Title

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Sustainable Transportation:

The Future of the Automobile in an Environmentally Constrained World

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Summary

"Sustainable Transportation: The Future of the Automobile in an Environmentally Constrained World has analyzed the nature of the problems confronting the transportation systems of industrialized countries [1] We seek to understand how travel and energy use for travel (and freight) is changing, how these changes may affect the environment, and how the environmental problems may in turn affect future travel and freight activity During its first three years, the study focused on the automobile During the final two years, we aim to examine other modes of transportation more closely, in order to produce an integrated picture of the options facing the U.S. and other developed nations Although we have focused on the U S and other major industrialized countries, we acknowledge that problems facing rapidly growing transportation demand are manifest in the Third World and in the economies in transition in Central and Eastern Europe

1. Background: The "Deadly Sins" of the Automobile.

There is a consensus among many transportation and energy experts that a multitude of challenges associated with ever increasing motorization, mobility, traffic, energy use, and pollution from road vehicles, confront the cities of OECD countries and major developing countries as well (Johnson 1993) The litany of problems that must be addressed includes traffic safety, congestion, noise, and many kinds of pollution resulting from the use of cars, especially greenhouse gas emissions from transportation fuels Figure 1 shows these greenhouse gas emissions on a per capita bases for the U S , Japan, and seven countries in Europe The

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[1] Other recent participants include Ruth Steiner, Roger Gorham, Wienke Tax, Nancy Kiang, Maria Josefina Figueroa all from the Univ. of California, Berkeley, Molly Espey from the Univ of California, Davis, Gunnar Eriksson from NORDPLAN Stockholm and Olof Johansson from the University of Gothenburg

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Opinions expressed herein are strictly those of the authors pollution generated by the manufacture of vehicles, use of, and disposal or recycling of transportation equipment cannot be ignored. Finally, the problems associated with obtaining a stable and secure transportation fuels supply continues to be a concern. More broadly, transportation planners and policy makers have confronted a variety of problems associated with access to growing, sprawling cities, including segregation of land uses and competition for land, and access to vital services for those who cannot drive or cannot afford the costs of either private or often even public transportation We have called these the "Deadly Sins" of the automobile.

The extent of these problems depends upon particular conditions of time, location, and in some cases on the kinds of fuels and vehicles used as well Most would be described as externalities. They are not easy to "monetize" or even to compare, since doing so requires both an objective evaluation of the damage they cause as well as the valuation of that damage, something that may vary among different groups or individuals in societies, and certainly depends on time and place DeLuchi has begun to evaluate systematically many of the "sins" of the automobile and has discovered wide variation in valuations of their "costs" per kilometer of automobile travel, or, in the case of fuels, per liter of fuel consumed He has tabulated a large number of costs that are both paid by drivers (trucks and cars), by society as a whole through funding of roads and other transportation-related services, and through environmental costs or externalities borne by specific groups in society. DeLuchi's calculations (currently being completed) show that the unpaid costs of transportation are large, albeit less than the total private benefits of transportation Breaking these costs into their marginal components, and then estimating them at specific locations and times (important for pollution, congestion, and noise) is difficult. Nevertheless, virtually all observers agree that at the margin, even the lower range of valuation placed on these sins is at least comparable to the pre-tax marginal fuel cost of driving a car 1 kilometer approximately 2 U.S cents per kilometer in the U S and Europe Some estimates of these hidden costs put them on a comparable level with the fully taxed cost of fuel in Europe (approximately \$1-\$1 25 per liter or about 8-9 cents/km)[2] At the same time, both critics and supporters of these kinds of calculations agree that growth in automobile use in Europe is evidence that consumers derive great private benefits, on average, from using their cars. The concern about car use is not about the "average" situation, nor should it be focused on eliminating private vehicles, but rather on the fact that some automobile use, perhaps even a significant share of all driving, might not be undertaken were consumers to somehow face more of the marginal external costs directly. Changing the way drivers pay for using their cars (and the roads) could have a profound impact on how the car is used.

While not all of these problems involve only the automobile, the automobile does stand at the center of many of them. Similarly, some of the problems (air pollution, greenhouse gas emissions importing oil) are related to the nature of the fuel used, others not Indeed, it appears that actions designed to remedy transportation-related problems could have as great an impact on fuel use as those aimed only at fuel, through provoking restraint in vehicle kilometers traveled

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2 See Kaageson 1993, COWIconsult 1993, or MacKenzie et al 1992

2. Quantifying Energy Use for Transportation

At the center of the problems of transportation and its resulting air pollution is an analysis of how energy is used by vehicles. In the initial phase of this study, we confronted the "vicious circles" of interdependent data and truly circular calculations lying behind "data" on travel and freight activity, fuel use, and fuel economy of each mode. Relying on national data sources provided by a large network of government academic, and private experts, we collected and analyzed data that describe the structure of travel (and freight) activity, fleets of vehicles, infrastructure, and energy use in nearly a dozen OECD countries from 1970 onward. This effort has resulted in a unique data base that offers the first ever quantification of the structure of transportation energy use in OECD countries [3]

Figure 2 shows per capita travel by mode in the U S , Japan, and an aggregate of seven European countries (Denmark, France, W Germany, Italy, Norway, Sweden, UK), Figure 3 shows the smooth time trend from 1970 to 1990 Figure 4 shows the energy use associated with activities in each of these modes (We have made similar tabulations for domestic freight, which are shown in Schipper and Meyers, et al 1992) Behind these figures lie careful tabulations of gasoline and diesel fuel (also LPG and natural gas) for each mode of road traffic, a split of energy use for domestic rail and water traffic into passenger and freight shares and a determination of the domestic share of fuel used for air travel One key finding is that automobile fuel use has grown in most countries far more rapidly than that of gasoline alone, the quantity traditionally used to represent automobile fuel. Increasing numbers of motorists in Europe have turned to diesel fuel, while fewer and fewer truckers use gasoline This is one subtle but important aspect of energy use for transportation that has come to light in our study

These data show important trends total energy use for both travel and freight (not shown) rose in every country between 1970 and 1991, although the net increase in the U S was very small, because per capita energy use for travel in the U.S fell (Energy uses not included here include military vehicles, international marine and air fuel, civil aviation, and some miscellaneous vehicles) The share of transportation energy use in total energy use increased in every country In virtually each case, activity (in passenger-km or tonne-km) increased, increasing energy use The mix of modes shifted towards more cars, air, and trucks in every country except Denmark. The energy intensities of most modes fell only slightly, with a few important exceptions

- For cars, energy use per passenger-km, or energy intensity, fell by over 20% in the U S , but by less than 5% elsewhere (or even increased), as the number of people in a car decreased,
- For air travel, energy intensity fell by around 50%,
- For trucking, energy intensity (energy use per tonne-km) increased slightly in most countries, largely because of the rising importance of smaller trucks or the rising frequency of smaller loads

Of all the countries we studied, only the U S showed a clear decline in the overall energy intensity of transportation. This was due to the huge decline in the use of fuel/km for automobiles, over 30% between 1973 and 1991. Since real fuel prices in almost all the countries studied were only high for two periods—1973-6 and 1979-1985—it is not surprising if we did not observe major changes in transportation energy intensities.

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[3] See Schipper, Steiner, Duerr, An, and Strøm 1992, Schipper and Meyers, et al , 1992, Schipper, Steiner, and Meyers 1993 Schipper, Steiner, Figueroa, and Dolan 1993 Schipper, Figueroa, Price, and Espey 1993

That air travel was a clear exception is due in part to enormous and irreversible improvements in both aircraft technology and in utilization. Fuel use per seat kilometer dropped almost 40%, in part because there were more seats per plane, and the fraction of seats filled rose from below 55% in most countries to well above 60%.

The calculations behind Figures 2-4 were the first ever presented in an international context, and narrowed many key uncertainties in the "gap" in the way we understand the link between fuel use and transportation activity. But we discovered an even more profound "gap" that has not been erased, and that is the large differences between the fuel intensity of new cars as measured in tests, and what these cars appear to deliver on the road, in real traffic.[4] Driver behavior, the influence of traffic, the difference between the test driving cycles and real driving cycles, and small differences in the make up of car models tested and those actually sold all distort the fuel economy drivers get on the road As Table 1 shows, this gap can be substantial except in Sweden. The reason for this exception is that the tests give more weight to urban driving than is the actual case for Swedish drivers, which roughly compensates for the inaccuracy of the tests While the tests still serve an important function, informing potential car buyers of the relative fuel economy of different makes and models, these provide increasingly unreliable information about actual fuel use for forecasting purposes or for estimating emissions in real driving conditions

These difficulties notwithstanding, Figure 5 shows the real, on the road fuel economy of the combined diesel and gasoline automobile fleets (including personal light trucks in Denmark and the U S) in OECD countries from 1970 to 1991. The decline in the U S (and Canada) is dramatic when compared with the very slow changes in Europe. On the other hand, the evolution of fuel prices is surprising (Figure 6) Fuel prices rose in 1973, and again more sharply after 1979, in all countries However they drifted downward in the early 1980s and crashed in 1986, as Figure 6 shows From the perspective of the time it to takes to turnover vehicle stocks (15 years) or influence significantly the transportation infrastructure (20 years or longer) the 1979/1985 period of higher prices was very brief Moreover, real fuel prices in 1991 were only significantly higher than their 1973 value in Italy, and slightly higher in W Germany, Sweden, and Norway, largely because of the imposition of new taxes after 1988 (and the short-term increase in prices during the Gulf War) Thus it is not surprising if fuel economy has not improved that much in most countries Instead, cars have become more efficient—but larger and more powerful—in Europe, and this trend resumed in the U S after 1982. Because fuel economy improved by 10% in European countries, fuel costs per kilometer rose very little, except in Italy. For the U.S., the 1991 fleet used 30% less fuel/kilometer than did the 1991 fleet, which means the cost/km was dramatically lower in 1991 than it was in 1973 It remains to be seen whether the price increases that occurred after 1988 will have any impact on fuel economy

An additional factor restraining these costs increases was the large rise in the use of diesel vehicles in Italy, France, and Germany after 1985. Because diesel fuel is significantly cheaper than gasoline in those countries, buyers of diesel cars lowered their driving costs, which in turn progressively lowered the average cost drivers paid for all fuel. While we have not yet studied explicitly the role of these price differences in influencing vehicle choice, the connection is clear Moreover, studying this connection will reveal better how much consumers are willing to invest in a more expensive (diesel) car that costs less to run

[4] Schipper and Tax 1994.

3. Energy-Use Gap?

Our preliminary manipulations showed that three factors—motorization (or car ownership), mobility (or travel), and macho (or the characteristics and fuel economy of cars—share roughly equally in explaining the three-to-one difference between per-capita fuel use in the U S and values in Europe (Figure 7) If Americans had driven the European fleet of vehicles in 1990, per capita fuel use would be about 25% lower than it was as the second column suggests; if instead Americans had driven their actual cars the distances Europeans drive, fuel use would have been about 30% lower, as the third column shows The fourth column shows the impact on U.S fuel use of combining these effects, while the last column, actual per capita fuel use for cars in Europe, also reflects lower car ownership there

Having quantified the differences in total travel, modal choice, and aggregate travel behavior that distinguish the U.S. from Japan and Europe, and the populations of Europe from each other, we turn to the issue of *why* European automobile fuel use is so different from that in the U S We have considered policy instruments that explain these differences, including energy prices and taxation and taxes on cars, as well as demographic and behavioral trends that interact with these factors

Fuel pricing has had an impact on fuel use and distance travelled Our preliminary cross-sectional econometric studies show that fuel prices affect fuel use primarily through the fuel economy of (new) cars but also through the affect of fuel prices on car use The long-term price elasticity of fuel use is -0 8 from cross sectional estimation (Schipper and Johansson 1994), with about -0 46 arising from differences in the fuel intensity of the car stock, -0 26 from differences in distance traveled, and the remainder from differences in car ownership. If we include each country's population density, the overall price elasticity falls very slightly, suggesting this factor plays a small but appreciable role [5] These findings are consistent with our study of car use (Espey and Schipper 1993), which show a relatively low elasticity of kilometers travelled with respect to fuel price (and fuel intensity) from time-series analyses of each country

Subtle differences in the way cars, and other parameters of car use, are taxed are also important to ownership and use, although the impact on fuel use is small in most countries because of the dominant effect of fuel taxation itself Schipper and Eriksson (1994) calculated the impact the tax schemes in each of seven countries would have had on the total costs for acquisition, yearly fees, and fuel for the mix of cars sold in the U.S. in 1990. Figure 8 shows both the untaxed U.S price of the car (and 10 years' of fuel at 14 000 km/year and 8 l/100 km), plus the taxes on acquisition, fuel, and yearly ownership over the same 10-year period (assuming constant costs or prices for each component from 1990) The enormous burden of ad-valorem taxes in Denmark, Norway, and even Holland contrasts sharply with the absence of heavy taxation in the U S and the modest taxes levied by other countries with important car industries

While differences in fuel prices explain much of the difference in fuel economy between the United States and Europe, they explain only a part of the differences in mobility The relative distances between urban areas, the pattern and density of settlements, and differences in fuel prices offer some explanation These factors also act to give such collective systems high enough ridership to keep the vicious circle of falling patronage from squeezing the system. Still, these modes require heavy subsidies in Europe for their continued survival and apparent popularity. Although the longer term trends show the car slowly gaining in

[5] In future work we will try to use a parameter that more carefully measures urbanization and urban density

Europe, it is doubtful that cars will ever provide the same share of travel, or the same level of mobility per capita, as they do in the United States

4. Patterns of Mobility

To understand more about these differences in transportation patterns, we have begun to analyze how people travel, how often, and how far, using national personal transportation surveys. In this analysis, we are trying to see whether the travel patterns of persons in the United States (roughly one-third of person-kilometers for work, one-third for family business like shopping, education, or medical needs, and one-third for free-time activities) are slowly developing in Europe, or whether the pattern is different in Europe because of their pattern of work locations, car ownership, urban density, land use, or availability of transit

One interesting preliminary result suggests that a single journey in a car in America is about as far as one in Europe. Figure 9 shows that the average trip length in a car does not vary substantially over the countries shown.[6] In particular, we were surprised that the average car trip in the U S is only around 15 km, comparable to that in Sweden or Britain, and only slightly longer than a trip in Germany or Denmark What explains the enormous gap between the U S and Europe in per capita distance travelled by car is thus the number of trips per capita and not America's allegedly sprawling distances However, the sprawl of America's suburbs certainly contributes to reducing walking and cycling trips to work, services, and leisure time. More subtly, however, it appears that it is the large number of short trips Americans make by car (which Europeans make with their feet, their cycles, urban transit, or simply don't make) that reduces the average distance an American travels when she uses a car That is, Europeans have virtually the same access to travel destinations as Americans, but they do not travel as far or as often to achieve this access

Figure 2 revealed this difference in another light We see that the distance Europeans travel by rail and bus (both intercity and within urban areas) is three to five times that covered by Americans Europeans' travel by collective modes neither compensates for the American's greater travel by car, nor acts as a direct substitute. Instead, a complex set of factors related to land use, urban density and fuel and transit prices both constrains Europeans to travel less and offers a more attractive framework for using collective modes

5. Travel and Urban Form

How does mobility, particularly automobile use, vary as a function of the density of the surroundings in which a person lives? To answer that question, we have examined national, multi-state regional, and local surveys. The national travel surveys show that the mobility of car owners living in dense built-up areas was somewhat less than people with cars living in less dense parts of cities or in rural areas (At the same time there are more poor people or those without cars, particularly childless individuals and couples, in urban areas.) Figure 10 shows how household driving in the U S. varies by multi-state region and by the location of household (central city, suburban, or rural)[7] The regions of the U.S represent those with the two highest

[6] We have made many adjustments to national figures for sake of compatibility The first U S figures exclude longer trips reported in a special section of the Nationwide Personal Transportation Survey, "Travel Period", the second set include these figures

[7] The data are taken from the *Residential Transportation Energy Consumption Survey Household Vehicles Energy Consumption 1991* (DOE/EIA 0464(91) Washington DC US Dept. of Energy Sadly, the data on fuel consumption are imputed from reported driving distances and the certified test fuel consumption of the model of the cars each household owns The distributions of travel agree with those in the U S. Nationwide Personal Transportation Survey (U S Department of Transportation 1992)

average and lowest vehicle use/household It is clear from the figure that households in the urban areas have the lowest mobility (measured in vehicle/kilometer of travel [vkt]/capita), those in the suburbs the highest vehicle use, and those in non-metro areas close to, but below that of those in suburban areas Notably, the variation between central city, outside city, and non-metro (rural) is larger than the variation between regions

The socio-demographic characteristics of "Those living in less dense parts of cities" are different from those in rural areas or those in city centers, just as households in one region may be quite different from those in other regions. If we examine travel/household as a function of both region and income as reported in the survey (Figure 11), the variation over income is significant and broader than the variation over geography (we show two groups from the bottom and top of the distribution) Similarly, if we stratify by whether or not the household has children (not shown), we also obtain a significant difference in vehicle use, even if we control for income. We find that life-cycle characteristics are important considerations as well. Single adults over 60 years old travel 15000 mi/year, ranging from a low of 6000 mi/year for those earning under $15,000 to a high of 27,000 mi/year for the wealthiest group Those under 35 travel 50% more, within a given income band than those over 60. Since the composition of a population by income, age, and demographic structure varies by region, it is important to understand the influence of each of these variables in order to explain some of the variation in total travel between different regions Thus, the mobility of people in any particular region, or location within a region, is complicated by income effects and life-cycle effects that depend on age and family status (such as number of children) Those living in central cities drive less, but they have fewer children lower income, and fewer cars.

When we studied European national surveys with regional detail, such as that undertaken in Denmark in 1992/3 or those undertaken in Britain approximately every five years, we find similar effects, location is an important determinant of mobility, but the differences in income, demography and the age structure of populations vary enough by locations so that these factors must also be examined with data gleaned from surveys Moreover, the difficulty of working with entire regions—not to mention countries—suggests we need a finer tool than simply household travel behavior by region if we wish to understand the relationship between location and travel.

As an example, compare travel in the inner and outer parts of two Scandinavian cities, Copenhagen and Stockholm.[8] Figure 12 shows shares of travel for residents of central Copenhagen and the Copenhagen suburbs from a new survey covering 1992/3 For comparison, we also show weekday travel of residents of central Stockholm and its suburbs from the 1986/7 survey of that city. It is clear that those living in the inner city travel less by car, and, of total mobility, less as well For the entire Stockholm region (and entire week) 75% of weekend travel is by car, vs. only 50% during the week. Interestingly, during the week travel within greater Stockholm makes up 80% of total travel, while on the weekend that figure falls to 75% as more residents leave the city.

In the case of Stockholm, inner city residents own fewer cars (half as many per household), are older have fewer children, and have smaller household incomes than those living in the suburbs How much of the reduced travel (or lower share of car ownership) is caused by these factors, how much by the higher density and proximity to stores and work? Thirty-five percent of those in inner Stockholm do not use cars or public

[8] Data from Oslo, Norway, show similar tendencies

transport to get to work; presumably they walk or use their bikes. In the rest of Stockholm this share falls to well below 1%! The average distance for all trips for those in the inner city is 4 km (bus) and 5 km (car), vs well over 10 km for each mode for those living outside of the inner city In 1971, the relationships were similar in the inner city. So there is clearly a density/proximity effect One reason those in the central city don t move as far is that congestion is bad six days a week Moreover, the population in the central area is aging and falling. In other words, the relative importance of these people to the total picture is shrinking. Thus while urban form and location certainly affect travel, they affect many other aspects of daily life as well And many factors besides urban form and population density affect travel

To probe the question more carefully, we examined a detailed survey of the San Francisco Bay Area Graphs of vkt per resident vs. density in the Bay Area show a sharp decline in travel as density increases The data taken from household travel surveys and Census housing reports are aggregated by the region's traffic analysis "superdistricts". Residential density is expressed here as persons per residential acre In Figure 13 the long tail of the distribution is created by the four City of San Francisco superdistricts the highest vkt/capita is produced by areas at the fringe of the metropolitan region Using a natural log scale we get a picture of the scattering in the middle levels and identification of apparent outlyers

The relationship depicted, however, is not so simple as first appearances might indicate It is well established for instance, that income is one of the most important factors influencing travel Higher income households travel more, on average, than their less affluent counterparts, they are more likely to live in low density areas and their household size tends to be smaller in cities, all of which contribute to boost per capita auto use, where all other factors are equal Therefore, the differences in driving may be even greater than implied by the per capita measurements.

Figure 14 explores the income effect. For each of 15 income ranges, households are classified as living in "high" density areas (averaging 49 persons per net residential acre) and "low" density ares (averaging 14 persons per acre). Simple regressions then were estimated for each of the density groupings for vkt vs income and vehicle trip length vs. income In each case, the regressions for the two density levels are statistically different. For example, households with an income of $10,000 per capita who live in low density areas generate about 60% more vkt than those with similar incomes who have chosen high density residential districts. Nevertheless, it is apparent that income per se is very strongly related to travel levels and environmental impacts.

Unfortunately, the analysis is hardly conclusive, since it too omits a number of variables which potentially could have a significant effect on travel For example, the "high density" average shown in the graphs corresponds to about 12 housing units per net acre, a level which is generally thought to be sufficient to justify reasonably good transit service. It would be expected, all other things being equal, that high quality transit service would lead people to substitute bus and train trips for car trips, reducing overall vehicle travel levels. The relatively low vkt levels found in San Francisco are probably explained, in part, by the high levels of transit services provided—services which in turn are feasible because development densities ensure a market for them.

This work is being extended. A fully specified model including density as well as other likely indicators of travel behavior, some of which were suggested by the national analysis shown above (age, household structure, housing tenure, etc.) is being developed, and exploratory analyses designed to identify what characteristics of higher density per se may affect travel choices are being carried out In addition, data for other metropolitan areas, including Los Angeles, Sacramento, San Diego, Seattle. and Portland (OR), have been assembled and will be analyzed. There is much to do—and in the meantime, inferences drawn from simple two-variable models should be treated with extreme caution

In particular, our analysis only measures one variable associated with density, and that is travel We know from both national and regional data that income and demographic characteristics also vary from city to city, or from place to place within a city We cannot tell the extent to which these are "causes" themselves of difference in travel behavior, or "effects" of the nature of the locality where people live Moreover, many household expenditures, such as insurance, food, and house rent or ownership and maintenance costs, are sensitive functions of where people live Most of these expenditures are quantitatively more important than marginal expenditures on travel, whether by car or other modes Therefore, it is both difficult to say how travel would vary if the densities of residential areas (or other aspects of urban form) were changed But it would be even harder to say how other important characteristics of daily living would change It would be foolish therefore to extrapolate from the tenuous relationships between population density and total travel to prescribe changes in the former as a way of influencing the latter, unless we understood how other features of the quality of life—and the cost of living it—were to change, too

6. People on the Move?

Why has travel been increasing? Where are people going? Certainly, rising income in many countries seems to encourage (or at least permit) people to spread out away from denser. urban environments—those that could support frequent, and convenient, transit service and walking Rising car ownership is the main route along which this change occurs Suburban development tends to undermine transit service (except for certain commuting corridors) and make people more auto-dependent This change in the physical layout of society is not spontaneous. Powerful tax policies have influenced both public and private decisions affecting housing, services, and other development

At the same time, many other policies, and some deep-rooted societal forces, have increased both the fuel used by cars, by encouraging the purchase of larger vehicles, and the distances people drive them through the provision of discounted gasoline One important policy is employer provision of company cars common in several countries in Europe Figure 15 shows that the weight and horsepower of company cars—nearly one-third of all new cars sold in Sweden each year—were significantly greater than those attributes of "private" cars (or the entire new car stock) Moreover, the policy stimulated car ownership, both by providing new cars to selected employees and by providing a steady source of "previously owned" cars to the used-car market. Other data show company cars are driven further Additionally, government or employer provision of subsidies for commuting (by car or transit) and tax deductions for interest on home mortgages (which encourages individuals to buy larger houses on larger lots) lead to more travel

Other important forces have boosted travel demand The very structure of employment, with more women in the workforce and more part-time or self-employment, has raised travel demand Figure 16 shows the distances men and women in different age groups in the U.S drove in 1990 Note that while men continue to drive more than women, the gap shrank in 1990 Since the number of women with access to cars grew so dramatically in the 1970s and 1980s in the U S (a phenomenon now apparent in Europe), this change drove important increases in total travel. Data from the U S and European countries show that the number of women having drivers' licenses at a given age is closing in on that for men, at least among populations under

55 years old Soon women will be as mobile as men

The aging of populations adds a new dimension to travel demand, particularly as baby-boomers who grew up with full access to automobiles retire, bringing their cars and their mobility with them As Figure 16 shows, distance driven also depends on age Note that older people drive less than younger Will these patterns persist as the present baby-boomers approach retirement? Finally, household size has been shrinking through a number of factors, including aging This means more single drivers, which tends to increase travel

Is total travel saturated? Certainly not in the U S., and probably not in Europe While congestion limits speed in certain parts of the travel cycle, most growth in travel is occurring outside of congested cities or the worst hours of crowding. And Europeans are traveling more in the evenings and on weekends, as stores and other attractions are open for longer hours For the most part, this extra travel is car- or air-based, modes that are more energy-intensive than buses or railways Between 1973 and 1990, shifts among modes alone accounted for increases of 3 to 15% in the energy used for travel While the hidden incentives for more travel and the sociodemographic forces stimulating travel may have saturated, the full impact of a mobile society have yet to be felt in the industrialized countries

7. Fuel Choices: Exploring the Alternatives

With people on the move, increasingly in more powerful cars, fuel use is on the rise But what is wrong with gasoline and diesel fuel? Energy security, the hidden cost of importing oil, say some The United States for example, imports well over 8 mn bbl/day of crude oil, Europe even more Most Western European countries (and Japan) import a far higher share of their oil (and energy) than the U S , so concerns about security are higher there than in the U.S. While only a fraction of these imports come from the Middle East, that region is still the lowest-cost marginal supplier The air pollution arising in most cities around the world is another reason for concern, most agree The carbon dioxide emissions from combustion, warn the experts from the Intergovernmental Panel on Climate Change, is a pressing worry as well Note, for example, that while these fell in the U.S., they increased in the other regions shown, and by even larger amounts in the developing world. Whatever the magnitude of these "sins" of automobile fuel use, increased fuel economy and alternative fuels offer considerable remedies

7.1. Fuel Economy

One important way of mitigating the rise in fuel use is to improve the fuel economy of vehicles Indeed enormous strides in better technology affected cars (and trucks) in all countries we studied In the U S , these improvements, combined with a modest decline in car size and power, led to a drop of more than 30% in the fuel used per kilometer in the entire stock of cars and personal light trucks by 1991 In Europe, car size and power increased, offsetting most of the apparent gains in fuel efficiency from better technology Few disagree that there is great potential for further reductions in each country, depending on the evolution of vehicle weight and performance. In Schipper and Meyers et al we spoke of a US fleet at near 7 5 l /100 km (compare with 12 today) and one in Europe close to 6 l/100 km by the year 2010 Our study of the gap between test and real fuel use, however, showed that driver behavior and congestion are eating into some of these potential savings. Nevertheless, cars can be made less fuel-intensive

The real issues for "potential" are two-fold manufacturer interest and consumer interest The latter is clearly stimulated by fuel prices, but also by consumer values for car performance vs economy The former is stimulated by competitive pressures on manufacturers to innovate, in turn related to fuel prices But there are many other automobile attributes that drive competition, too Since fuel use is a very small part of the total cost of owing and using an automobile, it is not surprising if both manufacturers and consumers look to other attributes of cars during periods of relatively low fuel prices, even if some fuel-saving options pay off in a few years. As Eriksson noted (1993), consumers may simply discount away future fuel savings after a few years. In any case, there are almost no cars on the market today that offer a variety of fuel-economy packages for essentially constant performance. The 1991 Honda Civic DX and the Audi 80 Diesel are two exceptions where differences in performance between two models with different fuel economy is vanishingly small

Koomey et al. compared the 1991 Honda Civic DX hatchback to the 1992 Honda Civic DX hatchback and the 1992 Honda Civic VX hatchback. These cars have equivalent horsepower (the 1992 DX has slightly higher horsepower) and are otherwise identical, with some small exceptions for which the authors correct They find that the 1992 DX offered significantly improved fuel economy over the 1991 model with virtually no increase in price. However, including the lean burn technology in the VX incurred extra costs with a long payback. In the case of the Audis, the Audi Diesel TDI (turbo direct injection) provided the same power at lower fuel use than the regular diesel Audi 80, with a payback of 8 to 10 years at German fuel prices (Wester 1992). In both cases, these options were relatively high cost, but they represent two rare chances to view virtually identical models side-by-side, from which informed buyers could choose extra fuel economy for a certain payoff.

Normally, consumers are not offered such options They much chose between performance or fuel economy. Present market trends point towards more power and performance, with technology providing these "amenities" at constant fuel economy, rather than providing better fuel economy at constant performance. As a result, fleet fuel economy is only improving slowly This does not mean that there is not a significant **potential** for fuel economy, only that present market conditions, including low fuel prices, have permitted consumers and manufacturers to look to other features of cars

7.2. Alternative Fuels

If insurance from disruption of oil imports is an important goal, why not switch to different fuels? This works, provided one is prepared to pay a premium Quite simply, there are no fuels whose costs compete with the marginal costs of producing oil in the Middle East, and virtually no alternative fuels available in significant quantities that can be delivered for the present pre-tax cost of gasoline in North America or Europe.

It might be possible to produce significant quantities of methanol cheaply from coal, but that process then raises significant questions about the environmental impact of significant increases in coal mining and methanol production. The same could be said of ethanol production from grain, but that process requires significant fossil fuel inputs for production, inputs that nearly equal the energy value of the gasoline displaced. Presently, grain ethanol receives very large subsidies in the U.S. through tax forgiveness to make its price competitive with that of gasoline. Ethanol production from forest biomass shows considerable promise Finally, natural gas offers some relief, but for most countries this also means importing fuels In every case, however, producing the equivalent of several million barrels a day leads to concerns that the costs of feedstocks (natural gas, coal, etc) could rise In other words, it is possible to produce or procure significant quantities of fuels domestically in the U.S (and in many European countries), but the costs are high Is it worth it?

The costs of alternative fuels are not always easy to calculate, although it is possible to provide an important range of uncertainty This range depends on the price of the feedstock, the various production efficiencies of the fuels, and the real costs of the investment in production capacity, and, implicitly, the cost of using that fuel in comparison with gasoline Unfortunately, that range usually spans the regimes of interest Unless we have a clear understanding of the value of an alternative fuel (ie , the value of reducing oil imports or reducing emissions), the best we can do is merely fan the flames of debate.

The emissions reductions resulting from using alternative fuels are difficult to estimate for several reasons Part of the problem is agreeing on which emissions to count, and how to weight them Another problem is that our knowledge of actual, in-use emissions (including evaporative emissions from standing vehicles) is poor; comparing a theoretical model or test results for an alternative fuel with emissions from "real" gasoline or diesel vehicles is problematic because our knowledge of the real emissions from existing vehicles is limited. Since it is the real difference between existing and proposed fuels that constitutes the main environmental benefit that can be compared with costs of fuels relative to gasoline, choice of the "best" fuel is difficult Finally, valuing these reductions in monetary terms, however unpleasant a task, is necessary at some point if we are to decide how to spend our money, or indeed to choose which alternatives are best for society Cost-benefit analysis cannot provide us all the answers, but it is helpful in choosing means towards an end

Figure 17 provides some qualitative insights into the impacts of alternative fuels We show a single impact—greenhouse gas emissions—calculated by comparing the full fuel cycles for producing the fuels shown (Sperling and DeLuchi 1989 and references therein) Two cases, one optimistic, one pessimistic are shown. Those feedstocks that depend on nuclear, solar, or wood biomass energy sources offer a clear reduction in greenhouse gas emissions, others are marginal or indeed increase emissions under some assumptions Almost all the alternatives improve local air quality, but electric cars and fuel cells, with no local combustion, provide the greatest benefits. Hydrogen is also a "winner", although combustion does produce NO_x and water vapor. Methanol and ethanol give some benefits to both local air pollution and, in some cases, CO_2 but measuring these benefits is more uncertain than in the case of other fuels

The costs of using and making alternative-fueled vehicles are also difficult to estimate because our experience is based on the small numbers of vehicles converted to alternative fuels, or small numbers of purpose-built vehicles. This difficulty poses a particularly unfair burden on our estimate of the cost of electric vehicles, since our experience with large-scale manufacturing of cars without combustion engines and battery and drive systems optimized to provide the performance of automobiles is limited. That is, the costs of making electric vehicles in large numbers would almost certainly fall from those we experience today For other fuels, we have good experience with methanol and ethanol and LPG as well, some experience (particularly in Europe and New Zealand) with compressed natural gas vehicles, but very little experience with hydrogen Since we understand gasoline and diesel engines the most, it is understandable that many lean towards given these fuels a second chance (through reformulation and better emissions technology) rather than jump to something new. In general, we can expect the costs of virtually any alternative fueled vehicles to decrease from today's estimates once we have set in motion competitive forces to produce large numbers of vehicles Much of today's debate, particularly in California, is really on how best to get started

Figure 18 attempts to put these considerations into a qualitative framework We show changes in local air quality, consumer cost, and consumer acceptance for five types of fuel/vehicle combinations (methanol. CNG, battery electrics, hydrogen combustion, and fuel cells) We have omitted "consumer cost" from electrics, because this is so difficult to determine Figure 18 suggests indirectly that the most important "fuel" is not really a fuel per se, but rather a vehicle, one using some form of electrical propulsion There are really many kinds of "electric vehicles" (EVs) In addition to the traditional battery-driven EVs, hybrids that use both a fuel motor and electric drive (including Amory Lovins' 'supercar' [1993]), city and neighborhood electric cars, and fuel-cell vehicles In reality, all these electric technologies are closely related and likely to be matched together in various ways in vehicles Electric propulsion may provide the best option for major reductions in pollution, greenhouse gases, and petroleum use because local emissions are nil (or small if a hybrid is properly used) while emissions for making electricity can be controlled at powerplants However the start-up barriers for EVs are large and the long-term costs still uncertain

In any case, it appears to us inevitable that most vehicles will someday be operating on some form of electric propulsion, possibly as fuel cells California has already mandated that at least 2% of new vehicle sales in 1998 be "zero emission vehicles" (ZEVs), ie , electric vehicles The question is how aggressively authorities should invest in and push these technologies at this time A government role is critical and necessary because most, but not all, of the attractions are external to the marketplace Some, but not all, of these problems can be overcome by pricing fuels properly to reflect environmental and other concerns, but this has eluded the U.S government for decades. Moreover, there is a chicken-egg problem related to the enormous infrastructure changes facing any alternative fuels Does the infrastructure (for charging, etc) change to accommodate a whole new kind of vehicle, or does the vehicle change first? Related to this are the large sunk investments by the oil and auto industries These important actors will understandably resist investments in electric propulsion unless their present investments are not put at undue risk The promise of electric propulsion is so great that it would be difficult for authorities not to start reducing barriers and supporting active R&D programs Further, it may be appropriate for governments to mandate that certain vehicles be produced and sold, as California does with the ZEV mandate. But the real difficulty with alternative fuels remains the cheap alternatives, gasoline and diesel fuel

It must be emphasized, too, that there is no one "solution" to transportation or energy problems If a very clean and cheap fuel appeared, say because of an unexpected breakthrough in fuel-cell technologies, the cost of using cars could actually go down At present, natural gas and electricity are not subject to road taxation in most countries: while the vehicles to use these sources may be expensive, use is cheap Some cities in Europe have offered incentives for electric vehicle ownership, such as access to special lanes during commuter hours or low-cost parking. Does this simply contribute to reducing air pollution while increasing congestion? Clearly a systematic approach to transportation problems, while it must involve technology and new fuels, must also involve proper pricing of fuels and of the use of the transportation infrastructure as well

The conclusion is that alternative fuels offer some relief from importing oil, and potentially significant or even enormous relief from both local air pollution and greenhouse gas emissions Are the costs worth the benefits? That is hard to decide But it is clear that the benefits of alternative fuels are minimized as long as the main route to their introduction is through subsidies, rather than taxes on the "dirty fuels" We discuss below some of the experience with fiscal stimuli, then attempt to answer part of this question

8. Fiscal and Administrative Policies to Clean Up the "Sins"?

Policy makers in Europe, Japan, and North America have taken note of the growth in travel (and freight) activity because this growth has complicated efforts to deal with the "sins". Ownership of (or access to) a car is the single most important determinant of total personal travel It is clear, however, that owning a car per se is no sin: a gas guzzler sitting in the garage pollutes and congests less than an efficient car driven several hours per day. Taxes and other measures aimed at curbing fuel use or boosting fuel efficiency can play an important role in curbing the problems arising from fuel use What some authorities have begun to realize is that taxes should be shifted away from fixed costs (such as those based on the value or weight of cars) towards variable costs.

The taxes on cars affect car ownership and size, and thereby total mobility and total fuel use Using cross sectional data, Schipper and Johansson (1994) estimated that the tax required to achieve a 1% reduction in lifetime fuel use for a VW Rabbit in 1981 was only $100 if placed on fuel but as much as $500 if placed on the attributes of a new car. This finding has important implications for policies that are constrained from taxing fuel use (or other "sins" of car use) directly The bright side of the heavy tax burden in Europe is that governments have been able to reduce taxes on clean fuels or new cars with the most modern pollution abatement. Governments reduced taxes on unleaded fuel, ushering in a rapid switch to new cars using unleaded fuel. Similar price differentials have driven the share of diesel vehicles up (and down) U S authorities, by contrast, have little to work with, so have subsidized or even mandated certain alternatives, such as ethanol or gasohol. On the other hand, European prices are so high that they may "cover" most of the externalities present when cars are used, so there is not much room left for manipulating prices, only the possibility of shifting some of the fuel tax burden to other aspects of car use

Using such stimuli as taxes to achieve these goals is nothing new and they work The experience of Europe, where fuel price differentials have driven the recent popularity of diesel cars or, more important unleaded fuel-using cars, suggests that pricing must be an important element of the tool box In the Nordic countries, small but noticeable taxes have been added to various fuels to represent their environmental damage These taxes include a CO_2 tax, which has the important benefit of exposing the CO_2 embodied in the production of fuels. But it is clear that in the United States, where it has proven virtually impossible to significantly tax gasoline for its problems (pollution, for example, or even for the risks of importing oil), and where authorities are only now beginning to burden the motorist with more of the marginal burden he or she puts on society when using the car, that it will be harder to expect rapid changes in either fuels or vehicles as long as users of the "dirty" fuel continue to enjoy that fuel at low costs

In the U.S., for example, ethanol use is subsidized because some local or federal taxes (5 4 cents/gallon) that apply to gasoline are not leveed on the gasohol made from ethanol Since gasohol is 10% ethanol, this amounts to $0.54 US per gallon of ethanol in forgiven taxes (or $0.72/gallons of gasoline equivalent, because ethanol contains less energy than gasoline). Additionally, states grant up to $0 04/ gallon of tax forgiveness on the gasoline/ethanol blend ultimately sold, which works out to ten times as much on the ethanol, since the blend is 10% ethanol, 90% gasoline. But that implies that the "sins" of gasoline use—pollution and oil imports—are at least this big, which may certainly be the case in smoggy urban areas But this strategy of subsidy provides drivers no incentive to buy a less fuel-intensive car, or drive less, or even use alternative modes of transport. Most would agree that in areas affected by smog, if gasoline were priced at $0 72/gallon more than its present cost (about half of the difference between the real 1994 price and the real price in 1981 the all-time high since World War II), that the present fleet of cars would be significantly more fuel-efficient and that people would use their cars somewhat less This alone would lead to large reductions in all of the problems of using automobiles and gasoline Additionally, such taxes on gasoline would certainly accelerate introduction of less polluting alternatives.

How much more efficient or less gasoline would be used is, of course, an open question But it can be shown that society is cheating itself out of true welfare by passing up these benefits when focusing only on subsidies. Subsidies may be important for getting technologies offering significant social benefits (at some risk) started, but when the subsidies become institutionalized (such as company car benefits in Europe), they become nearly permanent. And when problems are relatively well identified—gasoline use, pollution congestion—but solutions are diverse, incremental, and hard to identify, it is risky for society to "pick winners" through incentives rather than "declare the loser" through taxes, the approach taken in Europe If we are truly to reap the benefits of alternative fuels, and more efficient fuel use, options have to compete in a fair marketplace. Since the main goals are collective, ie , reducing pollution and the small but ever-present threat of an interruption in oil supplies, the first step in promoting these goals is to lay down a clear picture to gasoline (and diesel fuel) users illustrating the costs they impose on all of us

The externalities from fuel use alone and the resulting emissions (including CO_2), however, may not be the most important "sins" affecting the system, however While a variety of studies continue to debate this matter (Kaageson 1993; COWIconsult 1993, Roelofs and Komanoff 1994, Johnson 1993), it is clear that transportation problems go far beyond those related to the propulsion of vehicles Because so many problems are related to utilization of cars, both in general and at specific times and places, road pricing and other schemes that charge travellers for their use of the system may have a greater impact on reducing the impact of these sins. Unfortunately, there have been few road-pricing schemes implemented throughout the world Toll rings have been established around the principal cities in Norway, however, and in the old town of Tallinn, Estonia Related schemes attempt to raise the price of parking to market levels, ie , remove any hidden subsidies to on-street or public facility charges. Other measures collectively called "Transportation Demand Management" (TDM) can have small but noticeable impacts on automobile use, as Table 2, prepared by one of us for the California Energy Commission to model the San Francisco Bay Area illustrates (see also Steiner, 1992) In the U.S., workers will now face the prospect of paying taxes on the value of employer-provided parking or taking the taxable equivalent as income At the same time, the amount an employer can contribute tax-free for the use of mass transit will be increased, something that moves the U.S closer to European policies of subsidizing commuting! Note that three of the measures are fiscal in nature "Congestion pricing" means raising tolls significantly on the region's Bay Bridge during peak hours How acceptable are such measures? We do not know at this time, but we will be studying these and other schemes (such as those in three cities in Norway) in the future

Many countries use purely administrative measures to counteract some of the problems of automobile and their fuel use. For example, the U.S., Canada, and most countries in Europe require advanced exhaust emissions controls on new cars. In Sweden these are complemented by a taxation scheme that raises the taxes on new cars with the least advanced emission reductions and lowers taxes on new cars with the most advanced systems. Few countries enacted strong administrative measures to provoke improvements in fuel economy, but the Corporate Average Fuel Economy (CAFE) standards in the United States were an important exception. These were certainly a factor in narrowing the gap in fuel intensity between the automobile fleets in the U.S. and comparable ones in Europe (Figure 5). While fuel prices also stimulated some of this improvement, it is striking how little fleet fuel intensity fell in Europe over the period in which U.S intensity fell by more than 30% with only very small increases in driving distances per car. But as the problems specific to fuel use yield to those more related to automobile use or the choice of fuel, it is increasingly difficult to manipulate both the production and use of both cars and fuels with administrative measures. More and more researchers confront the same conclusion unless the marginal cost of using the car rises to close the gap between private and social costs, it will be harder and harder to atone for the "deadly sins", ie., promote all the alternatives on their own merits, whether they are new fuels, more efficient cars, less travel, more use of other modes (including walking and driving), and perhaps in the very long run, changes in the patterns of settlement that might themselves be one of the reasons why people are on the move more

Emission trading belongs an important set of hybrid measures that lie between purely fiscal ones and those relying on regulations. The aim of these measures is to maximize economic efficiency by allowing trading/selling of pollution rights or credits For example, vehicle manufacturers who could reduce the test emissions of their new products might "sell" some of the credit for pollution reduction to manufacturers who could only meet reduction targets at very high cost That way, the ratio of total emission reduction to investment cost is raised towards its maximum Or fleet owners could trade among themselves the "right" to pollute using gasoline vehicles against the use of cleaner vehicles, provided that authorities provide an overall benchmark standard Similarly, companies looking for ways to clean air where they have stationary sources of pollution may acquire certain credits towards pollution reduction by buying and junking old vehicles that lack smog controls, vehicles known to contribute to local air pollution far out of proportion to their actual numbers. And local authorities could permit vehicles of various emission levels to be sold, but tax those with higher emissions more heavily than those with lower ones, as has been established in Sweden

9. Sustainable Transportation?

Efforts and successes of the last two decades notwithstanding, an important reassessment is needed of both the nature of transport/energy problems and our changing options to deal with them It is clear that growth in the volume of individual transportation, cannot continue indefinitely Increasingly policy makers are asking whether present trends in transportation are "sustainable"? Can growth in mobility from cars (and increasingly, air travel) continue as long as fuel is relatively inexpensive and the carbon-dioxide emissions of present day fuels unimportant? Or will energy/environment problems hinder this expansion? Even if these fuel and environmental problems are solved through switching to nearly benign fuels or electricity, might not other transportation problems, notably congestion, sprawl, and noise, lead to a situation where an increment of transportation activity will cost society more than it brings in private and public benefits? Will changing perceptions of the "sins" of transportation, the many externalities (such as congestion, noise, recycling of automobiles, etc.) lead to new transportation policies that restrain or even reduce mobility and thereby restrain energy use and emissions from transportation? These are the challenges of "sustainable transportation"

If sustainable development means increasing the wealth of present day generations without making future generations worse off, then a definition of sustainable transportation could be

providing transportation services as long as those using the system pay the full social costs of their access, without leaving unpaid costs for others (including future generations) to bear.

Accepting this definition forces us to design a system so that those who derive private benefits from using the transportation system pay for the public costs that they incur Transportation has a special feature however; two vehicles cannot occupy the same space at the same time The space/time component of transportation requires that we develop a system to allocate these two resources when they are scarce, but such a system must not entirely shut out disadvantaged groups Some combination of road pricing, higher fuel prices, voluntarism, or other schemes must somehow reduce use of the infrastructure at peak times In the longer term, "planning" of how urban space is used to reduce the propensity to travel could reduce the growth rate in overall transportation demand Our studies will address this issue in the coming years However, internalizing present marginal social costs of transportation still does not insure that the interests of future generations are considered, an important element of "sustainability" by almost any measure

What would the transportation system look like if the costs and rules were adjusted to make its development sustainable? How much would people or goods move if prices and rules were adjusted through the political process to take into account the unatoned "sins" of transportation? In order to understand how travel-related fuel use and associated emissions could change between 1990 and 2025, we will build scenarios of future travel behavior and associated energy use for the United States and for other major industrialized countries. These scenarios will employ features of the technical, social and economic determinants of travel we have studied in our work.

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Table 1. Comparison of Test and Actual Fuel Economy Various Countries (l/100 km)

Country	*Year of Cf*	*Test*	*Actual*	*Avg Gap*	*% Gap*	*Comments*
Canada[a]	1988	8.0	10.0	2.0	20	Actual fuel efficiency from driver surveys vs [illegible] from laboratory test
Individual car models[b]	1985	8.6	10.7	2.1	19.6	
France[c]	1988	6.5	8.4	1.9	23	Travel diaries compared to 1/3 city 1/3 highway 1/3 road test values
Germany[d]	1987	7.7	9.8	2.1	21.4	DIN (test) vs DIW (actual)
Sweden[e]	1987	8.2	8.5	0.3	3.5	KOV compared with consumer reported survey data
U.S.[f]	1985					
Cars		9.7	11.9	2.2	18.5	RTECS survey vs EPA fleet average from dynamometer test
Trucks		11.6	14.5	2.9	20	
U.K.[g]	1989	7.2	9.3	2.1	22.6	Test value for registration-weighted average

Sources

a Statistics Canada 1990

b SOM, Inc 1988, Energy Mines and Resources 1992

c Bosseboeuf 1988

d DIW 1987

e KOV 1987

f Mintz *et al* 1993

g Sorrell 1992

For compilation and analysis, see Schipper and Tax 1994, *New Car Test and Actual Fuel Economy Yet Another Gap*

Table 2. Long Range Urban Transportation Policy Options for Reducing Fuel Consumption

Policy Type	Effect on Fuel Consumption
Rail Transit System EXtension	800-1000 Fewer Gallons/day/mile of fixed rail
Rail Transit Access Service	2 - 0.4% reductionin fuel use from extensive subsidy of 1) station-area on-call services, 2) employer suttles 3)activity center shuttles
Bus Transit Headway	0.2-0.6% reduction in car fuel use for a doubling of existing bus frequencies (subject to thresnhold load factor)
Fuel Price	20-25% reduction in fuel use for the first $1/gallon(1990) increasein fuel price 10-15% reduction for the second $1/increase
Employee Parking Pricing	2-3 fuel use reduction from $3/day employee parking floor
Congestion Pricing	5-8% reduction in fuel sue from elimination of all recurring delay
Pedestrian-Oriented Development	0.04-0.08% reduction in total regional fuel use for each 1% of new residential development in PODs
Increased Density Near Transit	0.2- 1% reduction in total regional fuel use for each 1% of new res. development in higher density conditions

Source: Deakin, E. and Harvey, G. 1994. *California Transportation Energy Analysis Report. Technical Appendices.* Sacramento, CA. California Energy Commission. Table shown is Table 4.4, p.44 from main report; see also Table 2.V.13 in Appendix 2.

OECD Transportation
CO2 Emissions 1973 & 1991

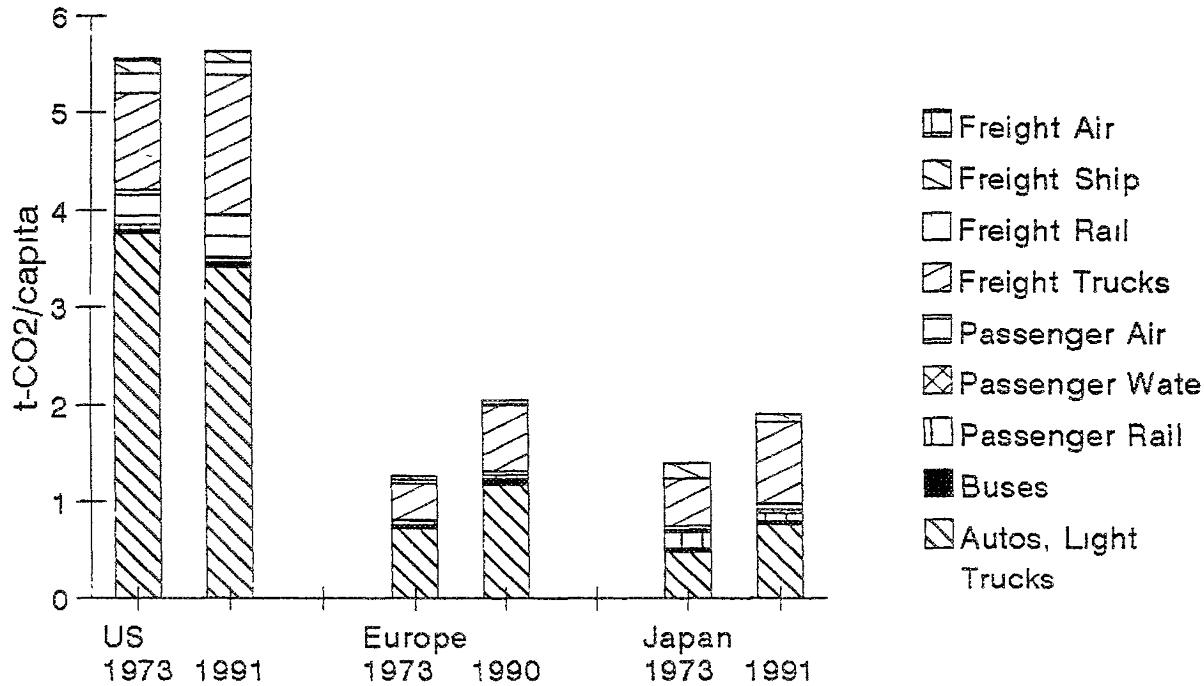
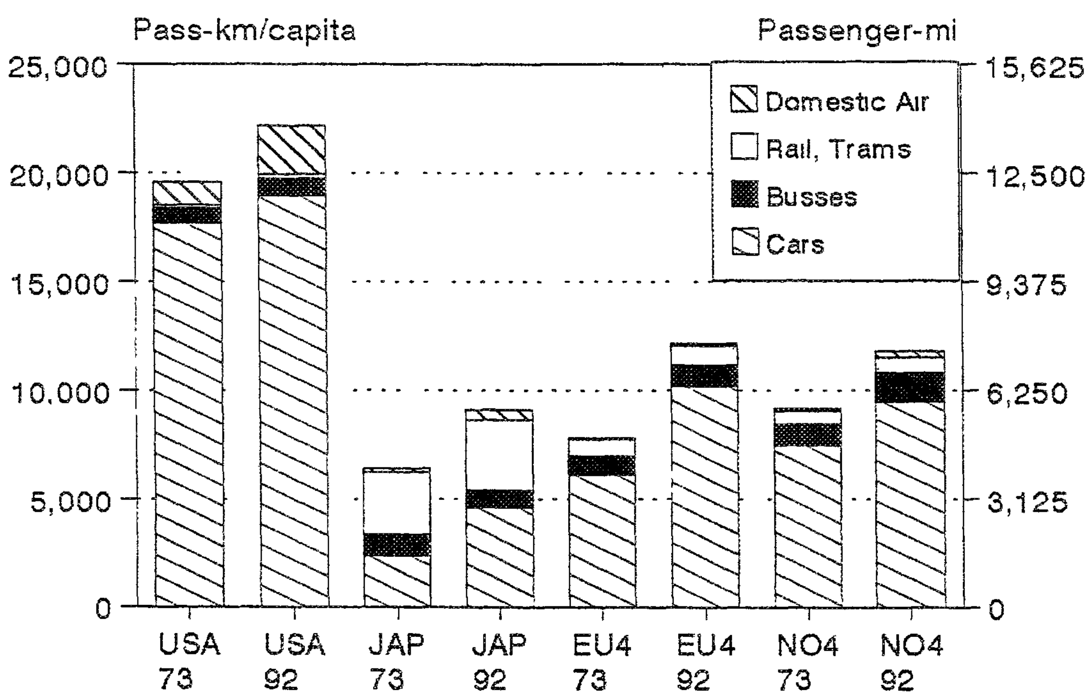


Figure 1

Travel by Mode in OECD Countries



NO-4 Sweden, Denmark, Norway, Finland
EU-4 Britain, France, W Germany, Italy

Figure 2

OECD Per Capita Travel 1970-1992
All Modes

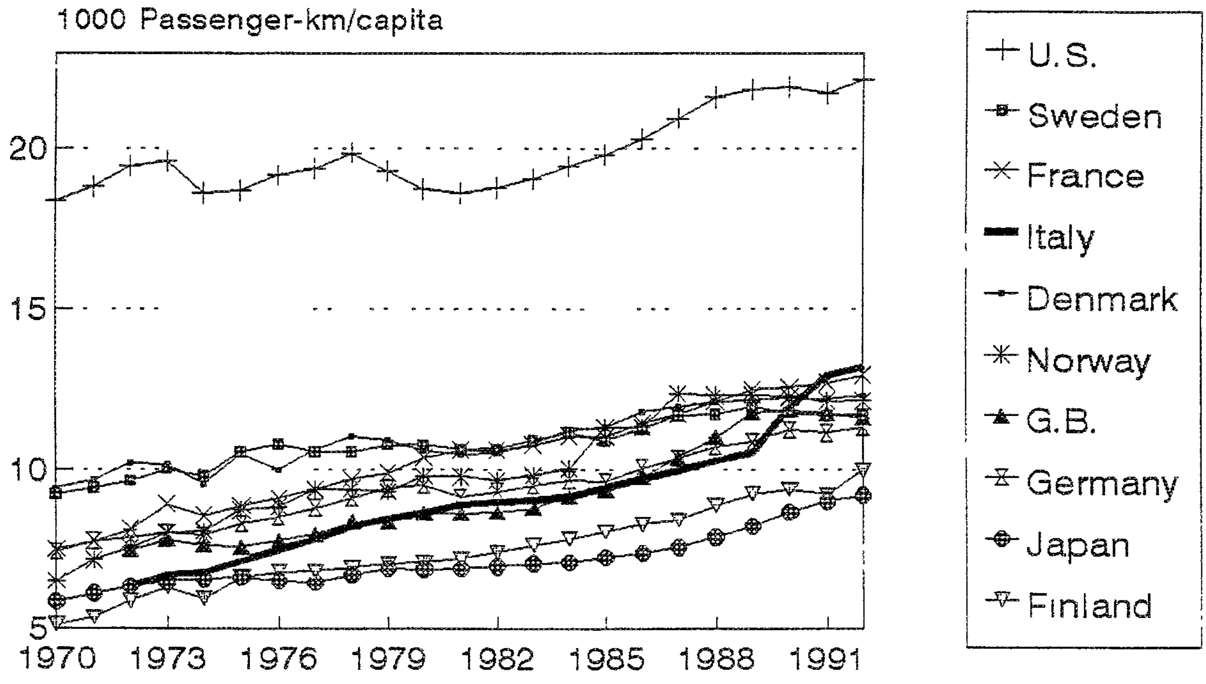
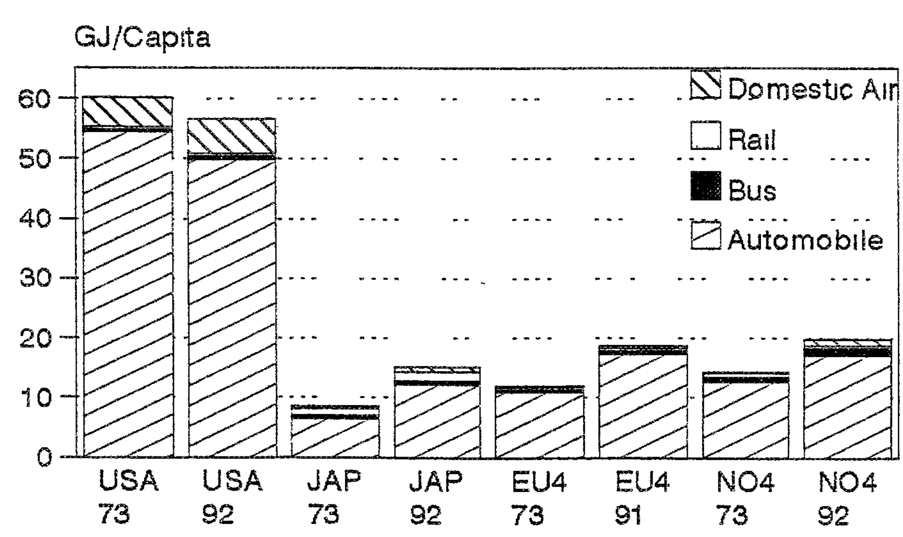


Figure 3

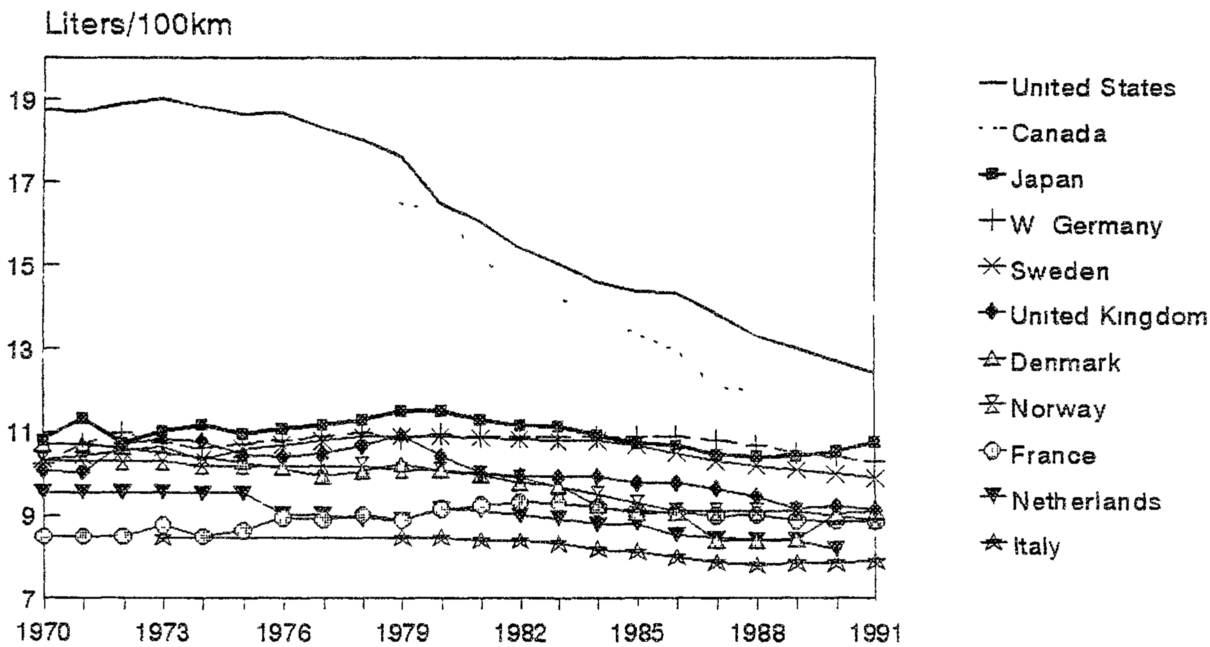
Energy Use for Travel
US, Japan, Europe-4 and Nordic-4



Nordic-4 Denmark, Sweden, Norway, Finland
EU-4 Britain, W Germany, France, Italy

Figure 4

Automobile Fuel Intensities
On Road (Actual) Fleet Averages



Includes diesels, personal light trucks
Liters of gasoline equivalent

Figure 5

Real Automobile Fuel Prices
Weighted By Auto Gasoline and Diesel Use

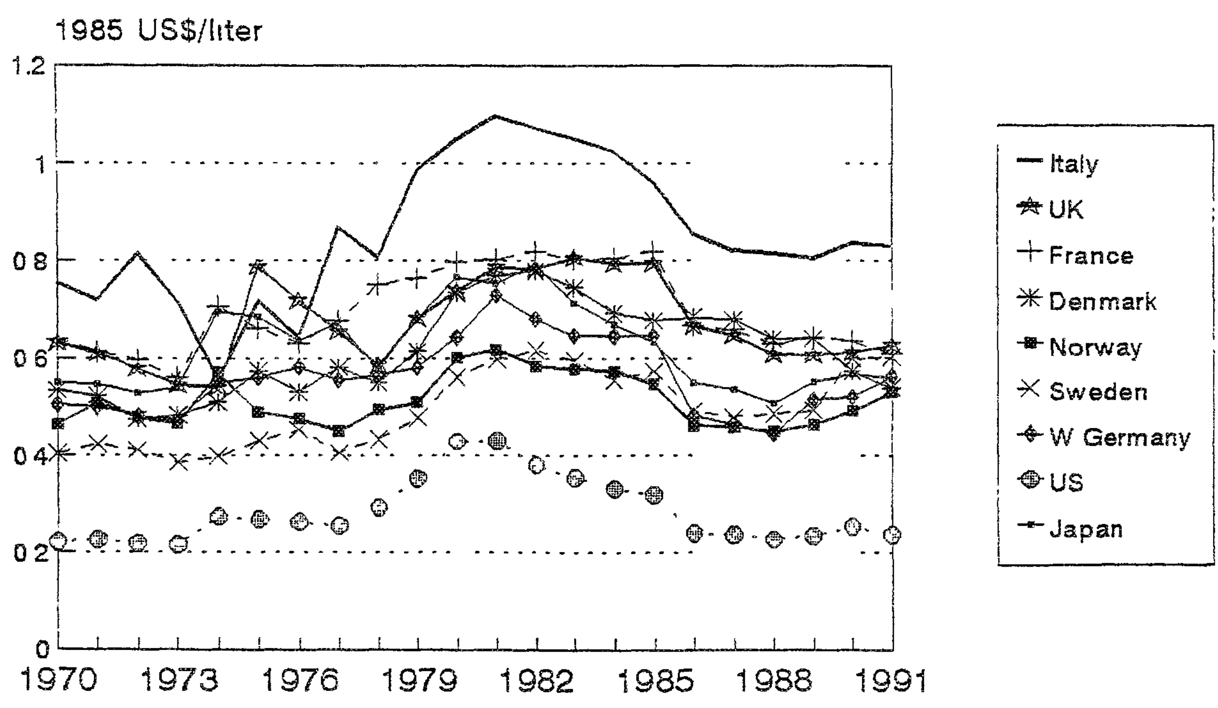
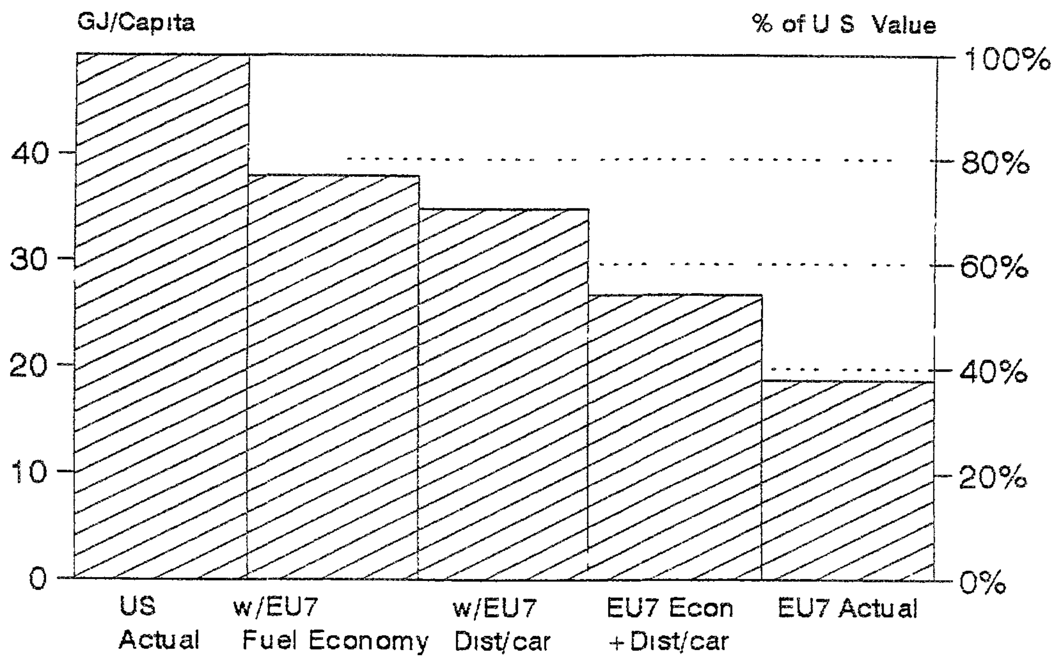


Figure 6

Per Capita Energy Use by Automobiles
Comparison of U.S. and Europe* in 1990



* W Germany, France, Italy, UK, Norway, Sweden, Denmark

Figure 7

Automobile Taxation - 1990 Tax Schemes

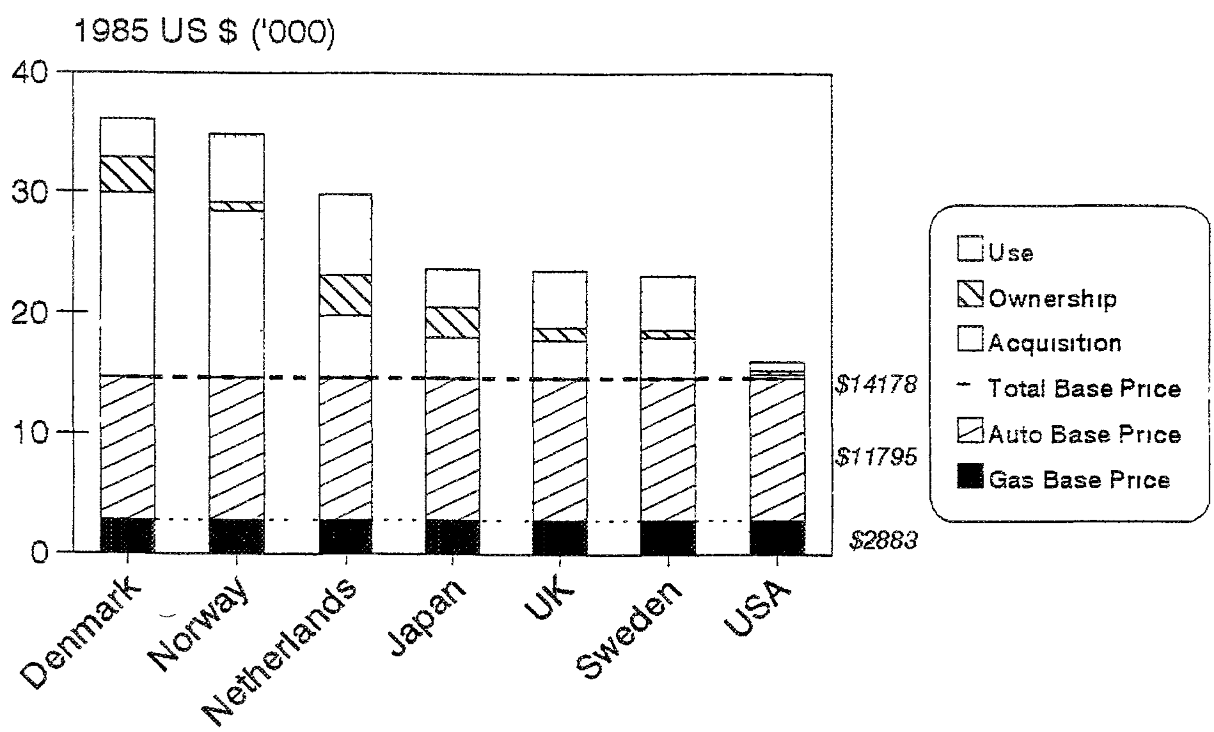


Figure 8

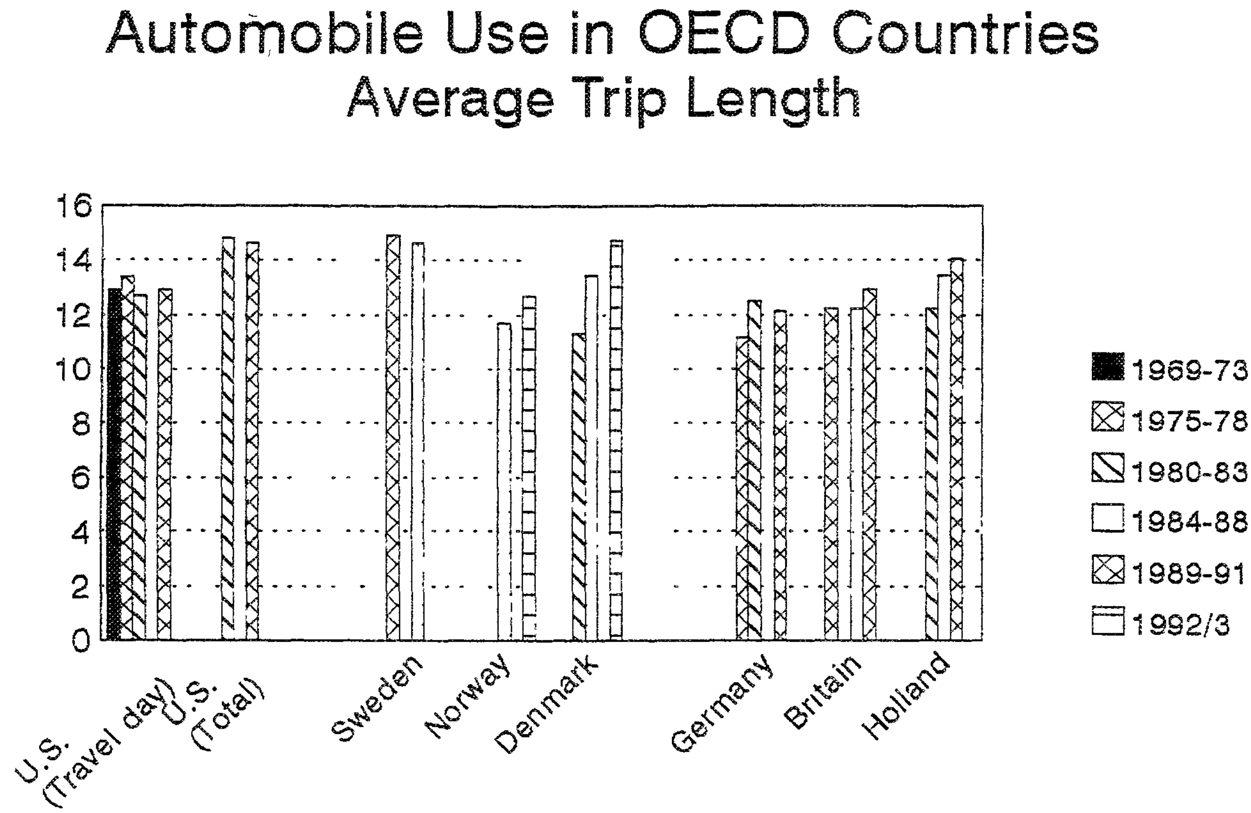


Figure 9

Source LBL Analysis of National Travel Surveys
Average Trip Distance for driver

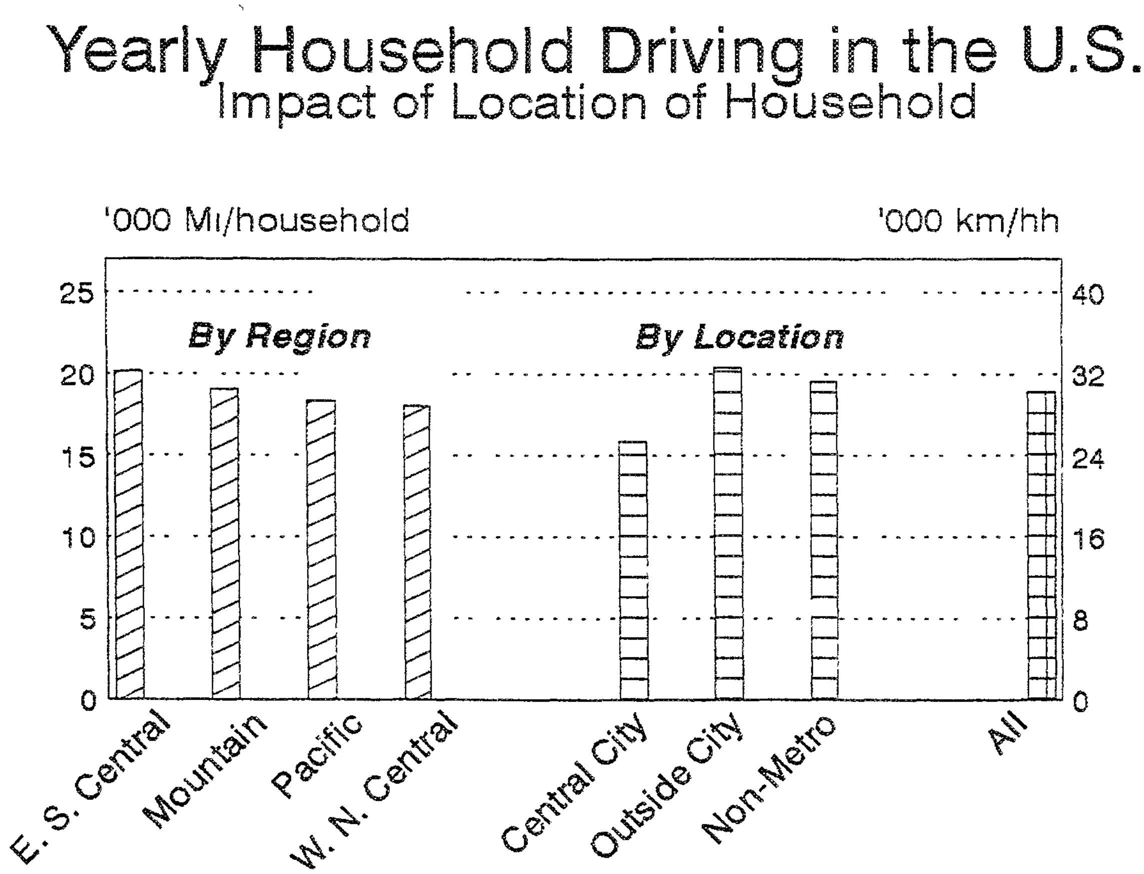
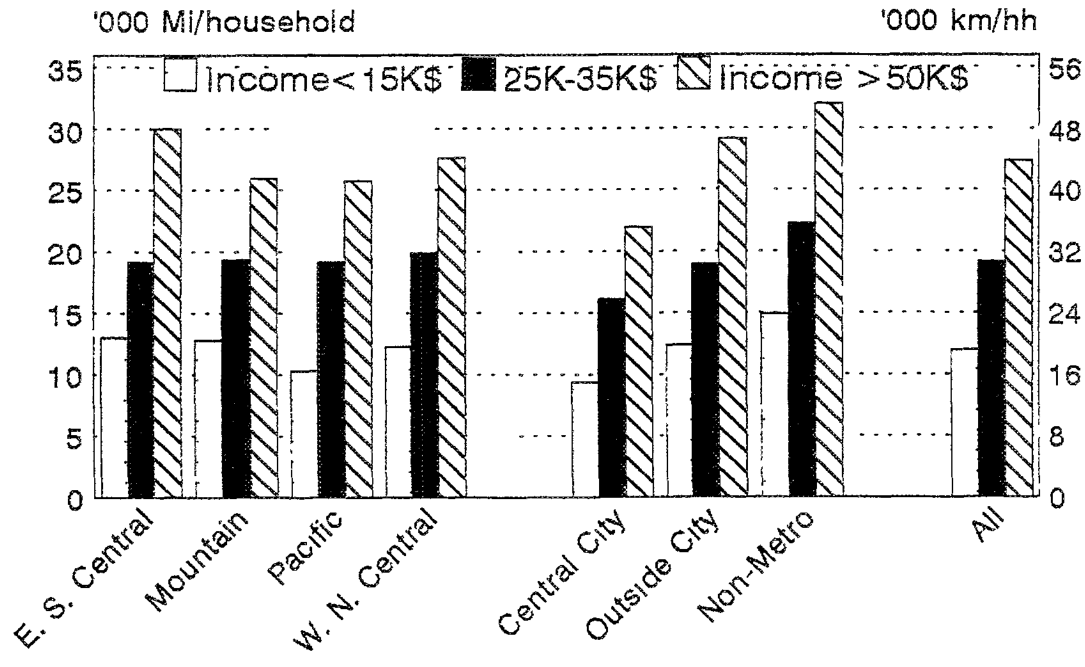


Figure 10

Yearly Household Driving in the U.S.
Location, Income, Demography



Source RTECS 1991

Figure 11

Per Capita Travel in Cities
Modal Splits

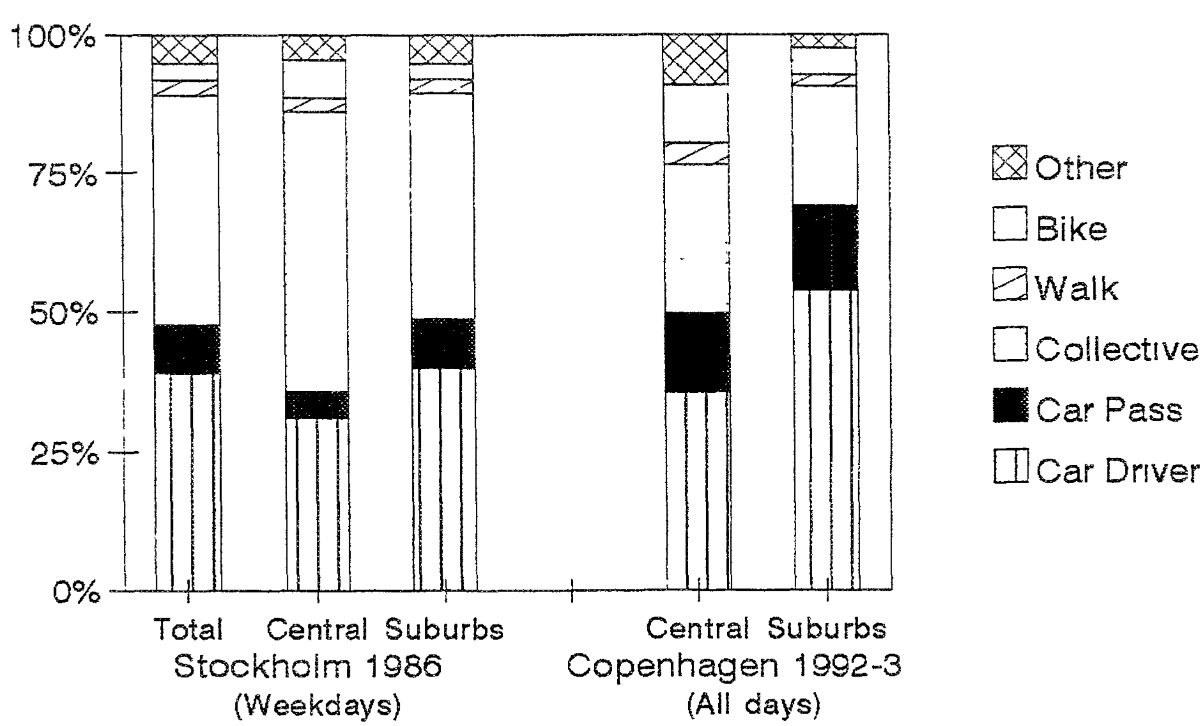


Figure 12

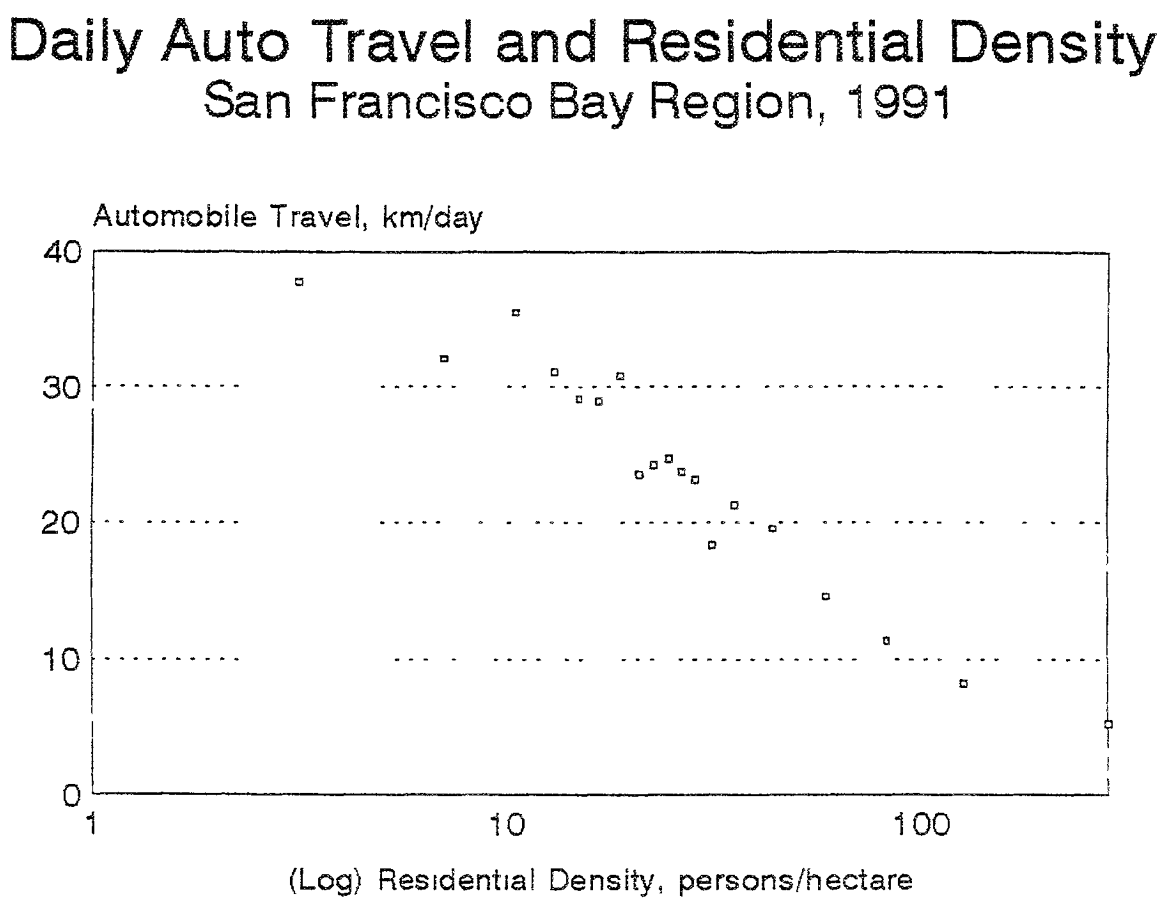


Figure 13

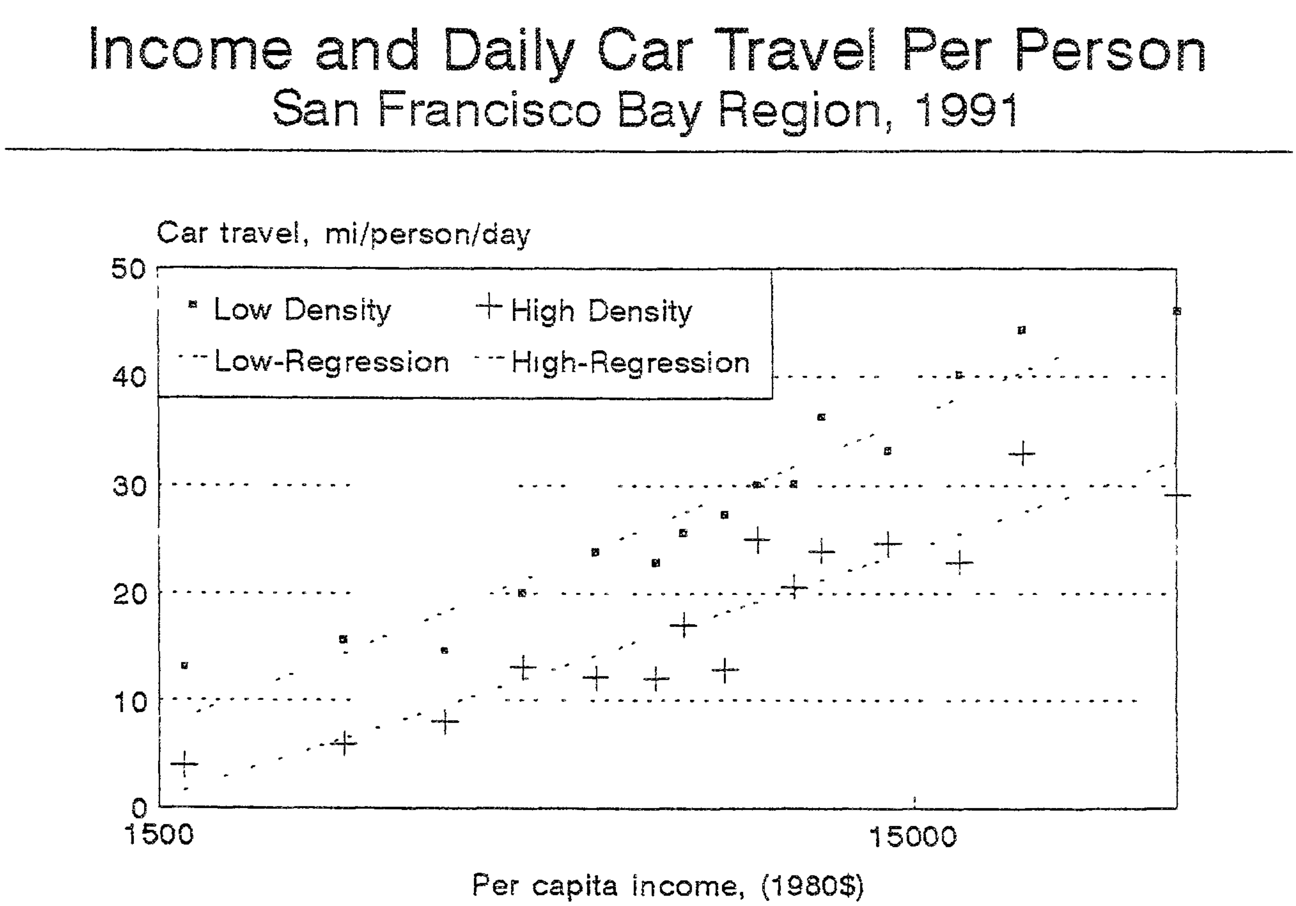


Figure 14

Sweden: New Cars by Power and Weight
Effects of Company Cars

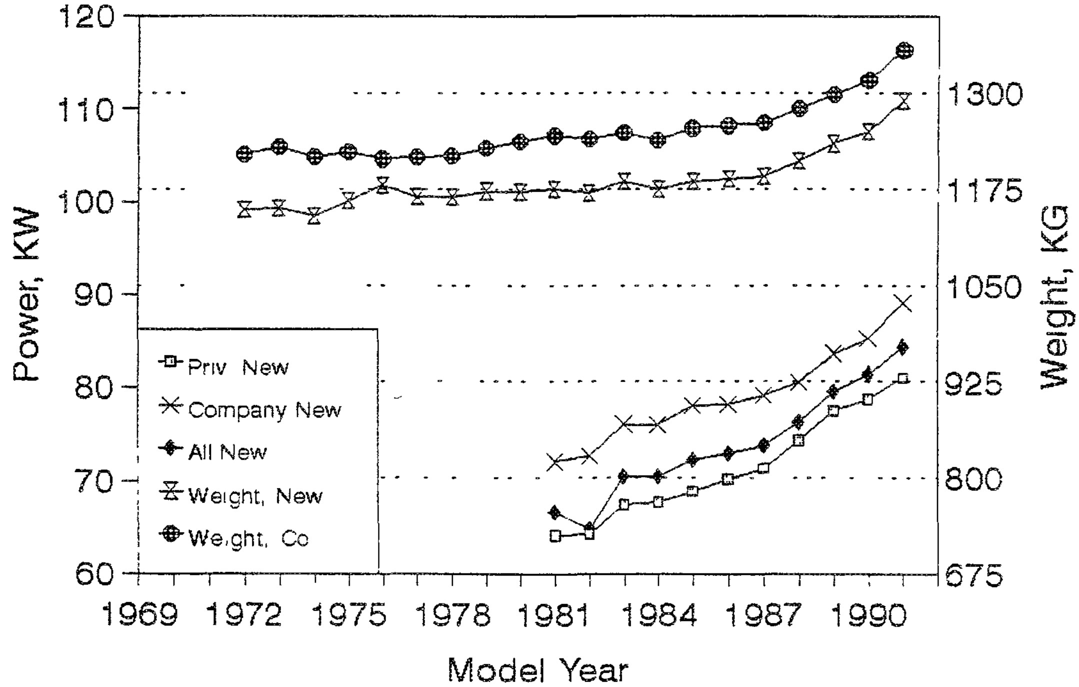


Figure 15

Mobility In the US 1969-1990
Sex, Age, and Driving

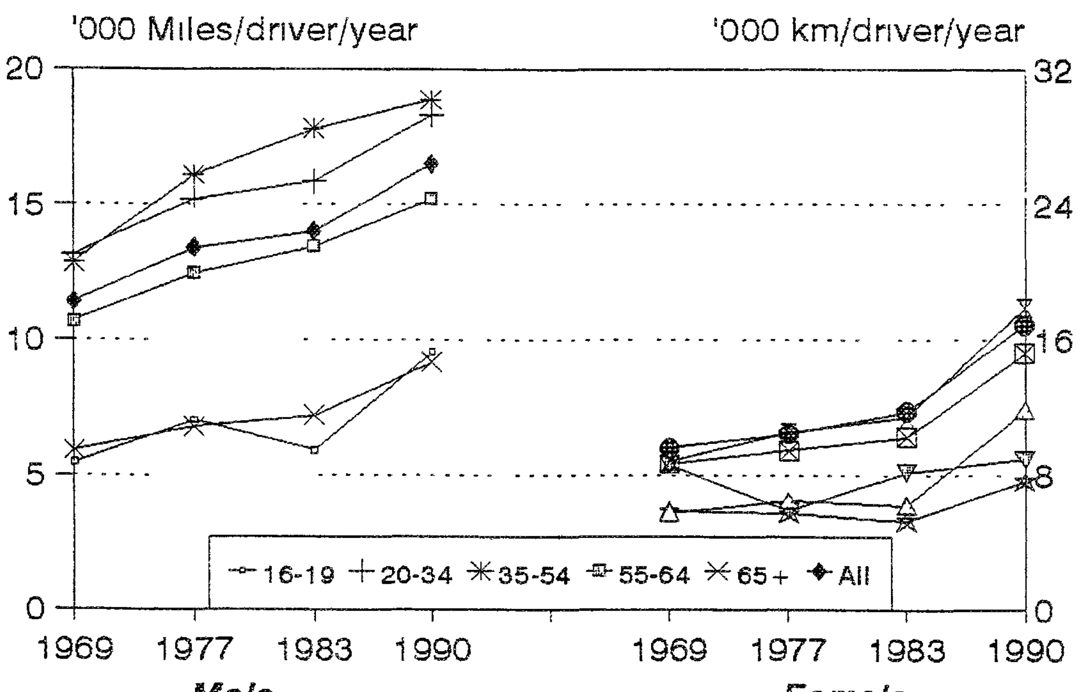


Figure 16

Environmental Impacts of Alternative Fuels

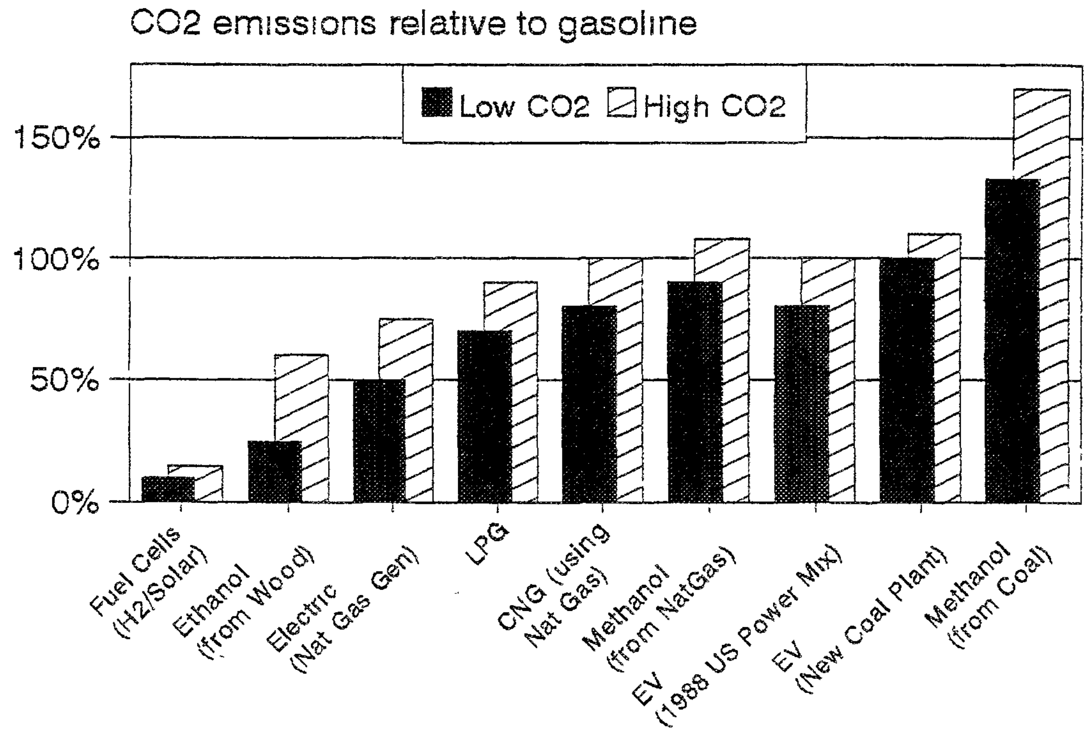


Figure 17

Attributes of Alternative Fuels
Relative To Gasoline

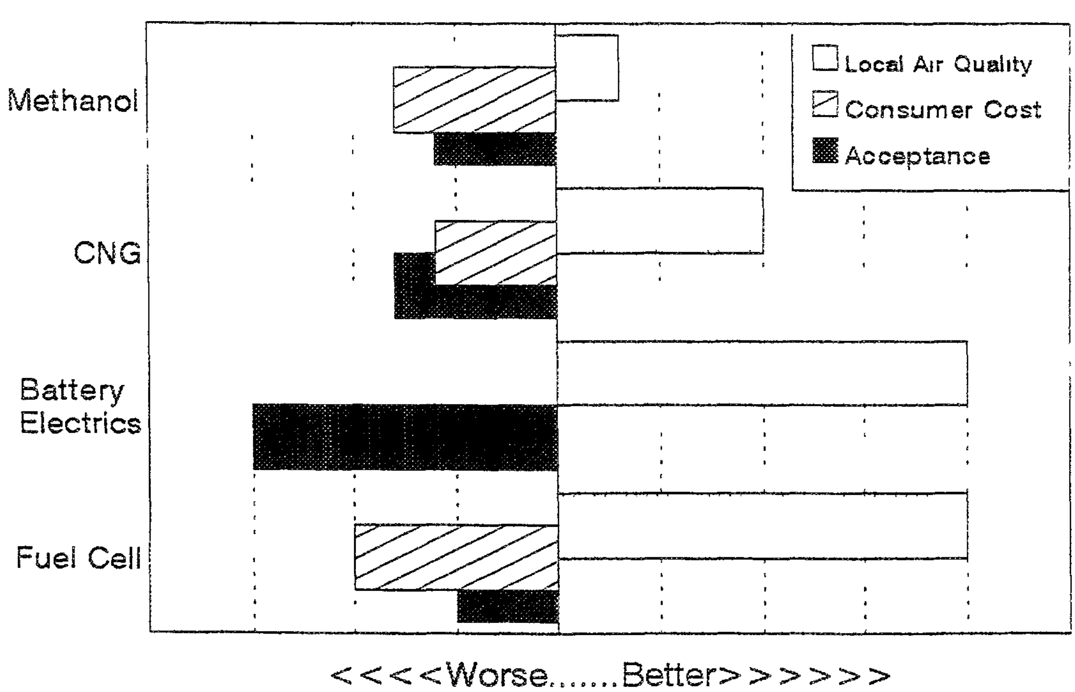


Figure 18