Wheels: Dream or nightmare? The case for true-cost pricing in the transportation sector

Leonidas Petrakis

The author is Senior Scientist and Chairman-Emeritus of the Department of Applied Science, Brookhaven National Laboratory, Upton, NY, USA. With a Ph.D in Chemistry from the University of California (Berkeley), he has extensive experience in the area of energy and the environment R&D at national laboratories, universities and industry. He has authored or edited six books and co-authored over 150 scientific publications. The opinions expressed in this article are his personal views, and they do not necessarily reflect the views of Brookhaven National Laboratory or the U.S. Department of Energy.

Introduction

As the Twentieth Century comes to a close, road-related transport remains the dominant mode of transportation in the industrialized world. It is an achievement that exceeds the dreams of all but the boldest visionaries who pioneered this mode at the beginning of the century. In fact, the automobile, as the means for personal transport, became the quintessential characteristic of the American Century, both by its dominance throughout the developed economies and also by its role as the paradigm for developing economies. Homo sapiens, in the words of a California advertisement, truly has become "auto-sapiens."

Senator Daniel P. Moynihan of New York has been a keen observer of the transportation scene and very influential in shaping transportation policy. For example, he was instrumental in the passage of the Intermodal Surface Transportation Act of 1991, the most significant legislation in this area since the Interstate and Defense Highway Act of 1956, which initiated the interstate highway system now in place. Senator Moynihan, in discussing transportation matters in one of his "Letters to New York,"[1] referred to a 1939 General Motors press release that reflected the high expectations for the automobile prevalent at that year's World Fair. Those high expectations defined the issue in the decades that followed. The press release exhorted one to visualize the cities of the future in the reign of the automobile (fig. 1). "Just imagine!... Living in New York when it looks like this: What with its buildings overhead of auto roads — aero rooming places atop 200-story buildings — the Metropolis of the World — as it will appear in the future." This vision of the perfect symbiosis of the limited access highway, especially as it cuts through the heart of the cities, and their inhabitants, we know now, has not materialized in the promised, utopian manner.

An encomium for the automobile is readily understandable. The contributions and advantages of this mode of transport are compelling, and include comfort, convenience, glamour, flexibility. There is hardly an aspect of 20th century life that road-

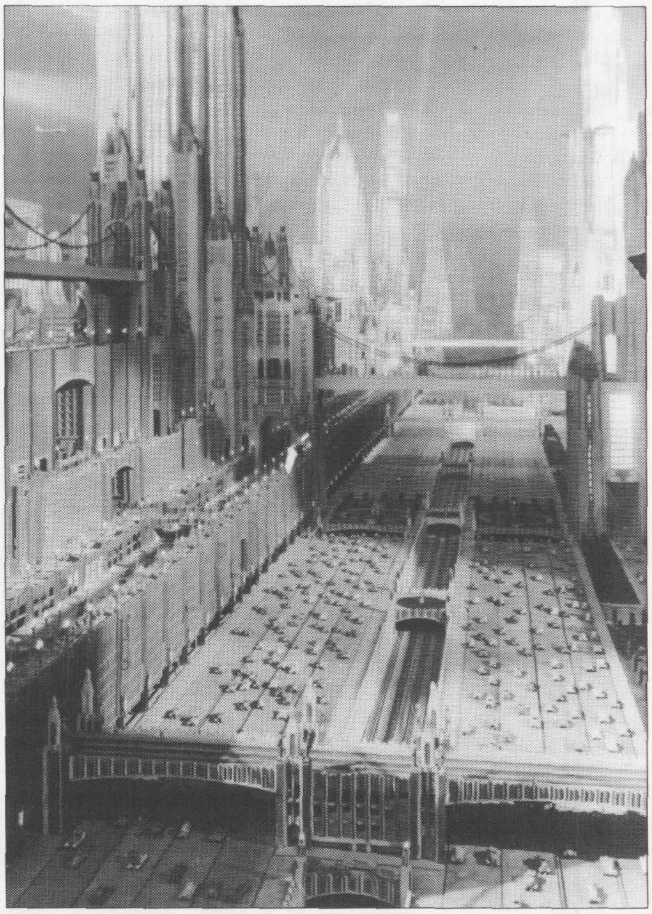

Fig. 1: General Motors' 1939 vision of the cities of the future in the reign of the automobile. (*Source:* Moynihan, "Letter to New York," January 1992,[1] published with permission of The Bettmann Archive, 902 Broadway Ave., New York, NY 10010).

related travel has not touched — the economy, popular culture, national security, education, entertainment, to mention some obvious ones. Road-related travel has had a democratizing effect; proved a great boon to the economy; made the distribution and availability of goods wider and more accessible; was critical in the attainment of the American dream by facilitating and accelerating the movement to the suburbs; gave a new meaning and impetus to the family vacation; provided compelling themes for the movies; helped open the national parks; allowed middle class folk to aspire to the life style of F. Scott Fitzgerald and his friends. A measure of this success is the rise of drive-ins of all kinds — theaters, banks, food establishments, churches.

Road-related travel, however, has another, darker side. Serious problems are associated with it — congestion, pollution, loss of productivity, injuries and other health effects, alienation, challenges to national security, war. Resorting to hyperbole, road-related travel has been called a scourge, the source of all that is wrong with our modern world. The darker side of road-related travel is reflected by contributions to the language that include traffic jams, car jackings, drive-by shootings, car bomb, urban sprawl, smog, rubbernecking, and the AIDS Highway. Richard Preston in *The Hot Zone* writes[2]: "The road to Mount Elgon (fig. 2) is a segment of the AIDS highway, the Kinshasa Highway, the road that cuts Africa in half, along which the AIDS virus traveled during the breakout from somewhere in the African rain forest to every place on earth. The road was once a dirt track that wandered through the heart of Africa, almost impossible to traverse along its complete length. Long sections of it were paved in the 1970s, and the trucks began rolling through, and soon afterward the AIDS virus appeared in towns along the highway."

A central challenge for all modern states is the plexus of energy-environment-economy. In the U.S. the impact of road-related transport on the economy, health and environment, and national security is enormous. It is understandable then that meeting overall U.S. energy needs, but transport needs in particular, has remained a dominant theme of national debate and policy — from the "first energy crisis" of 1973 to the present. Past and potential energy shortages are shortages of liquid fuels that affect primarily the transportation sector.

The war in the Persian Gulf, the expectations that the U.S. will continue to project its presence in the region well into the next century, the instability of the former Soviet Union, the environmental fragility of the possible oil-bearing regions in the U.S. (offshore, Arctic National Wildlife Refuge), and the very finiteness of the resource and declining production rates provide a good measure of the challenges in transportation.

Almost two decades after the 1973 oil embargo the U.S. found itself without a long-range and comprehensive energy policy. President Bush released in 1991 his National Energy Strategy[3] that laid the foundation for a "more efficient, less vulnerable, and environmentally sustainable energy future," and established criteria by which the energy future was to be judged, namely: the environment, health and safety, the economy, and national security.

The Energy Policy Act of 1992,[4] enacted by the Congress late in that session, emphasizes conservation and energy efficiency as it explicitly states: "It is the goal of the United States in carrying out energy supply and energy conservation research and development:

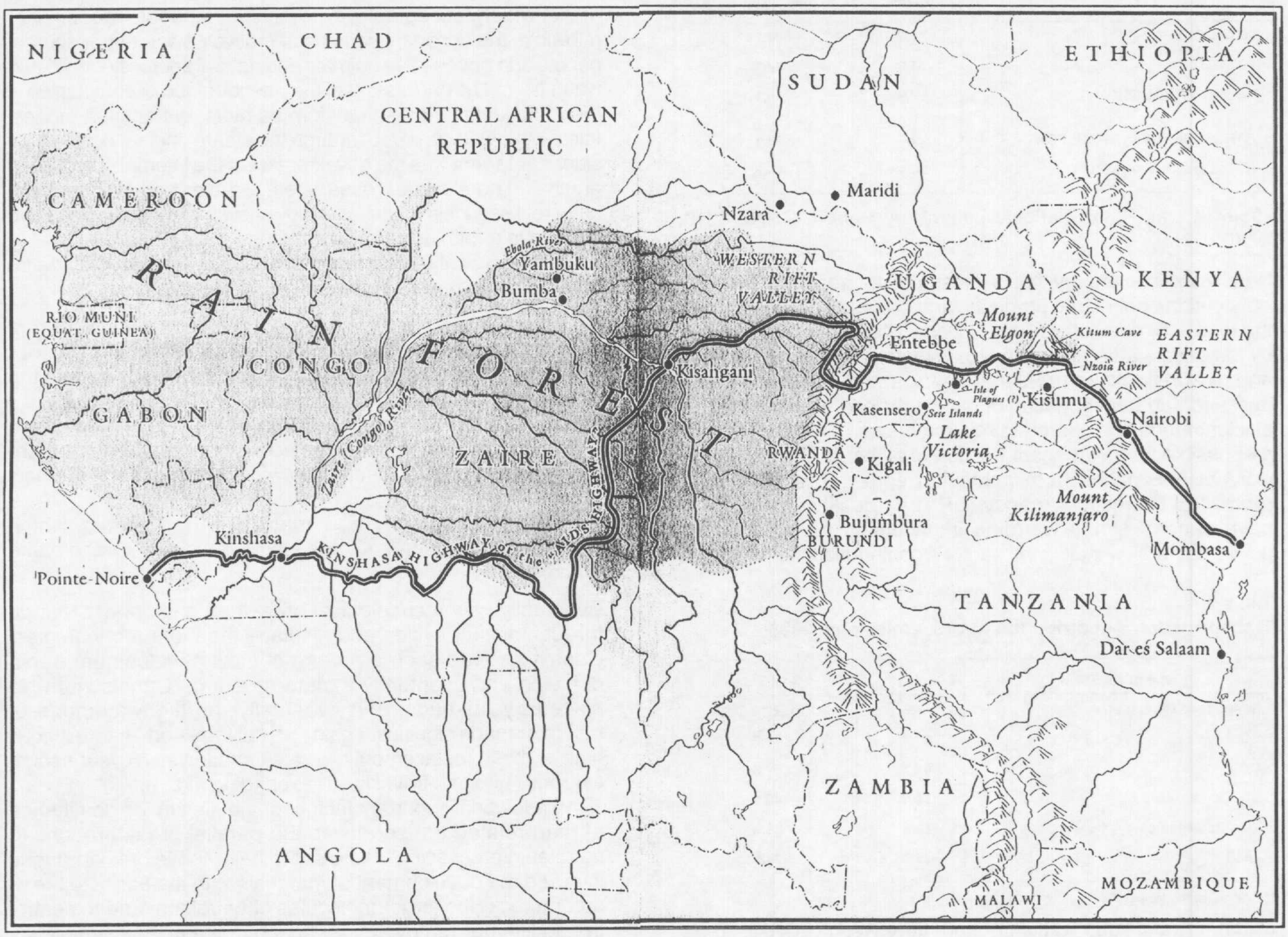

Fig. 2: The AIDS Highway. (*Source:* R. Preston, *The Hot Zone*[2]).

- to strengthen national energy security by reducing dependence on imported oil;
- to meet future needs for energy services at the LOWEST TOTAL COST to the Nation, including environmental costs;
- to reduce the air, water, and other environmental impacts (including emissions of greenhouse gases) of energy through the development of environmentally sustainable energy systems;
- to consider the comparative environmental and public health impacts of energy."

Regarding transportation, the Energy Policy Act specifically calls for the Department of Energy to evaluate "cost effective technologies to reduce demand for oil in the transportation sector for all motor vehicles through increased energy efficiency and the use of alternative fuels." (Emphasis added.)

When examined in terms of these criteria, the transportation sector is lacking greatly. Numbers that we show in a later section of this paper define and quantify the problem. At the same time, they suggest opportunities and strategies for improving the sector.

Transportation consumes more than a quarter of the total energy used by the U.S. (table 1). The scientific definition of energy is simply the "capacity to do work." Without energy, everything comes to a standstill, and in the case of transport, literally so. The energy that is consumed for transport is almost in its entirety petroleum products, and in quantities greater than the total U.S. domestic oil production. The sector is dominated by the private automobile and to an increasing degree by vans and pickup trucks for personal travel, and by diesel-powered trucks for the transportation of goods. These are less energy-efficient modes compared to rail and buses. Transportation is responsible for a significant fraction of all emissions that either prevent U.S. cities from achieving compliance with Environmental Protection Agency (EPA) air quality standards or have serious global warming implications as greenhouse gases (table 2). Finally, the sector's contributions to the Gross Domestic Product (GDP) and employment are incommensurately low compared with the high fraction of energy that the sector consumes.

Table 1
USA energy consumption, 1989

Type of consumption	Quads	Oil Equiv. (Million BBL/day)
TOTAL ENERGY	81.3	41.25
TOTAL OIL	34.0	17.2
U.S. OIL PRODUCTION	17.9	9.1
TOTAL ENERGY IN TRANSPORT	21.9	11.1
TOTAL OIL IN TRANSPORT	21.4	10.8

(*Source:* Oak Ridge National Laboratory Report, ORNL 6710, LPVG 017).

Table 2
Transportation's contribution to U.S. emissions, 1988

Type of emission	Quantity(1)	% of Total
Suspended Particulates	6.9	20.3
SO_2	20.7	4.3
CO	61.2	67.3
NO_x	19.8	40.9
Volatile Organics	18.6	32.8
Lead	0.0076	34.2

(1)Million metric tons per year

(*Source:* Oak Ridge National Laboratory Report, ORNL 6710, LPVG 009).

The course taken earlier and at easier times has led to the current predicament; and staying the course will only exacerbate a clearly unsatisfactory situation. As with the elimination of the deficit, we are still nowhere close to addressing seriously the problem and taking advantage of the opportunities that the restructuring of transportation presents. Addressing the problem is always postponed for "tomorrow," which in Washington does not ever seem to dawn. Yet, the potential rewards from addressing this problem are enormous. Restructuring the transportation sector to be more energy-efficient will create jobs on a sustained basis and provide the added dividends of cleaner environment and lower national security risk.

We examine below more closely challenges of the transportation sector. Because of technology's central role, we make brief reference to the trajectories followed by technologies as they are developed and become diffused throughout the economy. Following a brief profile of transportation's main components — energy, environment, economy — recommendations are offered regarding the opportunities presented.

Technological innovations

Technology has played the key role in the development of transport modes by increasing the elasticity of substitution among various modes and by shortening the time required to make widely acceptable a particular transport mode. For millennia, the dominant sources of motive power for transport of people and goods were animals and natural sources of wind and water flow. The harnessing of the phenomenon of combustion is the great landmark that transformed radically transport modes. Initially this was achieved through the steam engine, but the truly significant event was the development of the internal combustion engine. The Austrian researchers Grübler and Nakicenovic[5] have reviewed this matter and they show that technologies have evolved in remarkably similar patterns.

Technological breakthroughs proceed in three, well delineated phases that form the so-called S-curves.

- The first is a slowly developing induction period, during which there may be important technological developments, but the penetration of the new technologies into the economy is slow.
- This is followed by a second phase which is characterized by the rapid diffusion into the economic system of the technological changes resulting in wide acceptance of the new technology.
- Finally, there is a third mature period during which marginal improvements and also a definite saturation take place.

Eventually new technological breakthroughs appear that go through similar cycles and displace the older technologies. Canals showed such a pattern of slow development, rapid diffusion and eventually a mature period. Canals were replaced by railroads, and eventually the highway-mode of transport made significant gains on rail transport. Interestingly, both of these replacements were effected over 75-year spans. Currently airplane travel is still expanding (fig. 3).

An additional important factor contributing to the dominance of road-related transport was the parallel breakthroughs in petroleum processing. More specifically, these breakthroughs involved the development of materials with the ability to break up or "crack" the larger molecules of petroleum and to control the addition or removal of hydrogen in the chemical moieties that constitute gasoline, diesel and jet fuels. These common

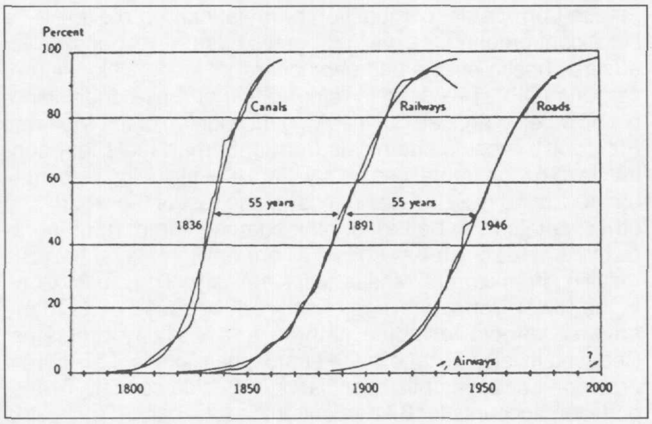

Fig. 3: Growth to limits of canals, railroads, and roads in the USA. (*Source:* Grübler and Nakicenovic, 1991[5]).

and cheap materials (e.g. silica aluminas) or more exotic zeolites, often modified through the addition of small quantities of carefully dispersed noble metals (e.g. platinum) or combinations of metals, have unique catalytic properties that carefully control on the molecular level complex, sometimes competing chemical reactions that result in fuels of remarkable predictability and quality. These technological developments have come from the private sector laboratories with contributions from university and government researchers as well. The 1994 Nobel Prize in chemistry was awarded to Professor George Olah of the University of Southern California for his many and insightful contributions to this elegant and at the same time extremely valuable line of intellectual inquiry. The breakthroughs have entailed great progress in understanding fundamental chemical phenomena and their technological harnessing in immense quantities through the use of materials that operate efficiently for long periods and in severely hostile environments of high temperature and pressure and in the presence of molecular poisons. J. Cusumano of Catalytica Inc.[6] has reviewed these fuel-related developments and has shown that they too followed similar patterns as the transportation modes themselves.

A look at the numbers

The transport of people in the U.S. is dominated by the private automobile.[7,8,9,10] The number of passenger-miles (all miles traveled by all passengers) due to private transport is about 100 times greater than those due to the public transport. This contrasts with a ratio of 8-to-1 for Germany and 4-to-1 for Japan. The transport of goods is more balanced in terms of road-to-rail distribution. In the U.S. slightly more metric tons of goods are shipped more miles (ton-miles) by railroads than by road-related means. There are now 190 million automobiles, vans and trucks — more than there are drivers — and only about 100,000 transit vehicles; almost 4 million miles of streets and highways, but only 7,000 miles of subways, street car lines, and commuter railroads; 275,000 airplanes, 18,000 locomotives, 20 million recreational boats, and almost 40,000 ships, barges and tugboats; 17,000 airports and landing fields; 26,000 miles of waterways in addition to the Great Lakes and the oceans; over 100,000 miles of railroads; and one-and-one-half million miles of intercity pipelines. This is the U.S. picture with about 5 percent of the world population. Worldwide there are currently about 750 million cars, trucks, vans and motorcycles.

A useful unit for measuring large quantities of energy is the QUAD (quadrillion of British Thermal Units; quadrillion is one million billion or 1 followed by fifteen zeros; British Thermal Unit or BTU is an old but common unit of energy). In recent years the U.S. has consumed over 82 Quads per year to meet all of its energy needs. This amount of energy was provided by domestically produced and imported oil, coal, natural gas, nuclear, and renewable energy. Of that total, in 1989, 22 Quads were used for transportation. This translates to 10.8 million barrels per day, which was higher than the total U.S. petroleum production, set at 9.1 million barrels per day! Thus, the entire U.S. oil production fell short by 1.7 million barrels per day of oil in meeting the transportation needs. That situation has deteriorated further during more recent years, as the decline in domestic oil production continues with no credible likelihood of reversal. In 1994 the U.S. imported some 45 percent of its oil compared to 30 percent in 1984. Despite the relatively soft oil prices, the U.S. spent $45 billion to pay for this imported oil. This was a major contribution to the trade deficit, while the national security implications of the shortfall are obvious.

The liquid fuel problems of the transportation sector relate primarily to road transport, with nearly three quarters of the energy being used by automobiles and trucks, and the remainder for meeting air, rail, construction, farming and military transport needs. The single-occupant personal truck and automobile are the most energy-intensive modes. Rail and buses have lower energy intensities, inter-city buses considerably lower. The energy required for one person to travel one mile by bicycling or walking (the two least energy-intensive modes of transport, and the most healthful, we might add) is 200 and 300 BTUs per passenger-mile respectively; by intercity buses, approximately 1,000; commuter rail, 3,200; transit buses, 3,400; automobiles, 3,600; domestic air travel, 4,800; and personal trucks, 5,000. These energy intensity figures of merit, coupled with distribution of energy use among the various modes, indicate what short-term steps, as well as longer term structural changes, might be pursued to bring about desirable improvements in the transportation sector. Clearly we must lower the energy intensity by shifting to inherently lower energy intensity modes (bicycling, lighter vehicles) or increasing the passengers (car pools, public transport), which has the effect of lowering the energy consumed per person (fig. 4).

The transport of freight presents an analogous picture.

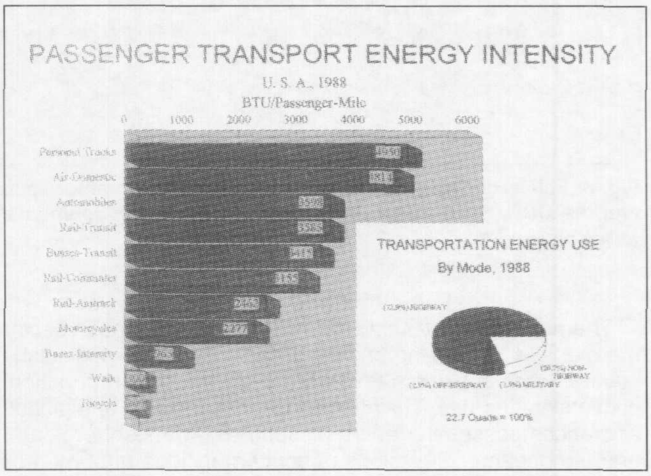

Fig. 4: Passenger transport energy intensity — USA, 1988. (*Source:* Davis and Morris, *Transportation Energy Data Book*[7]).

Trucks are the least energy-efficient mode requiring 3,500 BTUs to carry one ton of cargo one mile, while railroads require 430 and barges 360. Yet, trucks are the largest energy- consuming mode for transport of freight, using over three quarters of the total (fig. 5).

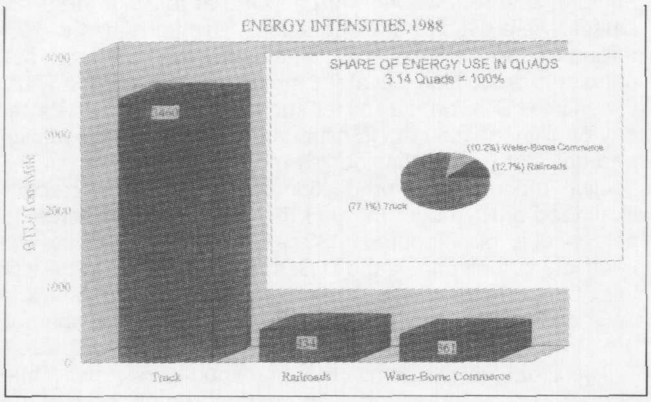

Fig. 5: U.S. freight transport energy intensities 1988. (*Source:* Davis and Morris, *Transportation Energy Data Book*[7]).

The fuel economy of the automobile population and the trends over the years tell the same story. The 1978 automobile population in the U.S. had an average efficiency of 13.8 miles per gallon, which was significantly lower than those of Japan (20 mpg) and Germany (21 mpg). By 1988 the U.S. automobile population showed a dramatic improvement to 17.8 miles per gallon, but still it lagged behind those of Japan and Germany which also had registered some improvements — 21.8 and 22.0 miles per gallon, correspondingly for Japan and Germany (fig. 6).

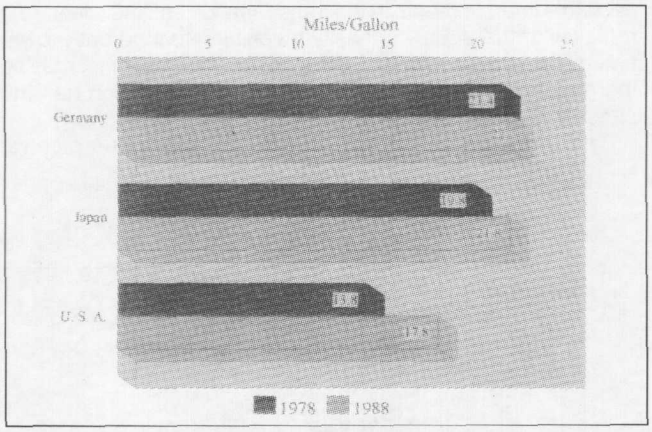

Fig. 6: Fuel economy of automobile population in Germany, Japan and the USA, 1978 and 1988. (*Source:* OECD, *Environmental Indicators*[10]).

The environmental implications of the transportation sector are many, wide-ranging and significant. They are particularly severe if one considers the entire cycle for fuels production, conversion and use. Their impact is local, regional and global, and encompasses the entire biosphere — atmosphere, land and the oceans. Emissions of concern include unburned or altered components of the fuels, products of combustion and heavy metals. Carbon monoxide — a very potent poison that results from partial combustion of fuels; carbon dioxide — a significant greenhouse gas; nitrogen oxides — responsible for adverse health effects and photochemical smog; chlorofluorocarbons (CFCs) — used in refrigeration and air-conditioning, but now being phased out following the signing of the Montreal Protocol[11]; organic chemicals from unburned fuels that contribute to ozone formation; heavy metals — including lead, now banned in the U.S. but not in most of the rest of the world, and other metals from batteries; oxygenates — important ingredients of reformulated gasoline; all are environmental hazards resulting from current transportation fuel use. Too much ozone in the lower troposphere is of concern because of its many adverse effects including asthma and visibility problems. Reduced levels of ozone in the stratosphere present a different problem, because of its association with skin cancer. Transportation accounts for 67 percent of the total carbon monoxide (61 million metric tons), 41 percent of nitrogen oxides (20 million metric tons), and 33 percent of the volatile organics (19 million metric tons each year) with which the atmosphere is burdened every year. In addition, transportation is a major contributor to the inventory of several key greenhouse gases with global climate change implications — carbon dioxide primarily, but also nitrogen oxides, and chlorofluorocarbons (table 3). Finally, there are non- emission environmental burdens that include noise, congestion, land use, solid wastes, discharges into waterways, injuries and health effects.

Table 3
Emissions in the USA, Japan and West Germany, late 1980s

Type of emission	USA	Japan	W. Germany
CO_2 (million tons)	1,433	272	198
(kg/$1,000 GDP)	324	181	294
(tons/capita)	5.8	2.2	3.2
NO_x (million tons)	19.5	1.18	2.93
(kg/$100 GDP)	4.5	0.8	4.3
(kg/capita)	80.4	9.6	46.7

(*Source:* Organisation for Economic Co-operation and Development, *Environmental Indicators,* 1991, pp. 19-23).[10]

Transportation and the economy

The need for quantitative assessment of human well-being has given rise to numerical indices that provide the basis for measuring progress and making comparisons over time and across regions. These efforts for quantification use descriptive language which is as imprecise as it is optimistic — "growth," "development," "standard of living," "goods," etc. — adding to the over-simplification of what are really complex issues. Often the tendency has been to give primacy and even exclusivity to the economic factor. However, human well-being, as Herman Daly[12] and others have pointed out, being multidimensional and encompassing psychological, environmental and other non-economic factors, is not reflected accurately in a simple numerical index.

Gross Domestic Product (GDP) is the most commonly employed numerical index. It measures market activity by monitoring money flow. GDP was developed in 1934 when the U.S. Department of Commerce began publishing data on the net product of the national economy. The British and Canadians followed with data in 1943, and in 1947 the United Nations convened a meeting on national income accounting. However, the index itself and its derivatives have been employed not just as a measure of market activity, but, by extension, as a measure of the health of the economy and even of human well-being. Economists often deny the validity of this extension, but the practice is well entrenched. The dissemination of the latest GDP figures, with the always hoped-for growth and its perceived importance as a gauge of human well-being, is a ritual widely practiced and eagerly awaited.

A causal relationship between energy consumption and economic growth has been a commonly held position both in the free as well as the planned economies. An important Office of Technology Assessment (OTA) study in 1990[13] pointed out that "economic growth was assumed to be linked to increases in energy use and public and private investments were made that rested on that assumption." The current consensus is that there is a decoupling between energy consumption and economic growth. The conclusion of the Office of Technology Assessment study was unequivocal: "economic growth is not necessarily contingent on using more energy." In fact, energy efficiency measures taken after the first energy crisis of the 1970s are credited to a large extent for the decline of the energy intensity of the economy between 1972 and 1985. (Energy intensity, as a measure of the energy efficiency of the economy, is the amount of energy required to produce a unit of GDP. Both Japan and Germany have economies with lower energy intensity than the U.S.) (fig. 7).

The OTA study documented some spectacular findings by comparing the trends in Energy Use, GDP, and the Energy Intensity of the economy from 1950 to 1988. Between 1950 and 1972 the energy intensity remained flat, since both GDP and energy use grew in parallel by 3.5 percent per year. Between 1972 and 1985 the use of energy in the economy was much more efficient, as shown by the lower energy intensity for that period. GDP growth was 2.5 percent per year, while energy use increased by only 0.3 percent per year. Thus, between 1972 and 1985, a smaller energy investment was responsible for a far greater GDP. Also, the energy efficiency improvements between 1972 and 1985 meant that the 1985 economy would have used 15 Quads more energy if these improvements in energy intensity had not been achieved. This of course would have had an adverse effect on the trade figures (fig. 8).

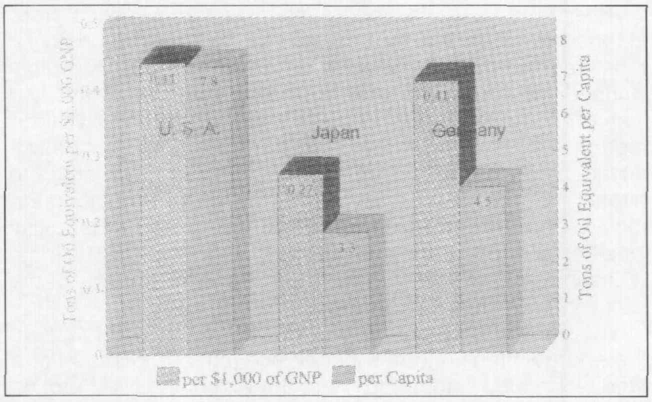

Fig. 7: Transportation sector — Energy intensity in the USA, Japan and Germany, 1988. (*Source:* OECD, *Environmental Indicators*[10]).

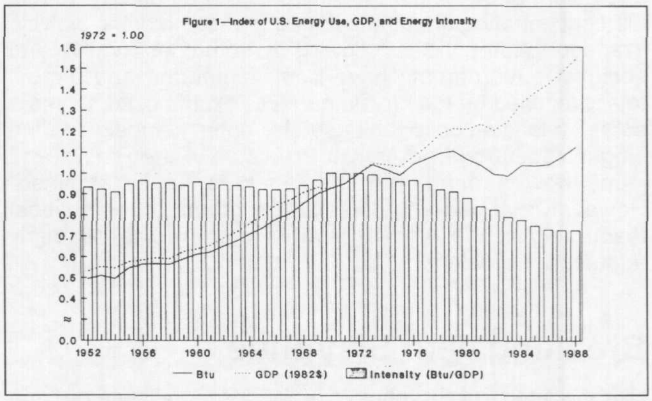

Fig. 8: Energy use and the U.S. economy, 1952-1988. (*Source:* Office of Technology Assessment, *Energy Use and the U.S. Economy*[13]).

The large investment of energy in the transportation sector in the U.S. (over a quarter of the total energy consumed) continues to make an incommensurately low contribution to the GDP and employment.[14] Transportation-related employment in 1992 was just over six million, out of a total of 126 million.[15] The Transportation Gross Domestic Product (motor vehicle and other transportation equipment manufacturing; railroad transportation; local and interurban passenger transit, trucking and warehousing; water transportation; transportation by air; pipelines, except natural gas; transportation services; and auto repairs, services and garages) accounted for less than 10 percent of the total GDP. Clearly, there is room for significant improvements here. The huge investment of energy that is being made in this sector should be required to produce many more jobs and greater wealth as well.

Actually the situation is more sobering, if one looks beyond the numerology and considers the impact of the transportation sector on the society's well-being. For in the drive to maximize GDP no distinction is made between costs and benefits, and instead of subtracting costs they are added. The manufacture and sale of a new automobile, the drive to a restaurant and the transport of milk to schools are all economic "goods" and are added to the GDP as are the costs related to the wreckage of an automobile accident from an intoxicated driver, the "rear-ending" — as car rear-end collisions are referred to in the American idiom — by a drowsy truck driver or the cost of treatment of emphysema due to automobile exhausts. All are defined as "goods" and are added to the GDP regardless of their true cost or impact on personal and societal well-being. One could envision a growing transportation GDP with ever-increasing contributions from the darker side of road-related transport.

If we require that the energy invested in the transportation sector produce more jobs and contribute a greater component to the GDP than is currently the case, then it is imperative that we move to more energy-efficient modes. Since the energy intensity of transportation is even lower than that of the overall economy, the sector presents excellent possibilities for gains, through long-term restructuring and short-term readjustments.

Developing economies present an even more challenging picture. The case of Greece illustrates this well.

The Athens basin is an ecological mess with dire implications on a very broad front, from the health of its citizens to the integrity of its unique and irreplaceable classical and Byzantine monuments. The recent introduction of the private car on a massive scale, coupled with the rising standard of living and the resulting phenomenal growth of consumption, has severely stretched an inadequate infrastructure. For example, often sidewalks (or *pezodromia*, literally "roads for pedestrians"), even when properly constructed (i.e. wide enough and unencumbered) truly for pedestrians, are being taken over as parking spaces.

Athens had a quite good system of trams, which were stripped to make way for cars and trucks. Not surprisingly, those earlier tram thoroughfares have become incredibly clogged and almost impassable, causing immense delays and loss of productivity. Only now is there an expansion of the metro under way; newer and cleaner buses are being introduced; and some early steps are being taken to alleviate the overall situation. Still, noise and air pollution are among the most serious examples in large cities. The incredibly beautiful weather and topography (similar to Los Angeles with almost 300 sun-days per year) have contributed to the severity of the situation, by fostering photochemical smog.

This reliance on the car and truck have actually caused the energy intensity of the Greek economy to increase at a time when the trend, certainly in the examples cited earlier, has been in the opposite direction.

The Athens metropolitan area has undergone during the last 40 years an explosive growth, accommodating currently almost 40 percent of the country's population. The density and height of buildings have increased dramatically as has the concentration of manufacturing and commercial activity. Transportation policies followed by both conservative and socialist governments have been expedient and almost totally focused on the private car. For example, some years earlier, a leading politician based his entire campaign on the slogan "pollution free cars." Predictably, the BMWs and jeeps now abound, but the clunkers have remained. However, it appears that finally a segment of the political leadership at the highest level is prepared to seriously address the problem.

Breaking with Sisyphus

Like the efforts of Sisyphus, our policies — reliance on, and subsidies to, energy-inefficient modes and the pursuit of incremental technological improvements — have led us to the current unsatisfactory state of the transportation sector. The situation, however, if rectified, has the potential for significant benefits for the U.S. and the global economies. The question therefore arises as to what can be done to develop a transportation system that has greater economic productivity, higher jobs-creating capacity, enhanced energy efficiency, reduced environmental insults, and lower national security exposure.

In response, there has been an outpouring of good intentions and a plethora of good words. President Nixon promised "energy independence," President Carter spoke of energy issues as the "moral equivalent" of war, while for the Reagan and Bush Administrations energy policy epitomized our dedication to "free markets." President Clinton and Vice President Gore, in their "Technology for America's Economic Growth,"[16] posit that "Technology is the engine of economic growth," and they call for transportation technologies "that increase the speed, reliability, and cost-effectiveness." And Speaker Gingrich has asserted that, as the dominant species on this planet, "we have an obligation to think through the management and the care of the planet."

However, words and commitments to even lofty goals are not extricating us from our predicament, as indicated, for example, by the ballooning oil imports. The problem will not be solved either by issuing regulations of ever-increasing complexity and scope or by gutting all regulations in the name of "free markets." For the former course can lead to gridlock, stifled initiative and stagnation; and the latter to anarchy and serious undermining of the integrity of the societal fabric. Too often we have made long-term decisions without a genuine understanding of all the issues involved, and we have provided subsidies for systems on an arbitrary basis while professing faith in what we define as "free markets."

Are markets really free when we create an uneven playing field through direct and indirect subsidies for the automobile, lesser but real subsidies for transit, and essentially ignore modes such as the bicycle? The most massive subsidies go to the automobile through, inter alia, building highways; providing traffic lights, police and ambulance services; and ignoring the huge losses of economic productivity due to traffic jams, health effects and the damage to materials, from bridges to irreplaceable historical monuments. The Natural Resources Defense Council in a 1993 report[17] indicates that "the annual external cost (i.e. societal costs plus government subsidies) of automobile transportation" is between $3.70 to $6.50 per gallon of gasoline, while the Conservation Law Foundation in a 1994 report[18] calculates that "fees and taxes paid by motorists cover only 9 to 18 percent of the total cost paid by the public for each mile of solo driving in the Boston region." Europeans and Japanese pay a higher percentage of the true cost of transportation through higher taxes than Americans, and of course this is reflected in the lower energy intensity of their economies. Hidden subsidies, confusion of costs with benefits in our accounting practices, avoidance of the inevitable pain of changes, charging the future generations for our convenience and lack of foresight, ignoring the finiteness of the resources and the fragility of the environment, all are hindrances to a thorough and accurate assessment of the situation that will continue to prevent us from realizing the great benefits that can be had from a restructured transportation sector.

- The first step out of this predicament must be an honest assessment of all the costs entailed by the various options. In the absence of such an accounting, there is no breaking the practice of convenient accommodations that are our current policy, and the markets, not really being free, cannot be said that they decide the least-cost course. For too long, economists have simply defined many actual costs as "externalities" and have dismissed them, thereby distorting the true economic picture and rendering unworkable the free markets. If we are to make progress, we must deal honestly with the issue of externalities. Knowledge as to their true nature does not undermine the freedom of markets, but it may disabuse us of our illusion as to what exactly is free and what is not. In addition, if we as a society decide to augment a particular choice and indeed opt to intervene, that should be done only on a thoroughly informed basis. The accounting that is needed goes well beyond the current call from some quarters for benefit-cost analysis, that at times appears to be a call to gut all regulations.

Honest accounting of all costs involved would simply mean carrying out the mandate of The National Energy Policy Act of 1992 which aims "to increase the efficiency of the economy by meeting future needs for energy services at the lowest TOTAL COST to the Nation." Even the Bush (no "environmental extremist") Administration for example, on the choice of fuels, had called that "motivating our technology and resource choices must be an improved understanding of TOTAL FUEL-CYCLE COSTS (emphasis added) ... including the cost of health and environment impacts."

Determining the real cost of all factors in a given transport mode is difficult, but doable, and methodological difficulties should not be an excuse for not considering true costs. Capability for assessing the complexities and interactions in energy, the environment and the economy has been developed at national laboratories and universities. For example, my own institution jointly with a number of other academic and governmental institutions, has developed a cost-minimizing, planning model that explores various technological futures and their interplay with the economy. One can evaluate technologies, policy options, and their relative costs in such diverse areas as strategies for reduction of emissions and sustainable development through these powerful tools. Indeed, they hold the promise of providing significant guidance in the development of least-cost energy strategies, including exploring technological, environmental, and economic implications of shifts among various transportation modes. Important uncertainties remain as well as areas of strong disagreements regarding their use. Furthermore, these capabilities are not an automatic pilot that determines the course to be followed, but they can provide significant inputs in our deliberations.

- Once we have assessed honestly the true costs of all factors involved, we must then take steps to insure that the markets become truly free and thereby determine the least-cost system. That means that the pricing of the various modes should reflect their true costs. There are significant caveats, of course, that we need to be mindful of as we embark on that course. For example, huge investments already have been made in the sector, and they cannot be disregarded. Too, an abrupt move to a true-cost pricing can have serious adverse impacts on significant segments of our society that cannot afford them. Therefore, readjustments need to be gradual and to be made in a manner that mitigates the hardships and dislocations that will necessarily result from the otherwise highly desirable long-term restructuring.

There exists a rich menu of proven or promising options that surely will define next century's transportation system. Technological breakthroughs appear feasible, and they should increase our choices as well as hasten the introduction and acceptance of the new systems. The possibilities are many and include **vehicular innovations** (electric vehicles, fuel cells, gas turbines, power batteries, low heat rejection diesel engines); **systems innovations** (high speed rail, magnetic levitation, intelligent vehicles and highways); and **fuels innovations** (cleaner fuels, advanced fuels from biomass, hydrogen). The National Science and Technology Council — a Cabinet- level group that coordinates, and advises the President on, the over $70 billion Federal Government investment in research and development — in its draft Strategic Implementation Plan for Transportation[9] earlier this year summarized the broad spectrum of research possibilities that merit support. It is a very impressive array of projects indeed, that the various Federal agencies are working on, often in collaboration with the private sector and with participation of universities. The emphasis is on high tech, big ticket items that focus on physical infrastructure (highways, airports, bridges); information infrastructure (Intelligent Vehicle Highway System, IVHS); next generation transportation vehicles (space launch, personal vehicles including the "clean car" under the Partnership for a New Generation of Vehicles or PNGV, heavy trucks, rail vehicles); and system design, planning and operations.

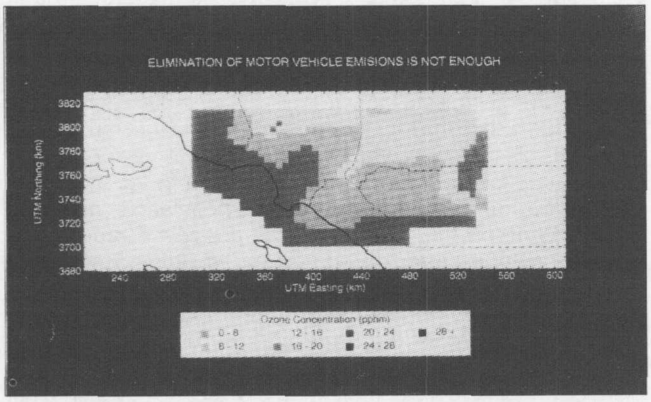

Fig. 9: Spatial distribution of the 1-hour maximum ozone concentration predicted for August 28, 1987 in Los Angeles County, Southern California, USA. (*Source:* California Institute of Technology[22]).

Research demonstrates that even complete removal of automobiles from an area such as Los Angeles, for example, would not be sufficient to eliminate the local ozone air quality compliance problem. Figure 9 illustrates this fact. It presents a map of Southern California, centered on Los Angeles County, showing the spatial distribution of the 1-hour maximum ozone concentration predicted by the California Institute of Technology (CIT) photochemical airshed model for August 28, 1987 for the case of zero highway motor vehicle emissions. Areas shown in two shades of raster are at or above the Federal ozone air quality standard of 0.12 ppm (12 pphm) even with zero highway motor vehicle emissions. This occurs due to the remaining emissions from other sources, which are substantial.

It is not our intent to discuss here the specifics of the possible options. Suffice it to say that the list is controversial. For example, the conservative Cato Institute[19] has advocated the elimination of federal support both for the clean car initiative (PNGV) and the production of ethanol as an additive to gasoline, calling the former a subsidy to the big three automobile manufacturers.

There is no doubt that the automobile reinvented can be a significant component of the future transportation system. Great efforts are being expended along several fronts with intriguing promises. There is clearly room for the electric car, the hybrid car, and the supercar. The electric car is commonly referred to as a "zero emissions vehicle"; however, it is not really that, for it needs recharging, and the system shifts the source of pollution away from the urban centers to the source of generating the electricity. Quite intriguing is the development of highly efficient cars with a goal of 80 or more miles to the gallon. This is the projected outcome of a collaborative effort between the big three and the Federal Government under the PNGV — Partnership for a New Generation of Vehicles. Even more ambitious are the possibilities for a "super" or "hypercar," capable of ten times the current mileage.[20]

Missing from the National Science and Technology Council list is Mag Lev (magnetically levitated trains), much touted in the 1991 Intermodal Surface Transportation Efficiency Act. The Act itself was heralded as a radical departure from the almost total focus of the past on highway building, since significant funds were earmarked for direct funding of transit, and R&D for Mag Lev and IVHS (Intelligent Vehicle Highway Systems). Too, the Act recognized the key role of local inputs, and promised the states flexibility to consider transport policies and approaches for solving such problems as congestion and air pollution noncompliance. The checkered history of Mag Lev is interesting in itself from another standpoint, for it is a good metaphor for the role of fundamental science and technology in our post-Cold War world. Mag Lev was developed at Brookhaven National Laboratory, the serendipitous result of fundamental studies. J. Powell and G. Danby of Brookhaven were issued the patents, but the prototypes of Mag Lev trains were built in Japan and Germany.

Beyond technology

Will technology prove a panacea and provide us with a way out from our predicament? This cannot be answered in the affirmative with total certainty. P. Ehrlich and J. Holdgren[21] have proposed a framework within which the impact of human activities such as those of the transportation sector may be viewed properly. Their simple but elegant analysis considers the total impact of a given activity on the environment to be the (multiplication) product of three different factors: Technology, Affluence, and Population.

This is probably best understood in terms of a concrete example. We may ask, what is the total amount of carbon dioxide emitted from burning fossil fuels in internal combustion engines in automobiles? The total amount is determined by three factors. The first is the emissions for each mile that each vehicle travels. This is a TECHNOLOGY factor — for the cleaner the car, the lower the emissions — and can be affected by such technological developments as catalytic converters, cleaner fuels, tuning of the engine, etc. The second factor is the number of miles that each person travels with his/her vehicle(s). This is an AFFLUENCE factor that reflects the availability and use of cars. The third factor is POPULATION, i.e. in this case, the number of persons that travel with personal cars. When I drive to my office, wrapped in 2,500 lbs of steel and plastic, I use one gallon of gasoline to drive 28 miles on a round trip. In the process I discharge into the atmosphere almost 24 lbs of carbon dioxide or the equivalent of 5 lbs of carbon. If we multiply together the amount that each vehicle-mile produces by the number of vehicle-miles each of us travels and by the number of people doing this, then we obtain the amount of carbon that we all discharge into the atmosphere by this activity. In 1991, man-made carbon dioxide from fossil fuels was about 6,200 million metric tons worldwide, with the U.S. contributing over 20 percent of the total.

The strategy to restructure transportation, in addition to the new high-tech, long-term options, needs to consider policies that significantly lower the energy intensity of the sector short term also. Appropriate incentives — credits, fees, taxes — can be provided to decrease the vehicle-miles traveled, but specific measures must be tailored to the local needs. What is appropriate for Long Island is likely not to be the right measure for rural Idaho. For the most part these are low-tech measures that need not await technological breakthroughs. High occupancy vehicle lanes and shifting of subsidies from individual cars to car pools or mass transit can be effective. Tax breaks for employers who provide parking or tolls to their employees, while denying similar tax considerations for train or bus tickets do not help persuade people to get out of their cars. Large, accordion-type buses, often almost empty, lumbering awkwardly in narrow streets in the center of towns are not helping solve the problem. Since congestion is primarily a commuter phenomenon or related to travel along specific axes, flex time, staggering of working hours, and lower mass transit ticket prices at peak hours, all would help to bring short-term improvements. Teleconferencing, incentives to accelerate scrappage of older cars, bicycle paths, appropriately variable tolls, and synchronized traffic lights can have obvious environmental and economic effects. The technical literature is replete with specific suggestions from experts. The emphasis has to be on meeting the local and regional needs through choices from an appropriately wide menu of options rather than being dictated by federal or state transportation planners who rarely seem to look beyond highways, parking, soundwalls and ever increasing accommodations for the automobile and the truck. Land-use and zoning policies need to be revisited. This is an especially critical issue. For example, with the increase of the number of people working in their homes, existing zoning regulations tend to limit this option that holds much promise for reducing the number of miles being travelled. It is ironic that often this limitation is due to ordnances put in place to guard against heavy traffic, and as a result, few professionals — doctors and dentists — can practice in their homes. Communities such as Palo Alto, Berkeley, Seattle in the U.S., and Milan and Munich in Europe are attempting to take advantage of the possibilities of a restructured transportation that considers the needs of the people and not of the cars exclusively.

Research and development efforts for mitigation of pollution have been focused almost exclusively on incremental technological improvements. Surely the achievements of these R&D efforts have been quite remarkable. Technology, however, has not been a panacea. The fact remains that today major urban centers have poor air quality. Gains that have been made through technological improvements (catalytic converters, cleaner fuels) have been diminished or negated by increases in the miles being travelled and the population. In a study at the California Institute of Technology[22] it was shown that "even complete removal of automobiles from the Los Angeles area would not be sufficient to eliminate the local ozone air quality compliance problem." This of course is due to the fact that emissions from other sources are quite substantial and no improvements in the technology of the automobile would bring about compliance with ozone air quality standards unless other activities were brought into compliance also.

MTBE, i.e. methyl-tertiary-butyl-ether, an important ingredient of reformulated gasoline, is another example of the difficulties that we encounter when we seek technological fixes in place of longer term, sounder approaches. In order to reduce atmospheric ozone especially during hot weather in urban areas that are in non-compliance with EPA standards, the Agency has mandated that oxygen containing materials such as alcohols and ethers be blended with gasoline. These blends tend to burn more cleanly and the industry has made large capital investments for their production and distribution. However, opposition has arisen to their use. Opponents have charged that the blends have deleterious effects on engine efficiency as well as being responsible for health effects, such as headaches and respiratory problems.

The interplay involving technology, development, and population growth has a global dimension also that has led to acrimonious encounters between economically developed and developing nations, as to who should be responsible for what in dealing with greenhouse gases and pollution in general. Rich nations with high consumption rates are a major offender. Likewise, poorer countries with large populations can make significant contributions through their sheer numbers. Of course, large populations with large consumption rates contribute through both factors. In order to solve this problem there are those who want to limit population growth, and those who want to limit consumption; and then there are the panglossians who in a vague manner put their whole faith in technological breakthroughs and insist that, while affluence and population increase, technological improvements can reduce the overall impact. However, no compelling basis is offered for such optimism.

Finally, what about the possible adverse effects of the newer technologies themselves? Radical restructuring through massive shift to telecommuting and proliferation of virtual organizations — developments which can significantly limit the need for commuting and transporting of goods — does not preclude that such restructuring, while it may reduce commuting to the office and to the factory, could also make that much more time available for more commuting of a different type. Affluence or consumption can overwhelm gains due to technological breakthroughs. In addition, increasing population could also impact negatively the situation despite possible improvements from technological breakthroughs. In fact, it is possible and even likely that population growth and increasing affluence can diminish or even negate gains made from technological improvements, as in the case of Los Angeles. Clearly, transportation in the long run, like all human activities in this planet, cannot be considered in terms of technology alone, but consumption patterns and population growth must also be taken into account. After all, we are dealing with finite resources, and it would be impossible to pave over the entire planet in order to make room for driving and parking the car.

Our choices in transportation loom starkly. The challenges are great, but matched by the potential gains. The obstacles are not insurmountable. In fact, positive developments, some only tentative, are appearing that augur well. Adversaries such as the conservative Cato Institute and environmental groups are finding common ground to challenge past policies that have created our predicament. Consortia of private, public and governmental groups are examining the feasibility and implications of true-cost pricing of various forms of energy. A number of environmental groups — from the Conservation Law Foundation, to the Union of Concerned Scientists, to the Energy Foundation, Sierra Club, and the Natural Resources Defense Council in the U.S. and corresponding groups in Europe — are attempting to focus attention on the costly and wasteful aspects of our transportation practices. The National Science and Technology Council draft on Transportation, in calling for System Assessment Tools and Knowledge Base as a priority item, is providing in essence the basis for addressing the issues of externalities. All these are hopeful signs that the required first step of honest accounting can be taken; that serious debate, based on thorough investigation and understanding, can replace our current parallel monologues; and that we can get ourselves on a course that leads towards the dream and away from the nightmare.

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