several countries for many years. (9-6)

This foreign interest in electric vehicles is stimulated not only by oil import dependence, but by vehicle usage patterns in these countries as well. All are densely populated, with relatively short driving distances under urban conditions predominating. These usage patterns, coupled with gasoline prices well over a dollar per gallon, make electric vehicles potentially more attractive than in the United States.

Foreign R&D programs, however, are likely to stimulate the use of electric vehicles in the U.S. as well. Substantial foreign markets for electric vehicles would allow manufacturers there to achieve significant economies of scale. The manufacturers could then export electric vehicles to smaller U.S. markets at costs below those which independent domestic firms could match. At the same time, the major U.S. firms, who are actually multi-national corporations with their own foreign subsidiaries, are likely to monitor foreign R&D efforts and subsequent U.S. marketing programs, offering their own competing electric vehicles if the U.S. and world markets prove to be sufficiently large.

The international energy situation favors electric vehicles much more than that of the United States alone. The resulting foreign R&D and marketing programs could well bring about a more rapid domestic introduction of electric vehicles than would occur through U.S. efforts alone.

9.5 CAPITAL AVAILABILITY AND MARKETS FOR MANUFACTURERS

The legislative history of the Electric and Hybrid Vehicle Act contains remarks, by electric vehicle manufacturers and others, that say a lack of investment capital is a serious bias against the introduction of such vehicles. (9-7) Indeed, lack of capital is a nearly universal problem of new business ventures and not an uncommon one for established corporations. While lack of financing clearly does create a bias against the introduction of motor vehicle systems like electric vehicles by new firms, there are no economic reasons to justify such a constraint.

The allocation of investment capital takes place in capital markets, where money is exchanged by creditors for the securities of borrowers. Rate of return on investment offered by borrowers determines which projects will be funded. The finite funds available at any one time for investment are distributed first to projects offering the highest returns and then sequentially to projects offering lower and lower returns until no more funds are available.

In most cases, however, the process is much more complex because borrowers cannot guarantee a rate of return. They may default on loans or may offer equity in assets for which the rate of return is uncertain. Risk is therefore a central parameter in capital markets and its fundamental role is quite simple: the riskier the proposed project, the higher the rate of return it must offer. Creditors charge a risk premium to make up for the larger proportion of failures among risky investments.

New business ventures are nearly always risky because of major uncertainties in production costs, market size and penetration, and the possible presence of significant factors overlooked in planning. Consequently, new ventures are seldom financed in capital markets unless they offer a substantially higher than average rate of return, a well-defined and acceptable "downside risk", or both.

For a new motor vehicle manufacturer, the risks are compounded by the presence of a well-established, very experienced, highly concentrated industry and a market with variable and sometimes unpredictable demand. The historical failure rate of auto companies has been high, and the prospects for small new ventures are accordingly poor. In this environment, it is hardly surprising that venture capital is difficult to obtain.

It is important to recognize, however, that this "bias" against new motor vehicle firms is not specifically related to vehicle characteristics. In the automobile market, introduction of any vehicle by a new firm would carry high risks. Since the risks are higher for radical new technology like electric vehicles, a bias against such vehicles can be said to exist. At the same time, however, this bias represents the efficient functioning of capital markets in allocating funds to productive investments.

Assessement of risk, of course, is typically a highly qualitative affair. There are frequently disagreements between borrowers and creditors about the riskiness of a proposed project; some fraction of the investments ignored by capital markets could be expected statistically to succeed. Unfortunately, there is no means of avoiding this inefficiency while capital is in finite supply.

More important, in a mixed economy private investment decisions can fail to achieve socially optimal results because of market failures. If, for example, the price of oil does not reflect its true social value, as is widely asserted, then consumers would lack the appropriate incentive to reduce gasoline consumption and investors, in turn, would lack the reason for supporting electric vehicle production. The loan guarantee provisions in the Electric and Hybrid Act (9-8) are intended to correct such market failures.

Finally, lack of capital is not a constraint against the introduction of electric vehicles by many existing firms. Companies both within and outside the auto industry could internally finance electric vehicle production, if they chose to do so. As discussed in an earlier section, there is no clear evidence that the auto industry is biased against electric vehicles, and firms from other industries have performed significant R&D on electric vehicle systems. Their failure to enter production is almost certainly a consequence of the perceived basic rate of return for such an investment rather than lack of capital.

9.6 AVAILABILITY OF INSURANCE

Several sources have reported that adequate insurance coverage is difficult to purchase for electric vehicles (9-9), suggesting that this might be a bias against their purchase and use. Since insurance practices and premiums vary locally, it is difficult to generalize about such a bias or to quantify its impacts. In order to gather information on the subject, discussions were held with a sample of Boston-area insurance agents and with a national industry organization. (9-9)

The same criteria appear to apply nation-wide in establishing insurance rates. They are:

- Value of the Vehicle
- Purpose of Use
- Driver Characteristics
- Location of Principal Garage

National underwriters compile a list of the market values of virtually all automobiles by model year offered for sale or used in the U.S. Values are ordinarily based on actual transaction records, but where insufficient information is available, formulas are applied to calculate probable depreciation from initial price.

These values are used to establish maximum coverage for collision and theft.

Vehicles are also classified according to primary purpose of use, the major classifications being household driving, business, and recreational. National data on compensation payments for these classes are used to establish rates.

Driver characteristics, primarily age and sex, also influence rates. Here again, national data on compensation payments are employed in setting rates. Companies may optionally offer discounts based on individual driving records.

The final criterion, location of principal garage, reflects the risks associated with each municipality or juridiction. Here, local data on compensation payments are used to vary rates.

Nowhere in the process of establishing rates is the propulsion system of the vehicle formally taken into account. Nor is there a routine evaluation of a vehicle's safety charateristics. Thus, there is no apparent bias for or against electric or hybrid vehicles in the insurance industry's typical practices.

However, where vehicles do not appear on a national underwriters rating list, the decision to provide coverage rests with the individual company and agent. Most frequently the companies rely on their agent's personal evaluation in making this decision.

Since electric vehicles are a new product, few statistics are available to agents in determining their insurance risks. Theft potential relative to other vehicles is difficult to assess. The value of the batteries, their accessibility, and marketability may increase the risks of theft by "professional" part theives. On the other hand, their low performance and uniqueness should decrease the risk of being stolen by amateur car thieves or juvenile "joy riders". According to the agents interviewed, their net theft potential may not differ from that of conventional private passenger vehicles.

The perception of the insurance risk of electric vehicles for collision damage, however, appears to be much higher than for conventional automobiles. Wide spread publicity arose when Consumers' Union reported of two electric vehicles available for purchase: "Neither provides anything close to adequate crash protection and neither handles well enough to give us confidence that they are capable of getting out of a tight spot." (9-10)

Consequently, some companies and agents have been discouraged from offering coverage for these specific electric vehicles. This does not appear to be a generic bias, however, and agents report that they will assess other kinds of electric vehicles on an individual basis.

At least one electric vehicle distributor has had national insurance adjustors evaluate his vehicles for risk. He reports that, as a consequence, insurance availability is no longer a problem and premiums are comparable to rates for conventional subcompacts. (9-11) If electric vehicle technology in general reaches the safety level currently existing for compact passenger vehicles, there is no reason to expect insurance companies to discriminate on the basis of the vehicles' propulsion system.

For many states, liability insurance is compulsory for any registered vehicle and any vehicle using a public road must be registered. For some of these states such as Massachusetts, insurance companies can not refuse this compulsory insurance unless the driver's license has been revoked or there is a history of non-payment of premium. Collision insurance must also be made available to anyone purchasing compulsory insurance. In these situations, higher than normal rates for EV's can be anticipated so long as the available electric vehicles are believed to be less safe.

In summary, the difficulties reported to date in insuring electric automobiles appear to have been less an institutional bias than individual agents' response to safety problems perceived in the available vehicles. These problems are not inherent, and many EV's -- particularly in commercial use -- have been insured in normal fashion with normal rates. Electric vehicle manufacturers and the federal government must demonstrate the safety of EV's and disseminate information on their safety characteristics before the highly decentralized insurance industry can be expected to offer the widespread, nearly automatic coverage extended to conventional vehicles.

9.7 FINANCING

Financing, like insurance, has been reported to be difficult to obtain for electric vehicles. Some buyers apparently have been required to make larger than normal down payments or to pay higher interest charges for EV purchases. These requirements could constitute a bias against electric vehicles on the part of consumer financing institutions.

Consumer financing, however, is even more decentralized than the insurance industry. Neighborhood banks, local credit unions, auto dealerships, and others all offer financing on car purchase. Their practices are similarly but not identical, and it is accordingly difficult to generalize. For the purpose of this report, several local sources of financing as well as two national industry organizations were interviewed to establish a broad picture of the variables involved. (9-12)

Most new purchases of private passenger cars are financed over a period of 2 to 4 years. Since the new car is the collateral for the loan, the vehicle must be insured against comprehensive and collision damage. The resale value of the car is a determinant of the credit terms available. Uncertainty as to the resale value and the possible reluctance to insure electric vehicles could adversely affect the financing of EV's.

The local bankers contacted had no experience with financing electric vehicles. The type of car purchased would not affect the terms of the loan with respect to the required downpayment or the interest rate. Consumer protection laws limit the flexibility of the banks in setting these terms. One banker suggested two possible differences in the financing of EV's. The payback period might be redced (to 30 months) and the bank might restrict such loans to consumers with above average credit ratings since the future resale value is uncertain. Another banker identified higher down payments as a third option.

If electric vehicles become more common and a used EV market eliminates this uncertainty in expected resale value, the financing of EV's should not present a problem. However, as with other new products, there is the possibility that with the rapid changes expected in electric vehicle technology, early EV's may become obsolete before their useful life has expired. Improved quality of electric vehicles and possible cost reductions due to economics of scale as the market grows could also depress resale prices. On the other hand, the rate of depreciation for electric vehicles could well be lower than that of conventional vehicles, allowing more favorable financing.

As with insurance, then, the financing of electric vehicle purchases may prove difficult until more and better information on their characteristics and market acceptance is available. While such difficulties may constrain somewhat the purchase of EV's, they are normal to most new durable products and do not reflect an inherent bias against electric vehicles.

CHAPTER 9 REFERENCES

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9-2. "Government and the Nation's Resources," report of the National Commission on Supplies and Shortages, U.S. Government Printing Office, Dec. 1976.

9-3. The most significant of these is Charles River Associates, Inc., "Policy Implications of Producer Country Supply Restrictions," sponsored by the Experimental Technology and Incentives Program of the National Bureau of Standards. The study entails some 10 volumes of analysis focusing on the principal materials for which supply restrictions could have serious domestic consequences.

9-4. See also, "Government and the Nation's Resources," op. cit.

9-5. Center for Policy Alternatives, "Research and Development in Materials Availability," MIT, Report No. CPA/76-6, August 1976.

9-6. The U.S. Manufacturers, through their foreign subsidiaries have access to the same potential markets. However, they probably cannot achieve the same level of foreign government support for electric vehicles.

9-7. See "Electric Vehicle Research, Development, and Demonstration Act of 1975," Hearings before the House Subcommittee on Energy Research, Development, and Demonstration, Committee on Science and Technology, June 3-6, 1975.

9-8. PL 94-413, Section 10.

9-9. Paul Henderson, New England Representative, Insurance Information Institute, personal communication, May 25, 1976; Robert Grant, All State Agent; M. Hanley, AAA National Headquarters; personal communications, April 1977.

9-10. "Two Electric Cars," Consumer Reports, October 1975.

9-11. Zagato International, S.S., personal communication, company representative, April 29, 1977.

9-12. Arthur Mikesell, National Savings Bank Association; Sheldon Golub, American Bankers Association; Nancy Webb, Shawmut Bank Association; James Carter, AAA, Framingham, Mass; M. Findley, Automobile Legal Association; personal communications, April-May, 1977.

10.0 SUMMARY

10.1 GENERAL

Institutional factors have been evaluated for their potential bias for (or against) electric and hybrid vehicles. Some 60 factors were reviewed deriving from laws and regulations, traffic patterns, urban design, electricity supply, federal policies and programs, automotive industry structure and practice and others. The results of these studies are presented in Tables 10-1 and 10-2. Table 10-1 is a summary of the number of factors studied, categorized by area, and the biases identified. Some factors produced no bias for or against EHV's and are described as neutral. A few factors, especially in the urban design area, could be argued as a source of bias either for or against EHV's depending on the assumptions and are so identified. Those factors clearly biased for, or against, the EV and/or hybrid vehicles are identified and explained, and where possible a measurement of the bias is supplied. This count of neutral, favorable and unfavorable biasing factors (Table 10-1) should not be construed as indicative of the overall relationship of institutional biases to EHV. Indeed, the categorizing of factors is judgmental and the importance of individual factors varies greatly.

A more detailed summary is presented in Table 10-2. Each factor is identified, the relevant vehicle characteristics (on which the analysis was based) are stated, the principal bias impacts are indicated, and the measured value used in the analysis is listed. While this summarization inevitably omits many of the details of the discussion it is a convenient compilation of the results of this study.

TABLE 10-1. SUMMARY OF CONCLUSIONS

Institutional Area	Total Number of Factors	Bias			
		For EHV	Against EHV	Neutral	Both For and Against
Taxes and Regulations	21	7	11	3	
Traffic Control	8		3	5	
Urban Design	9	1	5		3
Electricity Supply	5		4		1
Federal Policies and Programs	4	3	1		
Automotive Industry	6		6		
Miscellaneous	7	3	3	1	
Totals	60	14	33	9	4

TABLE 10-2. SUMMARY OF INSTITUTIONAL FACTORS ANALYSIS

TABLE 10-2

INSTITUTIONAL FACTOR	RELEVANT VEHICLE CHARACTERISTICS	PRINCIPAL BIAS IMPACTS (+) FAVORS ELECTRIC (-) AGAINST ELECTRIC +	-	MEASURED VALUE	COMMENTS
I. Taxes and Regulations					
A. Federal Laws and Regulations					
1. Excise Tax					
a. Fuel Tax	Fuel, Fuel Economy	✓		Tax of 1¢/l (4¢/gallon) Annual cost for study vehicles is ~ \$5 to \$22 (10,000 miles); 17 km/l (41 MPG) is \$9.76	It appears unlikely that E.V.'s would be able to avoid an equal tax if their market penetration is substantial
b. Lubricating Oil Tax	Power Plant	✓		Tax of 1.6¢/l (6¢/gallon)-Annual cost for study vehicles is ~ 10¢ to 40¢ fuel tax) is 17¢	This is a negligible bias against ICE's.
c. Tires and Tubes Tax			✓	Tax of 4.5¢/kg (10¢/lb) on rubber	This is a negligible bias against E.V.'s since they require bigger tires
2. Income Tax Deduction	Fuel, Fuel Economy, Fair Market Value		✓	Lessens bias against ICE brought about by state and local taxes on property and fuels	The effects of these laws depend on the itemizing of deductions and the respective income bracket.
3. Customs and Tariffs				None	There appears to be no bias for or against specific vehicles other than those provisions incorporated under other federal laws and regulations.
4. Safety Standards	Crashworthiness		✓	Due to different weight propagation factors (ICE = 1.45; E.V. = 1.75) the addition of safety standards equipment is favorable to E.V., i.e., the addition of 45 kg (100 lbs) of equipment to E.V. results in 34 kg (75 lb) propagated weight and \$160 price increase. The same equipment on an ICE results in 20 kg (45 lb) propagated weight and \$30 increase	Data concerning the required total weight increase is not readily available. Only available source is a 1974 Ford Study which shows that the conversion of an ICE vehicle (Pinto and Comet) into an E.V. would require an increase of 91-204 kg (200-450 lbs) due to safety standards. The results of the report, however, are not applicable to a new-design E.V. and are inflated due to the fact that they anticipate changing federal standards
5. Air Pollution Control	Emissions ($HC/CO/NO_x$)	✓		First cost, fuel costs, maintenance cost. Depending on emission level implemented costs are ≤0.2 to 0.6¢/km (2%-5% of life cycle costs of ICE study vehicles)	
6. Noise Control	Power Plant Noise				Not applicable to vehicles under 10,000 lbs

TABLE 10-2 (CONTINUED)

INSTITUTIONAL FACTOR	RELEVANT VEHICLE CHARACTERISTICS	PRINCIPAL BIAS IMPACTS (+) FAVORS ELECTRIC (-) AGAINST ELECTRIC +	-	MEASURED VALUE	COMMENTS
7. Energy Policy and Conservation Act	Fuel Economy	✓			Bias for E.V.'s under President's standby authority to ration petroleum fuels. Otherwise no bias since all study ICE vehicles surpass Act-specified fuel economies
8. Emergency Petroleum Allocation Act	Fuel Economy		✓	Price of Gasoline	Using the controlled price of gasoline as a reference point there is at least a 10¢/gallon difference between the reference price and the projected price based on the average cost of imported crude oil. This has a minor effect on the life cycle costs of study vehicle operation.
9. Rural Electrification Act	Electrical Equipment	✓		Vehicle first cost derived from low interest loans (2%) available under the Act	If applicable, REA provisions for financing the inital purchase of an electric van would reduce the net present value of the life cycle cost by 8%-12% for an electric van (as compared to outright purchase)
B. State Laws and Regulations					
1. Registration and Licensing fees	Varies according to individual state regulations. In some cases, fees are based on horsepower, passenger capacity, form of fuel				In most states fees are neutral in respect to E.V.'s. In some states biases appear split between favorable and unfavorable provisions. The unfavorable provisions are attempts to recover revenues lost due to the absence of an applicable fuel tax.
2. Fuel Tax	Fuel, Fuel Economy	✓		Tax ranges from 5¢-11¢ - Annual cost for study vehicles is ~$6 to $60	It appears unlikely that E.V. would be able to avoid an equal tax if their market penetration is substantial
3. Income Tax Deductions	Fuel, Fuel Economy		✓	Lessens bias against ICE's brought about by state and local taxes on fuels	Particulars vary according to individual states
4. Sales Tax					
a. First Cost	Retail value		✓	Tax of 4%-6% in four test states - due to higher acquisition cost of E.V.'s the buyer of an E.V. might pay $34-$240 more in first cost sales tax	

TABLE 10-2 (CONTINUED)

INSTITUTIONAL FACTOR	RELEVANT VEHICLE CHARACTERISTICS	PRINCIPAL BIAS IMPACTS (+) FAVORS ELECTRIC (-1) AGAINST ELECTRIC +	-	MEASURED VALUE	COMMENTS
b. Life Cycle Cost	Retail Value, parts and materials for maintenance (this includes battery)		✓	Annual ownership cost for E.V. owners is $11-$52 more than ICE	
5. Property Tax	Fair Market Value		✓	Average annual tax for E.V's is $3-$66 more than ICE tax depending on tax rate	Bias against E.V.'s due to the fact that assessed value is greater. Amount of tax depends on assessed value and tax rate
6. Utility Tax	Fuel, km/kw (Energy Economy)		✓	Cost of electricity	Small bias against E.V.s
7. Noise Control	Power Plant Noise	✓		Price of Muffler and Exhaust system	Slight bias against ICE - Easily rectifiable through the use of noise control system
8. Miscellaneous Regulations					
a. Discretionary Safety Laws	Speed, Gradeability, Acceleration		✓		Potential bias against E.V.'s due to the existence of regulations which, if applied, might exclude E.V. from some highway travel (i.e. high speed and/or hilly) as a result of their inability to maintain speed comparable to the average speed
b. Insurance Laws	Fair Market Value, Crashworthiness, Damageability, Theft Rate		✓		Potential bias against E.V.'s due to the possiblity that insurance rates will be higher - or even unavailable - given the uncertain E.V. accident and theft related costs
II TRAFFIC CONTROL					
A. Highway Traffic					
1. Speed Laws	Maximum Speed, Acceleration, Gradeability		✓	Increase in accident involvement rate: for E.V. at 65 MPH average highway speed the accident involvement rate for a 2 pax E.V. will be 22-90 times greater than for vehicles traveling at the average speed	In high speed road use the interaction between vehicle characteristics and highway grades causes E.V. performance measurably lower ar than ICE;s at the average highway speed resulting in greater accident involvement rate
2. Access Ramps	Acceleration, Gradeability		✓	Ability to enter high speed traffic: given ramp dimensions of 4%-6% grade and 213-304.8m(700-1000 feet) length; minimum required entry speed of 64 km/h (40 MPH); it would appear that E.V.'s can not utilize acceleration ramps	This is a substantial bias against E.V.'s especially if the following factors are considered: - Given the 1000 feet length of ramp the 2 pax E.V. and E.V. van would be unable to negotiate even a 1% grade - Limitations on ramp usage might still be manageable if, by using a 2-3 km detour, the driver could use a depressed or at-grade entrance point. Indications are, however, that this is not the case - At the average highway speed of 88 km/h (55 MPH) the entering speed of 64 km/h (40 MPH) would result in an accident involvement rate three times higher than entering 88 km/h at (55 MPH). Proportionatelly, at the average highway speed of 105 km/h (54 MPH) this rate would be 14 times higher.

TABLE 10-2 (CONTINUED)

INSTITUTIONAL FACTOR	RELEVANT VEHICLE CHARACTERISTICS	PRINCIPAL BIAS IMPACTS (+) FAVORS ELECTRIC (-) AGAINST ELECTRIC +	-	MEASURED VALUE	COMMENTS
B. Traffic Light Timing					
1. Fixed-Time Signals	Size, Acceleration			Intersection capacity: no significant effect	The effects of slower acceleration are generally offset by smaller size
2. Demand-Actuated Signals	Size, Acceleration			Intersection capacity, no significant effect	Even in an all small car traffic pattern, where E.V.'s could theoretically reduce the flow by 5%-15%, the problem can be alleviated by resetting the signals.
3. Travel Time	Acceleration, Size			Travel time: no significant effect	For E.V's with acceleration of 4.3 km/h/sec (2.7 MPH/sec.) independent from other traffic the travel time for a 8 km (5 mile) stretch is 4%-9% longer than for ICE with 8 km/h/sec. (5.0 MPH/sec.). The variation is due to the number of stops. For E.V. mixed with other traffic the difference is closer to the lower limit. Furthermore, signal timing could be adjusted to accommodate E.V.'s
C. Preferential Access Lanes (Car Pools)	Size (Passenger Capacity)			E.V. qualifications as car-pooling vehicle: no bias against E.V. if definition of carpool is 2 passengers. If definition is 3 passengers then there exists a prohibitive bias against 2 pax E.V. and a potential, but unquantified bias against 4 pax E.V.s	The potential bias against 4 pax E.V.'s is theoretically due to the possible unwillingness of commuters to travel in groups of 3 or more in a car similar in size to an ICE subcompact
D. Vehicle Segregation Policy	Size (Width)		✓	Street capacity for traffic flow: the sizing of some streets for small car use can increase capacity by temporarily deleting parking lanes and adding traffic lanes	Existing urban design and congestion patterns indicate that traffic flow can be greatly improved through the use of smaller cars. The deletion of parking lanes in large car traffic is not as efficient
E. Tolls and Congestion Pricing	Size (Passenger Capacity)			Qualifications for multi-passenger vehicle	A bias against E.V.'s might exist if pricing depended on passenger occupancy (see preferential access lanes)

TABLE 10-2 (CONTINUED)

INSTITUTIONAL FACTOR	RELEVANT VEHICLE CHARACTERISTICS	PRINCIPAL BIAS IMPACTS (+) FAVORS ELECTRIC (-) AGAINST ELECTRIC) +	-	MEASURED VALUE	COMMENTS
III URBAN DESIGN					
A. Urban Density	Multifunctional Capability	✓	✓	1. Car ownership - multi-car ownership is inversely proportional to urban desnity	Extreme urban density is a bias against E.V. to the extent that E.V.'s are more suitable to multi-car households
	Range	✓	✓	2. Trip length - proximity of work, shopping, and home	To the extent that trip lengths are beyond the E.V. range low density settlement is a bias against E.V.
	Range	✓	✓	3. Commercial vehicles stem trip length	In high density areas E.V. vans are not excluded from pick-up and delivery operations by range alone
B. Intermodal Planning	Range		✓	Automobile segment of home to work trip	Insufficient intermodal facilities planning (i.e., Park and Ride and Van Pool) creates unnecessarily long automobile segment of home to work trip
C. Access Policies	Noise and Emissions		✓	Accessibility of some urban areas to E.V.	Indiscriminate application of policies designed to minimize urban pollution from automobiles would create an unnecessary bias against E.V's
D. Parking Supply					
1. Commercial	Size		✓	Apportionment of parking fees - 30% reduction in parking fees for small cars is possible	This is a potential bias against small cars
2. On Street	Size		✓	Apportionment of congestion costs and parking fees-potential for 30% increase in parking facilities through small car sizing	This is a potential bias against small cars
3. Residential	Recharging Requirements		✓	Off-street parking facilities and electrical outlets. 60% of households do not live in single-family houses with covered parking	Recharging of batteries is easiest in residential covered parking situations. However, required data on uncovered off-street parking, multi-family parking and relative difficulties of home recharging situations is not available
E. Covered/ Uncovered Parking Facilities	Emissions	✓		Cost of ventilation equipment is less than 7% of CBD covered garage costs	Insignificant bias

TABLE 10-2 (CONTINUED)

INSTITUTIONAL FACTOR	RELEVANT VEHICLE CHARACTERISTICS	PRINCIPAL BIAS IMPACTS (+) FAVORS ELECTRIC (-) AGAINST ELECTRIC +	-	MEASURED VALUE	COMMENTS
IV ELECTRIC SUPPLY					
A. Electric Utility Industry					
1. Capital Intensity	Fuel, Fuel Economy		✓	Price charged for industry's product	This is a small bias against E.V.'s since fuel costs constitute a small part of vehicle life-cycle costs. Major increases in price of electricity will have little impact.
			✓	Effect of demand on supply due to E.V.'s: 10 million E.V.'s (1995) would constitute only 2% of demand	The significance of potential capacity shortfalls appears limited.
2. Government Regulations			✓	Impact of laws on fuel availability and price	Government regulations could be interpreted to create a bias against E.V.'s by retarding generating capacity expansion, increasing the cost of new capacity, reinforcing high capital requirements, and increasing uncertainty in planning
3. Rates and Pricing Policies	Fuel, Fuel Economy	✓	✓	Regional and time-of-day pricing effects on E.V.'s. Based on regional variations in E.V. could cost $130/yr in N.Y. $20/yer in Seattle (4 pax E.V.)	The variations in regional pricing might have a negative bias against E.V. since higher prices occur in densely populated urban areas. Peak load pricing policies might create a positive bias on E.V.'s by allowing owners to recharge at night at much lower prices.
B. Electricity Distribution	Recharging cycle				
1. Recharge at Home	(See Urban Design Section)				
2. Rapid Recharge/Battery Exchange Service	Recharging Cycle, Range		✓	Availability and potentials of recharging stations	The lack of recharging infrastructure is a bias against E.V. This bias re-emphasizes the use of private facilities. The bias is further enhanced by the availability of electric power for individual recharging needs. Since there appears to be no institutional bias against recharging stations, the development of a recharging infrastructure is quite possible. The factors to be considered, however, are: the implications of rapid charging and battery exchange.

TABLE 10-2 (CONTINUED)

INSTITUTIONAL FACTOR	RELEVANT VEHICLE CHARACTERISTICS	+	-	PRINCIPAL BIAS IMPACTS (+) FAVORS ELECTRIC (-) AGAINST ELECTRIC MEASURED VALUE	COMMENTS
V FEDERAL POLICIES AND PROGRAMS					
A. Energy Research Development and Demonstration					
1. Federal Energy RD&D					
a. Electric and Hybrid Vehicle Research, Develop. and Demonstration Act	All	✓		Current planned expenditures are $160 million over the next five years	Short term demonstration could speed up the introduction of E.V.'s. On the other hand, the emphasis on short-term demonstration could hurt a sustained research and development effort if initial results are disappointing.
b. Research in Alternative Energy Sources	Fuel	✓		Current RD&D funds for electricity generation are $1,741 millions compared with $106 millions for synthetic gaseous fuels and $95.3 millions for synthetic liquid fuels	Emphasis on electricity generation is due to the following factors: - electricity generation currently accounts for 25% of U.S. primary energy consumption and is growing rapidly. - conversion to alternative fuels for the generation of electricity can produce sizable short-term savings. - Some of the nation's abundant energy sources (e.g. nuclear) can achieve widespread use only with electricity as the intermediate fuel.
B. Federal Fleet Procurement	Initial Cost		✓	Standards for federal procurement usage requirement: - 12,000 miles/yr - life-span requirement: replacement after 6 yrs or 60,000 miles.	Federal policies appear to favor vehicles meeting general standards at lowest initial cost. By ignoring life-cycle costs, the procurement policies are biased against vehicles with high initial costs, but which offer savings through superior durability, lower maintenance requirements, or better fuel economy. Some biases against E.V.'s should be eliminated by Sec. 11 of the Electric and Hybrid Vehicle Act which directs federal agencies to study the possibility of E.V. procurement.

TABLE 10-2 (CONTINUED)

INSTITUTIONAL FACTOR	RELEVANT VEHICLE CHARACTERISTICS	PRINCIPAL BIAS IMPACTS (+) FAVORS ELECTRIC (-) AGAINST ELECTRIC +	-	MEASURED VALUE	COMMENT
1. Low-Emission Vehicle Procurement Programs	Emission System	✓		Emission standards for federal procurement although authorized under the Clean Air Act has not been significantly implemented (i.e. $25,000 out of $20 million low emission vehicle demonstration project)	Bias could develop in favor of E.V.'s assuming these cars can satisfy individual agency needs.
VI AUTOMOTIVE INDUSTRY					
A. Industry Structure					
1. Economies of Scale	Flexibility of Performance, Interchangeability of Components		✓	Requirements for operations: - full economies of scale reached at 250,000-400,000 vehicles per year - true market segmentation is limited to approx. 6 classes varying mostly by size	Bias against E.V.'s due to their limited range of performance capabilities, numerous specialized components and distinct design features
2. Capital Requirements			✓	Entrance requirements estimated to be ~$2 billion	Bias against all new entrants and not against vehicle characteristics. However, high capital requirements create a bias within the existing "four", against the introduction of innovative new technology substantially altering vehicle characteristics.
3. In-Place Infrastructure	Sales, Financing, Maintenance, and Reseale Characteristics		✓	Components of supporting infrastructure	It would appear that in-place infrastructure favors ICE's, but many infrastructure elements are consistent with or could easily be adapted to electric cars.
4. Demand Variations	Innovative Characteristics		✓	Uncertainty of revenue due to demand variations	Demand fluctuations intensify the barriers to entry brought about by economies of scale and capital requirements.

TABLE 10-2 (CONTINUED)

INSTITUTIONAL FACTOR	RELEVANT VEHICLE CHARACTERISTICS	PRINCIPAL BIAS IMPACTS (+) FAVORS ELECTRIC (-) AGAINST ELECTRIC +	-	MEASURED VALUE	COMMENTS
B. Industry Practice					
1. Research and Technological Innovation	Innovative Characteristics		✓	Time-frame for introduction of innovative ideas	The introduction of major innovations is undertaken only after long studies and, if possible, in conjunction with the phasing out of fully depreciated facilities. The process is gradual due to the less than perfect competition among manufacturers and due to the risks involved, risks that are largely there because of automation. One factor that might reduce this time-frame is the expanding role of the foreign imports.
2. Pricing Practice and Profitability	Projected Profitability		✓	Profitability of E.V.'s based on standards of target return pricing. (G.M. standards 20% return on capital with plants operating at 80% capacity)	The nature of the automobile industry (oligopoly) allows flexibility in determining production volumes and price levels. Two consequences are target return pricing and higher than average profit expectations
VII Miscellaneous Factors					
A. OPEC					
1. Cartel-Set Oil Prices	Fuel, Fuel Economy	✓		Effects of high oil prices ($12-$13/ barrel) on the transportation industry	Bias in favor of efficiency and non-oil consuming vehicles
2. Potential Supply Shortfalls	Fuel, Fuel Economy	✓		Effects of scarcity of fuel on the transportation industry	Bias in favor of non-oil consuming cars
B. Other Mineral Cartels	Raw Materials Need			Effects of pricing and availability of raw materials on the transportation industry	Potential supply restrictions should create no significant bias against particular vehicle characteristics. Availability of some materials and possible substitution of others will eliminate any potential bias.
C. Foreign Energy Programs	Energy Efficiency	✓		Effects of foreign competition on the transporation industry	Due to the greater dependency on imported oil, and therefore greater demand for alternate systems, foreign manufacturers could achieve significant economies of scale in E.V. production. Their products could then be introduced on the U.S. market at lower prices spurring the U.S. manufacturers into competitive action.

TABLE 10-2 (CONTINUED)

INSTITUTIONAL FACTOR	RELEVANT VEHICLE CHARACTERISTICS	PRINCIPAL BIAS IMPACTS (+) FAVORS ELECTRIC (-) AGAINST ELECTRIC +	-	MEASURED VALUE	COMMENT
D. Capital Availability and Markets	Innovative Features		✓	Factors affecting the introduction of new vehicles	Bias against new vehicles is not specifically related to vehicle characteristics. The introduction of all new vehicles carries great risks.
E. Availability of Insurance	Value, Purpose, Crashworthiness, Theft, Potential, Damageability		✓	Effect of specific vehicle characteristics on insurance availability	While no specific rules discriminating against E.V.'s exist, due to their absence from national underwriters rating list and the limited data on their insurance risk potential a possible bias against E.V.'s does exist
F. Financing	Resale Value		✓	Availability of financing due to unmeasured vehicle potential	The bias is not specifically against E.V. reflecting the situation of most new durable products

APPENDIX A

COST AND PRICE ESTIMATES OF MODEL ICE AND ELECTRIC VEHICLES OF INTEREST TO THE STUDY

A.1 INTRODUCTION AND SUMMARY

In this appendix, the economics of the various vehicle of interest to the study are examined. For each of these vehicles, the retail price and the life cycle operating costs were estimated.

The characteristics of the nine vehicles of interest are listed in Table A-1. This list includes seven passenger vehicles and two light duty vans. Of the seven passenger vehicles, two are commercially available sub-compact automobiles and five are model vehicles that evolved out of design calculations. The two commercial vehicles used in the study are 1977 California models of the General Motors Corp. Chevette Scooter equipped with a 1600cc (98 CID) engine, and the Honda Civic CVCC Hatchback sedan equipped with a 1490cc (91 CID) engine. The emissions from these vehicles are less than 0.4 HC, 3.4 CO, 1.5 NO_x (gm/mile), and should be capable of meeting the emission requirements likely to be in force within the foreseeable future. These two automobiles are the type of ICE vehicle that a small urban electric passenger automobile would have to compete against and displace in the market place.

The Chevette is representative of the sub-compact vehicles now manufactured and sold in the United States. As such it was used as a basis of reference in the cost calculations performed in the study. The Honda Civic CVCC represents a sub-compact vehicle that incorporates advanced engine technology of a type that may be incorporated in American subcompact automobiles as the market for these vehicles matures over the next decade. In particular, the Honda can meet the California emission standards without requiring an exhaust catalyst system of the type used on the Chevette. The Hatchback model of the Honda CVCC, while not the cheapest model available, was chosen since it is the most popular model of the line.

The weight and performance characteristics of the 2-passenger (2 PAX) and 4-passenger electric vehicles, and of the hybrid vehicle were supplied by General Research Coporation (GRC).(A-1) The low performance 2 PAX and 4 PAX ICE's are model vehicles designed at TSC in order to compare electric and ICE vehicles of more similar performance characteristics than those of the Chevette or Honda and the GRC electric vehicles. While the Chevette and the 4-passenger electric vehicle are comparable in size and passenger capacity, the Chevette is distinctly superior to this electric vehicle in terms of range, acceleration, and gradeability. The low performance 2 PAX and 4 PAX ICE's were designed to have the same acceleration, load capacity, and volume as the 2 PAX and 4 PAX electric vehicles. However because of the inherent differences in the power curves of an internal combustion engine and an electric motor, these "comparable" vehicles still differ in terms of gradeability. The vehicles also differ significantly in range. The range of the ICE's could have been made comparable to that of the EV's by providing them with smaller gasoline tanks. To do so would have been unrealistic, and since the size of the gas tank has negligible impact on the total price of an automobile, the issue was not pursued any further.

Two light duty vans are also listed in Table A-1. The performance characteristics of the electric van were provided by GRC. Except for the substitution of a nickel-zinc battery for the lead-acid battery, the model van is very similar to the AM general DJ5E "Jeep" acquired recently by the Postal Service and discussed in the Powel and Rosenberg Transportation Systems Center (TSC) study report.(A-2) The ICE van, presented for purposes of comparison are those of a typical 1/4 ton DJ-5C "Jeep" as used in postal delivery service and which was also discussed in the TSC study report.

The estimated retail prices and life cycle operating costs obtained for these vehicles are also listed in Table A-1. The assumptions on which these costs are based are developed in subsequent sections. The retail prices presented are for the base vehicles without options. The price of the Honda CVCC includes an

TABLE A-1. CHARACTERISTICS OF ELECTRIC AND ICE VEHICLES OF INTEREST TO THE STUDY

VEHICLE CHARACTERISTIC	ELECTRIC AND HYBRID VEHICLES				INTERNAL COMBUSTION ENGINE (ICE) VEHICLES				
	2 PAX EV Near Term Pb-Acid Battery	4 PAX EV Intermediate Technology Ni-Zn Battery	Light Duty Van EV Intermediate Technology Ni-Zn Battery	Hybrid Intermediate Technology Ni-Zn Battery	Low Performance 4 PAX	Low Performance 2 PAX	CHEVETTE	JEEP VAN	HONDA CVCC
Battery Weight, kg (lbs) EV only	355(781)	298(657)	382(842)	366(806)					
Curb Weight, kg (lbs)	1012(2229)	1193(2628)	1531(3372)	1547(3408)	658(1450)	878(1935)	933(2053)	1171(2500)	814(1745)
Gross Vehicle Weight, kg (lbs)	1192(2622)	1525(3366)	1900(4180)	1879(4138)	826(1820)	1210(2665)	1265(2783)	1538(3388)	1144(2475)
W_B/GVW	0.30	0.20	0.20	0.19					
Driving Cycle	J227 a/C	J227 a/D	J227 a/D	J227 a/D	← EPA Combined	→	→	Post Office	EPA Combined
Acceleration, time to 48 km/hr (30 mi/hr)sec	11	9	11	9	10	8	5		
Top speed km/hr, (mi/hr)	80(50)	90(56)	85(53)	90(56)	112(70)	120(75)	144(90)		
Gradeability, km/hr-% (mi/hr-%)	30/10(19/10)	70/7(44/7)	70/7(44/7)	85/7(53)/7)	29/16(18/16)	85/7(53/7)	27/30(17/30)		
Range, km(mi) for driving Cycle	50(31)	130(81)	130(81)	50/300(30/180)[a]	657(408)	725(450)	690(429)	190(118)	661(413)
Fuel Capacity, liter(gallons)					30(8)	38(10)	49(13)	57(15)	40(10.6)
Electric Energy Consumption, kWh/km	0.212	0.226	0.263	0.284					
Hydrocarbon Fuel Consumption, liters/100 km				8.7	4.6	5.7	7.2	29.7	6.1
Hydrocarbon Fuel Economy (MPG)				27.1	51.	41.	33.	7.9	39.
Engine Displacement, cm^3, (in^3)				36	737(45)	1065(65)	1606(98)	3770(232)	1488(91)
ICE Horsepower				24	30	43	63	90	60
Electric Motor Horsepower									
Retail Price $ Base Vehicle	4600	2900	3700	4200				3800	3464
Battery	540	1840	2360	2200					
Total	5140	4740	6060	6400	2400	2900	3054	3800	3464
Assumed Vehicle Life, years	12	12	10	12	10	10	10	6	10
Annual Usage km/yr (mi/yr)	10000(6200)	16000(10000)	7000(4300)	16000(10000)	10000(6200)	16000(10000)	16000(10000)	7000(4300)	16000(10000)
Fuel Costs[b], ¢/km (¢/mile)	0.85(1.4)	0.90(1.5)	1.05(1.7)	1.12(1.9)	0.74(1.2)	0.91(1.5)	1.14(1.8)	4.75(7.6)	0.96(1.5)
Life Cycle Costs ¢/km(¢/mile)	13.76(22.1)	10.77(17.2)	30.86(49.4)	13.69(21.8)	9.17(14.7)	8.24(12.7)	8.62(13.8)	33.45(52.8)	8.95(14.3)

a) Range of Hybrid 50 km(30mi) electric, 300 km (180 mi) ICE

b) Cost of Fuel Assumed;
electricity @ 4¢/kWh
Gasoline 15¢/1 (60¢/gal.)

AM radio, not present in the other vehicles, as part of its standard equipment. This piece of equipment adds approximately $60 to the retail price of the vehicle. The retail price of the Honda also includes the 3% duty on automobiles imported into the U.S., a cost that is not factored into any of the other vehicles in the study.

The first cost of the intermediate technology 4 passenger electric vehicle to a consumer is higher than the first cost of the competitive ICE vehicles by approximately the price of the battery. The life cycle costs of the ICE vehicles are lower than the life cycle costs of the electric vehicle principally because of lower charges related to first costs (depreciation and interest). At the assumed costs of electricity of 4¢/kWh and gasoline at 60¢/gallon, the fuel costs of the electric and ICE vehicles are comparable. These fuel costs represent only a small fraction (10% or less) of the total costs of vehicle ownership.

There is relatively little difference in the price of the various ICE vehicles examined in the study. There is a difference between the Chevette Scooter and the 2-passenger ICE low performance vehicle of about $650, and of $150 between the Chevette Scooter and the 4-passenger low performance ICE. The Honda is about $400 more than the Chevette Scooter. There is little difference between the life cycle costs of these vehicles. The life cycle costs of the 2-passenger ICE vehicle are higher than those of the 4-passenger vehicles because of a lower assumed utilization.

The near term 2-passenger electric vehicle is an expensive vehicle because the cost of components is based on current state-of-the-art technology in limited production, as compared to that of automotive manufacturing. The retail price of the base vehicle is estimated to be $4600. The lead-acid battery raises the vehicle price by $540, to $5140. The life cycle costs of this electric vehicle are about 50% higher than the life cycle costs of the comparable 2-passenger ICE vehicle.

The hybrid vehicle is the most expensive of the various model passenger vehicles examined herein, both in terms of initial price and life cycle operating costs. The base vehicle price is $4200. With a $2200 battery, the retail price is $6400. This is more than twice the retail price of the 4-passenger ICE vehicles, and nearly one third more than the price of the intermediate technology 4-passenger electric vehicle. The life cycle costs of the Hybrid are significantly higher than either the corresponding ICE or electric four-passenger vehicles.

The price/cost comparison of electric and ICE vans is essentially the same as that in the TSC study. The electric van has a higher initial price than the ICE van. Because of the mode of operation assumed for these vans, it is estimated that the life cycle costs of the electric van will be less than those of the ICE van.

A.2 LIFE CYCLE COST CALCULATIONS

Life cycle operating cost estimates for the various model vehicles of interest to the study are presented in Table A-2. The methodology used is essentially the same as that used in the TSC study. Capital sensitive costs are the depreciation of the base vehicles, depreciation of the battery for the electric vehicles, interest on the base vehicles, interest on the battery, and taxes and fees. Depreciation and interest costs are a function of the assumed vehicle utilization and useful life, which were provided by GRC. The interest charges reflect an assumed acquisition cost of money of 5 percent, compounded over the life of the item being considered (e.g., 10 or 12 years for a base electric vehicle,* 6 or 10 years for an ICE vehicle,* 5 years for a battery system.) Annual taxes and fees were assumed to be 3 percent of the initial retail cost of the vehicle.[A-3]

*The lower life is assumed for vans, the higher for passenger autos.

TABLE A-2. LIFE CYCLE COST OF OWNERSHIP OF ELECTRIC AND ICE VEHICLES OF INTEREST TO THE STUDY

VEHICLE CHARACTERISTIC	ELECTRIC AND HYBRID VEHICLES				INTERNAL COMBUSTION ENGINE (ICE) VEHICLES				
	2 PAX EV Near Term Pb Acid Battery	4 PAX EV (Intermediate Technology Ni-Zn Battery)	Light Duty Van (Intermediate Technology Ni-Zn Battery)	Hybrid (Intermediate Technology Ni-Zn Battery)	Low Performance 4 PAX	Low Performance 2 PAX	Chevette	Jeep Van	Honda CVCC
Vehicle Life, yrs	12	12	10	12	10	10	10	6	10
Annual Vehicle Utilization, km/yr (mi/yr)	10000(6200)	16000(10000)	7000(4300)	16000(10000)	10000(6200)	16000(10000)	16000(10000)	7000(4300)	16000(10000)
Total Vehicle Travel km(mi)	120000(75000)	192000(120000)	70000(43000)	192000(120000)	100000(62000)	160000(100000)	160000(100000)	42000(26000)	160000(100000)
Battery Life, Cycles	1000	600	600	600	-	-	-	-	-
Battery Life, Years	5	5	5	5	-	-	-	-	-
Batteries/vehicle(over vehicle life)	2.5	2.5	2.0	2.5	-	-	-	-	-
Base Vehicle Price $	4600	2900	3700	4200	2400	2900	3054	3800	3464
Battery Price $	540	1840	2360	2200	-	-	-	-	-
Vehicle Acquisition Price $	5140	4740	6060	6400	2400	2900	3054	3800	3464
LIFE CYCLE OPERATING COSTS, ¢/Km (¢/mile)									
Base Vehicle Depreciation	3.84 (6.2)	1.51 (2.4)	5.29 (8.5)	2.17 (3.5)	2.40 (3.8)	1.83 (2.4)	1.91 (3.1)	9.05 (14.5)	2.17 (3.5)
Battery Depreciation	1.09 (1.7)	2.36 (3.8)	6.74 (10.8)	2.90 (4.6)	-	-	-	-	-
Interest on Base Vehicle (5% Compounded)	3.09 (4.9)	1.22 (1.9)	3.33 (5.3)	1.75 (2.8)	1.50 (2.4)	1.14 (1.8)	1.19 (1.9)	3.08 (4.9)	1.36 (2.2)
Interest on Battery (5% Compounded)	0.30 (0.5)	0.64 (1.0)	1.89 (3.0)	0.79 (1.3)	-	-	-	-	-
Taxes & Fees (3% Vehicle Acquisition Price/Year)	1.54 (2.5)	0.89 (1.4)	2.60 (4.2)	1.21 (1.9)	0.72 (1.2)	0.56 (0.9)	0.56 (0.9)	1.63 (2.6)	0.65 (1.0)
Sub-Total, Capital Sensitive Costs	9.86 (15.8)	6.62 (10.5)	19.85 (31.8)	8.82 (14.1)	4.62 (7.4)	3.52 (5.1)	3.67 (5.9)	13.76 (22.0)	4.18 (6.7)
Repairs and Maintenance	0.80 (1.3)	1.00 (1.6)	1.50 (2.4)	1.40 (2.2)	1.56 (2.5)	1.56 (2.5)	1.56 (2.5)	6.48 (9.7)	1.56 (2.5)
Insurance	1.00 (1.6)	1.00 (1.6)	3.71 (5.9)	1.00 (1.6)	1.00 (1.6)	1.00 (1.6)	1.00 (1.6)	3.71 (5.9)	1.00 (1.6)
Parking Tolls, etc.	1.25 (2.0)	1.25 (2.0)	4.75 (7.6)	1.25 (2.0)	1.25 (2.0)	1.25 (2.0)	1.25 (2.0)	4.75 (7.6)	1.25 (2.0)
Sub-Total Non Fuel Operating Costs	12.91 (20.7)	9.87 (15.7)	29.81 (47.7)	12.47 (19.9)	8.43 (13.5)	7.33 (11.2)	7.48 (12.01)	28.70 (45.2)	7.99 (12.8)
Cost of Fuel Electric @ 4¢/kWh	0.85 (1.4)	0.90 (1.5)	1.05 (1.7)	0.80 (1.3)					
Gasoline 15¢/l @ 60¢/gal				0.42 (0.6)	0.74 (1.2)	0.91 (1.5)	1.14 (1.8)	4.75 (7.6)	0.96 (1.5)
Total Operating Costs	13.76 (22.1)	10.77 (17.2)	30.86 (49.4)	13.69 (21.8)	9.17 (14.7)	8.24 (12.7)	8.62 (13.8)	33.45 (52.8)	8.95 (14.3)

GRC's assumed repair and maintenance costs for the model electric and hybrid vehicles were incorporated in the calculations. The value of repair and maintenance costs used for the ICE passenger vehicles is the one developed for four-passenger vehicles in the Motor Vehicle Goals Study Report.[A-4] The repair and maintenance costs for the ICE van are those developed in the TSC study.

The average cost of insurance, parking, and tolls presented in the Motor Vehicle Goals Study, on a per mile basis, were assumed to apply to all the passenger vehicles considered here.[A-5] Higher costs were assumed for the vans due to the higher cost of insuring and storing commercial vehicles.

The cost of fuel for the electric vehicles presented in Table A-2 is based on a nominal cost of electric power of 4¢/kWh. The cost of fuel for the ICE vehicles presented in Table A-2 is based on a nominal cost of gasoline at 15.6¢/liter (60¢/gallon). The impact of the cost of electricity on the cost of operating electric vehicles is presented in Figure A-1. Figure A-2 presents the impact of gasoline cost on the operating costs of the ICE vehicles.

A.2.2 Net Present Value Cost Estimates

A.2.2.1 Introduction

The net present value of the costs of ownership for each of the vehicles of interest to the study was also calculated. The net present value, P, to the current worth of an amount of money, f, that will be received or spent at some future time, is defined by the following equation

$$P = f \frac{1}{(1+i)^y}$$

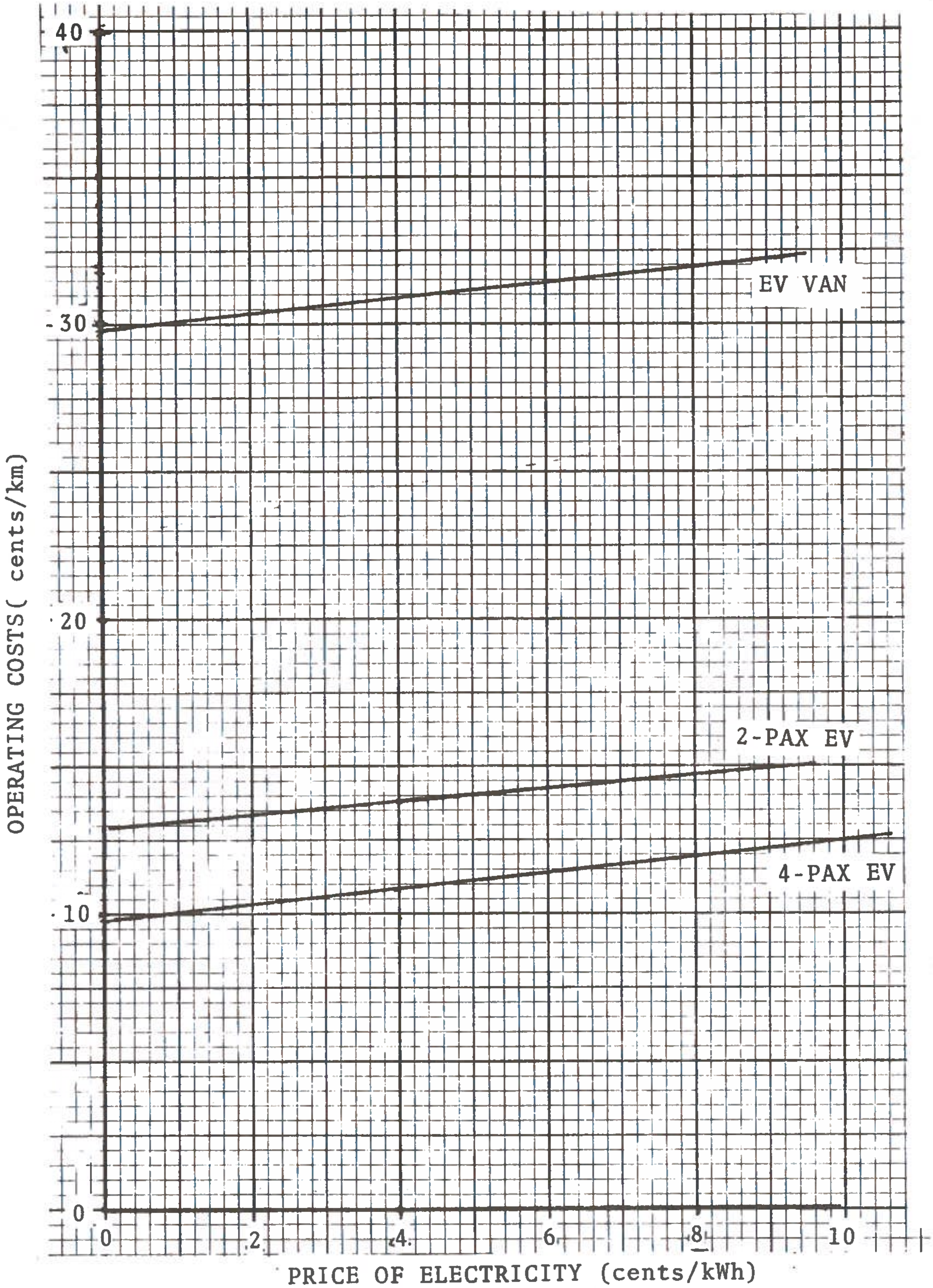


FIGURE A-1. OPERATING COSTS OF MODEL ELECTRIC VEHICLES AS A FUNCTION OF THE PRICE OF ELECTRIC FUEL

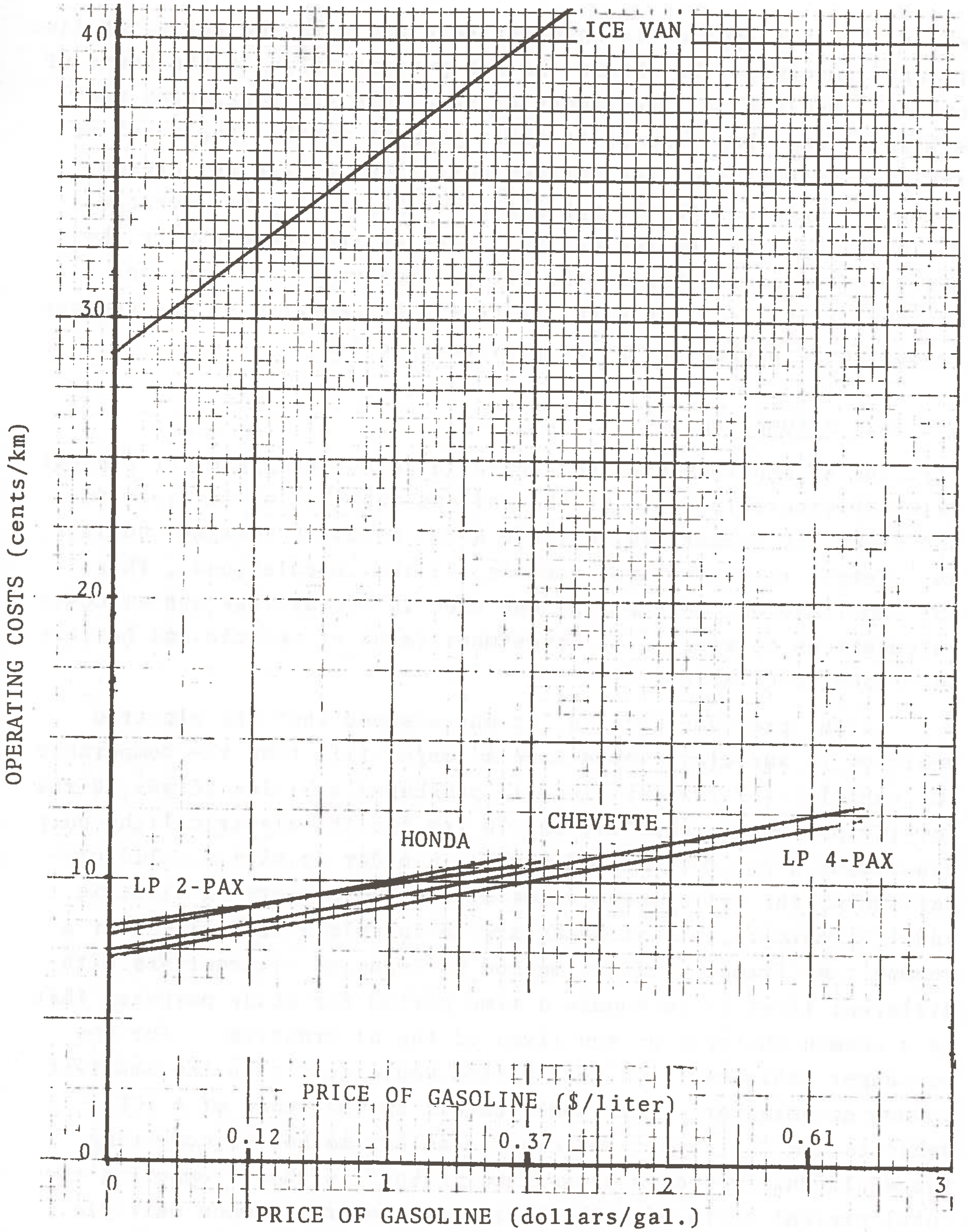


FIGURE A-2. OPERATING COSTS OF MODEL ICE VEHICLES AS A FUNCTION OF THE PRICE OF GASOLINE FUEL where i is the applicable interest rate and y is the period of time (years) involved. To obtain the net present value of the costs of owning a vehicle, all the costs of ownership are forecasted and scheduled and then reduced to their present worth. The total of the present worths of the various cost items is the net present value of the costs of the vehicle ownership of a given vehicle. Dividing the total by the nominal usage of the vehicle over the period of interest, yields the net present value of costs per distance travelled, in ¢/km, which can be compared to the average annual costs presented in the previous section.

A.2.2.2 Assumptions

The assumptions that were used in calculating the net present value or ownership costs of the various vehicles of interest to the study are summarized in Table A-3. Assuming constant dollars, an interest rate of 5% was used in all the calculations. This is the same interest rate as the one used in the average annual costs calculations to assess the investment value of vehicle and battery purchases (see Table A-2).

In the previous section, it was assumed that the electric vehicles in any class would have a longer life than the comparable ICE vehicles (12 yrs for electric passenger vehicles versus 10 yrs for ICE passenger vehicles; and 10 yrs for the electric light duty van versus 6 yrs for the ICE van). In order to have a valid comparison of the net present value of ownership costs of electric and ICE vehicles, it was necessary to calculate the costs over a common time frame. A first method of reducing alternatives with different lives is to choose a time period for study purposes that is a common multiple of the lives of the alternatives. For the passenger vehicles, a 60 year period would result in the smallest common denominator. This would entail the purchase of 6 ICE vehicles and 5 electric vehicles. Another method of comparing these alternatives on a present worth basis without computing the total present worth of each alternative over a common multiple lifetime, is to compute the annual cost of each alternative and

TABLE A-3. ASSUMPTIONS USED IN CALCULATING THE NET PRESENT VALUE OF OWNERSHIP COSTS FOR THE VEHICLES OF INTEREST TO THE STUDY

VEHICLE CLASS	2 PAX AUTOMOBILES	4 PAX AUTOMOBILES	LIGHT DUTY VANS
Annual Discount Rate	5 percent	5 percent	5 percent
Useful Life of Vehicle, yrs	10	10	6
Useful Life of Battery, yrs	5	5	5
Annual Utilization, km	10,000	16,000	7,000
Vehicle Purchase Terms (ex battery)	48 monthly payments at 8% annual interest on balance due, no down payment	48 monthly payments at 8% annual interest on balance due, no down payment	Cash Payment
Battery Purchase Terms	60 monthly payments at 8% annual interest on balance due, no down payment	60 monthly payments at 8% annual interest on balance due, no down payment	Cash Payment
Salvage Value at End of Useful Life (as % Initial Retail Price)			
ICE Vehicle	none	none	none
EV, Base Vehicle	10%	10%	40%
EV, Battery	none	none	80% of 2nd battery
Taxes & Fees, Insurance, Parking and Tolls, Fuel	Values presented in Table A-2 multiplied by annual utilization above	Values presented in Table A-2 multiplied by annual utilization above	Values presented in Table A-2 multiplied by annual utilization above

then determine its present value over a given number of years of service. In this case, the vehicles have a different residual value (e.g. salvage value) which is treated as a negative cost or credit. This latter approach was the one used.

The passenger vehicles were compared over a 10 year period, which is the assumed lifetime of the ICE vehicle. At the end of this period, the electric vehicles were assumed to have a residual value of 10% of the initial retail price of the base vehicle. No salvage credit was assumed for the batteries of the electric and hybrid vehicles.

The light duty vans were compared over a 6 year period which is the assumed service life of the ICE van. At the end of this period, the ICE van was assumed to have no residual value. The electric van was assumed to have a residual value of 40% of the retail price of the base vehicle. In this instance, because the second battery is only 1 year old and presumably it still has 4 yrs of useful life, a salvage value of 80% of the battery first cost was assumed. These are generous assumptions that favor the electric vehicle.

The passenger vehicles were assumed to have been purchased with an extended loan with no down payment required. The interest rate assumed was 8% per annum on the unpaid balance, which is 3% higher than the discount rate of 5% assumed. A 48 month (4 yr) loan was assumed for the ICE passenger vehicles and for the base electric vehicles, without battery. A 60 month (5 yr) loan was assumed for the purchase of each battery. Monthly payments were calculated by the nominal retail price by factors obtained in standard 2/3% interest tables for the time periods involved. (A-6)

It was assumed that the commercial vans and the required batteries would be purchased on a cash basis, without financing. It was assumed that the commercial firms would not need a consumer loan or find it attractive financially.

The same annual vehicle utilization for the different classes of vehicles was assumed here as in the average annual cost calculations. Annual costs of taxes and fees, insurance, parking and tolls, and of fuel were obtained by multiplying the costs presented in Table A-2 for the vehicle of interest, by the nominal annual vehicle utilization for each year of the time period considered. Total vehicle utilization was obtained by multiplying annual use by the total time period considered.

Two additional calculations were performed for the Chevette Scooter ICE passenger vehicle only. In Case B, it was assumed that the vehicle was purchased with an initial outright cash payment instead of a 48 month loan. In Case C, it was assumed that the vehicle use pattern would not be constant from year to year, but would decrease over its lifetime in the same manner assumed by Liston and Aiken. (A-7) This affects annual fuel costs, increasing near term costs and decreasing longer term costs. Maintenance costs were also assumed to vary from year to year about the mean calculated previously in the same manner as the maintenance costs presented in the referenced paper.

A.2.2.3 Results

The net present value of vehicle ownership costs for the various vehicles of interest to the study are summarized in Table A-4. In this table, the net present values of these costs per kilometer of vehicle use are also presented and compared to the average annual costs presented for these vehicles in Table A-2.

The net present value of ownership costs for each of the vehicles considered is presented in Tables A-5 to A-15 in the order outlined in Table A-4.

A.2.2.4 Discussion of Results

The net present value of ownership costs of the 4 passenger ICE vehicles ranges from about $9500 for the low performance 4 PAX ICE vehicle to about $10,300 for the Honda CVCC. The various ICE passenger vehicles as a class are less expensive than the 4 PAX electric vehicle which has an ownership cost of about $12,500.

TABLE A-4. COMPARISON OF LIFE CYCLE COSTS BASED ON NET PRESENT VALUE AND AVERAGE ANNUAL UTILIZATION FOR VEHICLES OF INTEREST

Vehicle	Ownership Costs, Net Present Value ($) (NPV)	Total Vehicle Utilization (km) & Life (yr)	Life Cycle Operating Costs		
			NPV per km (¢/km) (a)	Annual Average Costs from Table A-2 (¢/km) (b)	Ratio a/b
4 PAX AUTOMOBILES		160,000 km 10 yr			
Chevette ICE, Case A	9,991.77		6.24	8.62	0.72
Chevette ICE, Case B	9,873.84		6.17		
Chevette ICE, Case C	10,016.81		6.26		
Honda CVCC ICE	10,294.87		6.43	8.95	0.72
L.P. 4 PAX ICE	9,523.65		5.95	8.24	0.72
4 PAX E.V.	12,518.47		7.82	10.77	0.73
4 PAX Hybrid	15,750.35		9.84	13.69	0.72
2 PAX AUTOMOBILES		100,000 km 10 yr			
L.P. 2 PAX ICE	6,562.62		6.56	9.17	0.72
Near Term 2 PAX EV	9,711.52		9.71	13.76	0.71
LIGHT DUTY VANS		42,000 km 6 yr			
ICE VAN	11,374.96		27.08	33.45	0.81
EV VAN	10,231.49		24.36	30.86	0.79

TABLE A-5. NET PRESENT VALUE OF THE COSTS OF OPERATING A CHEVETTE ICE PASSENGER VEHICLE OVER A PERIOD OF 10 YEARS - CASE A

Items	Net Present Value, $ (a)	Expenses (Credits), $.									
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)	3,172.63	894.72	894.72	894.72	894.72						
Battery Purchase (c)											
Taxes & Fees	704.22	91.20									
Repairs & Maintenance	1,927.35	249.60									
Insurance	1,235.48	160.00									
Parking & Tolls	1,544.35	200.00									
Fuel, Gasoline	1,408.44	182.40									
Fuel, Electric											
Sub-total	9,991.77										
Vehicle Salvage Value (d)											
Battery Salvage Value (é)											
TOTAL	9,991.77										

a) 5% Discount Rate

b) Vehicle Price = $3,054, 48 month, 8% Annual Interest Purchase, Monthly Payment = $74.56

c) not applicable

d) none

e) not applicable

TABLE A-6. NET PRESENT VALUE OF THE COSTS OF OPERATING A CHEVETTE ICE PASSENGER VEHICLE OVER A PERIOD OF 10 YEARS - CASE B

Items	Net Present Value, $ (a)	Expenses (Credits), $									
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)	3,054.00										
Battery Purchase (c)											
Taxes & Fees	704.22	91.20									
Repairs & Maintenance	1,927.35	249.60									
Insurance	1,235.48	160.00									
Parking & Tolls	1,544.35	200.00									
Fuel, Gasoline	1,408.44	182.40									
Fuel, Electric											
Sub-total	9,873.84										
Vehicle Salvage Value (d)											
Battery Salvage Value (e)											
TOTAL	9,873.84										

a) 5% Discount Rate

b) Vehicle Price = $3,054, cash payment

c) not applicable

d) none

e) not applicable

TABLE A-7. NET PRESENT VALUE OF THE COSTS OF OPERATING A CHEVETTE ICE PASSENGER VEHICLE OVER A PERIOD OF 10 YEARS - CASE C

Items	Net Present Value, $ (a)	Expenses (Credits), $									
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)	3,172.63	894.72	894.72	894.72	894.72						
Battery Purchase (c)											
Taxes & Fees	704.22	91.20									
Repairs & Maintenance	1,905.56	116.91	139.50	264.54	343.27	279.97	324.58	458.47	205.10	293.92	66.91
Insurance	1,235.48	160.00									
Parking & Tolls	1,544.35	200.00									
Fuel, Gasoline	1,454.57	264.48	237.12	209.76	182.40	180.58	180.58	173.28	155.04	136.80	103.97
Fuel, Electric											
Sub-total	10,016.81										
Vehicle Salvage Value (d)											
Battery Salvage Value (e)											
TOTAL	10,016.81										
Vehicle Utilization, km/yr (mi./yr)		23200 (14500)	20800 (13000)	18400 (11500)	16000 (10000)	15800 (9900)	15800 (9900)	15200 (9500)	13600 (8500)	12000 (7500)	9205 (5700)

a) 5% Discount Rate

b) Vehicle Price = $3054, 48 month, 8% Annual Interest Purchase, Monthly Payment = $74.56

c) not applicable

d) none

e) not applicable

TABLE A-8. NET PRESENT VALUE OF THE COSTS OF OPERATING A HONDA CIVIC CVCC ICE PASSENGER VEHICLE OVER A PERIOD OF 10 YEARS

Items	Net Present Value, $ (a)	Expenses (Credits), $									
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)	3,598.57	1014.84	1014.84	1014.84	1014.84						
Battery Purchase (c)											
Taxes & Fees	803.06	104.00									
Repairs & Maintenance	1,927.35	249.60									
Insurance	1,235.48	160.00									
Parking & Tolls	1,544.35	200.00									
Fuel, Gasoline	1,186.06	153.60									
Fuel, Electric											
Sub-total	10,294.87										
Vehicle Salvage Value (d)											
Battery Salvage Value (e)											
TOTAL	10,294.87										

a) 5% Discount Rate

b) Vehicle Price = $3464, 48 month, 8% Annual Interest Purchase, Monthly Payment = $84.57 for 4 yrs.

c) not applicable

d) none

e) not applicable

TABLE A-9. NET PRESENT VALUE OF THE COSTS OF OPERATING A LOW PERFORMANCE 4 PAX ICE VEHICLE OVER A PERIOD OF 10 YEARS

Items	Net Present Value, $ (a)	Expenses (Credits), $.									
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)	3,012.68	849.61	849.61	849.61	849.61						
Battery Purchase (c)											
Taxes & Fees	679.51	88.00									
Repairs & Maintenance	1,927.35	249.60									
Insurance	1,235.48	160.00									
Parking & Tolls	1,544.35	200.00									
Fuel, Gasoline	1,124.28	145.60									
Fuel, Electric											
Sub-total	9,523.65										
Vehicle Salvage Value (d)											
Battery Salvage Value (e)											
TOTAL	9,523.65										

a) 5% Discount Rate

b) Vehicle Price = $2900, 48 month, 8% Annual Interest Purchase, Monthly Payment = $ 70.80 for 4 yrs.

c) not applicable

d) none

e) not applicable

TABLE A-10. NET PRESENT VALUE OF THE COSTS OF OPERATING A 4 PAX ELECTRIC VEHICLE OVER A PERIOD OF 10 YEARS

Items	Net Present Value, $ (a)	Expenses (Credits), $.									
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)	3,012.68	849.61	849.61	849.61	849.61						
Battery Purchase (c)	3,457.02	447.70									
Taxes & Fees	1,099.58	142.40									
Repairs & Maintenance	1,235.48	160.00									
Insurance	1,235.48	160.00									
Parking & Tolls	1,544.35	200.00									
Fuel, Gasoline											
Fuel, Electric	1,111.93	144.00									
Sub-total	12,696.50										
Vehicle Salvage Value (d)	(178.03)										(290.00)
Battery Salvage Value (e)	-										
TOTAL	12,518.47										

a) 5% Discount Rate

b) Base Vehicle Price = $2900, 48 month, 8% Annual Interest Purchase, Monthly Payment = $70.80 for 4 yrs.

c) Battery Price + $ 1840, 2 batteries purchased with 60 month, 8% Annual Interest Loans, Monthly Payment = $37.31 for 10 yrs

d) 10% of Base Vehicle Retail Price after 10 yrs.

e) none

TABLE A-11. NET PRESENT VALUE OF THE COSTS OF OPERATING A 4 PAX HYBRID VEHICLE OVER A PERIOD OF 10 YEARS

Items	Net Present Value, $ (a)	Expenses (Credits), $.									
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)	4,363.19	1230.47	1230.47	1230.47	1230.47						
Battery Purchase (c)	4,133.29	535.28									
Taxes & Fees	1,494.93	193.60									
Repairs & Maintenance	1,729.67	224.00									
Insurance	1,235.48	160.00									
Parking & Tolls	1,544.35	200.00									
Fuel, Gasoline	518.90	67.20									
Fuel, Electric	988.38	128.00									
Sub-total	16,008.19										
Vehicle Salvage Value (d)	(257.84)										(420.)
Battery Salvage Value (é)	-										
TOTAL	15,750.35										

a) 5% Discount Rate

b) Base Vehicle Price = $4200, 48 month, 8% Annual Interest Purchase, Monthly Payment = $102.54 for 4 yrs.

c) Battery Price = $2200, 2 batteries purchased with 60 month, 8 % Annual Interest Loans, Monthly Payments = $ 44.61 for 10 yrs

d) 10% of Base Vehicle Price after 10 yrs.

e) none

TABLE A-12. NET PRESENT VALUE OF THE COSTS OF OPERATING A NEAR TERM 2 PAX ELECTRIC VEHICLE OVER A PERIOD OF 10 YEARS

Items	Net Present Value, $ (a)	Expenses (Credits), $.									
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)	4,778.74	1347.66	1347.66	1347.66	1347.66	-					
Battery Purchase (c)	1,014.56	131.39									
Taxes & Fees	1,189.15	154.00									
Repairs & Maintenance	617.74	80.00									
Insurance	772.17	100.00									
Parking & Tolls	965.22	125.00									
Fuel, Gasoline											
Fuel, Electric	656.35	85.00									
Sub-total	9,993.92										
Vehicle Salvage Value (d)	(282.40)										(460.)
Battery Salvage Value (e)	-										
TOTAL	9,711.52										

a) 5% Discount Rate

b) Base Vehicle Price = $4600, 48 Month, 8% Annual Interest Purchase, Monthly Payment = $112.30 for 4 yrs.

c) Battery Price = $540, 2 batteries purchased with 60 month, 8% Annual Interest Loans, Monthly Payment = $10.95 for 10 yrs.

d) 10% of Base Vehicle Price after 10 yrs.

e) none

TABLE A-13. NET PRESENT VALUE OF THE COSTS OF OPERATING A LOW PERFORMANCE 2 PAX ICE VEHICLE OVER A PERIOD OF 10 YEARS

Items	Net Present Value, $ (a)	Expenses (Credits), $									
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)	2,493.26	703.13	703.13	703.13	703.13						
Battery Purchase (c)											
Taxes & Fees	555.96	72.00									
Repairs & Maintenance	1,204.59	156.00									
Insurance	772.17	100.00									
Parking & Tolls	965.22	125.00									
Fuel, Gasoline	571.41	74.00									
Fuel, Electric											
Sub-total	6,562.62										
Vehicle Salvage Value (d)	-										
Battery Salvage Value (e)											
TOTAL	6,562.62										

a) 5% Discount Rate

b) Vehicle Price = $2400.00, 48 month, 8% Annual Interest Purchase, Monthly Payment = $58.59 for 4 yrs.

c) not applicable

d) none

e) not applicable

TABLE A-14. NET PRESENT VALUE OF THE COSTS OF OPERATING A LIGHT DUTY ICE VAN OVER A PERIOD OF 6 YEARS

Items	Net Present Value, $ (a)	Expenses (Credits), $									
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)	3,800.00										
Battery Purchase (c)											
Taxes & Fees	579.14	114.10									
Repairs & Maintenance	2,302.33	453.60									
Insurance	1,318.16	259.70									
Parking & Tolls	1,687.67	332.50									
Fuel, Gasoline	1,687.67	332.50									
Fuel, Electric											
Sub-total	11,374.96										
Vehicle Salvage Value (d)											
Battery Salvage Value (e)											
TOTAL	11,374.96										

a) 5% Discount Rate

b) Vehicle Purchase Price of $3,800, cash payment

c) not applicable

d) none

e) not applicable

TABLE A-15. NET PRESENT VALUE OF THE COSTS OF OPERATING A LIGHT DUTY ELECTRIC VAN OVER A PERIOD OF 6 YEARS

Items	Net Present Value, $ (a)	Expenses (Credits), $.									
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)	3,700.00										
Battery Purchase (c) Battery 1	2,360.00										
Battery 2	1,849.12					2,360.					
Taxes & Fees	923.78	182.00									
Repairs & Maintenance	532.95	105.00									
Insurance	1,318.16	259.70									
Parking & Tolls	1,687.67	332.50									
Fuel, Gasoline											
Fuel, Electric	373.06	73.50									
Sub-total	12,744.74										
Vehicle Salvage Value (d)	(1,104.40)						(1,480)				
Battery Salvage Value (e)	(1,408.85)						(1,888.)				
TOTAL	10,231.49										

a) 5% Discount Rate

b) Vehicle, Base, Purchase Price= $3700.00, cash payment

c) Battery Price = $2,360.00, 2 batteries purchased with cash payments

d) Vehicle Salvage Value of 40% Base Vehicle Retail Price after 6 yrs of use

e) 80% of initial price of Battery 2 after one yr of use of this battery

The hybrid was the most expensive 4 PAX vehicle with an ownership cost of about $15,800.

The near term 2 PAX electric vehicle was about 50% more expensive than the comparable low performance 2 PAX ICE vehicle.

The ICE van was about $800 more expensive over the assumed 6 year life than the electric van.

The net present value of the life cycle costs per kilometer of use for each of these vehicles is lower than the life cycle costs based on average annual use. This is to be expected since future costs are discounted. For any vehicle class the ratio of net present value of unit costs to the average annual value unit costs is essentially the same for all vehicles in the class. For the passenger vehicles considered over a 10 year period the net present value of the costs per kilometer is approximately 72% of the annual average life cycle operating costs for all the vehicles. For the vans, which were compared over a 6 year period, a larger ratio of 0.80 $\pm$ 0.01 was found.

The purpose of the calculations presented in the study was to compare relative costs of ownership of a given class of electric or hybrid vehicles to those of comparable ICE vehicles. The same comparative costs are obtained whether these costs are treated on an annual average cost basis or a net present value cost basis. The conclusions as to the relative costs of the ICE and electric vehicles do not vary with the method of calculation.

In this study, costs are compared on an average annual cost basis as described in the previous section, unless otherwise specified.

2.3 NET PRESENT VALUE OF COSTS OF ELECTRIC VAN ASSUMING REA FINANCING

The net present value of the life cycle costs of operating an electric van assuming REA financing is calculated in this section. Instead of purchasing the electric van on a cash basis, as shown in Table A-15, it was assumed that the initial purchase (base vehicle and battery) would be financed by either a 5% or 2% REA loan, in an inflationary period with a 5% annual inflation rate. All other assumptions inherent in the cost calculations presented in Table A-15 are retained.

The effective interest rate of an REA loan in constant dollars is lower than its apparent interest rate due to the devaluation of future payments as a result of inflation. Assuming a 5% inflation rate, a 5% loan is eventually an interest-free loan in constant dollars; and a 2% loan effectively results in a subsidy.

The net present value, in constant dollars, of the costs of owning an electric van, assuming 2% or 5% current dollar financing, is presented in Tables A-16 and A-17. Five equal current dollar annual payments are assumed for the purchase of the vehicle and initial battery. The annual payments shown in Tables A-16 and A-17 include a correction for an annual inflation of 5%. The net present value of the cost of the loans, in constant dollars, involves two discounting operations; the first reflects inflation, the second the earning power of money.

A.3 STRUCTURE OF THE PRICE OF AN AUTOMOBILE

As outlined in Figure A-3, the price structure of an automobile can be considered to consist of the following elements:

a) the manufacturing cost which represents the direct costs of making the vehicle and is further discussed below.

b) the unit wholesale price which is the price the manufacturer receives for a vehicle. The unit wholesale price includes manufacturing costs, as well as indirect costs not associated with the manufacturing facility. The unit wholesale price includes a return on the capital investment in land, buildings, equipment and special tools as well as corporate overhead and profit.

c) the retail price which is the amount of money an individual consumer pays for a vehicle. This price includes the wholesale selling price marked up by the dealer to cover the costs of distribution, transportation, delivery, other costs of operations and his profit.

TABLE A-16. NET PRESENT VALUE OF THE COSTS OF OPERATING A LIGHT DUTY ELECTRIC VAN OVER A PERIOD OF 6 YEARS WITH A 2% INTEREST, CURRENT DOLLAR LOAN

Items	Net Present Value, $ (a)	Expenses (Credits), $.									
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)	2,948.17	746.21	709.27	675.49	643.35	612.69					
Battery Purchase (c) Battery 1	1,880.46	477.78	454.13	432.50	411.92	392.29					
Battery 2	1,849.12						2,360.				
Taxes & Fees	923.78	182.00									
Repairs & Maintenance	532.95	105.00									
Insurance	1,318.16	259.70									
Parking & Tolls	1,687.67	332.50									
Fuel, Gasoline											
Fuel, Electric	373.06	73.50									
Sub-total	11,513.37										
Vehicle Salvage Value (d)	(1,104.40)						(1,480.)				
Battery Salvage Value (é)	(1,408.85)						(1,888.)				
TOTAL	9,000.12										

a) 5% Discount Rate

b) Base Vehicle Purchase Price = $3700. Assume 2% Financing for 5 yrs, with 5% Annual Inflation. Current Dollar Annual Payment = $781.99

c) Battery Price = $2360, Battery 1 purchased in same manner as base vehicle. Current Dollar Annual Payment= $500.69 Battery 2 purchased cash in 6th year.

d) Vehicle Salvage Value of 40% Base Vehicle Retail Price after 6 yrs of use. e) 80% of initial price of Battery 2 after one year of use

TABLE A-17. NET PRESENT VALUE OF THE COSTS OF OPERATING A LIGHT DUTY ELECTRIC VAN OVER A PERIOD OF 6 YEARS WITH A 5% INTEREST, CURRENT DOLLAR LOAN

Items		Net Present Value, $ (a)	Expenses (Credits), $.									
			Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Vehicle Purchase (b)		3203.84	813.92	775.12	738.20	703.08	669.58					
Battery Purchase (c)	Battery 1	2043.52	519.15	494.40	470.85	448.45	427.08					
	Battery 2	1849.12						2,360.				
Taxes & Fees		923.78	182.00									
Repairs & Maintenance		532.95	105.00									
Insurance		1318.16	259.70									
Parking & Tolls		1687.67	332.50									
Fuel, Gasoline												
Fuel, Electric		373.06	73.50									
Sub-total		11932.10										
Vehicle Salvage Value (d)		(1104.40)						(1,480)				
Battery Salvage Value (e)		(1408.85)						(1,888)				
TOTAL		9418.85										

a) 5% Discount Rate

b) Base Vehicle Purchase Price = $3700. Assume 5% Financing for 5 yrs, with 5% Annual Inflation. Current Dollar Annual Payment = $854.60

c) Battery Price = $2360, Battery 1 purchased in same manner as base vehicle. Current Dollar Annual Payment = $ 545.10 Battery 2 purchased cash in 6th year.

d) Vehicle Salvage value of 40% Base Vehicle Retail Price after 6 yrs of Use.

e) 80% of initial price of Battery 2 after one yr of use

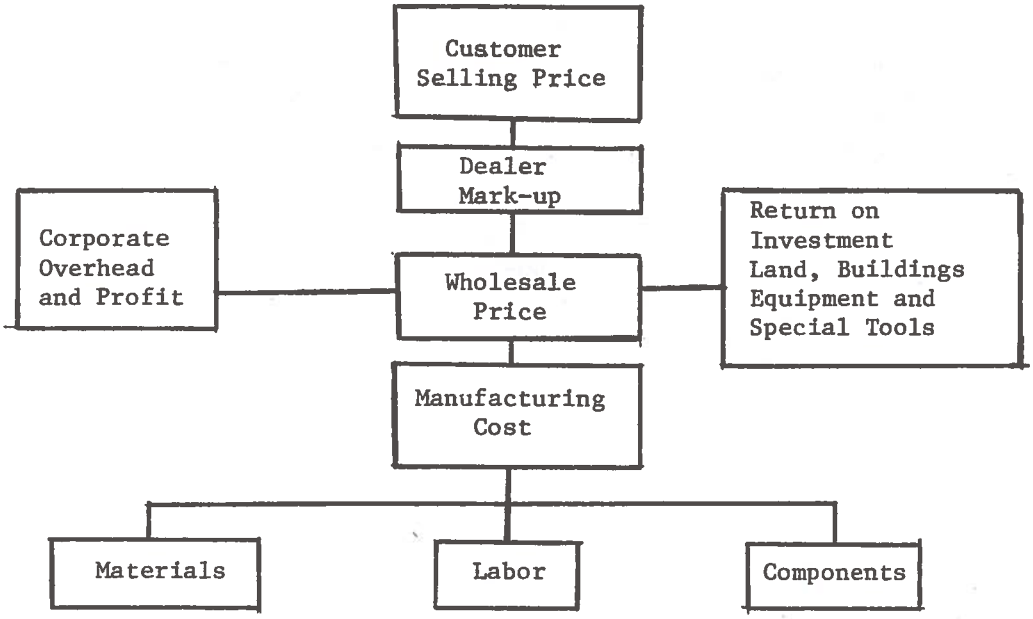


FIGURE A-3. SIMPLIFIED MANUFACTURING COST STRUCTURE FOR AUTOMOTIVE VEHICLES

In comparing the costs and prices of internal combustion engine (I.C.E.) vehicles and electric vehicles, it was considered that while the manufacturing cost elements would be different for the two types of vehicles, the remainder of the cost/price structure would not be a function of the type of vehicle considered. Under otherwise similar conditions, these would be the same for both types of vehicles. Indirect costs and profits would be a function of the nature of the enterprises involved and their methods of operations.

The relationship between the direct manufacturing costs of an automobile and its retail price to the consumer is complex and dynamic. It depends on the type of vehicle being sold, its market potential and image, the type of dealership selling the car, and even the bargaining ability of the consumer purchasing the vehicle. However, on the average, some well established patterns exist in the relationship between the average direct manufacturing costs of an automobile and its average listed retail price ("sticker" price). Over the past few years, the Council on Wage and Price Stability has been publishing detailed information on the average cost/price structure of American automobiles. (A-8) This information was used to develop ratios which relate the direct manufacturing costs of a vehicle in 1975 to its nominal retail price in 1977. These ratios are presented in Table A-18. Manufacturing costs were calculated in 1975 dollars in order to utilize the data on manufacturing costs previously collected and described in the TSC report. (A-9) Current retail prices are used in order to compare the estimated sticker price of the 1977 Chevette Scooter, unless otherwise stated.

The costs and prices considered in the present report are those of the base vehicles without options (except for an AM radio on the Honda, as previously mentioned). It was considered that equipping the vehicles with optional components would distract from the thrust of the cost analysis which was to compare the economics of an electric or hybrid vehicle to that of a competitive ICE vehicle.

A.4 DIRECT MANUFACTURING COST ESTIMATES

For purposes of estimating direct manufacturing costs, a vehicle was assumed to consist of four parts:

a) the power source

b) the transmission

c) the suspension structure

d) the occupant structure

As discussed in the TSC report, the power source of an ICE vehicle consists of the engine and its accessories, including the fuel system. The power source of an electric vehicle consists of the battery pack, motor, and control elements.

The transmission is the mechanism which transfers the power from the power source to the wheels of the vehicle. In the present analysis, the same transmission characteristics were assumed for equivalent ICE and electric vehicles.

TABLE A-18. AUTOMOTIVE COST-PRICE RATIOS BASED ON COUNCIL OF WAGE/PRICE STABILITY DATA

Ratio	Year	All Automobiles	Sub-Compact Automobiles	Compact Automobiles
Direct Manufacturing Cost / Manufacturers' Total Costs	1975	0.805 - - - - - - - - - - - - - - - - - -		
Manufacturers' Total Costs / Wholesale Price	1975	0.976 - - - - - - - - - - - - - - - - - -		
Wholesale Price / Customer Selling Price	1975	0.794	0.855	0.846
1975 Customer Selling Price / 1977 Customer Selling Price	1975/1977	0.914	0.903	0.871
1975 Direct Manufacturing Cost / 1977 Customer Selling Price		0.57	0.61	0.58
or				
1977 Customer Selling Price / 1975 Direct Manufacturing Cost		1.75	1.65	1.73

Source: Executive Office of the President, Council on Wage and Price Stability, Washington, D.C.

a) CWPS - 203, "1977 Automobile Prices," Oct. 27, 1976.

b) CWPS - 122, "1976 Automobile Prices Update," Jan. 12, 1976.

c) CWPS - 102, "1976 Automobile Prices," Nov. 11, 1975.

The suspension structure consists of the system needed to support a vehicle and make it roadworthy. As a first approximation, it was assumed that for a given vehicle, the weight of the suspension system is equal to 15 percent of nominal gross vehicle weight. (A-10)

The occupant structure consists of the balance of the vehicle. The occupant structures of equivalent purpose ICE and electric vehicles were assumed to be the same.

This led to the consideration that the costs of comparable ICE and electric vehicles would differ only to the extent that the costs of their power generating equipment and suspension structure differed.

The weights and costs of the above elements for the Chevette and for the five model passenger automobiles of interest to the study are summarized in Table A-19. The sum of the cost of the major vehicle parts are the direct manufacturing cost of the vehicles; retail prices are derived from these manufacturing costs. These results are also given in Table A-2. Retail price estimates rounded to the nearest $100 are also given in Table A-1. The methodology for each vehicle is further discussed in the subsequent sections.

A.5 MANUFACTURING COST ESTIMATES OF PASSENGER VEHICLES

A.5.1 Reference Case - 1977 Chevette Scooter

The initial step in the analysis was to estimate the manufacturing costs of the various components of the 1977 Chevette Scooter equipped with a 98 CID engine for use in California. The current manufacturer's recommended sticker price for this automobile is $3054. Based on this price and using the information presented in Table A-18, a 1975 direct manufacturing cost estimate of $1857 was obtained for this vehicle.

The second step in the analysis was to identify and cost the power generating equipment. Lacking specific data on the weight of various components of the Chevette, the values developed

TABLE A-19. ESTIMATED WEIGHT, MANUFACTURING COST AND RETAIL PRICE OF MODEL PASSENGER AUTOMOBILES AND OF THE CHEVETTE SCOOTER

	ICE VEHICLES			ELECTRIC VEHICLES		
	Chevette Scooter (Reference Auto)	Low Performance 2 PAX	Low Performance 4 PAX	Near Term 2 PAX	Intermediate 4 PAX	Hybrid
Weights kg (lb)						
Gross Vehicle Weight (GVW)	1268 (2783)	801 (1765)	1199 (2640)	1190 (2622)	1515 (3660)	1866 (4113)
Curb Weight	933 (2057)	623 (1372)	867 (1908)	1012 (2229)	1193 (2628)	1534 (3381)
Support Structure Weight (0.15 GVW)	189 (417)	120 (265)	180 (396)	178 (393)	229 (504)	280 (617)
Power Source Weight						
Battery				355 (781)	298 (657)	358 (789)
Motor				52 (115)	98 (210)	162 (269)
Controller				15 (33)	28 (61)	35 (76)
Generator						162 (269)
ICE (Wet Weight)	200 (440)	89 (195)	150 (330)			74 (164)
Weight Occupant Structure	543 (1196)	412 (907)	543 (1196)	412 (907)	543 (1196)	543 (1197)
Estimated Manufacturing Costs (1975 $)						
Occupant and Support Structures						
Chevette Occupant Structure						
Chevette Support Structure	1375	1375	1375	1375	1375	1375
Modification to Chevette Occupant Structure		(153)		(153)		
Modifications to Chevette Support Structure		(40)	(3)	(4)	13	30
Power Source (without battery)						
Motor (Motor/Generator)				925	242	618
Controller				640	145	371
ICE	482	260	410			210
Total Manufacturing Cost	1857	1442	1782	2783	1775	2550
Estimated Retail Price (1977 $)						
Base Vehicle	3054	2371	2930	4577	2919	4182
Battery Pack				540	1840	2209
Vehicle with Battery Pack	3054	2371	2930	5117	4759	6391

for the weight and cost of the power generation system of the model 908 kg (2000 lb) 4-passenger ICE vehicle in Appendix I of the TSC study are used. (A-11) The Chevette Scooter with a curb weight of 933 kg (2057 lb) is a closely analogous automobile. According to the quoted report, the power generating system weighs 200 kg (440 lb) (on a wet basis, which includes fuel, lubricants and coolants) and has a 1975 manufacturing cost of $482. By difference, the cost of the Chevette occupant, transmission and support structures is $1375.00

A.5.2 <u>Cost of the 4 PAX Electric Vehicle</u>

The model 4-passenger intermediate technology electric vehicle proposed by GRC has a curb weight of 1192 kg (2628 lb) which includes 298 kg (657 lb) of nickel-zinc batteries. With 4 passengers and 60 kg (132 lb) of luggage, this vehicle has a GVW of 1515 kg (3360 lb). Using 0.15 GVW factor for the support and suspension structure, a weight of 229 kg (504 lb) is calculated for this group, or 40 kg (87 lb) more than the support structure of the Chevette. The weight of the occupant structure and transmission of this electric vehicle is assumed to be that of the Chevette 543 kg (1196 lb). Subtracting the weight of the identified components from the curb weight of the vehicle, a combined weight of 123 kg (271 lb) for the electric motor and controller is obtained (This is slightly more than the combined weight of 115 kg (252 lb) for the motor and controller developed in GRC's estimate.) The electric motor represents about 75 percent to 80 percent of the combined weight, or approximately 98 kg (210 lb).

The estimated manufacturing cost of the base 4 passenger EV without batteries is assumed to be equal to the sum of the following:

a) <u>The Manufacturing Cost of the Chevette minus the cost of its power generation group</u>, or $1375.

b) <u>The additional costs incurred in making the heavier support structure of this vehicle as compared to the support structure of the Chevette</u>. It was assumed that the support structures of the two vehicles were of the same level of complexity to manufacture so that the only difference in direct costs was due to additional material requirements which were assumed to be steel. The labor component was assumed to be the same for both vehicles. The additional costs were thus the weight difference times the unit cost of steel which was taken as $0.33/kg ($0.15/lb). The additional cost of the support structure is thus (504-417)(0.15) = $13.

c) The cost of the motor and controller. The methodology developed in Appendix I of the TSC study was used to estimate the direct manufacturing costs for the mass production of the motor and controller. It was estimated that the motor of the 4 passenger E.V. would cost $242 (predicated on a unit weight cost of $2.53/kg ($1.15/lb)) and that the controller would cost $145 (60 percent of the cost of the motor).

Based on the above, the total direct manufacturing cost of this model 4 passenger electric vehicle is $1775, not including the cost of the battery pack.

The 1977 retail price of the model 4 passenger electric vehicle is obtained by multiplying the 1975 manufacturing cost by ratios, developed in Table A-18. This assumes that the ratio of 1977 retail price to the 1975 manufacturing cost is the same for all the passenger vehicles considered in the present study. The estimated retail price of the base 4 passenger electric vehicle is estimated at $2919. The price of the battery pack ($1840) is added to obtain the total vehicle retail price of $4759. The battery price is based on a battery weight of 298 kg (657 lb) and a unit retail price estimate of $6.16/kg ($2.80/lb) for nickel-zinc batteries. (Methodology for battery pack calculation is described in Section A.7 of this appendix.)

A.5.3 2-Passenger Near-Term Electric Vehicle

The estimate of the manufacturing cost of a 2-passenger near-term electric vehicle presented here was obtained by considering this vehicle as a smaller variant of the 4-passenger electric vehicle. GRC's assumptions as to gross vehicle weight, curb weight, motor weight, controller weight, and battery weight formed the basis of the estimate.

Based on a gross vehicle weight of 1190 kg (2622 lb), a support structure weight of 178 kg (393 lb) is obtained. This is 11 kg (24 lb) less than the weight of the support structure of the Chevette Scooter.

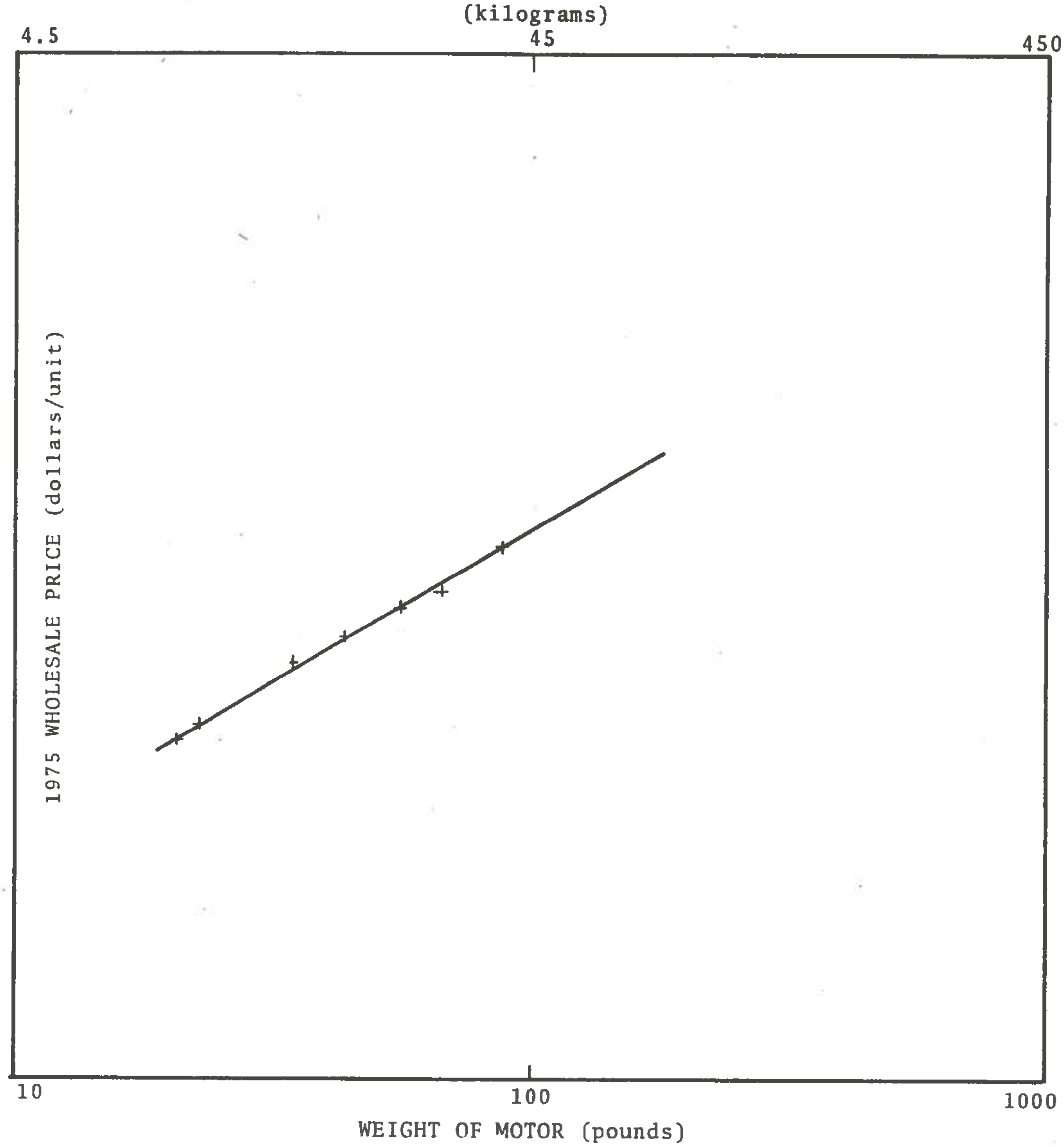
The weight of the power generation train is 422 kg (929 lb). It consists of a 355 kg (781 lb) lead-acid battery pack, a 52 kg (115 lb) motor and a 15 kg (33 lb) controller.

The weight of the occupant structure and transmission is 412 kg (907 lb). It is obtained by subtracting the weights of the support structure and the power generation train from the vehicle curb weight of 1012 kg (2229 lb). The occupant structure weighs 131 kg (289 lb) less than the occupant structure common to all of the 4-passenger vehicles.

The manufacturing cost of the occupant structure was obtained by adjusting the cost of the 4-passenger vehicle occupant structure in order to reflect the lighter weight and reduced complexity of the 2-passenger vehicle occupant structure. It was assumed that there would be a cost savings of $0.63/kg ($0.29/lb) because of the reduced weight, and an additional reduction of 5 percent of the total direct manufacturing cost of the Chevette occupant structure to reflect reduced costs of labor for fabrication and assembly. The value of $0.63/kg ($0.29/lb) is the average 1975 value of raw materials in a weight-conscious automobile developed in the Motor Vehicle Goals Study. (A-12) The manufacturing cost of the occupant structure is therefore $1375 - (289 x $0.29) - ($1375 x .05) = $1222.

The 11 kg (24 lb) reduction in the weight of the support structure compared to that of the Chevette results in a manufacturing cost savings of about $4.

The cost of the motor is based on Figure A-3 which presents the 1975 oem price of high performance electric traction motors as a function of their weight. Figure A-3 is based on Table F-3 of the TSC study. (A-13) This table presents the characteristics of



Source: U.S. DOT, Advisability of Regulating Electric Vehicles for Fuel Economy, Report to Congress and the President. (S.P. Powel III and N. Rosenberg, "The Advisability of Regulating Electric Vehicles for Energy Conservation," Report No. DOT-TSC-OST-76-36, August, 1976.) Table F-3.

FIGURE A-4. 1975 WHOLESALE PRICE OF HIGH PERFORMANCE ELECTRIC TRACTION MOTORS AS A FUNCTION OF MOTOR WEIGHT currently available electric motors which would be expected to be used on electric vehicles in the near-term. According to Figure A-3, a 52 kg (115 lb) motor would have a 1975 oem price of $925.

The cost of the controller is estimated to be $640. This assumes $200 for a 200-ampere switching transistor, and $240 for a DPDT contactor and $200 for other circuit elements.

The motor and controller costs for the near-term 2-passenger electric vehicle reflect the near-term cost of these components. They are not to be compared to the costs of the motor and controller of the intermediate four-passenger electric vehicle which assumed a totally different scale of production.

The estimated total manufacturing cost of the base 2-passenger near-term electric vehicle without batteries is the sum of the above or $2783.

Using the same ratio of retail price to manufacturing cost as was used for the Chevette (1.64x), an estimated retail price of $4577 is obtained for the base vehicle, without batteries. The lead-acid battery adds $540 to the retail price. The total retail price of this near-term vehicle is estimated to be $5117. The price of the lead-acid battery is based on a 1975 battery oem cost of $0.92/kg ($0.42/lb). Multiplying this unit cost by 1.64x results in a current retail price estimate of $1.52/kg ($0.69/lb).

On a mass production basis, the motor of the 2-passenger electric vehicle would only cost $1.15 x 115 = $132, with the controller costing $132 x 0.6 = $79. Under these circumstances the total manufacturing cost of the base vehicle is estimated to be $1430.

The resulting retail price of the base vehicle is estimated at $2352. Adding $540 for battery, a delivered vehicle price of $2892 is obtained. This is still $500 more than the low performance 2-passenger ICE vehicle.

A.5.4 Intermediate Technology 4-Passenger Hybrid

The estimated costs of the hybrid 4-passenger automobile were obtained by adapting information provided by GRC into the methodology used herein. The characteristics of this vehicle were provided by SRI.[A-15] This vehicle is a nickel-zinc battery powered electric vehicle that is provided with a small auxiliary internal combustion engine - electric generator system that is used to recharge the battery while the vehicle is in use. This extends the range of the vehicle. The hybrid vehicle consists of the occupant structure, electric drive motor controller, electric generator, ICE engine, a battery and support structure.

The weight of the occupant structure is assumed to be that of the Chevette, 543 kg (1196 lb). Using the methodology outlined in unpublished notes that were provided by GRC/SRI, (A-16) the weight of the other components were estimated as a fraction of the gross vehicle weight as shown in Table A-20. The gross vehicle weight is obtained by dividing the sum of the known weights of the occupant structure and of the payload by the sum of the weight fractions of the other components. As shown in Table A-20, an estimated GVW of 1866 kg (4113 lb) is obtained. The corresponding curb weight is 1534 kg (3381 lb). These weights are about 45 kg (100 lb) lighter than the weights calculated by SRI on which GRC's performance characteristics are based. This discrepancy can be neglected for costing purposes.

Based on the SRI calculations, a 197kW (24 HP) ICE engine is required. As discussed in a later section, it is estimated that this engine will have a displacement of about 590 cm^3 (36 in^3). and will have a maunufacturing cost of approximately $210.

The manufacturing costs of this vehicle are estimated from the sum of the following:

Chevette equivalent components	$1375
Additional support structure:	
91 kg x $0.33/kg	30
(200 lb) x ($0.15/lb)	

TABLE A-20. ESTIMATION OF WEIGHT OF COMPONENTS OF A MODEL HYBRID VEHICLE

Component	Weight Component / Gross Vehicle Weight	Source	Known Weights kg (lb)	Estimated Component Weight, kg (lb)
Electric Motor	0.0655	SRI/GRC		122(269)
Electric Generator	0.0652	SRI/GRC		122(269)
ICE Engine (Dry Weight)	0.0259	SRI/GRC		48(106)
NiZn Battery	0.192	SRI/GRC		358(789)
Electric Control System	0.0185	TSC EST		35(77)
Fuel/Lubricant for ICE	0.0141	TSC EST		26(57)
Suspension Structure	0.15	TSC EST		280(617)
Sub-Total	0.531			
Occupant Structure			543(1197)	543(1197)
Curb Weight				1534(3381)
Payload			332(732)	332(732)
Sub-Total			875(1929)	
Gross vehicle weight			$\frac{875(1929)}{(1-0.531)}$ =	1866(4113)

Motor/generator:	244 kg x $2.53/kg (537 lb) x ($1.15/lb)	618
Controller:	60% of motor/generator	317
36 CID ICE Engine (See Figure A-5)		210
	Total Manufacturing Cost	$2550

Using the same mark up factor as for the Chevette Scooter, a retail price estimate of $4182 is obtained. The 358 kg (789 lb) nickel-zinc battery pack increases this retail price by $2209 to a total of $6391.

A.5.5 Low Performance 4 Passenger ICE

The horsepower-to-vehicle weight (curb weight and 1-passenger) ratio of the Chevette is 0.442 kw/kg (0.0276 HP/lb), which allows the vehicle to accelerate 48 km/h (30 mi/hr) in 5 sec. A 4-passenger ICE vehicle with the acceleration characteristics of the model advanced 4-passenger electric vehicle designed by GRC would require a horsepower-to-vehicle weight (curb weight and 1-passenger) ratio of only 0.0215 HP/lb. A 4-passenger ICE vehicle with the same occupant structure and transmission (which weighs 543 kg (1197 lb)), pay load 332 kg (732 lb), and acceleration characteristics as the 4-passenger electric vehicle, would have a 45-HP engine and a gross vehicle weight of 1199 kg (2640 lb). The engine has a displacement of 65 CID (1065 cm^3), and will weigh 150 kg (330 lb) according to Figure A-4. The support structure of this vehicle would be (2640) (0.15) = 396 lb (180 kg), or 21 lb (10 kg) less than that of the Chevette. This vehicle would have an estimated fuel economy of 17.5 km/l (41 mpg).

The 1975 manufacturing cost of this low performance 4-passenger ICE vehicle is estimated to be the sum of the following:

Chevette occupant structure, support structure and transmission	$1375
Modified suspension structure	(3)
65 CID Air Cooled ICE (see Figure A-5)	410
Total manufacturing cost	$1782

Using the same ratio of 1977 retail price to 1975 manufacturing cost as for the Chevette, an estimated 1977 retail price of $2930 is obtained for the vehicle.

A.5.6 Low Performance 2-Passenger ICE

According to Withjack, a 2-passenger ICE vehicle with the same acceleration characteristics as the near-term 2-passenger electric vehicle would have a horsepower-to-vehicle weight ratio (curb weight and 1-passenger) of 0.0309kw/kg (0.0188 HP/1b).[(A-17)] This vehicle,which would also have the same occupant structure, transmission, and payload would be powered by a 29 HP/43.5 CID engine and have a gross vehicle weight of 801 kg (1976 lb). Based on Figure A-4 it is estimated that the ICE will weigh 89 kg (195 lb). Based on Figure A-5, it will have an estimated manufacturing cost of $260.

The suspension and support structure for the vehicle would weigh (1765) (0.15) = 120 kg (265 lb). This is 69 kg (151 lb) less than for the Chevette.

Total 1975 manufacturing cost of this vehicle is obtained as the sum of the following:

Chevette occupant structure, transmission, support structure	$1375
Modified structure (same as 2 PAX/EV)	(153)
Modified support structure	(40)
43.5 CID air-cooled ICE	260
Total	$1442

Using the same ratio of 1977 retail price to 1975 manufacturing cost as was used for the Chevette, the estimated 1977 retail price of the vehicle is $2371.

A.6 MANUFACTURING COST ESTIMATES OF LIGHT DUTY VANS

The manufacturing costs of both the intermediate technology electric light duty van, without batteries, and of the equivalent function ICE van, were the values developed in a TSC Study. (A-14)

According to this study, an electric van in mass production, would have a 1975 manufacturing cost of $2045 not including the battery. The ICE van, assumed to be a 1/4 ton postal delivery van, such as AMC's DJ-5C Jeep, has an estimated 1975 manufacturing cost of $2077.

The estimated customer retail prices of these vans were obtained by multiplying those costs by 1.73, the 1977 customer selling price/1975 direct manufacturer cost ratio obtained for compact automobiles in Table A-18. This ratio is slightly larger than the ratio used for the passenger automobiles of interest to the study which were treated as subcompact automobiles.

The 1977 customer retail price of the ICE van is estimated to be $3726. Based on a retail price estimate of $6.16/kg ($2.80/lb) for nickel-zinc batteries, the 382 kg (842 lb) battery pack adds $2358 to the retail price. The customer acquisition price of the electric van equipped with its battery is estimated to be $6083.

A.7 MANUFACTURING COST ESTIMATES OF SPECIFIC COMPONENTS

A.7.1 Estimated Price of Nickel-Zinc Batteries

The estimated price of the nickel-zinc batteries in mass production that would be used to power the intermediate vehicles was based on the cost structure of lead-acid battery manufacture, adjusted for the differences in cost of materials.

The current retail price of lead-acid batteries is approximately $1.54/kg ($0.70/lb). This price has not changed significantly in the past few years. It was previously established that the 1975 oem price of lead-acid batteries was $0.92/kg ($0.42/lb). Based on industry average data published in the 1972 Census of Manufacturers, the oem price consisted of the following elements. (A-18)

Materials	52%
Labor	22%
Overhead and Profit	26%

Assuming the same cost structure to hold in 1976, based on a $0.92/kg ($0.42/lb) OEM price, the 1975 manufacturing cost of a lead-acid battery could be restated as follows:

		$/lb
Materials (52%) ($0.42/lb)		0.22
Labor (22%) (0.42/lb)		0.09
	Sub Total	$0.31
Overhead and Profit (26%) ($0.42/lb)		0.11
	Total	$0.42

Labor and materials represent 74 percent of the manufacturer's price. Overhead and profit which represent 26 percent of the manufacturer's price can be restated as being equal to 35 percent of the cost of labor and materials.

The composition of a typical nickel-zinc battery is presented in Table A-21, as are the unit prices of the contained materials. Depending on the form of nickel used, there can be a significant variation in the materials cost of this battery. If nickel oxide is used, in which contained Ni is worth $5.51/kg ($2.50/lb), an average materials cost of $2.27/kg ($1.03 lb) is obtained. If nickel is used as a mill product, its cost then rises to $8.84/kg ($4.00/lb), and the average material costs of the battery is then $3.33/kg ($1.51/lb).

Based on these two material cost estimates, calculation of the estimated price range of a nickel-zinc battery are presented in Table A-22. The cost of labor is assumed to be the same as for lead-acid battery manufacture. Depending on whether the two batteries are compared on an equivalent energy storage basis or an equivalent weight basis, labor cost estimate of $0.07/kg (0.03/lb) to $0.20/kg ($0.09/lb) is obtained for the nickel-zinc battery. The same overhead and profit markup factor (0.35) that was derived for lead-acid battery manufacture was used to calculate the oem price estimates of the nickel-zinc battery. These range from $3.15/kg ($1.43/lb) to $4.76/kg ($2.16/lb). The range of the estimated retail prices was obtained by multiplying the oem price estimated by the ratio of retail price to oem price previously found for a lead-acid battery, which is equal to 1.75.

The retail price estimates ranged from \$5.51/kg (\$2.50/lb) to \$8.33/kg (\$3.78/lb). It is unlikely that the most expensive form of nickel will be used when nickel-zinc batteries are mass produced. It is believed that techniques will be developed to utilize nickel oxide as the source of nickel, but with some slight additional costs over the price given in Table A-22. Based on this presumption, an estimated retail price of \$6.17/kg (\$2.80/lb) for a nickel-zinc battery was used in the vehicle cost calculations.

TABLE A-21. MATERIAL COMPOSITION AND COSTS FOR A NICKEL-ZINC BATTERY

Component	Weight, A kg (lb)	Unit Price, B \$/kg (\$/lb)	A X B
Nickel	164 (362)	8.83 (4.00)[a]	1,448[a]
		5.65 (2.56)[b]	927[b]
Zinc Oxide	149 (328)	0.95 (0.43)	141
Potassium Hydroxide	49 (109)	0.36 (0.16)	17.40
Copper	5 (11)	1.56 (0.71)	7.80
Water	91 (200)	-	
Plastics	36 (80)	0.78 (0.35)	28
Totals	494 (1090)		1642[a]
			1121[b]
		Cost per kg (lb) of battery	\$3.32 (\$1.51)[a]
			\$2.27 (\$1.03)[b]

[a]Nickel Plate
[b]Nickel in Nickel Oxide

TABLE A-22. ESTIMATED PRICE RANGE OF NICKEL-ZINC BATTERY IN MASS PRODUCTION (1977)

Assumption	Ni as NiO $/kg	($/lb)	Elemental Nickel $/kg	$/lb
Cost of materials	2.27	(1.03)		3.32 (1.51)
Cost of labor (same as Pb-Acid)	.07- .20	(0.03-0.09)	.07- .20	(0.03-0.09)
Sub-total	2.34-2.47	(1.06-1.12)	3.39-3.52	(1.54-1.60)
Overhead and profit @ 35% L&M	.81- .86	(0.37-0.39)	1.19-1.23	(0.54-0.56)
Manufacturer's oem price	3.15-3.32	(1.43-1.51)	4.58-4.75	(2.08-2.16)
Estimated Retail Price 1975 (1.75) (oem)	5.50-5.81	(2.50-2.64)	8.01-8.32	(3.64-3.78)

A.7.2 Scrap Value of Batteries

It was assumed that the batteries had a negligible scrap value in calculating vehicle life cycle costs, as far as the vehicle operator is concerned. This assumption is well substantiated for lead-acid batteries for which there is an existing secondary market, and most probably will be valid as well for nickel-zinc batteries.

A.7.2.1 Lead-Acid Battery

The near-term electric vehicle is equipped with a 355 kg (781 lb) lead-acid battery that had an assumed retail price of $540 or 69¢/lb. On June 24, 1977, depending on the locality, the dealer buying price for desired whole lead batteries ranged from 2¢/lb to 5¢/lb, delivered to the scrap yard. (A-19) Based on an electrolyte content of 28% (A-20), the above battery has a drained weight of 256 kg (562 lb). Its present scrap value would range from $11.24 to $28.10. The scrap value of this battery is approximately 2 percent to 5 percent of its initial retail price.

It is to be noted that the scrap value of a drained battery is lower than purer forms of scrap lead, such as heavy soft lead which has a scrap value of 13¢/lb to 20¢/lb, because of the associated processing costs needed to recover the lead from the battery.

A.7.2.2 Nickel-Zinc Battery

There is presently no established scrap market for used nickel-zinc batteries. While nickel batteries are expected to have a higher scrap value than lead-acid batteries, this scrap value will still represent only a small fraction (possibly 10% to 20%) of the initial cost of these batteries. It is considered that the potential salvage value of these batteries is less than the uncertainties presently associated with their first costs, which vary by over 30%, and thus would not have any substantial effect on the costs of electric vehicles considered in the study.

A maximum price for a scrap nickel battery can be estimated on the basis of the scrap nickel, zinc and copper content of these batteries and current scrap prices for these metals as shown in Table A-23. Insofar as the listed scrap prices of the metals are for clean, segregated metals, the estimates of 36¢/lb to 54¢/lb for the scrap value of a nickel-zinc battery, are too high. It would be more realistic to assess the salvage value of this battery at 20¢/lb to 30¢/lb.

TABLE A-23. MAXIMUM SALVAGE VALUE OF NICKEL-ZINC BATTERY

Metal	Weight Fraction of Metal based on Total Battery Weight (a)	Nominal Scrap Dealer's Buying Price, ¢/lb (b)	Value ¢/lb
Nickel	0.33	105 - 155 (c)	35-51
Zinc	0.24	4 - 13 (d)	1-3
Copper	0.01	31 - 43 (e)	<1
			36-54

a) Based on metal content presented in Table A-6.

b) Dealers' Buying Price, Delivered to Yard, June 24, 1977, (Reference: American Metal Market, 85 (123), June 27, 1977, p. 27).

c) Price for New Nickel Clips and Solids.

d) Price for Old Scrap Zinc.

e) Price for Light Copper Scrap.

A.7.3 ICE Engines for Low Performance Vehicles

The reasoning used to arrive at the weight and costs of the low performance ICE engines used in the 2-passenger low performance ICE, 4-passenger low performance ICE and 4-passenger hybrid vehicles is discussed in this section.

The weight of the ICE power generation train of nine automotive vehicles is presented as a function of the engine displacement in Figure A-5. These data are based upon Table 5B-4 of the Motor Vehicle Goals Task Force Report. (A-21) The weight includes the weight of the engine, fuel system and fuel, exhaust and electrical system listed in the referenced table. The referenced engines are all water cooled.

The weights of smaller 1 cylinder air cooled engines sold by a major retail chain are also presented as a function of their CID in Figure A-5. (A-22) These weights include the weight of fuel when the gas tank is filled.

The ICE engines of interest in the present study have a larger displacement than the small air cooled engines and a smaller displacement than the relatively large water cooled automotive engines depicted in Figure A-5. By interpolation, the weight of the engines of interest will be somewhere in the shaded triangular area depicted in Figure A-5.

It was assumed that the low performance vehicles and the hybrid vehicle would most probably have air cooled engines and that the weight of the ICE power generation system could be represented by the double dashed line in Figure A-4. These engines would have a power output of .305 kW/cc (0.67 HP/CID.[A-17] These engines would be improved versions of the air cooled engines that powered small European cars about twenty years ago. Examples of the latter would be the following.

VW engines: a) 1131 cc (68 CID), 224 kW (30 HP); b) 1192 cc (72 CID), 268 kW (36 HP); c) 1200 cc (72.5 CID), 298 kW (40 HP), d) 1300 cc-(78.6 CID) 373 kW (50 HP).

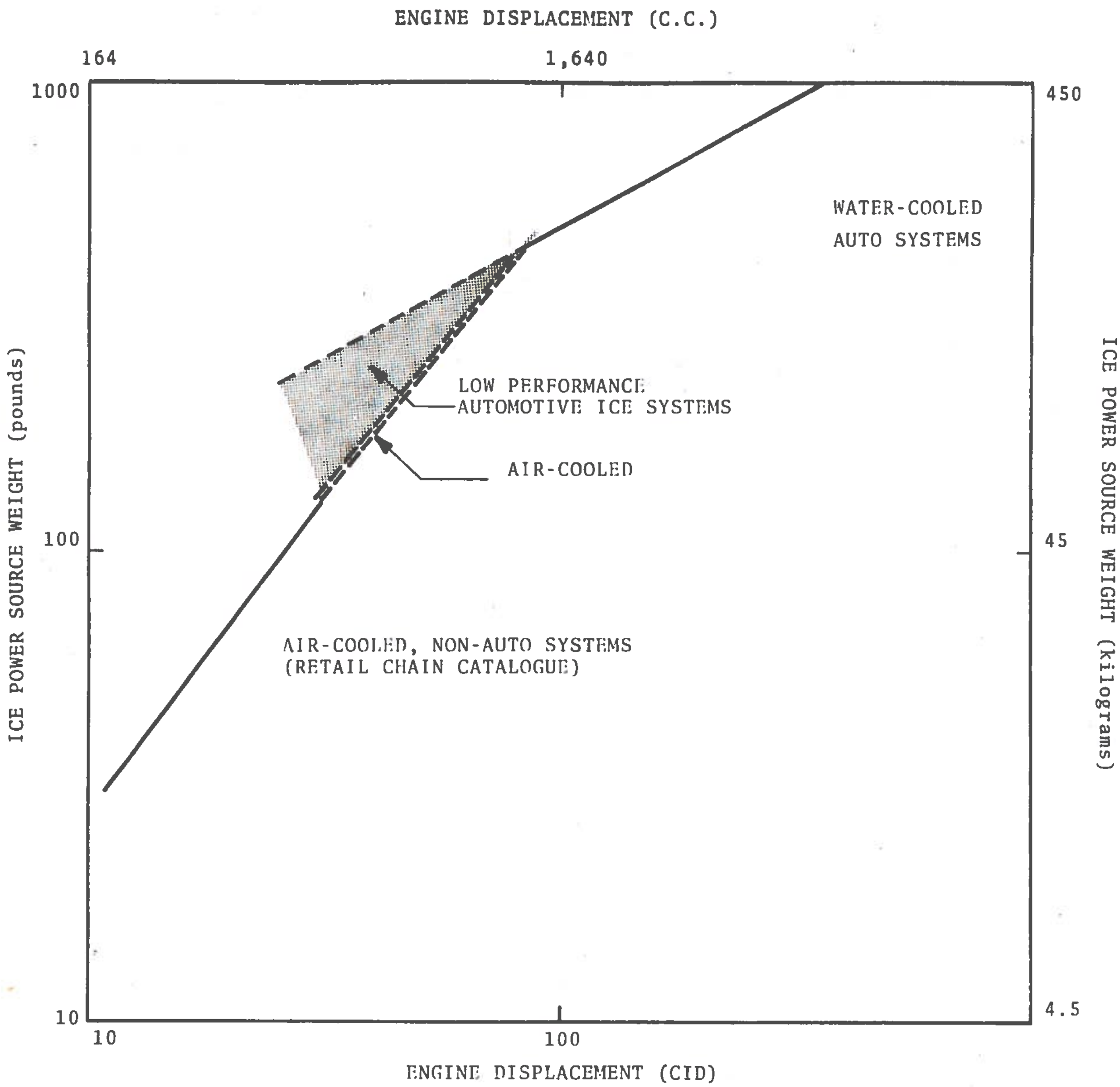


FIGURE A-5. AIR-COOLED, NON-AUTO SYSTEMS (SRC CATALOGUE)

Based on the above, the weight of the 17.9 kW (24 HP) 590 cc (36 CID) ICE engine system for the 4-passenger hybrid vehicle would be 70 kg (155 lb). This agrees quite closely with the 73.8 kg (164 lbs) estimate based on the SRI calculations, adjusted for the weight of fuel and lubricants.

The 22.4 kW (30 HP) 737 cc (45 CID) ICE engine system for the low performance 2-passenger vehicle would weigh 95 kg (210 lb). The 32.1 kW (43 HP) 1065 cc (65 CID) ICE engine system for the low performance 4-passenger vehicle would weigh about 150 kg (330 lb).

The 1977 catalogue retail prices of the low CID air cooled engines of a major retail chain are presented as a function of engine displacement in Figure A-6. As can be seen in the figure, there is a good correlation between unit price and engine CID. A first order approximation of the 1975 manufacturing cost of these engines is obtained by dividing these numbers by an appropriate ratio. Based on experience with other products of similar nature sold by this chain, this factor is approximately 1.9.

As shown in this figure, the 1975 manufacturing cost estimate for the air cooled ICE engines and associated equipment for the three vehicles of interest are:

Hybrid	$210
L.P. 2-passenger	$260
L.P. 4-passenger	$410

The estimated cost of the Chevette engine is also presented for reference in Figure A-6.

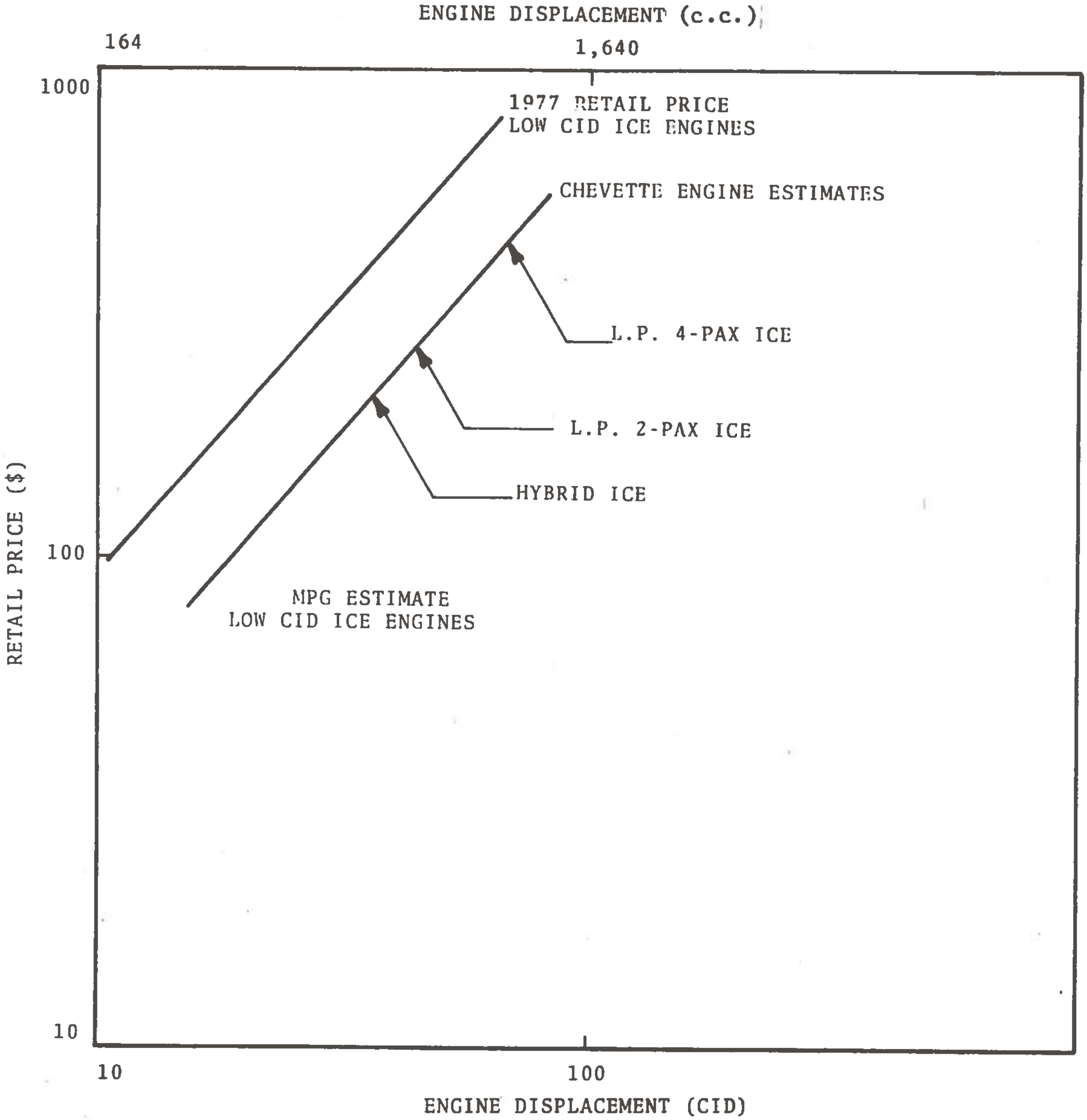


FIGURE A-6. 1977 RETAIL PRICE - LOW CID, ICE ENGINES

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APPENDIX B

IMPACTS OF REGULATION AND TAXES ON THE WEIGHT AND COST OF ELECTRIC VEHICLES

B.1. IMPACT OF ADDITIONAL CHASSIS WEIGHT ON COST OF ELECTRIC AND ICE VEHICLES

Increasing the weight of the chassis of a vehicle by a given amount is more detrimental to an electric vehicle than to an ICE vehicle. This is due to the fact that the weight of the power generating group is a much greater fraction of the gross vehicle weight for an electric vehicle than for an ICE vehicle. Furthermore, the unit cost of the power generating group is much higher for an electric vehicle than for an ICE vehicle.

Increasing chassis weight increases both first costs and operating costs for both electric and ICE vehicles, but not proportionately.

It can be assumed that the performance characteristics (acceleration and range) of a vehicle are a function of the ratio of the weight of the power generation group to the gross vehicle weight, and of the ratio of the weight of the suspension and structure group to the gross vehicle weight. Increasing the occupant structure weight of a vehicle results in further increases in the weight of the power generation group and the suspension and structure group in order to maintain the same performance characteristics. Since the vehicle mass would be increased, fuel economy would be decreased. For purposes of this discussion it can be assumed that fuel economy is inversely proportional to gross vehicle weight.

The above can be exemplified by calculating the effects of increasing the chassis weight by 45 kg (100 lb) on the first costs and life cycle costs of competing electric and ICE vehicles, while keeping vehicle performance characteristics constant.

In Appendix A, the characteristics and costs of owning and operating an intermediate technology 4-passenger electric vehicle and a Chevette Scooter are presented. Key characteristics of these vehicles that are of interest to the present discussion are summarized in Table B-1.

TABLE B-1. CHARACTERISTICS OF REFERENCE ELECTRIC AND ICE 4-PASSENGER VEHICLES

	Electric	ICE
Gross Vehicle Weight, kg (lbs)	1523 (3355)	1264 (2783)
Weight Fraction, Support/Suspension Group	0.15	0.15
Weight Fraction, Power Generating Group		
Electric Motor/Controller	0.09	-
Battery	0.19	-
ICE	-	0.16
Sub-total	0.28	0.16
Total, Support-Power Generation Groups	0.43	0.31
Weight Propagation Factor	1.75	1.45

It is to be noted that the power generation group represents 28 percent of the gross vehicle weight for an electric vehicle and only 16 percent for an ICE. As a result the weight propagation factor is higher for an electric vehicle than for an ICE vehicle. Increasing the chassis weight by 45 kg (100 lbs) results in a weight increase of 80 kg (175 lbs) for an electric vehicle and of only 60 kg (145 lbs) for an ICE. This weight increase is however much more costly for an electric vehicle than it is for an ICE. Small increases in the weight of the ICE power train do not greatly increase its price because of the predominance of cast iron and steel in the components of the power train. These are low cost components. However, this is not true for an electric vehicle which contains extremely expensive batteries and a relatively expensive electric motor.

The results are presented in Table B-2 which is based on the methodology outlined in Appendix A. It is estimated that adding 45 kg (100 lbs) of chassis weight increases the retail price of an electric vehicle by $190 which is more than three times the

TABLE B-2. EFFECT OF INCREASED CHASSIS WEIGHT ON CHARACTERISTICS OF ELECTRIC AND ICE 4-PASSENGER VEHICLES

	Electric Vehicle	ICE Vehicle
Gross Vehicle Weight Reference Vehicle, kg (lb)	1523 (3355)	1264 (2783)
Additional weight due to Heavier Chassis		
Chassis weight, kg (lb)	45 (100)	45 (100)
Structural weight, kg (lb)	12 (26)	10 (22)
Power Generation Group:		
Electric Motor/Generator, kg (lb)	7 (16)	
Battery, lbs	15 (33)	
ICE, lbs		10 (23)
Sub-total Power Generation Group, kg (lbs)	22 (49)	10 (23)
Total Weight Increase kg (lbs)	79 (175)	66 (145)
Gross Vehicle Weight of Modified Vehicle, kg (lbs)	1602 (3530)	1329 (2928)
Retail Price Base Vehicle	$4740	$3054
Retail Price Increase due to Vehicle Modification		
Base Vehicle	$ 100	$ 60
Battery	$ 90	
Total increase	$ 190	$ 60
Retail Price Modified Vehicle, $,	$4930	$3014
Percent increase in Retail Price	4.0	2.0
Life Cycle Cost Reference Vehicle, ¢/km	10.77	8.62
Increase in Life Cycle Costs due to Vehicle Modification ¢/km	0.33	0.08
Modified Life Cycle Costs, ¢/km	11.10	8.70
Percent Increase in Life Cycle Costs	3.1	0.9

estimated price increase of $60 for the ICE vehicle. The retail price increase of $30 due to additional chassis materials is included in these figures. The cost propagation of $30 for the ICE vehicle is significantly less than the cost propagation of $130 for the electric vehicle. The absolute increase in the retail price of the vehicles is thus four times as high for an electric vehicle as for the ICE vehicle. This effect is also reflected in the life cycle costs of the vehicles. The life cycle costs of electric vehicles were estimated to increase by 0.33¢/km whereas the increase in the life cycle costs of the ICE vehicle were only 0.08¢/km. These cost increases differ by more than a factor of four.

B.2. IMPACT OF TIRE AND TIRE SELECTION STANDARDS

B.2.1 Introduction

FMVSS 110 (for passenger vehicles) and FMVSS 120 (for commercial vehicles) require that these motor vehicles be equipped with tires that meet the requirements of FMVSS 109 and FMVSS 119, respectively. The purpose of these standards is to prevent tire overloading. FMVSS 109 specifies tire dimensions, laboratory test requirements for bead unseating resistance, strength, endurance and high speed performance, defines tire load ratings, and specifies labeling requirements for passenger car tires. Appendix A of FMVSS 109 presents detailed tables listing tire sizes and tire constructions with proper load and inflation values. FMVSS 119 establishes performance and marketing requirements for tires for use on multipurpose passenger vehicles, trucks, buses, trailers, and motorcycles.

A consequence of the above standards is that the required size of tires that may be used on a vehicle increases with gross vehicle weight. The large tires are heavier and usually more expensive.

To the extent that electric vehicles of a given class are heavier than functionally comparable ICE vehicles, FMVSS 110 and FMVSS 120 can be considered to be biased against electric and hybrid vehicles. The bias takes on these forms:

a) The larger tire is more expensive on a unit basis. This will result in higher first costs and tire replacement costs for an electric/hybrid vehicle than for an ICE vehicle.

b) To the extent that the larger tires weigh more, the additional tire weight will increase the first cost of an electric vehicle because of the weight propagation considerations. This will result in an increase in life cycle costs as well.

c) To the extent that larger tires weigh more, the owner of an electric vehicle will pay higher federal tire excise taxes than the owner of a comparable ICE vehicle.

The ability of ICE vehicles to operate at high speeds is implicit in the tire selection charts of FMVSS 109. It may be questioned whether an electric or hybrid vehicle, which would not operate at high speeds, should require the same size tire as an ICE vehicle of comparable weight that could operate at significantly higher speeds.

B.2.2 Methodology for Tire Sizing

For comparative purposes, it was assumed that all the vehicles of interest would be equipped with radial tires inflated to a common pressure of 24 psi.

The tire size required for each of the various model vehicles of interest in the study was obtained as follows:

a) The gross vehicle weight of the vehicle was divided by four to obtain a nominal tire load.

b) The nominal tire load was multiplied by a safety factor, further explained below, to obtain a design tire load.

c) The tables in Appendix A of FMVSS 109 were then used to determine the minimum required tire size which would be used on the vehicle. This minimum tire size was the tire size that had a tabulated NHTSA load-bearing capability that most closely exceeded the design tire load of the assumed design pressure of 24 psi (1.63 atm)

The choice of tires used on the Chevette established a basis of reference and a measure of the safety factor that should be used. The Chevette specifications call for a P155/80R 13 radial tire which has a load bearing capacity of 361 kg (795 lbs) at 24 psi (1.63 atm) according to Table I-AA for FMVSS 109, Appendix A.(B-1) The gross vehicle weight of the Chevette is 1263 kg (2783 lbs), so the average tire load is 316 kg (696 lbs). The ratio of 361 kg (795 lbs) to 316 kg (695 lbs) was assumed to be a safety factor which was applied to the size of the tires of all the vehicles in the study. The results are presented in Table B-3. A 33.0 cm (13 in.) wheel diameter was chosen for the four passenger autos since this is the size of the wheels of the Chevette. The hybrid required a very large 33.0 cm (13 in.) tire or a 35.6 cm (14 in.) tire. A 30 cm (12 in.) tire is specified for the Honda. This diameter was also assumed for the 2-passenger vehicles. A 38.1 cm (15 in.) diameter tire was assumed for the vans since this is the wheel diameter of both the electric and ICE Jeeps in postal service.

As an example, the nominal tire load of the four-passenger electric vehicle was one-fourth of 1523 kg (3355 lbs.). Referring to the tables in Appendix A of FMVSS 109, it was noted that the following tire sizes: BR 78-13, 185-13 and 175-14 were the smallest tires in their respective tables that had a load rating at 24 psi that exceeded the design load.

B.2.3 Cost of Tires

The Fall/Winter 1976 mail order catalogue(B-2) of a national retail firm was used to obtain the retail price, federal excise tax, and weight of a representative tire for each vehicle in the

TABLE B-3. SIZE OF TIRES ON VEHICLES OF INTEREST

VEHICLE CLASS		PASSENGER AUTOMOBILES					2-PASSENGER AUTOMOBILE		LIGHT-DUTY VANS	
VEHICLE		CHEVETTE ICE*	HONDA CVCC	LOW PERF. ICE	ELECTRIC	HYBRID	LOW PERF. ICE	ELECTRIC	ICE	ELECTRIC
Gross Vehicle Weight	kg(lbs)	1262(2783)	1122(2475)	1209 (2665)	1521(3355)	1877(4138)	825(1820)	1189(2622)	1536 (3388)	1896(4180)
Average Load per Tire = $\frac{GVW}{4}$	kg(lbs)	316 (696)	281 (619)	302 (666)	380 (839)	469(1035)	206 (455)	297 (656)	384 (847)	474(1045)
Safety Factor Based on Chevette		1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
Design Tire Load at 24 psi	kg(lbs)	361 (795)	320 (705)	343 (756)	432(952)	533(1175)	234 (516)	338 (745)	436 (961)	538(1186)
Smallest Radial Tire Sizes Corresponding to Design Tire Load		P155/80R13 155-13 155 R13	155-12 155R12 145-13	155-12 185-13 155R13	BR78-13 185-13 175-14	195-14 185R13 FR78-14	14R10 135-12 135R12	155-12 155-13 155R13	165-15 165R15 BR78-15	195-15 195R15 ER78-15
Nominal Tire Size for Cost Comparison		155-13	155-12	155-13	BR78-13	195-14	155-12[a]	155-12	165-15	195-15
Tire Weight	kg (lbs)	6.8(15)	6.3 (14)	6.8 (15	10 (22)	163(25)	6.3(14)	6.3 (14)	9.1 (20)	11.8 (26)
Retail Tire Price (no tax)	$	37.00	38.00	37.00	44.00[b]	61.00[b]	38.00	38.00	54.00	61.00[b]
Federal Excise Tax per Tire	$	1.45	1.34	1.45	2.11	2.44	1.34	1.34	1.94	0.58
Total Price	$	38.45	39.34	38.45	46.11	63.44	39.34	39.34	55.94	63.58
Tires used over Life of Vehicle		12	12	12	16	16	12	12	8	12
Replacement Tires Purchased		7	7	7	11	11	7	7	3	7
Cost of Replacement Tires over Vehicle Life	$	269.15	275.38	269.15	507.21	697.84	275.38	275.38	167.82	445.06
Cost of Replacement Tires per Km, over Life of Tires	¢/km	0.27	0.28	0.27	0.32	0.45	0.39	0.39	0.80	0.91
Federal Excise Taxes over Vehicle Life	$	17.40	16.08	17.40	33.76	39.04	16.08	16.08	17.44	30.96
Federal Excise Tax per km	¢/km	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.04	0.04

*Reference Vehicle

a) sizes 145-12 or smaller are uncommon, assume use of 155-12 tire for this vehicle

b) White Wall Tire

study - this information is also presented in Table B-2. It was learned that 135-12 tires are not easily available commercially. Therefore, it was assumed that the 2-passenger ICE vehicle would be equipped with the smallest tire size listed in the catalogue, which was a 155-12, the same size tire as would be used by the 2-passenger electric vehicle. As a result, for this vehicle class only, there is no difference in the size of tires needed for the ICE and electric vehicles. This does not hold true for the four-passenger auto and the light delivery van. For these vehicles, the tire sizes specified for the hybrid and electric vehicles are larger than those specified for the ICE vehicle.

B.2.4 Lifetime Tire Costs

The size of a tire on a vehicle increases the cost of a vehicle in a number of ways.

a) The larger the tire, the higher the initial price of the vehicle. Only part of this price increase is due to the higher price of the five tires on the vehicles. A significant part of the price increase is due to weight propagation resulting from the use of heavier, and thus larger tires.

b) Any increase in the weight of a vehicle results in a decrease in fuel economy.

c) Increasing the size of the tires on the vehicle increases the costs of maintenance and repairs since the price of tires generally increases with the size of the tire. This does not hold for very small tires. There is also a commensurate increase in Federal tire excise taxes paid by the vehicle owner.

The bias resulting from the Federal tire and tire selection standards were measured by the cost increases emanating from the use of larger tires on a given electric or hybrid vehicle as compared to the appropriate ICE vehicle. These results are given in Tables B-3 and B-4. To arrive at a value for the number of tires

TABLE B-4. IMPACT OF LARGER TIRE SIZE ON WEIGHT AND COSTS OF ELECTRIC AND HYBRID VEHICLES

		4-PASSENGER AUTOMOBILES					2-PASSENGER AUTOMOBILE		LIGHT DUTY VANS	
		CHEVETTE ICE*	HONDA CVCC	LOW PERF. ICE	ELECTRIC	HYBRID	LOW PERF. ICE	ELECTRIC	ICE	ELECTRIC
Tire Size		155-13	155-12	155-13	BR78-13	195-14	155-12	155-12	165-15	195-15
Tire Weight	kg (lbs)	6.8(15)	6.3(14)	6.8(15)	10 (22)	11.3 (25)	6.3(14)	6.3(14)	9.1(20)	11.8(26)
Weight of 5 Tires on Vehicles	kg (lbs)	34(75)	31.7(70)	34(75)	49.9(110)	56.7(125)	31.7(70)	31.7(70)	45.4(100)	59(130)
Additional Weight of Tires on EV or Hybrid Vehicle as Compared to ICE Vehicle	kg (lbs)				15.9 (35)	22.7 (50)		-		13.6(30)
Additional Weight of Structure and Power Groups Propagating from Differential Tire Weight	kg (lbs)				11.8 (26)	17.2 (38)		-		10.4(23)
Total Weight Increase	kg (lbs)				27.7 (61)	39.9 (88)		-		24 (53)
Gross Vehicle Weight (GVW)	kg (lbs)				1521(3355)	1877(4138)		1189 (2622)		1896(4180)
ΔWeight Tires as Percent of GVW					1.8	2.1		-		1.3
Retail Price of Tires on Vehicle		192.25	196.70	192.25	230.55	317.20	196.70	196.70	279.70	317.90
Additional Price of Tires on EV or Hybrid Vehicle as Compared to ICE Vehicle	$				38.30	124.95		-		38.20
Additional Retail Price of Base Vehicle due to Weight Propagated by Heavier Tires	$				42.70	61.60		-		37.10
Additional Retail Price of Battery due to Weight Propagated by Heavier Tires	$				51.90	79.20		-		47.70
Total Retail Price Differential Resulting from Differences in Required Tire Size	$				136	266		-		123
Retail Price of Vehicle	$				4740	6400				6060
Retail Price Differential as Percent of Retail Price					2.9	4.2				2.0
Reference Life Cycle Ownership Costs**	¢/km				10.77	13.69				30.86
Increase in Vehicle Life Cycle Costs due to Large Tire Size	¢/km									
Capital Costs					0.19	0.37				0.40
Repair & Maintenance					0.06	0.19		-		0.11
Fuel Costs					0.02	0.03				0.01
Total					0.27	0.59				0.52
Total as % Reference Life Cycle Costs					2.5	4.3				1.7

*Reference Vehicle.
**Table A-2.

used over the life of a vehicle, it was assumed that a tire would last either 58,000 km (36,000 miles) a typical warranty value for steel belted radial tires, or four years which ever came first.

Using this approach results in a variable bias which differs with the class of vehicle considered. There is no bias in the case of the two passenger vehicles which use the same minimum size tire. For the 4-passenger automobile and the light-duty van, the tire selection statutes result in a bias against the electric vehicle (EV). The major impacts of the use of larger tires on the electric or hybrid vehicles are the increased capital cost of ownership due to the increased retail price resulting from weight propagation.

B.3. IMPACT OF BUMPER STANDARDS

B.3.1 Introduction

The Federal Motor Vehicle Safety Standard 215, Part 581, specifies that bumpers of vehicles manufactured after September 1, 1979 may exhibit no greater than .95 cm (3/8 inch) deep permanent local dent or a 1.9 cm (three-quarter-inch) permanent gross deviation from the original position of the bumper after two longitudinal impacts of the pendulum at 8 km/h (5 mph), two corner impacts at 4.8 km/h (3 mph), and barrier impact at 8 km/h (5 mph). In addition, this standard specifies that other components of the vehicle will have suffered no damage and will be operational. In these tests, the effective impacting mass is equal to the mass of the tested vehicle.

Part 581 imposes a much stricter standard of exterior protection than the present FMVSS 215 whose purpose is to prevent low speed collisions from impairing the safe operation of vehicle systems. This is less restrictive than the purpose of Standard 581 which is stipulated to reduce physical damage to the front and rear ends of a passenger motor vehicle from low speed collisions.

B.3.2 Chevette Bumper System

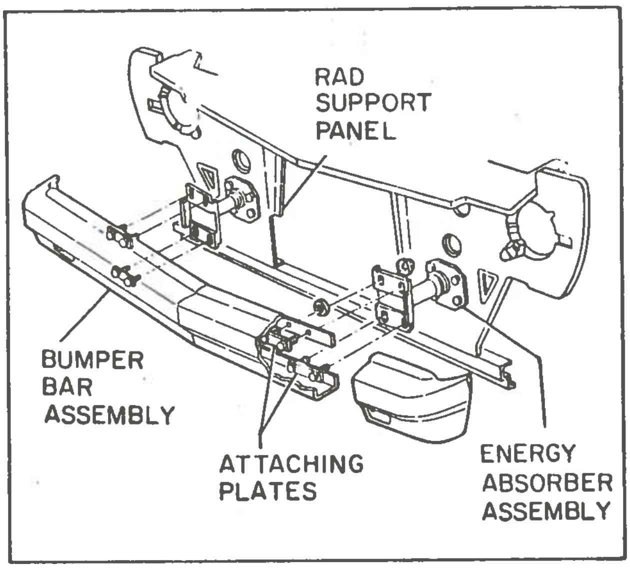
Many alternate approaches are being considered for the design of bumper systems that will meet the above standards and still not greatly increase the weight of an automobile. The Chevette bumper system described below has been considered one of the more innovative approaches to the problem.(B-3)

The Chevette bumper is formed from 58,000 psi (400 M Pa) yield HSLA steel 0.095 in. (2.29mm) in thickness in what is basically a closed C section with cupped ends as shown in Figure B-1. This configuration eliminates the need for a reinforcement bar. The weight of this bumper system is estimated to be 15.8 kg (34.8 lbs) by prorating the weight by the ratio of metal gauge thicknesses to the weight of a similar system for 1135 kg (2500 lb) vehicle. This latter bumper assembly, in which 0.105 in. (2.7 mm) gauge HSLA steel was used, consisted of the following:(B-4)

Face Bar	:	12.5 kg (27.5 lbs)
Brackets	:	1.6 kg (3.5 lbs)
E.A. Shocks	:	3.4 kg (7.5 lbs)
Total		17.5 kg (38.5 lbs)

Based on the above, the thickness of the face bar, and thus the weight of the bumper, varies as the 0.5 power of the vehicle weight.

The combined weight of the front and rear bumper on a Chevette is slightly less than 32 kg (70 lbs). Using the weight propagation factor of 1.45 for an ICE vehicle, as developed in Section B-1, the presence of these bumpers will require that an additional 14 kg (30 lb) be added to the vehicle support structure. In toto, the requirements of FVMSS 215 results in a contribution of approximately 45 kg (100 lbs) to the weight of a Chevette.



Source: Hatch, D.E., "Aluminum Automobile Bumper Systems," SAE Paper 770268, presented at the SAE Automotive Engineering Conference, March 1977.

FIGURE B-1. CHEVETTE BUMPER SYSTEM

B.3.3 Bumper System for 4-Passenger Electric Vehicle

For purposes of this discussion, it can be assumed that the 4-passenger electric vehicle will be equipped with a bumper assembly of the same design as that as now used on the Chevette, but of greater thickness and weight because of its increased curb weight. It is assumed that the thickness and weight of the bumper, and the weight of the bumper system increase as the square root of the curb weight of the vehicle. The thickness of HSLA alloy that would be used for the 4-passenger EV is thus estimated to be 0.110 in. (2.8 mm).

This neglects second order corrections for the assumed weights of the bumpers already in place. The calculated weight of a bumper assembly is 18.3 kg (40.3 lbs), or 2.5 kg (5.5 lbs) more than the weight of a Chevette bumper assembly.

The combined weight of the front and rear bumpers on the four passenger E.V. is thus 36.6 kg (80.6 lb). The total increase in the weight of this vehicle, using the weight propagation factor of 1.75 developed in Section B-1 for an electric vehicle, is therefore 64.1 kg (141.1 lbs).

B.3.4 Comparative Weight Impact of FMVSS 215 on Four Passenger Electric and ICE Vehicles

The weight contributions of comparable bumper systems that meet FMVSS 215 for an electric four passenger vehicle and a four passenger gasoline vehicle (the Chevette) are as follows:

	Weight Bumpers System, kg (lb) (2 each)	Resulting Weight Propagation kg (lb)	Total Additional System Weight kg (lb)
Electric Vehicle	36.6 (80.6)	27.3 (60.1)	64.1 (141.1)
ICE Vehicle	31.6 (69.6)	14.2 (31.3)	45.8 (100.9)
Difference	5.0 (11.0)	13.1 (28.8)	18.3 (40.2)

The bumper requirements increase the weight of an electric vehicle significantly more than the weight of an ICE vehicle, with over 70% of the weight difference being due to differences in weight propagation resulting from the placement of the bumpers. As discussed further below this results in significant differences in manufacturing costs.

B.3.5 Cost Impact of FMVSS 215 on Electric and ICE Vehicles

The requirements for bumpers that meet FMVSS 215 are significantly more expensive in the case of an electric vehicle than an ICE vehicle. This difference arises mainly because of the high cost of weight propagation for an electric vehicle.

A variable manufacturing cost estimate of $34 has been recently published for a Hard Fascia HSLA bumper system that has a two unit weight of 34 kg (76 lbs) (i.e., front and rear bumpers).[B-3] It will be assumed that the difference in the estimated variable manufacturing costs of the bumper systems of the two vehicles here considered will be mainly due to differences in the weight of materials used. Assuming a 30 percent scrappage rate and a unit material cost of $0.33/kg ($0.15/lb), the 31.6 kg (69.6 lbs) Chevette system has a manufacturing cost of approximately $33, and the 36.6 kg (80.6 lb) electric vehicle system has a variable manufacturing cost of $35. Using a variable manufacturing cost-to-retail-price ratio of 0.61, the corresponding retail prices are $54 and $57.

Based on the discussion presented in Section B-1, the additional retail price of propagated weight is $40 for 30.4 kg (45 lbs), or $1.45/kg ($0.66/lb), for an ICE vehicle. The 14 kg (31 lbs) of propagated weight result in a retail price increase of $21. The total contribution of the bumper system to the retail price of a Chevette is estimated to be $75. For the electric vehicle, the additional price of weight propagation is $160 per 34 kg (75 lbs), or $4.7/kg ($2.13/lb). The 27.3 kg (60.1 lb) of propagated weight result in a retail price increase of $128. The total contribution of the bumper system to the retail price of the 4-passenger E.V. is thus estimated to be $200 ($124 increase in the base vehicle and $76 increase in the battery).

B.3.6 Bias due to FMVSS 215

Based on the above discussion, FMVSS 215 results in a bias against electric vehicles. Satisfying the requirements of FMVSS 215 increases the acquisition price by $200 as compared to $75 for an equivalent ICE vehicle. The difference of $125 is a measure of this bias.

These first cost differences are reflected in their relative impacts on the life cycle costs of the two vehicles, as shown in Table B-5, which compares the costs of the reference 4-passenger electric vehicle and ICE Chevette, discussed in Appendix A, to vehicles that would not be equipped with the bumper systems discussed previously. Energy costs for the bumperless vehicles are assumed to vary as the gross vehicle weight. As shown in Table B-5, the presence of the bumpers discussed add 0.37¢/km or 3.6% to the lifecycle costs of the electric vehicle, as compared to 0.13 ¢/km, or 1.5% to the life cycle costs of the ICE vehicle. Over the respective lives of the two vehicles this becomes a difference of about $500.

It should be noted that no attempt was made to analyze an optimized bumper system for an electric vehicle. The purpose of the above was to exemplify the relative impacts of FMVSS 215 on comparable E.V. and ICE vehicles with similar bumper systems. The choice of alternate, lighter weight bumper systems would result in different first and life-cycle cost estimates.

TABLE B-5. IMPACT OF FMVSS 215 ON LIFE CYCLE COSTS OF ICE AND ELECTRIC FOUR PASSENGER VEHICLES

	Reference Electric Vehicle	Bumperless Electric Vehicle	Reference Chevette	Bumperless Chevette
Vehicle life, yrs	12	12	10	10
Annual Vehicle Utilization km/yr	16,000	16,000	16,000	16,000
Total Vehicle Travel, km	192,000	192,000	160,000	160,000
Battery Life, Cycles	600	600	-	-
Battery Life, Years	5	5	-	-
Batteries/Vehicle (over life	2.5	2.5	-	-
Curb Weight, kg(lb)	1192 (2,628)	1121 (2,471)	931 (2,053)	885 (1,952)
Gross Vehicle Weight,kg(lb)	1526 (3,366)	1455 (3,209)	1262 (2,783)	1216 (2,682)
Base Vehicle Price	$ 2,900	2,776	3,054	2,979
Battery Price	$ 1,840	1,764		
Vehicle Acquisition Price	$ 4,740	4,540	3,054	2,979
		Life Cycle Operating Costs, ¢/km		
Base Vehicle Depreciation	1.51	1.42	1.91	1.86
Battery Depreciation	2.36	2.26		
Interest on Base Vehicle[(a)]	1.22	1.15	1.19	1.16
Interest on Battery[(a)]	0.64	0.61		
Taxes and Fees[(b)]	0.84	0.85	0.57	0.56
Sub-Total, Capital Sensitive Costs	6.62	6.29	3.67	3.58
Repairs and Maintenance	1.00	1.00	1.56	1.56
Insurance	1.00	1.00	1.00	1.00
Parking Tolls, etc.	1.25	1.25	1.25	1.25
Sub-Total, Non-Fuel Operating Costs	9.87	9.54	7.48	7.39
Cost of Fuel Electric @ 4¢/kWh Gasoline @ 60¢/gal	0.90	0.86		
Total Operating Costs	10.77	10.40	8.62	8.49
Cost of Bumper System		0.37		0.13

(a) 5% Compound Interest
(b) 3% of Acquisition Price Annually

B.4 INTENTIONAL AND ACCIDENTAL BIAS OF STATE MOTOR VEHICLES AND TAXES ON REGISTRATION AND LICENSING

Alabama

a) Taxicab fees are weight based:

Up to 2500 pounds	$21.00	(to 1134 kg)
2501 to 3000 pounds	27.00	(1134.5 to 1361 kg)
3001 to 3500 pounds	30.00	(1361.5 to 1588 kg)
3501 to 4000 pounds	40.00	(1588.5 to 1814 kg)

Arizona

a) License tax at a flat rate not to exceed 4 percent and based on retail price with fixed schedule of values for following years.

Arkansas

a) Passenger vehicle and automobile-for-hire registration fees are weight based:

Unladen Weight	Fee	
Up to 3000 pounds	$12.00	(to 1361 kg)
3001 to 4500 pounds	19.00	(1361.5 to 2041 kg)
4501 pounds or more	26.00	(2041.5 kg or more)

California

a) Electric Passenger Vehicles not subject to weight fees have an additional registration fee of $10.00 (Repealed in 1970).

b) Gasoline-powered vehicles, of a 1975 or later model year, whose emission of pollutants is not within allowable limits are subject to an additional registration fee if first sold and registered in California, which fee is related to compression ratio and the fee range of 50 to 300 dollars.

c) Commercial vehicles pay additional registration fees which are both weight based and relate to mode of power:

	Electric Vehicles	Vehicles (other than electric) 2-axle	3-axle
Less than 1361 kg (3000 pounds)	54.00	$ 5.00	$ 17.00
1361 kg (3001 pounds) to 1814 kg (4000 pounds)	54.00	15.00	31.00
1814.5 kg (4001 pounds to 2268 kg (5000 pounds)	54.00	32.00	62.00
2268.5 kg (5001 pounds) to 2722 kg (6000 pounds)	54.00	62.00	92.00
2722.5 kg (6001 pounds to 3175 kg (7000 pounds)	108.00	83.00	124.00

d) License fee of 2% of vehicle market value is assessed annually in lieu of all ad valorem taxes.

Colorado

a) Registration fees for passenger vehicles are weight based:

Up to 907 kg (2000 pounds)	$ 6.00
Up to 2041 kg (4500 pounds)	6.00 plus $0.20 per 45 kg (100 pounds) over 907 kg (2000 pounds)
Over 2041 kg (4500 pounds)	12.50 plus $0.60 per 45 kg (100 pounds) over 2041 kg (4500 pounds)

b) Registration fees for motor trucks and buses are weight based at rates similar to those for passenger vehicles.

c) Intercity trucks registration fees are strongly weight based on 100 pound empty weight increments and range from $7.60 at 907 kg (2000 pounds) to $106.25 at 2948 kg (6500 pounds).

d) Annual specific ownership tax based on factory list price of vehicle on a descending flat rate depending on years of service of the vehicle.

Connecticut

a) Electric Vehicle registration fee is $10.00 whereas passenger vehicles (other than electric) fee is $20.00

Delaware

a) Fees for taxicabs are based on gross load weight at $8.00 for up to 1814 kg (4000 pounds) and $12.00 for over 1814 kg (4000 pounds).

District of Columbia

a) Registration fees for passenger vehicles are weight based and type of fuel based:

	Taxable Fuel	Other Than Taxable Fuel
Up to 1270 kg (2800 pounds)	$50.00	$100.00
1270.5 kg (2801 pounds) to 1587 (3499 pounds)	57.00	114.00
1587.5 kg (3500 pounds) to 1814 kg (3999 pounds)	83.00	166.00
1814.5 kg (4000 pounds) or more	96.00	192.00

b) Registration fees for trucks are weight and type of fuel based:

	Taxable Fuel	Other Than Taxable Fuel
Less than 1361 kg (3000 pounds)	$ 95.00	$190.00
1361 kg (3000 pounds) to 1814 kg (4000 pounds)	105.00	210.00
1814 kg (4000 pounds) to 2268 kg (5000 pounds)	123.00	246.00
2268 kg (5000 pounds) to 2721 kg (6000 pounds)	143.00	286.00
2721 kg (6000 pounds) to 3175 kg (7000 pounds)	163.00	326.00

c) Title issuance excise tax based on fair market value with rates increasing with vehicle weight:

Weight	Rate
Up to 1270 kg (2800 pounds)	4%
1270.5 kg (2801 pounds) to 1587 kg (3499 pounds)	5%
1587.5 kg (3500 pounds) to 1814 kg (3999 pounds)	6%
1814.5 kg (4000 pounds) or more	7%

Florida

a) Registration fees for automobiles for private use are weight based:

Under 1134 kg (2500 pounds)	$12.50
1134 kg (2500 pounds) to 1588 kg (3500 pounds)	20.00
1588 kg (3500 pounds) to 2041 kg (4500 pounds)	27.50
2041 kg (4500 pounds) or more	35.00

b) Registration fees for motor trucks and buses are weight based:

	Less than 907 kg (2000 pounds)	$ 2.50	plus $0.50 per 45 kg (100 pounds)
907 kg to 1361 kg	(2000 to 3000 pounds)	5.00	plus $0.60 per 45 kg (100 pounds)
1361 kg to 2268 kg	(3000 to 5000 pounds)	7.50	plus $0.75 per 45 kg (100 pounds)
	More than 2268 kg (5000 pounds)	10.00	plus $1.10 per 45 kg (100 pounds)

c) Local buses fee of $12.50 plus $1.50 per 45 kg (100 pounds).

Georgia

a) Registration fees for passenger vehicles are weight based:

Up to 1361 kg (3000 pounds)	$ 5.00
1361.5 kg (3001 pounds) to 1588 kg (3500 pounds)	7.50
1588.5 kg (3501 pounds) to 1814 kg (4500 pounds)	10.00
1814.5 kg (4501 pounds) and over.	15.00

b) Registration fees for motor buses are $1.50 per 45 kg (100 pounds).

Hawaii

a) Vehicle weight tax is determined locally at county level and paid to the county.

b) All motor vehicles are subject to a state vehicle engine displacement tax equal to $0.10 per 1600 cubic cm (100 cubic inches) of the vehicle's total engine size.

Idaho

a) Passenger vehicles not used for hire and propelled by special fuels pay a fee of $3.75 per month in lieu of ordinary motor vehicle fuels tax.

Illinois

a) Registration fees for vehicles carrying not more than ten passengers are based on <u>mode of power</u>:

<u>Gasoline or Steam</u>:	<u>Fee</u>
Less than 26.1 kW (35 horsepower)	$18.00 annual
Over 26.1 kW (35 horsepower)	30.00 annual
<u>Electric</u>	Not to exceed $28.00 for a two-year plate.

Indiana

a) Annual license excise tax in lieu of ad valorem property tax is imposed and is based on age of vehicle (decreasing with age) and value of vehicle when first sold (increasing with value).

Iowa

a) Electric Automobile registration fees of $25.00 annually for first five years and then $15.00 annually as compared to other passenger vehicle rates which are 1% of value plus $0.40 per 45 kg (100) pounds

Kansas

a) Electric Private Passenger Vehicles registration fee of $6.50 as compared to other vehicle fees which are weight based with a minimum of $13.00.

b) Electrically Propelled Motor Truck fees are specifically identified as identical to trucks propelled by other power.

c) Usage tax of 5% of the retail price on use of motor vehicles other than carriers.

Maine

a) Excise tax based on maker's list price at a flat rate which decreases with years of service.

Maryland

a) Passenger car registration fees increase by 50 percent for shipping weights over 1678 kg (3700 pounds).

b) Registration fees for trucks, buses and contract carriers are weight based on various schedules depending on use of vehicle. For example

Chassis Weight	Contract Carrier Fees
Up to 680 kg (1500 pounds)	$18.00
680 kg (1500 pounds) to 1134 kg (2500 pounds)	23.00
1134.5 kg (2501 pounds) to 1814 kg (4000 pounds)	34.00
1814.5 kg (4001 pounds) to 2268 kg (5000 pounds)	50.00
2268.5 kg (5001 pounds) to 4536 kg (10,000 pounds)	103.00

c) Titling excise tax of 4% of fair market value.

Massachusetts

a) Electric Truck Registration fees of $10.00 per 454 kg (1000 pounds) weight and maximum carrying capacity (minimum of $80.00) as compared to $5.00 per 454 kg (1000 pounds) (minimum of $80.00) for a non-gasoline (except electric) driven truck.

b) Taxicab fees of $7.00 (gasoline driven) and $22.50 (non-gasoline driven).

c) Fees for buses on a seating capacity and form of fuel basis with a minimum of $7.00 for gasoline driven and $20.00 for non-gasoline driven.

d) Excise tax of $66.00 for $1000 valuation with schedule of valuation for successive years.

Michigan

a) Passenger vehicle for pleasure registration fees of $0.55 per 45 kg (100 pounds) with a minimum of $12.00.

b) Truck fees per 45 kg (100 pounds) of empty weight are scaled with weight ranges

Empty Weight	Fee Per 45 kg (100 pounds)
Up to 1134 kg (2500 pounds)	$0.80
1134.5 kg (2501 pounds) to 1814 kg (4000 pounds)	1.00
1814.5 kg (4001 pounds) to 2722 kg (6000 pounds)	1.25

c) Commercial passenger vehicle fees are similar to truck fees (above).

Minnesota

a) Registration fee for passenger vehicles is $10.00 plus 1.25% of the "base value" of the vehicle with the amount of tax on a schedule which reduces the amount with years of service.

b) Tax on trucks is based on total gross weight with two schedules dependent on the age of the vehicle (decreasing for older vehicles).

c) Excise tax at the same rate as the sales and use tax and based on purchase price.

Mississippi

a) Registration fees for passenger vehicles are weight based:

Up to 816 kg (Up to 1800 pounds)	$10.00
816.5 kg to 1814 kg (1801 to 3000 pounds)	12.00
1361.5 kg to 1814 kg (3001 to 4000 pounds)	15.00
More than 1814 kg (More than 4000 pounds)	20.00

b) Taxicabs and passenger coaches at $0.15 per horsepower and $0.50 per 45 kg (100 pounds) empty weight.

c) Annual ad valorem taxes at rates and valuations fixed by the State Tax Commission.

Montana

a) Electric Passenger Vehicle registration fee of $10.00 as compared to weight based fees for other passenger vehicles ($5.00 for up to 1293 kg (2850 pounds) and $10.00 for over 1293 kg (2850 pounds).

b) Sales tax when applying for original license plates at fixed rates applied to list price.

Nevada

a) Motor trucks registration fees are based on unloaded weight:

Up to 1588 kg (Up to 3500 pounds)	$ 9.00
1588.5 to 1610 kg (3501 to 3550 pounds)	10.00
1610 to 1656 kg (3550 to 3650 pounds)	12.00
1656 to 1701 kg (3650 to 3750 pounds)	14.00
1701 to 1746 kg (3750 to 3850 pounds)	16.00
1746 to 1792 kg (3850 to 3950 pounds)	18.00
1792 to 1814 kg (3950 to 4000 pounds)	20.00
1814 to 2291 kg (4000 to 5050 pounds)	25.00
2291 and over (5050 pounds and over)	0.50 per 45 kg (100 pounds)

b) Privilege tax of 48 percent in lieu of personal property tax.

New Hampshire

a) Passenger vehicle registration fees are weight based:

Gross Weight	Fee
Not over 1361 kg (Not over 3000 pounds)	$12.00
1361.5 to 2268 kg (3001 to 5000 pounds)	24.00
Over 2268 kg (Over 5000 pounds)	36.00

b) Truck registration fees are weight based:

Gross Weight	Fee
Not over 1588 kg (Not over 3500 pounds)	$15.00
1588.5 to 1905 kg (3501 to 4200 pounds)	20.00
1905.5 to 2268 kg (4201 to 5000 pounds)	25.00
2268.5 to 2722 kg (5001 to 6000 pounds)	30.00

c) Taxes assessed on a municipal basis with rates constant throughout the state and based on year of manufacture and list price.

New Jersey

a) Registration fees for passenger vehicles are weight based:

Less than 1225 kg (Less than 2700 pounds)	$14.00
1225 to 1724 kg (2700 to 3800 pounds)	23.00
1724 kg and over (3800 pounds and over)	44.00

New Mexico

a) Registration fees for motor vehicles other than motorcycles, trucks, buses and tractors are weight based and related to age of vehicle. For the first five years:

Shipping Weight	Fee
Not over 1361 kg (Not over 3000 pounds)	$16.00
1361.5 kg to 1814 kg (3001 to 4000 pounds)	24.00
Over 1814 kg (Over 4000 pounds)	36.00

b) Titling excise tax of 2 percent of sales price.

New York

a) <u>Electrically Propelled Passenger Vehicle</u> registration fees of $15.00 as compared to weight based fees of other powered vehicles which have a minimum fee of $15.00 for any 6, 8 or 12-cylinder engine and a minimum fee of $12.00 for any other motor vehicle.

b) Auto truck and light delivery car registration fees are $2.50 for each 227 kg (500 pounds) of maximum gross weight but $3.75 for each 227 kg (500 pounds) if <u>OPERATED BY ELECTRICITY NOT GENERATED BY A MOTOR CONTAINED THEREIN</u> and excluding the weight of the battery.

c) Fees for omnibuses <u>OPERATED ENTIRELY BY ELECTRICITY NOT GENERATED BY AN ENGINE CONTAINED THEREIN</u> are 50 percent in excess of the rates for other powered omnibuses, which rates are related to seating capacity.

North Dakota

a) Passenger motor vehicle registration fees are based on weight and age of vehicles. For the first three years:

Gross Weight	Fee
Less than 907 kg (Less than 1999 pounds)	$27.00
907.5 kg to 1088 kg (2000 to 2399 pounds)	29.00
1088.5 to 1270 kg (2400 to 2799 pounds)	31.00
1270.5 kg to 1451 kg (2800 to 3199 pounds)	33.00
1451.4 kg to 1633 kg (3200 to 3599 pounds)	37.00
1633.5 to 1814 kg (3600 to 3999 pounds)	41.00
1814.5 to 2041 kg (4000 to 4499 pounds)	51.00
2041.5 kg to 2268 kg (4500 to 4999 pounds)	67.00
2268.5 kg to 2721 kg (5000 to 5999 pounds)	95.00

b) Excise tax imposed on the purchase price of any motor vehicle required to be registered.

Ohio

a) Registration fees of motor buses and trucks are based on weight:

Fully Equipped Weight	Bus Fee/100 pounds	Truck Fee/100 pounds
First 907 kg; First (2000 pounds)	$0.70	$0.85
Excess of 907-1361 kg; Excess of (2000-3000 pounds)	1.10	1.40
Excess of 1361-1814 kg; Excess of (3000-4000 pounds)	1.50	1.90
Excess of 1814 kg-2722kg; Excess of (4000-6000 pounds)	1.75	2.20

Oklahoma

a) Registration fees for passenger vehicles related to manufacturer's list price.

b) Excise tax based on value at time of transfer.

Oregon

a) $50.00 for four wheeled ELECTRIC PLEASURE VEHICLES and $20.00 for two or three wheeled ELECTRIC PLEASURE VEHICLES are both higher than standard rates.

b) ELECTRIC COMMERCIAL VEHICLES - Truck fee plus 50 percent

c) 5.5 mils per mile (diesel and other fuels) versus 1.5 mils per mile (gasoline) for carriers up to 2722 kg (6000 pounds).

Rhode Island

a) Registration fees for passenger vehicles are weight based:

Not more than 1134 kg (2500 pounds)	$10.00
1361 kg (3000 pounds)	11.00
1588 kg (3500 pounds)	12.00
1814 kg (4000 pounds)	14.00
2041 kg (4500 pounds)	17.00

	2268 kg (5000 pounds)	20.00
	2495 kg (5500 pounds)	24.00
	2722 kg (6000 pounds)	28.00

b) Registration fees for motor trucks and buses are weight based:

Not more than 1814 kg (4000 pounds)	$17.00
2268 kg (5000 pounds)	20.00
2722 kg (6000 pounds)	24.00

c) Registration fees of every motor vehicle for hire are double the passenger vehicle rates which are weight based (see (a)).

South Carolina

a) Registration fees of passenger vehicles are weight based at $1.00 for each 227 kg (500 pounds) over 907 kg (2000 pounds) with a $1.00 rate for the first 907 kg (2000 pounds).

b) Registration fees of common carriers of passengers are weight based at $3.00 for each 227 kg (500 pounds) over 907 kg (2000 pounds) with a $9.00 rate for the first 907 kg (2000 pounds)

South Dakota

a) Registration fees of passenger vehicles, buses and motor trucks are weight based as are the maximum fees for trucks and buses used exclusively within the corporate limits.

b) Excise tax of 3 percent of fair market value at time of registration.

c) Certificates of compensation fees on all motor carriers are weight based.

Texas

a) Registration fees of passenger cars, street or suburban buses are weight based at $12.00 for up to 1588 kg (3500 pounds), $22.00 for 1588 to 2041 kg (3501 to 4500 pounds) and $30.00 for 2042 to 2722 kg (4501 to 6000 pounds).

b) Sales and Use Tax at 4 percent of consideration paid on retail sales is paid at first registration.

Vermont

a) Registration fees of motor buses are weight based at $1.10 per 45 kg (100 pounds)

b) Sales and Use Tax of 4 percent of value to a maximum of $300.

Virginia

a) Registration fees of passenger vehicles other than private automobiles, common carriers of passengers, vehicles for rent or hire and taxicabs are weight based at rates from $0.30 to $0.90 per 45 kg (100 pounds) with a $5.00 surcharge if the weight is above 1814 kg (4000 pounds).

b) Registration fees of non-passenger vehicles are $15.00 for up to 1814 kg (4000 pounds) weight and $20.00 for 1814.5 to 2948 kg (4001 to 6500 pounds) weight.

c) Sales and Use Tax rate of 2 percent of value.

Washington

a) Additional motor truck registration fees based on maximum gross weight and mode of power:

Weight	Gasoline	Steam, ELECTRICITY, Diesel, Natural Gas
Up to 1814 kg (4000 pounds)	$ 6.00	$ 6.00
1814 kg to 2722 kg (4000 to 6000 pounds)	11.00	12.25

b) Excise tax, in lieu of property tax, at 2 percent of fair market value.

c) Utilities and Transportation Commission fees for all carriers of freight are weight related.

West Virginia

a) Registration fees for passenger vehicles, motor trucks, buses, and carriers of persons or property are weight based at different rates with (for passenger vehicles not operated for compensation):

Up to 1361 kg (3000 pounds)	$20.00
1361.5 to 1814 kg (3001 to 4000 pounds)	24.00
Over 1814 kg (Over 4000 pounds)	30.00

b) Titling tax of 5 percent of fair market value.

c) Motor carriers of persons or property for hire pay special license fees in addition to all other fees and taxes and such special license fees are weight based.

Wisconsin

a) Registration fees of motor trucks and buses are weight based:

Gross Weight	Fee
Not to exceed 1361 kg (3000 pounds)	$16.00
Not to exceed 2041 kg (4500 pounds)	25.00
Not to exceed 2722 kg (6000 pounds)	35.00

Wyoming

a) Intrastate motor vehicles and trucks registration fees at 3 percent of percentages of factory price descending with years of service.

b) Bus and truck fees are based on unladen weight with normal rates doubled for the current period until July 1, 1977:

Unladen Weight	Normal Fees
Up to 454 kg (1000 pounds)	$ 1.00
454.5 to 1588 kg (1001 to 3500 pounds)	7.50
1588.5 to 2041 kg (3501 to 4500 pounds)	10.00
2041.5 to 2495 kg (4501 to 5500 pounds)	15.00
2495.5 to 2722 kg (5501 to 6000 pounds)	20.00

c) Compensatory fees for every carrier are based either on weight or mileage with rates for vehicles not using gasoline for fuel being about twice that of vehicles using gasoline.

B.5 IMPACT OF STATE TAXES ON VEHICLES OF INTEREST IN THE FOCUS STATES

In the following Tables (B-6 to B-9) the effects of state taxes on the study vehicles are developed.

TABLE B-6. IMPACT OF CALIFORNIA STATE TAXES ON VEHICLES OF INTEREST

Vehicle Class		2 PASSENGER AUTOMOBILES		4 PASSENGER AUTOMOBILES					LIGHT-DUTY VANS	
Vehicle		ELECTRIC (near term)	LOW PERF. ICE	ELECTRIC	HYBRID	LOW PERF ICE	CHEVETTE	HONDA CVCC	ELECTRIC	ICE
Vehicle Acquisition Price	$	5,140	2,600	4,740	6,400	2,700	3,054	3,464	6,060	3,800
Vehicle Curb Weight	kg(lbs)	1011(2,229)	658(1,450)	1192(2,628)	1546(3,408)	878(1,935)	931(2,053)	792(1,745)	1530(3,372)	1134(2,500)
Hydrocarbon Fuel Economy	km/l(MPG)		21.6(51)		11.5(27)	11.4(41)	14.0(33)	16.6(39)		3.4(7.9)
Electric Energy Consumption,	kWh/km	0.212		0.226	0.264				0.263	
Assumed Vehicle Life	yrs	11	10	12	12	10	10	10	10	6
Annual Usage	km/yr	10,000	10,000	16,000	16,000	16,000	16,000	16,000	7,000	7,000
Annual Fuel Consumption										
Gasoline	l(gal)		463.7(122.5)		420(111)	923.5(244)	1146.9(303)	969(256)		2096.9(554)
Electricity	kWh	2.120		3,616	3,181				1,841	
Sales Tax on Initial Vehicle Purchase (Tax Rate: 6%)	$	308.40	144.00	284.40	384.00	162.00	183.24	207.84	363.60	228.00
Average Annual Cost of Taxes										
Sales Tax (6%)		52.92	52.27	61.08	81.53	37.92	39.18	43.32	76.44	68.10
Property Tax (2% market value)		29.98	16.32	27.65	37.33	19.72	20.77	23.56	41.21	38.61
Gasoline Motor Fuel Tax 1.8¢/l (7¢ gallon)			8.58		7.77	17.08	21.21	17.92	-	38.08
Registration Fee		11.00	11.00	11.00	11.00	11.00	11.00	11.00	54.00	5.00
Weight Fee										
Other										
Public Utility Tax ($0.0001/kWh)		0.21		0.36	0.32				0.18	
TOTAL	$/year	94.11	88.17	100.09	137.95	85.72	92.16	95.80	171.83	160.79
Total State Taxes over Life of Vehicle	$	1,129.32	881.70	1,201.08	1,655.40	857.20	921.60	958.00	1,718.30	964.74
Total State Taxes per Km.	¢/km	0.94	0.88	0.63	0.86	0.54	0.58	0.60	2.45	2.30

TABLE B-7. IMPACT OF FLORIDA STATE TAXES ON VEHICLES OF INTEREST

Vehicle Class		2 PASSENGER AUTOMOBILES		4 PASSENGER AUTOMOBILES					LIGHT-DUTY VANS	
Vehicle		ELECTRIC (near term)	LOW PERF. ICE	ELECTRIC	HYBRID	LOW PERF ICE	CHEVETTE	HONDA CVCC	ELECTRIC	ICE
Vehicle Acquisition Price	$	5,140	2,600	4,740	6,400	2,700	3,054	3,464	6,060	3,800
Vehicle Curb Weight	kg(lbs)	1011(2,229)	658(1,450)	1192(2,628)	1546(3,408)	878(1,935)	931(2,053)	792(1,745)	1530(3,372)	1134(2,500)
Hydrocarbon Fuel Economy	km/l(MPG)		21.6(51)		11.5(27)	11.4(41)	14.0(33)	16.6(39)		3.4(7.9)
Electric Energy Consumption	kWh/km	0.212		0.226	0.264				0.263	
Assumed Vehicle Life	yrs	11	10	12	12	10	10	10	10	6
Annual Usage	km/yr	10,000	10,000	16,000	16,000	16,000	16,000	16,000	7,000	7,000
Annual Fuel Consumption										
Gasoline	l(gal)		463.7(122.5)		420(111)	923.5(244)	1146.9(303)	969(256)		2096.9(554)
Electricity	kWh	2,120		3,616	3,181				1,841	
Sales Tax on Initial Vehicle Gasoline (Tax Rate: 4%)	$	205.60	96.00	189.60	256.00	108.00	122.16	138.56	242.40	152.00
Average Annual Cost of Taxes										
Sales Tax (4%)		35.28	19.52	40.72	54.35	25.28	26.12	28.88	50.96	45.40
Property Tax (None)										
Gasoline Motor Fuel Tax 2.1¢/l (8¢ gallon)			9.80		8.88	19.52	24.24	20.48		44.32
Registration Fee Weight Fee Other		12.50	12.50	20.00	20.00	12.50	12.50	12.50	25.40	15.00
TOTAL		47.78	41.82	60.72	83.23	57.30	62.86	61.86	76.36	104.72
Total State Taxes over Life of Vehicle	$	573.36	418.20	728.64	998.76	573.00	628.60	618.60	763.60	628.32
Total State Taxes per km	¢/km	0.48	0.42	0.38	0.52	0.36	0.39	0.39	1.09	1.50

TABLE B-8. IMPACT OF MASSACHUSETTS STATE TAXES ON VEHICLE OF INTEREST

Vehicle Class		2-PASSENGER AUTOMOBILES		4 PASSENGER AUTOMOBILES					LIGHT DUTY VANS	
Vehicle		ELECTRIC (near term)	LOW PERF. ICE	ELECTRIC	HYBRID	LOW PERF ICE	CHEVETTE	HONDA CVCC	ELECTRIC	ICE
Vehicle Acquisition Price	$	5,140	2,600	4,740	6,400	2,700	3,054	3,464	6,060	3,800
Vehicle Curb Weight	kg(lbs)	1011(2,229)	658(1,450)	1192(2,628)	1546(3,408)	878(1,935)	931(2,053)	792(1,745)	1530(3,372)	1134(2,500)
Hydrocarbon Fuel Economy	km/l(MPG)		21.6(51)		11.5(27)	11.4(41)	14.0(33)	16.6(39)		3.4(7.9)
Electric Energy Consumption	kWh/km	0.212		0.226	0.2[illegible]4				0.263	
Assumed Vehicle Life	yrs	11	10	12	12	10	10	10	10	6
Annual Usage	km/yr	10,000	10,000	16,000	16,000	16,000	16,000	16,000	7,000	7,000
Annual Fuel Consumption										
Gasoline	l(gal)		463.7(122.5)	-	420(111)	923.5(244)	1146.9(303)	969(256)		2096.9(554)
Electricity	kWh	2,120		3,616	3,181				1,841	
Sales Tax on Initial Vehicle Purchase (Tax Rate: 5%)	$	257	120	237	320	135	153	173	303	190
Average Annual Cost of Taxes										
Sales Tax (5% p.p.p.)		44.10	24.40	50.[illegible]0	67.94	31.60	32.65	36.10	63.70	56.75
Property Tax ($66/1000 evaluation)		83.42	43.56	76.9[illegible]	103.88	52.67	55.44	62.90	110.02	98.34
Gasoline Motor Fuel Tax 2.2¢/l (8½¢/gallon)			10.41	-	9.44	20.74	25.76	21.76	-	47.09
Registration Fee		7.00	7.00	7.00	7.00	7.00	7.00	7.00	80.00*	20.00*
TOTAL	$/year	134.52	85.37	134.86	188.26	112.01	120.85	127.76	253.72	222.18
Total State Taxes over Life of Vehicle	$	1,614.24	853.70	1,618.32	2,259.07	1,120.10	1,208.50	1,277.60	2,537.20	1,333.08
Total State Taxes per km	¢/km	1.35	0.85	0.84	1.18	0.70	0.76	0.80	3.62	3.17

*Minimum

TABLE B-9. IMPACT OF MICHIGAN STATE TAXES ON VEHICLES OF INTEREST

Vehicle Class		2 PASSENGER AUTOMOBILES		4 PASSENGER AUTOMOBILES					LIGHT-DUTY VANS	
Vehicle		ELECTRIC (near term)	LOW PERF. ICE	ELECTRIC	HYBRID	LOW PERF ICE	CHEVETTE	HONDA CVCC	ELECTRIC	ICE
Vehicle Acquisition Price	$	5,140	2,600	4,740	6,400	2,700	3,054	3,464	6,060	3,800
Vehicle Curb Weight	kg(lbs)	1011(2,229)	658(1,450)	1192(2,628)	1546(3,408)	878(1,935)	931(2,053)	792(1,745)	1530(3,372)	1134(2,500)
Hydrocarbon Fuel Economy	km/l(MPG)		21.6(51)		11.5(27)	11.4(41)	14.0(33)	16.6(39)		3.4(7.9)
Electric Energy Consumption	kWh/km	0.212		0.226	0.284				0.263	
Assumed Vehicle Life	yrs	11	10	12	12	10	10	10	10	6
Annual Usage	km/yr	10,000	10,000	16,000	16,000	16,000	16,000	16,000	7,000	7,000
Annual Fuel Consumption										
Gasoline	l(gal)		463.7(122.5)		420(111)	923.5(244)	1146.9(303)	969(256)		2096.9(554)
Electricity	kWh	2,120		3,616	3,181				1,841	
Sales Tax on Initial Vehicle Purchase (Tax Rate: 4%)	$	205.60	96.00	189.60	256.00	108.00	122.16	138.56	242.40	152.00
Average Annual Cost of Taxes										
Sales Tax (4%)		3[illegible].28	19.52	40.72	54.35	25.28	26.12	28.88	50.96	45.40
Property Tax (None)										
Gasoline Motor Fuel Tax 2.4¢l (9¢ gallon)			11.03		9.99	21.96	27.27	23.04		49.86
Registration Fee) Weight Fee) Other		12.65	12.00	14.85	19.25	12.00	12.00	12.00	29.00	20.00
TOTAL	$/year	47.93	42.55	55.57	83.59	59.24	65.39	63.92	79.96	115.26
Total State Taxes over Life of Vehicle	$	575.16	425.50	666.84	1003.08	592.40	653.90	639.20	799.60	691.56
Total State Taxes per km.	c/km	0.48	0.43	0.35	0.52	0.37	0.41	0.40	1.14	1.65

B.6. NOISE CONTROL

(Adopted from the Bureau of National Affairs Inc. - Noise Regulation Reporter)

TABLE B-10. STATE MOTOR VEHICLE NOISE REGULATIONS

State	Vehicle Operation			Sale of New Vehicles
	Posted Speed	Level Street Test	Stationary Test	
California	X	X		X
Colorado	X			X
Connecticut	X	X		
Indiana	X			
Idaho	X		X	X
Minnesota	X			X
Nebraska	X			X
New York	X		X	X
Nevada	X			X
Oregon	X		X	X
Pennsylvania	X			X

TABLE B-11. STATE NOISE REGULATIONS OF MOTOR VEHICLES FOR STREET AND HIGHWAY USE

(All levels in dBA measured at 15.2m (50 feet) unless noted otherwise)

State \ Criteria	Vehicle Wt. Class/Type	Operation at Posted Speeds: Effective Date	Under (35 mph) 56 km/h	Over (35 mph) 56 km/h	Other	New Sales: Date Mfg.	Max. Level
1. Federal	Interstate Only >10,000 lbs GVWR	10-15-75	86	90	ST 88	N/A	N/A
2. California	GVWR over 2722 kg (6000 lbs)	1-1-73	86	90	LS 82	A 1967 A 1972 A 1974 A 1977 A 1987	88 86 83 80 70
	Motorcycle	N/S	82	86	LS 77	B 1970 A 1969 A 1972 A 1974 A 1977 A 1987	92 88 86 80 75 70
	Other Vehicles & Combination of Vehicles	N/S	76	82	LS 74	A 1967 A 1972 A 1974 A 1977 A 1987	86 84 80 75 70
3. Colorado	GVWR over 3629 kg (8000 lbs)	B1-1-75 A1-1-75	84 80	86 82	N/S N/S	A1-1-73 A1-1-74 A1-1-75	86 83 80
	Motorcycle	B1-1-75 A1-1-75	80 74	82 80	N/A N/A	A7-1-71 A1-1-73 A1-1-74 A1-1-75	88 86 83 80
	Other Vehicles & Combination of Vehicles	N/S	74	80	N/S	A1-1-68 A1-1-74 A1-1-75	86 83 80
4. Connecticut	GVWR of 2722 kg (6000 lbs) or more	B1-1-75 A1-1-75	86 84	90 88	LS 82 LS 82	N/S N/S	
	Motorcycle	B1-1-75 A1-1-75	82 80	86 84	LS 77 LS 77	N/S N/S	
	Other Vehicles & Combination of Vehicles	N/S	76	82	LS 74	N/S	

B – Before
A – After
LS – Level Street
N/S – Not Specified
N/A – Not Applicable
ST – Stationary Test

TABLE B-11. STATE NOISE REGULATIONS OF MOTOR VEHICLES FOR STREET AND HIGHWAY USE (CONTINUED)

(All levels in dBA measured at 15.2m (50 feet unless noted otherwise)

State \ Criteria	Vehicle Wt. Class/Type	Operation at Posted Speeds: Effective Date	Under (35 mph) 56 km/h	Over (35 mph) 56 km/h	Other	New Sales: Date Mfg.	Max. Level
5. Indiana	GVWR of 3175 kg (7000) lbs or more	N/S	88	90		N/S	
	Motorcycles	N/S	82	86		N/S	
	All other vehicles	N/S	76	82		N/S	
6. Idaho	All Vehicles		92@20	92@20	92@20		
7. Minnesota	GVWR of 2722 kg (6000 lbs) or more	B1-1-75 A1-1-75	88 86	90 90		A1-1-72 A1-1-75	88 86
	Motorcycle	B1-1-75 A1-1-75	88 86	90 90		B1-1-72 A1-1-72 A1-1-73	92 88 86
	Other Vehicles and Combination of Vehicles	N/S	82	86		A1-1-72 B1-1-75 A1-1-75	86 86 84
8. Nebraska	GVWR of 4536 kg (10,000) lbs or more	B1-1-75 A1-1-75	88 86	90 90		A1-1-72 A1-1-73 A1-1-75 A1-1-80	88 86 84 80
9. New York	All Motor Vehicles		88	88	ST 88		
10. Nevada	GVWR >2722 kg (6000 lbs) and or towed vehicle	B1-1-73 A1-1-73	88 86	90 90		A1-1-72 A1-1-73	88 86
	Any Motorcycle		82	86		A1-1-72 A1-1-73	88 86
	Any other vehicle and/or towed vehicle		76	82		A1-1-72 A1-1-73	86 84

B – Before
A – After
LS – Level Street
N/S – Not Specified
N/A – Not Applicable
ST – Stationary Test

TABLE B-11. STATE NOISE REGULATIONS OF MOTOR VEHICLES FOR STREET AND HIGHWAY USE (CONTINUED)

(All levels in dBA measured at 15.2m (50 feet) unless noted otherwise)

State \ Criteria	Vehicle Wt. Class/Type	Operation at Posted Speeds				New Sales	
		Effective Date	Under (35 mph) 56 km/h	Over (35 mph) 56 km/h	Other	Date Mfg.	Max. Level
11. Oregon	Truck/Bus	B 1976 B 1978 A 1978	86 85 82	90 87 84	ST 94 ST 91 ST 88	1975 A 1976 A 1978	86 83 80
	Motorcycle	B 1975 1975 B 1978 A 1978	84 81 78 73	88 85 82 77	ST 94 ST 91 ST 88 ST 83	1975 A 1976 A 1978	86 83 80
	Automobiles, light trucks, all other vehicles	B 1976 B 1978 A 1978	81 78 73	85 82 77	ST 92 ST 88 ST 83	1975 A 1976 A 1978	83 80 75
12. Pennsylvania	GVWR >3175 kg (7000 lbs) and/ or towed vehicle		90	92		A1-1-73	90
	Motorcycle		90	92		A1-1-73	90
	Any other vehicle and/ or towed vehicle		82	86		A1-1-73	84

B – Before
A – After
LS – Level Street
N/S – Not Specified
N/A – Not Applicable
ST – Stationary Test

NOISE REGULATION AT THE LOCAL LEVEL

INTRODUCTION

The following data summarize existing noise control regulations of local jurisdictions. Tables 6 and 7 address noise regulations for self-propelled motor vehicles registered for operation on streets and highways. Table 8 lists those local jurisdictions having explicit regulations governing the operation of snowmobiles and other off-road recreational vehicles. Table 9 summarizes those communities having intrusive noise regulations and identifies major sources and the respective limits placed upon them.

There are currently in excess of 54 local jurisdictions with existing land-use noise regulations and approximately 100 more that have enabling legislation permitting the development of noise regulations. Because of the large number of communities, detailed listings of acoustic criteria regarding zoning are not provided here. However, Table 10 presents a summary of those communities with existing land-use noise regulations along with their principal noise descriptors. Specific regulations should be consulted for detailed information.

Table 11 lists those local communities with noise regulations governing construction equipment and on-site activities. Again, the reader is directed to specific regulations for detailed acoustic criteria.

Finally, there is a summary of miscellaneous noise regulations that cannot be readily classified in the preceding tables.

It should be noted that the following local jurisdictions' noise regulations may be subject to preemption by either Federal or state regulations, or by both.

TABLE B-12

SUMMARY OF LOCAL JURISDICTIONS
WITH MOTOR VEHICLE NOISE REGULATIONS

Community	Vehicle Operation	Sale of New Vehicles
Anchorage, Alaska	X	X
Birmingham, Michigan	X	
Boston, Massachusetts		X
Boulder, Colorado	X	
Broward Co., Florida	X	
Chicago, Illinois	X	X
Colorado Springs, Colorado	X	
Cook Co., Illinois	X	X
Honolulu, Hawaii	X	
Kalamazoo, Michigan	X	
Kansas City, Missouri		X
Grand Rapids, Michigan	X	X
Lakewood, Colorado	X	
Lincoln, Nebraska	X	
Marengo, Illinois	X	
Minneapolis, Minnesota	X	
New York, New York	X	
Rockford, Illinois	X	X
Salt Lake City, Utah	X	X

TABLE B-13. LOCAL JURISDICTION NOISE REGULATIONS FOR SELF PROPELLED MOTOR VEHICLES

(All levels in dBA measured at 15.2 m (50 ft) unless noted otherwise)

Jurisdiction	Vehicle Type/Wt.	Effective Date	Operation <35 mph	Operation >35 mph	Other	New Sales Date Mfg.	New Sales Max. Level
1. Alaska, Anchorage	All				8 am/8 pm 85 8 pm/8 am 70	5-19-74	85
2. Colorado, Colorado Springs and Lakewood	GVWR <10,000 lbs. >10,000 lbs				80 @<45 mph 88 @<45 mph		
3. Florida, Broward County	GVWR >8000 lbs		94	96			
		A1-1-78	88	90			
	Motorcycle		88	92			
		A1-1-78	82	86			
	Other		82	88			
		A1-1-78	76	82			
4. Hawaii, Honolulu Island of Oahu	GVWR >6000 lbs	A1-1-74	D 84 E 84 N 73	84	Truck Routes 88		
		A1-1-77	D 75 E 67 N 65	75			
	GVWR <6000 lbs	B1-1-77	69 @<25 71 @ 30 73 @ 35	75 @ 40 79 @ 50 83 @>60	levels specified at 5 mph increments		
	GVWR <6000 lbs	A1-1-77	61 @<25 63 @ 30 65 @ 35	67 @ 40 71 @ 50 75 @>60			

D – Day; E – Evening; N – Night; A – After; B – Before

TABLE B-13. LOCAL JURISDICTION NOISE REGULATIONS FOR SELF PROPELLED MOTOR VEHICLES (CONTINUED)

(All levels in dBA measured at 15.2m (50 ft) unless noted otherwise)

Jurisdiction	Vehicle Type Wt.	Effective Date	Operation <35 mph	Operation >35 mph	Operation Other	New Sales Date Mfg.	New Sales Max. Level
5. Illinois, a) Chicago	GVWR >8000 lbs	B1-1-73	88	90		A1-1-68	88
		A1-1-73	86	90		A1-1-73	86
						A1-1-75	84
						A1-1-80	75
	Motorcycles	B1-1-78	82	86		A1-1-70	88
		A1-1-78	78	82		A1-1-73	86
						A1-1-75	84
						A1-1-80	75
	Other Vehicles & Combination	A1-1-70	76	82		A1-1-73	84
		A1-1-78	70	79		A1-1-75	80
						A1-1-80	75
b) Cook County	GVWR >8000 lbs	B1-1-73	88	90		B1-1-73	88
		A1-1-73	86	90		A1-1-73	86
						A1-1-75	84
						A1-1-80	75
	Motorcycles	B1-1-78	82	86		B1-1-73	88
		A1-1-78	78	82		A1-1-73	86
						A1-1-75	84
						A1-1-80	75
	Other Vehicles & Combination	A1-1-73	76	82		B1-1-73	86
		A1-1-78	70	79		A1-1-73	84
						A1-1-75	80
						A1-1-80	75
c) Marengo	All				70 @ 200 ft.		
d) Rockford	GVWR >8000 lbs		86	90			
	Motorcycles		82	86			
	Other Vehicles		76	82			
6. Massachusetts, Boston	GVWR >10,000 lbs					1-1-70	88
						1-1-73	86
						1-1-75	84
						1-1-80	75
	<10,000 lbs					1-1-70	86
						1-1-73	84
						1-1-75	80
						1-1-80	75
	Motorcycles					1-1-70	88
						1-1-73	86
						1-1-75	84
						1-1-80	75

A – After; B – Before;

TABLE B-13. LOCAL JURISDICTION NOISE REGULATIONS FOR SELF PROPELLED MOTOR VEHICLES (CONTINUED)

(All levels in dBA measured 15.2m (50 ft) unless noted otherwise)

Jurisdiction	Vehicle Type/Wt.	Effective Date	Operation <35 mph	Operation >35 mph	Operation Other	New Sales Date Mfg.	New Sales Max. Level
7. Michigan,							
a) Birmingham	>10,000 lbs	B7-1-78	86	90			
		A7-1-78	82	86			
	Motorcycle	B7-1-78	82	86			
		A7-1-78	78	82			
	Other Vehicles	B7-1-78	76	82			
		A7-1-78	70	79			
b) Grand Rapids	>10,000 lbs	B7-1-73	88	90		B7-1-73	88
		A7-1-73	86	90		A7-1-73	86
						A1-1-75	84
						A1-1-80	75
	Motorcycles	B7-1-78	82	86		B7-1-73	88
		A7-1-78	78	82		A7-1-73	86
						A1-1-75	84
						A1-1-80	75
	Other Vehicles	B7-1-78	78	82		B7-1-73	86
		A7-1-78	73	79		A7-1-73	84
						A1-1-75	80
						A1-1-80	75
c) Kalamazoo	>10,000 lbs				82		
	<10,000 lbs				74		
	Passenger Cars				74		
	Motorcycles				82		
8. Minnesota, Minneapolis	>12,000 lbs	A1-1-72	D86	86			
		↓	E84	↓			
		B1-31-72	N73				
		A1-1-74	D84	84			
			N73	↓			
		A1-1-77	D75	75			
			E67	↓			
			N65				
	<12,000 lbs	B1-1-77		73* @ 35	*levels specified		
		A1-1-77		65* @ 35	by speed		
9. Missouri, Kansas City	>8000 lbs					12-31-73	86
	Motorcycle					12-31-71	92
						12-31-73	86
	Passenger Car					12-31-71	86
						12-31-73	82

D – Day E – Evening N – Night A – After B – Before

TABLE B-13. LOCAL JURISDICTION NOISE REGULATIONS FOR SELF PROPELLED MOTOR VEHICLES (CONTINUED)

(All levels in dBA measured at 15.2m (50 ft) unless noted otherwise)

Jurisdiction	Vehicle Type/Wt.	Effective Date	Operation <35 mph	Operation >35 mph	Operation Other	New Sales Date Mfg.	New Sales Max. Level
10. Nebraska, Lincoln	>8000 lbs		88	90			
	Motorcycle		82	86			
	Other Vehicles		76	82			
11. New York, New York	>8000 lbs	A9-1-72	86	90			
	Motorcycles	A9-1-72	82	86			
		A1-1-78	78	82			
	Other Vehicles	A9-1-72	76	82			
		A1-1-78	70	79			
12. Utah, Salt Lake City	>10,000 lbs				88 $\leq$ 40 mph		
	<10,000 lbs				80 $\leq$ 40 mph		

D – Day E – Evening N – Night A – After B – Before

B.7 FAIR MARKET VALUE OF AUTOMOBILES

In some states, the automobile is taxed on the basis of its nominal fair market value. This value is obtained from car value books published on a quarterly basis by national vehicle dealer groups for various regions of the country. The published car values are determined by a canvass of selling prices of vehicles in each geographic area. The listed value of an automobile is a complex function which depends on its age, size, class, make and options as well as on the demand for new and used automobiles in general. For a particular vehicle the listed value is only a general indication of its market value since the latter also depends on the mileage and the physical and mechanical condition of the vehicle.

In order to measure the bias for or against electric vehicles in those jurisdictions that base taxation on fair market value, it was necessary to develop estimated depreciation schedules for the various vehicles of interest to the study.

B.7.1 ICE Passenger Automobiles

Representative depreciation schedules for standards, compacts and sub-compact 1976 model year ICE automobiles were recently published by Liston and Aiken (B-5). These values, presented in Table B-14, apply to vehicles driven for 100,000 miles for a 10 year period. It was assumed that the fair market value of the various ICE passenger vehicles of interest to the present study would follow the same depreciation schedule, on a percentage basis, as the sub-compact ICE automobile in Liston and Aiken's study. These values are presented in Table B-15.

B.7.2 Electric Passenger Automobiles

At the present time, there are not enough electric or hybrid vehicles in use to have any basis for establishing realistic depreciation schedules. Establishing the value of a used electric vehicle, for purposes of tax assessment or of resale may be more difficult than for an ICE vehicle. This is because the expected life of the base vehicle is signifcantly greater than the life of the battery.

TABLE B-14. AVERAGE DEPRECIATION SCHEDULES FOR 1976 ICE PASSENGER AUTOMOBILES (a)

	Total or Average*	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Standard 1976 Passenger Auto											
Annual Depreciation	($) 4864	1215	748	637	466	340	306	292	292	291	277
Depreciation as % Initial Price	100.0	25.0	15.4	13.1	9.6	7.0	6.3	6.0	6.0	6.0	5.6
Year End Residual Values as % Initial Price		75.0	59.6	46.5	36.9	29.9	23.6	17.6	11.6	5.6	-
Average value in given year, as % initial price	35.6*	87.5	67.3	53.1	41.7	33.4	26.8	20.6	16.0	8.6	2.8
Compact 1976 Passenger Auto											
Annual Depreciation	($) 3830	536	498	441	402	383	377	354	307	283	249
Depreciation as % Initial Price	100.0	14.0	13.0	11.5	10.5	10.0	9.8	9.2	8.0	7.4	6.6
Year-End Residual Value as % Initial Price		86.0	73.0	61.5	51.0	41.0	31.2	22.0	14.0	6.6	-
Average value in given year, as % initial price	43.6*	93.0	79.5	67.3	56.3	46.0	36.1	26.6	18.0	10.3	3.3
Sub-Compact 1976 Passenger Auto											
Annual Depreciation	($) 3189	383	351	350	341	329	319	309	294	274	239
Depreciation as % Initial Price	100.0	12.0	11.0	10.0	10.7	10.3	10.0	9.7	9.2	8.6	7.5
Year-End Residual Value as % Initial Price		88.0	77.0	66.0	55.3	45.0	35.0	25.3	16.1	7.5	-
Average value in given year, as % initial price	46.5*	94.0	82.5	71.5	60.7	50.2	40.0	30.2	20.7	11.8	3.8

(a) Source: L.L. Liston and C.A. Aiken, "Cost of Owning and Operating an Automobile. 1976". U.S. Department of Transportation, Office of Highway Planning, Highway Statistics Division.

TABLE B-15. ASSUMED FAIR MARKET VALUE OF ICE PASSENGER AUTOMOBILES OF INTEREST TO STUDY

	Initial List Price	Ten Year Average	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Average Value of 1976 Sub-Compact ICE vehicle in a given year, % (From Table	100.0	46.5	94.0	82.5	71.5	60.7	50.2	40.0	30.2	20.7	11.8	3.8
Low Performance 2 Passenger ICE	2400	1116	2256	1980	1716	1457	1205	960	725	497	283	91
Low Performance 4 Passenger ICE	2900	1349	2726	2393	2074	1760	1456	1160	876	600	342	110
Chevette Scooter	3054	1420	2871	2520	2184	1854	1533	1222	922	632	360	116
Honda	3464	1611	3256	2958	2477	2103	1739	1336	1046	717	409	132

For tax purposes, an electric vehicle could be assessed in at least three different ways:

i. The value of the vehicle is based on the combined value of the base vehicle and battery. These are then treated as a unit that is depreciated over the life of the vehicle.

ii. The value of the vehicle is based on the value of the base vehicle with the battery being considered as an expendable accessory. The assessed value is then a function of the rate of depreciation of the base vehicle alone.

iii. The value of the vehicle is based on the sum of the separate values of the vehicle and of the battery. The assessed value is then a function of the rate of depreciation of the base vehicle and of the rate of depreciation of the battery.

The basis of evaluation of an electric vehicle can greatly alter the amount of property tax an owner would have to pay. Neglecting the value of the battery would be most favorable to owners of electric vehicles, especially if expensive, advanced batteries are used. Treating the vehicle and battery separately for tax purposes may be difficult and could result in the possibly unacceptable anomaly that the owner of an old vehicle with a new battery would have to pay a higher tax than the owner of a newer vehicle that has an older battery.

For purposes of the present study, it was arbitrarily (but hopefully reasonably) assumed that electric passenger automobiles would exhibit similar depreciation characteristics as their ICE counterparts but over a longer period of time, twelve instead of ten years. The ten year depreciation schedule for an ICE sub-compact automobile shown in Table B-14 was arbitrarily adjusted to a twelve year schedule by assuming that the annual depreciation, as a percentage of the initial price, of an electric vehicle would be 90% of the depreciation of an ICE sub-compact for years 1 through

10, and then 6% in year 11, and 4% in year 12. It was further assumed that the applicable initial price would be that of the combined base vehicle and battery. This results in the least favorable treatment for this class of vehicles. The depreciation schedule and the corresponding annual values for the 2-passenger electric, 4-passenger electric and 4-passenger hybrid vehicles are presented in Table B-16.

B.7.3 ICE Vans

The present values of six cylinder CJ-5 Jeeps manufactured between 1970 and 1977 are presented in Table B-17. The CJ-5 Jeep is a larger and more powerful consumer version of the DJ-5 Jeeps used in Postal Service. The ratio of the present value of a used Jeep of a given model year to the list price of a 1977 Jeep was calculated for each year to establish a depreciation schedule. This assumes that there was little difference in the characteristics of these vehicles of different model years.

For tax assessment purposes, it was assumed that the value of the ICE van considered in this study would depreciate in the same manner as a CJ-5 Jeep. The corresponding values are also given in Table B-17. This depreciation schedule is different than the one used to calculate life cycle ownership costs of the vehicle. In the latter calculations, it was assumed that the vehicle would depreciate completely in six years with little or no salvage value.

B.2.4 Electric Vans

As with the electric passenger automobiles, there are no data available on the value of used electric vans. The depreciation schedule assumed for the first ten years of the life of electric passenger vehicles was assumed applicable to electric vans. This schedule and the assumed values of an electric van as a function of time are presented in B-17. As with the ICE, the depreciation schedule assumed for tax evaluation purposes is higher than the depreciation schedule assumed for the cost of depreciation for the life cycle cost calculations.

TABLE B-16. ASSUMED FAIR MARKET VALUE OF ELECTRIC/HYBRID VEHICLES OF INTEREST TO THE STUDY

		Total of Initial Price	Lifetime Average	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Annual Depreciation of Sub-Compact ICE Automobile (From Table B-14), %		100.0		12.0	11.0	11.0	10.7	10.3	10.0	9.7	9.2	8.6	7.5		
Assumed Annual Depreciation of Electric/Hybrid Passenger Auto %				10.8	9.9	9.9	9.6	9.3	9.0	8.7	8.3	7.7	6.8	6.0	4.0
Year end Residual Value of Electric/Hybrid Passenger Auto. % of Initial Price				89.2	79.3	69.4	59.8	50.5	41.5	32.8	24.5	16.8	10.0	4.0	0
Average Value in Given Year of Electric/Hybrid Passenger Auto, % Initial Price			44.0	94.6	84.2	74.3	64.6	55.2	46.0	37.2	28.7	20.7	13.4	7.0	2.0
Assumed Fair Market Value of Electric/Hybrid Passenger Autos of Interest															
2 Passenger Electric (Near Term)	$	5140*	2262 (a)	4862	4328	3819	3320	2837	2364	1912	1475	1064	689	360	103
4 Passenger Electric (Long Term)	$	4740*	2086 (a)	4484	3992	3522	3062	2616	2180	1764	1360	981	635	332	95
4 Passenger Hybrid (Long Term)	$	6400*	2816 (a)	6054	5389	4755	4134	3533	2944	2381	1837	1325	858	448	128
Electric Van (Long Term)	$	6060*	3145 (b)	5733	5102	4503	3915	3345	2788	2254	1739	1254	812		

* Includes Price of Battery

(a) 12 year life

(b) 10 year life

TABLE B-17. ASSUMED FAIR MARKET VALUE OF ICE VAN OF INTEREST TO STUDY

Model Year	1977	1976	1975	1974	1973	1972	1971	1970
6 Cyl CJ-5 Jeep								
List Price, $	4399	4199	4099	3524	3086	2955		3155
May-June 1977 Used Sale Price $		3950	3400	2625	2275	1800		1360
1977 Used Sale Price / 1977 List Price	1.0	0.90	0.77	0.60	0.52	0.41	0.36 *	0.31

ICE Van of Interest	List Price	Life Time Average Value	AGE Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Annual Depreciation Based on CJ-5 Jeep, % List Price			10.0	13.0	17.0	0.08	0.09	0.05
Year End Residual Value, % List Price			90.0	77.0	60.0	52.0	41.0	36.0
Average Value in Given Year, % List Price		66.3	95.0	83.5	68.5	56.0	46.5	36.5
Assumed Reserved Value, ICE VAN, $	3800	2519	3610	3173	2603	2128	1767	1463

*by interpolation

SOURCE: Car and Truck Appraisals, American Auto Appraisal, Royal Oaks, Mi., April-May-June, 1977.

APPENDIX B - REFERENCES

B-1. 1977 MVMA SPECIFICATION FORM, PASSENGER CAR, General Motors Corp., Chevrolet Motor Division, Chevrolet, Model Year 1977 (September 1976).

B-2. Sears Catalogue, Fall/Winter 1976 Edition.

B-3. Gottesman, C.A., "Bumper Pendulum Swings to New Designs", Automotive Industries, 154 (2), 19-23 (Jan. 15, 1976).

B-4. Hatch, D.E., "Aluminum Automobile Bumper Systems" SAE Paper 770268, PRESENTED AT THE SAE Automotive Engineering Conference, March 1977.

B-5. Liston, L. L. and C.A. Aiken, "Cost of Owning and Operating an Automobile, 1976". U.S. Department of Transportation, Office of Highway Planning, Highway Statistics Division.

B-6. Car and Truck Appraisals, American Auto Appraisal, P.O. Box 930, Royal Oak Mi. 48068, April-May-June, 1977.

APPENDIX C

COMPARATIVE IMPACTS OF ICE AND ELECTRIC VEHICLES ON AIR QUALITY

C.1 EMISSIONS FROM ICE VEHICLES

Conventional ICE vehicles can release significant quantities of hydrocarbons, carbon monoxide and nitrogen oxides, as well as sulfur oxides and particulates. Legislation to date has emphasized the reduction of the levels of the first three pollutants per distance of vehicle travel. Particulate and sulfur oxide exhaust emissions are considered minor in comparison to the first three emissions. No Federal standards for these two pollutants are presently in effect, although many areas have opacity (antismoke) regulations applicable to motor vehicles. (C-1)

C.2 EMISSIONS FROM ELECTRIC VEHICLES

The impact of electric vehicles on air pollution depends on the local characteristics of the electricity power generation process. While electrics do not produce vehicle exhaust gas emissions, they transfer the air pollution emission problem to the electricity generating plant. To the extent that the vehicles use electricity generated from non-fossil fuel sources, they do not contribute to air pollution. However, electric vehicles that use electricity from coal and oil sources contribute to air pollution.

The air pollution characteristics of power plants differ from the emissions of conventional vehicles in both type of pollutant and in the way the pollutant is emitted into the atmosphere. The principal emissions from a coal burning power plant are sulfur dioxides, nitrogen oxides and particulates. These emissions are generally discharged from tall stacks which are removed from the ground surface. Consequently the concentration of power plant originated pollutants is usually substantially reduced at ground level due to dispersion in the surrounding air volume. However, power plants are major point sources that have an impact over a wide area.

Aside from air pollution considerations, power plants also generate significant amounts of solid waste and can cause thermal pollution problems, depending on the way the energy not converted into electricity is disposed of.

Table C-1 lists the air pollution and solid waste residuals for several different boiler fired power plants burning different fuels. The coal data are based on a pulverized-feed furnace burning coal with an ash content of 12.53% and a sulfur content of 2.59%, characteristic of a national average coal. The controlled plant assumes that a wet limestone scrubber system is employed with SO_x removal efficiencies of 85% and particulate removal efficiencies of 99%. The oil fired plant assumes a 1.5% sulfur oil. In all these plants, an overall energy conversion efficiency of 38% is assumed. (C-2)

It has been estimated that the assumed emission control system would require an additional investment of $27/kW to $46/kW and would result on increase in the cost of electricity of 1.1 mil/kWh to 2.2 Mil/kWh. These costs are in 1973 dollars. (C-3) By using the M+S equipment cost index, the costs were adjusted from 1973 dollars to 1976 dollars. (C-4) The equivalent costs in 1976 dollars are estimated to be $37/kW to $63/kW for the incremental investment and 1.5 mil/kWh to 3.0 mil/kWh. This cost increase is 4% to 8% of the normal cost of electricity of 4¢/kWh assumed in the study.

Table C-2 presents the above data in terms of grams of pollutant per kilowatt-hour of electricity delivered at the plug. In arriving at these values, a transmission efficiency for electricity of 91% was assumed.

B.3 COMPARATIVE EMISSIONS

The pollution emissions of various vehicles of interest to the study are compared in Table C-3, on the basis of grams of pollutant discharged per unit distance travelled. The values for the three ICE vehicles presented are those obtained in the 1977 model year EPA certification tests. (C-5) The standards that these vehicles were required to meet are also listed for reference,

TABLE C-1. RESIDUALS FROM BOILER FIRED POWER PLANTS[a]

SYSTEM AND FUEL	AIR POLLUTANTS metric tons/10^{15} joules (short tons/10^{12} Btu)						
	Particulates	NO_x	SO_x	HC_x	CO	Aldehydes	Solid Wastes
Convential Steam System, No Controls:							
- coal[b]	70.3 (82.2)	316 (369)	1730 (2020)	5.26 (6.15)	17.5 (20.5)	0.09 (0.1)	4320 (5050)
- oil[c]	23.3 (27.2)	305 (357)	685 (801)	583 (6.81)	0.12 (0.14)	2.9 (3.4)	- -
- gas	6.2 (7.3)	163 (191)	0.3 (0.3)	16.8 (19.6)	0.16 (0.19)	2.9 (3.4)	- -
Conventional Steam System, with Controls:							
- coal[b]	17.6 (20.6)	316 (369)	173 (202)	5.26 (6.15)	17.5 (20.5)	.09 (0.1)	12493 (14600)

a) Thermal efficiency of 38% Assumed

b) National average coal 12.53% Ash, 2.59% Sulfur

c) Oil: 1.5% sulfur oil

Source: Energy Alternatives, A Comparative Analysis by the Science and Public Policy Program, University of Oklahoma, Norman, Oklahoma, May 1975, Table 12-4.

TABLE C-2. RESIDUAL/KLOWATT HOUR OF FOSSIL FUEL DERIVED ELECTRICITY DELIVERED AT THE PLUG

gm/kWh

Air Pollutants

System	Particulates	NO_x	SO_x	HC	CO	Alde-hydes	Solid Wastes
Conventional Steam, No Controls:							
Coal	0.74	3.31	18.1	0.055	0.18	0	45.3
Oil	0.24	3.20	7.18	0.061	0.001	0.030	0
Gas	0.066	1.71	0.003	0.18	0.002	0.030	0
Conventional Steam with Controls:							
Coal	0.18	3.31	1.81	0.055	0.18	0	131

Source: Based on Table C-1 and an electrical transmission efficiency of 91%.
1 kWh = 3413 BTu

as are estimated precontrol emissions levels for automobiles and light duty trucks. No data are presented for the model ICE vehicles considered in the study. The values for the electric and hybrid vehicles are based on the electricity consumption data presented in Table A-1 of Appendix A, and the data presented in Table C-2. The emissions presented for the hybrid vehicle are for its operation as an electric vehicle.

Inspection of Table C-3 indicates that substitution of electric vehicles would result in a reduction of carbon monoxide and hydrocarbon emissions, a significant increase in sulfur dioxide emissions, and no significant change in nitrogen oxide emission levels, and an unknown change in particulate emissions. The replacement of the Postal Service ICE delivery vans by electric vans would have more impact than the replacement of either the Honda or Chevette by their electric or hybrid counterparts. This is because the two ICE passenger automobiles exhibit significantly better emissions characteristics than the Postal Service van. The passenger automobiles meet the 1977 California passenger vehicle emission standards whereas the Postal Service Van only has to meet the much more lenient Federal emission standards for light duty trucks. The comparison between electric vehicles and ICE vehicles also has to take into consideration the mode of operation of the vehicle. For the ICE vehicles, hydrocarbon and carbon monoxide emissions are much lower in highway use and in city use.

The data on exhaust particulates from ICE engines is sketchy in comparison to the data on the other pollutants. However, it is interesting to note that the uncontrolled particulates from the ICE vehicles could be as high or higher than the particulates from a coal fired boiler with no controls.

TABLE C-3. COMPARISON OF AIR BORNE EMISSIONS FROM ICE VEHICLE EXHAUSTS TO EQUIVALENT POWER PLANT EMISSIONS FOR ELECTRIC VEHICLE OF INTEREST TO THE STUDY

Passenger Vehicles		Hydrocarbons		Carbon Monoxide		Nitrogen Oxides		Sulfur Oxides		Particulates	
		g/mi	g/km	g/mi	g/km	g/mi	g/km	g/mi	g/km	g/mi	g/km
Estimated Precontrol Emissions (a)		8.74	5.43	86.5	53.7	3.54	2.20	0.13[c]	0.08[c]	0.34[c]	0.21[c]
1977 California Emission Standard		0.41	0.25	9.0	5.6	1.5	0.9				
1977 Chevette Scooter, California Model (e)											
EPA City		0.25	0.16	3.20	1.98	1.35	0.84				
EPA Highway		0.04	0.02	0.30	0.19	1.12	0.69				
1977 Honda Civic CVCC, California Model (e)											
EPA City		0.27	0.17	3.20	1.98	1.37	0.85				
EPA Highway		0.02	0.01	1.20	0.74	2.16	1.84				
2 Passenger Electric Vehicle (Near Term)											
Electricity from	Coal - No Controls	0.02	0.01	0.06	0.04	1.13	0.70	6.19	3.84	0.25	0.16
	Coal - With Controls	0.02	0.01	0.06	0.04	1.09	0.70	0.62	0.38	0.06	0.04
	Oil - No Controls	0.02	0.01	<0.01	<0.01	1.13	0.68	2.46	1.52	0.08	0.05
4 Passenger Electric Vehicle (Intermediate)											
Electricity from	Coal - No Controls	0.02	0.01	0.07	0.04	1.21	0.75	6.60	4,98	0.27	0.17
	Coal - With Controls	0.02	0.01	0.07	0.04	1.21	0.75	0.66	0.41	0.07	0.04
	Oil - No Controls	0.02	0.21	<0.01	<0.01	1.17	0.72	2.62	4.62	0.09	0.05
4 Passenger Hybrid (InElectric Mode)											
Electricity from	Coal - No Controls	0.03	0.02	0.08	0.05	1.52	0.94	8.29	5.14	0.34	0.21
	Coal - With Controls	0.03	0.02	0.08	0,05	1.52	0.94	0.83	0.51	0.08	0.05
	Oil - No Controls	0.03	0.02	<0.01	<0.01	1.47	0.91	3.29	2.04	0.11	0.07
Light Duty Vans											
Estimated Precontrol Emissions (b)		17.0	10.6	12.5	77.6	4.2	2.6	0.36[d]	0.22[d]	0.91[d]	0.56[d]
1977 Federal Standard for Light Duty Trucks		2.0	1.2	20.0	12.4	3.1	1.9				
1977 Post Office Delivery Vehicle (e)											
EPA City		1.40	0.87	14.20	8.80	2.58	1.60				
EPA Highway		0.52	0.32	3.00	1.86	3.73	2.31				
Electric Van											
Electricity from	Coal - No Controls	0.02	0.01	0.08	0.05	1.40	0.87	7.68	4.76	0.31	0.19
	Coal - With Controls	0.02	0.01	0.08	0.05	1.40	0.87	0.77	0.48	0.08	0.05
	Oil - No Controls	0.02	0.01	<0.01	0.01	1.36	0.84	3.05	1.89	0.10	0.06

a) Supplement No. 5 for Compilation of Air Pollution Factors, 2nd Edition, U.S. E.P.A., Research Triangle, N.C., December 1975
Values for pre-1968 Low Altitude Vehicles in Table 3.1, 2-1
b) Loc Cit Citations, values pre 1968 vehicles in Table 3.1.4-1, c) Loc Cit Citations, Table 3.1.2-13 for pre-1973 automobiles.
d) Loc Cit Citations, Table 3.1.4-13, for all light duty trucks, all years
e) Buyers' Guide Data, U.S. EPA, Ann Arbor, Mich. Feb 22, 1977.

APPENDIX D - POTENTIAL USE OF ELECTRIC VEHICLES ON THE FARM

D.1 INTRODUCTION

There is a large fleet of ICE vehicles that presently are an integral part of farming operations.

Many of the smaller tractors, lighter trucks and passenger automobiles are presently used on farms for light chores and short trips, tasks which, in the opinion of the U.S. Department of Agriculture and the National Rural Electric Cooperative Association (NRECA), could be effectively carried out by electric vehicles. Some of these tasks include materials handling (on premise transport of feed and fertilizer), the powering of portable elevators and feed mixers, other similar tasks which do not generally require a high torque output from power units, and the running of errands on or off the farm.

According to NRECA, "... most farmers have need for a small service vehicle, perhaps a small pick up truck, designed for hauling small loads (fuel, feed, produce, etc.) or just running errands around the farmstead. A 50 mile range would be adequate for most tasks and speeds of 40 to 50 mph would rarely be exceeded. Tractors or full sized pick-up trucks usually used for these duties are not only inconvenient but are costly to maintain." (D-1) According to a representative of the U.S. Department of Agriculture (D-2), an electric vehicle equivalent to a light truck (1/2 ton to 3/4 ton capacity) would be greatest utility on a farm. Such a vehicle would be a larger version of the light duty electric van considered in the present study, with approximately twice to three times the hauling capacity. A 1/4 ton van was considered to be too small to find general applicability on a farmstead but a larger electric van meeting the above criteria could potentially replace a large majority of the light duty trucks in use in agricultural applications.

D.2 MOTOR VEHICLES IN AGRICULTURE

Statistics compiled by the Department of Agriculture and by the Department of Commerce's Bureau of the Census indicate that there are a few million ICE motor vehicles in use on the farm or in agriculture. The various studies did not consider the same populations and there are significant differences in the published estimates of the truck populations associated with farming or agriculture.

The source of the data presented in Table D-1 is the Department of Agriculture (D-3). The data for Jan. 1, 1970 are those published by the Bureau of the Census in its Dec. 31, 1969 Census of Agriculture. (D-4) The methodology used to collect the Census data is published in Volume II, Chapter 1 of the Census. (D-5) Statistics were gathered on the population on farms of farm equipment and machinery, including tractors, motor trucks and automobiles which are listed in Table D-1.

The source of the data presented in Table D-2 is the 1972 Census of Transportation, Truck Inventory and Use Survey (D-6) also prepared by the Bureau of the Census. In this survey trucks for agriculture were those trucks used principally for agricultural purposes on own farm or ranch <u>or for other agricultural activities</u>. Other agricultural activities may include non-farm trucks used to transport agricultural products.

According to Table D-1, there were 2,943,000 motor trucks on farms in the United States in 1972. According to Table D-2, there were 4,258,000 trucks used for agriculture in the United States in 1972. The difference of 1,315,000 trucks is not insignificant, and should be reconciled.

The Census of Transportation contains a substantial amount of information on the characteristics of trucks used in agriculture. These results are presented in Tables D3-A to D3-E. Most trucks in agricultural use are lightweight trucks with a G.V.W. of less than 10,000 lb (4,540 kg). They are typically pick-up trucks that are used in the near vicinity of their base of operation. Nearly

TABLE D-1

NUMBER OF MOTOR VEHICLES ON FARMS
IN THE UNITED STATES, JANUARY 1, 1970-75

Year	Excluding Garden Tractors	With Garden Tractors	Motor Trucks	Automobiles
	(THOUSAND VEHICLES)			
1975	4263	5128	2882	
1974	4376	5236	2906	
1973	4387	5232	2915	
1972	4469	5299	2943	
1971	4562	5382	2969	
1970	4619	5424	2984	2688

Source: U.S. Department of Agriculture
Agricultural Statistics, 1975
Table 599

TABLE D-2. AGRICULTURAL TRUCK POPULATION IN 1972

	U.S. Total Trucks	Trucks in Agriculture	Trucks in Agriculture As % of U.S. Total Trucks
Number of Trucks, (10^3 units)	19,745	4,258	21.6
Truck-miles (10^6)	244,492	37,082	15.2
Annual Average Miles/Truck	12,400	8,700	
Number of Pick-up Trucks (10^3 units)	12,345	2,686	21.8
Pick-Up Truck Miles (10^6)	130,243	25,622	19.7
Annual Average Miles/Pick-up Truck	10,600	9,500	
SINGLE UNIT TRUCKS			
2 axle	18,289	4,115	22.5
3 axle	548	83	15.2
Total	18,836	4,198	22.3
SINGLE UNIT TRUCK MILES			
2 axle	193,315	34,217	
3 axle	8,868	940	
Total	202,177	35,157	

Source: 1972 Census of Transportation

TABLE D-3a

CHARACTERISTICS OF TRUCKS
USED IN AGRICULTURE IN 1972

A-Weight Class

Weight Class	GVW, lbs (Kg)	As Percent of Trucks in Agriculture	As Percent of Truck Miles in Agriculture
Light	10,000 or less (4540 or less)	68.8	73.4
Medium	10,001 to 20,000 (4541 to 9080)	21.3	14.5
Light-Heavy	20,001 to 26,000 (9081 to 11804)	6.5	4.1
Heavy-Heavy	26,001 or more (11805 or more)	3.6	8.2
TOTAL		100.0	100.0

Source: Reference D-6.

TABLE D-3b

CHARACTERISTICS OF TRUCKS
USED IN AGRICULTURE in 1972

B-Body Type

Body Type	Percent of Trucks in Agriculture	Percent of Truck Miles in Agriculture
Pick-up	63.1	69.1
Platform	20.3	13.3
Cattlerack	10.4	9.8
Other	3.3	7.8
TOTAL	100.0	100.0

Source: Reference D-6.

TABLE D-3c

CHARACTERISTICS OF TRUCKS
USED IN AGRICULTURE IN 1972

C-Range of Operations

Range	As Percent of Trucks in Agriculture	As Percent of Truck Miles in Agriculture
Local	87.9	81.4
Short Range	3.7	7.9
Long Range	0.6	3.1
Not Reported	7.8	7.6
TOTAL	100.0	100.0

Local: Mostly local area use within a short distance of place where vehicle is stationed
Short Range: Mostly over-the-road (beyond the local area) but usually not more than 200 miles one way to the most distant stop from place vehicle is stationed.
Long Range: Mostly over-the-road trips that usually are more that 200 miles one way to the most distant stop from place the vehicle is stationed.

Source: Reference D-6

TABLE D-3d

CHARACTERISTICS OF TRUCKS
USED IN AGRICULTURE IN 1972

D-Annual Use

Annual Miles (Km)	As Percent of Trucks in Agriculture	As Percent of Truck Miles In Agriculture
Less than 5000 miles (Less than 8000)	39.1	10.2
5000 to 9999 miles (8000 to 16,100)	28.6	21.4
10,000 to 19,999 (16,100 to 32,200)	24.2	34.1
20,000 miles or more (32,200 or more)	8.7	34.6
	100.0	100.0

Source: Tables 4 and 11, Reference D-6

TABLE D-3e

CHARACTERISTICS OF TRUCKS
USED IN AGRICULTURE IN 1972

E-Truck Fleet Size

Truck Fleet Size	Percent of Trucks in Agriculture	Percent of Truck-Miles in Agriculture
1 Truck	57.4	57.6
2 to 5 Trucks	36.6	32.8
6 Trucks of More	6.0	9.6
TOTAL	100.0	100.0

Source: Reference D-6

40 percent of these trucks are driven less than 5,000 miles per year (8,000 km/yr), and nearly 70 percent of them are driven less than 10,000 miles per year (16,000 km/yr). The majority of owners of agricultural trucks possess only one truck. However, slightly over one-third of the trucks used in agriculture are part of small fleets of two to five trucks. There are very few large truck fleets in agricultural use.

The above data tend to support the comments made in the introductory part of this section.

D.3 MOTOR FUEL CONSUMPTION BY TRUCKS IN AGRICULTURE

Data for the motor fuel consumption of selected motor vehicles are presented in Table D-4. According to the 1972 Census of Transportation, trucks in agriculture logged 15.2 percent of total mileage logged by all trucks in that year. Single unit trucks in agriculture logged 17.3 percent of total mileage logged by all single unit trucks in 1972. By assuming the average fuel efficiency of a given class of trucks in agriculture to be equal to the fuel efficiency of the same class of trucks of the total population, an estimate of the fuel consumption by a given class of agricultural trucks can be obtained by multiplying the known total fuel consumption of the overall class by the fractional mileage of agricultural trucks in that class. The estimates of the fuel consumption of agricultural trucks are based on this assumption. According to this calculation, agricultural trucks accounted for 4.3 percent of the U.S. consumption of motor fuel in 1972, with single unit trucks consuming most of this fuel, 3.5 percent of the total. This fuel consumption includes trucks with a GVW in excess of 10,000 lbs. However, as shown in Table D-3a, most of this fuel in consumed by pick-up trucks that logged over 70 percent of truck miles associated with agriculture in 1972. If it were assumed that a typical pickup truck had a fuel economy of 10 mpg (4.2 km/l), agricultural pick-up trucks would have consumed 2.5 x 10^9 gallons (9.7 x 10^9 liters), which is 2.3 percent of the national motor fuel consumption, or about 66

TABLE D-4. FUEL CONSUMPTION BY MOTOR VEHICLES IN 1972

MODE OF TRANSPORTATION	MOTOR FUEL CONSUMPTION, 1972		
	10^9 gallons	10^9 liters	% of Motor Vehicle Consumption
All Motor Vehicles in U.S.	108.9[(a)]		100.0
All Trucks in U.S.	30.7[(a)]	116.3	28.2
Single Unit Trucks in U.S.	22.1[(b)]	83.7	20.3
Trucks in Agriculture	4.7[(c)]	17.7	4.3
Single Unit Trucks in Agriculture	3.8[(d)]	14.5	3.5
Non-highway Agricultural Use of Gasoline	1.7[(a)]	6.4	1.6

Source:

(a) U.S. Federal Highway Administration
Highway Statistics. 1972 Annual Report
(b) 1972 Census of Transportation, Truck Inventory and Use Survey
(c) Assumes 15.2 percent of fuel consumption of all trucks in U.S.
(d) Assumes 17.3 percent of fuel consumption of single axis trucks in U.S.

percent of the fuel consumption of all single unit trucks on agriculture, given in Table D-4. These results tend to support each other.

Some additional insight is obtained on the consumption of motor fuel on farms from data published by the Federal Highway Administration on the non-highway agricultural use of gasoline D-7. In 1972, non-highway agricultural use of gasoline amounted to 1.7 x 10^9 gallons (6.4 x 10^9 liters) or 1.6 percent of the national consumption. This fuel consumption is partially included in 3.8 x 10^9 gallons (14.5 x 10^9 liters) of fuel consumed by single unit trucks in agriculture, to the extent that these trucks are used on the farm and off the public roads. A significant fraction of this non-highway use of gasoline in agriculture is to power gasoline fueled tractors and other agricultural machinery. In addition, there is also a significant consumption of diesel fuel and special fuels by non-highway agricultural machinery.

Based on the data presented in Table D-4, agricultural uses approximately 5 percent of the national consumption. Approximately half of this fuel is consumed by lightweight trucks (and presumably some tractors) that could be potentially replaced by electric vehicles.

D.4 AGRICULTURAL MARKET FOR ELECTRIC VEHICLES

Replacing all pick-up trucks in agriculture by electric vehicles would result in a market for slightly less than 2.7 million electric vans. This maximum is based on the population of pick-up trucks given in Table 2 and may be high. Depending on the assumed life of the vehicle, which may be from 6 years (used in the present market estimates) to 10 years or more, there is a maximum replacement market of 270,000 vehicles/year to 450,000 vehicles/year. This is of the order of magnitude needed to install one, and possibly two, assembly lines.

A more realistic estimate of the penetration of the electric van in agriculture would be to consider a maximum market of no more than one quarter of the above line. This would mean a maximum annual production of 70,000 units to 100,000 units. This demand would be marginal in terms of U.S. production levels and would require electric vans to find additional significant markets outside of agriculture so that they could be manufactured at a level which would take advantage of all economies of scale.

D.5 OTHER USES FOR ELECTRIC VEHICLES IN AGRICULTURE

Aside from the on-the-road electric trucks, discussed above, there is also a potential on farms for specialized electric trucks (D-1, D-2) that can best be described as an all-terrain traction version of the electric materials handling trucks and forklift trucks that are in common use in warehouses and factories. These vehicles could be used as work horses for farmstead operations such as hay lifting, barnyard operations, manure handling, etc. None of these applications require the capability of larger ICE tractors characteristically found on farms.

D.6 AVAILABILITY AND COST OF ELECTRICITY ON THE FARMSTEAD

As of September 30, 1976, 98.6 percent of the farms in the United States received central station electric service. With the exception of three states (Arizona with 85 percent, Nevada with 89 percent and New Mexico with 90.1 percent), over 97 percent of the farms in each state received central station electric service. The national average electricity consumption per residential consumer of Rural Electrification Act (REA) distribution borrowers was 840 kWh/month in 1975. Rural electricity consumption increased at an average annual rate of 5.8 percent from 1964 to 1975. Rural residential customers paid an average of 2.90¢/kWh during calendar year 1975. On a state basis, in 1975, electricity consumption ranged from an average of 402 kWh/month in New Mexico to 1528 kWh/month in Washington (D-8).

Farms that receive central electric power usually are supplied by at least a 5 KVA substation. Most farms are supplied from a 10 KVA substation with a 220 volt output. It is not unusual for large farms to have 400 ampere service (88 KVA), (D-9).

The light duty electric van discussed in Appendix A consumes 0.263 kWh/km and has a nominal range of 150 km. The maximum amount of power needed to recharge the battery of this vehicle is 39.5 kWh. Assuming a recharging rate of 8 hours, a 5 kWh electric supply would be required.

For farms that draw from substations with a capacity of at least 10 KVA, the demand placed by recharging an electric vehicle would be well within the capacity of the electric service of a typical farmstead, especially if this vehicle were recharged at night when there is low demand from other users of electricity

The average load capacity for rural electric utility systems is lower than national average. Therefore, it is anticipated that the additional load that would be generated by the introduction of a large population of electric vehicles in rural areas would be handled with the existing electrical supply system.

APPENDIX D REFERENCES

D-1 L. Endahl, Statement of National Rural Electric Cooperative Association on HR 5470, "Electric Vehicle Research, Development and Demonstration Act of 1975." Before the Subcommittee on Energy Research, Development and Demonstration, Committee on Science and Technology, U.S. House of Representatives, June 6, 1975.

D-2 Personal Communication, June 16, 1977.

D-3 U.S. Department of Agriculture, Agricultural Statistics 1975

D-4 U.S. Department of Commerce, Social and Economic Administration, Bureau of the Census, 1969 Census of Agriculture, Vol. II, General Report Chapter 4. Equipment, Labor, Expenditures, Chemicals (July 1973).

D-5 Ibid, Chapter I General Information; Procedures for Collection, Processing, Classification (April 1973).

D-6 U.S. Department of Commerce, Social and Economic Administration, Bureau of the Census. 1972 Census of Transportation, Truck Inventory and Use Survey, TC72-T52, October 1973.

D-7 U.S. Department of Transportation, Federal Highway Administration, Highway Statistics 1972.

D-8 U.S. Department of Agriculture, Rural Electrification Administration, Report of the Administration, Fiscal Year 1976.

D-9 L. Endahl, National Rural Electric Cooperative Association, Washington, D.C. Personal Communication, June 16, 1977.

APPENDIX E
DERIVATION OF CURVES FOR VELOCITY AND GRADE

Electric vehicles have generally been designed to be slower than ICE vehicles. As a result, minimum requirements have been established for maximum speed to assure reasonable speed compatibility with surrounding traffic. These maximum speeds are for level road operation and speed will diminish whenever significant upgrades are encountered.

Gradeability criteria have been established to assure that some minimum performance is maintained. The gradeability standard is stated in terms of a minimum sustained speed on a stated grade. For the four study vehicles, the following standards were established.

	Maximum Speed	Gradeability
Hybrid	90 km/h (56 mph)	85 km/h (53 mph) on 6%
4-Passenger EV	90 km/h (56 mph)	70 km/h (44 mph) on 7%
Commercial EV	85 km/h (53 mph)	70 km/h (44 mph) on 7%
2-Passenger EV	80 km/h (50 mph)	30 km/h (18.5 mph) on 10%

Gradeability curves for each of the study vehicles were established to see how sustained speed is related to road grade. This was accomplished by first establishing the power requirements to meet the gradeability specification for each of the study vehicles. Power requirements were calculated by estimating the power required for level road losses at different velocities and then adding the power required to maintain the velocity on different grades. Results are shown in Fig. E-1.

The calculations are based upon a companion study on EV characteristics being completed concurrently at GRC. (E-1) Power required for level road losses is shown as the 0% grade curve. Assumptions for the car aerodynamics include 1.9m^2 (20 ft^2) frontal area, drag coefficient of .35, and a vehicle weight of 907kg (2,000 lbs.) Curves at each grade were then derived by adding in power required for the grade by using the following equation

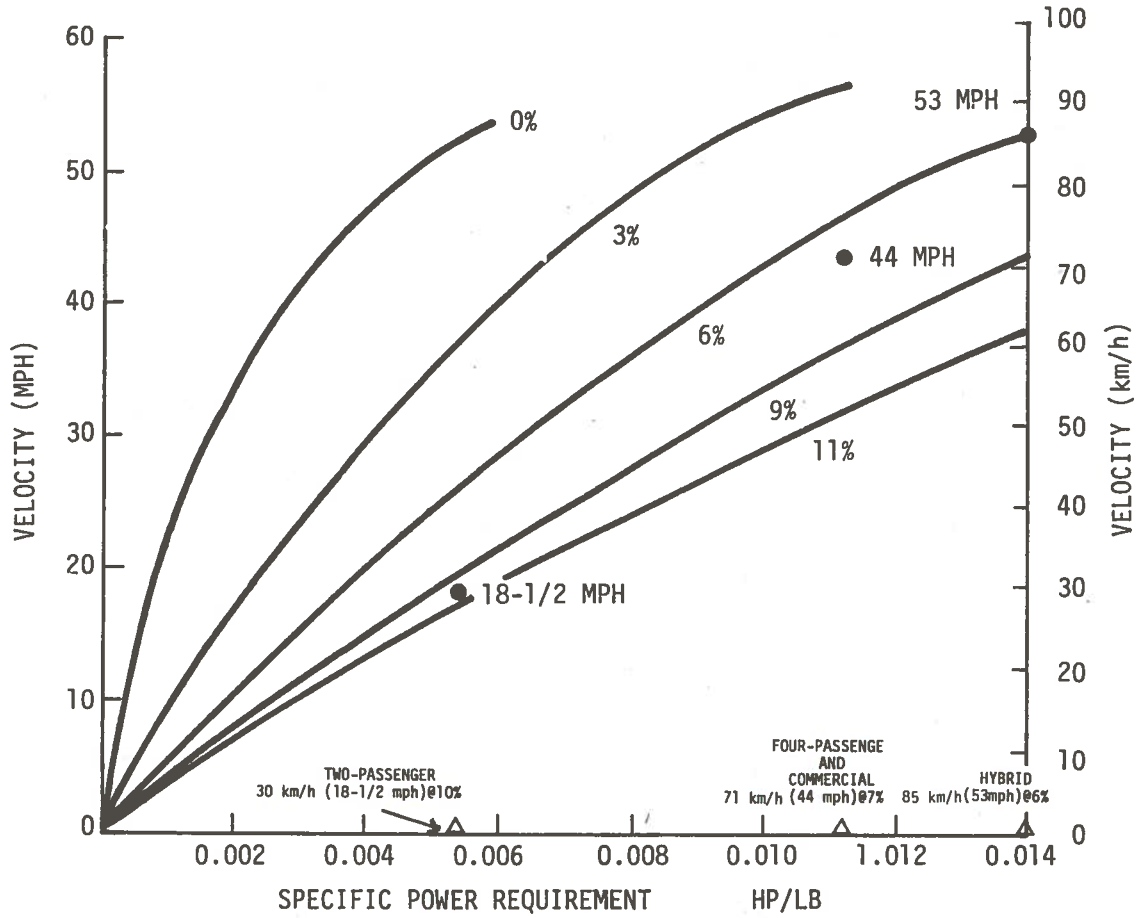


FIGURE E-1. GRADEABILITY VERSUS SPECIFIC POWER

$$\text{Specific Power Requirement} = (\text{hp/lb}) \frac{\text{Velocity (mph)}}{375} \text{Sin}(\text{ARCTAN} \frac{\text{\% Grade}}{100})$$

From these curves it was possible to pick the specific power required for the gradeability specifications. The following results were obtained.

Vehicle	Specific Power	Gradeability Criteria
Hybrid	.014	85 km/h (53 mph) @ 6%
Four-Passenger	.0112	71 km/h (44 mph) @ 7%
Commercial Van	.0112	71 km/h (44 mph) @ 7%
Two-Passenger	.0052	30 km/h (18-1/2 mph) @ 10%

Using these specific power requirements, curves for velocity and grade were derived using the intersection of the specific power and the various grade lines of Fig. E-1. Results are shown in Fig. E-2. Note the calculation assumes that the EV motor has been sized for maximum speed and gradeability. Figure E-2 shows that gradeability is a more stringent requirement than maximum speed for all the vehicles.

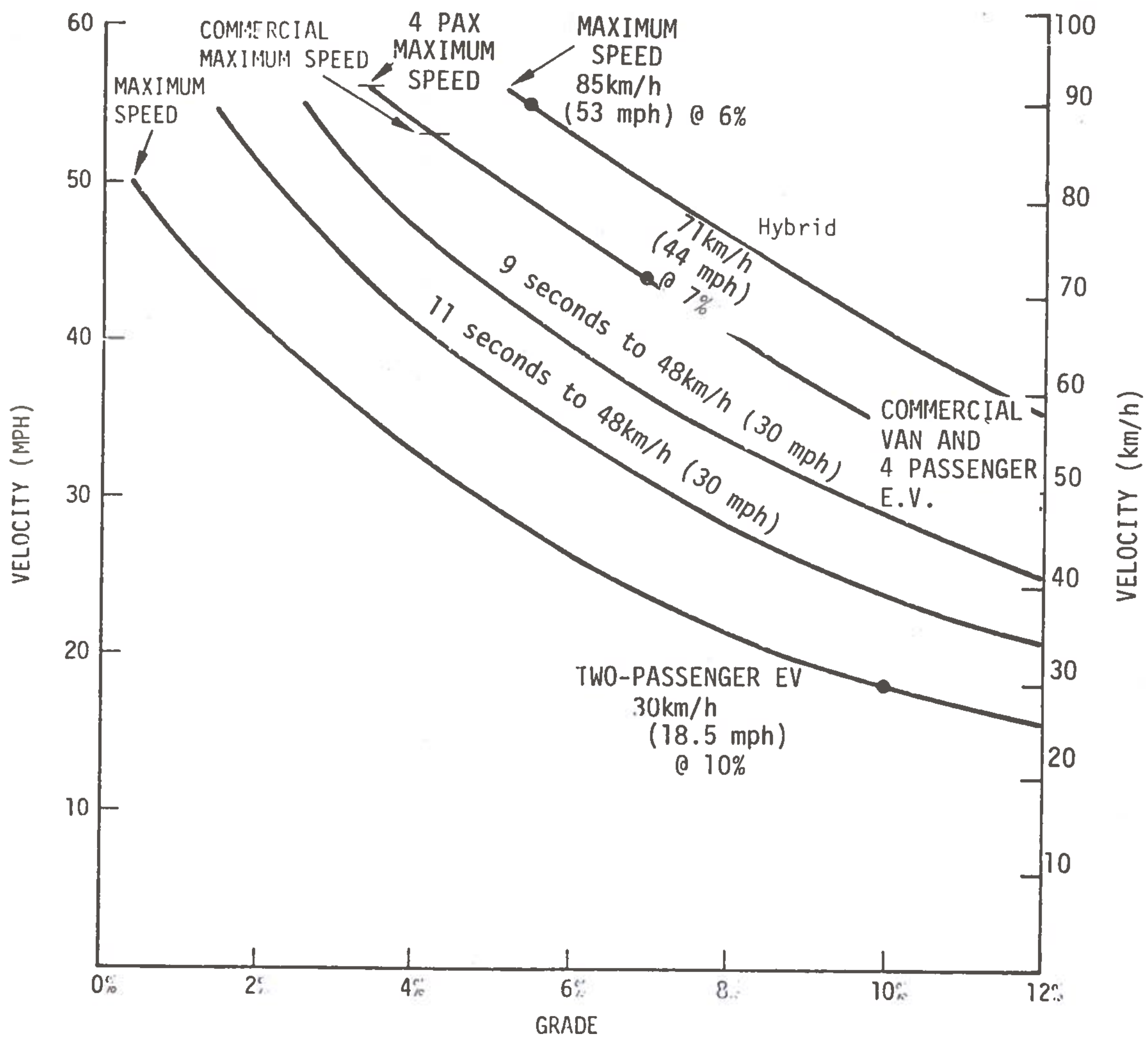


FIGURE E-2. GRADEABILITY FOR DIFFERENT VEHICLE CHARACTERISTICS

APPENDIX E - REFERENCES

E-1. Graver, C.A. and Carr,R.H., "Institutional Bias with Respect to Electric Vehicles in Traffic Control." Internal Memorandum No. IM 2109, General Research Corp., Santa Barbara, CA, May 1977.

APPENDIX F
RAMP LENGTH ESTIMATE

An equation was developed (F-1) which estimates the length of the ramp required to enter the freeway at a minimum velocity as a function of average grade and vehicle acceleration characteristics. Aerodynamic drag was not included in the equation so required ramp lengths are conservative. However, for the entering speed evaluated, 64.4 km/h (40 mph), the aerodynamic drag is negligible over most of the speed range, 0-64.4 km/h (0-40 mph). The equation (in metric units) is given below:

$$S = \left[-\frac{V}{.12 + g\theta}\right]\left[\frac{V}{2} + \frac{P}{M(.12 + g\theta)}\right] - \frac{P^2}{M^2(.12 + g\theta)^3}\ \ln\left[1 - \frac{(.12 + g\theta)}{P/M}V\right] \quad (1)$$

where

S = Length of ramp (meters)

V = Entering velocity (meters/second)

g = Gravity coefficient (9.8 meters/second^2)

θ = Grade (decimal)

P = Power

M = Mass

$P/M = V_a{}^2/2T_a$

where

V_a and T_a describe the acceleration characteristics of the vehicle. V_a is measured in meters per second and T_a in seconds. Thus, if the vehicle has an acceleration characteristic of 50 kmh in 9 seconds, then $V_a = 13.89$ and $T_a = 9$. P/M in this case equals 10.72.

For an example, using the above equation, consider a vehicle with acceleration characteristics of 50 km/h in 9 seconds, an entering speed requirement of 64.4 km/h (40 mph) and a 2% grade. Then

$P/M = 10.72$

$\theta = .02$

$V = 17.88$ meters/second

$g = 9.8$

$S = 304$ meters or 1,000 feet.

Using this equation, ramp length requirements for various grades were calculated for selected acceleration characteristics including those in the study. A 64.4 km/h (40 mph) entry speed onto the freeway was assumed to be the minimum requirement. Results are shown in Fig. F-1.

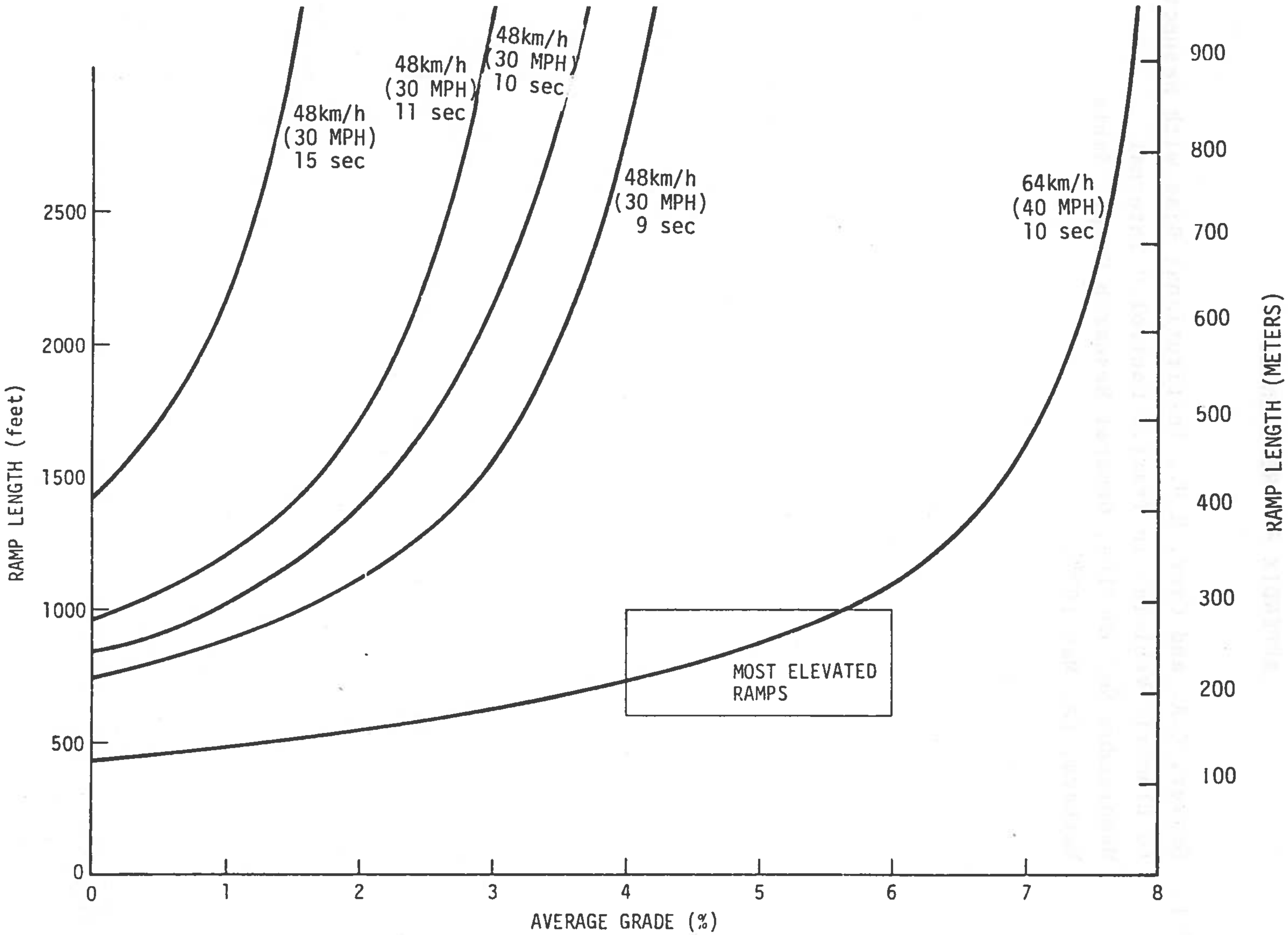


FIGURE F-1. REQUIRED RAMP LENGTH TO ENTER AT 64.4 km/h (90 mph)
(AERODYNAMIC DRAG EXCLUDED)

APPENDIX F - REFERENCES

F-1. Graver, C.A. and Carr, R.H., Institutional Bias with Respect to Electric Vehicles in Traffic Control," Internal Memorandum No. IM 2109, General Research Corp., Santa Barbara, CA, May 1977.

APPENDIX G - SUMMARY OF PUBLIC DOCKET

G.1 INTRODUCTION

On February 16, 1977 the U.S. Department of Transportation publicly requested comment on issues that should be addressed in this study on institutional factors relevant to electric and hybrid vehicles. Public Docket, OST File No. 50 was established at the Office of General Counsel, DOT, Washington D.C. and has been open for public inspection and responsive comment before and after the April 1 closing date. A total of twelve written comments were received. Each was carefully studied and relevant suggestions were incorporated into the design and scope of this study.

G.2 SUMMARY

The following individuals, transportation officials, and businesses submitted written comments to the Docket:

- E.B. Schmidt, Pittsburgh, Pennsylvania
- Automobile Club of California, Los Angeles, California
- Florida Department of Transportation, Tallahassee, Florida
- American Motors Corp., Detroit, Michigan
- George R. Hoffmann, Overland Park, Kansas
- Joseph Yarmus, Brooklyn, New York
- Schwitzer Engineering Co., Indianapolis, Indiana
- Richard J. Maurer, Cypress, California
- Transportation Alternatives, New York, New York
- Rohm and Hass Company, Philadelphia, Pennsylvania
- David P. Crooks, Kansas City, Missouri
- J.A. Stanley & Associates, Chatsworth, California

Issues identified in these comments included those relating to:

- Difficulties in EV insurability.
- Need for low speed transportation corridors.
- Discriminatory registration procedures and fees.
- EV emergency road service.
- Possibilities of electrifying highways.
- Design and demonstration of electric and hybrid buses.
- Applicability of FMVSS to EV's.
- Need for high-performance in EV's, if vehicle segregation is to be avoided.
- Adequacy of electric power to handle projected E.V. demand.
- Need for government help in development of EHV technology.