"People on the Move": Human Factors and Carbon-Dioxide in Industrialized Countries"

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Synopsis:

CO_2 emissions from travel increased in most IEA countries between 1973 and the 1990s from income-related behavioral factors. Broad transport might reverse these trends significantly.

Abstract

We introduce the notion of transportation externalities, noting that in many authoritative national studies these are not seriously internalized according to their likely range of marginal social costs. CO_2 emissions are seen as a small problem today compared with other transport externalities. We review trends in car ownership, mobility, characteristics, and fuel economy in IEA countries from the early 1970s to the mid-1990s. Except in the US through the early 1990s, these factors changed towards higher fuel consumption per capita and higher CO_2 emissions. We also find that the share of total travel provided by cars and air travel increased virtually everywhere. We show how each contributed to changes in CO_2 emissions.

Technical efficiency of cars improved markedly, feeding larger size and greater performance in Europe, and boosting these in the US after the early 1980s. Thus factors increasing emissions were principally behavioral factors, and, except in the US, these were stronger than the technological factors restraining emissions. Noting that both incomes and real fuel prices are powerful determinants of this evolution, we credit the CAFE standards in the US for some of the large reduction in fuel use/km in cars, or fuel use/capita relative to incomes per capita there. We close speculating over options to restrain future emissions, concluding, as do many national studies, that only broad transportation policy reforms that hit at all of the externalities in transportation could support genuine restraint in CO_2 emissions from travel.

1. Introduction: Why the Concern for Transportation

Concern has been expressed in many government and private studies over the costs of externalities from transportation, which include safety, air pollution, noise, competition for urban space, balance of payments associated with oil imports, and risks from importing oil (Barde and Button 1990; Houghton 1994; Government of Denmark 1995; CEC 1996; KOMKOM 1996; World Bank 1996; TRB 1997). While few doubt that these costs in total are still less than the total social benefits, there is a strong case that in many places, and at many times, marginal social costs of transport do exceed private benefits or even total social benefits. Recent attempts to evaluate external costs (MacKenzie et al. 1992, Kaageson 1993; COWI 1993; Roelofs and Komanoff 1994; OECD 1995; Pearce et al. 1996; COWI 1995a; COWI 1996; Oekonomiske Raad 1996) suggest that even the lower range of valuation placed on these externalities for cars is comparable to the pre-tax marginal fuel cost of driving a car requiring 8,5 l/100 kilometers of fuel, the rough average for W. Europe. If the individual(s) benefiting at the time faced those costs, the travel (or shipment) behind the externality might not take place, or technology would be applied to reduce the extent of the problem. For large trucks and buses, the costs (per vehicle-km) are considerably higher. Expressed as per unit of travel (passenger kilometers) or per unit of freight, i.e., taking into account the utilization of the vehicle, the specific cost change because of economies of scale. Transportation is a valuable part of our economy, but it is no free lunch.

Emissions of CO_2 or carbon from road transport are also on government agendas in industrialized countries. (IPCC 1990; Houghton 1994; TOK 1994, 1995; Government of Denmark 1995; BTCE 1996; KOMKOM 1996; TRB 1997). Not surprisingly, CO_2 emissions from travel and freight have increased in most industrialized countries faster than population, albeit less rapidly than GDP (Schipper et al. 1996). This paper reviews some of the factors driving that increase.

Whatever the “real” external costs of each mode, all studies suggest two important findings: First, these costs are sometimes comparable to, or higher than, direct fuel costs per kilometer at the margin; second, the value attached to the externality for carbon emissions tends to be low compared to those associated with other problems. Hence this suggests that CO_2 by itself may not be ”felt” as a strong stimulus for change, but that changes to deal with the other problems may affect traffic, and therefore CO_2 emissions, profoundly.

While the other externalities in transportation may be more serious than CO_2, they threaten us today and in that way lead to feedbacks, by which technologies and policies could be brought to bear to reduce the problems. In this sense, these are not necessarily threats to “sustainable transport”, if we use a definition of sustainability limited to imploring not to pass on costs to future generations, costs arising while reaping the benefits in the present. Present beneficiaries of the system are beginning to realize that they are not paying their full costs. In another sense, however, “sustainable transport” may also mean creating a system whose beneficiaries are bearing their real social costs and at the same time not propelling growth in the system that still raises those costs for the future.

This leads to a special concern over CO_2 emissions from transport. CO_2 emissions threaten future generations by an uncertain degree but cost little or nothing to present users of transportation. Were CO_2 emissions not increasing, authorities could wait for more information on possible damages before taking action. But the increases themselves may be hard to reign in, hence the interest in a better understanding of the factors underlying the increases. Moreover policy makers have discovered transportation’s rising share of CO_2 emissions, and are asking why? This brief review addresses the main trends in personal transport, and points to some of the underlying causes of increased emissions.

2. Trends in Transportation Activity, Energy Use, and Carbon Emissions

Automobile ownership (Figure 1) has risen with income or GDP per capita, although it is showing some saturation in the most motorized countries. Distance traveled per vehicle (vehicle-km, or v-km) is rising slowly, but distance traveled per capita on all modes (Figure 2) is rising more rapidly because of increasing car ownership. Because the number of people per car has fallen, travel in cars (in passenger-km) has not risen as fast as total vehicle-km. This means that energy use and CO_2 emissions rise faster than travel, all else being equal.

Figure 3 shows per capita travel by mode in the US, Japan, and aggregates of four European countries and four Nordic ones (France, W. Germany, Italy, and the UK; Denmark, Finland, Norway, and Sweden). Knowing the energy use for each mode we can tabulate emissions of CO_2 in a straightforward way. Figure 4 shows these patterns (in tonnes of carbon per capita) for travel (Schipper 1995; Scholl, Schipper and Kiang 1996)[1]. Emissions per capita for both travel and freight rose in every country between 1973 and 1993 except in the US, but that situation ended in 1993[2]. Moreover, the share of transportation energy use and carbon emissions in total energy use or emissions increased in every country studied. What drove these changes?

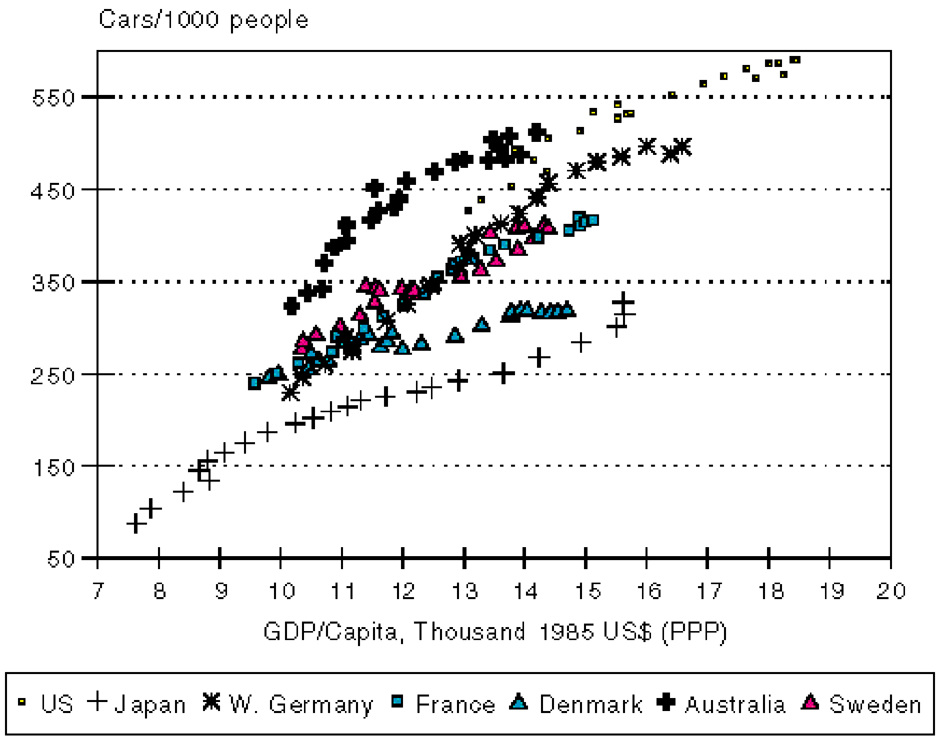

Figure 1. Automobile ownership and GDP. Includes diesel and LPG vehicles, household light trucks/vans
Source: National transport statistics, vehicle registers, national accounts

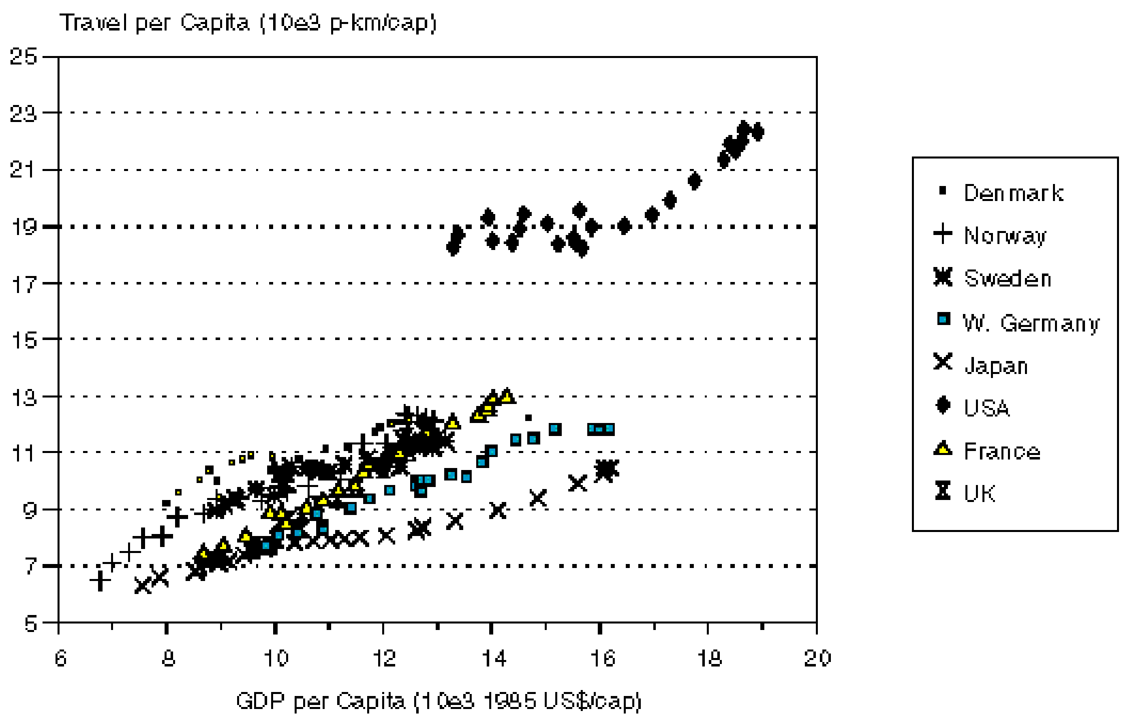

Figure 2. GDP and Domestic Travel
Source: National Travel Statistics and Lawrence Berkeley National Laboratory

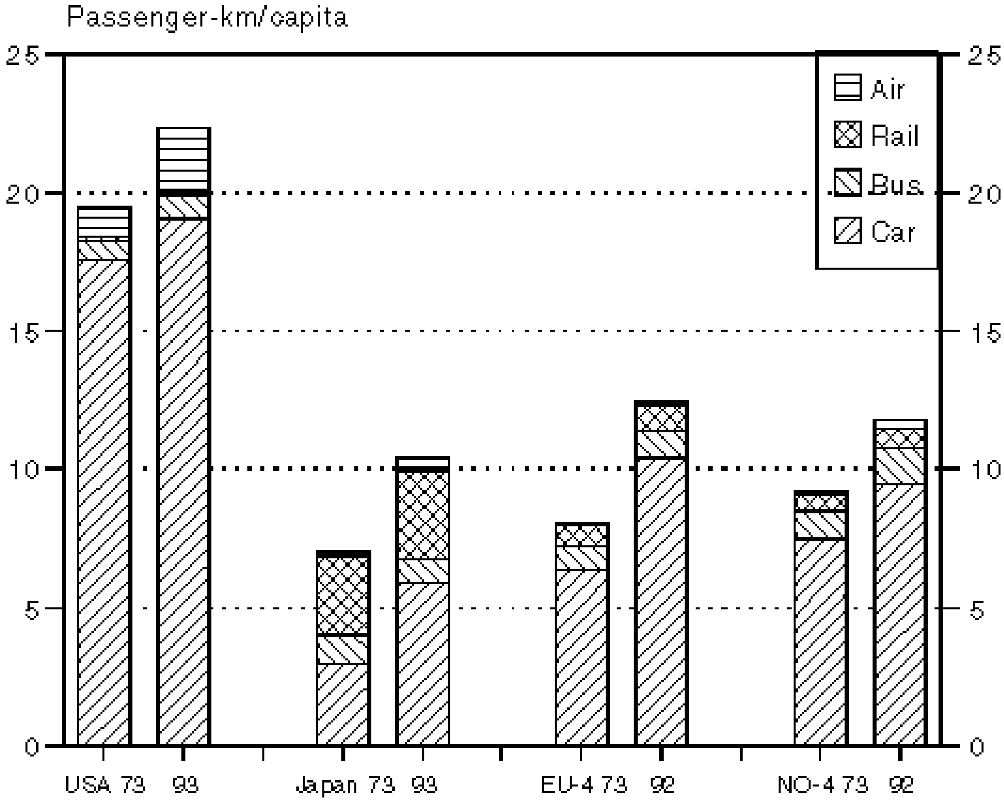

Figure 3. Per Capita Travel in OECD Countries
Source: National Transport Statistics. NO-4: DK, SF, N, S; EU-4: D (West), F, I, UK

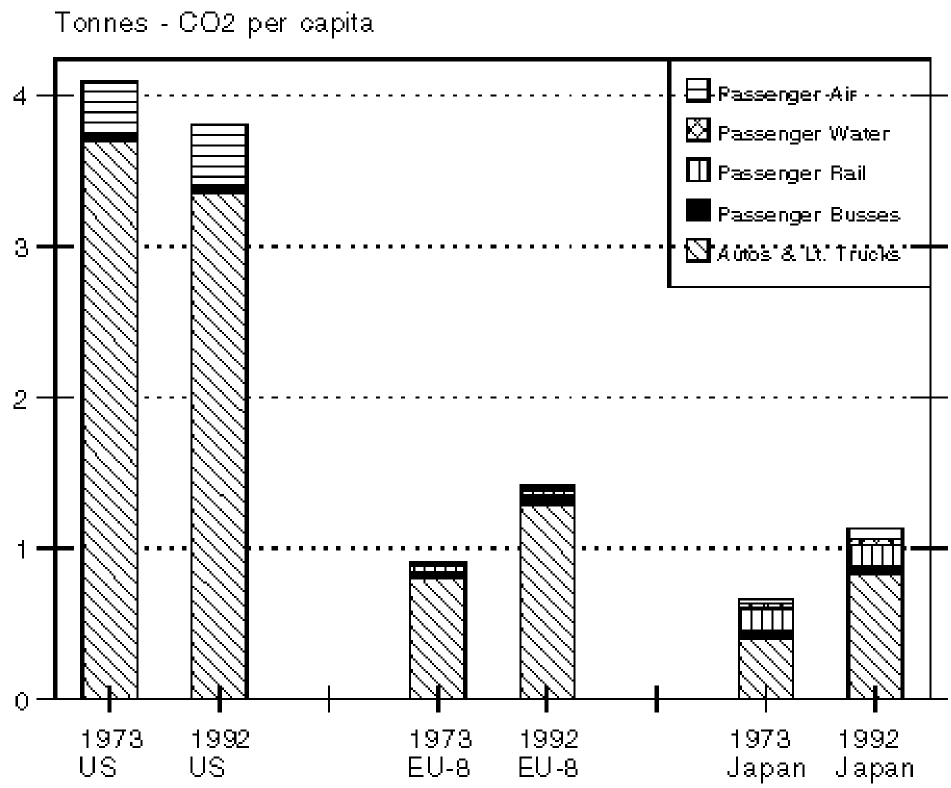

Figure 4. Carbon Emissions from Passenger Travel
Source: Calculated from National Data using IPCC Coefficients. EU-8: EU-4 and NO-4 from Figure 3

3. Underlying Factors Increasing CO_2 Emissions for Travel

To answer the question how emissions changed, Lawrence Berkeley National Laboratory carried out an index decomposition of the factors underlying changes in CO_2 emissions from both freight and travel, as well as from other sectors (Schipper et al. 1996; Scholl, Schipper and Kiang 1996; Schipper, Scholl and Price 1997; Greening, Ting and Schipper 1997). Recognizing that petroleum fuels dominate this sector and that the differences in emissions per unit of energy contained are relatively small (except when the “fuel” is electricity), we write

emissions for travel = (total travel) x (share of travel in each mode) x (energy use/unit of travel in each mode) x (carbon emissions per unit of energy for each mode)

and similarly for freight. This relation can then be used to study changes over time, and the results expressed as indices (Greening, Davis, Schipper, and Khrushch 1996). Many indices serve this purpose, but LBNL chose Laspeyres for simplicity. Comparison with Divisia indices shows that the results are similar. The carbon emissions from electricity generation are apportioned to each mode in proportion to the share of final electricity used in that mode (for rail, metro, and tramways).

For travel, higher per capita travel (total activity) increased emissions in every country, as Figure 5 shows for the group of aggregates. Modal shifts towards more energy-intensive modes (cars, air) increases emissions by as much as 30% (in Japan), but in most countries by up to 5%[3]. Falling energy intensities of vehicles themselves reduced emissions in more than half of the countries, but falling load factors in cars (and bus and rail in many countries) offset this restraint, leading to a net increase in energy use (and CO_2 emissions) per passenger-km in cars. Shifts in fuel mix and utility mix had almost no impact, for two reasons. First, the emissions per unit of energy released from diesel and gasoline are very close, but diesel is actually higher. Second, the role of electricity for travel (rail, trams) is so small that even the almost complete transition away from fossil fuels in some countries (Sweden, France, Finland) had only a very small impact on emissions from this sector. Thus by 1993, behavior factors had clearly increased CO_2 emissions, even after a period of more than a dozen years of relatively high road fuel prices.

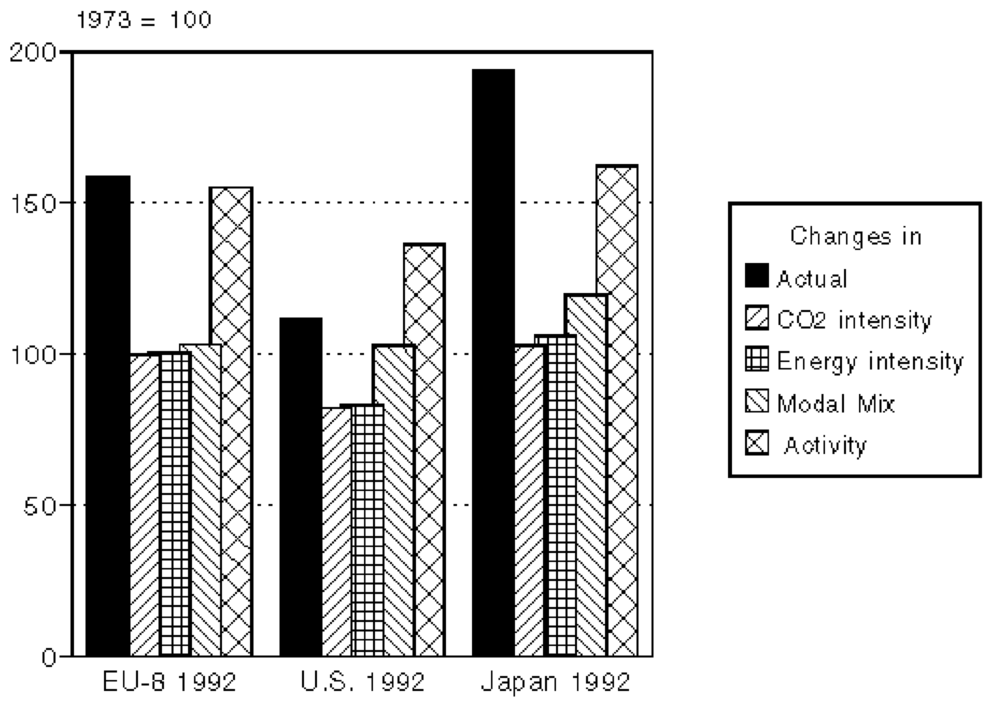

Figure 5. Changes in CO2 Emissions from Travel. Factoral Decomposition 1973-1992

Closer examination of trends in automobile characteristics confirms this finding. While the average tested fuel use per kilometer driven and per kilogram of new cars fell dramatically in all countries, the weight (and performance) of new cars increased in all countries, absorbing much of the effects of improved technology. Worsening driving conditions—both more high-speed vacation driving and more driving in congested areas—raised fuel use/km above what tests would predict (Schipper and Tax 1994). Once again, behavior thwarts technology. The result is shown in Figure 6: actual fuel use (gasoline and diesel weighted for actual consumption, and by energy content) per km fell dramatically in the US (and Canada, not shown), but barely changed in Japan and most European countries. Note that the figures for the early 1990s reflect car fleets that have been almost completely renewed since the early 1970s.

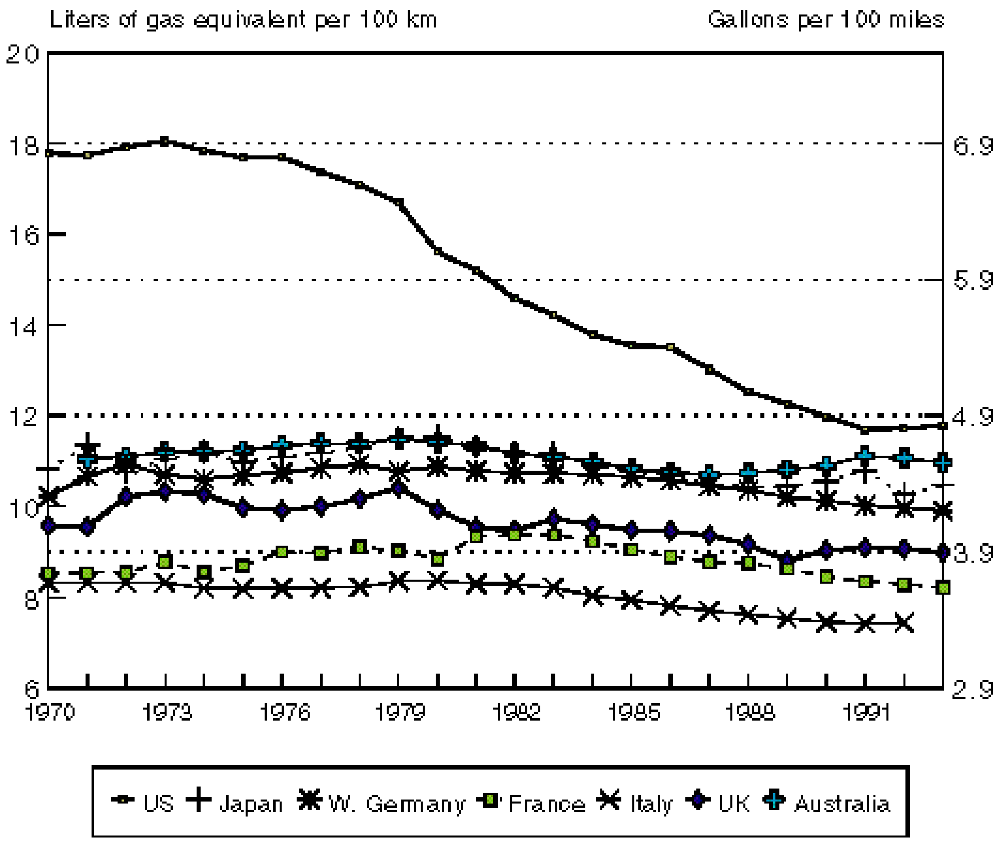

Figure 6. On-Road Automobile Fuel Intensity in OECD Countries.
Includes diesel, LPG for all countries: household light trucks for US, UK. Gasoline, Diesel, and LPG included at energy content

Factors related to vehicle performance are absorbing some of the savings of fuel technology offers. Figure 7 shows that indeed fuel use per km per kilogram of new car, averaged over each year's new cars, is falling steadily and uniformly in every country, and in fact differs little from country to country. But Figure 8 shows that weight is also growing steadily, propelled mainly by higher incomes. In a similar way, engine power per unit of engine displacement is increasing, indicating more efficient engines. But power per unit of weight is increasing, boosting acceleration. Not surprisingly, engine size itself is increasing, giving an even bigger boost to horsepower (and acceleration). Thus, higher energy efficiency is indeed improving among new automobiles sold, but most of the results enable cars to become larger and more powerful with only modest declines in real fuel consumption. Consumers seem to enjoy this.

Travel patterns are also changing. Figure 9 gives a snapshot of travel by purpose, based on the national one-day surveys of the countries shown (Schipper, Gorham, and Figueroa 1995). Note the relatively constant pattern: work travel (mostly commuting, but some trips within work) accounts for 20-30% of travel, services for about

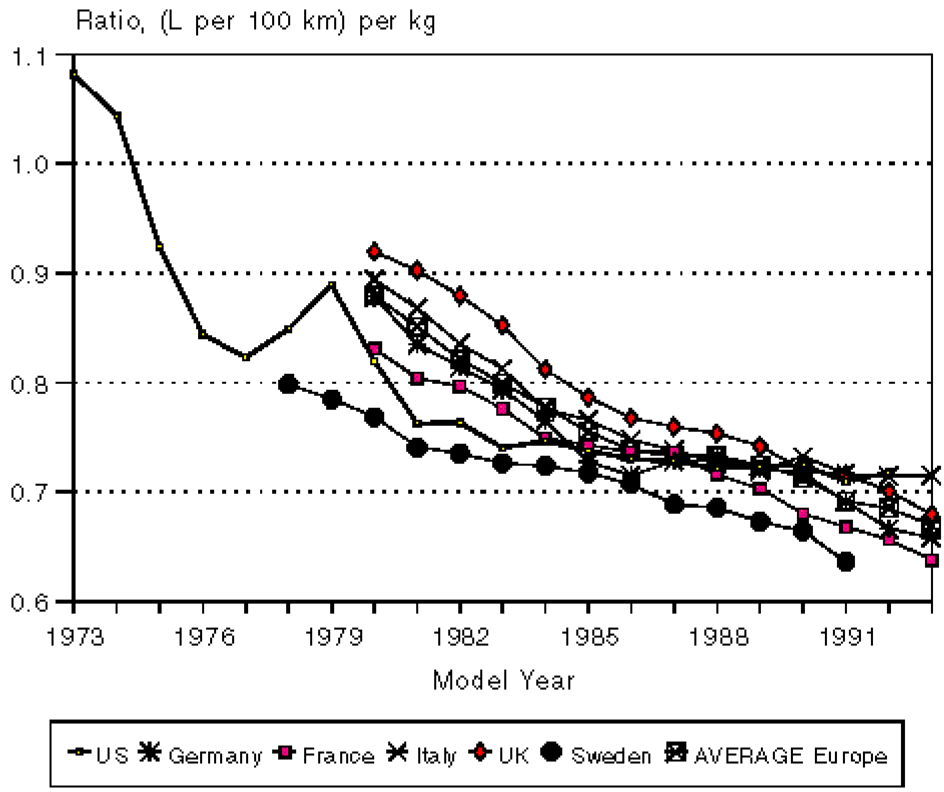

Figure 7. Test Average New-Car Fuel Intensity per Unit of Weight. Figures for gasoline cars only. Europe average also includes NL, B, A

Source: European Association of Automobile Producers

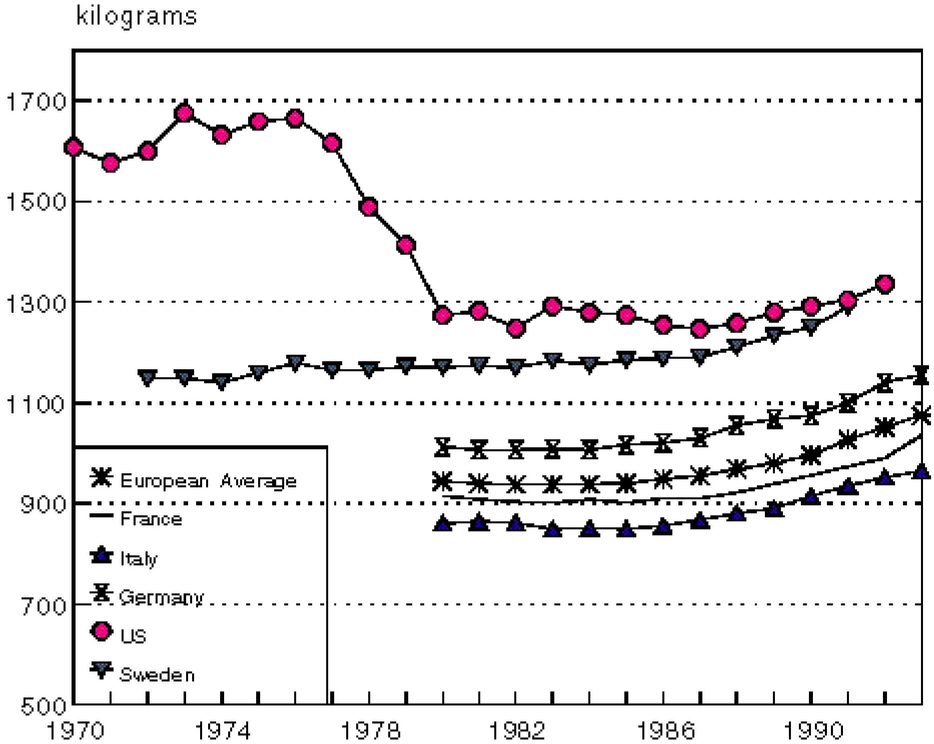

Figure 8. Average New Car Weight in Europe, U.S.

Source: European Car Manufacturers Association, US Dept. of Transport. Excludes vans, light trucks

25% (except in the US) leisure for the rest. The car dominates the latter two categories, but outside of the US, the car accounts for only 40-60% of work trips, since these are more easily taken on collective modes. Including walking and cycling has little impact on total travel, but an important impact on total trips, since these can account for as much as 1/3 of trips. But it is travel in cars (or by air) that accounts for the growth in mobility, except for the few exceptions (Denmark and Sweden) noted earlier. Not shown in these figures but clear from comparing surveys taken in different years is the growth in Europe in use of the car for work trips. By contrast, non-work trips seem to be leading growth in the US, probably the result of much greater saturation of trips to work by car since the 1970s (over 85% of work trips, of which only 1 in 10 as a passenger). People are not only moving more, but the structure of mobility, in terms of mode and purpose, is changing slowly.

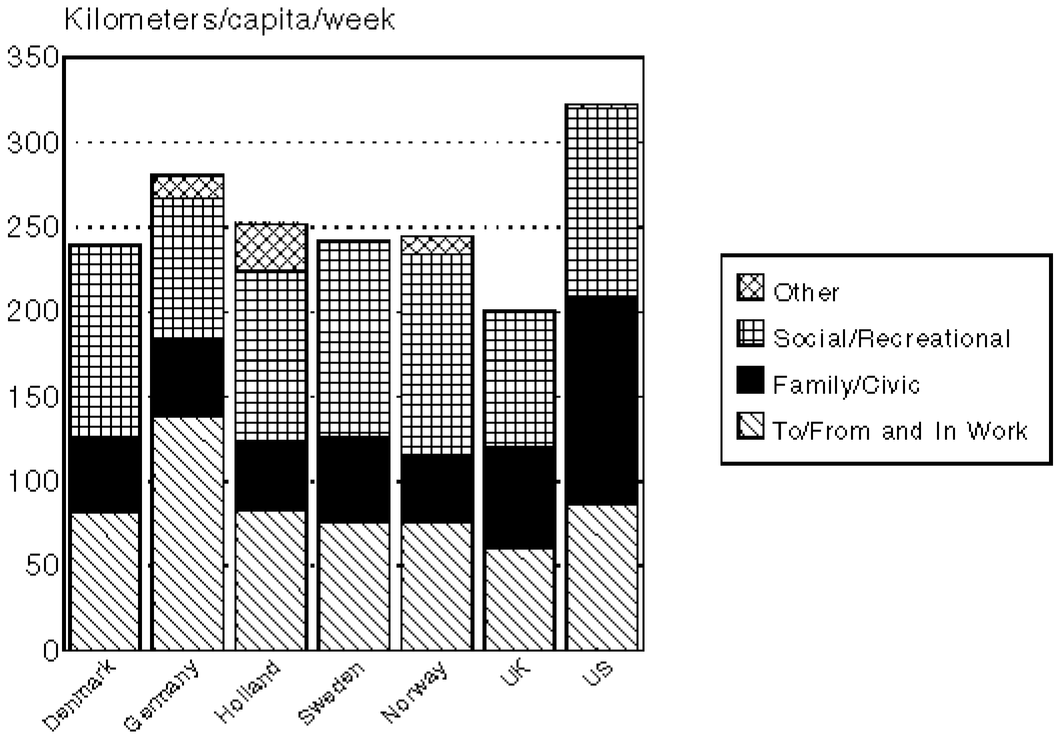

Figure 9. Travel by Purpose.
Travel day data all countries. Norway and Sweden unweighted data

One interesting result from comparing the travel surveys suggests that a single journey in a car in America is about as far as one in Europe, around 13-15 km. What explains the enormous gap between the US and Europe in per capita distance traveled 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 he 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 10 shows this similarity in car use in a way very critical for CO_2 emissions. We plot the share of all trips less than a given length (in km) vs. that length. Note that nearly 65% of all car trips are less than 10 km in all countries. Many or most of these trips are on cold engines, which raises fuel consumption/km (and emissions of many local air pollutants as well). Consumers are both using their cars for increasing numbers of short trips they previously walked or did not take, and also for longer trips at higher speeds. The result is increasing fuel consumption/km, all else equal. Combined with increasing congestion for much of the driving cycle, this raises fuel consumption over what is obtained in tests at relatively controlled conditions. This has important implications for technology: increasingly cars appear to be optimized for longer trips at relatively high speeds, yet the predominant use is in short trips with many stops and some congestion.

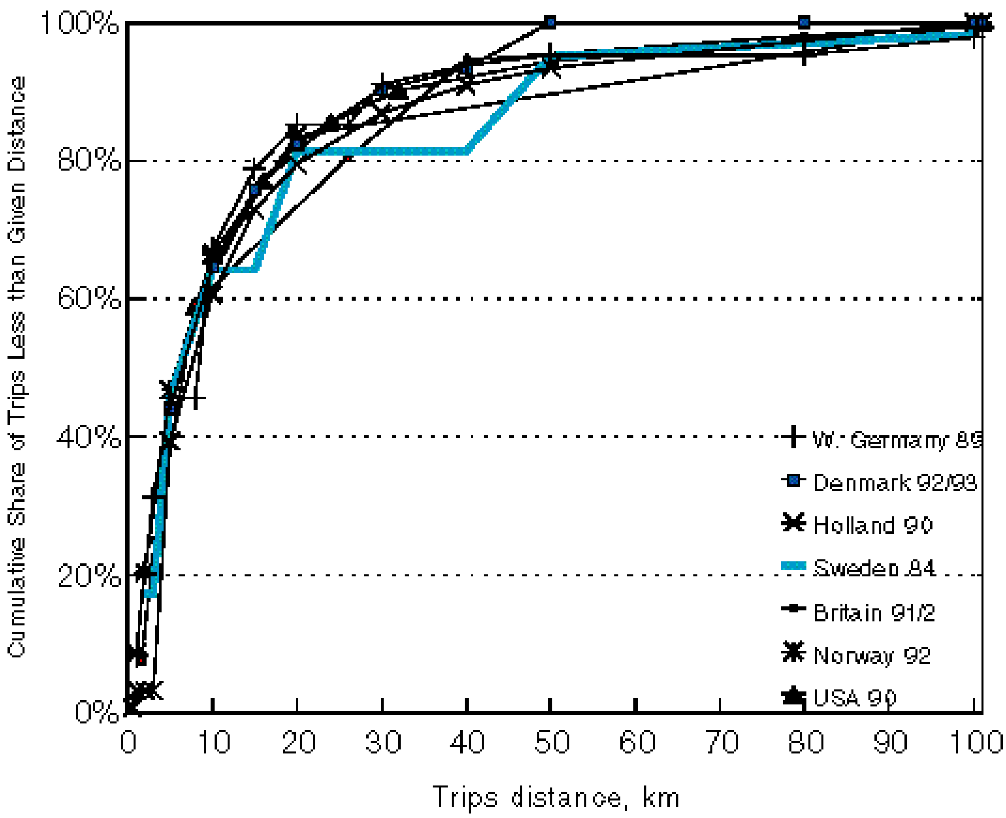

Figure 10. Length of Car Trips: Number by Distance*
One Day ("Travel Day") Travel Surveys
*Points right of 100 are "greater than 100 km", 50 km Germany, 20 km Norway. *Trip means "car, driver"*

The continual development of behavior and lifestyles had predictable effects on the use of cars over other modes. More Europeans became the first car owners in their families, as a majority of households approaching 75% had access to at least one car. This point had already been passed in North America before 1973, and explains why Europe appears to be "catching up" to the US in many of the indicators presented in Figures 1-3. Life-cycle factors are also important in explaining the continued rise of car ownership and differences among countries (Greening, Schipper, Davis and Bell 1996). Increased women working noted above often resulted in two-car households with each adult driving in a different direction. Liberalized shopping hours and more automobile-oriented services in general also increased the utility of cars, as noted by Schipper et al. (1989). Company car taxation policies, which may have a big influence on new-car market decisions in the UK, Sweden, W. Germany, and Holland, and tax treatment of commuting expenses in general also encouraged more use of larger cars. Finally, higher incomes in general permitted more families to own cars and larger, free-standing homes in suburbs: In Paris or Stockholm, for example, the inner city populations have barely grown, while populations in the near and distance suburbs grew significantly. Whether these changes are short-term or even reversible has been discussed in terms of the CO2 problem (Michaelis et al. 1996), but there no simple solution: Changes in travel behavior contribute to greater CO_2 emissions.

4. Summary: Behavior Drove Changes in Emissions for Travel

Changes in the way people travel have been the dominant cause of rising emissions. Technical factors, as the vehicle and modal energy intensities represent, led to some restraint of emissions in a few cases for cars but only gave a net reduction in per capita emissions for travel in one country. Behavior and managerial factors (i.e., modal choices and utilization), as well as overall increases in activity coupled to GDP, clearly boosted emissions overall. In households, by contrast, behavioral factors, such as lower indoor temperatures, persisted to some degree to restrain fuel use and emissions, and technologies added a large component as well. But in both travel and households, consumer lifestyles became increasingly "emissions intensive" as more space was occupied at home, in and in the service sector, and consumers' mobility between these places increased (Schipper 1996).

Did higher fuel prices not affect fuel use or emissions? It is often forgotten that for most countries, real fuel prices were higher only for two brief periods, 1974-7 and 1979-1985, periods too short to expect radical changes in both vehicle technology and use and modal choice to occur, let along major rearrangement of the housing and mercantile infrastructure affecting the origin and destinations of travel and freight respectively. Still, emissions per unit of GDP did fall somewhat in these periods, and emissions unit of activity fell as well. Some of that decline continued after oil prices crashed because of the technological gains that were started in the high-price years, gains still working their way into the fleet through vehicle turnover. Figure 11, however, shows that there is a significant relationship between car fuel intensity (or per capita car fuel use) and real fuel price (with diesel included at its share of car fuel in each country). Thus in a cross-national comparison, prices levels are inversely associated with fuel intensity of either cars (or trucks, see Schipper, Scholl and Price 1997) to some extent, but inversely associated with fuel use strongly in all cases. (If fuel use for cars in Figure 11 were normalized by GDP instead of population, the US point would fall somewhat closer into the line.) Since it is use, not intensity, that most closely drives CO_2 emissions, this means fuel prices have an important relationship to emissions.

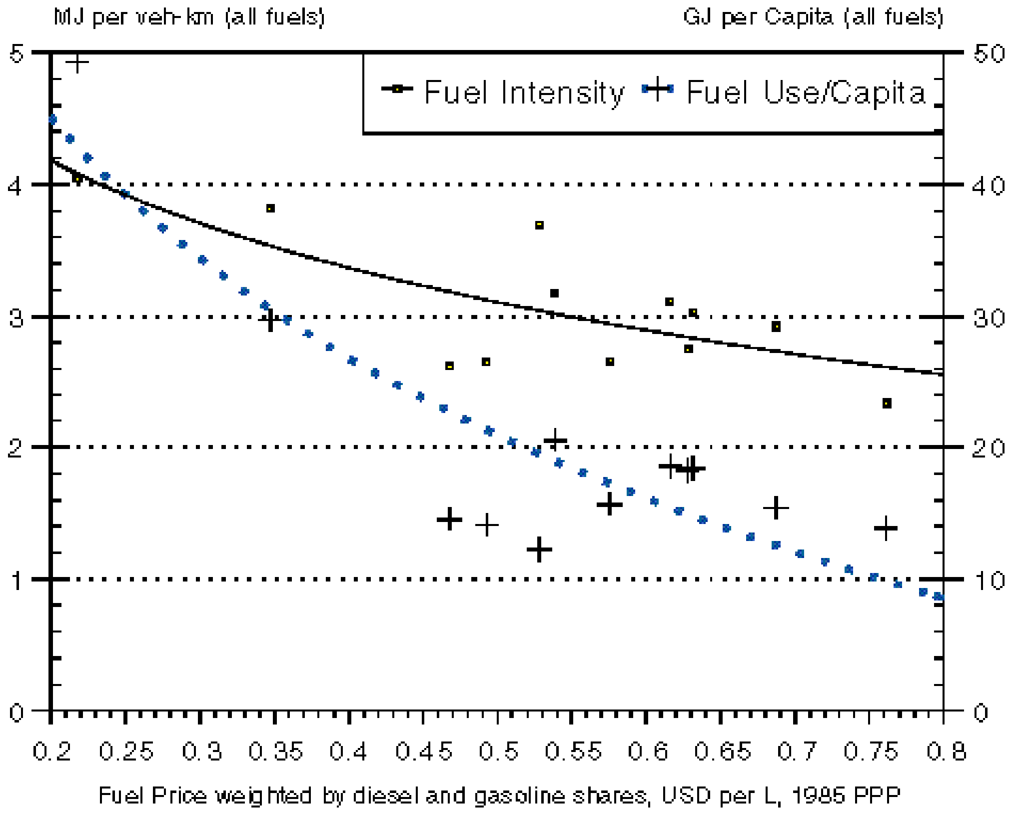

Figure 11. Fuel Prices and Fuel Consumption in 1993. Fuel Intensity and Fuel Use
Source: International Energy Agency and Lawrence Berkeley Laboratory

The fact that car fleet fuel intensities appear to be almost linearly related to fuel prices in cross national comparisons, and that US vehicle fuel intensity in 1993 appears consistent with the points from the other countries, is striking. This suggests that automobile fuel intensity is a function of fuel price. But automobile efficiency in a technical sense now varies little among countries (cf. Figure 7), since vehicles are produced by international companies sharing largely the same technologies. Instead fleet-average automobile size or weight (cf. Figure 8), power, and features that differentiate the points for fuel intensity in Figure 11, with vehicle ownership and use taxation, including the impact of company car taxation, certainly explaining some of the scatter, since these policies affect not only the ultimate cost of fuel to the user but the cost of using the vehicle as well, which is much more significant (Schipper and Erickson 1995; Schol and Smokers 1993; NEDC 1991; Fergeson 1990). It is not unreasonable to assert, without formal proof, that these characteristics depend on incomes (including car taxation) and fuel prices, but this dependence will have to be subject of future study.

Thus factors causing changes in CO_2 emission are intimately related to the nature of transportation—comfort, convenience, speed. Those driving activity—distance—as well as modal choice are related to individual and societal choices about housing, work and leisure location. The same is true for freight. But the cost of fuel is but a small fraction of the total cost of either travel or freight, even before the cost of the transport infrastructure is considered. And the choices noted here are deeply-rooted in a transportation context. This means that these choices—today's slowly-evolving transportation patterns—may be difficult to stop simply because of CO_2 concerns. To be sure, natural limits (saturation of distance or time of travel, potential saturation of the distance physical goods are sent around) or local constraints (congestion, parking problems, local pollution) may slow or reverse some of these trends. But most national transport plans still foresee increases in personal and goods transportation with GDP if no policies intervene.

It is significant that air travel showed uniform and deep reductions (50-60%) in fuel use or emissions per passenger-km in all countries from both improved technology and higher load factors. In this case, however, fuel reached as much as 20% of operating costs and even in 1997 remains a source of cost pressure to airlines. Thus the distinction between enterprises and private automobile use may be important for explaining differences in the evolution of fuel intensities and CO_2 emissions from these different branches of transportation.

6. The Challenge: Reducing Emissions from Transportation

As pointed out by the IPCC (Michaelis et al. 1996), there are a variety of means that would reduce emissions: reducing travel or freight activity, shifting some of that activity to less CO_2-intensive modes, reducing the energy intensity of each mode (particularly the dominant ones, road and air), and reducing the CO_2 contents of each fuel or propulsion source.

To be sure, there is a plethora of studies showing how each of these factors could affect emissions. Yet the stark facts are simple and need not be reviewed here (see Scholl and Schipper 1996 in this context): modal shifts continue towards more energy- and CO_2- intensive modes, perhaps driven by higher incomes; the energy intensities of key modes have not fallen according to the most optimistic studies of "potentials"; load factors of cars have dropped or not risen; utilization of trucks remains low; technological efficiencies keep increasing, but these increases seem to be feeding increased power or features. It is hard not to associate these development with the fall in fuel prices and slow rise in incomes.

Alternative fuels might offer some relief. There are many propulsion sources that offer <u>nearly</u> the same performance as gasoline and diesel but with lower net CO_2 emissions (Sperling and Deluchi 1989; 1993; Wang and Deluchi 1992; Sperling 1994). These are only making slow progress in the market place, most likely because of the higher costs of vehicles and because the sources themselves are more costly than gasoline or diesel fuel. Or it is possible that "nearly" the same performance is not really correct, which is another behavioral issue. There is no easy fix using alternative fuels.

Diesel engines themselves offer significant potential for lower net fuel intensity and CO_2 emissions (Wester, Volkswagen AG 1992, private communication, Michaelis 1996). Models are now appearing in Europe with turbo-direct-injection using less than 4 l/100 km in 90 kph traffic. New-car statistics, however, show that the diesel model of a car tends to have a larger engine than its gasoline counterpart. And it must be remembered that diesel fuel is taxed much more lightly than gasoline in some countries; not surprisingly, its consumption is associated with significantly higher car travel. And, as noted, diesel releases more CO_2 per unit of energy in combustion than gasoline, although its production may require less energy in refineries. Therefore, the net impacts of switching to diesel, or indeed any other fuel, must be evaluated taking actual usage—a behavioral question—into account. Comparisons must also use full fuel cycle studies that take into account the marginal release of CO_2 anywhere in the fuel chain.

Electric propulsion may offer attractive ways of removing combustion from cars to power plants, often released away from cities. But how is the electricity made? How will electric cars be used? And if that use of electricity remains untaxed as a road fuel while incentives are offered to provide easy entry to cities or low-cost parking, then consumers may again find a cheaper way to use cars than before, resulting in more driving. It is clear that alternative fuels may offer significant CO_2 benefits, but until we better understand all the costs, all the emissions, and above all the real interaction between alternative propulsion as a system and travel behavior, our expectations should be at best guarded.

What about changes in lifestyles? Schipper et al. (1989) explored a home-oriented ("HO") scenario in which people spent more of their free time at home and used local outlets more for services. Certainly this future is plausible, but is not occurring. And while it is suggested by some that changes in land-use could reduce the "need" for travel, particularly through densification of settlements, so far, however, those changes are all towards more spreading out. Indeed, the US Nationwide Personal Transportation Survey used in Figure 9 (see Hu and Young 1992) shows that an increase of population density of over a factor of one hundred is associated with only a halving of car travel per capita, while studies of San Francisco and Paris (cited in Schipper 1997) suggest a similar association between population density, as one marker of land-use, and travel. Clearly higher densities are associated with lower travel, but the relationship is too weak to be considered a major "source" of shift in land-use towards lower travel. The problem is that very few localities have figured out how to change land-use through regulations in a way that leads to observed and significant reductions in travel. At the same time it is hard not to observe that total travel is related to the cost of travel: It may well be that higher costs of travel (and housing and land) are a major factor keeping European settlements denser than those in the US, Canada, or Australia. If this is true, then planning to increase densities must be related to important measures that change other key costs, costs far more important to the household budget than the marginal cost of using a car.

Schipper et al. (1989) and Schipper (1995) suggest there may be saturation in total travel caused both by saturation in car ownership and saturation in distance traveled, as limited by travel speeds. Similarly, changes in the socio-demographic make up of the population, changes in workforce composition, etc., may also retard growth in travel with income. This growth may not be inevitable, and a variety of endogenous forces may bring the growth to an end. Indeed, there seems to be some sign of saturation in Figures 1 and 2. But there is still no major downturn in either travel or (except for the US in the 1980s) in the energy use for travel.

It is noteworthy from Figure 1 that Danes, with significantly fewer cars per capita, use these cars more intensely, resulting in a position in Figure 1 that belies the low car ownership there. That fuel use per capita is low for income may be more a function of the enormous burden of taxation (nearly 200% of the pre-tax value) on new cars, forcing them to be small, but not necessarily efficient. Comparison of travel-behavior surveys (Schipper, Gorham, and Figueroa) shows indeed that the Danes travel differently than others, more bikes and walking and somewhat more bus travel, complemented by slightly less car travel than in other European countries of similar incomes. The Netherlands has a similar set of travel patterns. How much is due to planning or to a geographical or cultural interest in biking (in a flat country), and how much is due to the enormous taxes on new cars in Denmark, or somewhat lower, but still large, taxes in the Netherlands, is not clear.

We noted above important feedback loops relating fuel economy and efficiency to car performance and possibly car use. That car size and performance are absorbing some of the benefits of new technology, rather than giving larger reductions in fuel use per kilometer, is one that may be hard to avoid if incomes grow while fuel prices are steady or falling. It is possible that if technology jumps more quickly to reduce the energy (and CO_2) costs of that performance, or if a fuel truly low in CO_2 emissions becomes available, that emissions could head downward for a long time as the new technologies appear in the market. Nevertheless, some countries, notably Denmark and Sweden, anticipate this in their CO_2-related policy discussions, and are considering higher fuel taxes to offset the lower costs of car use afforded by greater efficiency. For Danish calculations, it is assumed that a 10% reduction in fuel costs/km leads to a 4% increase in km driven (COWI 1996), but others (Green 1992) find that coupling much smaller, closer to 1.5%. The difference may arise because costs in Denmark are so much higher than in the US, such that the elasticities are different. Either way, however, this kind of feedback cannot be ignored, particularly if the increases in car use raise more external costs associated with noise, congestion, and safety than the net reduction in fuel use save from lower CO_2 emissions. Significantly, the Danish government proposals for reducing CO_2 from automobiles include both a target for greatly boosted fuel economy and an increase in fuel prices of roughly the same magnitude to keep the cost of using cars from falling. Equally significant, virtually no major US proposals for raising the costs of fuel beyond a few percent have survived debate in Washington DC.

7. The Future: Pushing with Policies?

Lest the trends presented appear to herald continuing increases in CO_2 emissions from transport, there is a positive message from this work. From each national study there appears to be a combination of technological change (including that driven by RD&D and pricing policies, complemented to some extent by regulations or targets), higher costs for lower-emitting fuels, and application of transportation measures that could improve transportation and restrain or even reduce CO_2 emissions over the next decade. These could change <u>both</u> emissions per km <u>and</u> total km enough to make a real break in travel fuel consumption, as clearly happened in the US in the 1970s and 1980s. Thus while the bad news is that CO_2 policies alone, or technologies aimed at CO_2 alone, may not have a great enough impact on emissions to reduce them, CO_2 measures in intimate combination with transport policy measures could leave European, Japanese, and N. American transportation systems with lower total CO_2 emissions in the early part of the next century than at present.

We will not speculate here on which policies might affect these variables in the future, and therefore restrain or reduce CO_2 emissions from travel (or freight). However, the opening comments about transport externalities served to emphasize that only a broad framework that integrates concerns for CO_2 with strategies to solve other transport- related problems can be successful. If the transport problems are indeed as serious as the literature suggests, then their prompt and thoughtful treatment, together with measures designed to address CO_2, including taxation, could break the links shown in the opening figures. And if governments are really as concerned both about “Sustainable Transport” and with CO_2 emissions as their prolific reports suggest, the forces could be mustered for this important integration.

As noted in the introduction, authorities at all levels, from local to national to international (Michaelis et al. 1996, CEC 1996) have taken note of these problems related to transportation. Since the studies cited find the likely costs to society of externalities besides CO_2 greater than the costs of CO_2 (at least per km of vehicle, personal, or goods travel), then it may be more reasonable to expect that the greatest changes in transportation will be motivated not by CO_2 concerns but by those concerns rooted in problems of transportation. As the COWI study suggests, measures that integrate CO_2 concerns into a larger packet of transportation environmental reforms may lead to both serious restraint in emissions and in growth in other externalities from transportation with a net gain in overall social welfare. We believe these kinds of results, while only approximate and only validated for a model for Denmark, point the way to both how to inlay the CO_2 problems in a transport context, and, more important, where to find solutions. But no measures that ignore human behavior (or the way people run the freight system as such) can possibly succeed in stemming the rise in emissions, given the history of behavior as a key factor in boosting them.

End Notes

1. 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. Energy uses not included here include military vehicles, international marine and air fuel, civil aviation, and some miscellaneous vehicles. See Schipper et al. (1992) for the first decomposition study, Schipper (1995) for a review of trends in automobile energy use, Scholl

Schipper and Kiang (1996) for the analysis of CO2 from travel. Kiang and Schipper (1996) for the analysis of Japan, Schipper, Scholl and Price (1997) for the analysis of freight or Schipper, Meyers et al. (1992) for detailed information on how these splits (and original data) were obtained. Many of the data used in this study are published by the Oak Ridge National Laboratory in their "Energy and Transportation Handbook".

2. Freight will not be considered explicitly here but can be reviewed in Schipper, Scholl, and Price 1997.

3. For Denmark this factor led to reduced emissions, a result of our use of a falling load factor for cars, in contrast to practice by Vejdirektorat.

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