ENVIRONMENT DEPARTMENT
PAPERS

20023

PAPER NO. 69

TOWARD ENVIRONMENTALLY AND SOCIALLY SUSTAINABLE DEVELOPMENT

CLIMATE CHANGE SERIES

Transportation and CO_2 Emissions: Flexing the Link — A Path for the World Bank

Lee Schipper
Céline Marie-Lilliu

International Energy Agency, Paris, August 1998

September 1999

ESSD

Environmentally and Socially Sustainable Development

The World Bank

THE WORLD BANK ENVIRONMENT DEPARTMENT
and THE TRANSPORT, WATER, AND URBAN UNIT

Transportation and CO_2 Emissions: Flexing the Link — A Path for the World Bank

September 1999

Contents

BOXES

FIGURES

Figures (*continued*)

Tables

Foreword

This paper will address the issue of reducing carbon dioxide (CO_2) emissions from transportation. We will focus on how the World Bank, through its analytical capabilities, lending practices, and policy influence, could contribute to significant mitigation in client countries and elsewhere. We will not cover the entire range of greenhouse gas (GHG) emissions but rather focus on CO_2 emissions arising from transportation in developing countries (DCs). We will use many examples from member countries of the Organization for Economic Co-operation and Development (OECD) to illustrate important relationships often difficult to quantify in other regions because of data and measurement problems. We will suggest some options for GHG restraint as illustrations but not provide a full list by any means. Rather, we will discuss the more generic advantages – and challenges – of these options, particularly as seen from the perspective of the World Bank.

The goal of this study is to develop the first steps of a World Bank strategy for restraining GHG emissions from transportation. With funding provided by the Global Environment Facility, the Bank's *Global Overlay Program* is to be extended to include the transportation sector in the identification of climate change externalities in Bank Economic and Sector Work (ESW). While few developing country policy-makers are immediately concerned about restraining their own emissions, many have come to realize that the costs of climate change may well be significant for lower-income, principally agricultural economies. They also recognize that climate change mitigation projects usually have secondary benefits in energy efficiency and local pollution reduction.

It is clear that transport is a key link between small isolated communities or societies and industrial economies, by permitting exchange of goods over distance and enabling socio-cultural interchange (Braudel 1992). Effective transportation is also a key element in keeping markets competitive and raising choices for both producers and consumers. Transport has historically been instrumental in allowing people access to goods, services, and activities, and enhancing their opportunities for exchange, and hence economic growth. For most observers, therefore, transport has given society an enormous surplus. There is, nevertheless, widespread concern over the costs of externalities from transportation, which include safety, air, water, and noise pollution, competition for urban space, balance of payments problems, and risks associated with importation of oil as the main transport fuel. How to internalize these costs, and how such changes would affect vehicles, transportation activity, and the transportation infrastructure is now the subject of considerable worldwide debate.

The emission of greenhouse gases, of which CO_2 is the most significant, is arguably of less immediate impact in monetary terms. Unlike congestion, noise, or air pollution, CO_2 emissions are not perceived as a problem that affects a localized area or even present generations enough to provoke major changes in transportation or fuel use. Nevertheless, CO_2

emissions from travel and freight have increased in most industrialized countries faster than population, and in many cases as rapidly as gross domestic product (GDP). Indeed, in virtually all regions of the world, CO_2 emissions from transport are rising relative to total emissions. Policy-makers in the major oil consuming countries are attempting to understand and address this phenomenon, even though it still may not be a high-priority issue for policy makers in developing countries (DCs) and the economies in transition (EITs).

This paper begins with a brief review of global trends in CO_2 emissions, with a more detailed analysis of emissions in International Energy Agency (IEA) countries provided in an annex. Next, approaches and tools available to the Bank as part of the Global Overlays approach are delineated. These tools come under the heading of "better practices" (Technology "better practice" options are reviewed in Annex 2). The paper concludes by outlining a series of steps towards designing a strategy for the Bank in its transportation sector work with client countries.

Executive Summary

Transportation is one of the most rapidly rising sources of greenhouse gas (GHG) emissions, often increasing faster than Gross Domestic Product (GDP) in developing countries (DCs). Public and private authorities in these countries tend to place a low priority on the externalities associated with GHG damages, and are more immediately concerned by those damages associated with safety, congestion or air pollution. This is largely because present generations are exposed directly to these externalities at the local level, while policies aimed specifically at reducing or restraining GHG emissions contain elements of political and economic uncertainty or have few rewards from a national perspective, as the December 1997 negotiations in Kyoto revealed. Given this uncertainty, the strategic option is to align initiatives to restrain GHG emissions within overall transport reform. Vigorous research and marketing of new less fuel-intensive vehicles, and carbon taxes favoring low-carbon fuels can achieve significant restraint; stabilization or even reductions in emissions from transport could occur by the second or third decades of the next century.

For DCs, with significantly more rapid growth in vehicle stocks and utilization, the real policy challenge is to reform transportation policies and customs *now*, in order to eliminate obvious and hidden subsidies and make users pays full social costs while boosting overall social welfare. Even in rapidly growing countries, it will take decades for policies, technologies, and alternative fuels to halt the rise in emissions and ultimately to reduce emissions. The most attractive option for DCs is to encourage wider and more rapid development and marketing of low-CO_2 vehicles (including two and three wheelers in urban areas), and to develop movement patterns that create access without an excessive demand for kilometers.

The World Bank plays a key role in lending for transportation in many DCs and Economies in Transition (EIT). These projects, in the process of raising overall welfare and mobility, raise GHG emissions as well. A number of changes in policy, as well as expansion of efforts into new areas, could

- Reduce GHG emission increases implicit in many Bank transport projects
- Lead to greater restraint or abatement in its client countries
- Encourage the international vehicle and fuel suppliers to make greater technology innovation efforts by helping shape the market for low-carbon motorized vehicles in the rapidly growing DCs and the restructured EITs.

The Bank can achieve these objectives by undertaking a strategic plan that contains the following elements:

- Help establish a policy framework in which client country authorities and stakeholders can evaluate and debate the options for improving the environmental performance of transport
- Encourage policies that allow cost recovery and price externalities into transportation costs (fuels, road use, and so forth)

- Accelerate development and share deployment of low-CO_2 cars and trucks, as well as "clean" two- and three-wheeled alternative vehicles
- Finance development of infrastructure that supports innovative and financially viable collective transport systems (for example the system in Curitiba, Brazil reduces automobile use in a town with the highest car ownership in the country)
- Link CO_2 emission reduction efforts to major initiatives to reduce air pollution, congestion, and other severe local problems created by rapidly growing volumes of traffic
- Assume a proactive role, working directly with vehicle suppliers, technology developers, and client country policy-makers to broker agreements among these stakeholders to develop new markets with low-emissions transportation options
- Provide Technical Assistance (and in-country capacity building) for basic passenger and goods movement surveys, fuel-use and emissions testing of new and existing vehicles, as well as land-use development models.

The *Global Overlay Program* represents an excellent opportunity for Bank initiatives to embrace a full range of low GHG options. The Program's objective is to integrate global climate change externalities into Bank Economic and Sector Work, and to identify GHG-reduction friendly options that could then be financed through the Global Environment Facility (GEF), the proposed Prototype Carbon Fund, or the Clean Development Mechanism of the Kyoto Protocol. The **ASIF** methodology described in this paper offers an analytical framework that is in line with these objectives. By decomposing trends in emissions into transportation **A**ctivity, modal **S**hares, the energy **I**ntensities of each mode and the **F**uel mix of each mode with its GHG emissions characteristics, the key components of change in transportation activity are analyzed. For example, interventions in **I** and **F** (technologies and utilization) have the largest promise for restraint, while policies that affect **A** and **S** through broader transport reform will also restrain emissions.

To achieve meaningful results, the Bank must look beyond individual project planning towards a strategy where sequential projects and policy planning is viewed in a longer-term perspective. Policy actions must be few but clear in nature and strong in impact to reduce the risks of having no impact or perverse outcomes. Taking this longer-term perspective ensures an active Bank role during a significantly long period of development (one to two decades). Such an approach is required if low-GHG vehicles and systems are to be developed and successfully implemented.

Acronyms and Definitions

IEA
The International Energy Agency, whose participating countries are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.

OECD
The Organization for Economic Co-operation and Development, whose countries include those of the IEA as well as Iceland, Poland, the Czech Republic, Republic of Korea and Mexico.

DC
Developing Countries

EIT
Economies in Transition, which includes countries of the Commonwealth of Independent States (CIS), and countries of Central and Eastern Europe, including for this discussion those that have joined the OECD or IEA.

GHG
Greenhouse gases. As defined by the IPCC (IPCC 1990), these include a variety of gases that increase the atmosphere's ability to trap infrared radiation and thus warm up. The most important of these is carbon-dioxide (CO_2), but methane (CH_4), nitrous oxide (N_2O) are also counted in many assessments, and there are other substances which in the atmosphere can increase the total warming effect. In this study, we refer principally to CO_2 emissions and count them as carbon that is burnt as fossil fuels. Further, we count available carbon, since only careful measurements determine how much carbon in fossil fuel combustion is fully oxidized to carbon dioxide.

Energy Use and Carbon Emissions
This study considers emissions arising from final energy uses in transportation including the average emissions associated with generating a unit of electricity in a country. We generally count carbon, rather than CO_2, since we do not know exactly how much carbon that is combusted really winds up as CO_2.

Full Fuel Cycle Analysis
We do not consider emissions associated with the fuel cycle of making other transportation fuels. These are much smaller than those associated with production of electricity from fossil fuels. However, the differences in full fuel-cycle emissions from transport fuels must be carefully considered in the future as alternatives are offered that may indeed release fewer GHG in vehicles while being associated with greater GHG emissions in preparation, of the converse. Diesel fuel, for example, releases more carbon per unit of energy contained (and holds more energy/liter) than gasoline, but has much smaller carbon releases associated with its

production. So-called renewable ethanol from corn, as produced in the United States for blending with gasoline in gasohol, represents at best a 10 percent decline in net carbon emissions per unit of energy compared with gasoline, and possibly even an increase (Delucchi 1997). This is because of the fuels used to harvest and process the ethanol, release so much carbon. In each country full fuel cycle analysis must be applied to truly see the GHG implications of alternative fuels.

GHG Reduction

Three important concepts are associated with the general goal of GHG emissions reduction. All are relative concepts.

- Abatement means quasi-permanent absolute reduction, particularly in the short or long term. Abatement might occur if there is a rapid switch in fuel to one with lower emissions per unit of energy, rapid enough to outweigh overall increases in the size of the economic system or the output or activity for which that fuel us used.
- Avoidance connotes growth in a particular activity that by design or accident is not associated with increasingly higher GHG emissions. Development of a transportation system based only partly on automobiles, with low-CO_2 fuels (relative to gasoline and diesel fuels) and high access of people to each other and goods to markets with relatively low distances involved is the "ideal system", but such a system does not exist today.
- Restraint in GHG emissions means active policies designed to increase the size of the wedge between growth in GDP and growth in emissions. In some IEA countries this could mean a decline in the absolute (or per capita) level of emissions. In developing countries this in practice means increasing the gap between economic growth (measured by GDP) and emissions growth. In EITs, restraint could well mean falling emissions and rising economic activity as the least efficient power plants, factories, and most CO_2 intensive fuels (coal and lignite) are simply abandoned.

1 Trends in Energy Use and CO_2 Emissions

The following sections present a brief global overview, followed by detailed analysis of trends in IEA countries. Similarities between IEA countries' transport sectors and those of high income DCs suggest many of the forces that affect transport trends in IEA countries are important for DCs. These trends reveal many important variables and forces that must be understood, if transport policy and Bank action is to affect the future of transportation and resulting GHG emissions in non-IEA countries. The section concludes with a description of the ASIF methodology, which is a useful analytical framework for analyzing past changes in emissions and essential for confronting possibilities for the future.

In this section, we principally refer to Carbon Dioxide (CO_2) as the major gas listed under the definition of Greenhouse Gases (GHG).

Global trends in energy use and CO_2 emissions

Figure 1 reviews important trends in carbon emissions. While the OECD countries still account for the vast majority of world CO_2 emissions, the developing countries are responsible for most of the growth. Figure 1 shows share of emissions both in 1980 and 1994. Figure 2 shows the relative changes between 1980 and 1994. Clearly emissions in DCs are growing. Transportation itself is a major source of energy-related emissions, growing in most regions more rapidly than emissions on average (Figure 3). The most notable exceptions to this pattern are China and the Middle East. Indeed, in the OECD, emissions from energy-related sources other than transport in the early 1990s were barely higher, or even lower, than they had been in 1973. Normalized per unit of GDP, emissions in every major IEA country for all sectors but transportation fell significantly. In other words, all sectors of the economies of IEA countries

Figure 1. Share of CO2 Emissions (Mt CO2), 1980 and 1994

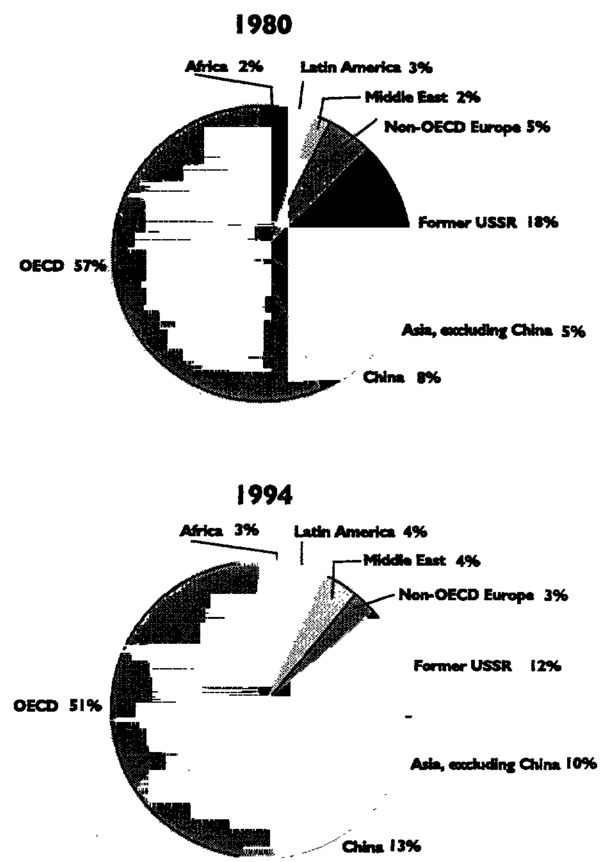


Figure 2. Relative changes in CO_2 emissions in 1980 and 1994

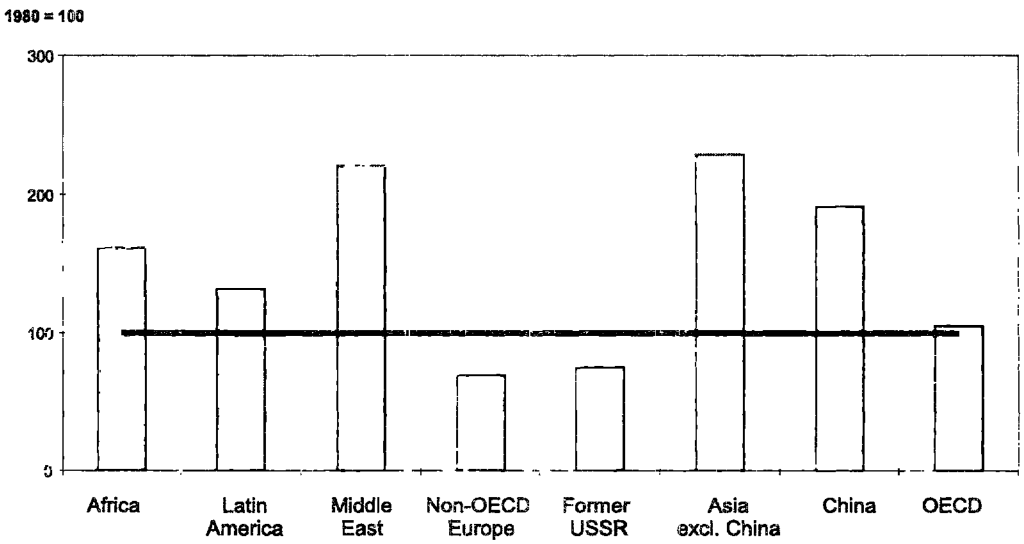
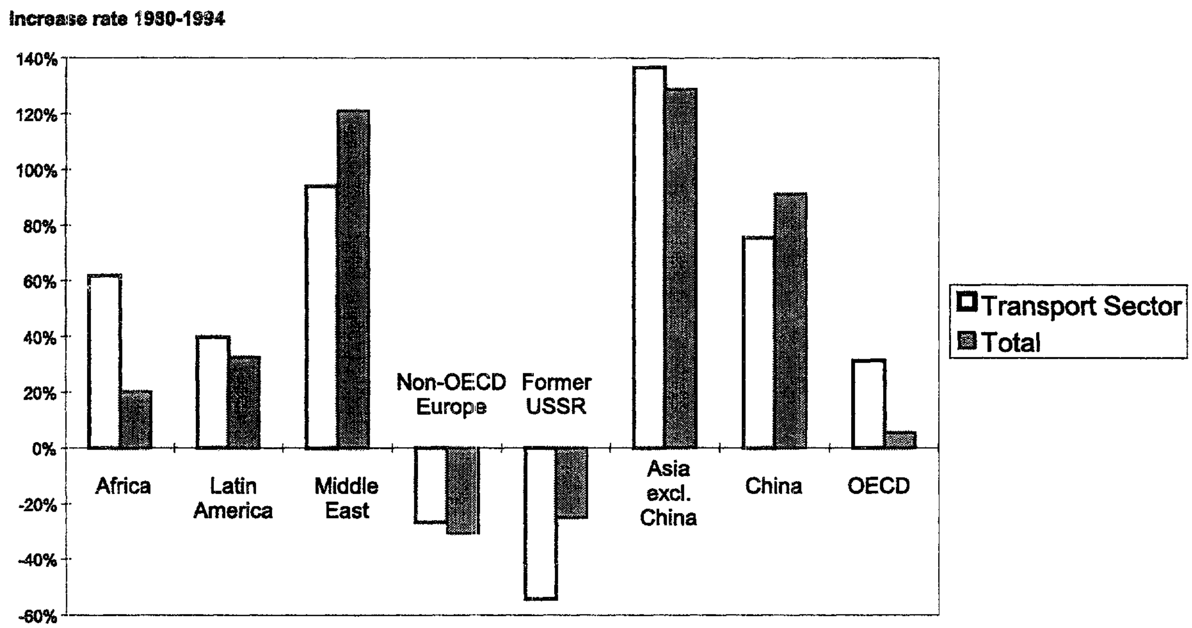


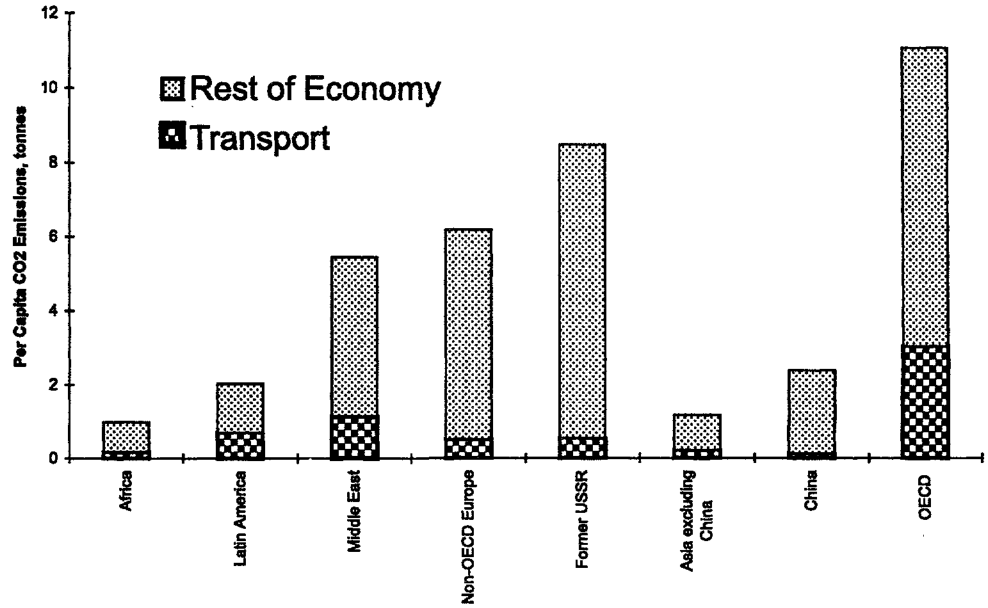
Figure 3. Growth in CO_2 emissions in transport sector and total economy from 1980 to 1994



except transportation have become less energy intensive over the past 25 years.

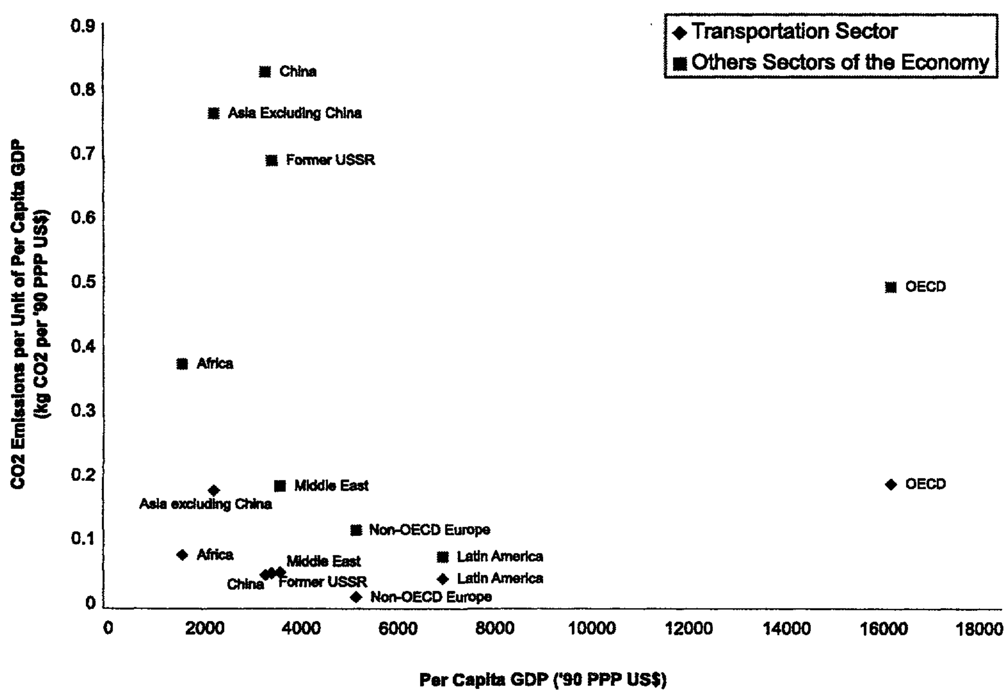
On a per capita basis, GHG emissions, as represented by CO_2, are far lower in the non-OECD than in the OECD world, as shown in Figure 4. However, relative to real gross domestic product (GDP, converted to a common currency using purchasing power parity), emissions in DCs tend to be higher, in cross section, than in developed countries (Figure 5). Clearly, if OECD countries begin to

Figure 4. CO_2 per capita, 1994



restrain their emissions, while developing countries—whose economies are growing more rapidly than those of the OECD—do not, total emissions from the DCs will overtake those from the OECD within a fairly short time period. Politically, however, GHG mitigation in

Figure 5. CO_2 emissions per unit of GDP and GDP, 1994



DCs has a negative connotation today because it is perceived as a denial of the basic right to growth in human services and economic activities. The key to changing this perception is both to link GHG mitigation to policy initiatives in other sectors with goals that are perceived to be of far greater immediate relevance than GHG mitigation, and to try to uncouple, or at least "flex," the heretofore rigid link between economic growth and GHG emissions, as IEA countries have done outside their transportation sectors. The transportation sector provides many opportunities for the former, and many challenges for the latter.

Table 1 summarizes key trends in population, economic activity (real GDP), primary energy use, and CO_2 emissions. The latter two are based on submissions to the IEA by member countries and other authorities, with emissions from energy tabulated according to IPCC practice.

The challenges from the transport sector are hinted at in Figure 6, which shows the relationship between per capita GDP and per capita CO_2 emissions from transportation for various world regions. Unlike those from stationary uses of fuel, emissions from transportation grew strongly, pausing in all but a few countries only briefly after each of the two oil shocks of the 1970s. This coupling is in part a reflection of the constancy of emissions per unit of energy for transportation, which is almost entirely based on oil products with little variation in CO_2 emitted per unit of energy contained.

Figure 5 showed emissions from transport and from other sectors in cross section. What is striking from these two figures is how the emissions per unit of real GDP fall as income increases for non-transport sectors, but seem to remain constant for transport. We shall refer constantly to this apparent constant or inflexible link.

The goal of CO_2 mitigation, of course, is to "flex" this link. To do that, however, we have to

Box 1

Considering CO_2 reduction as a collective good

CO_2 emissions reduction has the characteristics of a "collective good" – that is, the benefits are transnational and are non-excludable (that is, they accrue to everyone, even to those not restraining emissions). The problem of "free-riding," therefore, is integrally bound up in the CO_2 emissions reduction problematique. With most of the present industrial-age carbon emitted by the wealthy countries, the rest of the world does not feel an obligation to moderate this burden. Ironically, the consequence, in terms of climate change, might hurt the agriculturally oriented developing economies of the South more than the industrial economies of the North.

Determining how emissions can be reduced or restrained in all economies through techniques and policies that are low in cost to the growing economies is a necessary component of any CO_2 reduction strategy. In doing so, however, developing economies may find that through the larger process of economic reform and growth, their economies become far less energy-intensive (in terms of energy use per unit of activity) than today. Similarly, through structural reforms in particularly energy-intensive sectors, such as electricity, industry, and transport, these economies might reduce energy- and carbon-intensity. In short, they may find unique development paths that lead to overall less energy- and carbon-intensive development patterns, at a given level of real income, than is (or was) the case for the older economies of the North, which developed when carbon emissions were not a concern.[1]

Ironically, gradual but large success in restraining carbon emissions in northern countries could lead to somewhat lower prices for fossil fuels than otherwise because of the restraint in world-wide demand growth that would follow. All else equal, this would stimulate demand for the same fuels in DCs. At the same time, improvements in energy efficiency forged by the North as part of its restraint strategy would be available to the South for free. While we do not argue here that lack of world agreements on a global strategy to restrain emissions means actions must halt, it must be acknowledged that the picture of participation is complicated.

Table 1. Key trends in population, economic activity and CO_2 emissions, 1971 and 1994, except China: 1980 and 1994

	Year	*Population* (*Millions*)	*Per Capita GDP* (*90 PPP US$*)	*Primary Energy Supply* (*Mtoe*)	*CO_2 Emissions* (*Mt of CO2*)	*Per capita CO_2 Emissions* (*kg CO2 per capita*) *Total*	*Transport*	*CO_2 Emissions per Unit of GDP* (*kg CO2 per Unit of GDP (90 PPP US$)*) *Total*	*Transport*
Africa	1971	370	1560	76	251	*677*	157	0.43	0.10
	1994	694	1526	221	684	*984*	164	0.65	0.11
Latin America	1971	235	5043	143	391	*1,665*	511	0.33	0.10
	1994	379	6917	308	770	*2,029*	710	0.29	0.10
Middle East	1971	67	4370	54	147	*2,195*	377	0.50	0.09
	1994	151	3548	297	823	*5,435*	1,136	1.53	0.32
Non-OECD	1971	89	4762	178	606	*6,785*	737	1.43	0.15
Europe	1994	103	5128	202	638	*6,168*	510	1.20	0.10
Former USSR	1971	245	4891	768	2,433	*9,909*	1,065	2.03	0.22
	1994	294	3373	936	2,488	*8,450*	545	2.51	0.16
Asia ex China	1971	1095	977	171	551	*503*	105	0.52	0.11
	1994	1772	2181	709	2,050	*1,156*	216	0.53	0.10
China	1980	981	1755	413	1,481	*1,510*	84	0.86	0.05
	1994	1190	3247	791	2,835	*2,380*	122	0.73	0.04
OECD	1971	813	10644	3,249	9,116	*11,211*	2,245	1.05	0.21
	1994	992	16148	4,521	10,968	*11,046*	3,036	0.68	0.19

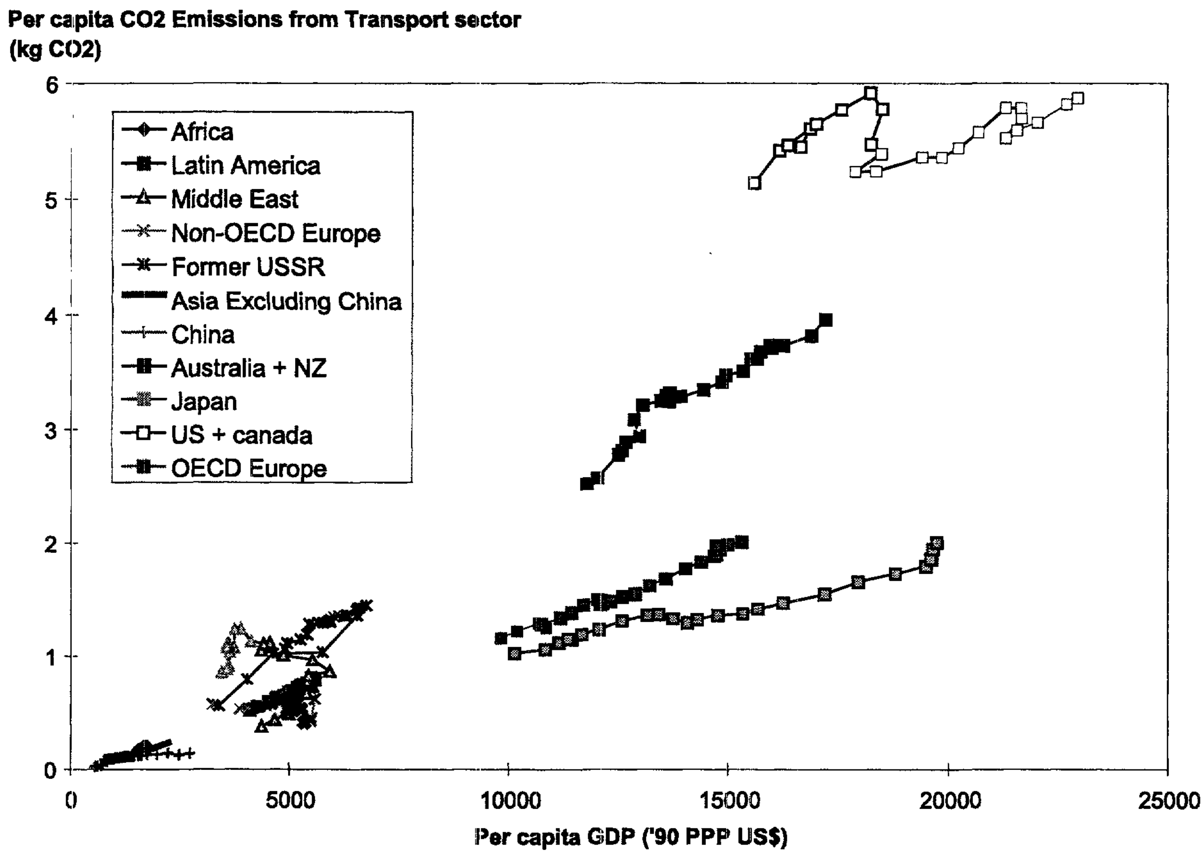
Source: International Energy Agency, Energy Balances of Member Countries, Energy Balances of Non-Member Countries, and IEA Secretariat calculations.

understand the apparent inflexibility. We do this by examining more closely some countries of the IEA, for which data allow finer analysis.

Trends in carbon emissions from energy use in IEA countries[2]

Schipper and others (1997) reviewed trends in emissions from energy end-uses in nearly a dozen IEA countries. The analysis indicates that the predominant reasons for the decline in emissions, relative to GDP, were lower energy intensities, that is, the amount of energy used per unit of activity. In the IEA, these lower intensities were particularly apparent for manufacturing (branch by branch, lower energy input to either material or per-sub-sector GDP), space heating in homes and other buildings (energy per square meter of space-heated), electric appliances, and for some countries, the

Figure 6. Per capita GDP and per capita CO_2 emissions from transportation, 1971–1995



freight sector (energy per ton-kilometer of goods moved). Only in the United States and Canada did energy intensities for travel—energy per passenger kilometer—fall significantly.

Structural changes within sectors—that is, changes in the underlying composition of activity within the sector—also contributed to some reductions emissions in some sectors for certain countries; for example, changes within the manufacturing sectors of West Germany, the United States, or Japan, or the overall decline of manufacturing in the United Kingdom, led to some restraint in GHG emissions. However, structural changes equally enhanced emissions in some sectors in many countries, notably the residential and buildings sectors (more space and more appliances per occupant), and the travel sector (more cars per person, and more car usage relative to other modes).

Overall, the intensity declines in IEA countries were quantitatively more important than the structure changes when all sectors are taken together; consequently, emissions per unit of GDP fell. Changes in the mix of raw fuels used to produce energy in IEA countries acted to reduce CO_2 emissions in some countries, particularly where coal and oil yielded to natural gas. In other countries, however, where coal-based electricity increased its share in final energy use, fuel mix changes actually increased CO_2 emissions. In the electricity sector itself, increased use of hydro, nuclear, natural gas, and renewables in a few cases, and overall improvements in generation efficiency reduced the emissions associated with a kWh of electricity used in every economy.

Figure 7 taken from a recent IEA book (Indicators of Energy Use and Efficiency), shows the 1973 and 1994 profiles by end-use of per capita carbon emissions in five IEA countries, each related to GDP. The reduction in the carbon intensity of most parts of the economy is clear. Equally clear is the lack of large reduction from transportation. The transportation share of emissions in most developing regions increased over this period, and the decline in the ratio of emissions to GDP was smaller than in the IEA countries depicted in Figure 7. This differential was largely because energy intensities outside of the IEA countries fell less than in the IEA countries and because structural changes boosted energy uses more in the non-IEA countries. The one common element of increase is transport.

Within the IEA countries studied, carbon emissions per capita between 1973 and 1994/5 for both travel and freight rose as a share of total emissions everywhere, and in absolute terms everywhere except the United States and Canada. The primary driver of this growth in relative and absolute emissions level was a growth in the overall level of travel and freight activity in each country, in turn driven by higher incomes. This coupling between transportation activity and income is not necessarily one to one, but the momentum of growth is strong. In addition, the mix of modes shifted towards cars (or household light trucks) and air for travel and to trucks for freight. All else equal, this shift also raised energy use and emissions because the aforementioned modes require more energy

Figure 7. Total carbon emissions per capita by major end use

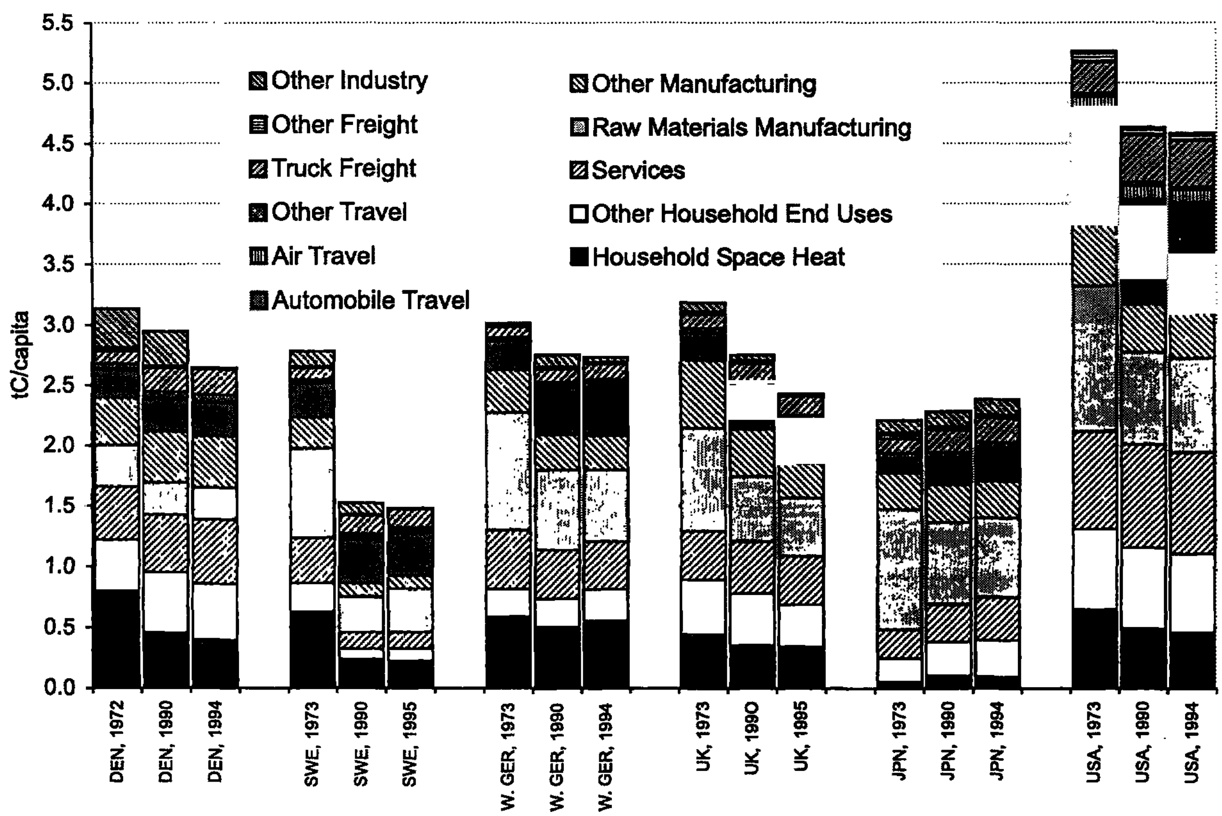


Figure 8. Per capita GDP and per capita carbon emissions from travel sector in some IEA countries, 1970-1994

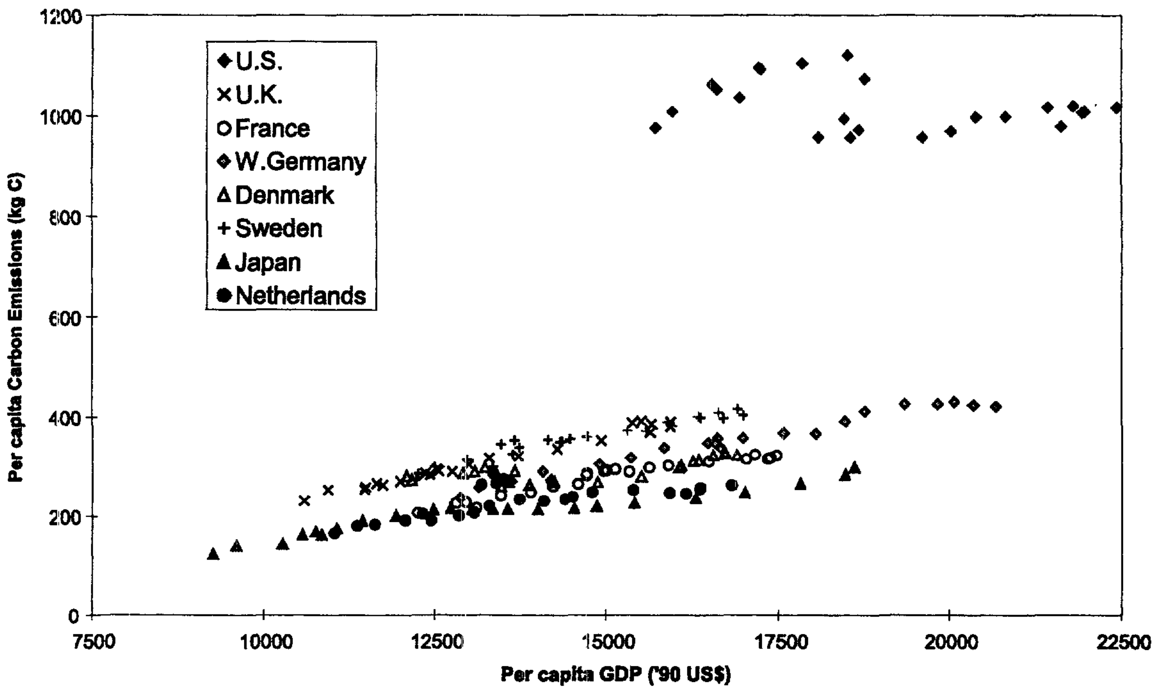


Figure 9. Per capita GDP and per capita carbon emissions from freight transport in some IEA countries, 1970-1994

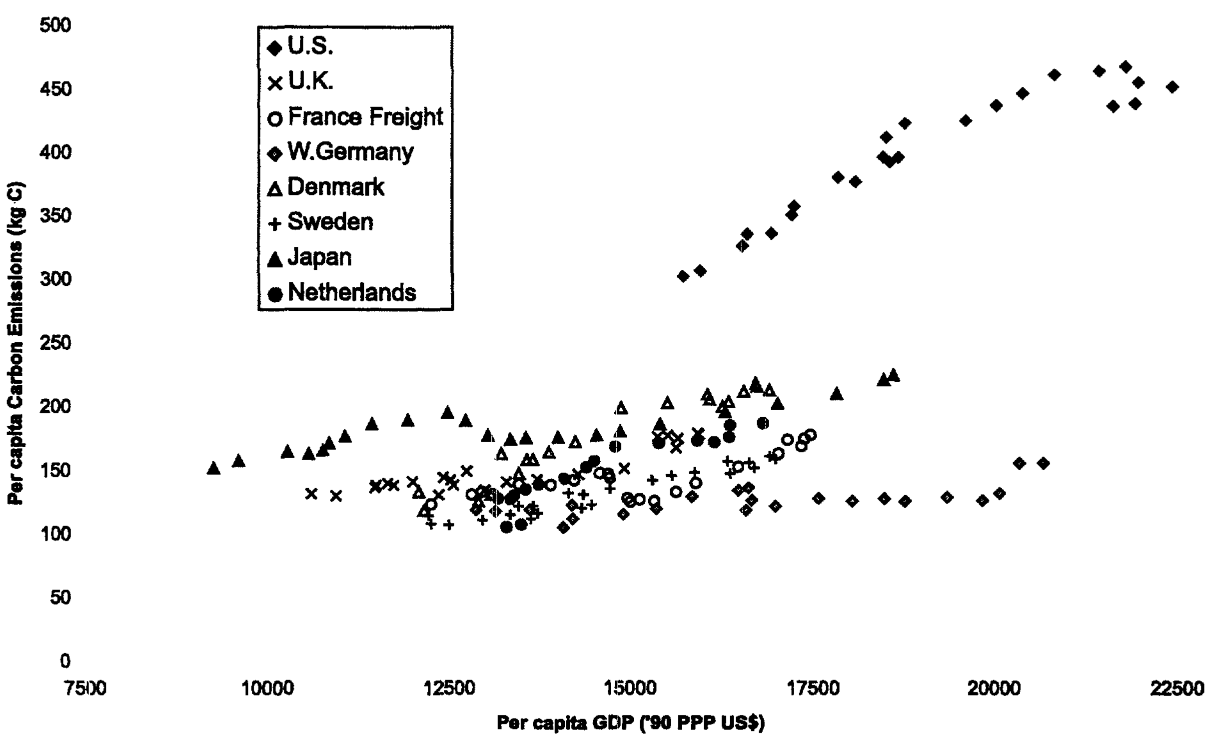
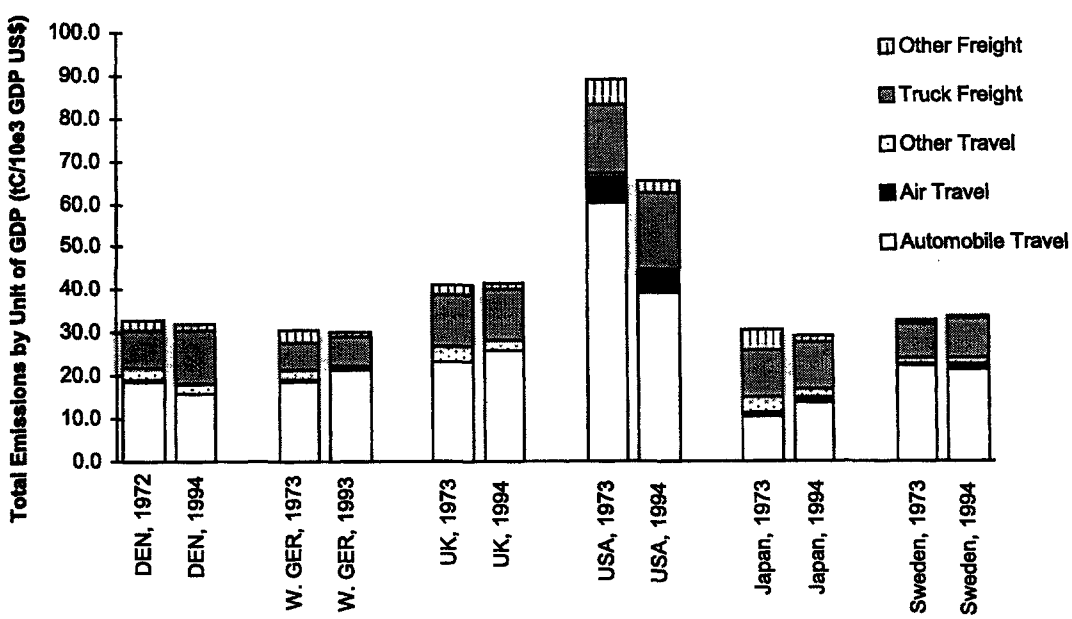


Figure 10. Breakdown of transport emissions per unit of GDP, 1973 and 1993/94



(and release more carbon) per passenger or ton-kilometer. Finally, while there were some reductions in specific intensities in many countries—for trucking and air travel in most countries and for car travel only the United States and Canada—these intensity reductions were too weak to reduce, and could therefore only restrain, the emissions caused by activity growth and structural shifts. When all these changes are counted, per capita emissions from freight are higher in every country in the 1990s than in the 1970s, and per capita emissions are rising everywhere, as shown in Figures 8 and 9.

The above analysis expresses in words a more detailed analysis conducted by Lawrence Berkeley National Laboratory, using an index decomposition of the multiplicative factors underlying changes in CO_2 emissions from both freight and travel. (Schipper, Steiner, Duerr, An, and Stroem 1992; Schipper and others 1996; Scholl, Schipper and Kiang 1996; Schipper, Scholl and Price 1997) This decomposition framework is useful not only for analyzing past changes in emissions but also for confronting possibilities for the future.[3] It forms the basis of our proposed analytical methodology for the Bank and, for that reason,

Table 2a. Changes in carbon emissions from travel, 1973-1995, Laspeyres Decomposition, 1990 Modal Structure, 1973=100

Countries	*US (95)*	*Japan (95)*	*Australia (95)*	*W. Germ. (93)*	*Sweden (95)*
Emissions 95/73	119	226	174	158	136
Activity effect	148	189	190	150	124
Structure effect	101	125	161	104	101
Intensity effect	78	97	93	100	110
Fuel mix effect	100	101	99	99	99

Table 2b. Changes in carbon emissions from freight, 1973-1994, Laspeyres Decomposition, 1990 Modal Structure

Countries	*US (95)*	*Japan (95)*	*Australia (95)*	*W. Germ. (93)*	*Sweden (95)*
Emissions 95/73	163	157	172	113	105
Activity effect	162	137	166	138	106
Structure effect	124	140	116	113	104
Intensity effect	89	85	61	88	95
Fuel mix effect	101	105	103	99	100

we explore it in some detail here. The principal components of overall transport-sector emissions are taken to be Activity (in ton- or passenger-kilometers), modal Structure (that is, share of ton- or passenger-kilometers occurring on each mode.), the modal energy Intensity of each mode (in energy burned per ton- or passenger -km) and the Fuel-to-carbon ratio (carbon released per unit of energy burned). We refer to this decompositional approach throughout this paper as the ASIF methodology. A more technical exposition is presented in Box 2. Tables 2a and 2b summarize the results for a number of IEA countries and country groupings for the years 1973-1995 (1994 for Europe).

It is important to remember that the numbers in this table represent indexed 1995 (or 1993) values, relative to 1973 levels. For example, Americans experienced a 19 percent increase in emissions. Total travel increased emissions by 48 percent, and shifts towards cars and air travel multiplied this by an additional 1 percent. Changes in modal intensities (cars and air travel) lowered emissions 22 percent, while the fuel mix changed emissions very little. The base-year mode mix was 1990,[4] by which time air and auto travel had nearly the same energy intensities,[5] with bus not far behind. As a result, the shift from bus or rail to cars and air, and from cars to air, had very little impact. In Japan, by contrast, the shifts towards autos and air had a 25 percent upward impact on emissions, multiplying an 89 percent increase from travel alone. Since intensity and fuel mix had almost no effect, the result was a huge increase in emissions (+126 percent!). As can be seen, European Countries (represented by Sweden and W. Germany) behaved in an intermediate way, while Australia showed a larger growth in total travel (on cars and air) than Europe but a somewhat more important (7 percent) decline in emissions from lower intensities.

Freight patterns were different. All regions saw increased activity and shifts towards carbon-intensive trucking. With freight, however, many countries showed important declines in emissions from intensity changes (primarily trucking, which carries the greatest weight). All regions experienced greater emissions from fuel shifting to diesel, because diesel holds more carbon per unit of energy released.

The same framework can be used for comparing reference case with reform cases as set out in the Global Overlays Guidelines, because the elements of ASIF that policy-makers want to affect are more or less the same. A planner must decide which levels of each component are appropriate, either by running a complex model, or by sheer judgement. By examining each of these components in turn, the policy analyst can help identify unwanted consequences from a given policy strategy. He or she can also help identify more clearly what aspects of a given country's transport energy system are not well enough understood.

Box 2

Decomposition of changes in CO_2 emissions from travel or freight[6]

Consider that

$$G = A * S_i * I_i * F_{ij} \quad (1)$$

where G is the carbon emissions from the particular transport sector, A is total travel or freight activity (in passenger- or ton-kilometers), S is a vector of the modal shares, and I is the modal energy intensity of each mode *i*. The last term, F_{ij} represents the sum of each of the fuels *j* in mode *i*, using standard IPCC coefficients to convert fuel (or electricity) used into carbon emissions. Each of these terms responds—at different rates—to different underlying forces (incomes, prices, policies, new technologies, and so forth).

The modal energy intensity term itself is composed of several components:

$$I_j = E_i * C_i * U_i \quad (2)$$

where E_i is the technical efficiency of mode *i* (the energy consumed per vehicle kilometer),[7] Ci is the vector of vehicle characteristics for mode *i*, and U_i is the inverse of capacity utilization for each mode *i*. $E_i * C_I$ is the energy use per vehicle-km and is called vehicle fuel intensity.

Technical efficiency is the energy required to propel a vehicle of a given set of characteristics a given distance, and is affected by the motor, drive train, frictional terms (including drag), and so forth. For cars, characteristics could be represented by vehicle power (or gross weight), and technical efficiency by energy use/km/unit of power (or gross weight). Capacity utilization would be measured by people/vehicle, tons per vehicle, or as a dimensionless ratio of actual load (in people or tons) to potential load for every km a vehicle moves.

All three of these components share in determining how much energy is used to transport a person or one ton one kilometer by each mode. Fuel choice affects efficiency because some fuels, particularly diesel, are burnt more efficiently in their respective engines than others. Thus some terms in this decomposition that are nominally "technical"—energy intensities—actually have important behavioral components. Since all components of intensity are affected by policies, technology, and behavior, all must be considered as elements of a future GHG restraint strategy.

The components of emissions are not independent of each other. Total travel **A** depends on speed, so naturally a greater share of auto or air travel in S is associated with greater travel. Both **A** and some components of I (larger cars, lower load factors) increase with incomes, and, to the extent that increases in **A** also cause increased congestion, **A** can also directly affect I. Some fuels are associated principally with certain modes—for example, buses use almost exclusively diesel fuels now, as do almost all heavy trucks—so there is strong interaction between S and I. Finally, I and F determine the marginal fuel costs of using vehicles. To the extent I falls or F shifts towards lower-cost fuels, transportation variable costs could fall and transport demand could increase. In practice, it may not always be possible to quantify these interactions, but it is important to be aware of them.

The relationships illustrated by Equations 1 and 2 can be used to study changes in energy use or emissions over time, and the results expressed as indices marking the changes in each component. Numerous indexing techniques are available, including Laspeyres or Adapted Weighted Divisia (AWD). (See Greene and Fan 1992 or Greening, Davis, Schipper, and Khrushch 1997 for more discussion.)

Endnotes

1. Note, however, that the northern economies "developed" when energy was far more expensive—in terms of real, internalized costs—than it is today. Before the first oil crisis, real fuel and electricity prices had fallen for the entire period since World War II, which certainly aided their development. Energy prices are not necessarily a brake on economic growth.
2. Together with LBNL, the IEA has now studied the transportation patterns, fuel use, and CO_2 emissions from fourteen member countries: US, Japan, Canada, New Zealand, and Australia in the Asia Pacific region; Denmark,

Finland, France, W. Germany, Italy, the Netherlands, Norway, Sweden, and the United Kingdom in Europe.

3. Index decomposition is a useful technique for studying the influence of underlying multiplicative factors on a variable of policy interest. Indeed, a recent US National Academy of Sciences Workshop considered the same methodology applied to population, water use, and other important quantitative measures of resource use or pollution: "Workshop on the Decomposition of Complex Issues in Sustainable Development" Board on Sustainable Development, US National Research Council, US NAS, Washington DC (Feb. 27/28 1997).
4. That is, the modal shares as of 1990 were used to project emissions both in 1973 and 1990.
5. These energy intensities, however, are based on observed passenger occupancies. The potential energy intensities of the two modes are still quite different.
6. This summary is taken from Schipper and others (1997).
7. More specifically, it is the utilization-weighted average of the technical efficiencies of the different types of vehicles used in mode *i*.

2 Challenges Facing GHG Restraint in Transportation

Driving factors

This section examines attempts and causes for historical restraints of transport use, primarily in IEA countries. Efforts to restrain transport fuel use per se were weak and largely limited to the effects of higher oil prices (or economic stagnation) brought on by the oil crises. Empirical evidence suggests that with GDP rising, the only way to achieve a decline in CO_2 emissions is a combination of transportation policy reforms in the near term, technological changes in the longer term, and consumer/ shipper responses to both forces. What is required is a more integrated transport/ pollution & GHG reduction strategy that attacks a broad front of transportation externalities.

Changes in the amount people (and goods) travel are the dominant cause of rising emissions. Technical factors (vehicle and modal energy intensities) led to some restraint of emissions in a few cases for cars and trucks but only gave net reduction in per capita emissions (for travel) in two major countries. Behavior and system optimization factors (that is, modal choices and utilization), as well as increases in activity coupled to GDP, boosted overall emissions.

These developments are intimately related to the nature of transportation—comfort, convenience, speed. Distance as well as modal choice is related to individual and societal choices about housing, work and leisure location. The same is true for freight. 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. 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. Nevertheless, most national transport plans still foresee increases in personal and goods transportation with GDP without policy intervention.

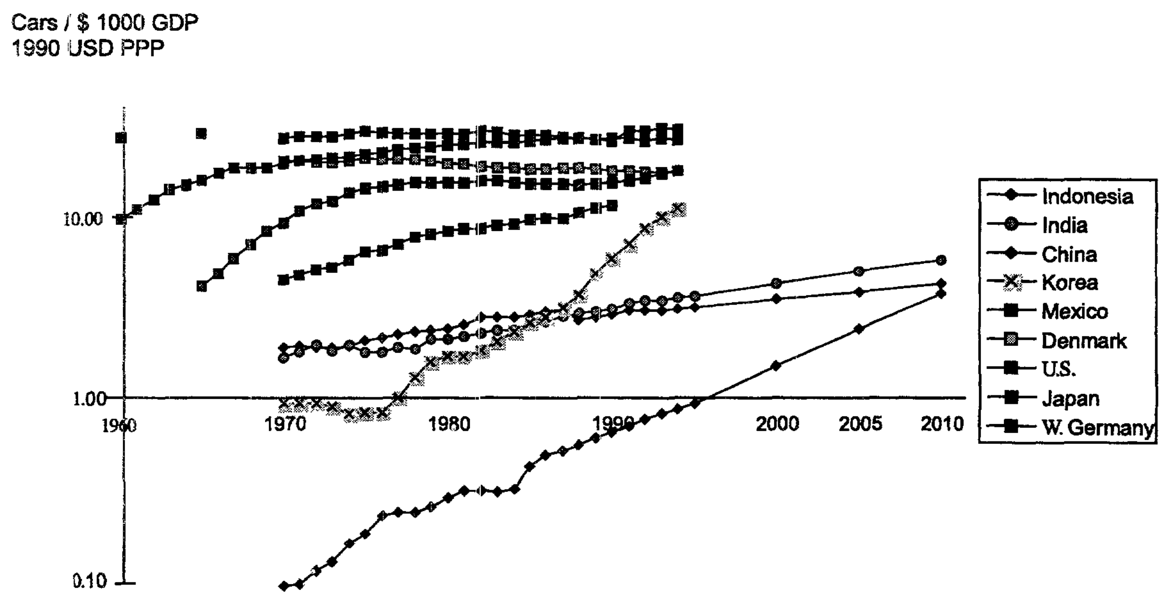
It is significant that emissions from freight, in contrast to those from travel, show restraint from lower energy intensities in roughly half of the countries studied. We speculate that this may be because structural effects on freight demand are more intense and also because freight services, unlike private transport consumption, respond to business needs and competition. Although the importance of fuel costs to total freight costs, or to the total costs of products delivered is small, there is clearly always room for saving fuel at the margin, subject to the constraints imposed by costs for equipment, labor, and maintenance.

The same is true for air travel, which showed uniform and deep reductions (50-60 percent) in fuel use or emissions per passenger-km in all countries from both improved technology and higher load factors. In this case, however, fuel accounted for as much as 20 percent of operating costs and even in 1997 remains a source of cost pressure to airlines. Thus the distinction between enterprises and private use may be important for explaining differences in the evolution of fuel intensities and CO_2 emissions from these different branches of transportation. This has implications for expected results of policies in developing countries: fuel taxes and other instruments applied to the transport sector will have different impacts according to the sector.

The analysis shown in Annex 1 applies only to some IEA countries. For developing countries, motorization is much lower. Of course, DC incomes are lower. As Figure 11 shows, however, car ownership in a variety of developing countries (and EIT countries) appears to be following in the path defined by that of the IEA countries depicted in Figure 8 (see also Dargay and Gately 1997). Indeed, the logarithmic scale in Figure 11 compresses entirely the gap in car ownership at a given income between the United States and Japan or Denmark. This emphasizes the important possibilities for growth in the population of cars in the developing world by more than an order of magnitude over the next thirty years, during which many of these countries will achieve per capita incomes associated with at least 200 cars/capita in IEA countries. Indeed, Figure 11 also depicts projections made by the IEA of car ownership in China, India, and Indonesia, assuming only continued economic growth at slightly below recent rates but a ratio of car ownership to GDP that rises to the present ratio for South Korea.

Whatever the actual number, we expect these basic factors driving transportation activity to grow, with the corresponding increase in GHG emissions. Indeed, in some Economies In Transition, car ownership picked up even during the years of economic decline, as illustrated by Poland (Meyers and others 1994) and Estonia (Martinot and others 1995). This means we must at least assume at the outside that transportation emissions represented an even stronger force for growth outside of the IEA than they do in the IEA. But is this bleak outlook inevitable? Will the trends suggested by Figure 11 be broken? We review the possibilities in the context of development, transportation reform, and Bank strategies in the remainder of this paper.

Figure 11. Car ownership and GDP



Facing carbon emissions from transport

The couplings between emissions from travel or freight and GDP illustrated by Figures 8 and 9 are daunting. In IEA countries, fuel prices have proven to have limited impact on the strength of this correlation. For the freight sector, part of the reason for this limited impact is undoubtedly due to the relatively low amount of input—in monetary terms—of freight energy into the overall costs of production. For the travel sector, changes in urban form and distributions of populations in metropolitan areas are also an important contributor to the inflexibility of this link. In short, fuel prices may need to rise significantly higher than populations and governments have a tolerance for in order for prices alone to begin to influence CO_2 emissions. Consequently, a CO_2 policy that is oriented to the transport sector will need to focus on transportation policy reforms in the short-run, technological changes in the medium term, industrial and urban planning measures in the long-term, and consumers' and producers' responses to all of these. Pricing, where politically feasible, should be used to support these other efforts.

The findings of Pearce and others (1996) support such a broad-based CO_2 strategy, based on finding linkages with other policy objectives in the transport sector:

> *CO_2 and fuel use represent a small influence on overall transport patterns, except during the fuel crisis years 1973-1985, when the fuel intensities of vehicles fell and concerns over fuel prices affected vehicle use and transport planning as well. Some of that decline in vehicle intensities persisted into the early 1990s, but emissions are rising because transport activity is rising. Since another key transport trend, modal mix, acted almost universally to raise emissions this means that the main technological ways of reducing emissions, by changing fuels or making vehicles less fuel intensive, have to be accentuated in strategies that focus closely on carbon per se. Other strategies aimed at GHG reduction in the transport sector should be set in the context of developments in the transport sector, and emissions possibilities both linked to wider transport reform (such as changes in regulations, fees and pricing, emissions standards, and so forth) as well as to emissions specific strategies related to fuels, fuel efficiency, vehicle type, and vehicle use.*

CO_2 policy in transport, therefore, must be flexible, broad-based, and synergy-seeking.

Other important lessons can be drawn from IEA experience. First, carbon emissions themselves have no natural limiting feedback mechanisms as long as the prices for fuels or the costs per km of using fuels remain roughly constant. By contrast, other changes in transport conditions or prices—safety, congestion, tolls, parking costs, vehicle acquisition, yearly registration, or use costs, and so forth—represent potentially important sources of feedback on the volume of transportation or to authorities who control policies and technologies.

Second, and suggested somewhat by the above considerations, stand-alone transportation strategies which seek to reduce CO_2 are probably less politically and socially feasible than those which can be coupled with other transport policy goals, such as congestion or noise reduction, or local air quality improvement. Local authorities, for example, might be more successful enacting policies encouraging shifts to public transport as part of a congestion-reduction, rather than a CO_2-reduction, package. CO_2 reduction as a strategy needs to find synergies with other, more locally pressing, policy needs.

Synergies, such as the modal shift example above, frequently exist in the transport sector, but they do not always. Some policies designed to improve local air quality, for example, may increase greenhouse gas emissions from cars. Oxidation catalysts, for example, reduce the amount of carbon monoxide and volatile organic compounds released into the atmosphere, but at the cost of increased NOx, which is both itself a greenhouse gas and a carbon dioxide precursor. Three-way catalysts, which also remove NOx, do so at the cost of reduced engine efficiency, resulting in an increase in CO_2 emissions per vehicle kilometer. Some policies may also backfire on themselves. For example, a policy to improve local air quality (and reduce CO_2 emissions) by allowing traffic to move at free-flow speeds—through, say, traffic management schemes or even roadway capacity enhancement—may induce more traffic (Downs 1993) than might otherwise have occurred. The CO_2 and local pollutant emissions from the increased overall activity including the newly induced traffic may be more significant than the intensity reductions caused by the new free-flow traffic conditions.

The third lesson from the IEA experience is that the apparent rigidity of many of the curves shown in the preceding section contains both a warning and several points of optimism, particularly for countries with presently low levels of motorization. The warning is, as has been noted above, that the demand for transportation services grows strongly with incomes, particularly in high-income countries. This is because transportation is a derived demand; it is derived from the demand for accessibility to goods and services (Gorham 1996). This demand for goods and services itself grows with income, and the nature of the accessibility undergoes a structural shift, as populations relocate from relatively dense, urban centers to outlying areas (ECMT 1998b).

The potential points for optimism stem from the fact that the observed periods of high fuel prices and national concern over fuel saving were rather short, and hardly allowed analysts to test either policies or technologies. There may indeed be many options for significant GHG restraint still available. Certainly, the literature is replete with possibilities for both greatly improving fuel efficiencies and introducing new fuel systems that are intrinsically lower in carbon (Sperling 1994; IPCC 1996; IEA 1997b; NAS 1997; Peake 1997). That few of these have come to market may be a function of the lack of economic demand (that is, low fuel prices) and the lack of time to see developments from the 1990s come to fruition. Recent announcements by Peugeot of their entry into the electric scooter market, acquisition by Daimler Benz of an important interest in Ballard, which makes fuel cells, and other developments are serious reason to believe technologies may be there soon. And the seriousness of some European country transport reform packages now on the market (Peake and Schipper [IEA 1997a]) suggests that in some countries, transport pricing and regulatory reform may be acceptable to a wide enough spectrum of governments to permit them to truly stimulate technological development. There is a very real possibility that policy, behavior, technology, and possibly even lifestyles could change in ways that truly de-couple growth in emissions from growth in incomes for a long enough period to allow truly low-CO_2 vehicles and fuels to be developed. On this more optimistic note, therefore, we turn to elements of a CO_2 reduction policy agenda in general, and specific actions for the World Bank.

Previous oil-saving and transport pollution control programs

Until 1973, the only concern limiting use of oil in developing countries was paying for imports. After the price of imports skyrocketed and supplies were thought to be insecure, worries about oil use multiplied, but few developing countries took concerted action to restrain imports. Important exceptions were Brazil, with its alcohol program, and Korea and Taiwan, which tried to develop integrated energy policies with an eye to reducing dependence on imported oil. Korea and Taiwan in particular took measures to limit urban air pollution from cars and even promote somewhat more efficient vehicles, but these were exceptions in the developing world. By the 1990s, many of these concerns faded and fuel prices for some products were often below market levels. Not surprisingly, vehicle ownership (as represented by figure 11 for cars) and transportation oil use increased with economic activity.

Urban air problems increased with greater use of motor vehicles, however. The World Bank has been involved in the study and promulgation of some air pollution control programs. These include promotion of the use of unleaded fuels and stricter air pollution controls in cities like Mexico City (Eskeland 1994). None of these programs had as its main purpose improvement of fuel economy of vehicles, reduction of fuel use, or restraint of CO_2 emissions. In fact, the first generation of controls on U.S. cars probably led to a slight increase in fuel consumption per km, although that effect disappeared as technology improved. Most transport pollution control measures are only weakly linked to GHG reduction technologies or strategies because they do not reduce fuel use explicitly through either technology or pricing and only tend to reduce vehicle use slightly. Indeed, Eskeland shows how the policy in Mexico City "Hoy no circulan" prohibiting use of a given car on one day (depending on the last digit of the license number) led to acquisition of extra vehicles and increased gasoline use (Eskeland and Feyzioglu 1995). Ironically, it is possible that some transport control measures aimed at reducing congestion also increase total traffic by their success. Keeping vehicles from penetrating the town center as a congestion control strategy might cause some vehicles to take longer routes to their destinations, for example. Similarly, without other compensating measures, unpriced congestion reduction amounts to an increase in roadway capacity, which Downs (1993) shows will lead to an overall increase in traffic using the facility, all else equal. In short, the overall coupling between transport control pollution programs has been weak or negative.

Only recently have analysts begun to tie pollution control and CO_2 together. In many cases, there are small but important synergies between CO_2 reduction and air pollution control strategies that either lead to reduced traffic or lead to improved operating efficiency of vehicles (although the danger pointed out in the previous section that these two strategies may work at countervailing efforts should be borne in mind). Eskeland and Devarajan (1996) argue that if a pollution control strategy uses both pricing/taxation and regulations, a balance could be obtained that both reduces use of vehicles and cleans them up, leading to lower total GHG emissions than if only a clean-up is ordered but no taxes or other fees are applied to raise the cost of using "unclean" vehicles. Pollution control per se can in a few cases raise GHG emissions. For example, switching to Liquefied Petroleum Gas (LPG) vehicles, which consume more fuel per km than gasoline or diesel vehicles; or switching to Compressed Natural Gas vehicles, the fuel delivery system for which is susceptible to methane leaks, probably raises slightly GHG emissions, all else being equal. The extent to which such increases are tolerated depends on the primary policy goal, and the nature of the alternatives. A small increase in GHG may be a reasonable price to pay for a big increase in local air quality.

3 Approach — Tools and Methods: How We Hook Solutions to Problems

This section introduces ways of quantifying transport flows, energy use, and resulting emissions to identify solutions. It also discusses briefly the policy landscape. Ways of actually reducing carbon emissions—so-called "best practices"—need tools for evaluation. Finally an economic framework is needed to begin to evaluate costs and benefits and, more important, to estimate the changes in transport trends that new policies and technologies might bring about.

Flexing the link—Analytical approaches to transport trends

The analytical approach discussed here involves understanding how equations 1 and 2 from the end of chapter 1 (see Box 2) apply to the country or region of interest. Analysts should try to understand how activity (A), structure (S), intensity (I) and fuel choice (F) have varied in the past, how they are changing at present, what the likely influences of incomes, prices, technologies, and policies (transport, industrial, planning and other policies) affect those changes, and how these components are likely to change in the future. These are the ingredients in scenarios that will be used in the Global Overlays methodology.

Small changes in all of these over present values could multiply to give a large overall change in emissions. More specifically, shifts in S, combined with a significant decline in I and shifts in F towards less carbon-intensive fuels, combined with restraint in the likely growth in A, could hold carbon emissions down to little or even no growth.

Of particular importance are past and anticipated future rates of change of each of these components. Analysts should think about the speed with which each of these components change, and the kinds of policies likely to influence that rate of change. This is particularly important in developing countries, where growth in the vehicle stock is far more important than turnover as a source of new vehicles entering the vehicle stock.

A varies at a rate determined largely by income, but during periods of rapid acquisition of cars (for example, W. Germany in the 1960s), A can grow faster than incomes, propelled principally by car ownership. In many eastern European countries during this decade, in fact, car ownership expanded rapidly, even while incomes stagnated or even declined. During periods of rapid motorization, S also naturally shifts rapidly towards cars but can shift by several percentage points back to collective transport during periods of higher fuel prices, doubts about fuel availability, or other constraining factors. The French press, for example, reported about 20 percent more riders on Paris commuter lines on 1 October 1997, when a pollution alert led the government to put into effect an odd/even restriction on driving in Paris.

The various components of I can change at different ways. The stock of cars takes nearly 20 years to be completely replaced, while that for heavy trucks and buses can take longer, and aircraft last typically more then 30 years. Safety or emissions regulations can accelerate stock turnover by making it expensive, difficult, or illegal to use highly polluting, unsafe, or older vehicles that generally have higher fuel consumption per kilometer than newer ones. Sudden fuel-price shocks also can speed this turnover. Changes in transport infrastructure also affect I both in terms of how well facilities are maintained (physical deterioration of road and rail surfaces are generally associated with a loss of vehicle fuel efficiency) and in terms of the growth in traffic competing to use given facilities at particular levels of infrastructure deployment. For aircraft acquisition, where fuel costs play a large role in choices, this effect is strong and even feeds back on producers to improve their technologies. With few exceptions, F cannot change more rapidly than the stock of cars can change.

A and S are affected by incomes, by the material content of the economy and distances goods travel between primary material gathering (or importing), assembly, wholesale and retail sites, and ultimate markets. Personal travel depends in part on distances between work, home, leisure, and services. All of these distances depend on the spatial distribution of each kind of destination, which in turn is influenced by the speed and cost of transportation as well as land, and structures. Put simply, in low income societies with little motorized travel and unsophisticated freight systems, or societies where congestion or other factors makes movement of people or goods expensive or slow, things are close together or individual radii of action (and market sizes) are small. Where travel is cheap or rapid, markets cover much wider areas, and so do people. All of these dimensions are expanded by higher incomes.

The World Bank promotes increases in **A** by financing urban transport systems, roads, rail systems, ports, and airports. This even includes bikeways (Lima, Peru Transport Rehabilitation). To the extent that the facilities and modes are priced correctly, modal mix and total travel will be "correct" in an environmental economics framework. But it is very important to see if this is the case. If there are large subsidies, do these essentially promote travel and a kind of sprawl (Budapest system)? If automobile use is underpriced, either because fuel taxes or other revenue do not really cover road building and maintenance costs, or because there are significant externalities ignored, financing of other modes may be a losing cause unless the client government agrees to deal directly with automobile use.

Geographical distribution of transport activity has an important impact on travel and freight. How much of **A** and **S** occurs in cities, suburbs, or between cities? How much traffic is between cities or otherwise distant locations because of the intrinsic location of certain resources? This will affect valuation of different kinds of externalities as well as the kinds of solutions that can be imposed or grown from technology. Danish and Swedish studies try to estimate some of the externalities split this way. If most of the activity and resulting emissions arise near or in cities, then transport policy approaches may have a big impact on CO_2. If most CO_2 is emitted in intercity traffic, where congestion, pollution, and noise are arguably less significant, then there is less pressure to impose changes for these problems that would also reduce CO_2 in many modes. The only exception is where roads are badly damaged or there are other externalities proportional to road-use that require attention. Here imposing road-user fees could have an important effect on traffic.[8]

Vehicle fuel intensities (E*C) are a question of both technology and vehicle characteristics, such as weight, engine size, horsepower, vehicle loading capacity, and so forth. In most countries, new (and sometimes existing) vehicles are taxed according to these characteristics in ways that indirectly affect fuel consumption. In the United States itself, fuel consumption is affected by the Corporate Average Fuel Efficiency Standards, by which the U.S. Government assesses a fine to an individual car manufacturer by the amount its models' sales-weighted test fuel consumption sold in a given year rises above a certain value (currently about 28 MPG or 8.3 l/100 km). The Danish government has just imposed a yearly "green owner fee" on all cars in the stock purchased after mid 1997.[9] Neither the US nor Danish approach specifies technologies or affect car characteristics directly, but because smaller (that is, lighter, less powerful) cars tend to use less fuel, these kinds of policies inevitably have some effect on car characteristics and not simply on technological efficiency alone. While most of the pre-CAFE characteristics of the U.S. fleet (except fuel use per km) have returned by the 1990s because of technological improvements made by U.S. and foreign car producers, it is not clear how Denmark (or modest developing countries with neither car producers nor large car markets) will fare unless consumers begin to buy less powerful cars.

The Bank has begun to deal with vehicle intensities by assisting regions purchase new, cleaner and more energy efficient buses (Budapest Urban Transport). But as more and more of the transport activity and resulting emissions are associated with private cars and trucks (or mini-buses), the Bank has to find ways of influencing the fuel intensities of these modes. Better maintenance and better traffic control will have a small effect, but the real improvements are up to both vehicle suppliers and buyers. The Bank could influence the market by working with government entities contemplating fleet purchases (this includes buses, locomotives, trucks, and aircraft). More appropriate might be assistance with governments to negotiate with providers of vehicles to the private sector, much in the way that the International Institute for Energy Conservation worked with lighting suppliers in Bangkok to get them to agree to supply less energy intensive bulbs and tubes while eliminating the more energy intensive ones from the market. Thus the Bank has to play an active role in helping client countries face international suppliers of vehicles and other equipment, suppliers with interests other than GHG emissions reduction.

U, the capacity utilization term, converts vehicle intensities to modal intensities. It has come under scrutiny as an important policy element. In the United States, many cities and regions have reserved some lanes of traffic during rush hours for vehicles with two or three occupants (or more). Alternately, such lanes are reserved for buses, which increases effective capacity of a particular lane to move people. Some countries have introduced off-peak rail fares to boost capacity, and some cities (Washington DC) have peak and off-peak pricing on metros as well. Similarly, load factors (both the total load that can be carried and the actual utilization factor) for trucking and rail have a great impact on the modal intensity of these freight modes, much greater than the efficiencies of the vehicles themselves within a given country. Better capacity utilization reduces vehicle movement for a given amount of people or goods moved, reduces pollution, and generally improves carrier costs. Therefore, this component of emissions reduction should be scrutinized carefully.

A key to better capacity utilization is in part not to overbuild or over-extend the system. Between 1970 and 1994 the average CO_2 intensity of travel on a city bus in the United States almost doubled, largely because government aid flowed to cities to put more buses on the streets, while little was done to discourage private car use. At the same time, continued growth of distant suburbs raised the physical dependence of families on cars for day-to-day life, even if rapid rail helped establish the viability of the suburbs themselves. In financing large transport systems, the Bank should be sure that the project will be run efficiently and effectively once the infrastructure and vehicles are in place. Working with urban planners to encourage that new housing is coordinated with existing or new transit lines is another key to success here. Even a good bus or rail system will lose riders to cars if housing and jobs are not where the buses go. While planners cannot force location on housing or jobs, poor planning can isolate a potentially good transport system from key destinations and leave the system—both public and private transport—with low vehicle occupancy. For freight, it is important to ask whether regulatory policies discourage filling up vehicles or returning home with a load.

F, the carbon content of a given fuel, has not varied much in the past. The Brazilian ethanol program is one example of a relatively low CO_2 source of renewable fuels, but it is not clear whether that can be repeated elsewhere with real costs comparable to the wholesale costs of gasoline or diesel. However, the Bank could carefully consider whether local conditions, costs, labor markets, and so forth, might make a truly renewable fuel profitable in a given region or country. In any assessment of alternative fuels, it is crucial to undertake a full fuel cycle analysis of both the GHG emissions from combustion as well as those in the preparation of fuels to be sure that an alternative is truly low in overall emissions (Sperling and Deluchi 1993; Deluchi, private communication of results underway, 1997).

Flexing the link — Approaches to the policy challenge

The Bank may find that, in developing a loan or assisting with policy, it is in a position to bring various actors together to define common interests. It might serve as an impartial umpire of sorts to help all sides weigh the advantages or disadvantages of technologies and policies vis-à-vis GHG emissions. Interactions with vehicle and fuel providers, closer relations with vehicle and system users and their representatives, and feedback from local and international interest organizations might put the Bank in a central position. One step in breaking or flexing the transport CO_2—GDP link, then is to consider the divergence of interests that represent the main stakeholders in transportation.

Vehicle producers have been the principal target of policies aimed at saving fuel and reducing local/regional pollutants like CO, NOx, in the past (or particulate matter (PM) today), and reducing CO_2 tomorrow. Indeed, their incentives to make "clean" vehicles arises largely from regulation or markets induced by regulation or pricing. Fuel producers, principally the multi-national oil companies, have been drawn into the policy debate principally to provoke improvements in gasoline and diesel fuels (Peake 1997), but in some cases in opposition to various moves to stimulate non-petroleum fuels, such as biomass or electricity as well.

Vehicle producers most active in the DCs today, and oil companies supplying most of the world crude oil and products, are based in IEA countries, with few exceptions. Thus technologies and ideas tend to flow from the developed world to the DCs. While retailing and in some cases refining is often controlled by state oil companies in DCs, the multi-nationals still have a dominant role in production, sales, and, most important technological developments in both vehicles and fuels. Both industries are keenly aware of the burgeoning markets represented by DCs (and EITs), and aware of the gaps in vehicle technology, fuel quality, road quality, and so forth between North and South. Because of their central importance to both vehicles and fuels around the world, both industries must be considered as partners in any attempt to change the path of GHG emissions by altering trends in vehicle ownership, vehicle use, fuel efficiency, or fuels themselves. Yet until recently World Bank activities relied principally on outside consultants for expertise on vehicle and fuel issues, and had little direct interaction with the main suppliers to study these actors' roles in the present situation. The Bank could take a more active role at this stage.

In particular countries where the Bank is active, local producers are also important (particularly Brazil, India, and China.) Many of these industries operate in protected environments, contemporary holdovers of import-substitution development strategies. In many cases (particularly for India and China) they represent important national symbols of economic development—an indigenous automobile industry is a sign both of self-reliance and a certain level of economic development. The Bank should use its unique position vis-à-vis these countries, and their automotive industries, to insure that they are as much included in global discussions of technological advances which may bring down vehicle carbon intensities as their OECD counterparts.

Vehicle importers are important players in many non-producer countries. National fleetwide strategies must be devised with active input from importers, since many operate under the same commercial pressures and need to anticipate and respond to demand as vehicle manufacturers in vehicle producing countries. Finally, the role of the informal sector in vehicle supply in many DCs and EITs must be acknowledged. These represent a potential weak link in any GHG reduction strategy which may be devised, since the vehicles the informal sector provides to a country's vehicle stock are outside of official mechanisms for control. The extent of informal sector participation depends on macro-economic factors out of the scope of this paper.

Public and government actors. Public actors are involved in the definition and design of public transport infrastructure in all countries, and in many, are also responsible for delivering it. They are also involved relatively recently (1960s/70s for the United States, 1980s for Europe, Japan and a few Asian countries, 1990s in some countries in Eastern Europe and elsewhere), they have begun to regulate the vehicles beyond safety concerns, or the quality of fuels such as lead content. National governments act as intermediaries between vehicle or fuel producers and transportation system users or household consumers. Local governments usually administer collective transport systems, while other authorities run ports, airports (and control air traffic), and so forth. National governments are the ones most closely associated with Bank activities, but increasingly transport policy must be carried out by local governments, and Bank activity has tended to focus on local problems related to transport system expansion (such as metros or buses) and more recently vehicle emissions (for example, Mexico City). To the extent that GHG problems are global and emissions arise everywhere, they require at least modest carbon taxes on fuels. These have to be brokered with national governments, most likely as means of raising general revenue.

Individual and business consumer interests. These are the people who use the vehicles on the infrastructure, otherwise known as a "commons." Their interests are diverse, but their enormous number is what gives transport its unique character vis-à-vis environmental problems. By contrast, GHG emissions from the energy sector can be pinned down to a relatively small number of well-identified power plants, refineries, coal beds, and so forth. In countries where there is significant voter power, public interests are constrained by what authorities can impose on the public. What may seem to be an economically "correct" policy may be difficult to impose because of social/distributional constraints, as the Bank and others have learned by examining the stories behind ending subsidies for energy and other basic commodities.

Special interests. Lobbies or political groups composed of configurations of the above groups appear regularly to favor or fight various policies: Raising diesel prices even in environmentally conscious countries of Europe encounters the trucking and shipping lobby; raising fuel taxes in the United States encounters the consumer and highway-users lobbies; imposing carbon taxes has run into the energy industry lobbies in IEA countries; developing European Union goals for automobile fuel economy improvements has encountered a long series of difficulties with automobile interests; plans for roads or infrastructure are always being proposed by regions and private interests that would benefit greatly from such development. Each of these groups has its point to make, often with justification. No GHG strategy can ignore them, however correct the steps proposed seem on paper.

The goal of Bank actions should be to help cement the above line up of interests, to encourage better investments, better technology, better policies, and more enlightened approaches as undertaken by each of the interests named above. Working directly with stakeholders in the client country, as well as the international commercial interests that supply the meat of the transport system, is an important new role the Bank could play.

Relationship to Bank policy and operations

Role of global overlays

The recently initiated Global Overlays Program is designed to add an extra dimension to Bank Economic and Sector Work (ESW) and the Country Assistance Strategy (CAS), and thus ultimately to Bank lending policies. Global Overlays represent "a new analytical tool for integrating greenhouse gas (GHG) externalities into the Bank's economic and sector work." (World Bank 1997, "Guidelines for Climate Change Global Overlays," Environment Department Paper no. 47), thus allowing the task manager to estimate the GHG reduction benefits from proposed activities. They are "global" because they incorporate into Bank procedures an accounting for a benefit of a project that accrues to the entire world, and not just a particular client country. As we will show briefly, the ASIF methodology presented above provides a useful framework for carrying out the bottom-up analysis that is part of the Global Overlay tool.

Connection to Bank practices

How much influence can the World Bank have? Under present policies, the answer is little. To some extent present projects probably make existing transportation systems work with slightly lower CO_2 intensity, but this effect is more than offset by the gains in total activity that Bank projects provide. Those gains often, but not always, represent real welfare improvements. To increase its influence, however, the Bank must actively seek out true reserves of "negacarbon," that is, low carbon fuels, very efficient vehicles, and patterns of settlement and activity participation that lead to lower movement—but higher welfare—per unit of GDP. Unfortunately, there is little the Bank can promote in the way of investments unless both technologies and policies match the problems at hand.

All of these policy initiatives presume we have found the "economically efficient" allocation of resources, the "best practice" solutions. Have we? Have we overlooked expanding what is economically efficient through stepped up local R&D, by reducing true market barriers or failures, or by finding how Bank actions can influence policy and markets by smoothing some of the political difficulties a country or region faces? This is a particular challenge to the Bank project leaders: use conservative technologies and existing relationships, or push for development of both new technologies and underlying market relationships.

For achieving the goal of GHG reduction, we need ways of measuring and valuing both externalities (not just from CO_2) and the real costs of options. In order to develop best practices we need a much better view of how technology can change, how people can change, how vehicle markets work, and so forth. To see how people can change, we need to know about elasticities and preferences, technology costs, R/D expectations, and so forth, to see where a small bit of influence through policy formulation or lending could have a big influence on technology uptake and behavior.

Endnotes

8. There is still a case for congestion pricing in intercity traffic. The Autoroutes in France offer peak-load tariffs designed to discourage use at beginnings and ends of long weekends or key holiday periods. Furthermore, the Dutch Minister of Transport has announced inter-city road pricing to be implemented shortly after the turn of the century, because even the intercity roads in that country are congested at peak hours. Compared with France, the traffic volumes are higher but distances shorter. The French system probably spreads traffic rather than discouraging it.
9. This fee rises with a car's original test fuel use, replacing the previous weight-related yearly tax. Gradually the steepness of this rise could increase, encouraging car buyers to seek ever less fuel intensive cars.

4 Tools for Flexing the Link — Better Practices

Because there are such great differences in speed, flexibility, and comfort between modes of transportation, no mode can be classified as "best" simply because it may lead to lower GHG emissions. This section suggests a range of "better" policy goals, policy tools, technologies, and analytical approaches to dealing with transportation problems and GHG emissions. These can be used to understand options in both the objective technical sense, as well as in the sense of consumer or firm preferences as set out above. In this sense, "better" means more economically efficient when externalities, including CO_2, are valued.

Better policies

"Best" policies may be hard to define and measure, because of the many objective functions to be considered, including "welfare." Nevertheless, it is generally agreed that proper pricing of the use of the transport infrastructure, the pricing of externalities, the matching of variable and fixed taxes to the appropriate direct costs and externalities represent the elements of overarching "best" transport policies.

However, many have begun to question this assumption. The goal of public sector transport policy was traditionally to provide for the demand for mobility by making infrastructure available, while the role of the vehicle industries is to sell vehicles at a profit. But it is recognized that providing these tools of transport without a framework that offers feedback to users when problems arise seems to lead to growth in activity beyond all forecasts, with the associated externalities. Indeed, one element of "sustainable transport" may well be that system users pay their full social costs without leaving any to future users. This is implicit in one of the goals of "Sustainable Transport," prepared by the Bank in 1996.

In the Bank study, sustainability as the basis of transport policy is defined as follows:

- Economic sustainability ("efficient responses to needs")
- Environmental sustainability (promoting more livable settlements and reducing adverse external effects
- Social sustainability (reducing poverty).

There are difficult trade-offs among these three goals, but synergies as well. Certainly better public transit, less air pollution and noise, reduced risks of accidents (particularly where vehicles hit walkers), and better provision of non-motorized transport opportunities or clean two- and three-wheeled transport advances all of these goals.

Land-use planning and other elements of physical coordination that influence infrastructure belong to "better" overarching policies, even though effective coordination is often difficult to bring off in practice (OECD/ECMT 1995). Land-use planning to reduce the overall need to travel, while maintaining access to goods, services, and activities is essential, but it is difficult to show at a global level the affects of such planning policies on travel or freight movements, to a great degree because there are so many confounding factors. Land-use policy, however, is probably an important long-term influence on the price-elasticity of demand for car-use, and as such, cannot and should not be ignored (ECMT 1998b).

Better practices: Technologies

Broadly, "better" technology practices can be divided into those that affect vehicles (C*E) and those that affect fuels (F). Annex 2 discusses some of the alternatives for each. The literature shows that there are enormous potential reductions in the fuel intensity of a given car (20-50 percent) or aircraft (20-40 percent) (Greene 1996; IPCC 1996). The precise amount of savings depends on the starting point, the price of fuel, the time frame for developing the larger savings potentials, and the timing of the entry of such technologies on the market. The potential may be lower for larger than smaller trucks because the former are already relatively efficient, but there is still much to be saved (10-30 percent).

These potential savings are not simply theoretical; many automotive companies around the world are actively and successfully involved in the development of the technologies that may bring them about, as discussed in Annex 2. The cost uncertainties of such development, however, are equally real, as is the eventual acceptance in the marketplace. Many companies are finding that those technologies that help consumers get features they want (which is not necessarily fuel efficiency for its own sake)—such as turbo-direct injection diesel in Japan—are easier and quicker (and, for the car companies, less controversial) to bring to market than those which focus specifically or exclusively on energy efficiency. Car manufacturers may publicly state a desire to advance technology in the service of fuel efficiency, or reducing carbon intensity, but in private, they are worried about costs and market acceptance, as business people should be.

Improvements in technology are not only reserved for motorized vehicles. For urban freight movements, improvements to both traffic management and pavement technologies and management can make non-motorized movements in urban centers more viable. For shipping, high technology "clipper" ships (that is, high-tech sailboats) have also been revived as a potentially viable non-motorized technology (Hansen 1996), as have the concept of dirigibles for long-distance air shipping of bulky goods. More efficient designs of metros, buses, and rail cars (particularly engines) could reduce energy use per unit of distance traveled for these vehicles as well. Technological advances in motive delivery (how power is converted to motion) can also be applied to non-motorized land-modes, potentially increasing their relative attractiveness as an alternative to the car or truck.

There are many uncertainties that affect the real estimates of how much GHG reduction a particular transport technology really offers. Finally, there are rapid changes occurring both to technologies themselves, and to the two dominant markets for vehicles, namely those for cars and trucks. These changes alone favor larger and more powerful cars, on the one hand, but smaller trucks that carry less freight per unit of fuel on the other. Both changes raise the energy use per unit of transportation services (I) even as technology (E) leads to reduced fuel use. The key dilemma for any project team is how to make an honest evaluation of not only today's options, but tomorrow's as well. Folding into this uncertainty the rapid expansion in total activity (A) and in many cases the shifts away from collective modes (S)—so often the focus of Bank Projects—makes it even harder to evaluate the benefits of technological options.

Given these uncertainties, the Bank should play a stronger role in the evaluation of technological measures and options for transport. This can happen directly, by building in-house capability for its own analysis or indirectly, by supporting development of testing facilities, research and development, and supporting exchanges and transfers of technologies, in client countries. In addition, the Bank could play a strong role in identifying barriers to technology adoption, including technical (fuel quality, road quality), institutional (trade barriers, monopolies), political, or market failures within a client country.

Alternative fuels present a similar dilemma. As Sperling and Delucchi (1993) show, there is a wide range in the estimated variable or life cycle costs of different fuels. This variation presents a critical problem for the Bank; the true costs and benefits of alternative fuels in the real world are not well known. Experience with low-cost diesel, LPG or subsidized farm ethanol mixes shows that low prices are an important component in bringing new fuels to the marketplace. Whether such low costs can and should be sustained in the long-run is unknown. There are no real examples of a long-term effort to promote alternative fuels, save perhaps the sugar-ethanol program of Brazil, which has played to mixed reviews. Even where alternative fuels are significant, it is often difficult to measure the real change in the fleetwide carbon component of fuel. Much more experience with alternative fuels is needed, and the Bank could support experiments in a variety of countries.

The foregoing discussion highlights an important consideration for the Bank's overall approach to transport policy, a consideration which should allow the Bank itself, in addition to its client countries, to undertake "better" practices. Individual transport system users matter, both in terms of *how* they use the system, and in terms of the vehicles they choose. Until recently, much of the Bank's transport strategy has focused on infrastructure, that is, the physical facilities for movement. Outside observers (IIEC 1996) as well as the Bank (World Bank 1996) itself have been increasingly aware of the need to address the behavioral choices of system users in various ways, instead of relying heavily on infrastructure policy. Car technologies are a significant part of these behavioral choices.

An important issue, therefore, is how the Bank should approach its technology policy. Should it push particular alternatives or kinds of vehicles? Or should it focus on generalized research and development? Should it focus on local technologies—that is, those that can be produced locally and optimized to local conditions—or should it focus on those which reflect best practices internationally?

In "better" practice terms, technology holds out some promising technologies to reduce emissions. Nevertheless, at present, there are no miracle cures just over the horizon, no technologies that promise to radically reduce GHG emissions. Dramatic action may be needed, and the Bank may be in a key position to support the search for truly low-carbon alternatives to present vehicles and fuels in client countries and across national and corporate boundaries.

Better tools for carrying out integrated policies

A full review of policy tools for transportation reform is beyond the scope of this paper (see Barde and Button 1990; CEC 1995a). However, several important policy tools might effectively influence near and medium-term emissions, both by influencing the specific carbon-intensity of vehicles, and by influencing the extent to which these vehicles are used.

Fuel taxation is one such policy. In the near term, higher fuel prices probably have a negligible effect on car or truck use (**A, S,** or **U**) and perhaps an even smaller effect on the use of other modes of travel or freight, because of the relatively low own- and cross-price elasticity. (Oum and others 1995) That this effect is "negligible," of course, is an aggregate result; location, income, family situation, life cycle stage, and other influences can affect individual or localized short-term responses to higher fuel taxes. (Greening and others 1997). In the medium term, however, higher fuel prices do encourage car buyers to choose cars with better fuel economy than they otherwise would have (such as reducing I). They may do this either by trading off that fuel-economy against other features, or by demanding technological improvements from suppliers which allow them to enjoy the same set of car characteristics at lower specific consumption levels. Manufacturers, for their part, will respond to such consumer demand, if they believe fuel prices will remain high enough for long enough to make it worth their while. Higher fuel prices may also discourage additional individual driving in the longer term, by stimulating demand for structural changes (for example, lifestyle or urban planning decisions) which are less car-intensive.[10]

Many governments are reluctant to consider tax measures to raise the price of fuel for any but revenue purposes. The reasons are threefold. First, it is often difficult to understand how car use changes with changes in prices. Energy prices have almost unceasingly fallen over the past thirty years (while car and truck ownership and use has expanded), and the relatively brief periods of energy price increases have been too short to be able to glean long-term consumer and producer reactions from the experience. Second, political resistance is nearly ubiquitous. The magnitudes of fuel price changes required to give big changes in car use in the short run are simply too large to be acceptable in most countries.[11] Third, many countries are worried about the macro-economic effects of such a tax, particularly the fear that it would slow GDP growth. Indeed, part of the justification for a Danish gasoline tax in 1995, was specifically to slow the economy and keep it from overheating. Thus, consideration of the timing of a fuel tax is important. Where inflation is threatening, and the risk of recession relatively small, introducing a fuel tax might not only make sound environmental sense, but might also be good economic policy.[12] Whether fuel taxes slow the economy in the medium and long-term is the subject of some debate; to a large degree, the ability of an economy to thrive in a period of high energy prices depends on the ability of its actors to access goods, services, and participate in activities. This, in turn, depends on the economy's ability to deliver such access in a less energy-intensive manner.

Taxing motor fuels because of health costs has a potentially large impact on driving costs. Small and Kazimi (1995) indicate that health costs of air pollution arising from the use of gasoline by automobiles in the Los Angeles region could be as high as 2 cents/km (3 cents/mile) or 60 cents/gallon at a fleet average of 20 miles/gallon (11.8 l/100 km). That rate is close to the wholesale price of gasoline (untaxed) in many countries. Such health costs would fall as new technology cleans the fleet in the region even more because the reduction in pollution would outweigh modest growth in traffic over the coming decade or more. (At the same time the costs would rise if traffic increased because smog concentrations and frequencies would rise.) A recent internal report of Experts assembled by ECMT gives similar figures for Europe: the marginal costs to health of an additional unit of fuel emitted are currently large in many locations (ECMT 1998a).

Health costs are perhaps the most dramatic because they affect so many people beyond those who drive. World Bank reviews indicate very high health costs from diesel and gasoline fuels arising in cities such as Mexico City, Santiago, and elsewhere. These may be reduced through new technology as well, but the prospects of further traffic increases in cities such as Beijing suggest that the health costs of air pollution from motor vehicles will remain high. It is likely that these two would yield high taxes per km of travel. In all cases, the tax on the fuel could have a rather significant effect on the use of vehicles. Indeed a recent Bank document questions where such taxes should be imposed when alternatives are not available. Yet there may be a chicken and egg problem: without the tax, drivers have no incentive to switch to cleaner fuels and refiners have no incentive to make cleaner fuels. Regulation could clean up the fuels and vehicles too (through retrofit, as in Mexico City). But a significant welfare loss remains if unimproved vehicles continue to be driven at fuel prices that do not reflect the damage imposed. Thus a combination of regulation and taxes is required to achieve an efficient solution (Eskeland and Devarajan 1996).

Fuel taxation is one method of "variabilizing" the costs of driving, which is considered an important step in effectively internalizing the external costs due to transport (ECMT 1998a). A second method involves charges for use *facilities*, such as road or parking pricing. Possible consumer responses to facilities charges are substantially different from fuel charges, since changing vehicles or vehicle technology does not affect consumption of the taxed good. Road pricing is often associated with *congestion* pricing, that is, choosing locales to price and setting rates with the specific policy goal of reducing congestion. In principle, road pricing could apply *per kilometer* charges to road use, either through periodic toll facilities, or through electronic pricing methods; in practice, though, it is more often enacted via a cordon around a pay-to-enter zone, such as a central business district. To the extent that road pricing is enacted as a *congestion* mitigation policy—that is, to alleviate congestion in particular areas—it might have the perverse effect of actually inducing *more* travel, as drivers take longer routes to avoid the toll cordon. In countries where value-of-time is lower (generally speaking, those with lower levels of GDP per capita), this avoidance behavior is probably more important than elsewhere.

Carbon taxes, however small, could play a potentially important role here, affecting in some way every component of **ASIF**. In theory, a carbon tax is the most economically efficient policy mechanism for reducing CO_2 emissions, since it specifically internalizes the external "bad" which is the policy goal; in practice, like fuel taxes, the amount of the carbon tax necessary to change behavior significantly may well be at politically unacceptable levels. A realistic carbon tax, therefore, likely would be smaller even than the present total tax burdens on fuel. Nevertheless, they might be quite effective at providing differential price signals for different kinds of fuel, as experience in Europe with diesel and unleaded fuel pricing has shown. And taxes on all fossil fuels play an important role in making carbon transparent in any comparison of alternative fuels. By placing the equivalent tax on all fossil fuels, governments can assure themselves that the alternative fuel is not cheaper because there is a carbon subsidy hidden in the fossil fuels used to prepare the alternative. Carbon taxes on all fossil fuels, therefore, are an essential element of any market-based alternative fuel strategy.

Vehicle ownership taxation has long been an instrument that steers characteristics of the vehicle fleet, characteristics which in turn affect fuel consumption. As reviewed by Schipper and Eriksson (1995) or the OECD (OECD 1995), these instruments tax engine size, power, or car weight, parameters that affect both consumer choice and ultimately producer supply. Vehicle taxation can apply at both acquisition and registration, the latter being a recurring tax on the owner every year. Acquisition taxes have been used by some governments to control or restrain rates of motorization. Such a use is tricky and dangerous, since it might have the perverse effect of retarding fleet turnover; car owners are reluctant to replace their aging vehicles with newer ones because of the tax burden they may have to bear. The result is an older (and usually dirtier and less fuel-efficient) car fleet overall.

Registration charges, however, are a potentially effective way of influencing the vehicle fleet mix, through differential pricing of different cars' registration fees depending on their green characteristics. Many policy analysts, however, are beginning to recognize the need to variabilize as many of the costs associated with cars as possible—that is, taxing *use*, not *ownership*—(Eskeland and Devarajan 1996, ECMT 1998a). The reason is that up-front household (and firm) capital costs become a justification for use of the vehicle. ("I spent so much money for the car, I might as well use it.") So while registration charges are potentially effective, it may make more sense to transfer these fees to a pay-as-you-drive basis.

Finally, there is the possibility of **regulating new car fuel economy** (C*E). Soft regulations or voluntary agreements (VAs), that is, non-binding targets agreed to by manufacturers or importers and governments, were put in place in the mid 1970s in Sweden, Germany, and Japan. These were recently offered by the German car industry (a 20 percent fuel intensity reduction, per press release in 1995), Volvo (a 25 percent fuel intensity reduction, per press release 1996), the French carmakers (a target of 125 grams of CO_2/km [Peake 1997]), and Fiat (Press release 1997). What is not clear is whether the VAs represent real efforts by manufacturers or just validation of what they already believe they can do. Not surprisingly, German producers and Volvo both say quietly that they need support through fuel taxes to make sure consumers do not simply demand larger cars.

In the United States, new car fuel economy has been regulated, on a fleet-wide average, since 1975, under the Corporate Average Fuel Economy program.[13] Debate has raged in the United States ever since, both as to whether they are a good idea, and as to whether they have been effective. Given the unwillingness of the U.S. Congress either to decontrol the price of crude oil or to impose new fuel taxes in the 1970s, there may not have been much alternative. The relative importance of CAFE vs. the higher prices of fuel from 1979-1985 will always be a subject of debate. One of the more controversial aspects of the standards is that those for vans and light trucks are less stringent that those for cars; as a result, buyers tending toward large cars, who are less demanding of fuel-efficiency as a characteristic, have tended to switch to vehicles in the van and light category (for example, sport utility vehicles). This shift has caused the real average new car vehicle fuel economy to rise only very slowly during the 1990s. Nevertheless, CAFE had a fundamental effect on car manufacturers, pushing them forward into deploying fuel saving technology, rather than riding out the short period of higher prices by simply selling smaller cars. Whether measured per household, per capita, per car, per kilometer, or per dollar of income, the average American household owning a car used less automobile fuel in 1994 than in 1973.

Which of the above policies might be appropriate for developing countries? The answer is all and none. Imposing higher car usage charges fuel prices, differentiated fuel taxes or carbon taxes, may be politically difficult today. Imposing high purchase taxes seems to be more politically acceptable, although, as noted this solution does not match the tax to the externality, places a greater share of car costs in the fixed, rather than variable, category, and may tend to discourage fleet turnover. Room to maneuver even on this relatively acceptable policy, however, may be limited by the presence of a indigenous car industry. In Europe, no car-producing countries impose heavy vehicle purchase taxes, although some with assembly only manage to do this.

Interaction of policies and components of emissions

The policies noted above affect different components of **ASIF**. The following tables summarize some of the more important interactions between policies and the components of emissions. One important step for Bank planners it to trace through this matrix to see where a project itself and the policies associated with that project are likely to affect the components of **ASIF**.

Recall for example that the largest cuts in emissions in time are likely to arise from a combination of very high efficiency vehicles and low-CO_2 fuels, complemented by increases in fuel prices. But increased fees related to distance driven (in part to compensate for distance-related externalities) might reduce total vehicle use from 10 to 30 percent. These reductions in vehicle use would eventually be offset by increased numbers of vehicles and their use in most low-income countries, while reductions in the components of the carbon-intensity of travel or freight could offer anywhere from 20 percent to 80 percent lower emissions per unit of activity, consistent with what Johansson and Schipper (1997) found for car use in IEA countries. Not surprisingly, local authorities should be more interested in these strategies because of their lasting effects, and because, with technological progress, they could face far less political resistance than packages emphasizing only higher costs of using vehicles.

From this table we could imagine that during a 20-year period in which per capita income doubled, we would expect a more than doubling of car ownership in a typical developing country. Fuel use and emissions

Table 3a. Interaction matrix: Which policies affect which components of travel related emissions?

Component/ option	***A** (Activity)*	***S** (Modal share)*	***I** (Veh. intensity, characteristics, load factor)*	***F** (Fuel mix)*
Vehicle Fuel Economy Technology	None except through rebound	Slightly encourage modes with lower running costs	All	Affected by fuel (e.g. diesel has lower fuel intensity)
Alternative Vehicle Technology (2, 3 wheelers)	Decrease for car users, increase for the un-motorized	Shifts from other modes	Reduce fuel intensity of 2, 3 wheelers	Depends on fuel: electricity has great potential
Overall Fuel Taxation	Slight restraint, elasticity low	Favors modes with low fuel intensities	Encourages improvement in all comps.	Neutral
Carbon Taxation	Slight restraint`	Favors low carbon modes	Same as above	Favors lower carbon fuels
Km Pricing (including congestion pricing, etc.)	Significant restraint. Depends on extent, costs, time of day, etc.	Favors modes with small footprints per passenger (i.e., bus, rail)	Little effect unless permits small vehicles selectively	Little effect unless cleaner fuels exempt
Alternative Fuels: development, pricing	Little effect unless price of fuel forced up	Little unless "clean fuel " modes given priority	Little, unless clean fuel more efficient	Potentially large (subsidies, taxes on dirty fuels)
Transit Development	Increases activity among low income, distance for all	Encourages its own use if supported by policies	Could take some hi-occupancy car	Could be developed to use nat. gas, electricity
Non-Motorized Transport Initiatives	Increases among those w low activity	Reduce other shares	None	None
Land use Planning	Supposedly would reduce total activity	Could increase transit share	Little	Little

Table 3b. (*continued*) **The interaction matrix for travel: Estimating the potential for changes that might occur relative to A base case**

Component/ option	*A (Activity)*	*S (Modal share)*	*I (Veh. intensity, characteristics, load factor)*	*F (Fuel mix)*
Vehicle Fuel Economy Technology			-20-75% less fuel/km compared with 8l/10 km today	
Alternative Vehicle Technology (2, 3 wheelers)				-30% from ngas -90% from true biomass
Overall Fuel Taxation	Price Elasticity of mobility wrt fuel cost 0.1--0.3	Small shift to lower-fuel intensive models	Elasticity of fuel economy wrt fuel price +0.6-0.8	
Carbon Taxation	same as fuel taxation	Very slight shift to less carbon intensive modes?	Same as above	Evidence from diesel/gasoline differences suggests potentially large effects

would probably rise accordingly, perhaps even more rapidly if the average car became more powerful. Imagine, however, that the real price of fuel also doubled during this 20-year period. We could estimate that this resulted in approximately 40 percent less fuel consumed/ km and 20 percent fewer km driven (leaving fuel costs/capita roughly constant, a falling share of household budgets for car fuel but a rising share for vehicles). Suppose furthermore that natural gas was introduced as the major fuel and by the end of 20 years dominated the overall vehicle fleet. Overall GHG emissions from the system could be lower in spite of the doubling of transport activity by car in this case. Transport measures might reduce activity growth even more. But is this a case representing higher socio-economic welfare? We cannot say because we cannot estimate the real costs of these options nor the often-hidden costs of implementing them.

A complementary approach can be taken to match actors or stakeholders and policies. Table 5 suggests these matches with a matrix. A key point is that vehicle and fuel-based strategies tend to be national and international, except where local conditions create a strong demand for a certain fuel (pollution) or certain vehicle (say, a very small vehicle because of congestion or parking problems.)

The table suggests that there are significant groups who would be opposed to fiscal or regulatory measures. Vehicle manufacturers are not opposed to improved fuel economy *per se*, but, because of fears about market acceptance, are reluctant to commit themselves or their products to significant improvements. The challenge for the Bank planner is to anticipate political opposition, economic difficulties, and other unforeseen problems and incorporate them into sensitivity analysis to gauge the real costs of any development. For developing countries, an additional political issue arises if a policy encourages use of a technology or product that must be imported. Conversely, the fact that some vehicle technologies are poor or old and outmoded in some countries may have more to do with trade and industrial policies than with any problems of local technical competence. India, where older models of British and Japanese cars were produced for many years, even decades, comes to mind

Table 4. Interaction matrix: Which policies affect which components of freight emissions?

Component/ option	*A (Activity)*	*S (Modal share)*	*I (Veh. Intensity, characteristics, load factor)*	*F (Fuel mix)*
Vehicle Fuel Economy Technology	Little	Slightly encourage modes with lower running costs, but so far shifts to trucking show weak effect	Reduces fuel use.	Affected by fuel (e.g. diesel has lower fuel intensity)
Overall Fuel Taxation	Slight restraint, elasticity low	Favors modes with low fuel intensities	Encourages improvements in all comps.	Neutral
Carbon Taxation	Slight restraint`	Favors low carbon modes	Same as above	Favors lower carbon fuels
Km Pricing (including congestion pricing, etc.)	Significant restraint. Depends on extent, costs, time of day, etc. Affects delivery	Favors modes with small footprints per unit of goods, i.e., larger trucks, or rail	Encourages better vehicle loading, utilization	Little effect unless cleaner fuels req'd for city use
Alternative Fuels: development, pricing	Little effect unless price of fuel forced up	Little unless "clean fuel " modes given priority	Little, unless clean fuel more efficient	Potentially large (subsidies, taxes on dirty fuels)
Information and Logistic Development and improved handling	Increases mobility among low income, distance for all	More intermodalism favoring modes in their respective best function	Scheduling, higher load factors, fewer backhauls,	Combine with natural gas, electric, fuel cell facilities to encourage alt fuels?
Changing market structures, land use	Lower distances goods need to move	Could increase rail share if more production located near rail	Little except improvements from less congestion	Little

immediately, as do the former Soviet bloc countries.

Expanding the knowledge base—Better analytical tools

Once transport and environmental policy goals are identified, technology and behavioral responses laid out, and both project and policy options discussed, the analyst must somehow make cost/benefit estimates of one kind or another. Previous Bank documents show how to begin to take credits for projects that affect local environment. The Global Overlays approach suggests how to take credit for GHG reduction as well. In this section we will talk about some of the difficulties inherent in quantifying and valuing the latter.

Top-down macro approaches

Traditionally, changes in fuel use have been estimated using econometric techniques that examine past behavior of the system. Price and

Table 5. Interaction matrix: Who cares about each policy?

Actor/ option	*National/local government*	*Vehicle makers*	*Consumers*	*Stakeholders and lobbies*
Vehicle Fuel Economy	Local: No influence except through procurement. Nat influence through fuel prices, standards, taxes	Hold the technologies	Choose vehicles and how to drive them.	Mainly Car industry opposing regulations to encourage or mandate. Less opposition to taxation
Fuel Taxation	Set by national or state governments	Mixed position; accept if alternative to regulation, but often defend status quo, especially through their industry associations.	Oppose!	Opposed in past by many groups
Registration, yearly, or Special Fees	Set by national or local governments	Oppose when aimed at new vehicles	Oppose	Opposed: by principal transport industries (e.g., airlines opposed landing fees, etc.)
Km Pricing (including congestion pricing, etc.)	Local and national favor for different reasons	Few have thought through what significantly lower utilization/year would mean for sales and planning!	Would oppose unless congestion benefits clear	Probably opposed, particularly by truckers and other transport professionals
Alternative Fuels: development, pricing	R&D, testing, pricing, introduction into market	Mixed reaction. Could favor	Suspicious unless price differential	Lobbies for fuels develop quickly
Transit Development	Crucial for planning, financing, running (?)	Some taking proactive stand (Volvo)	Urban interested; suburban not	All sides of issue
Land use Planning	Local Gov. implements, but can be based on national laws	No view	Take both sides	Usually real-estate interest, property owners organize to oppose

income elasticities derived from econometric analysis of revealed behavior have been applied to future scenarios, including ones assuming fuel price rises due to policy levers. Welfare losses, quantification of cleaner air and benefits associated with it, and estimates of overall welfare changes, therefore (net social cost or benefit) are in principle possible. In their analysis of the Mexico City "Hoy no circulan" program, Eskeland and Feyzioglu (1995) show that often such a macro-analysis yields important results. But this may be the exception, not the rule. The macro tools are important, indeed, but have their limits.

These limitations are caused by inadequate knowledge of the macro parameters that describe the demand for transport services and fuel use, particularly in developing countries. Above all, one cannot separate the **ASIF** components and estimate how each might change. One can obtain overall fuel price elasticities from the relatively accurate data on aggregate fuel sales, but such data tell us little about transport problems. McRae (1994) computed gasoline demand elasticities for a number of developing countries, but overlooked the use of diesel in cars or the use of gasoline in trucks and buses. Like Wheaton (1982, see Schipper and others 1993), McRae did not measure the demand for transport services and the consumption/km of different vehicles. The reality is that these approaches represented the best that could be done at the time with the limited data.

The problem is further aggravated because the range of uncertainties one obtains for income and price elasticities of fuel use may be too large for transport planning purposes. At one end of the uncertainty range (high income elasticities and low fuel price elasticities), there will be large welfare losses associated with imposing large taxes on fuels, and growth in the number of vehicles with income will soon erase the effects. At the other end of this uncertainty range, modest taxes could have an enormous effect on fuel use, distance traveled, or even vehicle ownership. But no macro approach can say whether substitution or fuel-saving possibilities exist unless they existed in the past and their effects were measured. Since part of the thrust of the present effort is to explore an area where few possibilities for GHG abatement were thought to exist in the past, by definition the macro approach to study the future is inappropriate.

Moreover, it is important to try to understand how vehicle ownership, vehicle use, and fuel consumption each varies among different classes of consumers. Each class imposes different levels of other costs (air pollution, noise, road wear, safety, or congestion) on other drivers and on the environment. But obtaining each group's likely responses requires the kind of survey work previously described. The approach of Greening and others (1997), which observed changes in car use in the United States observed during a period of sudden high prices (1990/1) through quarterly household surveys, established how different family types experienced different short-term responses to higher fuel prices. Similar information must be gathered for operators of other modes, too. Otherwise, it is hard to anticipate the real short- and long-term reactions to imposition of new fuel or vehicle taxation schemes or other policies that significantly changes the costs of owning and using vehicles. Conversely it is difficult to quantify the total environmental benefits of pricing strategies if some of the responses that may yield significantly fewer km-traveled cannot be quantified. This is particularly important for estimating how GHG abatement will affect traffic and how traffic control strategies will affect fuel use and hence GHG emissions. The interaction of the two strategies may be as important as each strategy taken separately (COWI 1996; Eskeland and Xie 1998). Indeed, this may be the key to a successful GHG reduction strategy for transportation and a key step in the Global Overlay analysis itself, tying non-GHG measures to incidental GHG reductions.

The same problem of uncertainties plagues estimation of macro responses from the freight system. In the IEA countries it appears that the GDP elasticities of domestic freight shipments vary from 0.8-1.2, and that the ratio of domestic ton-km to GDP varies by a factor of three depending on geography, raw materials production and other factors. (Schipper, Scholl and Price 1997). These results are not inconsistent with those of Thompson, Frasier and Benson (World Bank 1994). But those authors noted how poorly the parameters that describe freight are known in developing countries or even EITs.

Aggregate estimates for fuel price elasticities for trucking are also fraught with difficulties because of the problem of identifying trucking fuel use (Schipper, Scholl, and Price 1997). The resulting elasticities appear to be small, as do the elasticities of trucking fuel intensity with respect to fuel price. But estimating fuel intensity elasticities with respect to prices for trucks is particularly tricky. Shifts in the mix of trucks over time—in response to the needs of changing production mechanism—have boosted the importance of small trucks in many IEA countries. Consequently, even if capacity utilization of a given size truck and relative levels among different truck types remain the same, average modal intensity will increase, all else equal. Again, detailed surveys are required to see how trucking fuel use really varies under different conditions, and as a function of fuel price changes.

There is an interesting inverse correlation between trucking fuel prices and trucking energy use/GDP (Schipper, Scholl and Price 1997; Schipper [IEA] 1997). The geographically largest IEA countries have low trucking fuel prices and, because of geography, natural resource endowments, and natural economies of scale for modal alternatives, relatively low shares of trucking in overall freight, but they still have high trucking volumes/GDP because the overall volume of freight is large. The long distances raise the relative importance of large, well-loaded trucks and thus lead to low values of fuel use/ton-km, too. Is this a reverse policy, where large countries, such as Australia, Canada, or the United States, simply kept road fuel taxes low? Even in IEA Countries, little is known about the rationale behind policy formulation. For DCs and the EITs, the situation is much worse. Hence we must commence to measure even as policies that affect how goods are moved are implemented.

The demand for transport services is probably more income elastic for in DCs and EITs than in upper income countries. Demand for fuel is elastic where substitutes exist (other modes, more efficient technologies, or smaller vehicles). Over the longer run higher fuel prices mean less fuel-intensive vehicles, and observed behavior suggests that that response is more important that a decline in vehicle use or mobility. That is, the long-run response to higher fuel prices results mostly in more fuel efficient (or smaller) cars and to a lesser extent in reduced driving (Johansson and Schipper 1997). But how can we use these general statements for building GHG abatement strategies? The answer is to expand the analysis to bottom-up techniques.

Using a bottom-up approach to measure costs and benefits

Using these general results to formulate a strategy requires us to complement the meager survey data and macro elasticities with best estimates of the impacts of technologies in emissions, and the impacts of differences in various prices on both vehicle use or mobility and fuel intensities as well. That is, one tries to compare changes in emissions from changes in each of the components noted above in the **ASIF** formulation shown. Knowing something about cross price elasticities and how they affect modal shifts for travel is useful. Estimates of the marginal costs of changing technologies permit a rough sense of responses in the ideal world. The Budapest bus loan proposed expenditures to provide more energy efficient, cleaner buses. Knowing how much the buses are expected to run and how much less pollution they will emit permits a quantification of air pollution reductions and energy saved.

Even more useful is the approach of Eskeland and Xie in attempting to estimate marginal abatement costs and the quantities that will change as well, in a program of pollution abatement or fuel saving. This leads to a curve of pollution or CO_2 abatement. It is important to include any feedback from either higher or lower variable costs to estimate both how changed technology and changed driving affect overall emissions. It is also necessary to make at least a rough calculation welfare gains and losses. But the advantage of the bottom-up approach as a complement to the top down macro calculation is that the analyst or program manager can identify the key elements of change that lead to the greatest benefits, elements that might have to be monitored carefully.

Here a warning is necessary. Much of the argument among governments and between governments and NGOs in the COP-3 involved how and how much to value of the reduction of GHG emissions. A consensus on neither the extent of actual or projected damage existed, nor the willingness-to-pay of individuals, businesses, or governments. There is somewhat more consensus about the reality of the costs of other transport externalities, such as local air quality, pollution, and noise, but even this consensus is limited; representatives of transport industry, as well as some academics, regularly argue that such externality costs are small relative to the benefits provided by transport, while some health scientists contend that the costs for health alone are large. What is important for both GHG restraint and the valuation of other transportation externalities is to consider a range of costs and see where the boundaries lie, that is, at what lower valuation do GHG restraint benefits become truly insignificant, and similarly for other problems (noise, safety, and so forth). If officials in a host country are simply not willing to pay for reduced congestion, noise, dust, air pollution, traffic fatalities, then it will be difficult for any Bank manager to pursue any further the environmental aspects so important to a GHG strategy.

Finally, it is crucial to estimate the hidden costs. Is enforcement of a required retrofit of pollution control expensive? Would higher fuel taxes promote significant black-market sales of untaxed fuel or cutting of taxed fuel with similar, untaxed fuel, such as when untaxed, low cost kerosene is added to gasoline. Would improved fuel economy lead to more imported vehicles or vehicle components and less domestic production? These hidden costs might lead to resistance to abatement strategies on the part of important constituencies.

Feedbacks/bouncebacks

There seems little doubt that in lower income countries, more efficient or lower cost transport stimulates the demand for transport. This leads to an increase in welfare, but lower net restraint in CO_2. Will variabilization of costs, by lowering taxes on acquiring or owning vehicles, stimulate greater vehicle ownership but less use? Johansson and Schipper (1997) found that lower new-car taxes had a positive effect on ownership, while higher fuel prices had a small negative effect on ownership but a modest effect on use. Since the analysis applied only to upper income countries, conclusions about these must be guarded when applied to low-income countries where a small reduction in driving costs could be a big bonus to incomes.

Of greater concern to authorities is the possibility that a significant improvement in fuel economy or decline in vehicle use greatly cuts into future road-fuel tax revenues, even with the "bounceback" or "rebound" effect, hence it may be relatively easy to head off this problem by raising taxes. (The converse is the idea of the Danish Government, namely to declare a new-car fuel economy path implying a certain average annual increase. Real fuel prices rise at the same rate, so anyone buying a car with lower than the target fuel economy pays more.)

It should be noted that financing of extensive metro and bus systems, while increasing mobility at relatively low GHG emissions/km, could also be a rebound stimulation by permitting people to live much farther from work than previously. This is not to say that such systems do not increase welfare. Rather it is important to model both distance and modal choice and carbon intensity (that is, all terms in the ASIF formulation) where a new system is likely to stimulate interactions amongst the terms.

The rebound or bounceback effect is associated with an increase in economic welfare. If a household's ranges of action are increased by better transportation without subsidies or net increases in externalities, then everyone is better off. When part of a rebound is stimulated either by under-pricing of externalities (or fuel), one must anticipate the rebounds that will occur and guard against aggravating other transport problems. Overall this effect is small in high-income countries of the IEA but could be significant in low-income countries and must be studied carefully and anticipated.

Improving the knowledge base — Concrete steps in client countries

The foregoing discussion assumes that an analyst has at his/her disposal the same kinds of data as are available to developed country analysts and policy-makers. For most of the EITs and DCS, data is often either nonexistent or inaccurate. Under this situation, how can we begin to measure what is best?

Here the World Bank can look to its own record for "best practices," Starting in the early 1980s, the ESMAP program began a long and continuing series of surveys of energy use in industry and households. These were considered essential to energy-related industrial development for energy conservation, assistance projects related to rural and urban energy systems, and ultimately to judge the worthiness of large-scale fuel and power system expansion. Not understanding energy demand would have left planners to the mercy of notoriously inaccurate aggregates to estimate future energy demands. Without a clear picture of energy-use patterns, it was hard to convince authorities to lift subsidies and "get prices right." Finally, the industrial surveys often revealed the inefficiencies of basic processes and showed the benefits of improving towards "best practices."

The same tools must be developed rapidly in developing countries and EITs. These include:

- *Household vehicle/fuel use, travel surveys, and time-use surveys* such as the panels supported by the Dutch Government through the Bureau of Statistics. These cover both vehicles and people.
- *Fleet activity and fuel use surveys*, to determine the condition of bus, truck, small boat fleets (for example ferries, barges, even fishing vessels which are not considered here), their fuel use/km, their typical utilization factors and passenger or ton-km delivered. For example, Kenya Bus Services was able to provide a very accurate record of all of its buses to an energy survey there in 1981 (Schipper and Meyers 1983).
- Goods must be surveyed with *commodity flow surveys* attached *to truck utilization surveys*, such as the "TIUS" of the U.S. Department of Commerce. These show how and how far different goods move, as well as how different kinds of vehicles haul different kinds of goods.
- *Geographic regions themselves need to be surveyed* to better pinpoint vehicle flows, origin-destination patterns, local sources of emissions arising because of poor traffic conditions or micro climate (still air, and so forth). For urban regions this is essential to finding both where traffic is tied up, who is tying up traffic when, and estimating how different policy instruments might affect these traffic flows. Better understanding of how goods are distributed in detail allows for better location of distribution facilities so that competition for road space is reduced.

- *Better assessment of the real emissions from vehicles,* either from remote sensing (preferable) or other techniques applied in real situations, or from spot roadside tests, or from yearly inspections.
- *Test facilities for measuring fuel consumption of and emissions from vehicles both in ideal conditions and on the road.* On-road measurements are particularly important because they reveal the impact of driver behavior, traffic, and in lower-income countries, road surface quality and fuel quality as well.

This information is not cheap, but it is becoming cheaper rapidly. Without it, we cannot measure the economic and physical dimensions of a transport system we seek to change. Nor can we measure the impacts of policies or technologies. Both measurements are essential to estimating costs and benefits of policies *ex ante* and to evaluating policies *ex post.*

There are many techniques that can be implemented with Bank assistance. Among those readily available include simple meters that measure kilometers traveled, which were required on all diesel vehicles in Sweden, Finland, and Norway until 1993. Annual safety inspections can be expanded to note annual mileage and at least measure emissions under standard conditions. Remote detection of speed limit violations is already used in Germany and the United Kingdom, while manned-radar measurements are used in many other countries. Soon, road-pricing schemes that charge cars by where and when they travel will be relatively inexpensive. Like electronic tickets to metro systems in some US cities, these schemes can preserve the anonymity of the driver or car owner, who simply purchases an electronic card worth so much against the fees charged to drive in congested or polluted areas. The fees are deducted electronically. The same system could be adapted to a GSM to allow traffic monitors to follow problems in real time, much as large rail systems can be observed from a single board showing the status of each vehicle.

Whatever the technology or survey instrument, Bank experience with energy suggests that funds used to support data gathering and sensing experiments could go along way to both helping prove the systems and to convincing authorities and drivers alike that the systems are fair and reliable. Assistance for in-depth travel surveys and the other instruments mentioned in the list above would pay back in terms of far better information on both problems and results.

Endnotes

10. It must be noted that very few countries have achieved a significant, permanent, long-term change in fuel pricing that was not erased by inflation. Canada is one example, where fuel prices were raised from well below U.S. levels in 1980 to above U.S. levels in 1981 and now remain somewhere between U.S. levels and European ones. Data indicate that the fuel intensity of the Canadian fleet was higher than that in the United States in the early 1970s but lower today, suggestive of the impact of changed prices (NRCAN 1997). But Canada also followed the US CAFE regulations in law and through the sharing of many auto manufacturing plants. The lack of possibility of observing how a given country's car stock (and driving) changed is one reason why many are skeptical about the real power of changes in fuel prices, however.
11. Interestingly, the former West Germany accepted a very large fuel tax increase ($0.70 US/gallon in current 1991 prices) to finance the rebuilding of the former East Germany, and Canada implemented an increase of about $0.50 US/gallon in 1981 prices as part of a significant compromise on provincial/ federal energy policies in the early 1980s. Externalities related to fuel use were not the motivating factors in either case.
12. Of course, such a tax cannot take the place of sound monetary policy, and the mechanisms

of such policy must be in place to insure that the tax is not repealed during other parts of the economic cycle.

13. The United States developed CAFE standards, which were essentially followed in Canada, as well. These assessed a civil penalty to any manufacturer whose sales-weighted test fuel economy in a model year exceeded the standard, which itself began at 16 MPG in 1978 and rose to 28 MPG in the early 1980s, where it has remained. The penalty was proportional to total number of cars sold times the margin by which the limit was exceeded. Margins in one year could be credited to overshooting in another. During the period of higher fuel prices in the U.S., CAFE was not thought to be binding, in the sense that Americans bought less fuel intensive cars than the standards called for, but after 1982, from which time the real cost of fuel began to fall, CAFE was increasingly binding on one or more manufacturers. Their response was to set prices of cars such that enough smaller, less fuel intensive cars were sold to obtain a sales-weighted average that met the standard. Light trucks and vans were subject to a different, more lenient standard. That their share of new light duty vehicle purchases has now approached 50% suggests consumers in the U.S. do want larger cars today, particularly with fuel costs low.

5 Designing a Transportation/CO_2 Strategy for the Bank

There are several issues that ought to be central to any Bank strategy, and we develop them in this section. Following that, we discuss ways of relating to national circumstances. We note that the Bank cannot just insert a transport system—whether through a loan, help with technology, advice, and so forth—in a country, count up the repayments, and walk away. A carefully conceived transport/CO_2 policy framework is needed. This is particularly true for transit, land use planning, and other systems or strategies that interact closely with lifestyles, and where unanticipated and often unintended reactions by drivers, travelers, or shippers can be expected unless policies check spurts in transportation activity.

At the outset we noted that few developing countries are concerned about GHG emissions, particularly local or regional authorities. Still, in some cases, policies designed specifically to address GHG reduction may offer gains for the local/regional environment. Fuel taxes will reduce local traffic somewhat. Biofuels, such as alcohol/gasoline blends could offer significant benefits to local air pollution problems, as would natural gas. Encouragement of local production of clean two- or three-wheeled vehicles, bicycles, clean buses, or small freight vehicles, to meet transport needs and further environmental goals would encourage national and local governments to develop comprehensive CO_2, air pollution, and transport policies.

Actors in a Bank loan process of necessity have different perspectives. The Borrower (the Bank) wants the loan repaid at minimum risk and really examines the financial conditions, which at present do not include accounting for reductions in externalities *per se*. The Global Overlays provide a convenient way for estimating the benefits of the project that accrue to all, not just the borrower/borrowing country. The Borrower will benefit both from the implementation of the loan (say, a government borrowing for a transit system) but also from the reduction in transportation externalities, yet does not necessarily reap these benefits in direct financial terms. The analyst can measure what each of the first two actors "sees" but also must make a number of tricky calculations to estimate both environmental impacts *per se* and their valuation as well.

Finally, the Bank Task manager has not only to balance the first two perspectives using the analysis provided, but he/she also must balance the political, bureaucratic, and institutional or even personal forces that certain characterize any transaction involving millions of dollars, prestige, highly visible projects, and so forth. In this process, it is very important for the Task Manager to identify those aspects of environmental improvement (including GHG restraint) associated with the project and make sure these are not only evident to all parties, but "sold and accepted" by all as a plus in the overall loan process. Otherwise, the real thrust of applying the Global Overlays is lost.

Overriding issues facing any transport CO_2 strategy

The data present herein suggest that in countries with low motorized personal and goods mobility, growth in these activities alone will swamp most attempts to reduce GHG emissions from transport unless either low-CO_2 fuels or low-CO_2 modes truly dominate transportation. So far this has not happened anywhere. Few countries have an incentive to adopt bold strategies like Singapore or Hong Kong vis-à-vis congestion. Still, it is important to have in mind whether the goal is to cause minor changes in transportation activities (and possibly CO_2 emissions) or indeed cause major restraint or even decline. It is crucial to remember that CO_2 is not a key issue for either transportation, environment or energy policy in most DCs or EITs. Nevertheless, the Bank's actions could affect CO_2 emissions from transport directly and indirectly. We can conceive of three different paths or strategies that are by no means exclusive, and mention a fourth for consideration as well.

The first strategy is one of ***abatement***, whereby present-day patterns of transport and emissions are continually attacked and (hopefully) made less CO_2-intensive little by little. This goal is accomplished by chipping away, sometimes piecemeal, at all parts of the **ASIF** equation through requiring marginal changes in the actors, stimulated by price and administrative policies. Each new strategy lowers emissions a bit from where they would have been, but the system still keeps growing and so do emissions. These actions are each justified by modest changes in fuel and transport prices, revenue needs, cost-effective incremental changes to vehicles or systems, and technological developments whose pace exceeds the changes occurring in vehicles that are CO_2 intensive. The overall impact, however, is growth in GHG emissions.

If technologies permitted a radical reduction in CO_2 emissions, either by changing fuels or through greatly improved fuel efficiency, a resulting strategy would actually allow for CO_2 ***elimination***. Such technologies permitting such a large reduction are not yet commercially available, but they are under development, both to bring down costs and to increase the net reduction in CO_2 as well. More likely, however, there will be a significant lowering of the rate of increase in CO_2 relative to the rate of increase in GDP (for a given set of fuel prices). In DCs this path has to be constructed carefully, so that there is not a big rebound effect arising from significantly lower fuel costs, an effect that could make other transport problems worse. If this approach is successful, we will discover the path of restraint. Under this strategy, transport growth continues but development is successively less CO_2-intensive, although CO_2 emissions may continue to grow for a very long time. Note, however, that such a strategy does little to address other problems within the transport sector; congestion, pollution, road wear, noise, and other problems associated with transport may still continue to grow. Eventually, this activity growth may also begin to push up CO_2 emissions, in spite of the radical reductions in specific CO_2 emissions caused by the new technology.

A third approach is to try to define a long-term goal of far lower emissions per GDP than one sees today in the OECD. Curitiba in Brazil, and perhaps Singapore, are examples, but so far, have not been replicated elsewhere. Yet it is worth setting sights on this ***avoidance*** path whereby policies are established to build a low-CO_2 transport system rather than just reduce existing emissions from a high level. It is arguable whether Singapore really succeeded in reducing overall car dependence, or whether Curitiba will remain only half as car-intensive as other Brazilian cities. But in principle, strategies that restrain car and truck ownership and use in the name of sound transportation reform would contribute greatly to vitality of low-CO_2 modes. This is effectively the development that occurred in Denmark and the Netherlands, at least for cars. If this buys significant restraint, then one can expect that the next generation of vehicles, which could be far more fuel intensive than vehicles today, and the next generation of alternative fuels (which could power yet again the entire vehicle fleet in thirty years time) would each reduce emissions more. In other words, if **A** and **S** grow only half as fast in a country (relative to GDP growth), as they did in most of W. Europe in the 1960s or 1970s, and if **I** is cut in half from present values and **F** is eventually cut by more than one half, then one can foresee a system that grows to *avoid* high CO_2 emissions, by as much as a factor of 90 percent lower, per unit of GDP, than we experience today in Europe.

All of these approaches tend to follow the same paradigm of western style transportation development, even if some (like Curitiba or Singapore) appear radical to other communities: reduce transport demand somewhat and try to use less carbon intensive modes, more energy efficiency vehicles, and perhaps less carbon intensive fuels.

A fourth approach, the hardest, is to ask whether OECD patterns, which seem to serve as a goal for transport planning might change. Could this change be dramatic and rapid enough so as to illuminate new ways of providing access on fewer kilometers? These changes could arise from a combination of technology and land use/lifestyles changes. There is serious research into these possibilities examining both travel and freight and raising fundamental issues (FMS 1997; the ECN work; German Enquete Commission "Mobility and Climate" 1995, and so forth), and on more general changes in lifestyles (Schipper 1996; Schipper and others 1989). Car sharing, for example, may eliminate some driving by spreading car ownership over many people; selective tolls on all but the cleanest or smallest vehicles might eliminate many vehicles from commuting or city traffic in general.

It is possible that continued experimentation in select OECD countries or communities might yield stable, low-CO_2 transportation systems (even when all the leakages are counted). To some extent OECD governments have a stake in seeing that this option is pursued, even if it bodes ill for traditional supplies of vehicles, fuels, and much of the transportation infrastructure. Thus the Bank should monitor developments in this regard.

In all of these goals it is assumed that CO_2 *per se* is irrelevant in most countries. But policies closely related to CO_2 may be justified to reduce oil imports and thereby "fix" CO_2 by restraining transportation fuel use or encouraging substitution of natural gas (where available), with lower GHG emissions in most cases. Similarly, policies designed to stimulate production of local biomass fuels because they make economic sense on their own could lead to significant lowering of emissions where these are truly produces of biological processes and not simply "refined biomass" such as U.S. corn-based alcohol. Finally, fiscal measures affecting vehicle ownership would likely put downward pressure on vehicle fuel intensities (or encourage 2 or 3 wheelers instead of cars). This would also reduce fuel use. Note however that all of these policies have other justifications. Other options must be integrated with transport policy reform, land use, or other sectoral reforms for which CO_2 hardly appears as an important factor. Thus any Bank activity must somehow be related to either CO_2 (because it affects either fuel or vehicles) or non-CO_2 measures. In an integrated policy, the non-CO_2 concerns may be boosted by CO_2-justified strategies and vice versa, leading to synergies not present if specific policies or technologies are considered each by themselves.

Bank strategy will inevitably interact with the private sector, the vehicle manufacturers and sellers. Volvo, for example, played a key role in producing buses for Curitiba. They are now working with authorities in Bangalor, India both to establish production there and to grow a bus system for that city (press release from Volvo, March 1997). Vehicle manufacturers are always looking for other opportunities to provide buses in growing markets. More important, the international vehicle manufacturers see developing countries as huge potential markets for both cars and trucks. Therefore they must be brought into any Bank strategy, since their goals inevitably will collide with any policies designed to slow the growth in motorized mobility. At the same time some manufacturers have recognized that without overall measures to rein in uncontrolled growth in vehicle use, transportation in the very countries where they see future markets will become unsustainable. Therefore, partnerships with the private sector are needed now.

This point leads to a final, more sensitive issue. The politics of transport can be sensitive. Consumer/household interests, public and private transport unions, road boulders, road stoppers, even lobbies for bicyclists can be powerful interest groups that sway decision makers. The Bank must decide how to deal with these interests, which, for better or worse, do have the power to force trading best practices for second best, and often for first worst.

In the final analysis, a Bank strategy has to combine options (technologies, and so forth) with tools (policies, measurement, and so forth) that work in a given country in a way that will provoke sure change. This is quantitatively and qualitatively different than a lending policy that simply seeks to provide loans to transport projects for which environmental and transport policy implications are thought to be acceptable. In other words, the Bank can assume a reactive posture — do nothing unless trouble signs arise — or a proactive stance, which means acting to create reform, to open up options that both improve transport system performance at lower environmental cost and abate, restrain, or avoid GHG emissions at the same time. This is truly the essence of a"win - win" policy, but it can only be obtained from the proactive approach.

Issues facing development of a strategy in each region, country, or project

Time frame and timing

At the outset it was noted that the time frame for various measures can be from days to decades; the most important GHG reduction measures act through the replacement of the stock of vehicles, which takes two to three decades. For developing countries, most of the change in the stock is through growth, so strategies affecting principally new vehicles will have a rapid *downward* effect on the average emissions per unit of activity, even if the overall path of emissions is still upward.

Is the client country interested in GHG at all? Is short-term abatement of emissions, medium-term restraint, or long term avoidance the goal? Does the client country want to develop a long-term strategy for sustainable transport? Or is the client interest much more narrowly defined to getting a project completed? If the latter is the case, the Bank probably cannot do much to affect GHG emissions. This does not mean a project should not be evaluated as to its GHG impact, only that the real long-term impact will almost invariably be upward if the project contributes to increased traffic. By contrast, a strategy of purposeful replacement of vehicles and significant changes to the new vehicles entering the stock could have a very profound long-term impact on emissions.

A key element that affects costs is the timing cycles for capital replacement of equipment that makes vehicles (or components) or, in some limited cases, retrofits possibilities of vehicles. Are there local manufacturers who have just geared up for vehicle production, or are they just now considering production? If the later, intervention could change what is produced, particularly vis-à-vis engines and exhaust systems. Are local or international companies bringing in relatively modern vehicle technologies? Or do old designs for knockdown vehicles, or even used vehicles, dominate the market? If the latter, timing may actually be right for persuading car companies to retool for cleaner, more efficient cars. But if they have just tooled up for relatively new designs, they will not be willing to retool yet again.

Equally important for timing is the state of existing cars and trucks. Are consumers and truckers at a point where their demands for vehicles are changing with time and with incomes. In this case it may be difficult to change the direction of motorization in the short or long term. Or are there relatively few drivers, so that significant changes in vehicle taxation and technologies could start motorization in an entirely new direction? For fuel use, the only significant"retrofits" of vehicles were aerodynamic spoilers seen on large trucks and some technologies added to aircraft. Otherwise almost all fuel economy improvement comes from new cars and trucks. This means that vehicle and fuel taxation measures have to be phased in carefully except where there may be overriding air pollution concerns justifying rapid change.

Similarly, have large cities with urban transport problems frozen development patterns (most of Latin America and Asia) or are there potentials for significant new development following models of Curitiba or Singapore? A long-term strategy of replacement and refinement of patterns of settlement and production, which is what most OECD countries face, will yield results only slowly. By contrast, a greenfield development (perhaps as both households and business flee from over-congested megacities) could establish the viability of alternative modes of access tied to significantly less CO_2 per unit of income than seems to be occurring in the megacities of Latin America and Asia. Needed here are real data on new towns: are their transport patterns significantly less transport intensive because of co-location of places to live, to work, to shop, and to play or are the transport levels of inhabitants and workers just as high as elsewhere?

Policy framework and the interaction matrix

What is the scope of action called for? Overall transport reform, GHG measures, or just a minor transport project? Is there room to push a transport project into a GHG abatement framework in a way that will not be costly to the (uninterested) client?

What work is already underway? What policies support that work? Will a project the Bank is considering interact with other developments in a way that will increase or decrease GHG or transportation problems. The Budapest urban transport project shows marginal returns. Of particular worry is the 24 percent decline in both usage and capacity between 1987 and 1993. The real problem is probably burgeoning car ownership and relatively low cost car fuel by European standards. This is not to say that the Bus Company and the environment will not benefit from new, clean, more energy efficient buses. But for the project to have a major impact on transportation in Budapest, policies must also address automobile use, as this dominates the personal transport scene there.

What is the private sector role? In Hungary, as in other Eastern European countries, private importing of used cars skyrocketed after political reform began. These cars tended to be old and more fuel intensive (but technological more efficient) than the much smaller vehicles produced locally. Now, however, world car companies are producing and selling there too and the newer cars, while larger than the previously produced local product, are much cleaner from an air pollution point of view. In this sense the private sector might be seen in a negative role, although the new cars emit much cleaner exhaust than the older ones. But the private sector could assume a more environmentally friendly role. Few realize that for Curitiba, Volvo worked intensively on both the political side (that is, the policies necessary for success) and also invested in the buses themselves, particularly those with three sections. In other words, *when the private sector* *has a stake in the success of low-CO_2, low pollution transportation, it becomes a very pro-active partner itself.*

One way to entice private actors is to use *innovative procurement*, whereby local authorities ask for tenders for a particular vehicle with certain low-pollution properties. Another way is simply to provide a prize for development and marketing of "clean technologies," for example two- or three-wheelers, much as US utilities offered significant rewards to manufacturers of a low-energy refrigerator, which was eventually developed by Whirlpool. This does not mean that private producers will not respond to changes in economic boundary conditions, only that efforts to focus their attention from the beginning are likely to be rewarded both in the rapidity of response as well as lower costs and ultimately popularity of the product.

Geographical framework. Are the proposed actions of national or only local significance? National policies (fuel pricing, vehicle taxation, alternative fuels) can be crucial to supporting local initiatives. If local, do the proposed actions attack major transport problems in a megacity or potentially permit smaller conurbations to avoid such problems? While work in Mexico City or Santiago is important to improve the quality of the air there, modest investments in other areas *before* the pollution situation is virtually irreversible may have greater payoffs by leading to avoidance than investments (beyond basic abatement to clean the air) in the worst affected areas. National authorities may have to develop a kind of "triage" to decide how to best use limited resources (both economic and political) to affect change.

Present situation. Other basic characteristics of the present situation of client countries or regions must be examined. Where motorization is very high it is unlikely that transit or individual alternatives like two or three wheelers can beat back cars without serious policies (such as in Singapore). Where road conditions between cities or even in cities are poor, cars are clearly less attractive than other modes of transport. Where vehicle industries are strong (Korea, Taiwan, Brazil, Mexico) or potentially strong and under development (Indonesia, China), political sentiment to develop these industries for both domestic products and exports may be stronger than any concerns for a balanced program of sustainable transport. Finally, economic growth itself cuts two ways. On the one hand Curitiba shows that a low automobile society can be carved out of a rapidly growing and prospering region.

Vehicles, fuels, or entire systems? In considering technological investment strategies, it is important to distinguish between true "nega-carbon" investments (for example, fuel substitution towards a lower carbon intensive fuel) vs. energy efficiency investments (such as swapping TDI diesel engines for cars, or adding a wind spoiler to a truck to reduce real fuel costs, and so forth) vs. broader investments where energy efficiency is a by-product (such as developing a transit system) vs. really radical redesign (totally new car concepts, like the Daimler Benz Smart car). As noted earlier, many of these options have marginal costs that can be estimated. The trouble is that they are not necessarily options for Bank lending. Nevertheless, the Bank can affect how rapidly they appear on the market if the Bank can affect fuel or CO_2 pricing strategies.

For large-scale investments in vehicle systems (metro, bus systems, aircraft) there are always choices that have modest impacts on fuel intensities) there may be much larger choices affecting the performance, size and overall impact of the system. As with district heating, it may turn out that some branches or extensions of a system simply do not pay because of projected low utilization per unit of fixed or variable cost invested.[14] In any case, the possible CO_2 reduction from large-scale transportation system choices is very hard to predict because the new system itself changes patterns in so many ways. This is again why integrated policies are so important.

Table 6 examines a number of techniques/ technologies and supporting policies for possible relationships with Bank activity, other actors, barriers, and so forth. The various options listed are by no means exclusive, although there is some overlap.

Consider how present Bank activities affect the components in Table 6. Urging changes in fuel pricing or introduction of road pricing has some effect on fuel economy, total travel, modal choice, and possibly alternative fuels development as price signals indicate real costs of both using fuels and releasing carbon. But the Bank has no present mode of affecting vehicle fuel intensities directly, and only affects air pollution in countries with major Bank-related programs. The impact on freight fuel use and GHG emissions is weaker because the importance of fuel pricing to freight activity is less strong, although tough regulations on trucking use could affect the numbers of trucking runs and therefore fuel use. Only in transit development does the Bank play a strong role at present, through financing. But however important price signals are to transport reform, they may not be sufficient to bring forth both the technological responses that would ease GHG problems (that is, among vehicle manufacturers) and to clear up the complex maze of existing regulations and conflicting political and economic interests that may keep many GHG-intensive practices from changing. Hence the need for a pro-active involvement by the World Bank.

Another issue is that implied by the column "regional scope." Bank activity focuses on national or regional projects, such as a railway connecting major regions or a transit system within a region. What about smaller projects with only local public sector interest, like bikeways? Or international ventures that would require both public and private support in many countries, such as wide-scale manufacture of clean two- or three-wheelers? The Bank would not want to encourage a public-sector company do to such private sector work, but how to put the private sector into this business? Finally, what about working with the largest OECD-based automobile companies to encourage them to produce new kinds of vehicles primarily for LDC markets but with applications in OECD countries? These represent new modes of interaction between the World Bank (as a lender), borrowers, and authorities. In the final assessment, such interaction may be the key step for the World Bank if its policies are to have any significant impact on GHG emissions from transportation in developing countries.

First steps in a cooperative country assessment

The first Bank Energy Sector assessments focused principally on supply-side issues with only minimal attention paid to the structure and efficiency of energy use. Similarly, early assessments of carbon emissions focused on emissions by source, with little data on the sectors or uses from which carbon emissions resulted. Most transport assessments focus on quantities that are important for road or transit planning (capacity, traffic flows, number of passengers, aggregate emissions), but again, little on how transport services are actually linked to fuel and emissions.

Box 3 outlines steps that the Bank could take in cooperation with client countries to make a more accurate assessment of this link (see also Zegras and others 1995 IIEC). They reflect experiences with exploring the household sector. Sometimes a simple model suffices. Take for example the "Lisa" model of VTT, Espoo, Finland, prepared for the Finnish Road Authority. This model covers vehicles and veh.-km by vehicle type, fuel, road type and location (such as, rural, urban), CO_2, CO, NOx, and SOx emissions, and so forth. The model can then be

Table 6. Some potential strategies: Role of the World Bank and other actors

Components/ option affected	*Future Bank roles?*	*Other actors who would support*	*Regional scope*	*Potential barriers*	*Bank role in overcoming barriers*	*Impact in 10–20 years*
Technique						
*Vehicle fuel economy (C*E)*	Procurement, Stnds/ Vol. Agreements Financing Test facilities and Development of Local Vehicle options	Large Vehicle Buyers Manfacts/Importer Local University	National Int'l	Interest from major auto companies but fears of higher product costs, consumer acceptance; local trade barriers preventing importation of vehicles or components; low fuel prices	Supporting group purchase; supporting test facilities;	Lower Intensities 25% or more. Depends on fuel and vehicle taxation schemes
Alternative Fuels (F): development, pricing	Analysis, Financing production	Fuel companies, car companies, veh.fleet owners, operators	National, int'l.	Local factions or companies favoring one fuel or another	Assisting "losing interests" find other products to make or market	Biofuels: reduce CO2 significantly
Non-motorized or low-energy transport	Financing bikeways; financing production facilities for 2 and 3 wheelers	Local planning and housing or commercial interests. Investors.	Local	Crowding out from roads, etc., by motorized vehicles	Finance procurement and demon-stration, testing of viability against crowding out	Unknown, but potential large if starting fresh.
Freight facilities (U)	Financing of intermodal facilities to blend truck, rail, and water modes.	Truckers, rail road authorities, major shippers	Potentially regional	Freight companies, unions, shippers, int'l compatibility of systems	?	Build strong intermodal system
Transit development (S)	Financing, analysis of supporting policies	Local authorities, vehicle manufacturers	Local	Conflicts over land-use	Assist with land and right-of-way purchase	Depends on strength of supporting policies
Policies						
Fuel pricing (general, differentiated, i.e., CO2 taxes)	Analysis, Advice	Tax, road, energy authorities	National, local	Political resistance	Developing plans for redistributing revenue	Potentially large rel. expected demand
Km Pricing (A,S) (incl. congestion pricing, etc.)	Analysis; development of measurement, collection systems	Tax, Road authorities	Regional (congest) nat'l for motor-ways	Political resistance, difficulties introducing the technologies	?	Potentially large reduc. In growth in km, vehicle ownership
Cooperation among client countries	Arrange R/D, financing of production projects etc where single country efforts are too small or unrewarding	Virtually everyone, but important to guard against groups in one country resisting what is really in the bests interests of all	Potentially global, not limited to nearby countries	Trade barriers, protection of own vehicle manufacturers or potential manufacturers	Assemble conferences, draft proposed trade agreements	Unknown, but potentially HUGE if low CO2 technologies are developed and fostered to maturity and popularity
Land use planning	Affect sitting of homes, industry, etc. Assistance in planning	Housing, commercial interests; local authorities	Local	Existing land owners or other interests	?	Unknown, but potential large if starting fresh

Box 3
Steps in a transport GHG mitigation assessment—What we need to know

Quantitative Inventories

- Inventory of active vehicle stock, by vehicle type, fuel type, capacity or size (for trucks and buses), by domicile or garage site (large city, small city, rural), and by whether private, government, or commercial
- New vehicle sales, vehicle importing, assembly, or full manufacturing
- Approximate balance of fuel use by vehicle type and region (urban, rural)
- Estimate of veh.-km / year by vehicle type, and estimates of fuel intensity by vehicle type consistent with the fuel balance above
- Estimate of passenger and ton-km by mode, including non-motorized, non-commercial, and mixed modes (such as light trucks, boats, and so forth, carrying both passengers and freight). This must at some point be supplanted by careful survey of travel and freight
- Building of ASIF model for Base Case, with calibration of present situation based on previous steps
- Estimates of test fuel economy of new vehicles
- Any information on actual fuel economy or emissions testing, or monitoring of emissions from roadside locations.
- Fuel prices and taxation, vehicle taxation, import tariffs on cars, parts, used cars, and so forth, as well as existing road user charges, tolls, and so on.

Relatively Complex Qualitative Assessments

- Current land-use regulations and planning tools
- Projections of growth in major settlements, regions of industrial, agricultural or other economic activity, particularly those presenting greenfield opportunities for new transport planning experiments
- Assessment of transport-related revenue needs nationally and locally, and comparison with estimated generation of externalities to see what matches can be made
- Estimates of the impacts of fuel or road taxes on vehicle choice, vehicle use, or fuel use
- Building ASIF model for reform cases based on assessments of how the four components could develop in the region or country of interest
- Backwards calculation of ASIF components to see which combinations (with emphasis on I and F, the two technological components) permit a significant restraint or even reduction in GHG emissions from transportation.

used to simulate future strategies for abatement of any of these pollutants, and, if assumptions are included about price and income elasticities, future fuel use and vehicle-use levels as well.

Endnote

14. The parallel with district heating is important. In terms of recovering fixed costs, DH needs a certain number of customers per km of pipeline and per sq. km of city to make the heavy fixed costs pay. This has been easily met in the centers of cities of Sweden, Finland,

Denmark and much of E. Europe given the calculations used by authorities, but harder to justify elsewhere. A relatively high density of customers is also important to reduce the distribution losses (proportional to distance heat is sent) relative to sales. And district heating, like collective transit, faces bleak prospects when cost-recovery goals lead to rising variable charges which force customers off the system which leads to fewer customers over which to spread fixed charges which leads to more price increases. One fears the same experience in E. Europe today for public transport. As fares are raised and service cut back to reduce economic losses, many fear that more and more users will be driven to their cars, cutting transit system viability even more.

6 Conclusions

Carbon emissions from transportation are growing in all parts of the world, driven by increased mobility, an increasing share of which is provided by cars, trucks and aircraft. While the emissions per unit of output of these modes are still falling in many countries, the overall trends are towards higher emissions. Growth rates in developing countries are much higher than in developed countries, both because of more rapid economic growth and because overall mobility is so much lower in the developing world. Thus the challenge to restrain emission in the Third World is formidable.

World Bank policy can alter these trends, certainly by contributing to a slowing of the rate of growth, and in some cases by contributing to a radical decline in the growth in emissions. In some countries this departure may begin at relative low levels of emissions per capita or per dollar of GNP, as has been demonstrated in some developed countries and in some regions of the developing world as well. The key approach is to "grow" transportation in a way that is less CO_2 intensive in developing economies than is the case in OECD countries. This growth can take place by promotion of non-motorized modes, clean two- and three-wheel modes, and very efficient cars, trucks and other vehicles. Supporting such growth from low levels of emissions today are fuel and road use charges (including carbon taxes) that reflect social costs of additional mobility.

In aiming specifically at GHG emissions, it is important that the cost of emitting carbon be raised. There will be a short term reaction (somewhat less mobility, purchases of somewhat more fuel efficient vehicles, modal switches, and so on) and a longer term reaction (less carbon-intensive vehicles and use patterns, possibly different patterns of settlement.) The uncertainties lie more in terms of what is achievable in the near or medium term with only modest carbon taxes and a business as usual research effort.

Among the key analytical steps that project planners should consider, the bottom-up **ASIF** methodology offers many useful benefits. In addition to tracking present transport and emission patterns into future scenarios, the approach permits planners to identify technologies, policies, actors, and Bank opportunities that truly affect the development of each of these components.

Global Overlays can assist Bank planners in identifying the overall benefits of these strategies in terms of carbon not released. The **ASIF** methodology fits the Overlays approach, but the actual tabulation of data and relationships is complex. Still, it is possible to foresee changes in these components, particularly I and F, that would lead to lower future emissions than otherwise. **ASIF** is a useful way of calculation the reduction in emissions. However, GHG emissions are not the only transportation problems at stake. A larger set of avoided costs from other measures related to transportation reform that also restrain GHG emissions comprise a larger goal for Bank planners. The exact proportion of each benefit depends critically on local situations, because so many externalities and other problems of transportation are related to location and temporal factors. While the CO_2 problem is a global one, the problems that motivate local actors are certainly the growing health costs of air pollution, safety (including dangers to those using non-motorized transport), congestion, and noise.

Nevertheless, the likely small size of the CO_2 benefit relative to other benefits of infrastructure projects suggests that the Bank must take a proactive role in developing low-CO_2 transport systems. While intensive efforts among leading industrialized countries may result in much lower emissions from vehicles, experience with other equipment suggests that unless technologies and policies are tailored now to fit individual client needs (or regional needs), the likely wave of low-carbon transport may not arrive in developing countries until much of the traditional infrastructure and travel and freight patterns seen in the OECD today are laid down. From technology procurement and financing of new approaches to vehicles (and their local manufacture) or truly low carbon fuels to stronger leadership in the use of sound policy tools, as well as provision of technical tools (testing facilities, surveys, and so forth) there is an enormous gap to be filled if developing countries are to restrain the development of carbon-intensive transportation in a way that increases total welfare and well-being. If the World Bank desires to have a major impact on GHG emissions from transportation, it should take a pro-active role in the development and deployment of truly low carbon vehicles and fuels as well as policies that support their success in the marketplace. Such a strategy, if combined with strong transport reforms that restrain the unchecked growth in mobility, could lead to significant reductions in the growth of GHG emissions from transportation in the developing world.

Annex 1

Transportation Activity, Energy Use, and Emissions in IEA Countries—A Brief Review

Transportation energy use in IEA statistics is divided into four aggregates shaped by data availability from fuel supplies: road, rail, water, and domestic air modes, as well as a residual mode that may represent off-road vehicles, special vehicles (like cranes), military, or other uses of transportation fuels. For the four main modes, the analysis focuses on travel and freight separately.

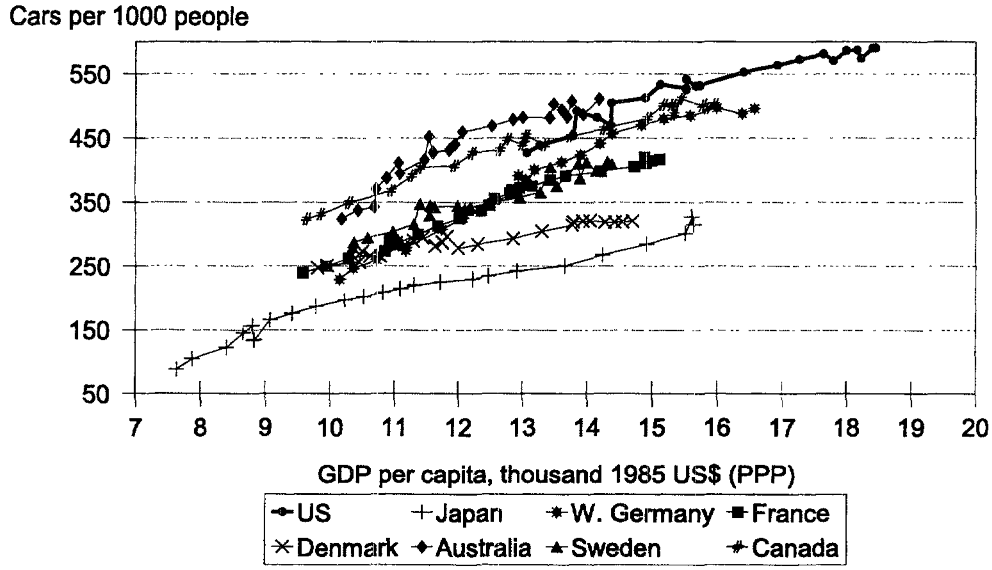
Cars, buses, and trucks account for 70–85 percent of fuel used and emissions in most countries. In a few IEA countries, vehicle energy intensities changed radically (United States and Canada, for example; see IEA 1997 or Schipper and others 1997) or the energy intensity of trucking (energy consumed per ton-km hauled) fell significantly (W. Germany, Norway, the United States in recent years). Where such changes occurred, emissions showed some restraint relative to vehicle activity or mobility. In all countries, the fuel intensity of domestic airline travel fell 45–55 percent from 1973 to 1993, but air travel is still only a small part of the emissions picture for most countries. Consequently, emissions tracked the output of basic transportation services, passenger and ton-km, which in turn tracked GDP. The coupling between each respective service and GDP, or the relative importance of one or the other service, varies significantly among countries, but within a country there were few deviations. This explains why the curves in figure 1 in the text appear so rigid for so many countries.

Regional distribution within a country of traffic and fuel use is important because transport policies and conditions may vary significantly from place to place. Unfortunately, it is very difficult to separate the fuel used in travel within or near cities from that used between cities. This is unfortunate, since the scope of transportation problems in built-up regions is much different than on the open road. As a rule of thumb, however, most rail energy (fuel or electricity) is for intercity travel, while most bus energy is for urban or suburban travel, intercity buses having only one third of the bus travel market or less in most IEA countries. Automobiles are principally used for short trips in and around cities simply because most automobiles are garaged in and around cities and most use is in these short trips. In all we estimate that in IEA countries, at most 20–30 percent of automobile fuel is for intercity traffic. By contrast, the majority of truck fuel is for intercity trucking or uses on the periphery of cities although as much as one third could be used for distribution itself.

Vehicle ownership and use trends

Automobile ownership in IEA countries (figure A.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 only slowly (and tends to fall as vehicle ownership increases), but distance traveled per capita on all modes (figure A.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 equal.

Figure A.1. Automobile ownership and GDP



Includes diesel and LPG vehicles, household light trucks and vans
Source: National transport statistics, vehicle registers, and national accounts.

Figure A.2. Car use and per capita GDP

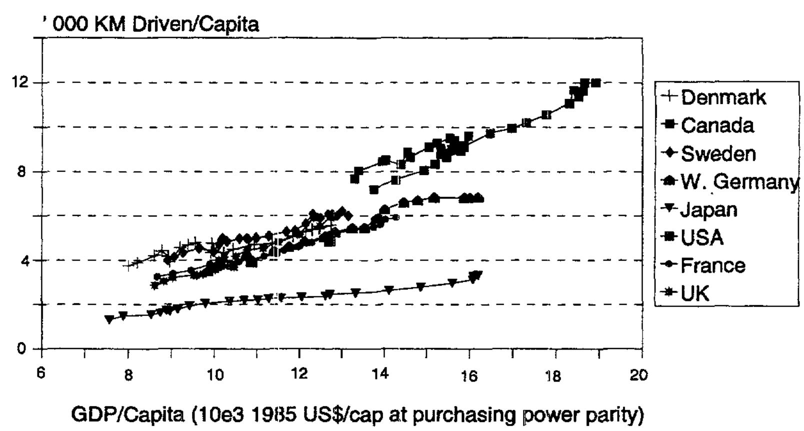
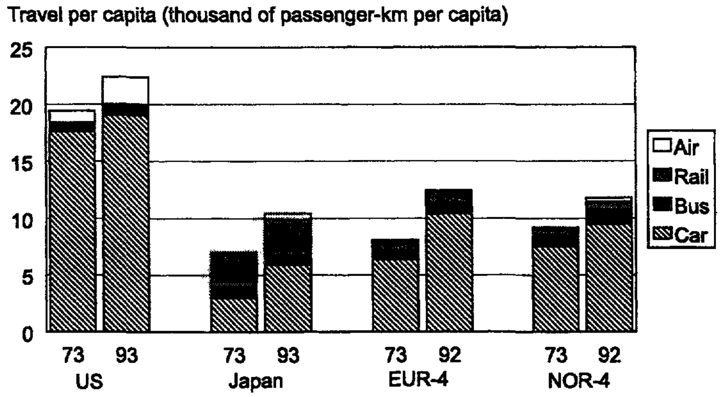


Figure A.3 shows per capita travel by mode in the United States, Japan, Australia, Canada and aggregates of four European countries and four Nordic ones (France, W. Germany, Italy, and the United Kingdom; Denmark, Finland, Norway, and Sweden). Knowing the energy use for each mode we can tabulate emissions of CO_2 in a straightforward way. Figure A.4 shows these patterns (in tons of carbon per capita) for travel (Schipper 1995; Scholl, Schipper, and Kiang 1996).

Figure A.5 shows how the level of freight activity (within a country, including the domestic portion of foreign trade but excluding transit goods) itself is coupled to industrial GDP. Figure A.6 shows the CO_2 emissions patterns for freight (Schipper, Scholl, and Price 1996).

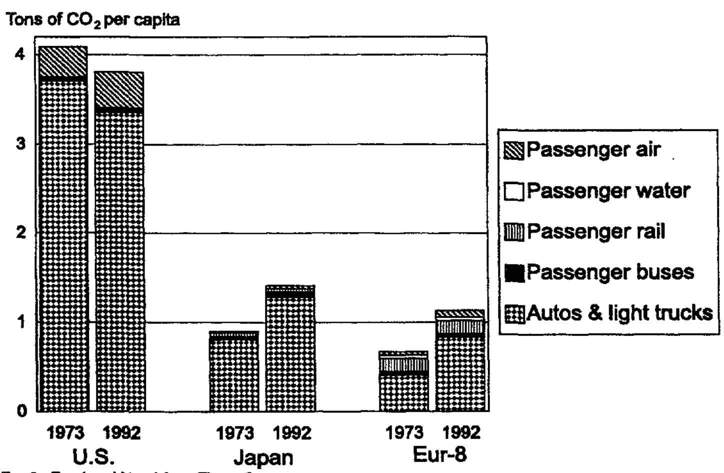
Factors related to vehicle performance are absorbing some of the savings that advances in fuel consumption technology offer. Figure A.7

Figure A.3. Per capita domestic travel in OECD countries



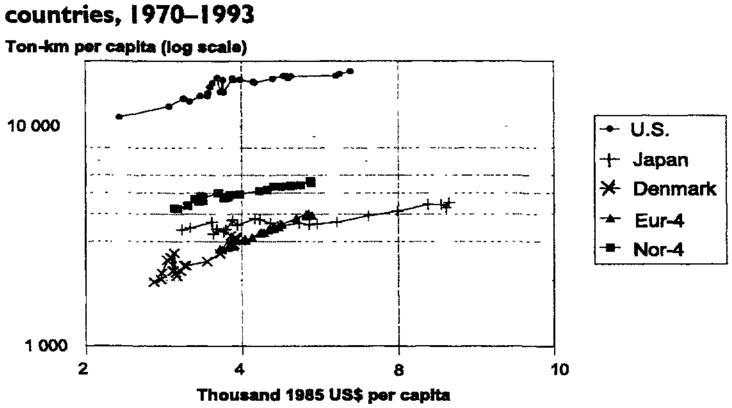
Nor-4: Denmark, Finland, Norway, Sweden;EUR-4: W. Germany,France, Italy, U.K.
Source: National Transport Statistics.

Figure A.4. Carbon emissions from passenger travel



Eur-8 : Eur-4 and Nor-4 from Figure 3

Figure A.5. Domestic freight and industrial in industrialized countries, 1970–1993



Industrial GDP = manufacturing, construction, mining, & agriculture
Source: Lawrence Berkeley National Laboratory.

shows that indeed fuel use per km per unit of new car power, 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 A.8 shows that power is growing steadily, propelled mainly by higher incomes. Thus new technology has made cars (and most other vehicles) more efficient, but only some of the results are now reducing fuel intensity.

Travel patterns are an important element of the picture. Schipper, Figueroa, and Gorham (1995) compared travel surveys from the United States and a number of European countries, work travel (mostly commuting, but some trips within work) accounting for 20–30 percent of travel, services for about 25 percent (except in the United States, where the share was higher) and leisure for the rest. The car dominates the latter two categories, but outside of the United States, the car accounts for only 40–60 percent 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 one third 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. Non-work trips seem to be leading growth in the United States, probably the result of much greater saturation of trips to work by car since the 1970s (over 85 percent of trips, of which only 1 in 10 as a passenger). In Europe, by contrast, there is still a slow increase in both the share of work trips taken in cars. People are not only moving more, but the structure of mobility, in terms of mode and purpose, is changing slowly. Moreover, the average trip in a car remains around 13–15 km for the United States and all the European countries studied. While cars are increasingly built for higher speeds and longer trips, they are still used predominantly for local transportation.

What about the impact of urban form, population density, or other parameters related to the physical layout of cities? The accompanying box, from Schipper (1997), suggests that there is a significant relationship between urban form and total travel. But is not clear whether there are policy variables that can be applied to squeeze people, jobs, services, and free-time into a given physical configuration. Nor does anyone know what configuration reduces travel significantly. The density relationship explored in the Box suggest enormous changes in density (orders of magnitudes) are associated with factors of two to four in travel. Since such large changes in density are associated with many other costs (and benefits) of every day life (land and housing costs, car insurance and parking costs, personal security and other problems associated with large cities, for example), it seems unfair to focus only on the apparent reduction in kilometers of travel as a goal of land-use policies *per se*. Indeed, the Bank's recent Transport

Figure A.6. Breakdown of transport emissions per unit of GDP, 1973 and 1993/94

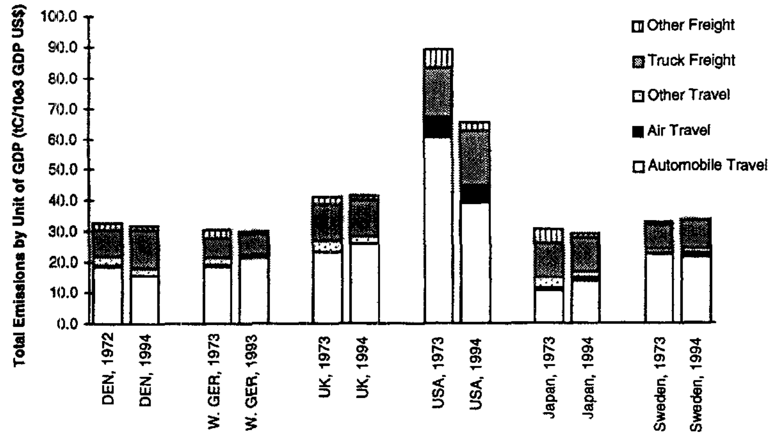


Figure A.7. Test fuel consumption per horsepower ratio

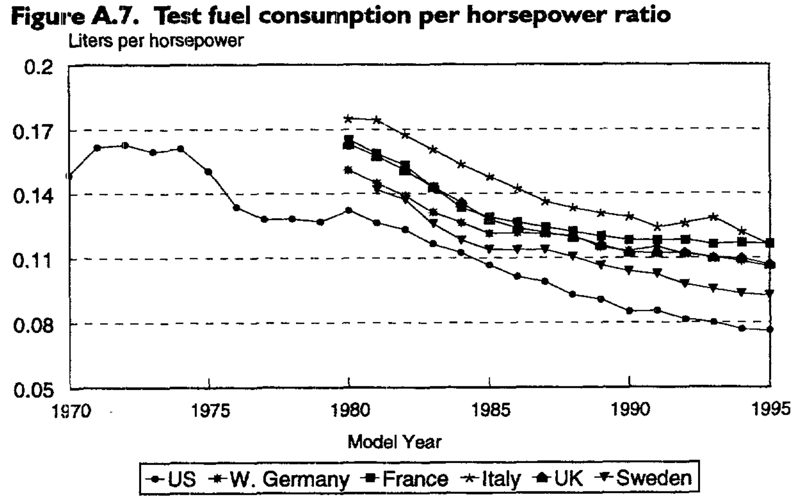
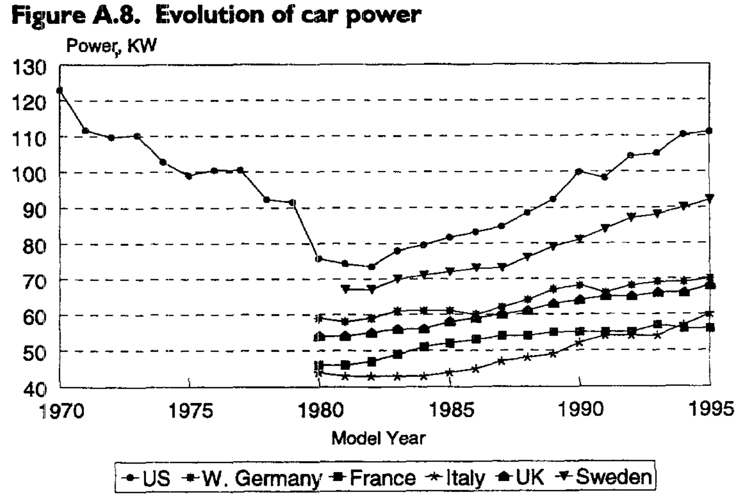


Figure A.8. Evolution of car power



study, taking off from the famous graph of Newman and Kenworthy (1989), shows that their figures for per capita fuel use rise with per capita home area in different cities.

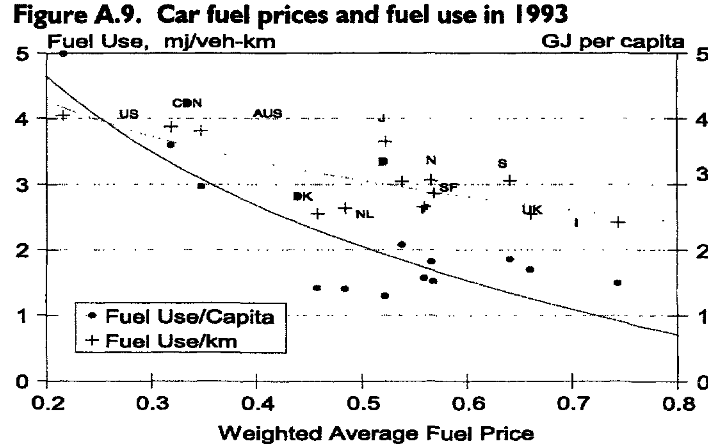
Economic forces and vehicle fuel use

Did higher fuel prices not affect fuel use or emissions? Johansson and Schipper estimated price and income elasticities of car ownership, car use, and fuel consumption based on the same data presented in the previous sections. This was the first international study to take due account of ownership, distance and use as quasi-independently determined from national data sources, including consumption of gasoline, diesel, and LPG by automobiles and for the United States, household light trucks used for travel as well.[A1] They also examined national population density. They summarized their results with "best guess" estimates based on parameters from several models, parameters shown in table 1. The results are typical with those found in the literature (Goodwin 1992). Income elasticities for car ownership near one but falling as car ownership approaches 100 percent among licensed drivers; car use elasticities w.r.t. fuel prices relatively low (0.2-0.4); fuel intensity of the car stock more elastic (0.4-0.7). That the influence of national population density appears so low is likely a function of the local-nature of most car use, where only Japan is truly constrained by very high densities.

The "tax parameter" modeled the relative taxation of new cars based only on a approximation, and found relatively small effects, mostly through the impact of the size of the car on fuel consumption. In fact, it was estimated that one dollar of taxation on fuel would lower fuel used in the car over its life at least four times more than one dollar added to the price of a new car.

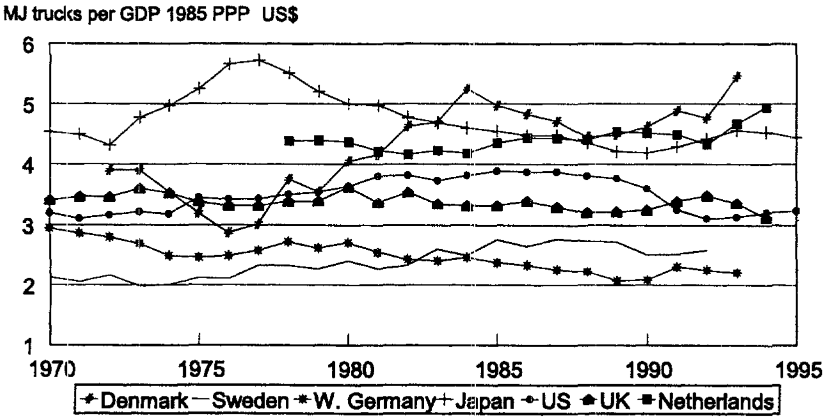
Why was there not a greater price effect on automobile fuel use in IEA countries? It is often forgotten that for most countries, real fuel prices were higher for two brief periods, 1974–77 and 1979–1985, periods too short to expect radical changes in both vehicle technology and use and modal choice to occur, let alone 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 per 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 A.9, 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). The correlation between trucking fuel intensity and truck fuel price is very poor, but the correlation between the ratio of trucking energy to GDP and trucking fuel price, shown in figure A.10, suggests that trucking energy depends somewhat on price, both through modal intensity and through total volume of truck freight shipped. Thus in a cross-national comparison, prices appear to affect both fuel intensity and fuel use in most cases. If fuel use for cars in figure A.11 were normalized by GDP

Figure A.9. Car fuel prices and fuel use in 1993



Source: International Energy Agency and Lawrence Berkeley National.

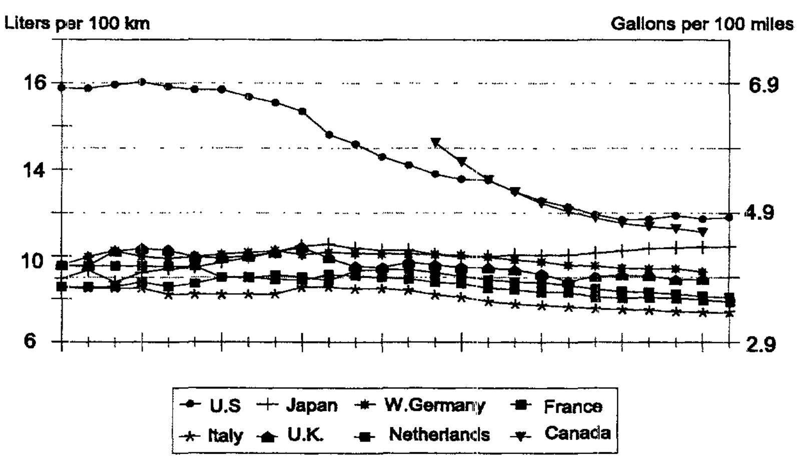
Figure A.10. Truck freight energy intensities in seven industrialized countries



Includes light trucks
Source: Lawrence Berkeley National Laboratory.

Figure A.11. On-road automobile fuel intensity in OECD countries

Weighted Average of Gasoline and Diesel Fuel Intensity



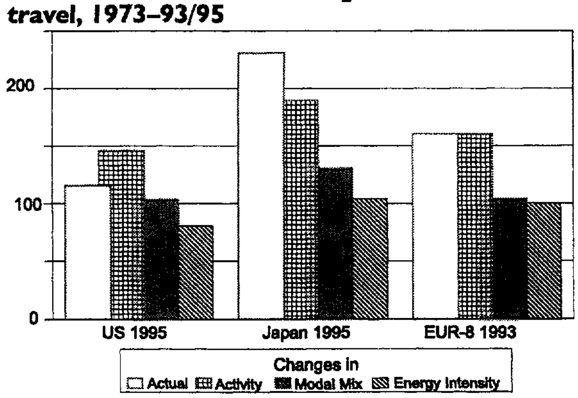
Includes diesel, LPG for all countries; household light trucks for U.S. and U.K.
Gasoline, diesel, and LPG included at energy.

instead of population, the U.S. point would fall somewhat closer into the line.

The fact that car fleet fuel intensities appear to be almost linearly related to fuel prices, and that U.S. 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 A.11). Vehicles are produced by international companies sharing largely the same technologies. Within a country fleet-average automobile size or weight, power, and features differentiate the points for fuel intensity. Vehicle ownership- and use-taxation, including the impact of company car taxation, certainly explain 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). Thus one key option affecting GHG emissions from travel, the characteristics of vehicles, is already shaped by fiscal policies in every IEA country, and likely in every developing country as well.

For travel, higher per capita travel (activity) increased emissions in every country and group depicted with Laspeyres indices (figure A.12). Modal shifts towards more energy-intensive modes (cars, air) increases emissions by as much as 30 percent (in Japan), but in most countries by up to 5 percent. 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. The only major exception was the United States (and Canada, not shown). 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,

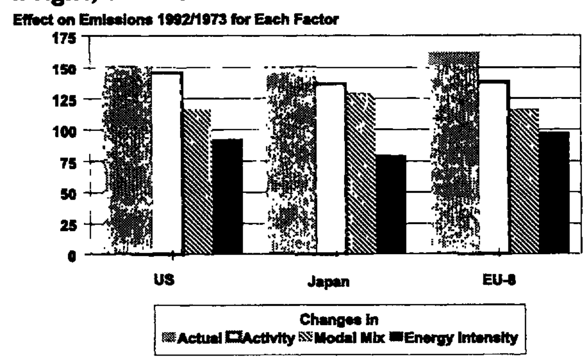
Figure A.12. Changes in CO_2 emissions from travel, 1973–93/95



particularly if the higher emissions in refining of gasoline are included (Delucchi 1997, private communication) 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, and Finland) had only a very small impact on emissions from this sector. Thus by 1993, behavioral factors had clearly increased CO_2 emissions, even after over a decade of relatively high road fuel prices from 1973 to 1985. Closer examination of trends in automobile characteristics shows further evidence of 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).

Figure A.13 decomposes changes in CO_2 emissions for freight in the same way as for travel. In all of the countries studied, absolute emissions increased, and in half of the countries studied, this increase was greater than that of GDP. In a majority of countries, modal shifts (towards trucking) increased emissions, often by more than was the case for travel. In contrast with travel, the modal energy intensities of freight (energy/ton-km) reduced emissions in more than half the countries. The impacts of changes in fuel mix (including fuels used to generate electricity) were again small, except where railroads underwent significant electrification and electricity was generated by low-CO_2 sources. Unlike travel, (electric) rail plays a more prominent role in carrying freight.

Figure A.13. Changes in carbon emissions for freight, 1973–1992



Source: Schipper, Scholl, and Price 1997.

Still, emissions from freight are dominated by those from trucks, so it is this mode, like cars, whose evolution is the most important for that of the sector's emissions.

Looking more closely at the coupling between energy and trucking reveals many surprises. Figure A.13 shows a wide spread in the ratio of fuel use to ton-km hauled, calculated to include local freight (and light trucks or vans) as well as intercity haulage. Since the trucks are produced by large, international firms, difference between the figures shown cannot be very much attributed to actual differences in the energy efficiency of trucks. Instead the differences arise largely because of differences in fleet mix (between large, medium, and light trucks), differences in traffic, and above all differences in the capacity utilization of each kind of truck (Schipper, Scholl, and Price 1997). Empty backhauls can account for as much as 45 percent of large-truck km in some European countries. Actual figures for fuel use/vehicle km of trucks by size class show declines in all countries, but not always in countries where the modal intensities fell. Again, it is changes in the loading and utilization of trucks that affect the overall evolution of each country's freight modal intensity the most. These changes have explanations in the need for just-in time deliveries, the rising value (as opposed to tonnage) of freight, and above all the importance of other costs besides those of fuel in determining the optimal use of trucks.

Endnote

A1. This is not a trivial issue. As Schipper, Figueroa, Dolan and Espey (1993) showed, there are many dangerous circularities in the way data are obtained. They found, for example, that Wheaton's (1982) classic study that included car use in many LDCs used gasoline use divided by the test fuel economy of a few models and the number of cars registered to obtain total km driven. Noting how uncertain total number of cars registered can be even in very mature countries, the huge gap between test and actual fuel economy, and above all the importance of gasoline to trucks and even buses in lower income countries, they warned that such derivations could not give reliable estimates of elasticities or even fuel consumption. They also showed that even in a majority of IEA countries, growth in "gasoline" widely misrepresents growth in automobile fuels, while growth in diesel also misrepresents growth in trucking fuel. For the Johansson and Schipper study, "quasi-independently" determined figures for fuel economy, fuel use, and distance driven were obtained from national sources where it was clear that two of the three were measured or estimated independently and the third derived. For the number of cars (and where significantl vans and light trucks used as household transportation vehicles) they used mid-year averages of vehicles actually in use.

Annex 2

Technologies —Vehicles and Fuels: The Potential Is There, but What Does It Cost?

Best Technologies: Vehicles. These are hard to define without an objective function. Cars that run on solar cells have been crossing Australia and the United States in competitions for years. Do these define"best practices?" Very efficient diesel engines using direct injection of fuel (so called "TDI") are now very popular in Europe, and reduce fuel use compared to ordinary diesels of the same power by as much as 30 percent, although there are problems with NO_x emissions. Chrysler is developing a gasoline-run fuel cell system (based on an on-board reformer, more recently announced by Arthur D. Little), while Daimler Benz is probing other approaches to fuel cells, buying a fuel cell company and announcing plans to build a fuel-cell Mercedes. Ford Motor Co. has since bought into the same fuel-cell manufacturer, Ballard Systems. Neither device has on-board combustion and so there are no thermal losses associated with these systems. Others advocate battery-based electric drive (the GM EV-1), combined combustion/electric hybrids (Toyota, Nissan, for example). Mitsubushi, Honda, and Nissan also place a great deal of hope on direct injection gasoline engines that would reduce fuel use to nearly parity with diesels for the same (or better) performance. Which are best depends both on the full costs to the users as well as the balance of externalities. If a Honda Lean burn gasoline engine reduces CO_2 emissions/km 25 percent over those of a similar Honda without the engine in question, but NOx emissions are higher, is the lean burn "better?" And what if the NO_x is eliminated but the performance is not as good? In other words, it is very difficult to define"best" for most kinds of vehicle technologies because the vehicles themselves have so many technical, environmental, and market requirements.

More difficult, marginal technology costs for vehicles are hard to pin down in order to calculate cost-benefit ratios, even assuming near-ideal pricing of externalities. The reason is that it is difficult to pin point the"marginal technology" and its impacts. For example, the U.S. National Academy of Sciences found that new U.S. cars could average about 34 MPG (7 l/ 100 km) in the early 1990s in a"cost effective" way. A study by Ross and Decicco suggested over 40 MPG (6 l/100km), while a study commissioned by the auto industry pointed towards 31 MPG (7.75 l/100 km). Who was right? Each considered packages of individual options. And the endless arguments over the welfare costs of achieving the U.S. new test average of 28 MPG (8.2 l/100 km) through imposition of CAFE standards revolve very much over measuring the"costs"of reducing fuel consumption, reductions in weight and power (much of which was won back in the longer term), and sacrifices of consumer surplus. "Costs"of new metro and rail systems, new highways are always uncertain, but the cloudiness of the incremental costs of saving energy in automobiles remain a source of controversy. Thus the cost of reducing GHG emissions from changing vehicles is hard to estimate. The same is true for infrastructure developments. And estimating both real costs of changing how vehicles are designed and produced, as well as what they will ultimately cost in the marketplace priced so consumers will buy them, remains the largest economic cloud over the promise of technology.

To be sure there are even more advanced proposals, such as Amory Lovins' "Hypercars" that promise to use very little fuel indeed (Lovins, Lovins, and Weizacker 1997). But just how little fuel these really would need, or indeed which of his many interesting ideas will find their way into real cars in ways that saves significant amounts of fuel, remains to be seen.

AUDI A6 Models (1997)	*1.8 T turbo*	*2.4 Tiptronic*	*2.8 Quattro*	*1.9 TDI*
ENGINE	4 cyl. 20 valve	V 6, 30 valve	V 6, 30 valve	4 cyl. 8 valve
RATING (HP to rpm)	150 @5 700	165 @ 6 000	193@ 6 000	110@ 4 500
TORQUE (Nm to rpm)	210 between 1 750-4 600	230 @ 3 200	280 @ 3 200	235 @ 1 900
ACCELERATION 0 to 100 kmh	9.4	10.2	7.9	12.3
SPEED (km/h)	217	217	234	194
CONSUMPTION at 90/120/town (l/100)	5.9/7.8/10.1	6.2/7.9/12.4	7/8.7/13.1	4/5.3/6.2
RATIO weight/power (kg/hp)	9	8.8	7.9	12.4
Rating for French Taxes	7 hp	14 hp	14 hp	5 hp

Further adding to the difficulty is defining the "base case." For example, cars are becoming more powerful, as noted earlier. On the one hand, the greater the fuel consumption, the more a technology that saves a given share of fuel consumption pays back. But if over the next ten years cars would have increased fuel consumption 5–10 percent to accommodate more power and features, than an investment that saved 10 percent of the fuel only returns fuel consumption to where it was today. And modest-sized cars in Europe are now being offered with air conditioning, which on a small car can increase fuel consumption 10 percent when operating. Thus the base case is difficult to define. More bluntly, we are losing ground slowly as consumers appear to derive greater surplus from more power and features than cost-effective approaches to lower fuel bills.

This point bears explanation. If there are truly equivalent choices (refrigerators differing only by compressor efficiency; houses only differing by the extra pane of glass and molecular coating on windows that filters or traps heat), we might say that the only criterion is whether the extra cost pays back in a sufficiently quick time to interest the consumer. But if a consumer has a limited budget and liquidity requirements, than an investment in more windows might boost her welfare more than the investment in more efficient glazing. Which of the cars is "best practices?" Clearly we need a model that maximizes surplus or welfare, not simply a method for calculating the payback from energy saving. For developing countries this approach is important because growing incomes tends to mean ability to afford larger and more fuel-intensive cars, all else equal.

Best Technologies: Alternative Fuels. Even among alternative fuels the definition of "best" is difficult because of the differences in service. Cars using liquefied petroleum gas (LPG) or natural gas (NG) instead of gasoline give equivalent performance but sacrifice consider space for storage tanks, and NG vehicles have lower range than gasoline ones. Electric vehicles are even less straightforward to compare with an internal combustion engine (ICE). No one claims that a battery-driven electric car is the same as that for an ICE, but the best electric cars perform as well as small or modest ICE except for range between charges. The greenhouse characteristics of electric vehicles, however, depend critically on a full fuel cycle analysis of both the gasoline and electricity, the charging routine of the batteries, and so forth. If the electricity is produced from present mixes (coal, some oil or gas) it is possible that there is no greenhouse benefit at all if the electric is compared with a small ICE. Hybrid electrics, by contrast, would easily reach the performance of ICEs, as would likely fuel cell vehicles (FC), and each would offer greater overall efficiency, that is, lower net GHG emissions. But hybrids and FC are still under development. Should the task of the car be redefined to fit the alternative? And energy use in all these alternatives depends on driver behavior. What should the analyst assume? To be sure, true biofuels (that is, ones without a great amount of fossil fuels hidden in the harvesting and processing) would give a real reduction in GHG emissions, but these are still elusive at costs competitive with gasoline or diesel.

Some analysts defined a shadow cost of gasoline or carbon that makes the alternative "cheaper." Sperling and others (1993) took this approach, using technologies of the early 1990s that included battery electrics, various kinds of biomass, natural gas, and other fuels. He found that were the shadow value of gasoline not used as much as $1.00/gallon over its market price, alternatives would pay off. The price of electricity itself was almost irrelevant to the comparison, because most of the cost of using an electric car is for the higher fixed cost.[A2] For other fuels, fuel costs mattered, but so did other vehicle costs.

With present technologies, the incremental costs of using alternative fuels tend to be significantly higher than for gasoline or diesel on an equal energy content basis. Expressed as differentials per unit of carbon not released, these differentials become very large unless the alternative fuel is truly low in carbon, that is, true biomass, or hydrogen produced from solar, renewables, or nuclear sources. If we express the marginal cost of a new fuel in terms of $/gallon of gasoline equivalent of fuel, then we can see how much more the new fuel costs relative to present costs, about $0.60–0.80 at the wholesale, pre-tax price. Of course, this requires us to model differences in both well-defined fixed costs (like the cost of a natural gas cylinder in the car) as well as costs harder to define, like the value of the loss of space to the cylinder. If we compare these incremental costs to the range of likely reductions in CO_2 emissions, we can arrive at shadow prices of carbon. But these also tend to be large. Since few believe that politicians will accept the value of reducing carbon emissions exceeds $30/ton of carbon (approximately $100/ton of CO_2), we only have a modest incremental cost we can afford to pay for alternative fuels. In terms of the cost per liter of gasoline equivalent, this is usually small compared with retail price levels in W. Europe, for example. Of course, advocates of alternative fuels point to the cost reductions they expect as particular options become popular.

There is another perspective on this comparison. With gasoline prices at approximately $1.25/liter, new cars in Italy on average are significantly smaller and less powerful than in the United States, and consume one third less fuel/km. The average new car in Italy still outperforms "average" electric cars. Does that mean that with an even higher market price for gasoline of, say $2/liter, electric cars would slide into the market with much more ease? We do not know. But it is true that if drivers in Southern California, where a certain fraction of new cars sold by 2003 must be electric, faced significantly higher fuel prices, their choices for new cars would match more closely what is available in electrics, and they might embrace the loss of trunk space and range to purchase CNG vehicles. Or they might choose less fuel-intensive gasoline vehicles. In other words, the first step towards any alternative fuels that affect the performance of cars must be a pricing strategy to first eke some fuel savings out of ICEs running on gasoline or diesel fuels. This strategy also defines the shadow value of reducing gasoline or diesel use by means of alternative fuels, and gives both fuel and car supplies something to shoot at. Unfortunately, most present-day strategies rely on edicts or tax breaks that favor the alternatives: Rather than first declaring the winner, it might be better to better define the loser!

Endnote

A2. This invites the prospect of somewhat higher driving levels, which we argue farther on is only a small effect in developed countries but could be a significant effect in developing countries.

References

Ararki, Y., General Manager, Powertrain Operations Planning, Nissan Motor Co., Tokyo, private. communication.

Barde, J.P. and K. Button. 1990. *Transport Policy and the Environment, Six Case Studies*. London, UK: Earthscan Publications Ltd.

Bennathan, E., J. Fraser, and L.S. Thompson. 1992. *What Determines Demand for Freight Transport?*. World Bank, Working Paper WPS 998 (October).

Braudel, F. 1992. "The Wheels of Commerce." In: *Civilization and Capitalism*, 15th–18th Century. Vol. 2, Berkeley, CA: University of California Press.

CEC (Commission of the European Communities). 1995a. *Towards Fair and Efficient Pricing in Transport—Policy Options for Internalising the External Costs of Transport in the European Union*, Green Paper COM(95) 691 final, Brussels, Belgium.

_____. 1995b. Communication from the Commission to the Council and the European Parliament, *A Community Strategy to Reduce CO_2 Emissions from Passenger Cars and Improve Fuel Economy*, COM(95) 689 final. Brussels, Belgium.

COWI Consult AS. 1996. *CO_2 reduktioner I Transportsektorn. Hovedrapport*. Copenhagen, Denmark: Ministry of Traffic.

Dargay J. and D. Gately. 1997. *Income's effect on car and vehicle ownership, Worldwide, 1960-2015*. Economic research Report.

Delucchi. 1997. Private communication.

Eskeland, G.S. 1992. "Attacking Air Pollution in Mexico City," In *Finance and Development* 29(4):28-30.

Eskeland, G.S., and T. Feyzioglu. 1995. *Rationing can backfire, The Day "Without a Car" in Mexico City*, The World Bank, Policy Research Department, Public Economics Division.

Eskeland, G.S., and S. Devarajan. 1996. *Taxing Bads by Taxing Goods, Pollution Control with Presumption Charges*, The World Bank.

Eskeland, G.S., and J. Xie. 1998. *Integrating Local and Global Environmental Benefits: Mechanisms and Case Studies in the Transport Sector*, World Bank, Global Environment Division, forthcoming.

European Conference of Ministers of Transport (ECMT). 1998a. *Efficient Transport in Europe: Policies for Internalization of External Costs*. Paris: Organization for Economic Cooperation and Development.

_____. 1998b. "Land-Use Planning and Sustainable Urban Travel: Overcoming Barriers to Effective Coordination." Background paper to conference Land-Use Planning and Sustainable Travel. Paris: Organization for Economic Cooperation and Development (forthcoming).

Fouchier, V. 1994. "The Density Concept and its Social Implications." In: Fouchier. V. and Merlin, P., eds., *High Urban Densities: A Solution for our Cities?* Hong Kong: French Consulate and French Institute of Town Planning.

Goodwin, P.B. 1992. "A Review of New Demand Elasticities with Special Reference to Short and Long Run Effects of Price Changes." In: *Journal of Transport Economics and Policy* 26(2):155-170.

Gorham, R. E. 1996. *Regional Planning and Travel Behavior: A Comparative Study of the San Francisco and Stockholm Metropolitan Regions*. Master's Thesis, Berkeley, CA: University of California.

Greene, D., and Y. Fan. 1992. Transportation Energy Efficiency Trends 1972–1992. ORNL 6828. Oak Ridge, TN: Oak Ridge Natl. Lab.

Greene, David L. 1996. *Transportation and Energy*, Eno Transportation Foundation, Inc., Landsdowne, VA.

Greening, L.A., W.B. Davis, L.J. Schipper, and M. Khrushch. 1997."Comparison of Six Decomposition Methods: Application to Aggregate Energy Intensity for Manufacturing in Ten OECD Countries."In: *Energy Economics.*

Greening, L., L.J. Schipper, R. Davis, and S. Bell. 1997."Prediction of Household Levels of Greenhouse Gas Emissions from Personal Automotive Transportation."In: *Energy—The International Journal,* 22(5) 449-460.

Hansen, J.M. 1996. Danish Energy Agency. Private communication.

International Energy Agency, 1997b. *Indicators of Energy Use and Efficiency: Understanding the link between energy and human Activity.* Paris, France. OECD/IEA.

International Energy Agency, 1997c. *Energy Technologies for the 21st Century.* Paris, France. OECD/IEA. 1997.

IPCC. 1996. *Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Changes: Scientific-Technical Analyses,* Cambridge.

IVL 1996. (Institutet för vatten-och luftvardsforskning), Mätning av Utsläpp I verklig Trafik Med Feat-Teknik, Ake Sjödin, Göteborg.

Johansson, O. and L.J. Schipper. 1997."Measuring Long-Run Automobile Fuel Demand: Separate Estimations of Vehicle Stock, Mean Fuel Intensity, and Measured Annual Driving Distances."In: *Transport Economics and Policy.* (September).

McRae, R. 1994. "Gasoline Demand in Developing Asian Countries."The Energy Journal, Vol 15, Number 1 pp 143-155.

Martinot, E., L.J. Schipper, M. Khrushch. 1995. "Energy Demand and Efficiency in Estonia: Structure, Potential, and Policies."In: *Energy Policy.* 23 (3) 217-233.

Meyers, S., L.J. Schipper, J. Salay. 1994."Energy Use in Poland: An International Compari- son."In: *Energy—The International Journal.* 19 (6) 601-617.

Ministry for the Environment (Italy), FIAT S.p.a. 1997. *Agreement of Intent between the Ministry of the Environment and FIAT.* Rome, Italy.

NAS. 1997. Transportation Research Board, Toward a Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology, National Research Council, National Academy Press, Washington, D.C.

Organization for Economic Co-operation and Development (OECD). 1995. *Environmental Taxes in OECD Countries.* Paris, France.

Oum, T. H. 1992. "Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates : an Interpretative Survey."In: *Journal of Transport Economics and Policy* 26(2):155-170.

Peake, S. 1997. *Vehicle and Fuel Challenges Beyond 2000: Market Impacts of the EU's Auto Oil Programme.* London, UK: Financial Times Automotive Publishing.

Peake, S., and L.J. Schipper, International Energy Agency (IEA). 1997a. *Energy Policy Making for Transport and Climate Change.* Paris, France. OECD/IEA.

Pearce, D., and others. 1996. *The True Costs of Road Transport.* London, UK: Earthscan.

Schipper L.J., and S.T. Meyers. 1983."Energy Use and Efficiency in Kenya,"In: *Energy Policy.* (September).

Schipper, L.J., S. Bartlett, D. Hawk, and E.L. Vine. 1989. "Linking Energy Use and Life-Styles: A Matter of Time?"In: *Annual Review of Energy* (14). Palo Alto, CA: Ann. Revs. Inc.

Schipper, L.J., R. Steiner, P. Duerr, An, F., and S. Stroem. 1992. "Energy Use in Passenger Transport in OECD Countries: Changes between 1970 and 1987." In: *Transportation,* 19:25-42. 1992.

Schipper, L.J., M.J. Figueroa, L. Price, and M. Espey. 1993."Mind the Gap: The Vicious Circle of Measuring Automobile Fuel Use."In: *Energy Policy* 21(12):1173.

Schipper, L.J., and G. Eriksson. 1995."Taxation Policies Affecting Automobile Characteristics and Use in Western Europe, Japan, and the United States."In: *Proceedings of 1993 Workshop "Sustainable Transportation,"*Washington, DC: American Council for an Energy-Efficient Economy.

Schipper, L.J. 1995."Determinants of Automobile Use and Energy Consumption in OECD Countries: A Review of the Period 1970-1992."In: *Annual Review of Energy and Environment,* (20) Palo Alto, CA: Ann. Revs. Inc.

Schipper, L.J., M.J. Figueroa, and R. Gorham. 1995. *People on the Move: A Comparison of Travel Patterns in OECD Countries.* Institute of Urban and Regional Development, University of California, Berkeley, CA.

Schipper, L.J., M. Ting, P. Khrushch, P. Monahan, F. Unander, and W. Golove. 1996. *The Evolution of Carbon Dioxide Emissions from Energy Use in Industrialized Countries: An End-Use Analysis.* LBL-38574. Berkeley, CA: Lawrence Berkeley Laboratory.

Schipper, L.J. 1996."Life-Styles and the Environment: The Case of Energy."In: *Daedalus* 125 (3, Summer 1996) 113-138.

Schipper, L.J., L. Scholl, and L. Price. 1997. "Energy Use and Carbon from Freight in Ten Industrialized Countries: An Analysis of Trends from 1973 to 1992."In: *Transportation Research–Part D: Transport and Environment* 2(1): 57-76.

Schipper, L. 1997. "People on the Move and Goods on the Go": A Research Program at Lawrence Berkeley National Laboratory.

Scholl, L., L.J. Schipper, and N. Kiang. 1996. "CO_2 Emissions from Passenger Transport: A Comparison of International Trends From 1973-1992". In: *Energy Policy,* 24(1): 17-30.

Small, K.A., and C. Kazimi. 1995. On the costs of air pollution from motor vehicles. *J. Transp. Econ. Policy.*

Sperling, D. 1994. *Future Drive: Electric Vehicles and Sustainable Transportation.* Washington, DC: Island Press.

Sperling, D., and M. Delucchi. 1993."Alternative Transportation Energy," Chapter 4, 85-141. In: *The Environment of Oil, Studies in Industrial Organization,* Richard J. Gilbert, ed., Kluwer Academic Publishers, Boston/Dordrecht/ London.

Steen, P., and others. 1997. *Faerder I Framtiden* (Trips in the Future), FMS (Research Group for Environment and Society) and Swedish Board for Communication and Transportation Research.

Westling, H. 1995. "Market Acceptance Process", IEA DSM Agreement, Annex III.

Wheaton, W.C. 1982. The long-run structure of transportation and gasoline demand. *Bell J. Econ.* 13(2):439-54.

World Bank 1997. *Guidelines for Climate Change Global Overlays.* Environment Department Paper no. 47. Washington, DC, The World Bank.

World Bank. 1996. *Sustainable Transport: Priorities for Policy Reform.* Washington, DC, The World Bank.

World Bank. 1994. *Chile—Managing Environmental Problems: Economic Analysis of Selected Issues,* Environment and Urban Development Division, Country Department 1, Latin America and the Caribbean region.

Zegras, and others. 1996. *The World Bank and Transportation.* International Institute for Energy Conservation.

Environment Department
The World Bank
1818 H Street, N W
Washington, D C 20433
202 473 3641 202 477 0565 FAX

Printed on 100% post-consumer recycled paper