Strategic Environmental Assessment of European High-Speed Train Network

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To ensure the objectives of a sustainable transport policy the European Commission intends to apply strategic environmental assessment as an integral part of the decision-making process for transport infrastructure policies and for the trans-European networks in particular. An overview of the results of a study on the environmental impact of the European high-speed train (HST) network is provided. The study was conducted by the research and consulting group Mens en Ruimte on behalf of the Directorate-General of Transport of the European Commission. The aim of the study was (a) to make a strategic assessment of the environmental impact of the European HST network and (b) to compare this with the impact of the conventional modes of long-distance transport of passengers (i.e., motorways, conventional rail, and aviation). The HST network studied corresponds to the master plan drafted by the European Commission. This plan has been drawn up with a view to the year 2010 and comprises the 12 member states, Austria, and Switzerland. In all, the network consists of ±9800 km of new lines able to cope with trains with speeds of up to 300 km/hr and ±14 400 km of upgraded old lines to handle trains with speeds of 200 km/hr and more. Environment has been interpreted in the broadest sense. The themes that are considered in particular are spatial impact (i.e., land use, barrier effects, impact on landscape and sensitive sites, and effects on the spatial organization of activities and on the urban environment), primary energy consumption, air pollution, noise pollution, and traffic safety. The evaluation of the influence of the HST network is performed by comparing scenarios with and without the HST network. The analysis relates to the year 2010, with 1988 as the base year.

To ensure the objectives of a sustainable transport policy the European Commission intends to apply strategic environmental assessment as an integral part of the decision-making process for transport infrastructure policies, plans, and programs and for trans-European transport networks in particular (*1*). In the present paper an overview of the results of a study on the environmental impact of the European high-speed train (HST) network is provided. The study has been conducted by the research and consulting group Mens en Ruimte (M + R) on behalf of the Directorate-General of Transport of the European Commission (*2*). The main purpose is to assist the Commission in making its decisions concerning the construction of the network and the development of HSTs and to provide the basis for coordinating the efforts of the member states and for guiding their national planning.

NETWORKS AND SCENARIOS

In the present study a strategic and comparative assessment was made. The assessment was of the environmental effects of the European HST network and the conventional modes that are used for the long-distance transport of passengers, that is, rail, road, and air transport, on networks that are in competition with the HST network. The HST network studied corresponds to the master plan proposed by the Commission (Figure 1) (*3*). This plan has been drawn up with a view to the year 2010 and comprises the 12 member states, Austria, and Switzerland. In all the network consists of ±9800 km of new lines able to cope with trains with speeds of up to 300 km/hr and ±14 400 km of upgraded old lines to handle trains with speeds of 200 km/hr and more. The classic railway network (±25 000 km) includes the existing interregional connections by classic trains with speeds ranging from 160 to 200 km/hr. The French TGV Sud-Est (Paris–Lyon), that is, the only high-speed line that was operational in 1988, is also included in this network (430 km). For road transport a network of main roads (mostly motorways) parallel to the HST lines has been selected (total length, ±31 450 km). For air transport a selection of 83 airports with regular intra-European commercial flights was made.

The analysis relates to the year 2010, with 1988 as the base year (the choice of 1988 was based on the availability of traffic data). The evaluation of the influence of the HST network was performed by comparing the scenarios with and without the HST network. The following scenarios were chosen:

- The 2010 Reference Scenario (2010 REF) corresponds to the situation in which no new HST lines are constructed and in which only the 1988 operational HST lines are included (i.e., Paris–Lyons).
- The 2010 High-Speed Train scenario (2010 HST) involves the complete realization of the HST network as it is proposed by the European Commission.
- The 2010 Forced Mobility scenario (2010 FM) has the same high mobility level as the 2010 HST scenario, but all traffic is achieved by using conventional traffic modes only.

TRAFFIC FLOWS

Traffic data and forecasts were derived from a study on traffic flows that was carried out by a consortium comprising INRETS (France) and INTRAPLAN (Germany) (*4*). That study analyzed the consequences of the completed network in terms of both traffic patterns and traffic growth distribution between the different modes operating on the market.

Following the completion of the HST network in 2010 the long-distance transport of passengers on the selected networks will amount to almost 924 billion passenger-km (pkm) (Figure 2). A small part of this (26 billion pkm) is induced mobility, that is, traffic generated by the HST network itself. This newly generated traffic is an immediate result of the fact that with the HST network journeys over long distances will become more attractive. The HST network will also cause important shifts between modes: rail traffic

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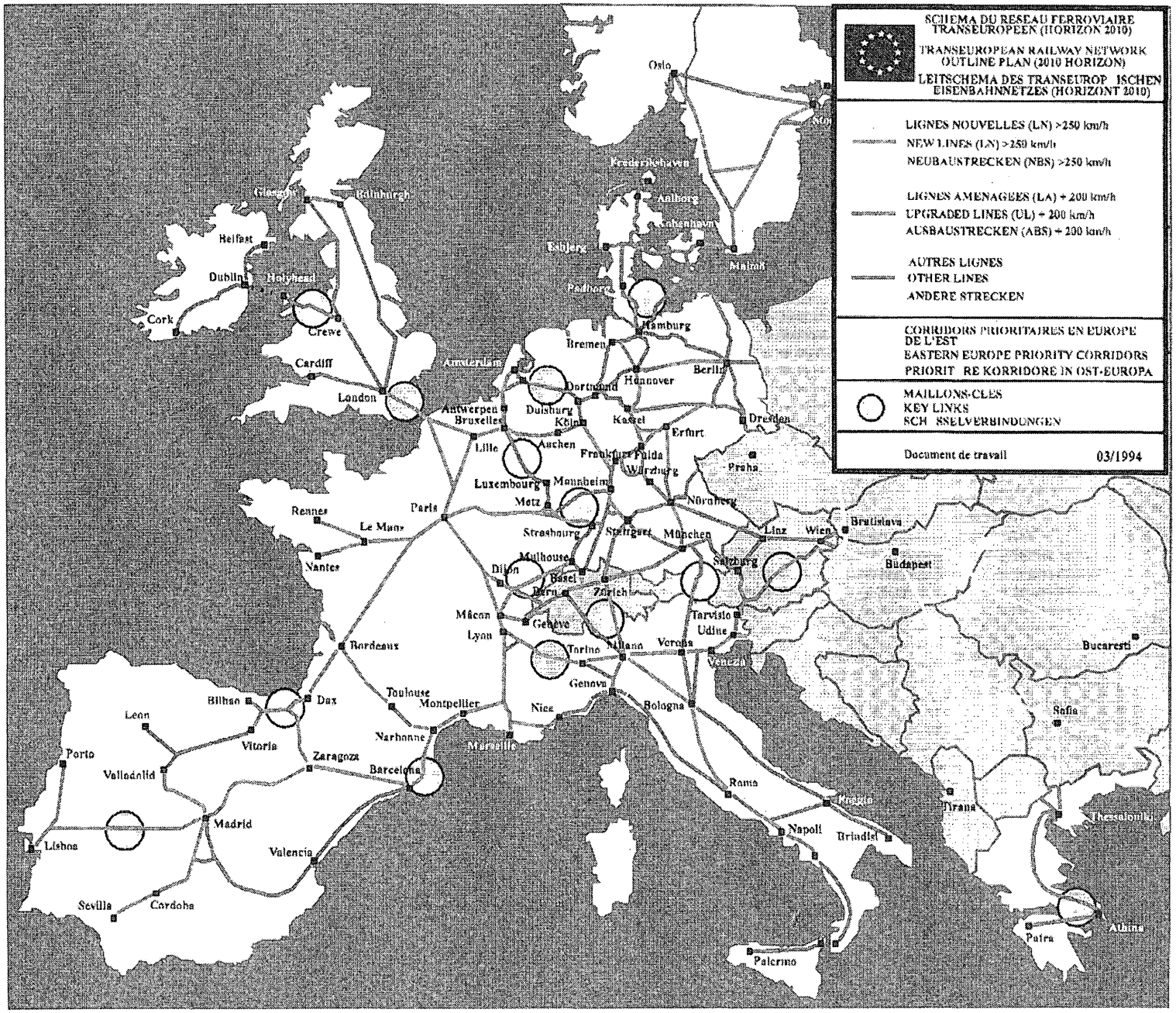

FIGURE 1 Trans-European Railway Network Outline Plan.

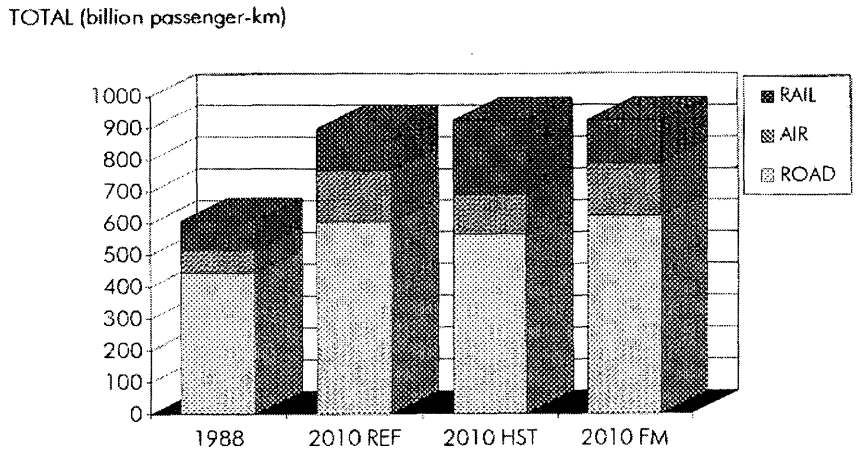

FIGURE 2 Long-distance passenger transport: traffic volume.

will increase its share from approximately 15 to 25 percent. This growth consists of some 40 percent former car traffic and some 34 percent former air traffic. This remaining part (26 percent) is induced traffic. Air transport will lose some 4 percent of the total market (going from 18 to 14 percent). Motorways will continue to support the most dominant part of long-distance transport, even though their share will decrease from 67 to 61 percent.

IMPACT ASSESSMENT METHODOLOGY

Environment has been interpreted in the broadest sense. The themes that are considered in particular are land use, barrier effects, impact on landscape and sensitive sites, effects on the spatial organization of activities and on the urban environment, primary energy consumption, air pollution, noise pollution, and traffic safety.

For most aspects a qualitative analysis has been made together with a quantitative evaluation. Aspects such as barrier effects and impacts on landscape and biotopes have been treated in a mostly qualitatively way and are illustrated by case studies. For each mode a survey of possible mitigation measures is given.

Projections for the year 2010 take into account developments in technology for vehicles (e.g., catalytic systems and Chapter 3 aircraft), changing driving behaviors (e.g., speed limits), and the more stringent standards that will be imposed for passenger cars and aircraft, as well as for power plants and refineries.

Another important parameter is the occupancy rate of the vehicle; higher occupancy rates will result in environmental impacts per pkm. The following average occupancy rates were used: 60 percent for HST and aircraft, 35 percent for classic trains, and 1.6 passengers per car. The occupancy rates of aircraft and HST, in particular vary considerably according to the country and the origin–destination served. For example, the occupancy rate of the French HST Paris–Lyon is approximately 70 percent, whereas the German ICE only realizes an average of 50 percent occupancy rate, the difference being entirely due to the countries' different reservation systems.

Because of the different fuel use of each mode (gasoline, diesel, LPG, kerosene, electricity), a well to wheel approach has been used to estimate energy consumption and emissions of air pollutants. This means that not only the operational energy consumption and emissions of the vehicle but also the energy consumption and emissions that are associated with the production and distribution of the fuel (taking into account the efficiency and emissions of refineries and of electricity production) are included. The calculations of energy consumption and air pollution also take into account the composition of the vehicle fleet of each country and the primary energy sources used for electricity production e.g., oil, gas, coal, nuclear, and hydro/geothermal sources.

Comparisons between modes and scenarios are based on estimates of total impact (i.e., in absolute numbers) and of the relative impact (i.e., impact per pkm). The main results are presented in Tables 1 and 2. All impacts were calculated on the lowest possible and feasible level, that is, per section of the network or per country. The results presented in this paper are aggregate results (totals and averages for the 14 countries).

LAND USE

Of all modes considered the motorway network is clearly the one that consumes the most land. It covers more than 3.5 times the surface needed by the HST network and about 7 times the surface of the airports. The proposed HST network requires a total land use of about 415 200 ha, 40 percent of which is completely new land needed for the construction of new HST lines and 15 percent is extra land used for the upgrading of lines. The remaining 45 percent is taken up by existing infrastructure. Of course, the extra land use of the HST network is not directly compensated for by a reduction in land use by the other modes of transportation. This balance can be put into perspective, however, when one considers the structural congestion problems of European air transport and motorways. To ensure a sustainable long-distance transport and in view of the current congestion problems, a clear need for additional infrastructure (motorways or lanes for long-distance traffic and extension of regional airports) exists. In this context the HST network offers scope for rational land use, because it uses less space and offers higher capacities than the competing modes of transport. Taking into account the capacities of a motorway (1,500 passenger car units per hour per traffic lane) and a high-speed railway line (15 trains per hour per direction) the capacity of the HST line equals that of a motorway with four lanes in each direction.

TABLE 1 Inventory of Environmental Impacts: Difference Between Scenarios

IMPACT		UNITS	2010 HST - 1988		2010 HST - 2010 REF		2010 HST - 2010 FM	
			TOTAL	IN % OF 1988	TOTAL	in % OF 2010 REF	TOTAL	IN % OF 2010 FM
primary energy consumption		PJ	295	+27%	-64	-4%	-107	-7%
emissions	CO	kt	-842	-52%	-63	-7%	-87	-10%
	NOx	kt	-305	-55%	-18	-7%	-26	-9%
	HC	kt	-119	-59%	-15	-15%	-19	-18%
	CO2	1000 kt	18.52	+26%	-6.75	-7%	-9.56	-10%
	SO2	kt	0.77	+2%	7.00	+18%	6.00	+15%
	PM	kt	5.19	+76%	1.00	+9%	1.00	+9%
	acid equivalents	1000 kt	-6.70	-50%	-0.18	-2.5%	-0.39	-5%
	CO equivalents	1000 kt	-162.2	-60%	-11.75	-9%	-15.55	-12%
unsafety		# fatalities	47	+2%	-232	-7%	-308	-9%

Source: M+R (1993)

1 MJ primary energy = 0.0209 kg gasoline
= 0.0220 kg diesel
= 0.0207 kg LPG
= 0.0233 kg kerosene
= 0.1056 kWh electricity

1 MJ = 10^6 J
1 PJ = 10^{15} J
1 kt = 10^3 tons

By changing the modal split of intercity traffic the HST network could relieve some of the growing capacity problems of the motorway network and the airports. On motorways the reduction of traffic intensities following the introduction of the HST network would be substantial only for those sections not yet saturated with traffic. This means that expansion of motorway infrastructure (or other measures that increase capacity) could possibly be postponed for some years. The HST network will not solve problems on heavily congested sections, however, especially because regional traffic and freight traffic remain unaffected. Airports will benefit more from a changing modal split. Because the number of intra-European flights would be reduced considerably (by some 25 percent), extra slots would become available for other commercial traffic. Major airports such as Frankfurt, Roissy (Paris), and Schiphol (Amsterdam) already see the HST network as an integral part of the development of the airport. If the HST network would not be realized major airports would be forced to dispose of some traffic, which in turn would create additional development (and more land use) at regional airports.

IMPACT ON RURAL LANDSCAPE

Motorways and railways form a category of linear transport infrastructure that can have a severe effect on rural landscapes and ecosystems. It creates a barrier, dividing functional units (parcels of farmland) and connections (roads). Part of the agricultural area is consumed or further exploitation is made impossible (substitution effect). In addition, the physical environment may be modified (e.g., by drainage, pollution, and microclimatic changes).

When no precautions are taken implantation of the HST network can have severe visual effects on landscapes. Particular efforts should also be made to minimize the damaging effects on fauna, flora (especially forests), biotopes, physical environment, and archaeological sites. The importance of these aspects must be acknowledged and evaluated in national or local environmental impact assessments (this in accordance with the EC Directive 85/337/EEC on the evaluation of the effects of large projects on the environment). A first and crucial step in this process should consist of defining and identifying valuable landscapes and sensitive sites.

IMPACT ON SPATIAL ORGANIZATION OF ACTIVITIES AND URBAN ENVIRONMENT

The reduction of time distances realized through the HST project will increase the accessibility of all cities and regions. This will particularly be the case for Brussels and Basel; Paris remains the central point in both the classical and the HST network. Larger cities

TABLE 2 Environmental Impacts Related to Passenger-Kilometers (2010) Traveled

IMPACT		UNITS	ROAD	AIR	RAIL (HST)
land use		ha/mio pkm	0.52	0.35	0.34
primary energy consumption		MJ/pkm	1.7	2.20	0.74
emissions	CO	g/pkm	1.3	0.51	0.003
	NOx	g/pkm	0.25	0.70	0.10
	HC	g/pkm	0.10	0.24	0.001
	CO2	g/pkm	111	158	28
	SO2	g/pkm	0.03	0.05	0.10
	PM	g/pkm	0.01	0.01	0.02
	acid equivalents	g/pkm	6.5	16.7	5.3
	CO equivalents	g/pkm	135	265	32
unsafety		# fatalities/billion pkm	5.1	0.35	0.30

Source: M+R (1993)

benefit from reductions in travel times more than smaller cities and nonurban areas. This could reinforce the already existing tendency toward the domination of some larger cities over the smaller ones. This is logical, since only large concentrations of population and activities can provide the HST network with the volumes of traffic needed for it to be profitable. Improvements in the accessibilities of smaller cities and regions depend on the quality of the connections of the HST network with other transport networks (e.g., regional trains and motorways).

So far the operational HST projects do not seem to have produced changes in the locational behaviors of economic activities. An analysis of the French TGV Sud-Est case shows that existing firms seem to have extended their market area without changing their location. The fear that the larger city (Paris) would attract the interesting activities of the smaller city (Lyon) has not (yet) become reality.

The impact on the urban environment, which may especially manifest itself in the neighborhoods of HST stations, is often important. The arrival of the HST almost always triggers a planned or spontaneous urban redevelopment of the whole neighborhood. This is because the HST network creates the positive image needed by often dilapidated neighborhoods to attract new activities. Also, the large sums of money needed to finance the new railway and station infrastructure must be raised partly or completely by the railway companies. It is therefore not surprising that they take part (sometimes as a majority shareholder) in these redevelopment schemes. Since commercial and office development projects offer the highest returns, these functions tend to monopolize the projects. Other functions (e.g., housing and social and cultural infrastructure) become likely only if urban or regional governments see station development or redevelopment as part of the general planning strategy.

Airports will develop into multimodal transport nodes and activity zones (offices), where the connection between air and HST transport is one of the key elements. The potentials of such airports as highly accessible economic growth poles are obvious.

PRIMARY ENERGY CONSUMPTION

Compared with its competitors the HST network has considerably lower average primary energy consumption per passenger-kilometer. The calculations show that for the same traffic performance passenger cars will consume 2.3 times more energy and aircraft will consume 3.0 times more energy than an HST (Table 2). Although an HST consumes more electricity than a classic train, this is more than compensated for by its higher occupancy rates, the use of HST material, and the improved track infrastructure. Per pkm an HST consumes about the same amount of energy as a classic train.

In 1988 energy consumption by the long-distance transport of passengers amounted to ± 1109 PJ, which is almost 10 percent of the energy consumption by all forms of transport. Energy consumption in the 2010 HST scenario will be about 27 percent higher than that in 1988 (Table 1 and Figure 3). Even though the energy efficiency of the modes will improve this effect will be more than undone by the drastic growth in mobility. Without the HST network, however, energy consumption would increase even faster and would be 32 percent higher in the year 2010 compared with that in 1988. This means that in terms of primary energy HSTs could lead to total energy savings of about 4 percent or ± 70 PJ compared with the 2010 reference scenario. In addition, more people will travel at higher speeds.

EMISSIONS OF AIR POLLUTANTS

An inventory is made of the emissions of the following air pollutants: carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HCs), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and particulate matter (PM). Two of these substances (NO_x and SO_2) are partly responsible for acidification. Emissions of CO, NO_x, HCs, and Pm can damage human health. CO_2 and NO_x are important factors in connection with the so-called greenhouse effect, about which there

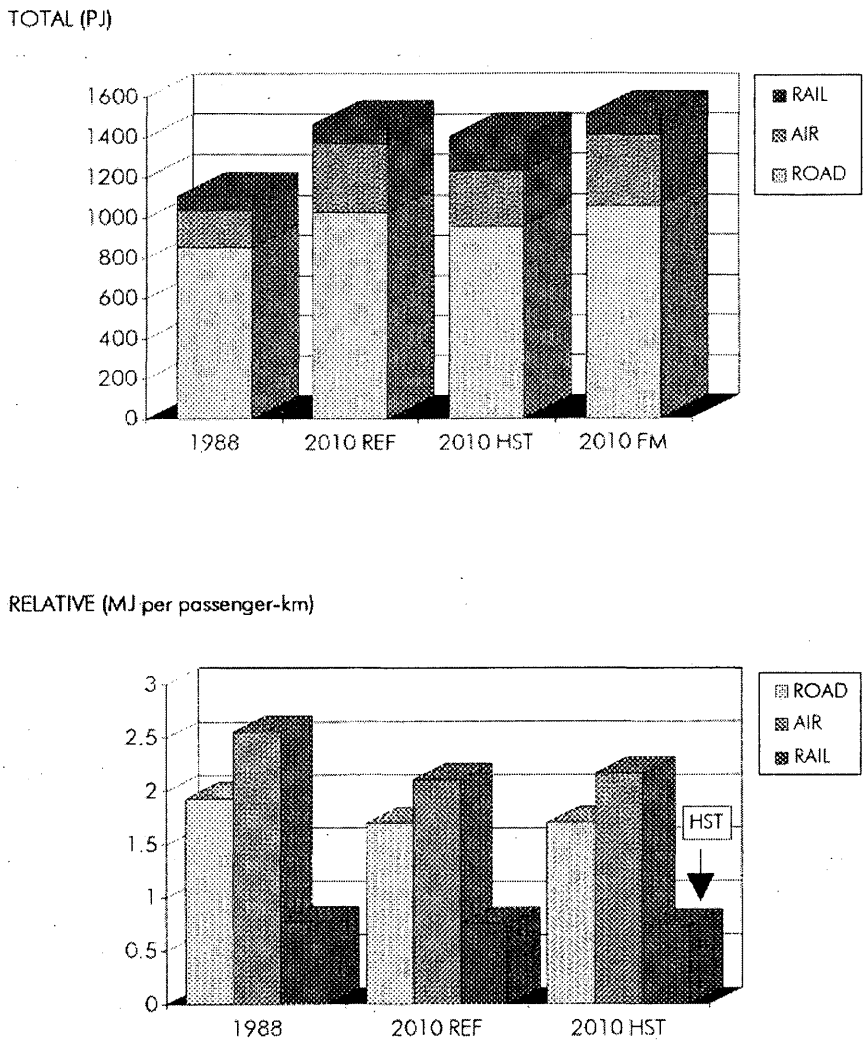

FIGURE 3 Primary energy consumption.

is a growing concern. HCs and NO_x also contribute to the buildup of ozone in the troposphere. The combined acidifying and toxic effects of the different substances have been made by converting emissions to acid equivalents and CO equivalents.

Emission factors for passenger cars were obtained from the European CORINAIR study (*5*). For electricity production the emission factors depend on the primary energy sources used and were therefore estimated on a per country basis. For aircraft the major data sources were the EPA Compilation of Air Pollutant Emissions and a recent study by the Dutch environmental institute RIVM (Rijksinstituut voor Volkgezondheid en Milienhygiëne) (*6*).

Emissions by road and air traffic take into account SO_2 emissions during refining and the evaporation of HCs during refueling. For electric rail the emissions from electricity-generating plants are the major source of air pollution. Estimates of future emissions take into account the more stringent standards that will be imposed on passenger cars and aircraft as well as power plants and refineries.

It has been shown that an HST has lower emissions of pollutants than the other modes of transport (Table 2). Exceptions are the emissions of SO_2 and PM, for which emissions from power stations would increase by a relatively marginal amount compared with those in 1988 following the increased use of electricity. Acid emissions (i.e., the joint emissions of NO_x and SO_2) and toxic emissions would be reduced, however (Figure 4). Although the report makes it clear that many of the reductions in air pollution are due to the technical standards established for motor vehicles, the modal shift that can be achieved through the development of the HST network in Europe will enable the transport sector to make a greater contribution to the European Community's air quality objectives (for NO_x, CO, and HCs) at a faster rate. The HST network will also make a positive contribution to the CO_2 stabilization objective by slowing down the forecast increase to 26 percent up to 2010 rather than 30 percent under the reference scenario of business as usual. As other studies have shown, however, the CO_2 strategy requires an integrated policy with a series of complementary measures, of which the HST network could be a necessary part. It can be concluded that for the same transport performance the HST network is an effective answer to reducing air pollution. Furthermore, it can be stated that the HST network can make a positive contribution toward achieving the Community's goals of reducing air pollution.

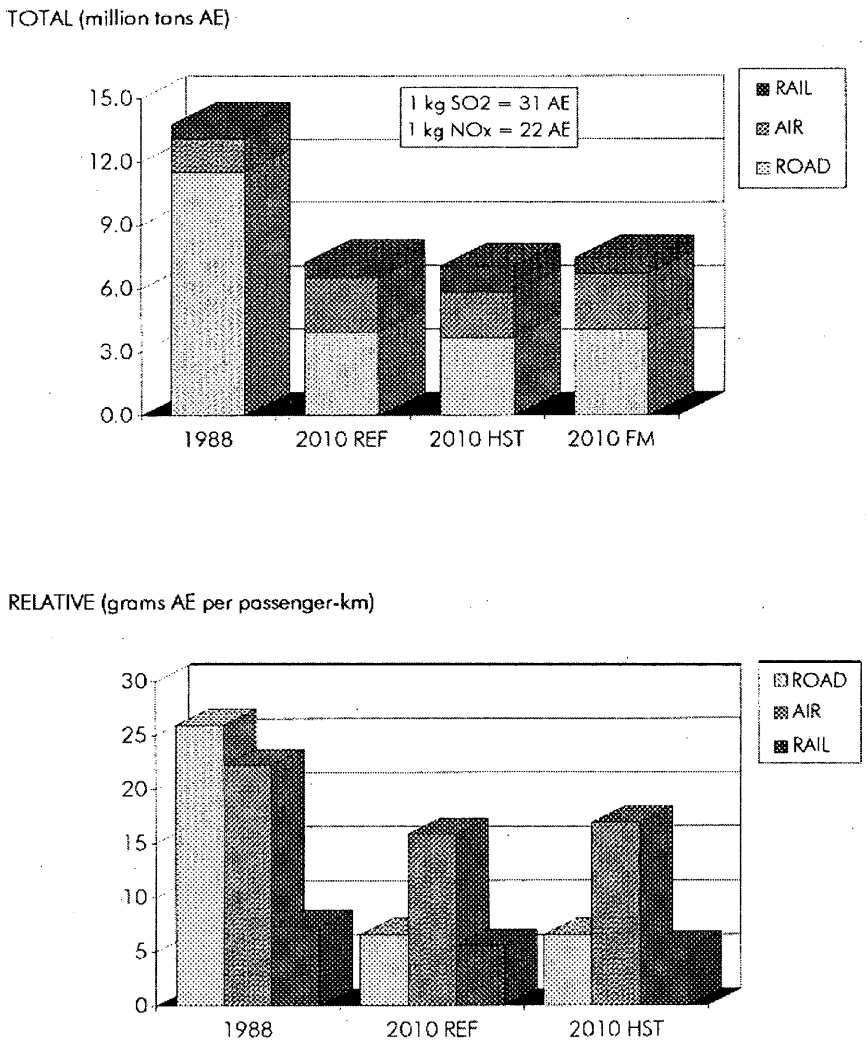

FIGURE 4 Emissions of acid equivalents (AE).

NOISE POLLUTION

How noise pollution will be affected by the construction of the HST network depends not only on vehicle characteristics, speed levels, and traffic intensities but also on the local characteristics of the transport infrastructure and its surroundings (noise abatement measures, relief, vegetation, etc.). However, these local aspects have not been incorporated into the evaluation, because sufficiently detailed data are lacking on the scale of the study and because the master plan for the proposed HST network is still too abstract (the exact locations of several HST links are not yet known). For the calculation of the location of noise contours, noise abatement measures, obstacles, and relief are not considered; the resulting contours are "polder contours."

To compare the noise nuisance caused by the different transport modes, the A-weighted equivalent noise level [Leq dB(A)] has been used. This is a measure of noise nuisance that averages out various sound levels over time to an equivalent continuous sound level. Rail noise is generally perceived as less annoying than road or aviation noise, which is generally translated by a bonus of 5 dB(A) (*7*).

Reductions in the number of trips by passenger cars following the implementation of the HST network will result in only a slight narrowing of noise contours around motorways. This is explained by the fact that long-distance passenger traffic forms only a small part of total motorway traffic, and noise pollution by other traffic (especially the relative share of trucks) will not be affected by the introduction of the HST network. For airports the effect is more pronounced; the transfer of transport toward the HST network would decrease the noise-affected surface around airports by about 10 percent on average. An interesting result is that by 2010 a drastic narrowing of the noise contours around airports can be expected. By then the general use of the much quieter Chapter 3 aircraft types will halve the noise-affected surface.

At the same speed an HST running on upgraded lines makes less noise than a conventional train owing to the technological advances built into it. When operating at higher speeds and greater frequencies an HST produces more noise than conventional trains. When no noise abatement measures are taken this will entail an increase in hindrance. New HST lines are to be seen as completely new sources of noise. However, current practice (e.g., the French HST

lines) shows that noise abatement measures will be an integral part of the planning and construction of new HST lines and the upgrading of existing lines. Effective noise reduction can be obtained by planning new lines next to existing motorways, the use of screenings, cuttings, or tunnels, and so forth.

TRAFFIC SAFETY

A survey of international safety statistics showed that fatalities are the most completely reported statistics. Thus, the analysis in the present study focused on calculating the number of fatalities among passengers. Correction factors were applied when needed to convert national statistics to comply with the UNO standard definition of a fatality, that is, died within 30 days after the accident. Of course, the restriction to fatalities favors the roadway mode, since for each roadway fatality a large number of injured must be counted (on average 25 injured for each fatality; for rail transport this ratio is 3).

The level of transport safety of conventional rail transport is relatively very close to that of air transport, whereas it is significantly higher than that of motorway transport. The figures indicate that by 2010 significant improvements in safety levels of all modes of transport can be expected. With the HST network rail transport would become the safest mode of transport. On the HST lines currently operated on a commercial basis there have as yet been no accidents involving fatalities. This record can be put down to factors inherent in both the fixed installation (design and protection of level crossings, fencing of lines, and station design) and the rolling stock (cab signaling and speed monitoring). An analysis based on the number of fatalities following traffic accidents was performed. It was shown that the introduction of the European HST network would make a contribution toward improving rail safety in general and of long-distance transport of passengers in particular.

CONCLUSION

The results of the study indicate that the European HST network can make a positive contribution to both the natural and the human environment, and thus to the development of a sustainable transport system. However, an important finding is also that mere technical measures and standard settings will not be sufficient for realizing the European Union's environmental targets (such as CO_2 emission reductions). Additional measures should be envisaged to reduce the drastic growth of road traffic and to encourage the switch to more environmentally friendly modes of transport (e.g., rail). Consensus is growing that this can be achieved in part by fully integrating external costs into the transport pricing system.

The study also demonstrates that strategic environmental assessment can be successfully applied from a very early stage in the decision-making process. The present method needs to be further developed as the HST network becomes more concrete. Local effects such as noise nuisance and visual impact on landscape can only be estimated when the exact location of the tracks is known. In the long run it is important to develop a flexible and dynamic assessment procedure that can also be applied to the other transport networks.

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