THE TRANSPORTATION SECTOR: GROWING DEMAND AND EMISSIONS

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Preface

This paper by Arnulf Grübler discusses the transportation sector from two perspectives that recently have received increasing interest in both national and international forums: global environmental change and its relationship to population growth.

The transport sector is of particular interest for two reasons. First, global transportation energy demand is the fastest growing end-use category, and has proven quite inelastic in response to the energy price increases that prevailed in the 1970s and early 1980s. Secondly, it is the sector where the impact of population growth on natural resource consumption and resulting environmental pollution is perhaps the most indirect of all energy demand categories. Access to, and ways of utilizing transport modes and associated technologies are the key variables determining levels of resource consumption and environmental impacts.

The paper concludes that the impact of population growth on transport energy demand is rather weak if analyzed at the appropriate level of disaggregation. Moreover, the paper candidly illustrates some of the complexities underlying transport choices and the wide heterogeneity across different regions, countries, and social strata. By adopting a quantitative perspective and by contrasting past and current developments with an overview of future transport energy demand scenarios the paper illustrates the background research being performed within the Environmentally Compatible Energy Strategies (ECS) Project at IIASA as input for the development of long-term scenarios that reconcile the objectives of economic and social development in an environmentally compatible manner.

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The transportation sector: growing demand and emissions

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This paper examines the current and historical energy demand for transportation at the global and world region levels. Its underlying structure and trends in goods and passenger transport are also discussed. Various scenarios for transportation energy demand over the next decades are reviewed and analysed with respect to the relationship between population growth and transport energy demand. The paper concludes that the relationship is rather weak if analysed at the appropriate level of disaggregation.

Introduction

The purpose of this paper is to sketch out some historical developments in the transport sector and to discuss a number of scenarios of its future evolution, with special emphasis on the role of population growth and its impacts on natural resources. The transport sector is of particular interest for two reasons: (i) global transportation energy demand is the fastest growing end-use category, and has proven quite inelastic in response to the energy price increases that prevailed in the 1970s and early 1980s; and (ii) it is the sector where the impact of population growth on natural resource consumption, and resulting environmental pollution, is perhaps the most indirect of all energy demand categories. Access to and ways of utilization of transport modes and associated technologies instead are the key variables determining levels of resource consumption and environmental impacts.

Table 1 summarizes the commercial energy demand in 1990 by different sectors, and by broad geographical/socio-economic world regions since 1971. Currently, transportation accounts for about one-quarter of commercial energy consumption world-wide, and accounts for around 43% of oil consumption. At the face value, this consumption, especially when compared to known reserves

Table 1. Final (commercial) energy demand by different sectors and different regions of the world (1971; 1990), (Mtoe), and average annual growth rates (percentage/year)

1971	Industry	Transport	Residential and commercial	Total	Transport or % of total
OECD—North America	499	392	456	1347	29
OECD—Europe and Pacific	518	199	336	1053	19
Eastern Europe and ex-USSR	430	112	243	785	14
Developing countries	145	110	312	567	19
World	1592	813	1347	3752	22
1990					
OECD—North America	542	526	461	1529	34
OECD—Europe and Pacific	527	372	443	1342	28
Eastern Europe and ex-USSR	577	167	420	1164	14
Developing countries	681	287	702	1670	17
World	2327	1351	2027	5705	24
Average annual growth rates (%/year)					
OECD—North America	0.44	1.56	0.06	0.67	74
OECD—Europe and Pacific	0.09	3.35	1.47	1.28	60
Eastern Europe and ex-USSR	1.56	2.12	2.92	2.09	15
Developing countries	8.48	5.18	4.36	5.85	16
World	2.02	2.71	2.17	2.23	28

Source: IEA (1993).

of crude oil or even to potential geological resources, does not suggest that Malthusian resource limits are likely to materialize well beyond the middle of the next century.

This situation might change, however, should some projected scenarios materialize. For instance, the recent global energy scenario developed by Greenpeace (Lazarus et al. 1993) discusses a baseline transportation scenario, which indicates that the present number of 700 million road vehicles (cars, motorcycles, and trucks) would grow to nearly 5 billion[1] by the end of the 21st century. Even considering efficiency improvements, this would translate into a demand growth of a factor of 3 to 4. Transportation alone would require, in such a scenario, up to 50% more than the present total oil consumption world-wide.

Two decades of transportation energy demand

Perhaps the most notable dynamic trend is the dominance of transportation energy consumption increases in total demand growth in the OECD (Organization for Economic Co-operation and Development) countries (Table 1). Around two-thirds of additional energy demand growth over the last twenty years has been derived from increases in mobility. Conversely, transportation demand growth, while being significant in both absolute and percentage terms, typically accounted for around 15% of additional energy demand in reforming and developing economies. Considering the differences in population growth, this allows us to conclude that increases in per capita consumption level is a more powerful influencing variable than population growth.

Based on the data presented in Table 1, per capita energy consumption for mobility of goods and people varies from around 70 in developing countries to 1900 kgoe (kilograms oil equivalent) in North America, i.e. nearly by a factor of 30. Looking across different income levels and individual lifestyles, these disparities are likely to be even higher. It has to be emphasized that such disparities exist not only *between* different countries but also *within* countries. Transportation energy demand differences between urban elites and rural poor in developing countries will be much larger than differences between income groups within their national capital or even between cities in different countries.

Thus, the situation with respect to transport energy demand and its resulting implications on resource consumption and the environment is quite heterogeneous. Significant disparities in levels of economic activity and its materials and transport intensiveness, access to motorized individual mobility, modal split choices, distances travelled, and energy efficiency of transport technologies among other factors have to be considered. A further complication is the absence of reliable statistics linking transportation energy demand to transport activities. In fact, energy statistics concentrate on a detailed account of products subject to market transactions and are usually blind to the different uses a product can serve e.g. a litre of diesel in a passenger car, a truck, etc. Conversely, transportation statistics and mobility surveys focus on level and structure of transportation services (such as tonnes or passengers/kilometre or number of trips) without collecting information on how these actually translate into final energy demand. The missing elements include, among others, information on load factors (e.g. passengers/car) and the energy or fuel efficiency of the technological devices used to render a particular transportation service.

Goods transportation

Based on estimates developed at International Institute for Applied System Analysis (Nakicenovic et al. 1993; Messner, Strubegger 1991) global transportation energy consumption can be roughly divided into two: 60% for passenger travel and 40% for movement of goods. In the materials and energy intensive economies of Central and Eastern Europe and the former USSR, this ratio is inverse—60% of transport energy serves for goods transport and only 40% for passenger mobility. These differences are due to many factors like structure and level of economic activities, size of the country and the spatial division of production and consumption, and international trade. They determine the amount of transportation services (tonnes/km) for an economy. Choice of different transport modes, their relative energy efficiency and capacity utilization, in turn, determine the amount of energy required to deliver the service demand.

Figure 1 shows estimates of total freight (tonnes/km) transported for a number of countries as a function of the size of the economy. Whereas the positive correlation comes as no surprise, it is nevertheless noteworthy to see persistent differences even between countries of similar size of economic activities and area (e.g. between India and China, or the USA in 1960 and the former USSR in 1980). Moreover, the correlation between economic activity and goods transport is not one to one. With increasing economic development, GNP (gross national product) growth requires the addition of fewer tonnes/km due to changes in output-mix and a shift towards more advanced, lightweight materials, i.e. *dematerialization.*

Counterbalancing effects for energy consumption come from changes in the goods transport, modal split from rail and inland navigation (low value bulk commodities) to trucks, even aircrafts. Schipper, Meyers (1992) have analysed resulting changes in the goods transport energy intensity of a number of OECD countries, concluding that, with the exception of West Germany and the UK, modal split changes (changes in structure) have outweighed declines in the transport intensity of OECD economies (Table 2). As a result, the goods transport

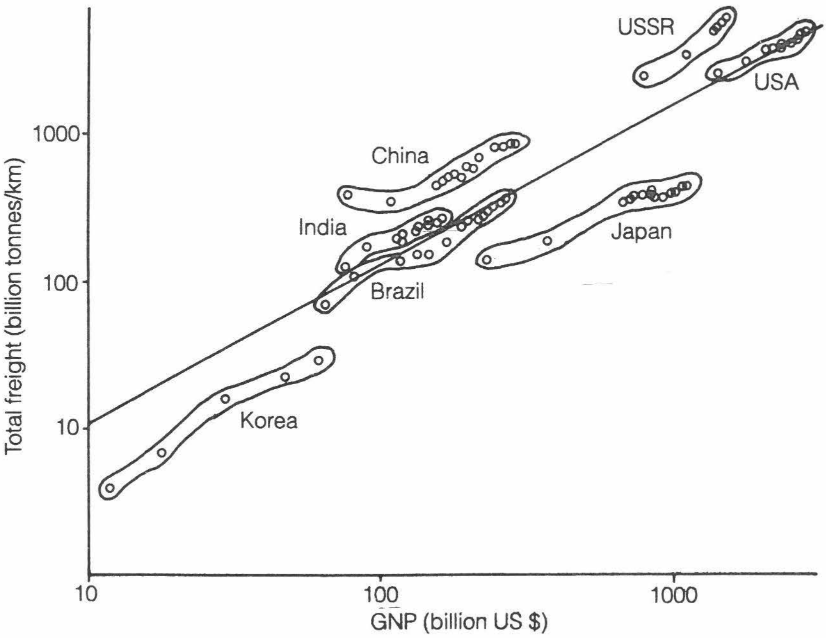

Figure 1. Total freight and GNP for selected countries (1960–1981)
Source: OTA (1992) based on Venny, Uy (1985)

Table 2. Decomposition of the change of aggregate freight transport energy intensity, 1973–88 (total percentage change over period), changes in aggregate intensity, and decomposition into structure (changes in modal split), and energy intensity proper (proxy for fuel efficiency)

Country/confederation/ organization	Change in aggregate intensity (%)	Decomposition (%)		
		Structure	Intensity	Interaction
United States	4	3	1	0
Japan	12	30	−13	−5
Europe-6	12	13	−2	1
West Germany	−6	15	−20	−1
Sweden	31	4	27	0
Norway	7	15	−5	−3
France	46	22	18	6
United Kingdom	−14	1	−12	−3
Italy	32	15	14	3
OECD-8	6	8	−2	0

Source: Schipper, Meyers (1992).

energy demand in the eight OECD countries analysed has increased by 41% over the 1973–1988 period, whereas tonnes/km has increased only by 31%.

Passenger transportation

The relationship between energy demand and passenger transport service requirements is even more intricate. The main reason is the diversity of human activities resulting in mobility and the complex nexus of values, preferences, and resulting lifestyle variables influencing mobility levels, and in particular, the choice of transport modes and their utilization. This can perhaps be best illustrated by analysing the different reasons for individual mobility as done in Table 3 for the US, one of the countries with the highest mobility levels.[2] Based on the detailed Nation-wide Personal Transportation Survey, the US population travelled around 6.7 trillion passenger-km in 1990 with, approximately 26 900 km per capita. It is perhaps surprising to note that less than 18% of all passenger-km is associated with commuting to and from the workplace, whereas some 44% is associated with household and childcare business. In 1990, nearly 2.5 trillion passenger-km were travelled in the US for leisure purposes, including vacations, seeing friends, and other social and recreational activities. This exceeds, for example, the total mobility level of the former USSR, a country with comparable geographical and population size. It was also noted that the trips for which respondents to the survey could not give any other reason than *to go for a ride* resulted in around 55 billion passenger-km, exceeding the total mobility of the Norwegian population.

Table 3. Individual mobility by purpose in the US and comparison to total mobility in selected countries (billion passenger-km, percentage)

Purpose[a]	10^9 passenger-km	Percentage
Work	1190	17.7
Household and family	2981	44.4
Leisure[b]	2484	37.0
Go for a ride	55	0.9
Total	6710	100.0
Total mobility in:		
China	607	—
Ex-USSR	1770	—
France	704	—
Norway	47	—

[a] Excluding walking and cycling.

[b] Vacation, seeing friends, other social and recreational activities.

Sources: NPTS (1992); SSB PRC (1991); IMF (1990–93); Grübler (1990).

About half the passenger-km travelled in the US are over short and medium distances, the other half over long distances. The situation in other OECD countries is similar to the one in US (Grubler 1990). For the OECD countries, the bulk of long distance passenger transport is covered by automobiles and aircraft, with bus and rail accounting for the remainder. Over time, public transport like railways or buses have lost out to cars and air travel (Figure 2), implying that modal split changes have favoured faster and more energy intensive transport modes. It is interesting to note that similar tendencies can also be observed for reforming and developing economies as shown in Figure 3 for the former USSR and China (with some lagged developments). The main difference in the OECD countries—apart from lower levels of per capita long distance mobility—is that instead of the dominant role of the private automobile, collective road transport (buses) account increasingly for the bulk of long distance mobility.

This dichotomy in modal split choices is mirrored also in the ways individual mobility is satisfied over shorter distances, primarily in urban areas (Table 4). On one extreme, more than four million cars were registered in the city of Los Angeles in the mid-1980s (over 1.6 cars per inhabitant), with car densities in Dallas being of similar magnitude. In such *automobile cities*, the market niche for public transportation is obviously rather small. Conversely, low car densities such as in Beijing or Hong Kong do not necessarily imply lower levels of mobility, but rather that public transport modes (metros, trams, buses, and rapid

Table 4. Transport in selected cities or MAs (metropolitan areas) in 1985, passenger cars registered (million), cars per 1000 inhabitants, and public transport trip rate

City	Passenger cars registered		Public transport[a] trips/day/1000 inhabitants
	10^6	per 1000 inhabitants	
Beijing	0.06	2	1641
Dallas	1.53	1624	160
Hong Kong	0.16	29	1274
Los Angeles (MA)[b]	4.18	1409	402
Mexico City (MA)	1.85	96	1570
Paris	1.00	460	1779
Sao Paulo	2.29	619	1878
Tokyo (MA)[b]	2.15	182	2139
Warsaw	0.32	193	2609

[a] Bus, taxi, metro, and railways.

[b] 1980 data.

• The two measures become comparable assuming on average each car is used for a trip per day (in fact, every second car for two trips a day as traffic surveys in European cities suggest).

Source: IEM (1988).

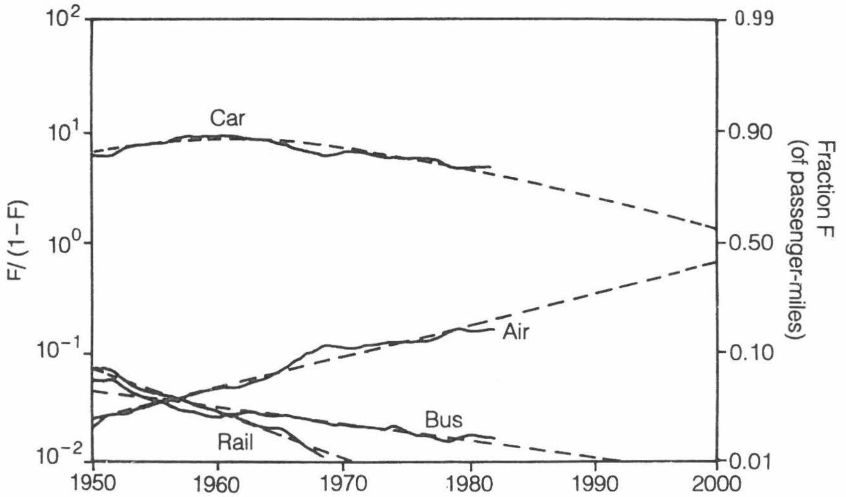

Figure 2. Changes in long distance passenger transport modal split in the US, in fractional shares (F) of intercity passenger-miles, logit transformation log(F/1−F)
Source: Grübler (1990), based on Nakicenovic (1986).

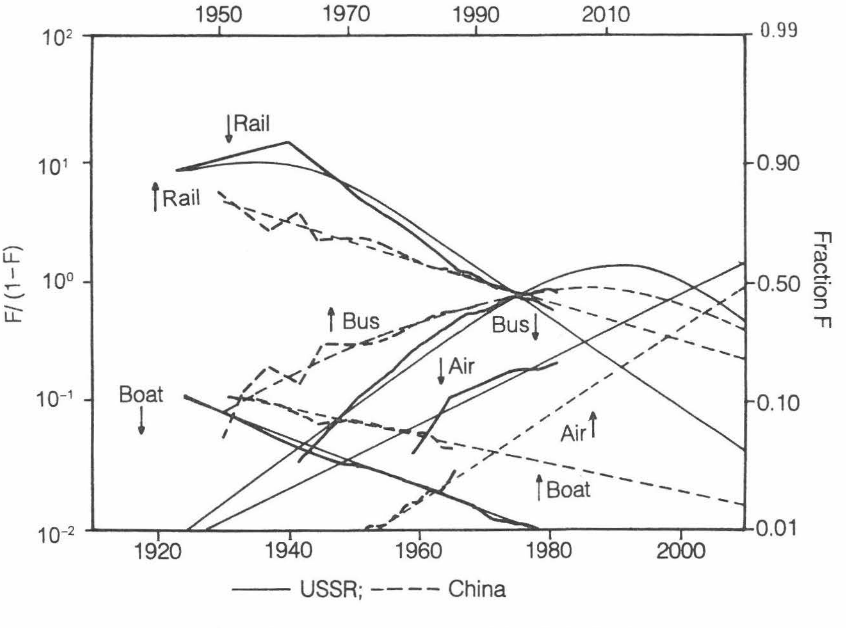

Figure 3. Changes in long distance passenger modal split in the former USSR and China (with shifted time axis), in fractional shares (F) of intercity passenger-km, logit transformation log(F/1−F)
Source: Grübler et al. (1992).

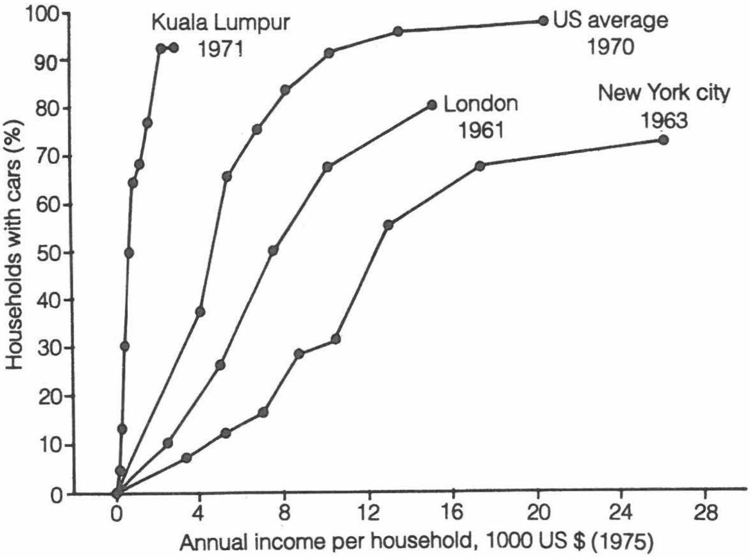

Figure 4. Diversity in car ownership rates *versus* family income for selected cities and US average, in percentage of households owning a car *versus* annual family income (constant US $1000; 1975). Note in particular the much lower elasticity of car ownership rates *versus* income in New York, and the high elasticity in Kuala Lumpur. The latter would remain significantly higher even if income would be corrected for purchasing power differences
Data source: Zahavi (1986).

rail systems) are used instead. Such differences are not the result of differences in income alone. Surveys of car ownership rates of households as a function of income indicate decisive differences between cities (Figure 4). Hence, transport policies, infrastructure availability, and urban form make a large difference in urban modal split choices.

Mobility in urban areas is of particular interest, because cities tend to focus on both the functional and environmental problems inherent to transportation. Limits of space and high densities of land-intensive individual transport modes (cars) result in congestion and a breakdown of the functional capabilities of transport systems to fulfill their very role—moving people.

Due to high population density and the resulting concentration of trips, another constraint that becomes apparent in cities is the limited capacity of the environment to assimilate emissions. Even cities, where most of the cars are already equipped with catalytic converters, like Los Angeles, are notoriously plagued by smog. Cities in developing countries share the problem of traffic congestion, like cities in the OECD countries, and have additional problems of their own (Figure 5). Some environmental problems, which have already been tackled with great success in many OECD countries, like lead poisoning, still

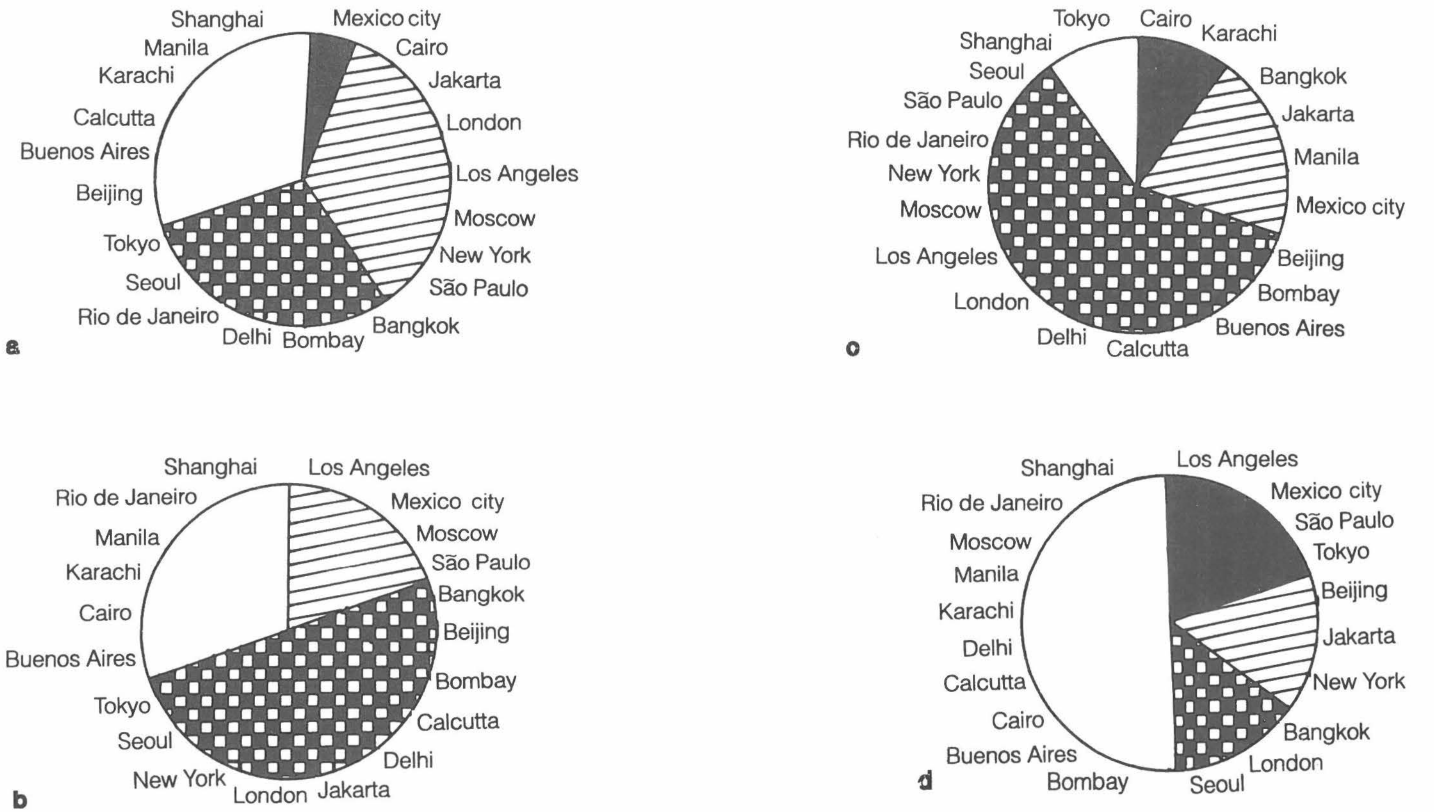

Figure 5. Overview of air quality in 20 megacities for lead, carbon monoxide, nitrogen oxide, and ozone. Colour coding: black denotes a serious problem (concentration at least two times above WHO guidelines), hatched area denotes moderate to heavy pollution (concentration exceeds WHO guidelines up to a factor of two), grey indicates low pollution WHO guidelines meeting, white refers to no data available. **a** Carbon monoxide; **b** Nitrogen dioxide; **c** Lead; **d** Ozone

Source: UNEP WHO (1992).

persist in cities of developing countries. Specific emissions per vehicle are larger due to the absence of control technologies, greater age of vehicles, and poor maintenance. Finally, and perhaps most important of all, capital shortages constrains investments on infrastructure and its upgradation. It also inhibits construction of efficient mass transit systems.

Thus, the overall conclusion of the analysis of current patterns of transport energy demand and their recent evolution indicates that limits of functionality and environment may have been reached already in many large cities. Additional demand growth due to the joint effects of population growth and rising incomes will therefore face constraints of available space, congestion, and local environmental quality, much earlier than any physical running out of crude oil reserves and resources.

Future transport energy demand scenarios

What is the current perception about possible future evolution of transportation energy demand and resulting environmental impacts? Comparisons are to some degree difficult as only few scenarios are sufficiently disaggregated to allow a detailed analysis, especially at the world regional level. Among the scenarios discussed here are: EPA's RCW (rapidly changing world) and SCW (slowly changing world) scenario (Environmental Protection Agency 1990); FFES (Greenpeace's fossil free energy system) scenario (Lazarus et al. 1993); two variants (A and B) of SHELL's (Shell International Petroleum) 1989 scenarios (Holmes 1991; SHELL 1990), and the ECS'92 (environmentally compatible energy strategies—1992) scenario developed at IIASA (Nakicenovic et al. 1993). For comparison, the global transport scenario of the IPCC-EIS (Intergovernmental panel on climate change-Energy and Industry Subgroup) (EIS 1990) is also discussed. One has to remember that these scenarios are not projections of what *will* happen in future, but rather what *could* (or is likely to) happen, given a set of circumstances, policies, and absence of potential surprises. These scenarios may also entail normative elements (describing more desirable futures),[3] illustrating the effects of policy changes and variations in other salient input assumptions of the scenario building exercise, without necessarily implying that these changes will actually happen with a high probability.

At the global level, transportation energy demand scenarios (Figure 6) can be regrouped into three categories: middle of the road, high, and low. Common to all these (with the exception of the Greenpeace scenario) is the perception that observed trends in increases in mobility, modal split changes, and evolution of fuel efficiency of transport vehicles will continue in the absence of radical changes in trends of socio-economic development and transportation policies. Such assumptions imply growth of global transportation energy demand at more

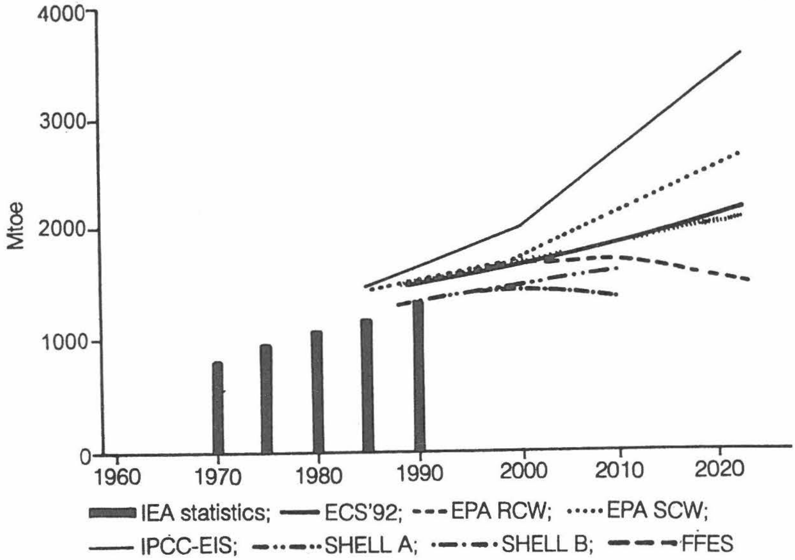

Figure 6. Global transport energy demand scenarios (Mtoe)

or less similar (linear) rates as in the past two decades. However regional development patterns and the resulting evolution of transportation energy demands will be quite different. Medium scenarios (e.g. the ECS'92 or EPA's SCW scenario) indicate the possible growth of global transportation energy demand to around two Btoe (billion toe) by the year 2020. EPA's RCW scenario is about 500 Mtoe higher. The IPCC-EIS scenario is beyond even the range spanned by the RCW scenario, reaching approximately 3.5 Gtoe by 2025, apart from having apparent calibration problems for the base year data. On the other end of the spectrum are the lower variant of SHELL's 1989 scenario (B) and the FFES scenario of Greenpeace, leading to a saturation of the transport energy demand by 2030 at 1990 levels.

Yet more interesting than these global aggregates are the regional scenarios of transportation energy demand (Figure 7). Perhaps the two most interesting regions are North America and the developing countries (i.e. non-OECD and countries outside the reforming economies of Central and Eastern Europe and the former USSR) as they portray two entirely different dynamic futures of transportation energy demand.

For North America, in fact no scenario anticipates noticeable growth in transportation energy demand. Approaching saturation of car ownership rates and continuation of historical improvements in car fuel efficiencies are the main rationale underlying such scenarios. The situation in other OECD countries is somehow similar—a very flat demand growth (with exception of EPA-RCW) and even a possible decline in transportation energy demand. The apparent discrep-

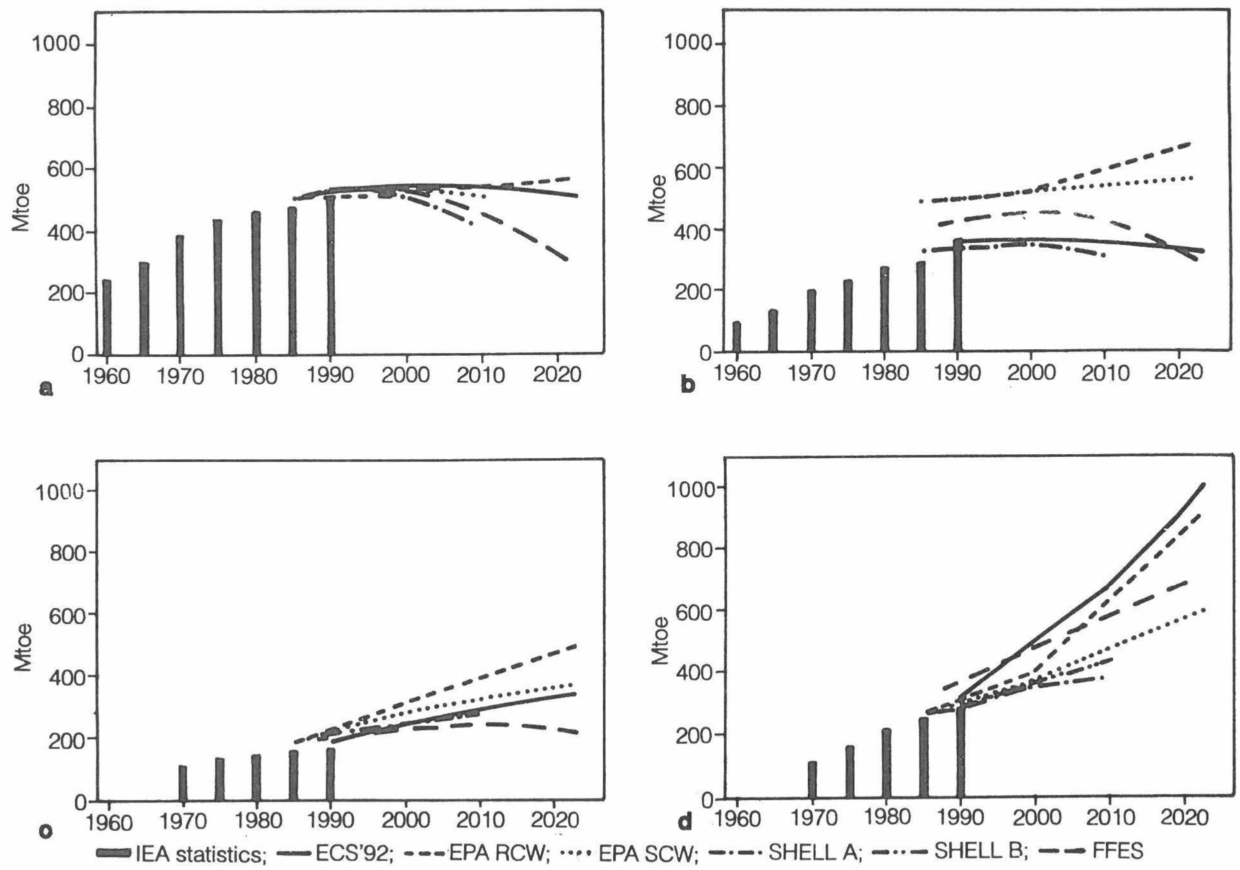

Figure 7. Transport energy demand scenarios for four world regions (Mtoe). **a** OECD—North America; **b** OECD—Europe and Pacific; **c** Central and Eastern Europe and ex-USSR; **d** Developing countries

ancies between the scenario base year values is due to variations in the regional definitions for the OECD region outside US/North America between the scenarios.

The range of scenarios spanned for the OECD region as a whole indicates certainly a change in perception. Despite vigorous demand growth in the past, historical trends are no longer extended out into the future. In addition, differences in per capita transportation energy demand between OECD countries continue to persist in all scenarios, indicating a departure from the frequently assumed hypothesis of a homogenization of transportation patterns. This however, does not mean that surprises (at both the higher and lower end) may not materialize, but rather indicates an increasing consensus that current patterns of mobility and resulting energy demand cannot continue to grow indefinitely. New technologies and new organizational forms for providing mobility of people and goods will be necessary in the long run to overcome the functional and environmental limits of present transport systems in the OECD countries.

For the transitional economies of Eastern Europe and the former USSR—despite the large uncertainties involved in their transition—there appears to be some agreement between different scenarios indicating a demand growth to about 300 Mtoe by 2020. On the low end, the FFES scenario assumes stabilization at about current levels. On the high end, EPA-RCW implies demand growth in the region reaching close to 500 Mtoe (million tonnes oil equivalent) by 2025.

Whereas the emerging scenario consensus for OECD indicates forthcoming saturation of demand, there is also the consensus that transportation energy demand in developing countries will increase substantially. It is interesting to note, that FFES, a scenario for the industrialized countries and systematically the lowest of the scenarios analysed, is higher than both the EPA-SCW and the two SHELL cases. Both EPA-RCW and ECS'92 are the most optimistic, with respect to future growth of mobility (or rather with respect to economic development and resulting mobility increases) in the developing world. In view of the current urbanization trends and the concentration of incomes in urban agglomerations, most of this increase in mobility will take place in cities. The perspective of a doubling of current (mostly urban) motorized mobility as in the Greenpeace scenario, or even a tripling as in the case of the EPA-RCW and ECS'92 scenarios, certainly represents a huge challenge for urban transport and environmental policy in developing countries.[4]

Impact of population growth

To conclude this discussion of future transport scenarios, an analysis of their implications for population growth and resource use is necessary. To this end, a simple decompositional analysis of the factors contributing to transport energy

Table 5. Decompositional analysis of factors contributing to transport energy demand growth for four world regions and the world on the whole, in contribution to absolute demand growth 1971–1990 (Mtoe)

1971–1990 Actual	Changes in population	Changes in toe due to changes in population[a]	Changes in toe due to changes in per capita toe[b]	Interaction[c]	Changes in toe
OECD—North America	50.3	86.9	38.5	8.0	133.4
OECD—other	55.9	22.4	135.2	15.3	172.9
C and EEU and ex-USSR	56.1	19.6	29.0	6.0	54.6
Developing countries	1436.1	59.6	76.3	41.2	177.1
World[d]	1598.3	351.6[d]	147.9[d]	38.5[d]	538.0

[a] Constant 1970 per capita toe × changes in the population.
[b] Constant 1970 population × changes in the per capital consumption.
[c] Interaction term, growth of per capita consumption of growth in population.
[d] Impact depends on level of aggregation. Regional and global values are therefore, not commeasurable non-additive.
• The impact of population growth is first of all the function of the level of aggregation.
Source: IEA 1993 (energy balances), World Tables 1993 (population).

demand growth, in terms of changes in levels of population and of changes in per capita consumption has to be performed. Table 5 presents an analysis of past trends per world region and for the world as a whole.

It is important to emphasize that the impact of population growth on resource consumption is primarily a function of the level of aggregation (Lutz et al. 1993). The higher the aggregation level, the higher will be the (hypothetical) impact of population growth. This is because such an aggregation does not differentiate where children are born as opposed to where (per capita) energy demand growth occurs. In a nutshell, aggregates mask disparities—it is the poor that have more children and it is the poor that have low energy consumption. Equating more children from the poor with the rising consumption of the rich can only lead to erroneous conclusions on the impact of population growth on resource use. This aggregation problem not only refers to comparisons between world regions, or between different countries but also between different social strata *within* countries. Thus, there is no relation between the population growth of the rural poor and the growth in energy consumption, and the motorized mobility of the urban elites in developing countries either, when discussing the nexus of population growth and the environment.[5]

Table 5 provides a simple illustration of this aggregation problem. In looking at the world total, population growth between 1971 and 1990 would be equated to a transport energy demand increase of 350 Mtoe. Taking a disaggregated look at the four world regions, the impact of population growth adds up to 188 Mtoe, or 54% of the (inappropriate) global calculation. A further disaggregation would still further reduce the impact of population growth proper on transport energy requirements.

It is with these precautions in mind that the conclusions on the impact of population growth on transport energy use over the last two decades needs to be arrived at. Population growth mattered ironically more in the *North* than in the *South*. Holding the 1971 per capita consumption constant, population growth (an additional 50 million people) in North America resulted in an additional 87 Mtoe transportation energy demand, which is larger than the 60 Mtoe additional energy demand for 1436 million additional people in all the developing countries taken together. Even more important however is the fact that, with exception of North America, *per capita mobility increases mattered more than population growth in all regions* in the period considered.

This indicates that much of the discussion on the impact of population growth on resources is misleading. What matters more than sheer numbers is the economic and social condition that the people live in and are born into. Levels of economic development, incomes, access to transport modes, and lifestyles have

Table 6. Decompositional analysis of factors contributing to transport energy demand growth: comparison of three scenarios until 2025/2030 for three world regions, in contribution to absolute demand growth (Mtoe)

Scenario	Changes in toe due to changes in population	Changes in toe due to changes in per capita	Interaction	Changes in toe
ECS'92 (1990–2025)				
OECD	127	−167	−24	−69
REFS	37	101	−21	159
DCs	221	264	195	680
FFES (1988–2030)				
OECD	159	−531	−69	−441
REFS	45	−19	−3	23
DCs	322	59	44	425
EPA-SCW (1985–2025)				
OECD	177	−51	−9	117
REFS	44	120	27	191
DCs	237	74	26	337

Source: Population projection: UN (1992) (medium variant), transport energy demand scenarios.

a much larger impact on transport energy demand than population growth proper. A child born into a poor rural family is unlikely to consume a lot of oil for its individual mobility. Instead, its spatial activity range is likely to remain at the village level, where mobility is assured by the oldest of the known transport technologies—walking on foot. Conversely, a child born into an affluent middle-class family (in Los Angeles and New Delhi alike) will enjoy an extended spatial activity range—going by bus to a school (chosen on preference rather than neighbourhood), going to vacations to the countryside or even abroad by car, or by air. Later on, it may enjoy even higher levels of individual mobility at work and at play through access to, or ownership of, a scooter or a private car.

Perceptions and anticipation of changes in the economic and social conditions that the people will live in influence future mobility and energy demand scenarios more than any projection of population growth. This can clearly be discerned by analysing again, through decompositional analysis, scenarios of future transport energy demand for the three world regions—OECD, REFS (reforming economies of the former Soviet Union), and DCs (developed countries) (Table 6).[6] The potential impact of population growth in the *North* remains considerable. However, due to the anticipated demand saturation and eventual decline, changes in per capita demand constitute the paramount influencing variable in the equation of the OECD. Compared to the historical experience (Table 5 above), this represents a major discontinuity. For developing countries, the situation is almost paradoxical—the more pessimistic the scenario with respect to development and resulting increases in mobility, the higher the impact on population growth. But, as discussed above, this result derives largely from the high level of aggregation of our analysis. If there is no or little development, the growing number of the poor is unlikely to be a major contributor to the (comparatively low) transportation demand growth in developing countries. Only in a scenario of high demand growth is there a higher probability that motorized transportation becomes affordable to a wider social strata. In such a scenario however, the decompositional impact of population growth would be no more than one-third, compared to the influence of per capita demand growth (refer the ECS'92 scenario in Table 6).

Conclusion

Energy versus environmental resource scarcity

This paper on human mobility is aimed at providing an overall framework against which one can assess possible scenarios of future transportation energy demand. The scenarios analysed agree to a large extent that future demand growth in OECD countries could be rather flat, even negative. Forthcoming saturation of ownership rates and continued improvements in fuel efficiency are the principal reasons for such anticipated developments.

Scenarios for developing countries indicate possible growth of transportation energy demand of a factor two to three over the next three decades. Existing disparities in rural/urban incomes are likely to persist over the time period spanned by the scenarios. This implies that the bulk of mobility increases will occur in urban areas, already plagued today by congestion and air pollution. This also clearly illustrates the challenge ahead for transportation and environmental policies in the metropolitan areas of the developing world. At the same time, these developments indicate that, in the decades to come, resource constraints will be noticed much sooner with respect to (urban) environmental quality than with the availability of crude oil resources for transportation purposes.

As regards transportation energy demand, a historical analysis concludes that population growth matters in the *North* rather than in the *South*. This is because of the persistent large disparities in per capita consumption levels. Motorized mobility and resulting energy demand is a privilege of the affluent who tend to have few children. Conversely, mobility of the poor, who have many children, is largely confined to non-motorized transport modes which do not consume fossil fuels. Future scenarios indicate that declines in per capita transport energy consumption are likely to dominate the demand picture in the OECD countries. Scenarios differ in their evaluation of per capita demand growth in developing countries. However, as argued above, only with genuine development will the impact of population growth on transport energy demand move from a statistical artefact to a reality. With no or slow development, demand will be confined to the urban elite, whose demand growth cannot be equated with the rapidly rising number of children of the poor.

Note

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Endnotes

1 One may note however that the objective of this baseline scenario might exactly have been to highlight the undesirability of such a high scenario. Alternative approaches indicate that developing countries may not follow the same development path of growing individual mobility based on private cars, or at least not at a comparable intensity level. Such a *saturation* scenario is presented in Grubler, Nakicenovic (1991) and Grubler et al. (1992).

2 Walking and bicycling are excluded as no data are available. In addition, in terms of passenger-km (not in terms of number of trips) their contribution will be quite small (less than five per cent of motorized mobility).

3 The FFES of Greenpeace in our interpretation is an example of such a normative type of scenario.

4 For a comprehensive overview of transportation and other urban policy issues in large cities of the developing world cf. the reports of the UN megacities project (UN 1986-1991). For a discussion of urban transport policy issues in Asia, see AEI (1993).

5 There are also environmental problems directly linked with population growth of the poor like overgrazing or deforestation.

6 The three scenarios were chosen on basis of their trends in transport energy demand growth in developing countries: high (ECS'92), medium (FFES), and low (EPA-SCW).

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