Incidental Report No. IR98-1
The Royal Society of Canada, 1998

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Summary of a Trilateral Workshop

by the **Steering Committee on Atmospheric Change and the North American Transportation Sector** *of the* **National Research Council** *of the* **National Academy of Sciences**

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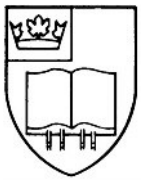

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Executive Summary

In March 1997 a workshop was held in Washington D.C. that convened a wide variety of experts from Canada, Mexico, and the United States to examine the relationship between the North American transportation sector and atmospheric change. This activity was meant to provide a broad overview of the issues involved, to help establish the groundwork for a truly comprehensive assessment, and to develop a stronger working relationship among the three countries for addressing these issues.

Workshop participants discussed the central role that transportation systems play in the current structure and future growth of the economies of all three countries. Recent trends in passenger and freight transport were considered, as were the range of technological, economic, and demographic forces that will influence the evolution of the transportation sector in the coming decades.

Speakers reviewed the many changes in atmospheric composition that result from transportation activities. Emissions from vehicles contribute to the local and regional scale air pollution (e.g. smog, particulates, and acid rain), and to the buildup of greenhouse gases on a global scale. These atmospheric changes can have detrimental impacts on ecosystems, climate, and on human health and well being.

Much of the workshop was devoted to the consideration of strategies that can be used to help the transportation sector evolve in a more environmentally sustainable manner, including improvements in vehicle design and changes in individuals' transportation use decisions. Technological improvements are being fostered through ongoing research and development efforts, for example, in the Partnership for a New Generation of Vehicles program. Participants debated the merits and feasibility of different options for influencing individuals' transportation choices including: providing economic incentives to drive less and to buy more efficient vehicles, improving and promoting mass transit, using land use planning to reduce travel demand, and educating the public about the merits of ‘sustainable' transportation options.

Participants identified many issues related to transportation and air quality that require additional research, as well as many scientific, technological, and policy issues which could benefit from more collaboration and information sharing among Canada, Mexico, and the United States. It was also recognized that addressing these problems in a comprehensive manner requires better integration between the transportation and atmospheric science communities, including sustained collaboration in research and modeling studies, policy development, and education.

Preface

In March 1997 a workshop was held in Washington D.C. that convened a wide variety of experts from Canada, Mexico, and the United States to examine the relationship between the North American transportation sector and atmospheric change. The workshop was sponsored by three divisions of the U.S. National Research Council (NRC) — the Board on Atmospheric Sciences and Climate, the Transportation Research Board, and the Board on Energy and Environmental Services, and by the Academia Mexicana de Ciencias, the Canadian Climate Program Board, the Global Change Program of The Royal Society of Canada, and the Commission for Environmental Cooperation, a body established under the North American Agreement on Environmental Cooperation.

The three-day workshop brought together scientists, economists, engineers, policy analysts and others from the many diverse communities that share an interest in this issue, including academia, industry, non-governmental organizations and the governments of the three nations. The workshop was organized as a series of panel discussions which addressed, in broad scope, the following questions:

- What is the importance of the North American transportation sector to the growth and integration of the three countries' economies?
- How will technological, economic, demographic, and lifestyle changes drive the evolution of the North American transportation sector in the coming decades?
- How has the North American transportation sector contributed to atmospheric changes on the local, regional, and global levels?
- What are the impacts of these atmospheric changes on climate, ecosystems, and human health?
- What are the most effective policies and programs that can be undertaken to help the transportation sector develop in a more sustainable manner, either through technological change, or through changing individuals' use decisions?

The objectives of the workshop were to identify areas of agreement and issues of contention among the participants, to outline research activities that would be necessary to resolve the identified controversies, and to explore opportunities for the three countries to work together in research and mitigation activities. This program was not intended to provide a complete, detailed review of all the important transportation and atmospheric change issues, many of which constitute entire fields of study in and of themselves. Rather, the aim was to provide a broad overview of these issues and to help establish the groundwork for a truly comprehensive, integrated assessment.

Although significant efforts were made to include a wide diversity of viewpoints and to equally represent all three countries at the workshop, not all points of view were ultimately covered. A large fraction of the information that is available, and which was presented, focuses on the United States. It should also be noted that most of the workshop discussion focused on road transport, because this accounts for over 80 percent of all transportation energy consumption in North America.

The workshop was organized by an NRC steering committee, supporting NRC staff, and several additional representatives from Canada and Mexico. This summary report, which is based largely on the notes compiled by the rapporteurs at each workshop session, provides a brief overview of the presentations and discussions that took place at the workshop, not a verbatim account of what was said by each speaker. No attempt was made to reach a consensus on recommendations or conclusions, either among the workshop participants or among the steering committee.

Publication of this report was financed by the Transportation Systems Branch of Environment Canada.

Introduction

The development of transportation infrastructures has played a key role in the industrialization of national economies and the development of a global economy. Rapid and economically efficient transportation of passengers, raw materials, and finished goods has become essential to the functioning of the linked economies of Mexico, the United States, and Canada. Although the transportation systems of these countries have brought great economic benefits, they also have led to considerable environmental costs. Emissions from this sector produce local and regional air pollution such as photochemical smog, particulates, and acid rain. On a global scale, the transportation sector contributes to the continued buildup of greenhouse gases in the atmosphere.

Over the past several decades, considerable resources have been expended to combat such untoward consequences of transport activity. But many have questioned whether sufficient progress is being made, and whether new approaches may be needed to guide the development of the transportation system in an environmentally sustainable manner. This issue is becoming more important in developing countries such as Mexico, which are increasingly adopting more energy-intensive technologies. The issue also remains high on the policy agendas of industrialized countries like the United States and Canada, where continued increases in passenger and freight transport are offsetting the environmental gains made by improved technology.

There is, of course, much work being done to analyze the pollution problems caused by the transportation sector. But much of this work tends to be compartmentalized, considering discrete parts of the overall problem, i.e., specific pollutants, specific impact end points, single modes of transportation, or relatively short time horizons. This trilateral workshop was organized as a first step in developing a more comprehensive understanding of these issues. Workshop participants sought to anticipate how the structure of the North American transportation system will change over the next several decades, and what would be the impacts of these changes on the atmosphere and, in turn, on human and ecosystem health. They sought to address the following questions about the transportation sector — what is the probable path and the desirable path of evolution, and how do we put the right elements in place to ensure that the desirable path is the probable path?

The Economic Importance of the Transportation Sector in North America

Damian Kulash, of the Eno Foundation, talked about the ways in which the North American transportation system provides vast economic benefits to the United States, Canada, and Mexico. From a historical perspective, transportation systems have played a central role in opening up new areas for development. They have been a catalyst for economic activity, and have served as a key factor in enhancing economic productivity. Transportation investments influence where economic growth happens and how much growth occurs. Most every facet of modern society relies on transportation to some extent, and many industries, such as catalog businesses and overnight package delivery, are almost entirely built around the transportation system.

In the future, continued growth in transportation services will likely occur in the United States and Canada, and will certainly occur in Mexico as it continues to develop economically. Because of the growing integration of these three countries' economies, particularly under NAFTA, transportation will play an increasingly important role in our shared economic future. Kulash noted that, in particular, maintenance and improvement of interstate highway systems may be of prime economic importance. Also, intermodal freight traffic is one of the fastest growing parts of the overall transportation scene, and thus greater attention needs to be paid to better integrating the road, rail, aircraft, and shipping transport systems.

In the United States, over $1,150 billion (about 1/6 of the country's GNP) is devoted each year to transportation products and services [1] ; the majority of this investment comes from the private sector. On the individual level, transportation accounts for about 19 percent of consumers' total expenditures, second only to housing. Canada, as one of the most urbanized countries in the world, also is highly dependent upon the transportation sector, and its private vehicle and parts manufacturing industries form a major part of its economy. While Mexico's economy is not nearly as dependent on transportation as the United States' or Canada's, it is rapidly heading in that direction.

[1] *Transportation In America,* 14th Ed. supplement, Eno Transportation Foundation, 1997.

Evolution of the North American Transportation Sector

There are many economic and technological changes that may influence the evolution of the transportation sector in the coming decades. Richard Mudge, of Apogee Research Inc., identified some of these trends including:

- International trade continues to increase, as does per capita consumption of goods and services.
- Light manufacturing and the service industry are the fastest growing business sectors, and most jobs today are created by small businesses.
- New paradigms for how business operates, such as less bulk inventory, just-in-time delivery, and dispersion of production facilities mean that transportation is becoming more specialized and is often contracted out.
- There is increasing use of Intelligent Transportation Systems (ITS), which use new computer and communications technology, global positioning systems, and automated vehicle identification to prevent accidents, to smooth the flow of traffic, and to develop more targeted transport pricing.
- The telecommunications revolution may change many patterns of work, although it is not clear at this point if it will substitute for travel or stimulate more travel.

Alan Pisarski discussed the demographic trends that will alter the transportation sector in the coming decades. In the United States, stabilizing forces include the fact that neither the population nor the size of the labor force is projected to grow significantly; also, certain segments of the population (white males) have reached saturation in the number of new driver's licenses. Other forces will lead to more growth in the use of personal passenger vehicles; in particular, the percentage of women, minorities, and immigrants who are licensed drivers will all likely continue to increase. At this time, the number of vehicles actually exceeds the number of drivers.The majority of American households have two or more vehicles, and most future growth in car and light truck purchases will be from multi-vehicle households.

Pisarski also reviewed some discouraging transportation trends in the United States with regards to fuel conservation. From 1980 to 1990, 22 million drive-alone workers were added to the roads while car pooling rates dropped sharply. Use of transit remains stagnant or is declining in most areas. Cities are continuing to spread out as jobs are now following people to the suburbs, and these suburban-suburban flows dominate growth in traffic. Ken Ogilvie, of the Ontario Roundtable, noted that Canadian cities like Toronto are also heading towards this urban sprawl model. In the newer suburban areas, vehicle ownership is almost twice as high and there are three times as many ‘lane-kilometers' of roads per capita than in the more mature, built-up areas.

Lee Schipper, from Lawrence Berkeley National Laboratory, explained that recent auto efficiency trends (for the United States) are discouraging as well. The fuel efficiency of new cars steadily improved from 1970 to the mid-1980s, but has since leveled off (Figure 1). There is a lot of potential for energy savings in the transportation sector; however, it is not happening for several reasons:

- Real prices for gasoline in the United States are lower than they were twenty years ago.
- A significant share of the gains made in improved engine efficiency are going to boost vehicles' power and performance, not to improving their fuel economy.
- There is a mismatch between vehicle design and operation. Most cars and light trucks are optimally designed for long distance travel, yet the great majority of their use is for short, local trips.

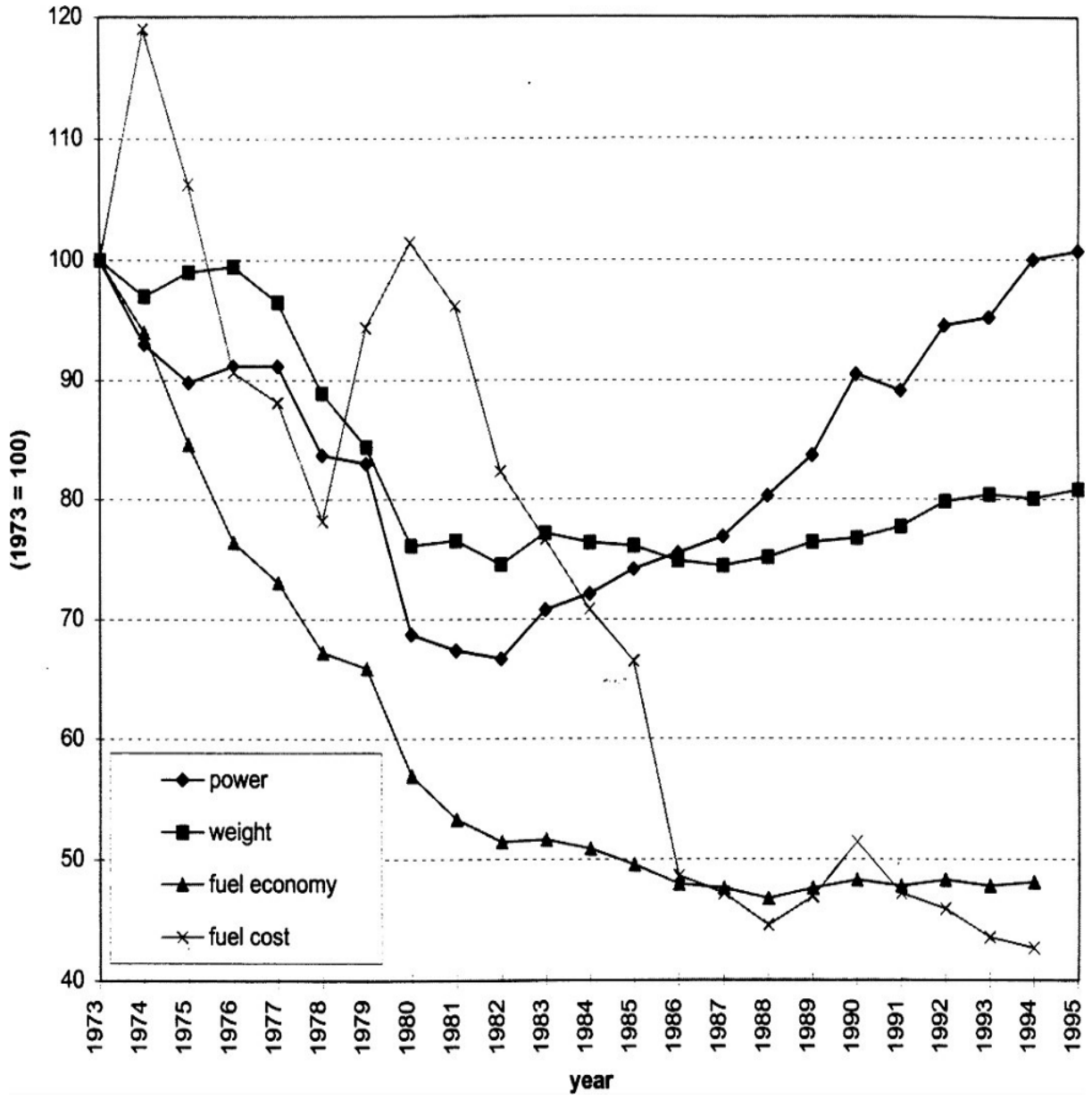

Figure 1. Evolution of the new car fleet in the United States. Shown are relative changes (normalized to the year 1973) in the new car fleet's average maximum engine power, average vehicle weight, average fuel consumption rate, and average consumer gasoline prices (in real dollars). From Lee Schipper, International Energy Agency, based in part on data from the U.S. National Highway Transportation Safety Association.

Mariano Bauer, from Universidad Nacional Autonoma de Mexico, emphasized that while Mexico may be following some of the same transportation trends as the United States and Canada, it is on a very different point in the development curve. For instance, there are more cars in the state of California than in the entire country of Mexico, and the dominant form of transportation in Mexico City is the 'microbus', not private vehicles. This difference is reflected in Mexico's much lower per capita CO_2 emissions (Figure 2). Bauer also reminded participants that, in addition to the many economic, technological, and demographic forces influencing the evolution of the transportation sector, there are less quantifiable cultural forces that play just as big a role in shaping trends.

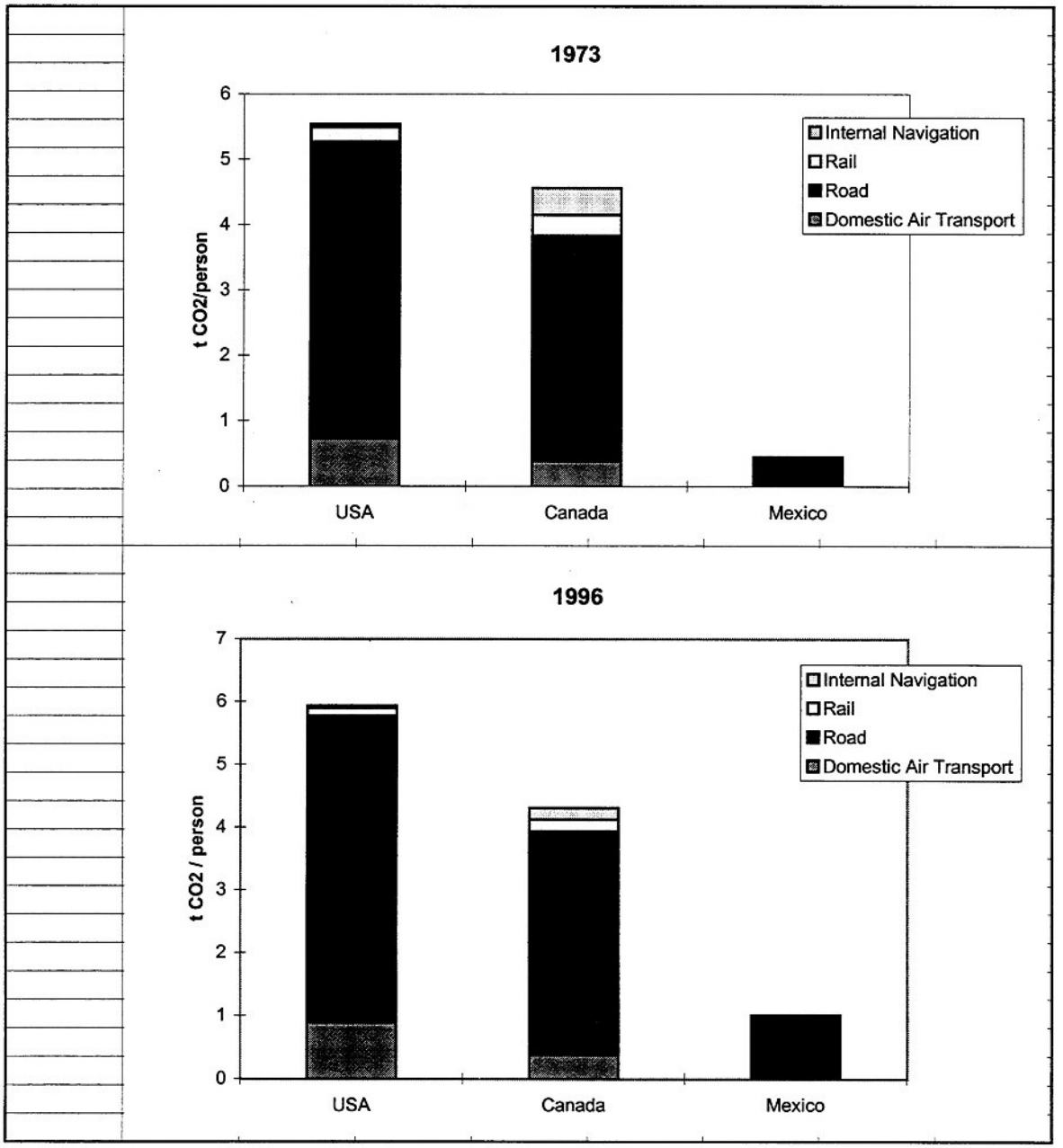

Figure 2. CO_2 emissions per capita, coming from different segments of the transportation sector in the United States, Canada, and Mexico. From Lee Schipper, International Energy Agency.

Atmospheric Changes Resulting from Transportation Activities

When fossil fuels are burned for transportation, gases and particles are emitted which lead to changes in atmospheric composition and functioning on local, regional, and global scales. The large contribution that transportation related emissions make to the total air pollution burden is illustrated by the data in Table 1.

Table 1. Contribution of the transportation sector to total emissions of major air pollutants for 1996 (comparable data for Mexico were not available)

United States [a] (%)		Canada [b] (%)
carbon dioxide (CO_2)	35	32
nitrogen oxides (NO_x)	49	40-80
volatile organic compounds (VOCs)	42	35-55
carbon monoxide (CO)	79	---
benzene	---	60-70
particulate matter (PM_{10})	26	10-40

[a] U.S. EPA,
[b] Environment Canada

Ruth Reck, currently with the National Institute for Global Environmental Change, noted that in Canada and the United States, emissions of many of these pollutants have been dramatically reduced since the early 1970s. Lead has been eliminated as a gasoline additive, and emissions of criteria pollutants such as VOCs, CO, and NO_x have been cut by over 90 percent. Although Mexico City has much higher atmospheric concentrations of many criteria pollutants (Figure 3), it too has managed to reduce emissions of CO, VOCs, and lead significantly in recent years.

However, in all three countries there has been only limited progress in meeting some air quality goals. Secondary pollutants such as ozone and some particulates have proven very difficult to control. Total emissions of greenhouse gases such as CO_2 are increasing. These continuing problems are largely attributable to the following factors: many old, highly polluting cars are still on the road, the total number of vehicle miles traveled keeps increasing, and few or no gains in fleet fuel efficiency have been made since the early 1980's.

Mobile source emissions

Michael Rodgers, from the Georgia Institute of Technology, explained that when looking at mobile source emissions (MSEs), most of the attention is usually given to passenger cars. However, other categories of surface transportation, including heavy and light duty trucks, off-road vehicles (such as farm machinery and construction vehicles), buses, trains, inland marine, and small engines (such as lawn mowers), also contribute significantly to MSEs. There also are several different ‘mechanisms' of mobile source emission to consider:

- tailpipe emissions — both hot-stabilized and startup phase (latter is responsible for a large fraction of emissions)
- evaporative — losses from refueling and fuel storage, losses while the engine is running and immediately after the engine is shut off
- excess — unintentional losses from broken vehicles; deliberate losses when vehicles use extra power for accelerating (emissions increase tremendously during this phase)

Because of this multitude of sources and emission mechanisms, MSE estimates are highly uncertain; emission inventories for some gases are thought to be incorrect by as much as a factor of two. Predicting future emission levels is even more challenging, as one must try to estimate fleet turnover rates, future travel demand, the market penetration of alternative fuel vehicles, and several other factors.

Local and regional scale atmospheric changes

Some pollutants, such as lead, carbon monoxide, benzene, and other hydrocarbons, have relatively short atmospheric lifetimes and thus their effects are generally confined to the local scale. Other pollutants, however, have lifetimes on the scale of days to weeks, and thus atmospheric transport plays an important role in determining their fate. Ann McMillan, from Environment Canada, described these regional scale atmospheric changes, including acidic deposition, photochemical smog/ozone, and particulates. The worst impacts of these pollutants often occur in different states, provinces, or even different countries than where they are emitted. For example, studies have shown that about half the smog pollution occurring in southern Ontario is due to emissions from the United States. Similar pollution transport issues could be expected for the U.S./Mexico border as well.

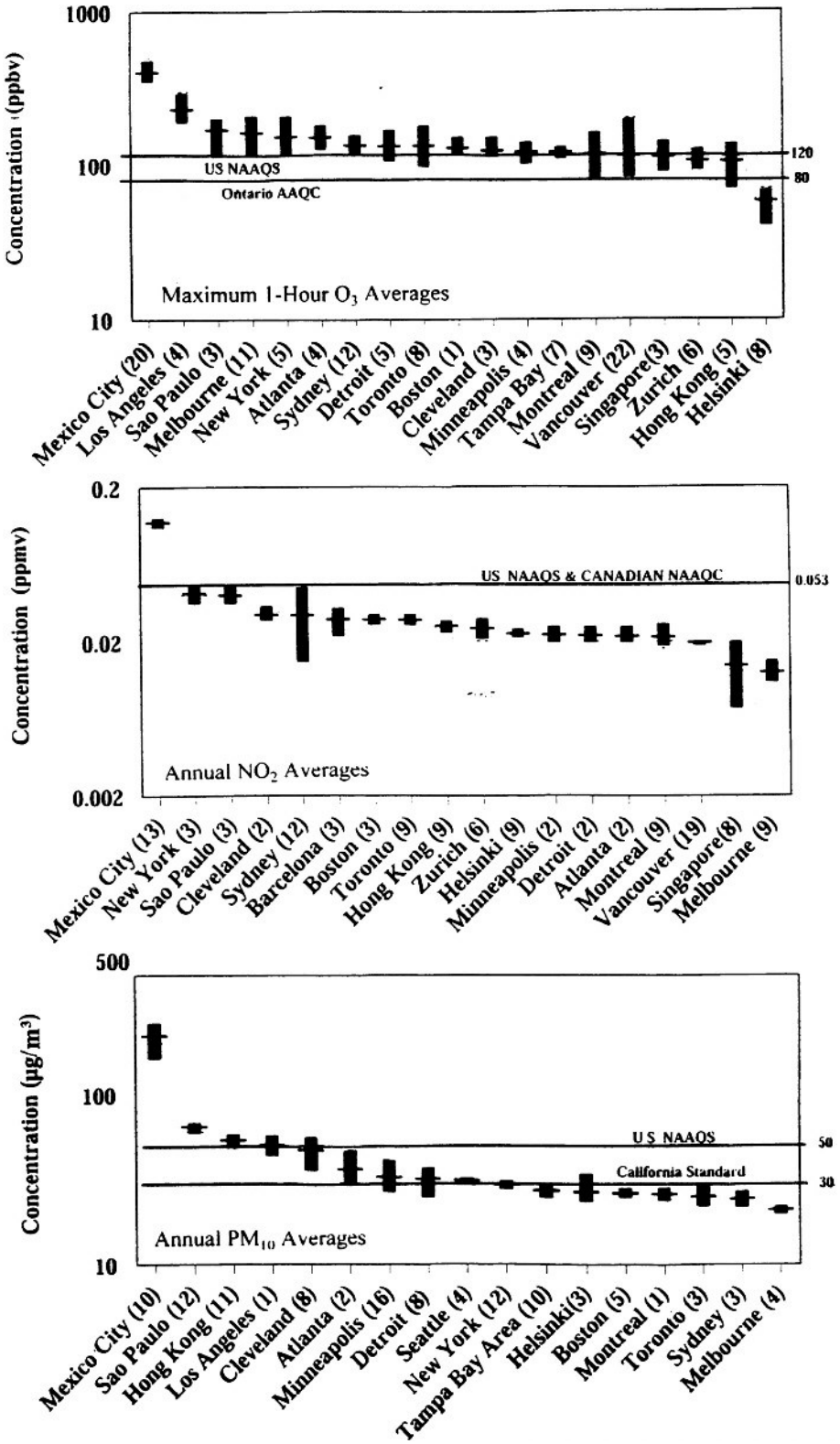

Figure 3. Average measured concentrations of the air pollutants O_3, NO_2, and PM_{10} in selected cities during the years 1988-1993. The values in parentheses denote the number of monitoring sites used in each city. (Note that the U.S. NAAQS 0_3 limit will be changing to an eight-hour average of 80 ppbv.) From the Ontario Ministry of Environment.

Acid rain: SO_2 and NO_x, which are emitted by both transportation related and other sources, are oxidized in the atmosphere to form sulfuric and nitric acid, leading to the well known phenomenon of acid rain. There is a relatively good scientific understanding of the issue of acid rain, and strong policies are in place to mitigate SO_2 emissions in the United States and Canada. With declining sulfur emissions, the role of nitrogen compounds in acidic deposition is now growing more important, and NO_x emissions from the transportation sector are still a major problem.

Photochemical ozone: Tropospheric ozone pollution continues to plague all three countries. Emissions of ozone's precursors, VOCs and NOx, are not easy to characterize, and as the relevant chemistry is complex, drawing simple relationships between precursor emissions and the occurrence of ozone is very difficult. In addition, surface ozone concentrations are highly dependent on local meteorology. There is now a major trilateral research program in place (the North American Research Strategy for Tropospheric Ozone, NARSTO) which is aimed at improving our understanding of the formation and transport of ozone.

Particulates: Particulate matter can affect human health, visibility, and climate and thus is the subject of intense research attention. Transportation related particulate sources include dust from unpaved roads, direct emission from fossil fuel combustion, and atmospheric formation from combustion gases. Measurements of the concentration, size distribution, and chemical composition of particulates are very sparse and need to be improved if we are to better characterize the impacts.

McMillan emphasized that these three issues are closely linked, and to whatever extent possible, assessments, research programs, and regulations should try to handle them in an integrated fashion. Because of the transboundary nature of the problems, they are most effectively addressed on a multinational basis. Michelle Broido, from the U.S. Department of Energy, pointed out that the NARSTO program provides a good example of this multi-national, cooperative approach.

Global scale atmospheric changes

Mary Anne Carroll, a professor from the University of Michigan, explained that the transportation sector also contributes to global scale atmospheric changes including perturbations in tropospheric oxidant levels, increased concentrations of greenhouse gases and aerosols, and stratospheric ozone depletion. Compared to the issues discussed in the previous section, these global scale problems can be much more difficult to address, because the ultimate impacts are usually indirect and difficult to quantify.

Tropospheric oxidants: Oxidants cleanse the atmosphere of many pollutants. The hydroxyl radical (OH) is the primary atmospheric oxidant, but is it hard to measure quantitatively due to its small concentrations and very short lifetime; as a consequence, ozone, which is the primary precursor of tropospheric OH, is often measured as a surrogate. Although tropospheric ozone is usually regarded as a regional scale pollutant, it can be affected on much larger scales. Evidence indicates that there has been a two-fold increase in levels of tropospheric ozone in the Northern Hemisphere since pre-industrial times. However, significant uncertainties remain about the distribution and shorter-term trends of ozone and other oxidants, as well as the impacts their changing concentrations may have on global atmospheric chemistry.

Greenhouse gases and aerosols: Decades of measurements document the accumulation of CO_2 in the atmosphere, and this increase is well correlated with emissions from fossil fuel combustion. The increased radiative forcing due to this build-up of CO_2 (and other greenhouse gases) is relatively well quantified. Atmospheric concentrations of particulate matter also have increased enough to cause significant perturbation of the global radiative budget. However, aerosol radiative forcing, which occurs both directly by scattering incoming UV, and indirectly by affecting cloud formation, is very poorly quantified at this time.

Stratospheric ozone depletion: At this point, both the gas phase and the heterogeneous mechanisms that lead to stratospheric ozone loss are relatively well understood. In response to the Montreal Protocol, the use of CFCs in vehicle air conditioning systems has been sharply curtailed, and now the atmospheric concentrations of these ozone depleting species are decreasing or at least leveling off. But it will still take decades for stratospheric ozone levels over the Antarctic to recover, and meanwhile, there have been measurable ozone losses over the arctic and temperate latitudes.

Carroll noted that, as with the regional scale issues, these global changes are highly interrelated. There are numerous feedbacks between atmospheric composition, climate, UV flux, biological productivity and emissions.

There is much research that needs to be done to gain a comprehensive, quantitative understanding of these relationships.

Surface transportation is not the only contributor to atmospheric change — aviation constitutes the fastest growing component of the transportation sector, and it may contribute to the global scale atmospheric changes described above. Howard Wesoky, from the National Aeronautics and Space Administration, talked about the major research and assessment programs (both in the U.S. and Europe) designed to quantify the atmospheric impacts of subsonic and supersonic aircraft. Aircraft emissions of CO_2, water vapor, and particulates can cause direct radiative forcing, although this effect is estimated to be quite small. A more recent concern is that contrails and particulate emissions may increase the abundance of cirrus clouds, which could, in turn, have significant climatic impacts. There is also concern that emissions of NO_x and other species can perturb the concentrations of ozone in the troposphere and stratosphere.

Impacts of These Atmospheric Changes

Ecosystem impacts of air pollution

Ellis Cowling, of North Carolina State University, presented several examples of how local and regional air pollution can have detrimental impacts on ecosystems. While some pollutants, such as ozone, are known to directly damage plant tissue, the effects of other pollutants are less straightforward. Nitrogen and sulfur compounds can be beneficial nutrients for plant life when provided in the right balance; but in the concentrations that often result from anthropogenic activities, these same compounds have toxic effects on ecosystems. Ozone exposure, acidification, and nitrogen deposition have all been shown to harm soils, surface water, and plant life, and in some cases, to decrease the productivity of crops and forests. However, to quantify these impacts, Cowling explained that we need more research and long term observations.

Of course, there are many ways that the transportation sector impacts ecosystem functioning other than through atmospheric changes. For instance, William Schlesinger, from Duke University, pointed out that roads and highways have altered the land surface dramatically, leading to great habitat loss and fragmentation and to dramatic losses in biodiversity.

Human health impacts of air pollution

A foremost concern about air pollution is the effects it has on human health. Bailus Walker, of Howard University, talked about many of these effects. Lately, there has been great interest in (and controversy over) the health impacts of particulate matter. Long term exposure to particulates may have deleterious effects on lung growth, development, and function, particularly in children. Toxicity appears to depend on particle size, with the finer particles causing more problems. Although there is much that needs to be learned about the mechanisms and extent of this problem, it has been shown in many instances that when the ambient level of fine particulates goes up, so do asthma attacks, emergency room visits, and death rates.

Walker mentioned some of the other pollutants that are understood or suspected to have detrimental impacts on human health. For instance, the health problems caused by carbon monoxide and lead are well known. Ozone is an eye irritant and can penetrate deep into the lungs; recent studies indicate that there is no ‘safe' threshold for exposure to ozone. NO_2 can potentially be a deep lung irritant, however ambient levels are not high enough to cause real damage. The gasoline additive Methyl Tertiary-Butyl Ether (MTBE) is suspected of causing headaches, dizziness, and other symptoms.

In addition to better quantifying the health impacts of each of these individual species, their additive effects should be considered, as exposure is rarely limited to a single pollutant. Also, because most studies to date have focused on the acute effects of air pollution, very little is known about chronic effects. Walker also noted that ambient air pollution health risks need to be placed in context of the total environment that people are exposed to, including indoor air pollution. In concurrence with this point, Richard Gilbert, from Canada's Centre for Sustainable Transportation, drew attention to evidence that in-vehicle levels of several pollutants can be much higher than nearby outdoor levels.

Dr. Victor Borja, from the Instituto Nacional de Salud Publica, explained that in Mexico it is estimated that six percent of acute health problems are due to air pollution, and that 5500 deaths a year could be related to particulates. He stressed that it is important for Mexican researchers to carry out their own health effect studies, as Mexico has different demographics, lifestyles, and ambient pollutant mixtures from the U.S. or Canada.

Impacts of global atmospheric changes

Robert Watson, who is now chair of the Intergovernmental Panel on Climate Change (IPCC), discussed the impacts resulting from global scale atmospheric changes, in particular stratospheric ozone depletion and climate change. Stratospheric ozone depletion leads to increased surface UV-B radiation levels, which in turn can harm human health and ecosystems. The human health impacts include an increase in melanomas (mostly for fair skinned people), greater incidence of eye cataracts, and potential suppression of immune systems. Terrestrial and aquatic ecological systems are also affected by UV-B, and more research needs to be done to understand exactly how ecosystem productivity may be harmed.

Assessing the impacts of climate change is difficult due to large uncertainties in the regional scale changes that may occur. On the global scale, however, most climate

models predict 1 to 3.5 degrees C warming over the next 100 years, which is a faster change than has occurred anytime in the last 10,000 years. Sea level rise and greater extremes of precipitation and drought are likely results of this warming. [2]

These kinds of climatic changes can have dramatic impacts on ecosystems, altering the distribution of forests, water resources, and animal species, and the productivity of agricultural systems. Such changes, in turn, will have important consequences for human well-being, because we depend on healthy ecosystems for so many essential goods and services, such as food, fiber, medicine, soil protection, water purification, flood control, and nutrient cycling. Climate change also could have direct deleterious impacts on human health, due to increases in vector borne diseases in the tropics and subtropics, and increased episodes of heat stress and urban smog. [3]

Watson emphasized that the sensitivity of different systems depends on both the rate and magnitude of the climatic changes. As long as these changes are incremental, it may be possible to adapt; however, unexpected, abrupt climatic jumps are possible and can lead to devastating consequences. The ability of human societies to adapt also depends on the economic resilience of the country affected; the developing nations will likely be most vulnerable. This adds an important ethical dimension to consideration of the climate change issue, because emissions of greenhouse gases are dominantly from the industrialized countries.

[2] *Climate Change 1995: The Science of Climate Change* (IPCC, 1996).
[3] *Climate Change 1995: Impacts, Adaptations, and Mitigation* (IPCC, 1996).

Reducing the Impacts of the North American Transportation Sector

Workshop participants discussed a variety of policies and programs that can be used to help the transportation sector evolve in a more sustainable direction. This includes both technological solutions to improve the emissions and fuel efficiency of cars and social/ economic solutions to change individuals' transportation use decisions.

TECHNOLOGICAL SOLUTIONS: CHANGING VEHICLE FLEET CHARACTERISTICS

Future technologies

Amory Lovins, Director of Research at the Rocky Mountain Institute, talked about the future of car design. He explained that due to recent advances in materials, electronics, software, and manufacturing technology, we are at a 'point of discontinuity' in the evolution of the automobile. He claimed that it is now possible to meet all of our stated goals for auto design — low emissions, high efficiency, power, safety — without having to make trade-offs between these goals. This approach is embodied in the 'hypercar' [4] . Hypercars are built from ultra-light carbon fiber composites rather than steel. They use hybrid electric propulsion systems, low-drag design, and energy efficient accessories. Hypercars have virtually zero emissions, 4 to 8 times the fuel efficiency of today's cars, and as much power and safety as top of the line models out today.

Lovins claimed that, from a production standpoint, hypercars should offer distinct improvements as well. In the long run, production costs should be equal to or cheaper than today's cars because the hypercars are mechanically much simpler, use less building material, and eliminate the need for painting. This could lead to an order of magnitude drop in production time, parts count, assembly time, and investment for tooling and equipment. The biggest barrier to mass production is the fact that the auto industry is so heavily invested in their current manufacturing equipment. Nonetheless, models of the hypercar may enter the market around 1999, and there have been recent announcements of both concept cars and early products.

The hypercars represent perhaps the most dramatic possibility for advance in vehicle design, but a wide range of more incremental new technologies are currently being developed, tested, and used. Fuel cells and hybrid electric technology were cited as particularly promising options for the future. Some of the other technologies discussed at the workshop include new options for energy storage (batteries, ultra-capacitors, flywheels), lighter materials, advanced electronics, and alternative fuels such as hydrogen, natural gas, propane, methanol, and ethanol. In response to a question about the future role of diesel technology, David Green, from Oak Ridge National Laboratory, explained that diesel engines do offer significant advantages in terms of fuel efficiency, but they need to be improved to reduce emissions of NO_x and particulates; this offers another candidate for hybrid technologies.

Most agreed that we cannot predict which of these technologies will eventually emerge as successful. Dan Sperling, from the University of California at Davis, pointed out that one possible outcome of this wide range of new technologies is the rise of specialized, 'niche' vehicles. Under such a scenario, households could have multiple cars, including small limited range electric vehicles for short trips.

Clearly, the technology options exist to make cleaner and more fuel-efficient vehicles. However, Christine Sloan, from General Motors, reminded the workshop participants about the significant hurdles that exist in mass producing and selling these vehicles. Many customers value factors such as cost, safety, power, and reliability more than low emissions and fuel economy. The challenge is to develop technologies that permit vehicles to be both efficient and affordable. The environmental benefits of new technologies must be based on a full life cycle analysis, including consideration of the recyclability of the materials used. Sloan also cautioned that there has not been enough attention paid to making these technologies practical from a manufacturing standpoint, and that production costs must be greatly reduced if the new vehicles are to be cost competitive.

On a similar note, some participants expressed concern over the dearth of effort to develop clean vehicle technologies that are suitable for developing countries

[4] Hypercars: The Next Industrial Revolution; Pub.T96-9; Rocky Mountain Institute; Snowmass, CO.

such as Mexico and China. Sloan responded that 'clean' cars are very difficult to sell to developing nations if they cost more than standard vehicles; the challenge will be to make them affordable so they will penetrate the market and achieve the desired environmental benefits. Other participants felt that it may take some kind of international standards to make the auto industry place higher priority on environmental impacts when selling and manufacturing vehicles to developing countries. There is a United Nations working group trying to harmonize vehicle regulations worldwide; however, some felt that the possibility of this effort succeeding is not high.

Wesoky pointed out that, in contrast to the auto industry, airlines are subject to international emissions standards (on take-off and landing only). Primarily because of economic considerations, aircraft fuel efficiency has continued to improve steadily over time. Most of the improvement has come from better propulsion technology, in particular smaller engine cores that run at higher temperature and pressures, thus requiring less fuel to produce a required thrust. Though NO_x generally increases with higher temperature, innovative combustor design has actually resulted in lower emissions of this pollutant. Current research programs promise as much as a further 70 percent reduction in NO_x below today's regulatory standards in about a decade.

Public/private partnerships

The principal United States policy instrument to promote energy-efficient auto technology is the Partnership for a New Generation of Vehicles (PNGV). Scot Staley, from the U.S. Commerce Department, and Christine Sloan explained that PNGV is an unprecedented public/private partnership program involving many government agencies, national laboratories, universities, the big three auto manufacturers, and several smaller suppliers. The ultimate goal of PNGV is to develop a car that gets up to three times the fuel efficiency of today's cars while maintaining performance, utility, safety, and affordability. Two important operating goals of this program are to bring any new technologies into use as soon as they are commercially viable and to pay attention to design and manufacturing costs as an essential research topic. A few 'concept' vehicles have already been made and are beginning to be sold by some of the major auto manufacturers. However, nothing is on sale yet in the United States that can meet all the PNGV goals.

All of the leadership, management, and technical teams in the PNGV program are jointly run by government and industry. The government objectives are to reduce pollutant and GHG emissions from cars, to reduce our dependence on foreign oil, and to change the balance of trade. Industry's objectives are to provide technology to help the U.S. auto industry maintain global leadership and to address environmental concerns without having to resort to command-and-control regulations. According to Staley, this partnership works because it helps all those involved to meet their objectives.

PNGV was largely viewed by the workshop participants as a highly successful program; however, some general concerns were raised. Staley, Greene, and others stated that the program warrants far greater levels of funding, guaranteed over reasonably long time scales. Sperling brought up the point that 'winner' technologies could be chosen prematurely, leaving good options behind. Some suggested that the program needs to be expanded to be more international in scope; but others disagreed, saying that this would be far too complex to handle. Sloan added that cooperative arrangements should not be *too* cooperative, that is, they should still try to take advantage of competition as a powerful motivating force within the auto industry.

Regulatory tools

In addition to such partnership programs, there are many regulatory tools that governments can use to encourage development of efficient and alternative fuel vehicles. Some of those discussed include: corporate and government fleet quotas; liability limits for companies bringing new products to market; tax credits to manufacturers for selling clean vehicles; tighter Corporate Average Fuel Economy (CAFE) standards, perhaps tradeable between manufacturers.

There were several points of disagreement among the participants about the effectiveness of these different policies. For instance, many people supported strong emission standards, but others stated that this approach was too inflexible and called for some kind of average fleet emissions standards (analogous to the CAFE standards). Some participants indicated that the fleet quotas and regulatory standards should be deliberately set ahead of the R&D curve, to drive the technology forward; but others argued that the public will not accept new regulations unless it is convinced that the needed technology is already available.

One recurring theme of the discussions was that policies for encouraging R&D alone aren't enough. Many environmental benefits have little market value (i.e., many consumers are not as interested in energy efficiency as they are in other features of cars). Government intervention is often needed to provide incentives for industry to sell these clean vehicles and for people to buy them. However, Sperling emphasized that government intervention should be flexible and incentive-based, and should not try to pick winners among the competing new technologies; because we have no way to predict which technologies will ultimately prove the best, diversity and experimentation in regulation is critical.

Finally, it was pointed out that because old vehicles are responsible for such a disproportionately large fraction of pollutant emissions, measures to fix these cars or to remove them from circulation can yield large benefits. Workshop speakers from all three countries attested to the effectiveness of strong vehicle inspection and maintenance programs and retirement/ buy-back programs for old vehicles.

SOCIAL AND ECONOMIC SOLUTIONS: CHANGING INDIVIDUALS' USE DECISIONS

Several speakers emphasized that individual choices about transportation use may ultimately be the most important factor determining the magnitude of impacts of the system as a whole. In particular, when it comes to the challenge of cutting CO_2 emissions, new technology will only get us so far; we will have to also greatly reduce the amount of vehicle travel. However, the freedom and mobility afforded by the personal vehicle has come to be seen as a cherished ‘right' in many countries, and direct attempts to restrict people's driving have not been successful. Thus, the workshop discussion focused on more indirect approaches, including demand management, pricing strategies, and educational measures.

Providing alternatives to the automobile is certainly an important part of the solution, and thus public transit is one of the primary answers that people look to. However, as pointed out by Lee Schipper, this has not proven to be a simple answer. The environmental benefits of transit often depend on how heavily it is being used; for example, in the United States today, an average city bus actually emits more CO_2 per passenger mile than an average car.

Schipper explained that around the world, transit only seems to work as an efficient, dominant form of transport in very large, dense cities — at least an order of magnitude increase in density would be required in most places. Also, non-work trips (for shopping, educational, recreational activities) account for much of the recent growth in vehicle miles traveled, and these activities are almost impossible to serve entirely with public transit. So simply providing the transit systems is not enough, they must be time and cost competitive with the automobile.

Land use controls to increase urban and suburban density and to encourage more compact, mixed-use communities, is a commonly suggested strategy for reducing transportation demand; however, several difficulties in implementing these changes were mentioned: zoning is usually a local issue; major infrastructural/developmental changes can take decades to occur; and planning cities so that people live near their work is complicated by the fact that most households have two workers traveling to different locations. Simpler land use changes include making cities more friendly to cyclists and pedestrians, and minimizing parking availability.

Many workshop participants emphasized the need for full cost pricing of transportation activities. Currently, the cost of transportation does not include the externalities such as accidents, air pollution, traffic congestion and noise, infrastructure development, and ecosystem and biodiversity loss. These externalities can be very difficult to quantify economically, particularly the environmental costs that are intergenerational in nature.

Neil Irwin, from the IBI Group, reviewed a study done in Canada to assess the true costs of different transport modes. [5] External costs in Canada for the urban car, defined to include the costs of accidents and air emissions, were $5.6 billion. Full costs, which also include the price of urban sprawl, parking, congestion, etc., totaled $26.2 billion. To have true full cost pricing, user charges would have to increase 10 to 50 percent for the urban car, 131 percent for urban transit, 258 percent for interurban rail. (The mass transit subsidies are so large due to the fact that they seldom operate at full capacity). It was concluded from this study that full cost pricing would be unrealistically expensive for urban transit and inter-city passenger rail; external cost pricing

[5] *Full Cost Transportation and Cost-Based Pricing Strategies*, IBI Group and Boon, Jones and Associates, Inc. 1995.

would be more appropriate, and would provide incentives to change people's travel behavior, by encouraging less use of single occupant autos and more use of transit, walking, and cycling.

Many participants felt that the most powerful way to influence personal decisions about transportation use is to send the right pricing signals, so that people can make choices that are economically reasonable as well as environmentally benign. In the United States in particular, the current pricing signals are motivating people to drive more — while the costs of driving (in terms of real fuel prices) keep getting cheaper, mass transit is often becoming more expensive. There was some debate about the most effective ways to change these pricing signals.

Raising fuel prices is one of the most direct ways to change pricing signals. Canada and Mexico have tried raising gasoline prices, but in the United States the political difficulty of this option is daunting. Mark Corrales, from Apogee Research, Inc., pointed out that this is a tool of limited effectiveness, as driving seems to be fairly price inelastic. In general, raising fuel prices was seen as a necessary but insufficient part of the solution.

John Flora, with the Transportation Division of the World Bank, and Erik Haites, from Margaree Consultants, Inc., both argued that new car taxes are not effective, because cars in and of themselves do not cause the externalities — driving does. Road or fuel taxes allow you to target the actual behavior that is causing the problem. Congestion pricing, which involves adjusting highway tolls with car occupancy, location, and time of day, was cited as a particularly flexible and directed tool for motivating where and when people use their cars.

The Canadian study mentioned above found that public support for new taxes often depends on the use of the revenue. Most people will support increases in the cost of driving if the revenue is spent to improve local transportation infrastructure or to mitigate air pollution from cars, but not if the money goes into the general revenue.

Schipper observed that even with the appropriate pricing signals, people often won't change their behavior until they are convinced that things have to be different. Climate change in particular does not resonate with most people as an issue they need to deal with personally. Other, more immediate transportation problems such as urban smog and traffic congestion are of greater concern to most people and thus are easier targets to start with. Fortunately, attacking these other transport problems almost always mitigates CO_2 in the process.

APPROACHES CURRENTLY BEING USED IN THE THREE COUNTRIES

An important part of planning future actions to reduce transportation sector pollution is to carefully examine the success of current and past actions. Thus one of the workshop panels reviewed the approaches that have been (and are currently being) tried in each of the three countries.

Canada. Richard Gilbert pointed out that the Canadian and U.S. auto industries are closely integrated, and it is difficult for Canada to act independently in regulating its part of the industry. Nonetheless, the government of Canada recognizes that current transport trends are not sustainable and has been putting a lot of effort into exploring and developing sustainable transportation plans.

Gilbert described a variety of actions taken in Canada. The federal and provincial governments both tax fuel. Taxes are higher than in the United States, but they are still much lower than might be necessary to move people towards sustainable transportation. Inspection and maintenance programs for private automobiles (mandatory in British Columbia and soon to be mandatory in Ontario) seem to be quite effective in maintaining fuel efficiency, even though they are aimed more at reducing local and regional pollution. Ontario levies a large tax on high-consuming autos and has a rebate for the most efficient vehicles; but this has not had a major effect because it applies to less than 10 percent of the cars. There is about twice as much public transit use in Canada as in the United States, which results from a generally more concentrated pattern of settlement as well as higher fuel prices.

Ken Ogilvie noted that recent changes in the political priorities of Ontario's government may affect transit adversely. Provincial subsidies for mass transit are being withdrawn, and more importantly, provincial restrictions on ‘greenfield' development have been lifted, which will likely lead to an increase in the rate of sprawl at the edges of Ontario's urban areas.

Mexico. Mariano Bauer explained that Mexico has experimented with many policies to reduce driving and emissions, and some have been more successful than

others. Charging large highway tolls to reduce driving caused people to travel along back roads instead. Instituting ‘no drive' days, based on license plate number, resulted in people purchasing second cars to get around the restrictions. On the other hand, recent laws requiring new cars to be made with catalytic converters and to use unleaded gasoline have been successful in reducing emissions of pollutants such as lead and carbon monoxide.

The World Bank has funded a major, comprehensive air pollution mitigation program for Mexico City. Carl-Heinz Mumme, from the World Bank, described the following components of the program:

- vehicle measures — centralized vehicle inspection programs were set up, as were a combination of command and control regulations (e.g. mandatory age limits on taxis, retrofits on high-emitting vehicles) and credit lines, so that people can make the necessary investments.
- fuel related measures — the price differential between leaded and unleaded gasoline was lowered; a surcharge was put on gasoline, with the profits going to set up a trust fund for environmental activities.
- scientific measures — strong air monitoring programs, emission inventories, and air quality modeling studies were established, and annual air quality audits are carried out to gauge progress.
- institutional measures — an environmental commission was created to provide a forum for federal and local authorities, energy industry representatives, air pollution scientists, and health officials to all work together in planning policies.

United States. Mary Nichols, with the Environmental Protection Agency (EPA), explained that U.S. transportation and air quality issues can be tightly intertwined with other policy issues, and often require coordination among several federal agencies. For instance, programs promoting the use of ethanol as an alternative fuel involve the EPA and the Departments of Transportation, Energy, and Agriculture. In recent multi-stakeholder, Federal Advisory Committee discussions about mitigating greenhouse gas emissions from mobile sources, there was consensus on the need to simultaneously address three challenges: auto design, fuel design, and vehicle use. However, there is still significant disagreement about which specific instruments are best suited to meet these challenges.

The Clean Air Act (in particular the 1990 amendments) contains a host of regulatory tools to address the issue of mobile source emissions, including tighter emission standards for highway and off-road vehicles, mandates for the use of clean fuels in highly polluted regions, particulate standards for urban buses, fleet quotas for efficient and alternative fuel cars, and strong inspection and maintenance programs. The other major legislation relevant to this issue is the Intermodal Surface Transportation Efficiency Act (ISTEA), which sets policy guidance and funding levels for highway and transit programs.

Nichols explained that some of the most successful and popular programs are those which take a decentralized approach to transportation planning. For example, the Congestion Mitigation and Air Quality (CMAQ) program, a part of ISTEA, provides state and local officials with the means to design and implement programs which are best suited to their communities' needs. This has helped to build up a large portfolio of effective programs for improving and promoting mass transit systems, for encouraging better land use planning, and for reducing transportation demand. A key component to success is providing local planners and decision makers with the financial and intellectual tools they need to make good choices about how to improve their transportation systems.

REDUCING THE IMPACTS — SUMMARY

On the whole, most participants expressed the opinion that there is no single ‘magic bullet' solution that will substantially mitigate the atmospheric impacts of the transportation sector, and that significant changes will require improvements in vehicles, fuels, and infrastructure on the one hand, and changes in the patterns of personal and freight transport on the other hand. These changes will have to be driven by a combination of regulations, economic and social policies, and private/public partnerships.

Ogilvie, as well as several other speakers, emphasized that the success of any of these changes will hinge upon substantial public education and information campaigns. It must be clear to the public what the full range of environmental impacts stemming from transportation are, how personal travel choices affect the problems, and what the options are for cleaner transportation. This kind of education will be needed not only to directly influence transportation use decisions, but also to shore up public support for political reforms and increased R&D funding.

It was also pointed out that these educational efforts will need to take into account the powerful influence of the media and advertising on the public psyche. Most of today's car advertisements tout the virtues of unlimited travel, high power, and the ability to ‘conquer' nature. Changing this message to emphasize the benefits of clean transportation could go a long way towards aiding the market penetration of new vehicles and changing people's use patterns.

Dan Sperling emphasized the need to consider long term goals. While most people want to have both an effective transportation sector and a clean environment, should this ultimately be achieved through universal ownership of pollution-free cars? universal use of transit? greatly reduced travel altogether? Of course, the optimal strategy will often depend on local or regional conditions. Francisco Guzman, from the Instituto Mexicano del Petroleo, noted that modeling studies are thus an important tool for evaluating the effectiveness of different strategies. These models, however, need to be comprehensive in nature, integrating technological, environmental, social, and economic factors, and they must consider the non-linear responses in both social and physical systems.

Mauricio Fortes, from Academia Mexicana de Ciencias, emphasized that these questions about long term goals are particularly poignant when looking at Mexico and other developing countries around the world. Most people in these countries hope to emulate the high-consuming lifestyle of more affluent societies, so the solutions will require not just technological and policy shifts, but paradigm shifts as well.

Finally, Sperling pointed out that addressing these problems in a comprehensive manner requires better integration between the transportation and atmospheric science communities. One immediate benefit of the workshop was simply the opportunity for such a diverse group of experts to share information and learn the ‘language' of each other's fields. But true interdisciplinary cooperation means more than just occasional conferences or consultations, it requires sustained collaboration in research and modeling studies, policy development, and education.

Trilateral Cooperation

Ultimately, all of the issues discussed here have global implications, but many workshop participants believed that it would be wise, and more feasible, for the United States, Mexico and Canada to first look for solutions on a trilateral basis. Whatever happens here, good or bad, will likely become a model for much of the rest of the world. Through the course of the workshop, the following items were mentioned as particularly good opportunities for more collaboration and information sharing among the three countries:

Scientific Issues

- mobile source emission inventories
- air quality monitoring
- atmospheric modeling studies to determine cross-boundary transport of particulates, ozone, acidic species
- understanding the long-term impacts of air pollution on human health and ecosystem productivity

Technological and policy issues

- assessing the successes and failures of different policies used to drive technological development (including cleaner fuels) and to change individual use decisions considering the interplay among zoning, development, transportation, and the environment
- public education/information campaigns
- ensuring that transboundary pollution issues are taken into account when developing environmental, economic, and trade legislation
- developing cleaner technologies for transcontinental shipping of goods

Critical Research Topics

Although almost all of the topics touched upon at the workshop could benefit from further examination, several issues in particular were identified by participants as critical research topics:

Scientific issues

- sources, composition, transport, and sources, composition, transport, and fate of particulate matter
- regional and temporal variations in tropospheric ozone and its precursors
- global distribution and trends of photochemical oxidants and the resulting impacts on atmospheric chemistry
- effects of increased UV-B radiation on the productivity of terrestrial and aquatic ecosystems
- impacts of nitrogen deposition on crops and natural ecosystems
- cumulative, chronic health impacts of pollutant exposure (versus short-term, acute impacts)
- health threat posed by indoor and in-car air quality (versus ambient, outdoor air quality)
- specific health problems caused by inhalation of fine particulates, ozone, air toxics, as well as the additive effect of multiple pollutant exposure
- regional impacts of climate change
- capacity of plant and animal life to adapt to rapid climate change
- coupled effects of climate change and other environmental stressors

Technological and policy issues

- potential for recycling new auto manufacturing materials
- how to make manufacturing of new technology vehicles more practical and cost efficient
- ways to influence the transport mix among road, rail, and air
- socioeconomic impacts of inspection and maintenance programs, fuel taxes, and other policies
- ways to assign economic value to indirect or non-market societal benefits, such as a clean environment
- how to improve mobile source emission estimates based on real driving conditions
- the effects of pricing signal changes on industrial R&D and personal use decisions
- the role of personal values in guiding transportation use decisions and the evolution of the transportation system as a whole

Acknowledgment of Reviewers

This report has been reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee.The purpose of this independent review is to provide candid and critical comments that will assist the authors and the NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The contents of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

Michelle Broido, U.S. Department of Energy
Mary Anne Carroll, University of Michigan, Ann Arbor
Robert Fleagle, University of Washington, Seattle
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John Johnson, Michigan Technological University, Houghton
Michael Meyer, Georgia Institute of Technology, Atlanta
Hugh Morris, Canadian Global Change Program, Delta, British Columbia

While the individuals listed above have provided many constructive comments and suggestions, responsibility for the final content of this report rests solely with the authoring committee and the NRC.

Appendix A: Workshop Program

TRILATERAL WORKSHOP ON ATMOSPHERIC CHANGE AND THE NORTH AMERICAN TRANSPORTATION SECTOR

Sunday, March 23, 1997

4:00 - 6:30 PM **REGISTRATION** — National Academy of Sciences; Washington, DC
2101 Constitution Ave. NW

5:00 PM **RECEPTION in the GREAT HALL**

6:30 PM **EVENING EVENT:**
Alternative Visions of the Automobile of the Future **—** A Discussion
CHRISTINE SLOAN — Technical Director, PNGV Program, General Motors
AMORY LOVINS — Director of Research, Rocky Mountain Institute & Director, The Hypercar Center

Monday, March 24, 1997

8:30 AM **OPENING of the WORKSHOP**
Workshop Chair: F. SHERWOOD ROWLAND

8:45 AM **KEYNOTE ADDRESS:**
DAVID GARDINER — Assistant Administrator for Policy, Planning & Evaluation, U.S. Environmental Protection Agency

9:20 AM **PANEL I: The North American Transportation Sector**
This panel will examine the importance of the transportation sector in North America, the societal and economic forces that will drive its evolution over the next several decades, and the possible outcomes of these forces in shaping its development
Chair: MARIANO BAUER
Rapporteurs: C. MICHAEL WALTON & STEVE PLOTKIN

9:20 - 9:30 **OVERVIEW by the panel chaiR**

9:30 - 9:50 **DAMIAN KULASH — The Eno Foundation**

- What is the present structure and size of the transportation sector in North America?
- How vital is expansion of the transportation sector to further economic development and integration of the North American economies?

9:50 - 10:10 **RICHARD MUDGE — Apogee Research, Inc.**

- What future technological and economic changes are likely to influence the development or operation of the North American transportation sector?

10:10 - 10:30 **BREAK**

10:30 - 10:50 **ALAN PISARSKI — Consultant**

- How will population and income growth, lifestyle preferences and the pursuit of economic advancement affect the structure and functioning of North American transportation systems?

10:50 - 11:10 **LEE SCHIPPER — LBNL & International Energy Agency**

- How does the transportation sector contribute to global change?
- How will emissions from this sector change in response to changes in its structure and operation?
- What are the key uncertainties in future projections of transportation emissions, and how can these uncertainties be incorporated into assessments of future impacts?

11:10 - 11:45 **PANEL DISCUSSION (includes questions from the floor)**

11:45 AM **LUNCH in the GREAT HALL**

1:00 PM **PANEL II: Atmospheric Change**
This panel will examine changes in the atmosphere over North America and globally, the role that the North American transportation system plays in inducing these changes, and how this role may change over the next several decades
Chair: RUTH RECK
Rapporteurs: CLAUDE LEFRANÇOIS & MIKE HEWSON

1:00 - 1:10 **OVERVIEW by the panel chair**

1:10 - 1:30 **MICHAEL RODGERS — Georgia Institute of Technology**

- How does the transportation sector contribute to atmospheric pollution?
- How do emissions from the transportation sector compare in magnitude with those from other economic sectors?

1:30 - 1:50 **MARIA ESTHER RUIZ — Instituto Mexicano del Petroleo**

- What changes in local air quality are occurring in North America?

1:50 - 2:10 **ANN McMILLAN — Atmospheric Service / Environment Canada**

- What changes in air quality on regional scales are occurring in North America?

2:10 - 2:30 **MARY ANNE CARROLL — University of Michigan**

- What continental to global changes are occurring in the atmosphere?

2:30 - 3:10 **PANEL DISCUSSION (includes questions from the floor)**
Speakers plus Additional Panelists:
MICHELLE BROIDO — NARSTO / Department of Energy
MICHAEL MacCRACKEN — US Global Change Research Program

3:10 PM **BREAK**

3:30 PM **PANEL III: Impacts of the Changing Atmosphere**
This panel will examine the range and extent of the effects of atmospheric changes on human health, socioeconomic systems and ecosystems, and how these effects may change in response to the atmospheric changes induced by the future evolution of the North American transportation sector
Chair: THOMAS GRAEDEL
Rapporteurs: MIKE HEWSON & CLAUDE LEFRANÇOIS

3:30 - 3:40 **OVERVIEW by the panel chair**

3:40 - 4:00 **ELLIS COWLING — North Carolina State University**

- What are the present acute and chronic impacts of air pollution on ecological and socioeconomic systems?
- How might these impacts change in response to future changes in air quality?

4:00 - 4:20 **BAILUS WALKER — Howard University**

- What are the present acute and chronic impacts of air pollution on human health?
- How might these impacts change in response to future changes in air quality?

4:20 - 4:40 **ROBERT WATSON — IPCC & World Bank**

- What consequences of climate change and stratospheric ozone depletion for ecological and socioeconomic systems have been identified?
- How might these impacts change qualitatively in response to future changes in climate and stratospheric ozone?

4:40 - 5:30 **PANEL DISCUSSION (includes questions from the floor)**
Speakers plus Additional Panelists:
VICTOR BORJA — Instituto Nacional de Salud Publica

RICHARD KLIMISCH — Association of American Automobile Manufacturers
WILLIAM SCHLESINGER — Duke University

5:30 PM **ADJOURN for DAY**

Tuesday, March 25, 1997

8:15 AM **PANEL IV: Reducing the Impacts: A. Technology-driven policies**
This panel will examine research and development needs, and the potential effectiveness of a range of alternative approaches to stimulate this research and development
Chair: C. MICHAEL WALTON
Rapporteurs: STEVE PLOTKIN & ERIC HAITES

8:15 - 8:25 **OVERVIEW by the panel chair**

8:25 - 8:50 **DANIEL SPERLING — University of California-Davis**

- What is the potential for scientific research and technology development to reduce future transportation emissions?

8:50 - 9:15 **FRANCISCO GUZMAN — Instituto Mexicano del Petroleo**

- Which policies are effective in the technological forcing of emission reductions for surface transportation?

9:15 - 9:40 **HOWARD WESOKY — National Aeronautics and Space Administration**

- Which policies are effective in the technological forcing of emission reductions for air transportation?

9:40 - 10:05 **SCOT STALEY — Department of Commerce**

- How effective are public/private partnerships for accelerating transportation research and development?

10:05 - 10:25 **BREAK**

10:25 - 11:45 **PANEL DISCUSSION**
Speakers plus Additional Panelists:
DAVID GREENE — Oak Ridge National Laboratory
ED WALL — PNGV Government Technical Council
CHRISTINE SLOAN — General Motors Research

11:45 - 1:00 **LUNCH in the GREAT HALL**

1:00 - 1:30 **PANEL DISCUSSION (with audience participation)**

1:30 - 1:55 **DISCUSSION SUMMARIZATION (panel chair with assistance of panel)**

1:55 - 2:00 PM **SHORT BREAK**

2:00 PM **PANEL V: Reducing the Impacts: B. Economic and social policies**
This panel will examine the effectiveness of a range of economic and social policies to mitigate the influence of transportation on atmospheric change
Chair: RICHARD MESERVE
Rapporteurs: JAMES BRUCE & DANIEL SPERLING

2:00 - 2:10 **OVERVIEW by the panel chair**

2:10 - 2:35 **LEE SCHIPPER — LBNL & International Energy Agency**

- Will social and economic policies be needed to capture the potential public benefits of advances in efficiency of transportation technology?

2:35 - 3:00 **NEIL IRWIN — IBE Group**

- What fraction of the full cost of transportation do users directly pay?

3:00 - 3:20 **BREAK**

3:20 - 3:45 **ERIK HAITES — IPCC & Margaree Consultants**

- How effective and attractive are economic and social policies to reduce emissions?

3:45 - 4:05 **BERNARDO NAVARRO — Universidad Autonoma Metropolitana Xochimilco**

- What strategies are effective in producing modal shifts that reduce emissions?

4:05 - 4:30 **KEN OGILVIE — Ontario Roundtable**

- What are the prospects for managing transportation emissions at the metropolitan and regional levels?

4:30 - 5:45 **PANEL DISCUSSION (includes questions from the floor)**

4:30 - 5:45 **PANEL DISCUSSION (includes questions from the floor)**
Speakers plus Additional Panelists:
JOHN FLORA — World Bank
MARK CORRALES — Apogee Research, Inc

5:50 PM **ADJOURN WORKSHOP for the DAY**

6:00 PM **RECEPTION in the GREAT HALL**

7:00 PM **SPECIAL PUBLIC LECTURE:**
What Is Actually in the Urban Atmosphere? Several Case Studies
F. SHERWOOD ROWLAND

Wednesday, March 26, 1997

8:00 AM **CONTINUATION of PANEL V:**
Reducing the Impacts:
B. Economic and social policies

8:00 - 8:10 **OPENING COMMENTS by Panel Chair**

8:10 - 9:10 **Current Legislative and Regulatory Approaches to Reducing Emissions**
RICHARD GILBERT — Centre for Sustainable Transportation
Canadian Approaches and Experience
MARY NICHOLS — Environmental Protection Agency
United States' Approaches and Experience
MARIANO BAUER — Universidad Nacional Autonoma de Mexico
Mexican Approaches and Experience
CARL-HEINZ MUMME — World Bank
International Lending Agencies' Perspectives

9:10 - 9:50 **PANEL DISCUSSION on Three Nations' Approaches (with audience questions)**

9:50 - 10:10 **BREAK**

10:10 - 11:40 **FINAL PANEL DISCUSSION on Effectiveness of Policy Measures**
(with previous speakers and panelists)

11:40 - 12:00 **DISCUSSION SUMMARIZATION**
(panel chair with assistance of panel)

12 Noon **LUNCH in the GREAT HALL**

1:30 PM **FINAL PLENARY SESSION**
This panel will examine the effectiveness of a range of economic and environmental policies to mitigate the influence of transportation on atmospheric change
Co-Chairs: JAMES BRUCE & MAURICIO FORTES
Rapporteurs: LOWELL SMITH & JAMES ZUCCHETTO
Panelists: CHAIRS of PANELS 1 - 5

- What investments in scientific research, technological development and economic and social policy research are needed both regionally and globally to reduce uncertainties and to foster future development of the transportation sector in North America in a sustainable manner?
- How might these investments be effective in aiding decision makers in the public and private sectors?
- What are the important elements of a decision framework for assessing impacts of current and future transportation systems on atmospheric change, and for analyzing the effectiveness of alternative policy instruments?

3:30 PM **BREAK**

4:00 PM **CLOSING of WORKSHOP**
Summarization of findings and conclusions led by the workshop chair. Where do we go from here? A plenary discussion of the next steps.
Chair: F. SHERWOOD ROWLAND
Rapporteurs: JAMES ZUCCHETTO & LOWELL SMITH

5:00 PM **CLOSING of WORKSHOP**