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Energy and transportation

Report of the Secretary-General

Summary

The transportation sector has been the major source of growth for oil demand over the past 25 years, and is expected to continue to be so in the medium term. During the period 1970-1994, world transportation energy demand grew at an average annual rate of about 1.9 per cent. In the Organisation for Economic Cooperation and Development (OECD) countries during this period, major transportation fuels demand increased at an annualized rate of about 1.4 per cent; in developing countries, as is to be expected considering their currently low levels of consumption, growth rates in major transportation fuels consumption were higher, exhibiting an average annual growth rate of about 5.3 per cent. There was a marginal decline in the transportation fuel demand of non-OECD Europe during this period.

The transportation system relies nearly completely on petroleum-based fuels, accounting for almost 60 per cent of final world oil consumption; the growing concerns over its environmental impacts, particularly greenhouse gas emissions, have stimulated research and development of alternative fuels and technologies. However, alternative fuel vehicles remain a small fraction of the total world vehicle stock.

Environmental impacts of transportation continue to be very large, but a few countries have made much progress in reducing some impacts, in particular vehicular emissions by means of catalytic converters and cleaner fuels. Carbon dioxide emissions, the major greenhouse gas of concern, continue to increase, which is unavoidable as it is a by-product of fossil fuel combustion. However, the environmental impacts of transportation are not confined to the combustion of transportation fuels but occur throughout the entire vehicle and fuel cycle.

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Governments have a significant role to play in reducing the environmental impacts of the transportation sector by putting in place and implementing an energy policy for the transportation sector that promotes improvements in transportation efficiency and the use of alternative fuels.

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I. Introduction

1. The report reviews global transportation trends, with particular emphasis on the major transportation consumer countries and the transport demand growth in developing countries. Both developed and developing countries are facing similar challenges, resulting from increasing mobility and freight activity as well as from a shift in modes – for both passenger and freight transportation, motor vehicles are gaining increasing modal shares, often at the expense of other modes.

2. Historically, the correlation between economic growth and the demand for transport has been strong, although this relationship may be moderated in the major economies by the increasing "dematerialization" of their economies. However, the demand for freight service in those economies is shifting towards faster and more flexible but more energy-intensive transportation system.

3. Environmental concerns over the increasing impacts of transportation fuels emissions and the near total dependence of transportation on petroleum products continue to stimulate interest in alternative fuels. The present report provides a brief review of a variety of alternative or replacement fuels and vehicles that are being tested, demonstrated and marketed.

4. The scope of the report is largely confined to the use and related environmental problems of transport fuels. Policy responses to those problems are not extensively treated in the report, although it is clear that transport policy can influence emissions of greenhouse gases and other gaseous as well as solid pollutants from transportation activity. Public policy responses to transportation infrastructure and land use, modal shifts and air quality, especially in urban areas, have had measurable success in many countries (for a useful discussion of policy approaches in energy and transport, see E/CN.17/1997/17/Add. 1).

II. Transportation and the economy

5. Transportation is an important component of any economy and makes a substantial direct contribution to gross domestic product (GDP). It provides valuable employment opportunities, and has large indirect benefits in facilitating national and regional development and globalization. Transportation, including equipment, travel and freight shipments, is one of the fastest growing sectors of the world economy. However, transportation also imposes considerable costs on society and the environment, notably in terms of accidents, pollution and the degradation of ecosystems and landscapes.

6. Although the exact relationship between transport and economic activity varies with the level of economic development, historical data confirm the relationship of GDP per capita to transport demand, as shown in figure I. Countries with high transport energy use relative to countries with similar income levels tend to have low population densities and/or lower relative prices of transportation fuels. Rising levels of transport activity have accompanied rapid economic development in a number of developing countries. Further changes in transportation demand and services can be expected in many developing countries, given that their development strategies are now focused on shifting from the processing of raw materials to the production of semi-processed and finished goods, higher unit value and lighter density.

7. In countries of the Organisation for Economic Cooperation and Development (OECD) growth in transport activity has closely tracked growth in GDP. Table 1 indicates average annual growth in GDP and transport activity in OECD countries. The importance of transport demand to the economy can be measured as the share of transport-related final demand in GDP. In the case of the United States economy, in 1995 total transportation-related demand was about 10.7 per cent of GDP, at about US$777.2 billion.[1]

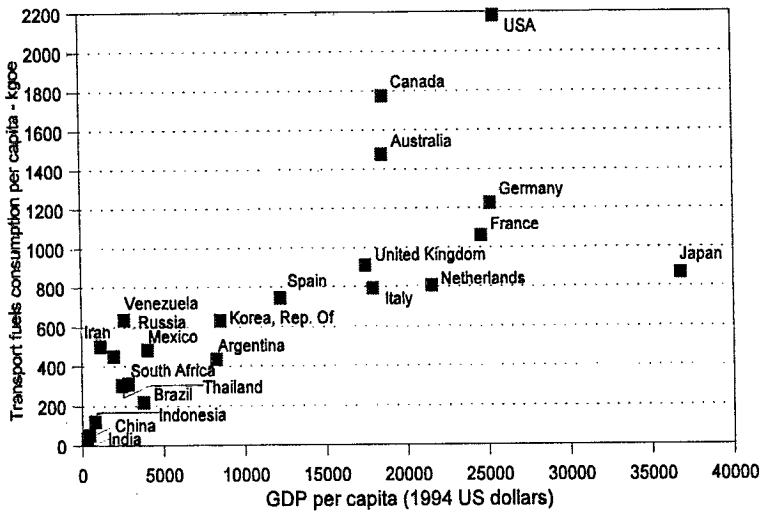
Table 1
Annual growth in gross domestic product and transport, OECD countries, 1975-1990

	GDP	*Freight traffic*	*Passenger traffic*
OECD – Europe	+2.6	+2.8	+2.8
United States	+2.8	+2.6	+2.3
Japan	+4.2	+3.6	+2.6

Source: World Energy Council, *Global Transport Sector Energy Demand Towards 2020* (1995), p. 27.

8. The public sector incurs large expenditures to build, maintain and regulate roads, mass transit facilities, ports and waterways, railroads and pipelines. In many countries, most of the direct costs of building and maintaining transportation infrastructure are recovered from user taxes and fees and through general tax revenues. The important role of the transport sector in improving general economic performance is widely accepted by policy makers, as manifest in their emphasis on investments in transport infrastructure since an efficient transport system is essential in the modern global economy.

Figure I
Transport energy use vs. gross domestic product, selected major users of transport fuels, 1994



Source: Department of Economic and Social Affairs of the United Nations Secretariat, based on United Nations, *Statistical Yearbook*, forty-first edition, and *Energy Statistics Yearbook, 1994*.

III. Energy and transportation

9. Over the next 20 years, growth in demand for transportation services is expected to be the major cause of growing world oil demand, as it has been over the past 25 years, despite large increases in oil prices on two occasions. During the period 1970 -1994, transportation energy demand grew at an average annual rate of about 1.4 per cent in OECD countries, while in developing countries it increased at about 5.3 per cent. The transport sector has not altered its near total dependence on petroleum products. Passenger cars are the main users of transportation energy, and the increase in vehicle-kilometres travelled has more than offset the increase in average vehicle fuel economy. Rapid growth in heavy truck and airline travel has also increased the demand for transportation energy. Increased use of heavy trucks substantially outpaced modest efficiency gains, and in the airline industry a rapid surge in passenger-miles travelled offset a substantial increase in per-passenger fuel economy.[2]

10. In 1970, total world consumption of motor gasoline, diesel oil and aviation fuels – the major transportation fuels – was about 1,135.7 million tons of oil equivalent (Mtoe), representing about 50 per cent of the total oil consumption of about 2,271.1 Mtoe, or about 26 per cent of total world commercial energy demand. By 1985, the major share of world total oil demand was for transportation fuels, their "cut of the barrel" having increased to about 55 per cent. In 1994, world demand for the major transportation fuels increased to more than 1,810 Mtoe (over 36 million barrels of oil per day), at an average annual increase of about 1.9 per cent during the 25-year period since 1970. The transportation fuels share of the total crude oil used (about 3,041.1 Mtoe) increased substantially to about 60 per cent, while their share of the total world commercial energy demand (7,880.6 Mtoe) declined to about 23 per cent (marine bunker fuels are not taken into consideration in the present report because of the difficulty in acquiring reliable data that would permit the correct attribution of fuel consumption to the countries concerned).

11. It is noteworthy that the transport sector is the only major sector of the economy in which consumption of crude oil has been increasing in the developed countries; in contrast, in developing countries oil demand has increased in all sectors of the economy. In OECD countries over the past 25 years, the transportation sector has remained almost totally dependent on oil products, while other sectors of their

economies have shifted away from oil. Oil use has declined in the residential and commercial buildings sector, as well as in the utility sector, although industrial oil use has remained stable, primarily due to the importance of petroleum as feedstock in the petrochemical industry.[3]

12. The share of world total major transportation fuels consumption of the OECD countries has been declining since 1970, from about 75.3 per cent to 65 per cent in 1990, but it marginally increased to 66 per cent in 1994. The decline in the share of OECD countries was largely the result of gains in the Asia and Pacific region, where its share of 4.8 per cent in 1970 increased significantly to about 12.8 per cent in 1994. Similarly, during the period 1970 to 1994, transportation fuels consumption in the Middle East region increased their share from about 1.1 per cent to 5.1 per cent, while the Latin America and the Caribbean region registered a relatively moderate gain, from 4.2 per cent to 5.5 per cent (see figure II).

13. During the 25-year period 1970-1994, the consumption of transportation fuels in OECD countries increased from about 855.8 Mtoe in 1970 to over 1,197.5 Mtoe in 1994, representing an average annual gain of about 1.4 per cent. Of the fuels, aviation fuels registered the highest growth rate of over 2.3 per cent, while motor gasoline gained 1.5 per cent and diesel oil gained the least – about 1 per cent. As is to be expected, growth rates in transportation fuels consumption were higher in the developing world given the starting point of very low levels of consumption. During the period under consideration, the average annual growth rate in consumption of transportation fuels was highest in the Middle East region, having increased substantially by 8.4 per cent from 12.5 Mtoe to about 90.3 Mtoe, followed by that in the Asia and the Pacific region for about 6.1 per cent from 52.4 Mtoe to 231.3 Mtoe. An average annual gain of about 4 per cent was registered in Africa, and in Latin America it was about 3 per cent. Very large differences in total consumption of transportation fuels in the different regions and groups of countries are clearly illustrated in figure III; the differences would be even greater if shown on a per capita basis.

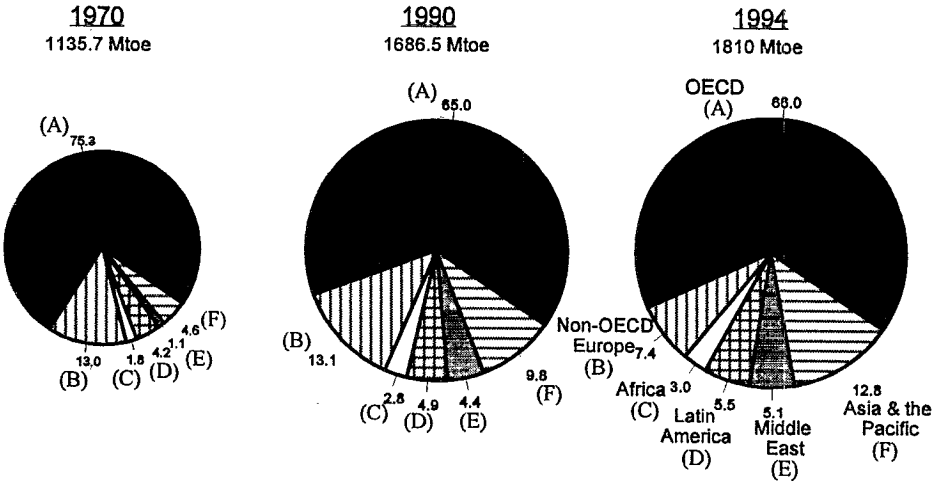
14. Motor gasoline and diesel oil account for the bulk of the transportation fuel used worldwide and taken in conjunction with the dominance of road transport among the different transport modes, motor vehicle registration would be a fairly good indicator of transportation energy consumption trends. Total passenger car registration in the world, as shown in table 2, increased significantly from about 194.1 million cars in 1970 to about 458.5 million by 1994. In the same period, commercial vehicles increased from 49 million to about 133.6 million. Passenger car ownerships in the OECD countries increased from 176.3 million cars in 1970 to about 384.9 million by 1994, while in the same period in non-OECD Europe and the rest of the world, passenger cars registration increased from about 17.8 million cars to about 73.6 million. In 1994, OECD countries – with a share of less than 20 per cent of the world's population – accounted for over 80 per cent of the total motor vehicle registration in the world – almost 83 per cent of the total passenger cars. Evidently, in the past 25 years there has been a tremendous increase worldwide in transportation activity as measured by passenger-kilometres, ton-kilometres and vehicle kilometres travelled. Almost all of the increase in transportation services was captured by road passenger and freight transport.

15. The growth rate in total world motor vehicle registration appears to have been on a linear trend during the 1970s and the 1980s, but the growth rate has slowed somewhat in the period 1990-1994, and may continue to be lower than in the past; the recent financial crisis affecting many of the newly industrializing economies may also contribute to reducing demand.

16. Table 3 shows aggregate passenger and commercial motor vehicles in use in selected countries, differentiated by income levels and on a per capita basis for passenger cars. It clearly illustrates the enormous differences in terms of population per passenger car, from a level of over 636 per car in China to less than 2 persons per car in the United States of America and under 3 per car in the other high-income economies of OECD. The number of motor vehicles in developing countries remain a small fraction of that of in the high-income countries, but there is greater potential for growth in developing countries, since not surprisingly, ownership rates are expected to grow more rapidly in the economies with the fewest vehicles. Despite higher growth rates of car ownership in developing countries, OECD countries will clearly continue to dominate in total car registrations. The 2 per cent average annual growth in passenger cars in the United States between 1970 and 1994 represented an increase of 58.3 million new cars on the road, more than 10 times as many as the 5.1 million additional passenger cars in the Republic of Korea as a result of a remarkable annual growth rate of 19.4 per cent during the same period.

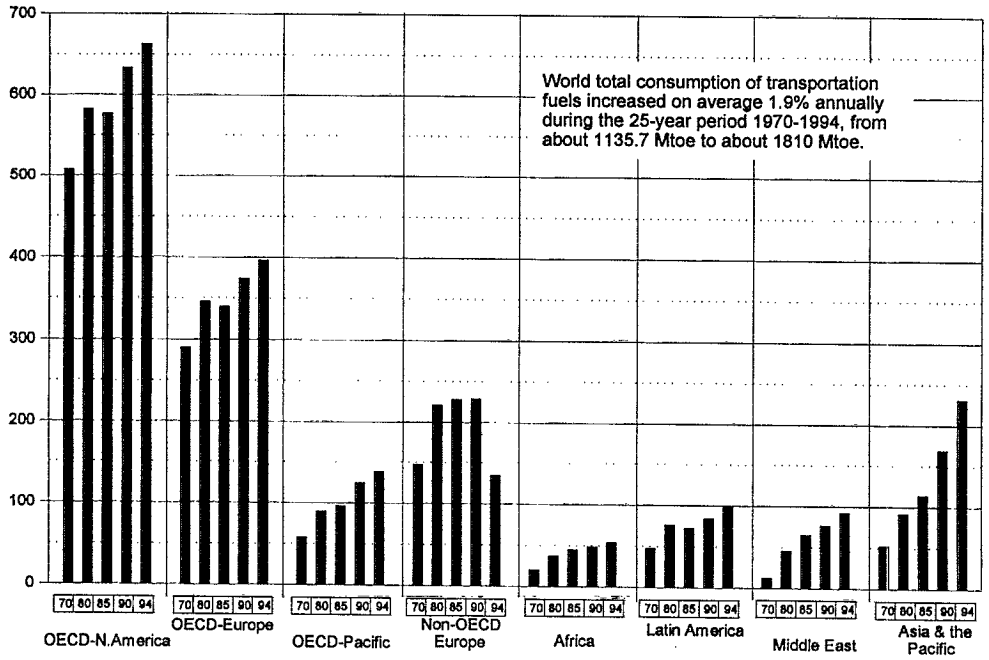
17. With the substantial increase in ownership, passenger car occupancy levels have declined considerably in OECD countries, and have increased the tendency towards low load factors for commercial vehicles. In contrast, despite relatively rapid growth in motor vehicle use in developing countries, buses and trucks, and for that matter trains, are

Figure II
Share of total major transportation fuels consumption, by region
(Percentage)



Source: Department of Economic and Social Affairs of the United Nations Secretariat, based on *Energy Statistics Yearbook* (United Nations publication), various issues.

Figure III
Total consumption of major transportation fuels, by region, 1970-1994
(Million tons of oil equivalent)



Note: The major transportation fuels are motor gasoline, aviation fuels and diesel oil; non-OECD Europe consists of Eastern Europe and the Republics of the former USSR.

Source: Department of Economic and Social Affairs of the United Nations Secretariat, based on *Energy Statistics Yearbook* (United Nations publication), various issues.

Table 2
Motor vehicles in use worldwide, 1970-1994
(Thousands of units)

					Shares of total (percentage)					
	Passenger cars		*Commercial*		*Passenger cars*		*Comm. vehicles*		*Annual growth*	
Region	*1970*	*1994*	*1970*	*1994*	*1970*	*1994*	*1970*	*1994*	*A*[a]	*B*[b]
World	194 140	458 489	49 040	146 501	100	100	100	100	3.5	4.5
OECD	176 325	384 871	40 644	102 030	90.8	82.9	83.9	69.6	3.2	3.8
Non-OECD Europe	4 686	15 487	2 455	12 885	2.4	5.0	3.4	8.8	4.9	6.9
Africa	3 290	9 411	1 297	4 887	1.7	2.6	2.1	3.3	4.3	5.4
Latin America	6 403	20 497	2 362	6 359	3.3	4.8	4.5	4.3	4.8	4.0
Middle East	963	9 065	364	4 523	0.5	0.7	2.0	3.1	9.4	10.6
Asia & the Pacific	2 474	19 158	1 918	15 818	1.3	3.9	4.2	10.8	8.5	8.8

Note: In a number of countries, motor vehicles in use in 1994 were estimated.

Source: Department of Economic and Social Affairs of the United Nations Secretariat, based on the *Statistical Yearbook* (United Nations publication), various issues.

[a] Passenger cars.

[b] Commercial vehicles

Table 3
Motor vehicles in use and population, selected countries[a]
(Thousands of units)

	Total Passenger cars		*Total Commercial vehicles*		*Annual growth rate (percentage)*		*Population per car*
	1970	*1994*	*1970*	*1994*	*Cars 1970-94*	*Commercial 1970-94*	*1994*
Low-income economies							
China	133.0	1 900.0	480.0	1 513.0	11.2	4.7	636.2
Egypt	130.7	1 225.0	35.4	445.0	9.4	10.7	47.2
India	627.2	3 330.0	413.9	2 396.7	6.9	7.3	275.8
Kenya	95.9	171.5	18.0	172.8	2.4	9.5	170.8
Nigeria	57.0	227.0	40.0	22.3	5.7	-2.3	477.8
Pakistan	154.5	955.1	63.6	359.5	7.6	7.2	132.6
Lower-middle-income economies							
Algeria	142.8	725.0	81.6	480.0	6.7	7.3	37.7

	Total Passenger cars		Total Commercial vehicles		Annual growth rate (percentage)		Population per car
					Cars	Commercial	
	1970	1994	1970	1994	1970-94	1970-94	1994
Colombia	238.5	761.7	83.5	672.6	4.8	8.7	45.3
Indonesia	238.9	1 890.3	125.9	1 903.6	8.6	11.5	101.7
Iran (Islamic Rep. of)	278.2	1 557.0	73.5	588.9	7.1	8.7	38.4
Poland	479.4	7 153.1	259.9	1 395.1	11.4	7.0	5.4
Czech Rep.	825.8	2 917.3	198.6	336.2	5.2	2.1	3.5
Thailand	184.7	1 798.8	162.8	2 384.1	9.5	11.3	33.0
Tunisia	66.4	325.0	37.2	222.0	6.6	7.4	26.9
Turkey	137.8	2 861.6	159.8	530.4	12.9	4.9	21.4
Upper-middle-income economies							
Argentina	1 439.6	4 427.0	754.8	1 239.0	4.6	2.0	7.7
Brazil	2 324.3	8 098.4	696.2	1 839.0	5.1	4.0	19.0
Hungary	240.3	2 176.9	159.4	297.1	9.2	2.5	4.7
Malaysia	279.4	2 333.0	31.0	422.0	8.9	11.0	8.5
Mexico	1 233.8	8 451.1	588.9	3 839.4	8.0	7.8	11.0
Republic of Korea	60.7	5 148.7	64.7	2 226.7	19.4	15.2	8.7
Saudi Arabia	64.9	2 664.1	50.4	2 272.8	16.0	16.5	6.6
South Africa	1 544.5	3 488.6	428.2	1 784.9	3.3	5.9	11.6
Venezuela	565.8	1 579.0	198.2	460.0	4.2	3.4	13.4
High-income economies							
Australia	3 898.5	8 209.0	971.5	2 151.0	3.0	3.2	2.2
Canada	6 602.2	13 639.4	1 481.2	3 764.9	2.9	3.8	2.1
France	12 900.0	24 900.0	2 904.0	4 027.0	2.7	1.3	2.3
Germany	14 673.4	32 652.0	1 398.6	2 826.0	3.3	2.9	2.5
Israel	151.2	1 057.5	89.2	251.7	8.1	4.2	5.1
Italy	10 181.2	29 600.0	1 306.7	2 745.5	4.4	3.0	1.9
Japan	8 832.1	42 679.0	8 740.5	20 916.0	6.5	3.6	2.9
Netherlands	2 258.0	5 883.9	293.0	687.3	3.9	3.5	2.6
Singapore	147.1	340.6	37.5	136.8	3.4	5.3	8.6
Spain	2 377.7	13 733.8	741.0	2 952.8	7.3	5.7	2.9
United Kingdom	11 665.8	21 740.0	1 709.9	2 994.0	2.5	2.3	2.7
United States	88 840.5	147 171.0	17 978.4	48 298.0	2.0	4.0	1.8

Source: Department of Economic and Social Affairs of the United Nations Secretariat, based on *Statistical Yearbook* (United Nations publication), various issues.

[a] Country classification based on World Bank *World Development Report, 1994* (Oxford University Press).

almost always overloaded with people and goods, often leading to safety problems, a situation that is unlikely to change in the near future. People in developing countries rely heavily on public and non-motorized transportation, such as bicycles and cycle-rickshaws (particularly in Asian cities), including foot travel.

18. As noted, the transport sector is almost totally dependent on petroleum products, and it is evident that its demand for oil will continue to increase substantially. Although there have been significant improvements in energy efficiency over the past 20 years, the efficiency gains appear to have tapered off or stalled for the largest energy-using modes. The efficiency gains in transport energy use prompted by the oil price increases in the 1970s had until recently been restraining the growth in transport energy demand. But after the sharp decline in oil prices in 1986, improvement in transportation energy efficiency appears to have slowed down almost to a halt. This may have significant ramifications on the world energy market since nearly all transport energy demand projections, particularly for OECD countries, have been based on the premise of continued improvements in transportation energy efficiency.

19. Furthermore, oil supply will not be a constraint to continued growth in world transportation energy demand. Currently, the world oil reserves to production ratio appears to be sufficient to meet total world oil demand for the next three decades and more, even if there should be a strong surge in transportation energy demand. Current trends indicate continued growth in world transportation energy demand in developing countries, underpinned by the strong correlation between economic growth and the demand for transport as demonstrated by historical data, and in high-income economies this relationship may be moderated by the increasing "dematerialization" in production, i.e., producing fewer tons per dollar of GDP. However, in OECD countries the demand for freight services is shifting towards faster and more flexible but energy-intensive transportation system. This shift to road-freight transport and much increased use of air freight, is largely due to the two interlinked trends in production, the move towards production of lighter high-value goods and the expanding use of "just in time" production techniques, requiring smaller and more frequent deliveries, which are best provided by road and air transport.[4]

20. International aviation travel and freight transport has grown tremendously during the past 25 years, as a result of economic growth, falling airline tariffs and technical advances. Air transport has played an important role in shaping the global economy. Decreasing air fares in a time of increasing real wages and the inherent time-saving aspect of air travel are the main contributors to the high growth rate in passenger traffic. Since 1960, air passenger traffic has expanded at an average annual rate of about 9 per cent and air cargo by 11 per cent.[5] World demand for aviation gasoline and jet fuels increased from about 108 Mtoe in 1970 to more than 180 Mtoe in 1994. World air travel is dominated by OECD countries, where aviation fuels consumption increased from about 72.4 Mtoe to 128.1 Mtoe during the same period, while in developing countries it increased from 12.3 Mtoe to 37.1 Mtoe. Growth in air travel has been more rapid than growth in travel by passenger car, with revenue air passenger miles having increased at an average annual growth rate of 6.8 per cent in the period 1970-1992.[6]

21. The relative position of the railway sector in the transportation system has remained fairly unchanged during the past two decades. Although it plays a vital role in freight transport in the OECD countries, overall rail freight volume in those countries has declined, but with significant differences among individual countries. In developing countries, both passenger and freight transport volumes have increased, especially in the larger developing economies. Rail passenger transport plays an important role in personal mobility in a number of developing countries. In China and India, each of their railways carry more passenger traffic than the combined railways of all OECD-Europe and the United States. In India, per capita passenger-kilometres travelled by rail are more than twice as high as in the United States. The type of rail traction used varies, with electric traction more heavily relied upon in Europe and Japan, and diesel traction more common in North America, Australia and the developing countries. Primary energy use does not differ significantly between electric and diesel locomotion, and the growth rate in energy demand by the railway sector appears to be relatively far lower than that of the road transport sector.

IV. Alternative fuels

22. The near total dependence of the transportation system on petroleum and the fact that the transport sector already accounts for 60 per cent of final world oil consumption, together with increasing concerns about environmental impacts of petroleum combustion emissions, have strongly stimulated research and development into alternative fuels and technologies. Ranging from agricultural biofuels and alcohols to electricity and gaseous fuels, a multitude of alternative fuels for transportation are being investigated. Many Governments worldwide are providing legislative and

fiscal incentives for the development and take-up of alternative fuels and engines.

23. Alternative transportation fuels (ATF) that have attracted the most interest and are actively being tested and developed are natural gas, electricity, liquefied petroleum gas (LPG), methanol, ethanol, rape seed oil methyl ester (RME) and hydrogen. To achieve wide use it is critical that ATF characteristics meet important requirements, such as cost, availability, safety and emissions. Apparently, almost any alternative fuel vehicle (AFV) technology can serve short-range (less than 100 kilometres) duty cycles, while ethanol, methanol and LPG are currently the only potential alternative transportation fuels for long duty cycles (over 300 km) and compressed natural gas (CNG) vehicles for a range of about 300 km per day.[7]

24. Increased market penetration of electric vehicles (EV) will depend on improvements in battery-charging rates, energy densities and power densities and market factors, including cost, consumer preference and the response of manufacturers to more stringent regulations for air quality. Environmental drawbacks to the types of EVs currently in use are the emissions from power stations that generate the electricity for battery recharging, and the introduction of significant amounts of lead into the environment regardless of best efforts to recycle lead-acid batteries. There is no consensus over what type of battery may be best for the future, and a variety of battery types are being developed. About 65 per cent of electricity generated is from fossil fuels, coal, oil and natural gas. Thus, there is some potential for emissions from power stations, associated with EV-battery recharging, to be higher than from low-emission vehicles powered by gasoline or natural gas.

25. The range and performance of an EV can be considerably improved when a turbine or combustion engine is coupled in series or parallel with an electric power-train, the hybrid electric vehicle (HEV). A number of major equipment manufacturers are putting some HEV models on the market, combining electric drives and internal combustion (IC) engines. HEVs can compensate for many of the shortcomings of the pure EV, through increased range, reduced vehicle weight (i.e., less battery weight), reduced operating cost per kilometre and generally increased road performance. The disadvantages of the HEV is its complex power train and emissions from the internal combustion auxiliary power unit (APU).

26. The limitations in range and durability of batteries in EVs are avoidable with the use of fuel cells, which are well suited as APUs, given their considerably higher efficiency than that of IC engines and turbines and very low emissions. Hydrogen is the ideal fuel for fuel cells, and methanol and natural gas and motor gasoline are also suitable after sufficient processing. There has been good progress in improving the efficiency of the fuel cell, so that power density has been improved by a factor of 6 in the past five years, with the use of platinum catalysts on each side of the fuel cell membrane and other recent breakthroughs in fuel cell technology.[8] Two leading car manufacturers have developed fuel cell cars based on carrying the hydrogen in methanol, with a range of 250 miles between fill-ups of liquid methanol, and an innovative way has been demonstrated to rid the automotive fuel cell of its waste water. Most major automobile manufacturers are moving forward with fuel cell cars. Some use hydrogen gas tanks, while others use liquid methanol and even gasoline. Hydrogen is expensive to produce and problematic to store. Methanol reforming is relatively simple, but the reformers are still too big for cars and the distribution system is not in place. There is a distinct advantage if gasoline is reformed to produce hydrogen, because it is readily available worldwide, so that such fuel cells could be widely introduced as a practical power source in the near term. Fuel cell cars can easily outperform today's battery-powered EVs. However, a key question for a fuel cell car is the cost of the fuel cell itself. Automobile industry experts estimate that for fuel cell cars to be marketable, fuel cell costs should be US$100 to 150 per kilowatt of capacity. In contrast, conventional gasoline engines cost about US$35 per horsepower, or about US$50 a kilowatt.[9]

27. EVs show potential for increasing market share in areas with strong restrictions on emissions, especially in congested urban areas and perhaps as a second family car in high-income economies. The HEV, although more complex may become an interesting AFV since it overcomes many of the shortcomings of the purely battery-powered electric car. Major car manufacturers, fuel cell manufacturers, national laboratories and universities are intensifying existing research efforts, as demonstrated in recent advances in fuel cell technology, and by forming alliances and openly linking research in the three basic areas of an AFV – power source, power plant and drive train – will probably accelerate the development of a commercially viable system. An alliance of a number of leading car manufacturers have set a target of the year 2004 for a commercial automotive fuel cell and drive train system.[10] With mass production, prices will come down, but many challenges remain to be satisfactorily addressed; constraints in using fuel cells in transportation applications are considerably different and more demanding than in stationary applications, and the determination of the power

source – whether hydrogen, methanol, gasoline or some other fuel – remains problematic. A key element in the expansion of alternative fuel use is increasing the availability and convenience of alternative refuelling facilities.

28. Among the ATFs within a near-term time horizon, natural gas appears to be the most likely significant alternative to motor gasoline and diesel, particularly for use in fleets, given its abundant resources, its possibilities as a high-performance fuel, its clean burning qualities and its convenient commercial availability to end-users, especially in the major transportation consumer nations. Natural gas can be stored onboard a vehicle in pressurized tanks in either a compressed (CNG) or liquid (liquefied natural gas (LNG)) state; in the latter case, fuel tanks must be insulated as well. Currently, in the use of natural gas, emphasis is on CNG, but LNG is being increasingly looked into because of its storage benefits, although the technology for transferring LNG from a refuelling station to a vehicle and vaporizing it en route to an engine largely remains to be demonstrated.

V. Transportation and the environment

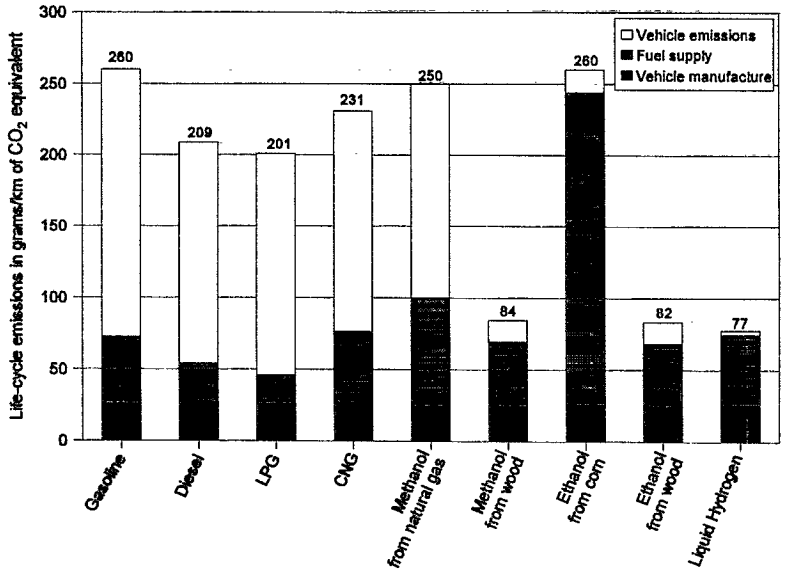
29. With the tremendous growth and the continuing high growth rates of travel and traffic around the world, it is becoming increasingly important to monitor the relationships between transportation and the environment. Transportation accounts for a substantial share of emissions of gaseous pollutants, particularly greenhouse gases, and particulate matter. Concern over air quality and greenhouse gas-induced global warming has led to actions to reduce some environmental impacts. In several OECD countries, measurable progress has been made in reducing some of those adverse environmental impacts. Technology-based strategies have been mainly applied to address the environmental impacts by improving the performance of IC engines and applying controls to motor vehicle emissions through the use of, for example, lead-free and sulphur-free gasoline; fuel additives to make fuels pollute less; and catalytic converters to reduce tailpipe emissions of gaseous pollutants, carbon monoxide, volatile organic compounds and nitrogen oxides. However, some emissions from transportation have increased, mainly carbon dioxide, the major greenhouse gas of concern, which is unavoidable since it is a by-product of fossil fuel combustion. Although this technology-based approach to mitigation of some of the impacts has worked well in some countries, the gap may further widen in the race between impacts-mitigation technology and the increasing demand for more transportation. Moreover, transportation activity has outpaced efficiency gains, resulting in increased energy use and thus increased carbon dioxide emissions, and the recent slowing in the rate of improvement in fuel efficiency will clearly exacerbate the problem.

30. Life-cycle emissions of a variety of transportation fuels are shown in figure IV, which should be viewed with the caveat that measuring actual emissions over the entire fuel cycle is extremely difficult, and dated material and assumptions are unavoidable. Synthetic liquid fuels derived from fossil fuels, including some biomass-derived fuels, provide little or no reduction in greenhouse gas emissions. LPG and CNG in optimized engines can reduce emissions relatively by about 10 to 25 per cent. Methanol and ethanol from wood or other low-input biomass feedstock, which have yet to be technically demonstrated on a large-scale basis, could result in greenhouse gas emissions of about 60 to 80 per cent. A large-scale replacement of the current fossil-fuel-based transportation system by fuels derived from completely renewable sources of energy, including hydrogen from electrolysis of water and EVs powered by electricity from renewable energy sources, could result in over 80 per cent reduction of greenhouse gas emissions from transportation fuels.

31. It is apparent that the greenhouse gas advantage of alternative fuels is drastically reduced by energy use in the upstream processing of alternative fuels. Even battery-powered EVs provide little or no benefit if the electricity is generated from fossil fuels. Therefore, unless there is a widespread switch to cellulosic ethanol from woody plants or to carbon dioxide-emission-free energy sources, such as solar, wind and nuclear energy and hydropower, even large market penetrations of alternative fuels could have little effect on emissions of greenhouse gases from transportation activity.

32. Considering the fast-rising share of transportation fuels in world total oil demand noted in section III above, a reduction in the use of petroleum-based transportation fuels by switching to alternative fuels would lead to a lower growth rate in world demand for oil and thus substantially moderate the increase in global carbon dioxide emissions. Given their vast resources in technology, human resources, manufacturing and finance, there is ample opportunity for fuel switching in the near term in the industrial nations, and consequently for influencing the pattern of demand for transportation fuels in developing countries.

Figure IV
Life-cycle greenhouse gas emissions of various automotive fuels[a]



Source: Organisation for Economic Cooperation and Development, *Cars and Climate Change* (1993).

[a] Based on North American vehicles and energy supply system.

VI. Conclusions and suggestions for further action

33. Petroleum demand in the transportation sector will continue to increase substantially for the next 20 years, since the transportation sector will remain reliant on petroleum-based fuels during this time. As crude oil supply is expected to be fully sufficient to meet total world oil demand through 2030, including any surge in transportation fuel demand, oil price developments that would influence a shift to alternative transportation fuels and substantially increase its widespread use, cannot be reasonably expected in the near term. Moreover, the existing stock of transport equipment will limit opportunities for fuel switching. Thus, market instruments and other measures, such as fiscal incentives and regulations, will be needed to encourage faster uptake of alternative fuels.

34. Evidently, Governments have a significant role to play in reducing the environmental impacts of the transportation sector by putting in place and implementing a transportation sector energy policy that promotes improvements in transportation efficiency and use of alternative fuels. Particularly for the reduction of greenhouse gas emissions, the main thrust of a transportation sector energy policy should be on increasing efficiency and fuel flexibility: promote short-term efficiency improvements, develop markets for alternative fuels, develop technologies for alternative fuel vehicles and reduce the demand for travel. Widespread introduction of alternative fuels will need special assistance: compared with gasoline and diesel fuels, such fuels require different refuelling infrastructure, vehicle fuel storage mechanisms, and engine and emission control technologies.

35. Due to recent environmental concerns but also prompted earlier by fiscal considerations and concerns over security of supply, most OECD countries have used market instruments to restrain fuel and motor vehicle use. Policy measures have also led to substantial reductions in gaseous (other than carbon dioxide) and particulate emissions from petroleum combustion in the transportation sector. However, many other policies and some deep-rooted social forces, such as an affinity for cars and a preference for private conveyance, have increased both the amount of fuel used by cars and the distances people drive them. In developing countries, although there are emission control measures comparable to those of OECD countries in place in some major cities, enforcement procedures are apparently not

adequate. Increasing population, urbanization and per capita income in developing countries will increase demand for and affect the nature of passenger transport; thus, strict control of emission standards is needed.

36. Market instruments and policy measures need to be applied evenly to all types of IC engines, whether mobile or fixed, large or small, or powered by gasoline, diesel or other petroleum-based fuels. For example, the efficiency of an average new car has improved to such an extent that it is estimated that running a lawn mower at home for an hour produces as much pollution as driving a new car for 2,000 km. And diesel-fuelled buses and trucks are allowed to operate at lower emission standards, especially for particulate emissions that are proven serious health hazards. Moreover, it is evident that in the largest energy-using transportation modes, improvements in efficiency have slowed, and there is therefore a need to reverse this trend.

37. Significant reductions in greenhouse gas emissions can be achieved in the transportation sector by improving the efficiency of drive trains, body shape and materials used in all vehicles, and by switching to alternative and improved fuels. In these key areas, changes in OECD countries can clearly influence the pattern of demand for transportation services in the rest of the world.

38. There are a wide number of possible policies for reducing the negative environmental and social impacts of transportation. A taxonomy of such policies could include the following: (a) measures to reduce demand; (b) measures to encourage change of transportation modes; (c) measures to raise energy efficiency within each transportation modes; and (d) measures to promote alternative fuels. In its report for the 1997 review of the Rio commitments, the High-Level Advisory Board on Sustainable Development concluded that the best prospect for securing significant gains in the transport sector would be through a combination of such policy measures, and it provided examples of several of them that together could constitute a programme of action. The Board also recommended that Governments give serious intention to launching such a programme of action at the international level. The Board further recommended that the programme of action be targeted on several cities in the various regions of the developing world, with international collaboration between city authorities, urban planners and bilateral and multilateral sources of finance, with a view to developing blueprints for implementing such schemes by the year 2002 (see E/CN.17/1997/17/Add.1).

Notes

[1] United States Department of Transportation, *Transportation Statistics Annual Report 1997* (Washington, D.C., 1997), table 2.1a.

[2] Statistics on the consumption of major transportation fuels in the present report are taken from *Energy Statistics Yearbook* (United Nations publication), various issues, and *Energy Statistics and Balances of Non-OECD Countries* and *Energy Balances of OECD Countries* (Paris, OECD), various issues.

[3] See *Energy Balances of OECD Countries* (Paris, OECD), 1991-1992 and 1994 issues.

[4] See United States Department of Transportation, op.cit., chap. 4, p. 85.

[5] See "Sustainable development: OECD approaches", contribution of OECD to the seventeenth special session of the General Assembly (Paris, OECD, 1997).

[6] See World Energy Council, *Global Transport Sector Energy Demand Towards 2020* (London, 1995).

[7] For an in-depth analysis and discussion of alternative fuels and technology, see United States Department of Energy, Energy Information Agency, "Alternatives to traditional transportation fuels: an overview" (Washington, D.C., 1994).

[8] See "Hydrogen, fuel for the twenty-first century?", *Energy Economist*, November 1996; and *New York Times*, 8 October 1997, p. D.1.

[9] *New York Times*, 21 October 1997, p. D.1.

[10] Ibid., 16 December 1997, p. D.1.