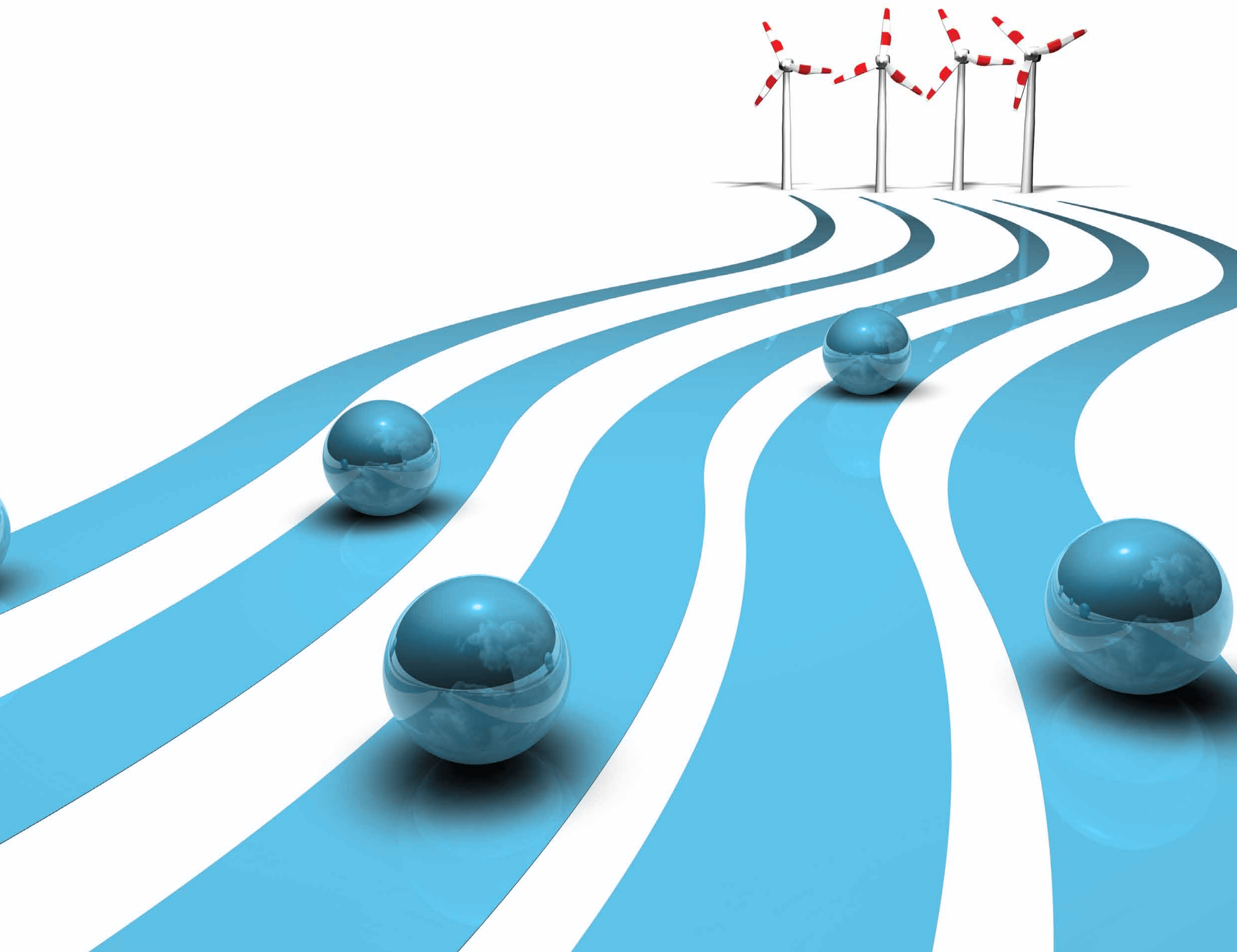
INTERNATIONAL UNION
OF RAILWAYS

# High Speed Rail and Sustainability



# High Speed Rail & Sustainability

Report

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## Abbreviations

| | |
|---|---|
| AVE | Alta Velocidad Española |
| $CH_4$ | methane |
| CO | carbon monoxide |
| $CO_2$ | carbon dioxide |
| dB(A) | unit of noise (decibels) |
| ETS | Emissions Trading Scheme |
| EU | European Union |
| RFF | Réseau Ferré de France |
| g | gram |
| GHG | greenhouse gas |
| HFC | hydrofluorocarbon |
| HSR | high-speed rail |
| ICE | Inter City Express |
| ICTx | Korean Train Express |
| kg | kilogram |
| km/h | kilometre per hour |
| KTX | Korea Train Express |
| KWh | kilowatt-hour |
| LGV East | Ligne à Grande Vitesse Est Européenne |
| NMVOC | non-methane volatile organic compounds |
| $NO_x$ | nitrogen oxide |
| PFC | perfluorocarbon |
| pkm | passenger-kilometers |
| $PM_{10}$ | particulate matter |
| $SF_6$ | sulphur hexafluoride |
| SNCF | Société Nationale des Chemins de fer Français |
| $SO_2$ | sulphur dioxide |
| TGV | Train à Grande Vitesse |
| tkm | tonne-kilometres |
| UIC | Union Internationale des Chemins de fer |
| UNEP | United Nations Environment Programme |
| VAL | Véhicule Automatique Léger |

# 1 Management Summary

Transport systems bring enormous benefits to society providing access and mobility that are essential for modern societies and economic growth. However, transport activities have many undesirable external impacts as well, such as $CO_2$ emissions, congestion, accidents, land use and many more.

At the same time, the transport sector will face many challenges in the future such as demographic development, urbanization, and the scarcity of natural resources, as well as increases in oil and energy prices. Meanwhile, the increase in travel demand could lead to overcrowded airports, delayed flights and congested roads. The urge to fight these challenges is therefore pushing economies toward more efficient, and sustainable, solutions. Rail, and particularly High Speed Rail (HSR), is an important means to meeting these challenges and contribute to sustainable mobility development.

HSR offers tangible advantages over other transport modes such as air, conventional rail and the car for medium to long distance journeys. Considering the evaluation of the complete life cycle it is in terms of sustainability the most efficient mode of transport. At the same time it combines many of the attributes that we most desire while travelling such as speed, reliability, comfort and safety. HSR's ability to compete with domestic air travel in terms of time and comfort has made a modal shift possible.

By not only encouraging a shift from air but also from traditional road transport for lengthy journeys in either cars or coaches HSR is contributing to congestion reduction and its associated pollution. By providing a suitable alternative for traditional transport modes travel which is greener and more energy efficient per passenger-kilometre it is contributing to the transport industries' need to reduce carbon emissions.

Furthermore, HSR, which is only operating on the electrified network, is today's only mode of transport that directly benefits from the "greening" of the energy supply sector towards low carbon electricity. Electricity from renewable sources can be HSR's main power supply without the need to develop specific and completely new technologies. Compared to aviation and road transport, which will be highly dependent on fossil fuels for many years, this is one of the main competitive advantages of HSR. The carbon intensity of HSR can even be further reduced by increasing the share of renewable energies.

A background paper to this report clearly shows that HSR is still more environmentally friendly even when considering the construction of the tracks and rolling stock in a full life cycle perspective. Thus, estimating the impacts during the full life cycle doesn't change the low environmental impact of the HSR compared to other transport infrastructure or transport modes.

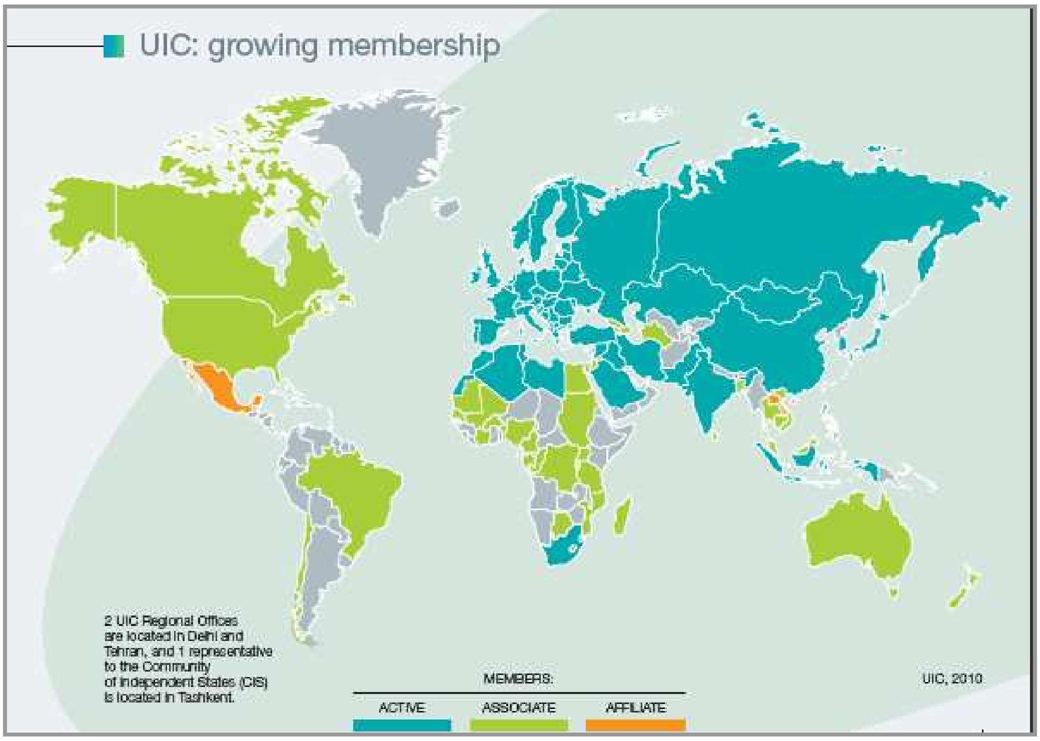
The European Union has clearly identified the rail network to be a tool to reinforce the economic and political cohesion of the Union since the Maastricht Treaty and especially to integrate peripheral regions in the longer term. HSR strengthens links between cities and is part of a global transport policy to improve territorial integration.

Financial resources targeted at sustainable transport are generally a small fraction of those allocated for traditional (unsustainable) transport. A wide range of transport–relevant financial flows need to be reoriented towards sustainable transport to achieve the required paradigm shift and ensure that HSR is rightfully seen as a core element of transport provision.

# 2 Introduction

This publication is launched by UIC, the International Union of Railways[a]. The UIC, founded in 1922 in Paris, today unites about 200 rail companies from 5 continents (see Figure 1). Of these there are 82 active members (including railways from Europe, Russia, the Middle East, North Africa, South Africa, India, Pakistan, China, Japan, Korea, Kazakhstan, and companies operating worldwide such as Veolia Transport); 80 associate members (including railways from Asia, Africa, America and Australia); and 37 affiliate members (related or ancillary rail transport businesses or services). UIC members cover over 1 million km of railway lines, serving 2,500 billion pkm and 9,500 billion tkm a year. The UIC is particularly interested in promoting sustainable mobility and transport and has issued a declaration to that effect.

**Figure 1** UIC members around the world




Source: UIC, 2010a

### SUSTAINABLE TRANSPORT SYSTEMS – A DEFINITION

Transport systems bring enormous benefits to society providing access and mobility that are essential for modern societies and economic growth. However, transport activities have many external costs, especially as transport is one of the main contributors to carbon dioxide ($CO_2$) emissions and thus to global warming. It is therefore necessary to decouple economic growth (associated with increasing travel demand) from its environmental impacts such as $CO_2$ emissions, air pollution and land use. At the same time, the transport sector faces many challenges in the future such as demographic development, urbanization, and the scarcity of natural resources, as well as increases in oil and energy prices. Meanwhile, the increase in travel demand could lead to overcrowded airports, delayed flights and congested roads. The urge to fight these challenges is therefore pushing economies toward more efficient, and sustainable, solutions. Rail, and particularly HSR (High Speed Rail), is an important means to meeting these challenges and contribute to sustainable mobility development.

A policy statement by the European Council of Ministers of Transport defined a sustainable transport system as one which:[1]

- Allows the basic access and development needs of individuals

[a] Union Internationale des Chemins de fer

- Supports safety and human health
- Promotes equity within and between successive generations
- Is affordable, fair and efficient
- Offers choice of transport mode
- Supports a competitive economy and balanced regional development
- Limits emissions and waste within the planet's ability to absorb them
- Uses resources at rates which permit renewal or substitution
- Minimises impacts on the use of land and the generation of noise.

In this context, sustainable mobility is also about combining different transport modes in a "smart" system - where all modes contribute with what they are best at. Sustainability in terms of the UIC, and its member railway companies, means to meet the expectations of society and customers and sustain business by responsible leadership. This study, therefore attempts to address, and illustrate, all aspects related to HSR operation and its particular environmental and sustainability advantages. The study gives broad information about the contribution of HSR toward sustainable mobility and a sustainable society in terms of its wider impacts on economic development. While HSR is usually designed for passenger travel, some HSR systems also carry some kind of freight service. For instance, the French mail service La Poste owns a few special TGV trains for carrying postal freight. A more significant impact of HSR on freight movement by train is that where new high speed lines are created for passenger transportation existing conventional lines have greater capacity for freight. However, this study concentrates on passenger transport as freight is still of minor importance for HSR compared to passenger transport.

The study will show that the decades when planes and cars have been quicker, more convenient, and usually more reliable ways to transport people are gone. Better HSR technologies have made the train an increasingly attractive alternative, and especially a "green" one.

# 3 High Speed Rail – at a glance

There is no single standard definition of HSR (nor even a standard usage of the term: sometimes it is called "high speed" and sometimes "very high speed"). The definitions vary according to the criteria used since HSR corresponds to a complex reality. UIC's High Speed Taskforce wants to reflect this diversity by considering HSR from all the standpoints: infrastructure, rolling stock and operations.

## HSR – A DEFINITION

First of all there is the European Union definition, given in Directive 96/48; this is a fairly broad definition which encompasses a large number of systems under the banner of high speed. But it is also necessary to take into account those railways which are making laudable efforts to provide HSR despite having a basis of old infrastructure and technology which is far removed from that employed by many railways of Western Europe. At all events, HSR is a combination of all the elements which constitute the "system":

**Infrastructure:**

- New or special dedicated lines designed for speeds above 250 km/h.
- Upgraded conventional lines which enable trains to operate up to 200 or even 220 km/h.

**Rolling stock and operating conditions:**

- Special trains that differ from conventional rolling stock with an increased power/weight ratio and several characteristics such as aerodynamics, reliability, safety.
- A special in cab signalling system since traditional line-side signals are inefficient above 220 km/h.[b]

In view of the fact that many HSR trains are also compatible with the conventional network, the term "high speed traffic" is also frequently understood to signify the movements of this type of train on conventional lines but at speeds lower than those permitted on the HSR infrastructure. Consequently, on some lines which are claimed to be HSR it is very difficult to specify a threshold when, in certain very densely populated regions, the speed is restricted to 110 km/h in order to avoid noise nuisance, or where, as in special tunnel sections or on long bridges, the speed is limited to 160 or 180 km/h for obvious reasons associated with capacity or safety. Finally, in many countries where the performance of the conventional railway is not very impressive, the introduction of some trains capable of operating at 160 km/h and offering a significantly higher quality - often as a first step towards a future genuinely high speed service - may already be considered as HSR.

For this report we interpret HSR as being able to offer train journeys with speeds of more than 220 kmh.[2]

## HSR – NETWORK IN THE WORLD

The earliest HSR, Japan's Shinkansen, started its operation in 1964. It is 515 km in length, and links Tokyo with Osaka in 3 hours 10 minutes. France's TGV began in 1981, linking Paris with Lyon in two and a half hours. Other European countries have followed: Italy's Direttissima was partly open in 1988, Germany's ICE in 1991, Spain's AVE in 1992, and Eurostar through the Channel Tunnel between France and England in 1994. Furthermore, the first HSR train in North America, the Acela Express, started service in December 2000.

In 2009 Japan was the country with the greatest HSR network in operation, followed by France, Spain and Germany. This distribution has changed taking into account HSR lines under construction in 2011. China now ranks first, with a total HSR operating mileage of 4,576 km as of March 2011, including Beijing-Tianjin, Wuhan-Guangzhou, Zhengzhou-Xi'an and Shanghai-Nanjing (with the highest operating speed in the world). According to the planning and current construction status, the total operating mileage of HSR in China will almost triple by 2020 and exceed 13,000 km[3]. The world network in 2011 totalled 15,231 km of HSR lines in operation, of which Europe represents 43.5%, Asia 54.0% and other countries 2.5%[c]; 9,172 km of lines are under construction and nearly 17,594 km of HSR lines are planned[5]. By 2025

[b] In order to resolve problems related to Europe's diverse signalling systems, the European Union founded the ERTMS (European Rail Traffic Management System). This system makes it easier for HSR trains to cross borders. (see also: http://www.uic.org/spip.php?rubrique853, updated 2010-10-22)
[c] Morocco, Argentina, Brazil, USA

the HSR lines in the world will reach 41,997 km. Europe already has an impressive HSR network as shown in

Figure 3.

**Figure 2** High Speed Rail lines in operation and under construction worldwide in 2010 & 2011

**2010**

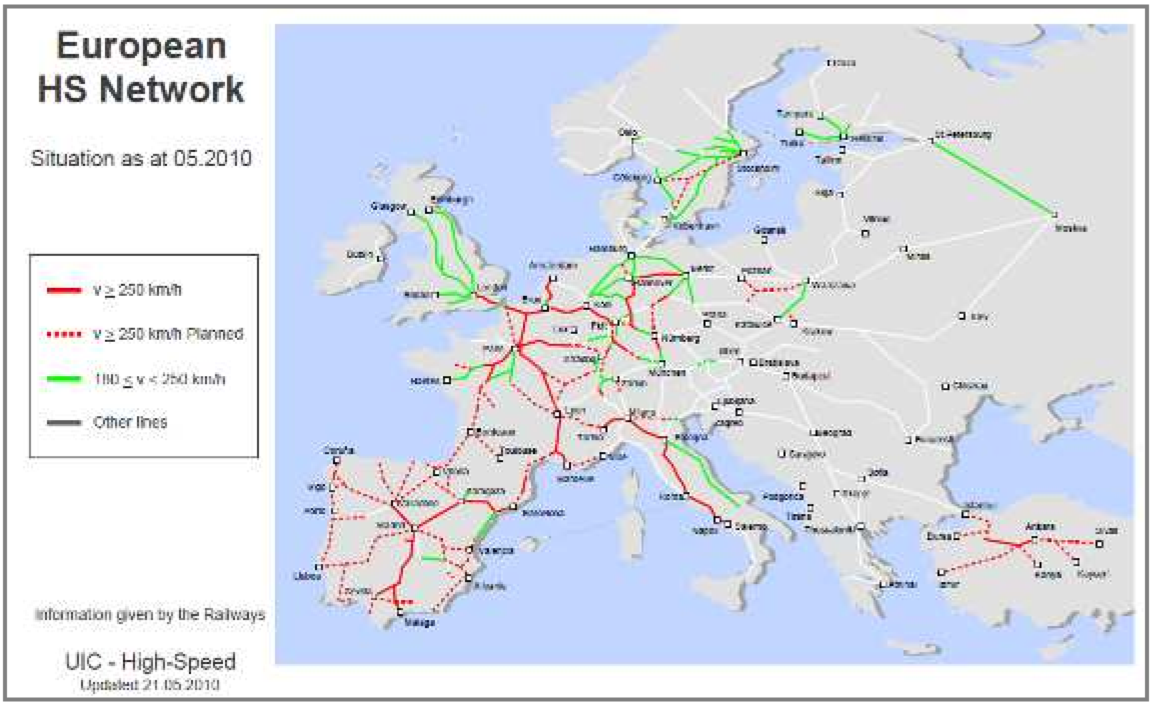

**2011**

| KM OF HIGH SPEED LINES IN THE WORLD | | | | |
|---|---|---|---|---|
| | In operation | Under construction | Planned | Total country |
| **Europe** | | | | |
| Belgium | 209 | 0 | 0 | 209 |
| France | 1896 | 210 | 2616 | 4722 |
| Germany | 1285 | 378 | 670 | 2333 |
| Italy | 923 | 0 | 395 | 1318 |
| The Netherlands | 120 | 0 | 0 | 120 |
| Poland | 0 | 0 | 712 | 712 |
| Portugal | 0 | 0 | 1006 | 1006 |
| Rusia | 0 | 0 | 650 | 650 |
| Spain | 2056 | 1767 | 1702 | 5525 |
| Sweden | 0 | 0 | 750 | 750 |
| Switzerland | 35 | 72 | 0 | 107 |
| United Kingdom | 113 | 0 | 204 | 317 |
| **Total Europe** | **6637** | **2427** | **8705** | **17769** |
| **Asia** | | | | |
| China | 4576 | 5657 | 2901 | 13134 |
| Taiwan-China | 345 | 0 | 0 | 345 |
| India | 0 | 0 | 495 | 495 |
| Iran | 0 | 0 | 475 | 475 |
| Japan | 2664 | 378 | 583 | 3625 |
| Saudi Arabia | 0 | 0 | 550 | 550 |
| South Korea | 412 | 0 | 0 | 412 |
| Turkey | 235 | 510 | 1679 | 2424 |
| **Total Asia** | **8232** | **6545** | **6683** | **21460** |
| **Other countries** | | | | |
| Morocco | 0 | 200 | 480 | 680 |
| Argentina | 0 | 0 | 315 | 315 |
| Brazil | 0 | 0 | 511 | 511 |
| USA | 362 | 0 | 900 | 1262 |
| **Total other countries** | **362** | **200** | **2206** | **2768** |
| | | | | |
| **Total World** | **15231** | **9172** | **17594** | **41997** |

Updated 20110312

**Source: UIC, 2010b[4] and 2011[5]**

**Figure 3** European High speed Network 2010




Source: UIC, 2010c[6]

# 4 High Speed Rail is a sustainable mode of transport

Any human activity causes damage to the natural environment. Mobility is a particular contributor to this through local pollution, extensive use of resources, landscape intrusion, habitat fragmentation, wildlife mortality, pressure over biodiversity, noise generation etc. Given this, dealing with increasing travel demands and increasing needs for mobility, as well as accommodating protection of the physical environment, appears to be a tricky issue. HSR, nevertheless, has characteristics that make it an efficient, and effective, solution to mitigate the impact of transportation on the environment, and climate, and make it an essential part of sustainable mobility systems. In addition, transport energy-related $CO_2$ emissions are predicted to increase by 1.7% a year from 2004 to 2030. The significant proportion of global emissions from transport indicates that the sector and HRS in particular can play a key role within the challenge of tackling climate change and sustainable development.

## 4.1 HSR has a lower impact on climate and environment than all other compatible transport modes

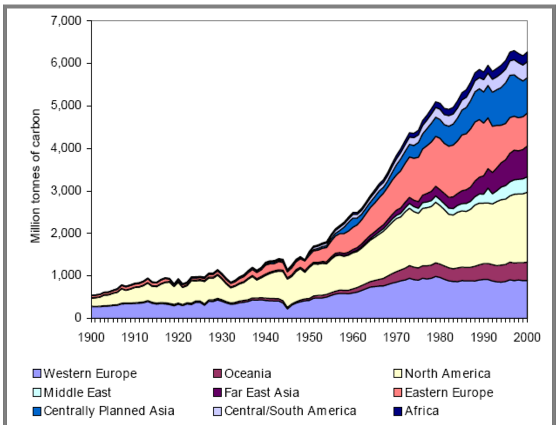
To compare the overall environmental performance of HSR with other competitive transport modes, all environmental impacts must be considered. These are, mainly: energy consumption and the combustion of fossil fuels; air pollutant emissions and noise; and environmental damage like land use and resource depletion. These impacts occur during the construction, operation and maintenance of HSR. The following chapter focuses on the most significant, and on-going, phase, the operation of HSR, and shows how HSR brings solutions to global challenges.

### 4.1.1 Energy consumption and GHG emissions

The reality of global warming is commonly admitted among the scientific community. The works of the International Panel on Climate Change (IPCC) are unequivocal on the question that climate change is happening and that human activities are largely responsible for it.

Global warming is a consequence of the well-known Greenhouse Effect, and the non-natural part of it especially is caused mainly by carbon emissions due to human activity. Anthropogenic emissions have been growing continuously since the 19th century (see Figure 4).

**Figure 4** Emissions from fossil fuel combustion from 1900 to 2000 (in million t of carbon)[d][e]




Source: Marland, G., T.A. Boden, and R. J. Andres, Global, Regional, and National $CO_2$ Emissions

Source: Marland,G, T.A Boden, and R.J.Andres, 2010[7]

The IPCC predicts temperature rises of between 1° and 6° Centigrade from current levels by 2100, depending on the levels of future greenhouse gas (GHG) emissions. If the higher

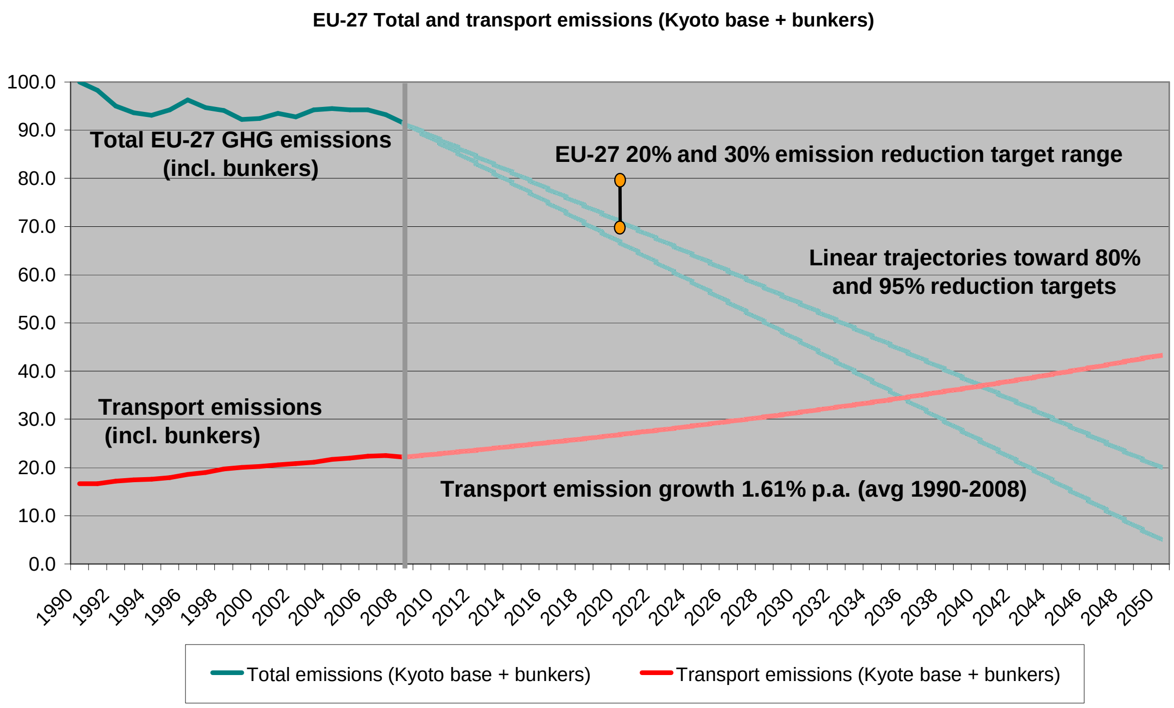
[d] They have to be multiplied by 44/12 in order to obtain the figures in $CO_2$ equivalent
[e] Centrally planned Asia: China, Laos, Mongolia, Korea (DPR), Vietnam

estimates are accurate, there could be catastrophic consequences, so decisive action is required.

The Kyoto Protocol regulates five GHGs beside $CO_2$: methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride ($SF_6$). International efforts are now focused on reducing GHG emissions from the activities of modern society to avoid unprecedented impacts from climate change. In March 2007, as part of a wide-ranging attempt to cut emissions, European heads of state agreed to set legally binding targets to reduce Europe-wide GHG emissions by 20% from 1990 levels by 2020 (increased to 30% with a strong global agreement), (EC, 2010)[f]. The European Commission has further stated that work must begin immediately on a longer-term target of a 50% cut in global emissions by 2050. In July 2008, the European Commission published its ‘Greening Transport’ package which included a series of proposals to make the transport sector more environmentally-friendly and to promote sustainable mobility. Yet the measures agreed so far are not sufficient to contain the negative environmental effects of transport growth. Furthermore, there is still no coherent ‘roadmap’ to reduce emissions from transport.

Figure 5 shows total GHG emissions for the EU 27 countries, including international maritime and aviation “bunkers”[g], projected on linear trajectory towards 80% and 95% reduction targets, alongside total transport emissions (including bunkers) assuming current trends continue. This shows that if the current growth in transport emissions continues, then even if all other sectors achieve a 100% reduction, targets for total emissions will be exceeded by transport alone by 2050.

**Figure 5** Transport emissions continue to grow while those from other sectors decline

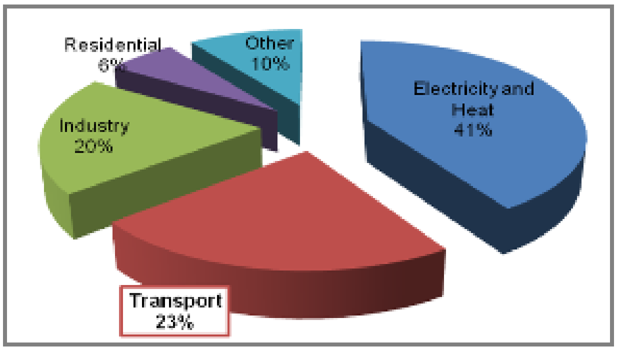



Source: EEA TERM Report, 2009

Transport has a key role to play within solutions to climate change as current transport structures are responsible for extreme pressures on energy resources and ecosystems through a high dependence on fossil fuels (80% of energy consumption is derived from fossil fuels). Producing 23% of all worldwide $CO_2$ emissions, transport is the second largest source of man-made $CO_2$, after energy production (see Figure 6).

[g] A “bunker” helps companies to manage their exposure to fuel price risk, by hedging against price changes.

**Figure 6** Distribution of $CO_2$ emissions in the world by activity sector – 2007




Source: IEA, 2009a[8]

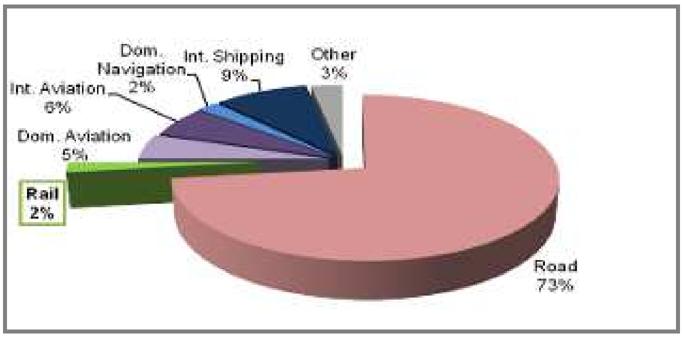
Among all sectors, the transport sector is the only one in which emissions are continuing to increase in spite of all the technological advances. Moreover, transport emissions, for instance in Europe, increased by 25% between 1990 and 2010. By contrast emissions from the industrial and energy sectors are falling.[9] Reducing transport emissions is therefore one of the most crucial steps in combating global warming and securing our future.

In the interests of people and the environment, the rail sector strongly recommends that transport policies in the EU and elsewhere start to make more use of the energy efficiency of railways in order to progress towards the 2020 CO2 reduction targets Railways already offer the most energy efficient performance and are constantly improving in terms of energy use per passenger km (pkm).

## HSR IS PART OF THE SOLUTION TO FIGHT CLIMATE CHANGE

The alarming performance of the transport sector is largely due to road traffic, which accounts for 73% of global transport emissions (see Figure 7). If domestic and international aviation is combined then it is the second largest emitter accounting for 13% of global transport emissions. By contrast, the rail sector accounts for just 2% of total transport emissions. In Europe rail accounts for only 1.6% of emissions, while it transports 6% of all passengers and 10% of all freight.[10] This is a clear indicator that railways can do more for less. A modal shift from road and air towards rail is one obvious way to reduce $CO_2$ emissions.

**Figure 7** Global transport $CO_2$ emissions by mode share in 2005




Source: ITF, 2005[11]

There are three primary strategy responses to the challenge of reducing the environmental impact of transport (Dalkmann and Brannigan, 2007):

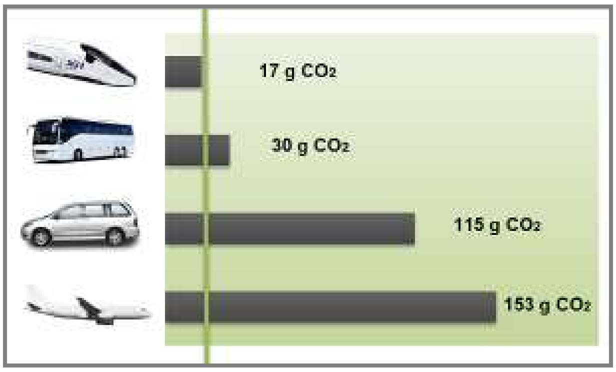
- **Avoid** - transport is reduced or avoided altogether; such as by land-use planning and public transport integration in order to enable efficient interconnectivity and reductions in km travelled.
- **Shift** - journeys are made by lower $CO_2$ per passenger emitting modes such as public transport (including rail), walking and cycling.
- **Improve** - efficiency of current transport modes is improved e.g. by innovations in technology.

In the context of rail the two most relevant strategies are ‘shift’ and ‘improve’, however rail does have a part to play in ‘avoid’ strategies within integrated land use and spatial planning.[12]

### HSR IS MORE ENERGY EFFICIENT THAN ALL OTHER TRANSPORT MODES

Rail in general is widely acknowledged as the most carbon efficient form of mass transport as Figure 8 illustrates. Calculations for HSR using the average European electricity mix, a 75% load factor and the electric consumption of a Alstom AGV (0.033 kwh/seat.km)[h] show a crucial advantage in terms of carbon emissions over air and road transport with around 17g $CO_2$ per pkm. Although average emissions depend upon many factors the graph indicates the benefits of railways.

**Figure 8** $CO_2$ Average emissions per pkm in Europe - modal comparison




Source: Data by Alstom[i] and Calculation by SYSTRA

Thus, in addition to not being a significant contributor to the transport sector’s problems in terms of emissions, rail needs to be given more attention because of its crucial role as an important part of the solution. In particular, efficient, 100% electric HSR can play a leading role in reducing transport related emissions and contribute to climate protection. HSR offers the best performance in terms of energy consumption and materials use.

HSR offers attractive alternatives to short-haul flights and long distance car journeys. Replacing short haul flights with HSR would release capacity constraints at airports, reduce the need for additional expansion whilst helping to tackle the challenges of climate change[j].

On four routes analysed in detail [13] HSR was the most energy efficient transport mode with the lowest carbon footprint, e.g. between Valence and Marseille in France (250 km) with only 2.75 kg $CO_2$ per passenger (Car: 31.8 kg $CO_2$) or in Taiwan between Taipei-Kaohsiung (345 km) with only 18.2 kg $CO_2$ per passenger (Plane: 56.6 kg $CO_2$). Studies into the Madrid to Seville AVE line have revealed that without the AVE an additional 48,000 tonnes of $CO_2$ would be produced on this route every year. Rail held 48% of the market share during these first 50 days, compared to 39% for air transport and 13% for road. The modal shift to rail translates to savings of 30,000 $CO_2$ tonnes per year.

Another example is the “LGV Mediterranée” built in the year 2004: According to the analysis of the carbon footprint, the environmental benefit of HSR can be calculated as about 237,000 t of saved $CO_2$ per year.

In 2009 the new line from Firenza to Bologna, in Italy, opened, reducing the Rome to Milan journey time by an additional 30 minutes, and it is estimated that the 46 HSR trains connecting Rome and Milan daily will absorb 60% of the transport demand from air (according to company estimates).[14]

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[h] http://www.networkrail.co.uk/documents/About%20us/New%20Lines%20Programme/5878_Comparing%20environmental%20impact%20of%20conventional%20and%20high%20speed%20rail.pdf (p. 19)

[i] Data for competitive transport modes are taken from the background report “Methodology and results of Carbon footprint” of this study and from Alstom http://www.transport.alstom.com/home/news/hot_events/agv/sustainable/_files/file_34560_24796.jpg

[j] Assuming that there are no rebound effects whereby space is given to long-haul flights which generate more carbon emissions.

**Good Practice Example – Europe:** The Paris-Marseille Route

| Paris – Marseille corridor | | Aircraft | Car | HSR |
|---|---|---|---|---|
| | |  |  |  |
| Basic facts | Commercial distance (km) | 634 | 769 | 750 |
| | Vehicle consumption | 4038 L / flight | 49 koe | 17.3 Mwh |
| | Average number of passenger per vehicle | 122 | 2 | 400 |
| | Number of seat per vehicle | 150 | 4 | 516 |
| | Load factor (%) | 80 | 50 | 77.5 |
| Consumption and CO2 emissions *Primary energy equivalent* | Consumption (toe) *Primary energy equivalent* | 3.9 | 0.1 | 3.8 |
| | CO2 emission (kg) *Primary energy equivalent* | 11823 | 179 | 692 |
| | Energy efficiency *goe (primary) / pass.km* | 51 | 37 | 13 |
| | Consumption *Koe (primary) / passenger* | 32.2 | 28.8 | 9.6 |
| | Environmental efficiency *kg CO2 / passenger* | 97 | 89 | 2 |

Source: ADEME (French Environment and Energy Efficiency Agency)[15]

Under comparable travel times and if typical occupancy levels are assumed, HSR is on average 2 - 5 times more energy efficient than airlines or cars. No other major transport mode can boast energy efficiency similar to that of rail transport for a similarly timed journey between two locations.

HSR $CO_2$ emissions per passenger can be compared on selected routes using the Internet-based tool "EcoPassenger"[k] that was developed by UIC and its members. This interactive service enables customers to calculate emissions for journeys made using different transport modes. EcoPassenger is based on sound scientific methodology, taking into account the entire life cycle of the energy production, including upstream emissions from the generation (i.e. the refining of raw oil to gasoline) and distribution (i.e. the electrical losses between power plant and locomotive)

## HSR TRAINS ARE JUST AS ENERGY EFFICIENT AS CONVENTIONAL TRAINS

A common objection to HSR is that energy consumption of trains increases non-linearly with speed, because of increasing air resistance, so that the energy required to power a high speed train is much greater than that needed at conventional speed. However if energy use per passenger kilometre (pkm) is compared, then HSR trains can be just as energy efficient as, or even better than conventional trains. The total energy consumption of HSR trains when in operation is higher, yet the additional necessary energy is compensated due to several factors[l]. HSR is a system where each part contributes: the rolling stock, the electric power system, the infrastructure and the operation system[m]:

- The most important reason that can make HSR a more energy efficient means of transport than conventional trains is the higher capacity utilization (load factor), the number of passenger-kilometres travelled as a percentage of the total seat-kilometres available. Higher speeds mean shorter travel duration and thus higher attractiveness for travellers in comparison with other modes. With a good load factor, the energy consumption per

[k] The tools are available at www.ecopassenger.org and www.ecotransit.org
Passengers can use EcoPassenger, while freight operators use EcoTransIT to compare energy consumption, $CO_2$ and pollutant emissions, depending on the mode of transport they choose – rail, road, air or waterborne.
[l] Energy consumption increases with the square of the train speed, so when the speed of a train is doubled, its energy consumption is multiplied by 4.
[m] The energy (and emissions) needed to build HSR trains are similar to those needed for a conventional train (around 25 kWh/kg) but in its whole life the HSR train will run about 15 million kilometres, this is twice the typical 7.5 million of a conventional train. Therefore, ceteris paribus, the share of the energy and emissions in the construction per kilometre is significantly lower.

passenger can be smaller than that achieved on conventional trains. The higher load factor has already been proved from experience in France, Germany and Japan HSR trains:[n]

- The higher permitted speed in the downhill phase leads to lighter braking. Less kinetic energy is lost during braking and thus less energy is needed to maintain speed on following level or climbing sections. Raising the speed from 300 to 350 km/h in the HSR Madrid-Barcelona line (gradient 2.5 mm/m) means a possible reduction in energy consumption in the downhill phases by 11%.
- In some cases the distance between two stations on HSR routes is shorter and more direct than on conventional lines. This means a reduction in the energy consumption per passenger. In Spain, for example, the average distance of HSR lines is 13% shorter than that of the conventional lines between the same points, if measured in static terms (as a simple average of the route coefficients), and 12% if the effective route coefficient is measured (the coefficients weighted by the anticipated pkm on each route). On some routes (e.g. HSR line Madrid - Segovia) the distance is as much as 23% shorter. However many HSR lines are not shorter or more direct and actually take a more circuitous route to the destination, such as in France or on the proposed UK HS2route. However as speeds are higher and passengers can reach their destination in a short time the actual energy per passenger is still relatively low.[16]
- Another aspect relates to energy consumed by auxiliary services of the train. These services are systems that consume energy for technical purposes (such as compressors, ventilators, etc.), and for the comfort of passengers (heating, air conditioning, lighting, etc.). Energy consumption from these services is proportional to the operating time and therefore, in the same proportion to the average speed increases, the consumption per kilometre decreases. This energy consumption is not directly related to the speed; thus, in the verification of a typical high speed case, a 50% increase in the average speed means a 29% reduction in the energy consumed by the auxiliary services. [17]

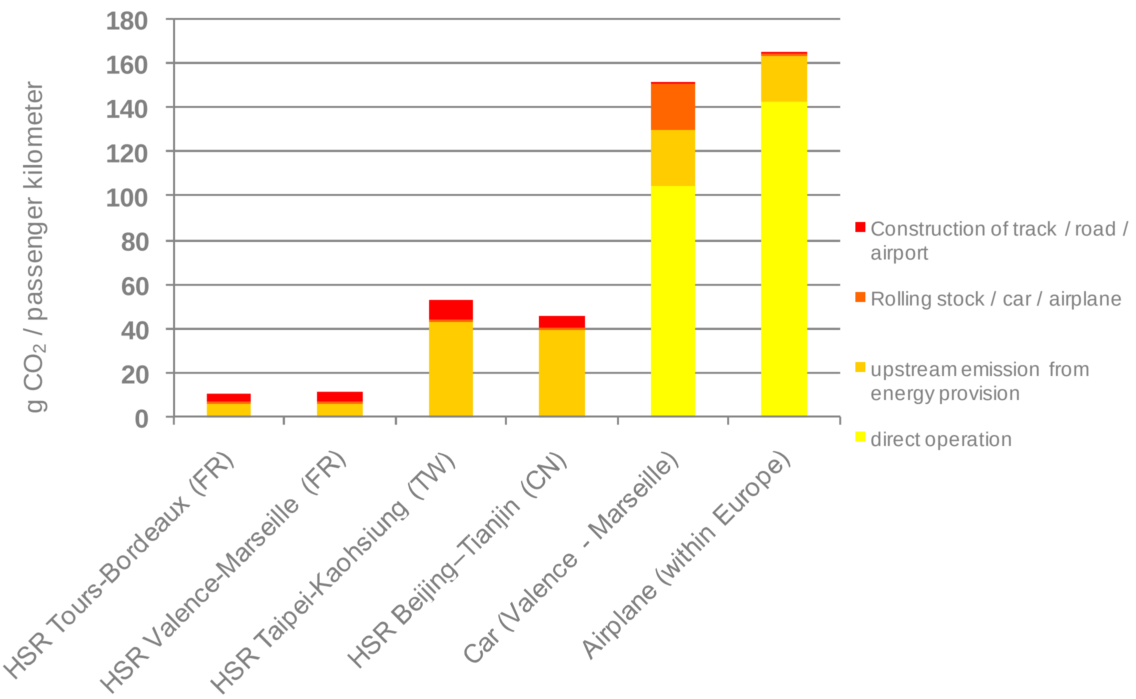
### HSR is still more environmentally friendly when considering the construction of the tracks and Rolling Stock

Another objection to HSR is that the track construction is linked with a high emission of $CO_2$ due to the earthworks needed, the construction of viaducts and bridges, the track and rolling stock. In a background report for this study, the carbon footprint of 4 different routes in Europe and Asia has been analysed, including the construction of track and rolling stock.

- The emissions from the construction of the high speed rail lines lies in the range of 58 t – 176 t of $CO_2$ per km of line and year. Lines with a moderate space and relief constraints (for example in France) emits around 60t of $CO_2$, By comparison, the carbon footprint of the construction of a 2x3 lane motorway is 73 t $CO_2$ (with similar transport capacity under the same geographical conditions). Projects with important space (China) or topographical constraints (Taiwan) are linked with a higher value of around 139 t – 176 t of $CO_2$ per km of HS-line and year due to the higher number of viaducts and tunnels.
- The carbon footprint of the track construction per Passenger and km is between 3.7 g $CO_2$ and 8.9 g $CO_2$, mainly depending on the share of viaducts and tunnels and the frequency of HSR trains.
- The construction, maintenance and disposal of the rolling stock lead to emissions of 0.8 $CO_2$ to 1.0 g $CO_2$ per pkm. Compared with the construction of a car (20.9 g $CO_2$ / pkm), the construction of a HSR-Train is 20 times lower. The construction of an airplane (0.5g $CO_2$ /pkm) is in the same order of magnitude as HSR.

[n] On some conventional railway lines the load factors are similarly high of course.

**Figure 9** $CO_2$ emissions per pkm of selected HSR routes and comparison to air / car



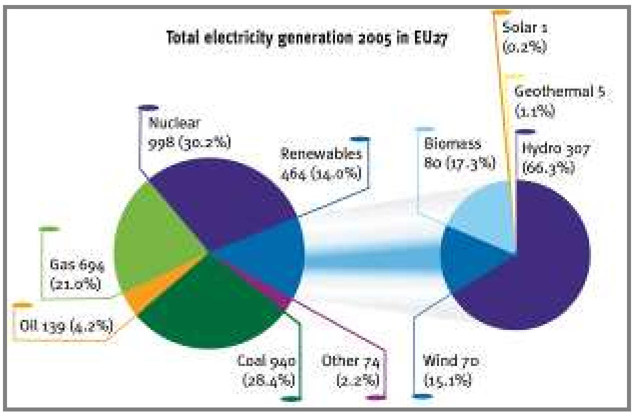

Source: UIC (2011) - Methodology and results of Carbon footprint [13]

Thus, estimating the impacts during the full life cycle doesn't change the low environmental impact of the HSR compared to other infrastructure/transport modes. It also shows that for HSR $CO_2$ emissions of rolling stock are significantly less, compared to the upstream emissions from energy provision. In addition, the construction of new HSR infrastructures allows it to replace other less sustainable modes such as aviation or the private car, which have GHG emissions factors 5 or 6 times larger. With the construction of new HSR lines, countries may effectively reduce their carbon emissions significantly. Hence, an integrated evaluation of the economical investments and the environmental impacts, of new HSR lines is needed to avoid some criticisms of new construction.

## HSR can be more efficient with further innovation and clean energies

Electricity produced worldwide currently comes from a variety of primary energy sources (see Figure 10). Currently, most of the sources are non-renewable: i.e. oil, natural gas and coal. Renewable energy supplies are a tiny part of the energy mix. By early 2009, renewable energy policy targets existed in some 73 countries around the world. The European Union, for example, set an objective to reach 20% of energy from renewable sources by 2020.

**Figure 10** Total electricity generation 2005 in EU27




Source: EC, 2007[18]

It is obvious that the performance in terms of GHG emissions is crucially dependent on the energy supply that serves the network. As HSR lines run on 100% electric power, it is the only motorised mode of transport which is capable of shifting from fossil fuels to renewable energy without any separate investment in the propulsion units or infrastructure, simply by changing the energy sources in the electric energy production. For example, in Spain, in 2010 more than 46% of electricity used by trains came from renewable sources.

Following a strict sustainability approach, one needs to acknowledge that in their electricity mix railways are using all kinds of energy sources, as provided by the public energy supplier. This also includes electricity from nuclear electric power. Even though nuclear power produces almost zero GHG emissions, it generates other impacts like nuclear waste. Nuclear waste strongly affects any sustainability assessment. However, it has been beyond the scope of the study to quantify and discuss this impact.

At the same time, railway industry has a driving role in the research for technological innovations and is pushing forward with numerous green initiatives to improve energy efficiency, including:

- Eco-driving techniques
- In-cab signalling (optimising energy use)
- Lighter vehicles
- Better aerodynamics (by reducing drag and running resistance)
- Traction technology and power transmission systems improvements
- Regenerative braking
- On-board ancillaries (e.g. thermo-efficient air-conditioning systems, lighting)
- Optimized facility management (energy efficient lighting and heating at stations and offices)
- Recycling infrastructure and rolling stock components[o]

Japan in particular is well-known for paying attention to energy efficiency, achieving with its Shinkansen 500 HSR trains a mean value of 0.029 kWh per seat-km mainly due to their lower mass and higher seating capacity. A 400 metre train set holds 1,323 passengers compared to 516 passengers for the TGV Duplex, so when both are full the train will have lower emissions per traveller.

Swedish Rail Statens Järnvägars (SJ), which operates only electrically powered trains, have taken the step to purchase 100% renewable energy from hydroelectric and wind-powered sources. The positive impact on emissions reductions is illustrated by the journey between Stockholm and Gothenburg, on which an SJ train can carry up to 300 passengers and emits only 400 g of $CO_2$ per passenger, compared to an average car which would emit on average 44.5 kg (over ten times more).[p]

[o] Further information in chapter 3.1.4 Resource efficiency (material use)
[p] www.sj.se in UIC http://www.traintocopenhagen.org/IMG/pdf/position_paper_full_version.pdf

**Good Practice Example – HSR "green" products aimed at reducing $CO_2$ emissions from travelling:**

Since spring 2009, the Deutsche Bahn AG (DB) has been offering corporate customers $CO_2$-free business travel. Unlike compensatory measures, this transportation avoids $CO_2$ altogether since the electricity used is produced exclusively from renewable energy sources in Germany. DB purchases the amount of renewable energy required for transportation and journeys in advance and feeds it into the traction current network.

All companies registered with the bahn.corporate program can use the new passenger transportation products, and services, and avoid $CO_2$ emissions altogether on their journeys. Companies pay a small extra cost equal to roughly 1% of travel costs. For example, there is an additional cost of around 76 cents for a journey from Berlin to Frankfurt. This is less than having to compensate for the $CO_2$ emissions from a flight – around €6 on this route. The lower added cost pays off for companies since the emissions avoided have a positive impact on their carbon footprint. DB calculates the electricity the customer's journeys consume and bills the additional cost.

The customer receives an attestation from TÜV SÜD on the origin of the electricity and $CO_2$ savings. In 2010 more than 60 corporate costumers used bahn.corporate and the number and the demand for green products is still growing (the most important customer is the federal government with all the subordinate offices).

http://www.dbecoprogram.com

Last, but not least, when more people choose to use rail over other modes, and trains are utilised closer to capacity, further reductions in the environmental impact of transport are possible. Providing information regarding the environmental benefits of rail tends to stimulate modal shift to a very small extent. Thus, better integration of environmental benefits from HSR in policies and financial measures to enhance modal shift is needed, e.g:

- Fair pricing through taxes and levies across the whole transport sector,
- internalisation of external costs,
- investments in infrastructure, and
- developments in technologies.

### 4.1.2 Air pollution

Over 50% of the world's emissions of carbon monoxide, hydrocarbons and nitrogen oxides caused by burning fossil fuels are produced by petrol and diesel engines. The following points are examples of the negative impacts air pollution has directly on human health and ecosystems:

- Acidification of soils and waters due to sulphur oxides ($SO_x$) and ammonia with potentially serious negative impacts on ecosystems and resources.
- Formation of ground level ozone because of non-methane volatile organic compound (NMVOC), nitrogen oxides ($NO_x$), carbon monoxide (CO) and methane ($CH_4$), that have adverse effects on human health and ecosystems.
- Airborne particulate matter ($PM_{10}$) that provoke respiratory and cardiovascular problems.

In the United Kingdom for instance, it is estimated that up to 24,000 people die prematurely every year as a result of poor air quality, mainly due to individual road transport.[q] Regulated emissions from transport have decreased significantly since 2003: $PM_{10}$ by 30%, acidifying substances (mainly $SO_x$ and $NO_x$) by 34% and ozone depletion substances by 40%. Nevertheless, local air pollution, in particular from road transport, remains a major hazard.[r]

[q] http://www.publications.parliament.uk/pa/cm200910/cmselect/cmenvaud/229/22905.htm
[r] UIC 2008, Facts & Figures

**HSR CAUSES LESS POLLUTANTS THAN COMPETETIVE MODES**

Around 80% of rail transport volume in Europe is powered by electricity, meaning the vast majority of trains emit no local air pollutants where they operate. [19] Newly constructed HSR lines are 100% electric operated and therefore no direct local air pollution is caused. Of course air pollution is caused, but in an indirect way, namely when producing energy for the railway system. The emissions performance of HSR therefore has a strong link to the source of energy supply. As the previous chapter showed, the energy mix varies significantly across the world. Whereas Sweden operates with 100% renewable energy from hydroelectric and wind-powered sources, Germany, for example, has an energy mix where more than 50% derives from fossil fuels. However, because of its high efficiency, HSR still emits less air pollutants than other transport modes as the following example (Figure 11) from Germany shows.

**Good Practice Example – Route Frankfurt - Hamburg**

**Figure 11 A** modal comparison of air pollutant emissions

| **Characteristics and components *(unit per person travelling)* Effects** | **Aircraft** | **Car** | **High Speed Rail** |
|---|---|---|---|
| **Duration (h:m )** | 02:30 | 04:14 | 03:37 |
| **Fare (€)** | 91 | 113 | 109 |
| **Energy Resource consumption *(converted into liter of petrol)*** | 32,8 | 38,6 | 11,1 |
| **Carbon dioxide (kg) *Greenhouse gas, Global Warming*** | 77,1 | 86,0 | 19,2 |
| **Particulate matter (g) *Human toxicity*** | 2,1 | 21,2 | 1,0 |
| **Sulphur dioxide (g) *Acidification*** | 43,4 | 3,2 | 19,5 |
| **Nitrogen oxides (g) *Acidification, nitrification, summer smog/ozone*** | 268,3 | 223 | 17,2 |
| **Non methane hydrocarbons (g) *Summer smog/ozone*** | 20,8 | 18,3 | 1,1 |

Source Source: IFEU 2008.

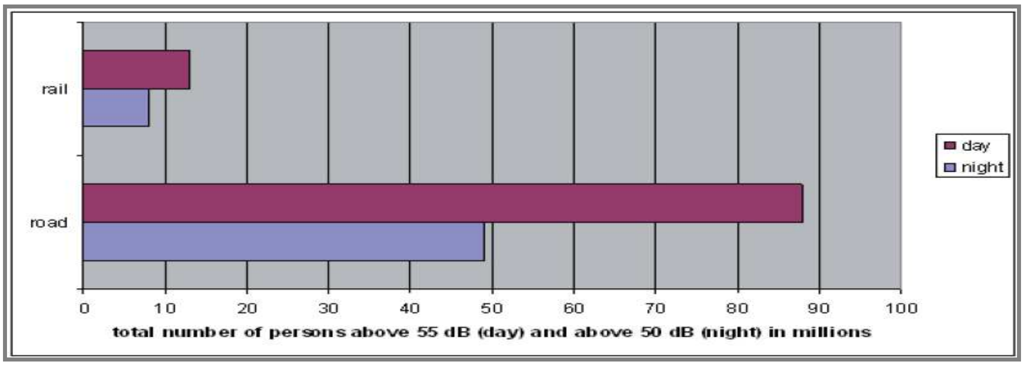
These results are significant and HSR is undoubtedly superior to other modes of transport by far. For $PM_{10}$ HSR is 14 times less polluting than car and air transport; for $NO_x$ HSR is 13 times less polluting, and considering non-methane hydrocarbons about 19 times less polluting than car and air transport.

### 4.1.3 Noise and Vibration

Noise disturbance, as well as vibration, is a particularly important issue when examining the sustainability of transport systems as millions of people are affected daily by noise, and especially by traffic noise in their home. Studies have shown that excessive noise exposure can lead to mental and physical health problems.

In the European Union a recent noise mapping exercise for fulfilling the European environmental noise directive resulted in the following picture for road and railway noise (see Figure 12):[s] [20]

**Figure 12** Number of persons affected by road and rail noise in Europe[t]

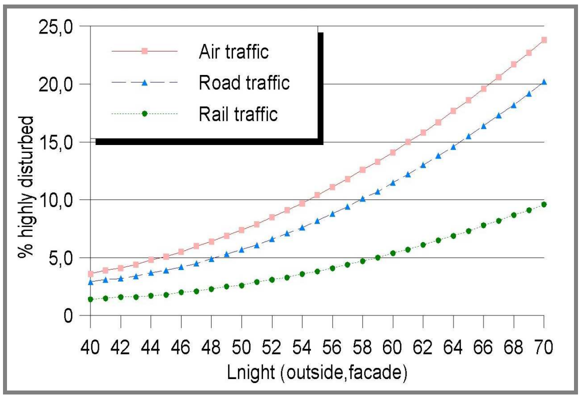



Road traffic is a major source of noise pollution. It affects almost 90 million persons in the daytime and 50 million during the night-time while railway noise affects some 12 million in the daytime and ~8 million persons in night-time in Europe. Noise is perceived as one of the most important environmental problems for people living close to roads and railway lines which for historical reasons were often designed to go through the heart of towns.

### HSR HAS LOWER NOISE IMPACT THAN OTHER TRANSPORT MODES

Many studies have proven that from all transport sources rail noise is perceived as least disturbing to the population. The European Commission Working Group on Health and Socio-Economic Aspects published a position paper on 11 November 2004 on dose-effect relationships for night time noise[u]. These analyses resulted in the graph below, based on self-reported (chronic) sleep disturbances: to disturb 10% of citizens highly a railway noise level $L_{night}$ of 70 decibels is needed, while for the road traffic this effect is reached already at a level $L_{night}$ of 58 dB(A) while for air traffic even a $L_{night}$ of 54 dB(A) is sufficient to be perceived by 10% of the population as highly disturbing (see Figure 13).

**Figure 13** Percentages of highly disturbed persons when exposed to air, road and rail traffic noise




Source: EU Working Group on Health and Socio-Economic Aspects November 2004[21]

Around every major airport several thousand persons are affected by aircraft noise, i.e. around Heathrow over 700,000 persons are exposed to the 55 dB(A) $L_{den}$ contour.[v] [22]

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[s] A current overview on railway noise has been published by UIC in 2010 in the report "Railway Noise in Europe; A 2010 state of the art report"

[t] Using data from: http://noise.eionet.europe.eu

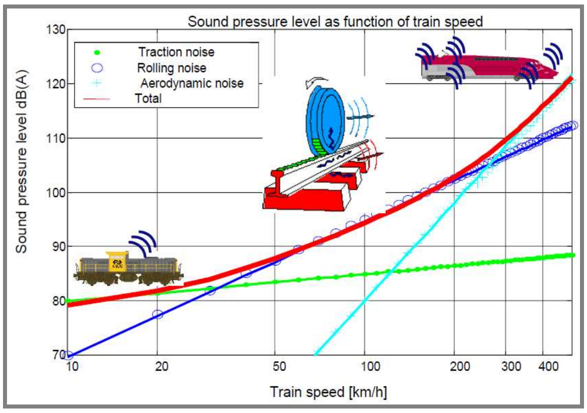
[u] Position Paper on Dose-Effect Relationships For Night Time Noise, European Commission Working Group on Health and Socio-Economic Aspects, 2004

[v] The main noise indicators for noise mapping are Lday, Levening, Lnight and Lden (day-evening-night). These are long-term averaged sound levels, determined over all the correspondent periods of a year.

When dealing with exterior railway noise three main sound sources have to be taken in account (see Figure 14):

- Traction noise such as engine (diesel) and gearbox noise, cooling fan noise (for motors and drive assemblies) or equipment of air conditioning, these sources are dominant at standstill or at low speed levels,
- Rolling noise (created in the contact zone of wheel and rail) dominant at moderate speeds up to ~220 km/h, and
- The aerodynamic noise (influenced by the aerodynamic design of the train set, especially its front and by pantographs or antennas on the roof) dominates at speeds above ~220 km/h.

**Figure 14** Railway exterior sound sources and typical dependence on train speed

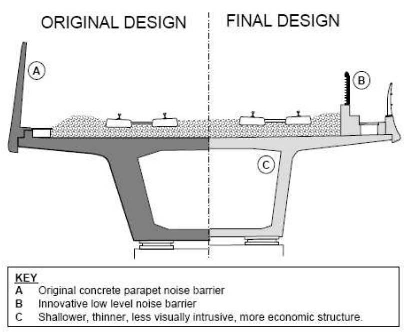



Source: EC, 2003[23]

Dealing with traction noise, and with rolling noise, is an issue relevant to every form of railway transport, while aerodynamic noise is special and only relevant to HSR trains. As noise abatement has to start at the source, traction noise and especially aerodynamic noise have to be handled in the design of a railway vehicle. When the noise at source is limited, further impacts on the population can be prevented by noise abatement measures on the propagation path, mostly achieved by installing noise abatement screens or noise insulation on buildings. These measures are common to all forms of railway transport and are the current state of the art in noise abatement.

HSR lines, where the trains are operated at high speeds (above ~220 km/h), are mostly newly built lines or at least to a large extent upgraded lines causing large construction activities. In these building processes noise abatement plays a dominant role forcing the infrastructure companies to install the necessary measures to ensure that the population is only minimally affected by the operation of the HSR trains. It is state of the art to fulfil all these obligations in order to secure planning permission. An example is the Medway viaduct (see Figure 15 below) for the HS1 line in England: specially designed new noise barriers with a thinner structure allowed the width of the bridge deck to be reduced and resulted in an efficient protection against noise while being less expensive and less intrusive in the landscape.

**Figure 15** Architectural noise barriers on Medway viaduct, England




Source: Channel Tunnel Rail Link: High Speed, Low Impact, Minimum Cost, EJ Allet, RJ Greer, C Manning, Proceedings of the Institution of Civil Engineers, Transport, 153, May 2002, pp 71-8

The main effort for HSR trains has been in the aerodynamic design of whole train sets, and especially of the pantographs (see Figure 16). The optimisation of the pantograph includes both its form, the design of the contact strip and may include shielding of the pantograph on the roof. Furthermore the number of pantographs needed to collect the current for the train set could be reduced, resulting in less aerodynamic noise sources.

**Figure 16** Aerodynamically designed ICE3

Road and rail traffic also generate vibration, and the population often becomes more aware of these vibrations when noise abatement has taken place. In the case of railways, vibration is caused by the dynamic forces created by the interaction of the wheels and the rails; they increase with the unsprung mass of the wheel set, with the weight of axles and also with the speed of train. Several influential factors can be described:

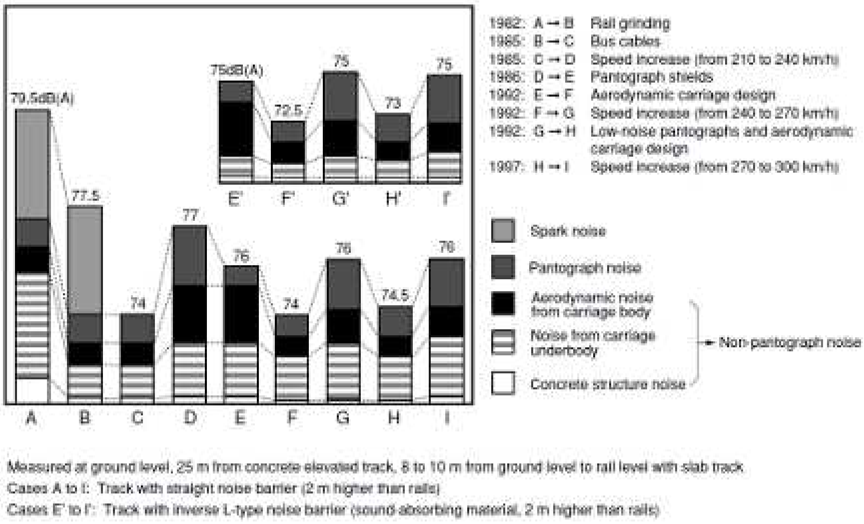
- Suspension systems on the train decouple the coach body and bogie from the wheelset and reduce dynamic forces and vibration.
- Interaction between the rail and axles depends on rail and wheel profile and irregularities.
- Rail track rigidity and soil characteristics. For instance, more rigid slab tracks generate less low frequency vibration than ballasted tracks but vibration of a much higher frequency.

Vibration generated by HSR is more intense than from conventional trains because of the higher velocity. Furthermore rail technology improvements proposed for tracks (e.g. under-ballast mats, resilient tie pads and fasteners) help to reduce ground-borne vibration levels considerably. See Figure 17 for an example.

**Good Practice Example – 30 years of noise reduction in Japan**

As the first country to introduce HSR, Japan early took measures to tackle noise pollution resulting from the Shinkansen railways. In 1975, the Environment Agency established a new environmental standards directive for HSR services. It fixed a limit for noise levels at 70 dB(A) (LAeq) for residential areas and 75 dB(A) for areas with industrial and commercial activities, and a clear methodology for measurement was created. The directive granted railways a period of time to comply with these new standards. The railways adopted solutions to reduce noise that proved to be efficient, as shown in the following charts.

**Figure 17** Relative importance of Shinkansen noise sources and results of noise countermeasure




Source: Japan Railway & Transport Review, 1999[24]

As speed increased with the new Shinkansen trains, noise levels increased in some periods and the sources of the noise changed. Specific measures were adopted and, in 1997, Shinkansen trains were quieter than those in 1982. Specific attention to aerodynamics and pantograph noise contributed to lowering the noise level in spite of the speed. Spark noise, which is an electrical noise caused by contact loss, and concrete structure noise almost disappeared.

Japanese experience also enabled research to discover particular disturbances such as sonic booms generated by HSR trains passing through long tunnels. This problem was discovered in 1975 with the Sanyō Shinkansen trial runs. Sound explosions resulted in protest from residents nearby the track. They were caused by compression waves expulsed from tunnel exits. When a HSR train enters a tunnel, sound waves propagate through the tunnel at the speed of sound and are then expulsed at the tunnel exit strongly enough to provoke vibration of doors and windows. Several solutions were chosen to solve this problem such as redesigning the tunnel portal hood to reduce the pressure wave, shelters with slits between adjacent tunnels, inclined or vertical shafts to bypass compression waves, or aerodynamic nose shapes of trains to minimize micro pressure waves.

These early concerns of Japan for noise pollution have led to the development of innovative solutions for nearly 30 years. Lessons from this experience can be used for future projects. For instance, solutions for sonic booms at tunnel exits have been implemented in Germany in 2005 for the Nuremberg Ingolstadt HSR Line.

### 4.1.4 Resource efficiency (material use)

The world population is expected to exceed 9 billion by 2050 according to the US Census Bureau.[w] This population growth will have significant impacts on global natural resources. As a consequence, setting up a more sustainable transport system that consumes fewer resources appears to be a central issue.

The ongoing growth in global consumption of raw materials is likely to cause shortages that could aggravate energy scarcity and hamper the development of a sustainable economy, e.g. when causing difficulties to promote a large scale electrification of land based transport.

All transport sectors contribute to natural resource depletion, including the HSR sector although this has a lower impact. Resource depletion takes place when using energy or raw materials. Resource efficiency means an optimized use. Further improvements in efficiency can be made by emphasising minimising emissions from the construction of any new rail infrastructure, focussing on using lower carbon materials and on the recyclability of train components.

During the construction phase a reduction in mass contributes to energy efficiency and is typically achieved by reducing the weight of specific components (e.g. carriage bodies, bogies etc.) or through a system-based approach to reducing weight (e.g. the articulated train design favoured by Alstom, which has reduced the number of bogies by around 20% by placing them between rail carriages).[25] Further weight reduction can be achieved by the improvement of traction equipment efficiency and the train configuration (i.e. articulated architecture). Furthermore, light-weight aluminium construction enables the vehicles to be designed for easy maintenance. The use of better insulating materials also allows higher energy efficiency.

Updating and modernizing the vehicle fleet throughout the lifetime of HRS trains improves the carbon footprint even further. For example DB's 59 first generation ICE trains were completely rebuilt between 2005 and 2008. According to experts, this modernization made for great reductions in the use of resources compared to the purchase of new trains, saving roughly 16,000 tons of steel and 1,200 tons of copper. Moreover, refurbishing the components, rather than using new manufactured ones, reduced $CO_2$ emissions by 35,000 tons.x

The use of composite and biomaterials (from renewable resources such as wood or hemp) allows a higher recyclability rate which in turn preserves resources. Also the replacing of hazardous materials or ozone-damaging solids contributes to better resource efficiency.

HSR offers several advantages to limit the extensive use of raw materials. Figure 18 shows how efficiently a tonne (used to produce a vehicle) is able to offer seat-km during its whole-life, assuming similar recycling rates for all vehicles, while shows an example of rail recycling:

**Figure 18** Comparison between the French TGV and an average car

| Mode | Mass (t) | Seats | Km/year | Life time (year) | Seat.km/tonne used |
|---|---|---|---|---|---|
| HSR (TGV Duplex) | 400 | 516 | 49K | 30 | 19160K |
| Average car | 1.2 | 4 | 15K | 10 | 480K |

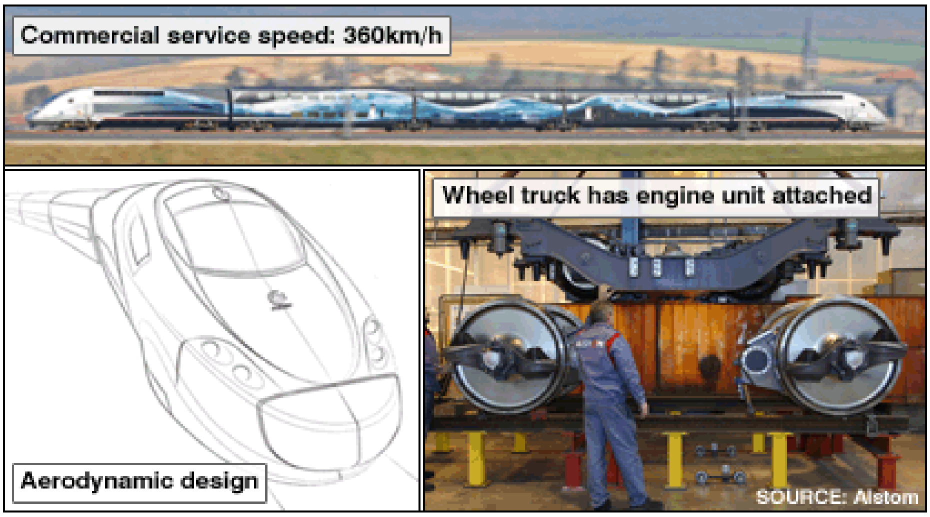
X40

Source: calculation by SYSTRA

[w] http://www.census.gov/ipc/www/idb/worldpop.php
[x] DB Sustainability Report 2009, http://www.deutschebahn.com/site/nachhaltigkeitsbericht__2009/en/our__products/sustainable__transportation/fleet/fleet.html

**Figure 19** Good Practice Example – The AGV, 98% recyclable[y]

**Good Practice Example – The AGV, 98% recyclable**




The AGV (Automotrice Grande Vitesse), a French HSR train with a commercial service speed up to 360 km/h is particularly environmentally friendly with 15% lower energy consumption than its predecessor [z]. Furthermore, the AGV is lighter than the TGV and also designed to be 98% recyclable.

Last, but not least, the long life of rolling stock and infrastructure contributes to resource efficiency. The life cycle is usually 30 years but in reality often much longer. Through upgrading and modernization further contributions to material efficiency could be achieved, for example from:

- Resource and waste management
- Waste and its role as resource / potential of recycling and re-use
- Recycling of materials / use of secondary raw materials
- Purifying waste water / cleaning of HSR trains
- Reprocessing ballast, ties or rails (e.g. steel as important raw material)

### 4.1.5 Biodiversity

The main impact of transport regarding biodiversity is the fragmentation and degradation of the natural and urban landscape due to the “barrier” effects of the infrastructure as well as wildlife accidents caused by collisions.

Wildlife mortality due to collisions can be significant. Mammals such as deer or wild boars, birds such as birds of prey or migratory birds, and chiropters seem particularly vulnerable. Wildlife mortality due to collisions on the Autoroute Paris-Rhin-Rhône[aa] was estimated at 3.3 collisions/km/pa.[26] Considering the environmental measures dedicated to prevent collisions, HSR lines cause a particularly low number of collisions with natural species. The Civil Aviation Authority (2006) suggests that 1000 air traffic movements lead, on average, to roughly 0.54 bird strikes.[bb]

Proper layout design of HSR lines is the most effective way to protect biodiversity. Adjustments made during HSR route planning to minimize the impacts on natural areas included the building of tunnels and viaducts and also rerouting around some areas. Fences that are implemented all along lines are also used to avoid collisions with animals and amphibians. During the final HSL works stages, zones temporarily affected by works are

[y] BBC News Corporation 2008 http://news.bbc.co.uk/1/hi/7227807.stm
[z] http://www.alstom.com/pr_corp_v2/2008/corp/48523.EN.php?languageId=EN&dir=/pr_corp_v2/2008/corp/&idRubriqueCourante=23132
[aa] The Autoroute Paris-Rhin-Rhône is 305 km long
[bb] Civil Aviation Authority 2006, http://www.caa.co.uk/default.aspx?catid=375&pagetype=90&pageid=3404

replanted, and landscaping undertaken to integrate the section into the natural setting. For this, indigenous species of trees, bushes and plants are used.

In some cases specific preventive measures are taken such as:

- Individualized protection for endangered flora.
- Tree and bush transplants.
- Special replanting campaigns.

Nearly 70% of alignments occur on existing transportation corridors and rail lines. Today's HSR projects come systematically with a wide range of impact reduction or even compensatory measures. Implementing a double series of measures is the most common approach to address the challenge of wildlife mortality:

- First, to make the whole line off limits with fences, whose characteristics are adapted to the type of wildlife (amphibians, small wildlife, large mammals, etc.)
- Second, to ensure the continuity of natural habitats (ecological network) by providing the high speed line permeability using wildlife overpasses and underpasses (see Figure 20).

**Figure 20** Wildlife overpass

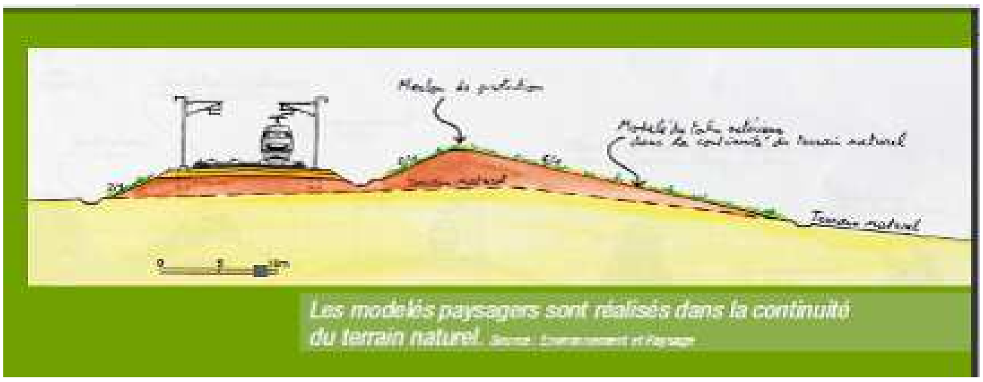
Source: RFF[27]

Even if the entire length of at-grade alignments is fenced, a large part of HSR lines can be fauna-permeable tunnels or viaducts. In the rest of the route considered not permeable, cross drains are enlarged beyond drainage needs to make room for dry cross paths, and vegetation is planted at their mouths. This type of work is most frequent in stretches running through high-value fauna zones. Large animal crossings (for ungulates) are also built.

### 4.1.6 Visual insertion

All transport infrastructures have visual impacts. These refer to the impacts of landscape change on observers (zone of visual intrusion). Figure 21 illustrates how lines can be integrated into the environment.

**Figure 21** The landscape lines are designed according to natural slopes




Source: SDPA SEA[28]

**HSR PROJECTS ARE BUILT WITH A VERY PRECISE LANDSCAPE INTEGRATION POLICY**

The landscape has an important public role in the cultural, historical, ecological, environmental and social fields, and constitutes an asset for economic activity and whose protection, management and planning can contribute to job creation. Infrastructure therefore has to be in accordance, or compatible, with the local landscape (emphasizing the landscape view from both the residents and infrastructure users' point of view).

Landscape fragmentation by infrastructure is closely related to population density and is greatest in western and central Europe where the population and transport network is the densest. The construction of infrastructure can be a cause of fragmentation of the space, when it affects an increase of residual, marginal and unused areas, that are hardly accessible and so become degraded (these are also called "infraspaces"). Landscape designs are proposed to provide a continuity of land-use beyond the railway-only area. Today's HSR projects are built with a very precise landscape integration policy. Various compensatory measures are planned and implemented. Among these, regeneration and planting of trees and shrubs, maintenance and management operations for different types of vegetation (e.g. grasslands, scrub and woodland) and other landscaping/ re-naturalisation works are effective. Figure 22 shows what can happen.

**Figure 22** Road Rail Parallel Layout

Source: UIC

### 4.1.7 Land use

Space consumption of transport infrastructure is a major issue in many countries depending on the geographical context. The amount of land occupied by transport infrastructure determines the impact on biodiversity and natural habitat and is thus a very sensitive indicator. For instance, an objective of land-take of 30ha per day by 2020 has been proposed for the Environment-Barometer indicator in Germany (increase per day in area covered by human settlements and transport routes). By comparison, it was 120 ha per day in 1997. These seem to be the first proper, and necessary, steps to counter the adverse trends in land use.

From 1990 to 1996, a total of some 25,000 ha (about 10 ha of land every day) were taken for motorway construction in the European Union.[29] Estimations by the European Environment Agency indicate that roads account for 93% of the total area of land used for transport in the European Union (EU15) while rail infrastructure takes only 4% in the EU15.[cc]

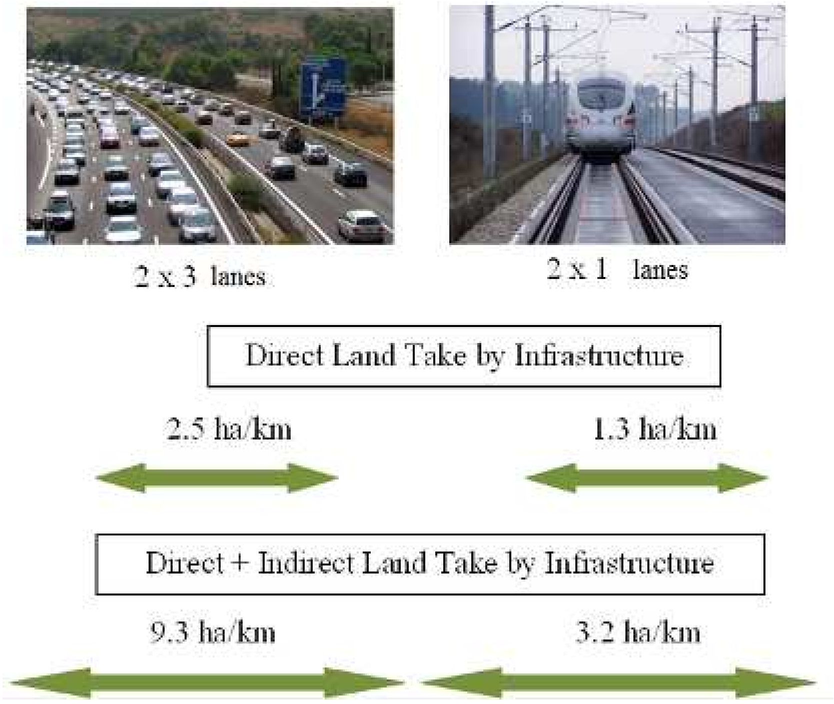
**HRS CAN CARRY LARGE NUMBERS OF PEOPLE WHILE USING RELATIVELY LIMITED LAND SPACE**

There are important differences in land-take efficiency[dd] from one infrastructure type to another. Railways have a lower requirement of land take per unit (i.e. passenger-km). Train tracks permit a far higher throughput of passengers per hour than a road does with the same width. By comparison, the maximum capacity of a single lane of highway is 2,250 passenger

[cc] http://www.eea.europa.eu/publications/ENVISSUENo12/page011.html
[dd] The ratio between land used and the infrastructure's traffic carrying capacity

cars per hour according to the Highway Capacity Manual (US)[30]. Figure 23 illustrates the different land-takes between rail and road infrastructure.

**Figure 23** Land-take by roads and rail




Source: UIC 2008[31]

Land occupied by airport infrastructure and aviation activities include: airport terminal and ground operations (runways), access to the airport (cars, buses, trains, parking, etc.) and associated projects such as hotels and airport related office developments.

It is acknowledged that a stringent comparison between rail and air depends on various structural differences, e.g. it is necessary to bear in mind that one airport flies to many destinations whereas HSR travels between a limited number of stations. A land-take comparison between HSR lines and airport infrastructure is as follows:

- Airport Paris CDG = 3,200ha[32]
- LGV Bretagne Pays de la Loire: 2,300ha
- LGV Rhine Rhone : 1,400ha for 140km

## 4.2 HSR is the safest transport mode

Safety in transport is a crucial issue in our modern society, both from a social and an economic point of view. HSR has the highest safety record with fatalities close to zero.

### HSR has proved to be the safest mass transport mode in the world

HSR is used for long or medium length journeys and in comparison with other transport modes for these journeys it performs very well in safety to passenger terms. Fatalities per billion pkm for airline passengers and bus and coach are both 0.4 with passenger cars accounting for 5.9 whilst HSR is effectively 0. Increased speed usually translates to an increase in the severity of collisions should they occur and HSR is no exception. However the number of fatal collisions occurring on HSR as more lines are built has not increased and to date only one recorded fatal HSR collision has occurred[ee].

Road proves to be by far the most dangerous mode of transportation in the world in both absolute and relative terms. Every year more than 1.17 million people die in road crashes

[ee] This was on a German ICE high speed train in 1998.

around the world. The Global Burden of Disease study[33] undertaken by the World Health Organisation (WHO), Harvard University and the World Bank showed that in 1990, traffic crashes were assessed to be the world's ninth most important health issue. The study forecast that by the year 2020 road crashes would move up to the third place in the table of leading causes of death and disability facing the world community.

Both passenger cars, and airlines, have a higher fatality rate per transportation mode per billion than HSR. Passenger car occupants record 5.9 fatalities per billion km.

Buses and coaches are 15 times less dangerous than passenger cars. Railways in general are 30 times less dangerous and HSR is the safest mode of transport.

Public authorities, constructors and operators have viewed transport safety as a priority action during the last decade, especially in the road sector. Public communication campaigns as well as public policies (e.g. the enforcement of stricter sanctions, adaptation of road infrastructure, reinforced norms of security for constructors etc) have led to a noticeable reduction in deaths on the roads. Though, despite these efforts the private car still remains a dangerous mode compared to air transportation and HSR.

Furthermore, HSR operators and infrastructure managers have continuously set up a risk management approach in order to maintain a high level of safety especially with the rise in maximum speeds.

## 4.3 HSR relieves roads and reduces congestion

On long distance corridors with high levels of demand HSR provides an attractive alternative to congested roads. National and international networks of passenger HSR will help ease traffic congestion. Road congestion is not limited to urban areas and is expected to worsen.
Even in the United States, since 1982, the average delay per highway rush hour traveller has grown from 16 to 47 hours per year. There were 65 million vehicles on the U.S. highways in 1955; they have reached 246 million today. This figure is expected to rise to 400 million vehicles by the year 2055. According to studies conducted in the United States, interstate travel is currently one-quarter of all vehicle miles travelled and is the fastest growing segment of vehicle miles travelled. According to the Federal Highway administration, it is expected that by 2020, 90% of urban interstates will be near to capacity.[ff]

Following the deregulation of air transport, air carriers have tried to provide connections at a lower cost. They consequently developed hub and spoke operations. The growth of hubs concentrated in a few big airports has then tended to increase air traffic congestion. One of the most visible related effects is the increase in delayed flights. For instance, the percentage of delayed flights in the USA was nearly 21% in 2004.[34]

In the United States, regional air services are among the fastest-growing segments of air travel. Yet corridors of 300-800 km serve distances where HSR could be particularly competitive.

Yet in the USA only one HST is in operation: the Acela Express tilting train running on the North East Corridor line between Boston and Washington, DC. Ten corridors across the USA have been designated for HST operation.[gg] However, President Barack Obama has revealed an ambitious plan to accelerate the development of US HSR transportation. The plan targets upgrades to existing rail lines as well as new rail lines devoted to 240-400 km/h trains.[hh] Jump-start funding the ten HSR corridors is already approved with over $8 billion provided through the American Recovery and Reinvestment Act of 2009 (ARRA). If this plan is approved the federal budget is anticipated to provide an additional $1 billion a year for five years

### HSR is a competitive mode for medium and long distance trips

An analysis of market shares in different countries and continents enables us to state that the primary market for HSR is trips between 300 and 1200 km, and under 4 hours.

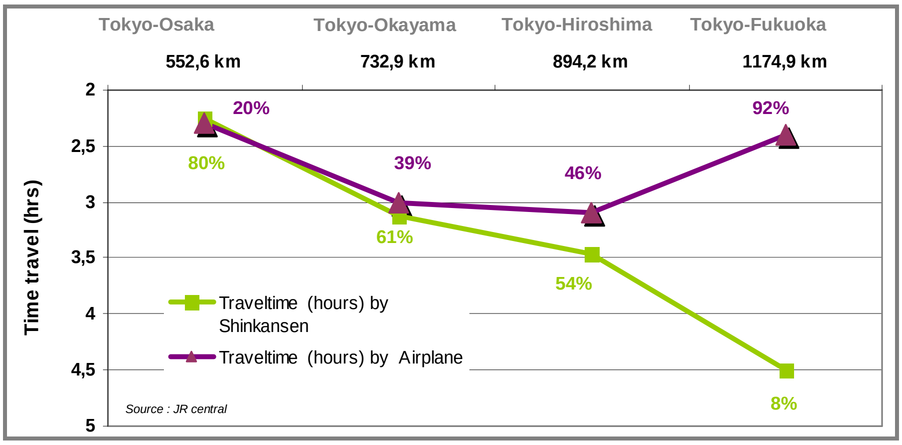
The following graph (Figure 24) shows the prominence of HSR in terms of market shares in Japan for journeys below 2h30. On the Japan Tokyo-Osaka HSR link an 80% market share is recorded. This market share decreases with the lengthening of distances. Up to 3h30 and approximately 850 km, the HSR market share goes beyond 50%.

[ff] Amtrak 2011 http://www.amtrak.com/servlet/ContentServer?pagename=Amtrak/HomePage

[gg] Development and Impact of the Modern High-speed Train: A Review, Moshe Givonia, Transport Reviews, 26: 5, pp593 — 611

[hh] http://www.traintraveling.com/leadtopics/04-usa-high-speed.shtml

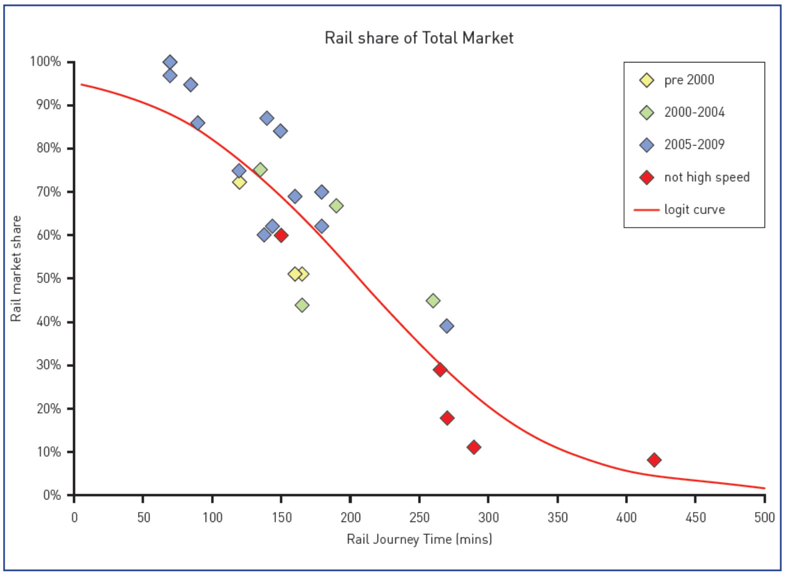
**Figure 24** Air/Rail market share depending on distance and time travel in Japan




Source: Central Japan Railway Company, 2008[35]

An international comparison also shows that the market share of HSR is particularly high for journeys of 50-200 minutes duration (see
Figure 25). For the market share by distance Figure 26 shows that under 200 km, road transportation secures at least a 50% market share considering the performance of the current Japan Shinkansen network. HSR ranks first on distances between 200 km and 850 km while beyond that aviation takes the lead.[ii]

**Figure 25** Rail market shares by journey time




Source: UK HS2 Demand Model Analysis

[ii] Details on the methodology:

Travel times have been calculated using timetables correct as of September 04

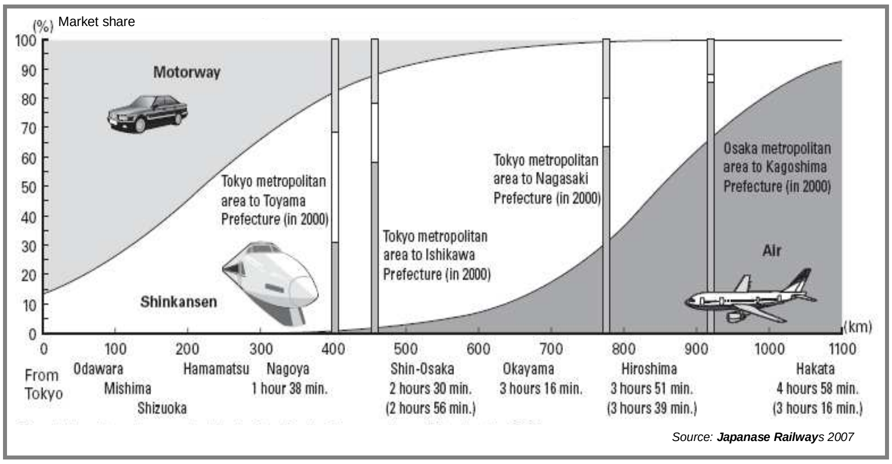
The lower figures in parentheses include transfer times to and from airports.

Shares have been calculated from results of the third net movement of Passengers on trunk routes throughout Japan Survey (2000)

Figures for the Tokyo Metropolitan area are calculated by summing the results Saitama, Chiba, Tokyo and Kanagawa prefectures.

Figures for the Osaka metropolitan area are calculated by summing the results for Kyoto, Osaka and Hyogo prefectures.

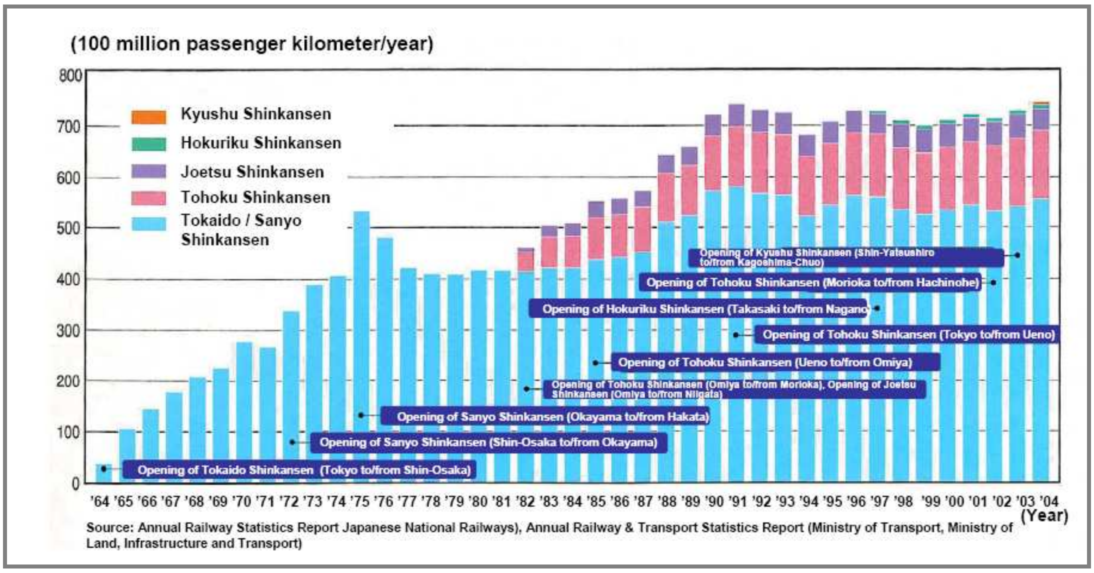
**Figure 26** Multimodal market share depending on distance and time of travel in Japan




Source: Toshiji Takatsu, 2007[36]

Since the opening of the Shinkansen corridors in 1964, the traffic volumes and the ridership have sharply increased. Figure 27 shows the evolution of the traffic volumes following the opening of the different Shinkansen corridors. The traffic reached more than 70 billion pkm/year in 2004.

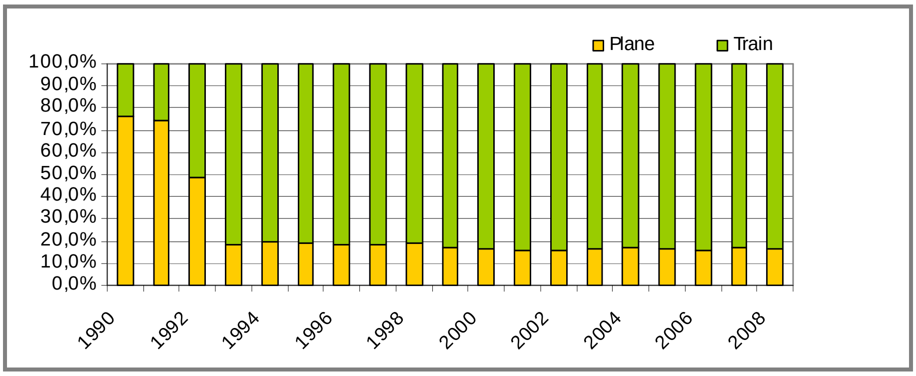
**Figure 27** Evolution of the traffic volumes (passenger kilometers)




**Source: Toshiji Takatsu, 2007**[37]

While up to the 1990's the Spanish rail network was experiencing great difficulties due to several decades of underinvestment, the introduction of HSR has boosted the rail sector. On some corridors such as the Madrid-Sevilla route, HSR is now the main transport mode. In fact, after the commissioning of the AVE in 1992, HSR has secured a 52% market share quite rapidly, beyond car (34%), air (4%), bus (8%) and conventional train (2%) (see Figure 28). By 2008 HSR accounted for over 80% of market share.

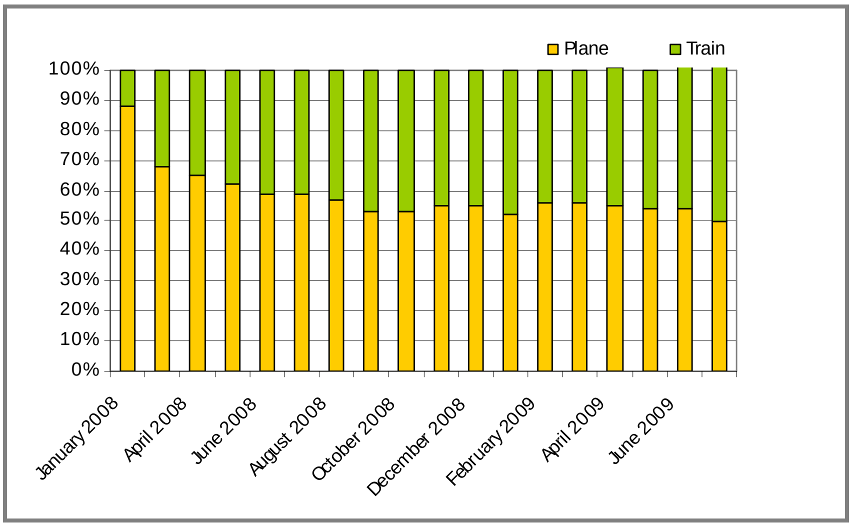
**Figure 28** Evolution of the rail/air market share on the AVE Madrid-Sevilla corridor




Source: Renfe, 2009[38]

When looking at specific corridors, we can state that only four months after its opening in February 2008, the AVE Madrid-Barcelona was carrying about 2.5 million passengers (see Figure 29) and its share of the market has grown to half.

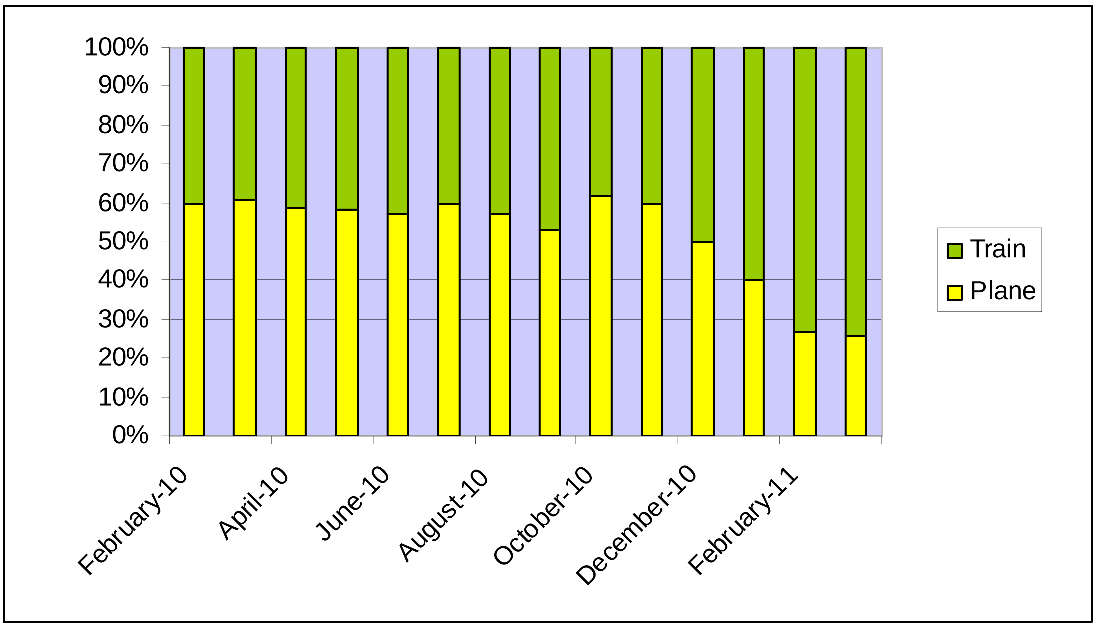
**Figure 29** Evolution of the rail/air market share on the AVE Madrid-Barcelona corridor




Source: Renfe, 2009[39]

The opening of the Madrid-Malaga HSR Corridor in 2007 has generated the same type of effects: an important reduction in the number of passengers transported by plane (-17.6% six months after the opening of the line). The most recently opened line between Madrid and Valencia shows how the rail/air market works with a very high degree of substitution of the flights by the new HSR services.

**Figure 30** Evolution of the rail/air market share on the AVE Madrid-Valencia corridor




Source: Renfe, 2011

### HIGH SPEED MAKES A BIG DIFFERENCE TO MARKET SHARE FOR RAIL

Although Bordeaux and Toulouse are about 1h10 from Paris by plane, the market shares are very different (see Figure 31).

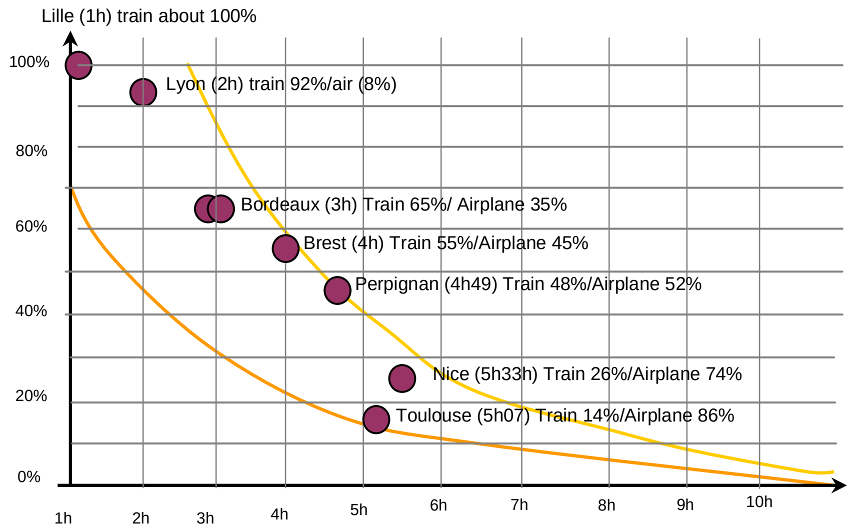
Train dominates the Paris-Bordeaux[jj] route while the plane has the main part in the modal split on the Paris-Toulouse connection. Moreover, to meet future mobility needs on these connections, French rail authorities are working on the extension of the HSR line between Tours and Bordeaux; the commissioning of the HSR should occur by the end of 2016. This will reduce the time travel to Bordeaux from 3 hours today to 2h05, and therefore will reduce the time travel to Toulouse to around 4 hours[kk] (currently it is more than 5 hours).

On the South East line, to/from Paris and Lyon, the rail market share was 73% in 1997 compared to 21% for the car (these market shares were 40% and 29% respectively in 1984, before the TGV Line).

The results of the South East HSR line linking Paris to Lyon (390 km as the crow flies) are very encouraging. Reducing travel time down to 3 hours between the two cities increased the rail market share from 40% to 73%, at the expense of planes and cars.[40]

[jj] High Speed benefit to the origin-destination for half of the travel
[kk] Source: SNCF

**Figure 31** Air/Train market share on several origin-destination




Source UIC, 2009[41] (Internal Data) HSR enhances sustainable combinations of transport modes

Sustainable combinations of transport modes regarding HSR means:

- Substitution of short haul flights and long-distance car travel
- Connections between long-distance trains and urban transport or intercontinental flights.

Private, and corporate, travellers usually want traffic systems allowing them to travel from door-to-door as easy and flexible as possible. Every transport mode has its advantages and HSR is an attractive and sustainable backbone for the whole transport system. Efficient co-operation between the different modes could lead to flexible, and more sustainable, door-to-door transport. HSR offers barrier-free, affordable networks providing entire travel chains to people of all ages and groups when it is integrated into the transport systems.

A combination of transport modes is a crucial element of sustainable transport systems. It is not possible to solve the mobility and transport challenges with single-mode parallel transport systems – intelligent combinations are needed for passenger transport with regard to local, regional and long distance (HSR) level.

Using 'combined' or 'intermodal' transport that links road, air and rail, GHG emissions can be reduced significantly as e.g. electric trains allow use of $CO_2$-free energy sources. Travellers in several countries can already make use of the multi-modal 'travel chain':

- Passengers can obtain door-to-door travel information on DB, SBB or ÖBB websites. On-line timetables include all modes of public transport and maps for those who prefer to walk the final section of their journey;
- Holders of the German 'BahnCard' can change from long-distance HSR trains to regional public transport at their final destination for no extra charge and without an additional ticket, since the 'City-Ticket' is automatically included;
- In Switzerland, hundreds of railway stations offer seamless transfer to carsharing. SBB's 'Halbtax-Abo' (half fare travelcard) and other public transport pass holders may use the nationwide car-sharing service at reduced fees.[ll]
- The ICE is the fastest means of transport on many domestic German connections. On lines from Cologne and Stuttgart to Frankfurt Airport, the ICE serves as a shuttle for Lufthansa passengers. The cooperation between the German Deutsche Bahn AG (DB) with AIRail helps avoid environmentally damaging short-haul flights because the plane ticket becomes a train ticket.[mm]
- HSR service combined with intercontinental flights is also a good example of how rail can substitute short distance flights within Europe and encourages co-modality.

[ll] UIC 2009, Railway and Environment
[mm] Sustainability Report DB AG 2009 http://www.deutschebahn.com/site/nachhaltigkeitsbericht__2009/en/our__products/passenger__transport/long__distance__transportation/long__distance__transportation.html

# 5 High Speed Rail is an attractive transport mode

More and more citizens around the world are concerned by environmental issues and responsible consumption, as the international polling institute GlobScan[nn] shows in various global surveys. Responsible consumption also includes transportation issues. While most consumers still base their travel decisions largely on price, value for money, service and availability, more and more people are taking environmental factors into account. [42]

In an internal study, the German Deutsche Bahn AG (DB) interviewed its business customers regarding their choice of transportation when planning business trips. Some 73% of respondents considered rail's environmental advantage to be "very important" to "somewhat important".[oo] With regard to future decisions, 58% believed a general shift of business travel onto rail to be "very likely" to "somewhat likely," with 41% of them putting the environmental friendliness of the train in one of the first five places as a reason for this shift. And around a quarter of business customers would no longer even use the train if it were to lose its environmental advantage.[pp]

Besides its eco-friendliness, rail, and particularly HSR, offers numerous advantages for its customers such as reliability, punctuality, comfort, time savings, access for all, the ability to work, direct travelling from city centre to city centre and last, but not least, personal safety (the latter was shown in the previous part of the study). These advantages, which will be the focus of the following chapters, make HSR an attractive transport mode; increase its utilization and therefore its role in a sustainable mobility system.

## 5.1 HSR increases quality and productive time

In today's hectic world quality time for oneself and chances to relax are precious for each individual. When travelling by rail, travellers gain time which they can use to do things they could not do if travelling by car or plane.

Regarding quality time as uninterrupted time – which is not reserved for transfer (using public transport/taxi/walking), waiting, security screenings or time when use of electronic equipment is not allowed – HSR has a significant advantage to air and car travel. The total of travel time is comparable between air and rail, yet time allocation is at the advantage of HSR because customers benefit from a less fragmented journey. Travel time on a train can be more productive due to fewer interruptions. Even when journey times are slightly longer than air travel, HSR still attracts customers, which is reflected in the high market shares it achieves. With HSR, time spent travelling is not wasted time. During travel one can mix business with pleasure: reading, playing, sleeping, and working, watching videos or the landscape. Some half of business rail journey time is used for working or studying[qq]; by comparison with other modes HSR journeys can be highly productive journeys.

In a car, both for passengers and driver, activities able to be carried out are more limited, firstly due to the space and secondly to safety reasons. On airplanes, check-in and -out procedures leave a smaller time slot. Time for constructive use is more fragmented. Although, on some HSR routes security screenings are developed, e.g. Madrid-Seville, Madrid-Barcelona or London-Paris/Brussels, they remain far less time consuming than air controls.

Depending on the location of the station HSR can be much quicker than other modes for example requiring shorter access time, fewer security checks and greater useable time on than fragmented journeys such as flying. An example is shown in the box below.

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[nn] The GlobScan institute is one of the world leaders in objective global survey research and follows the ecologic practices (amongst others transportation) of 17,000 consumers throughout 17 countries, among them Argentina, Australia, Brazil, Canada, China, France, Germany, Hungary, India, Japan, Mexico, Russia, South Korea, Spain, Sweden, United Kingdom, the United States.

[oo] Other factors also affect modal choice, including: value of time, interchange penalty etc but the emphasis given to environmental issues by business travellers is important.

[pp] http://www.deutschebahn.com/site/nachhaltigkeitsbericht__2009/en/our__customers/passenger__transport__customers/customer__needs/customer__needs.html

[qq] The use of travel time by rail passengers in Great Britain, Lyons. G., Jain. J., Holley. D., 2007,Transportation Research Part A 41 () 107–120

**Example – Frankfurt (Main) to Paris Est**

For the trip Frankfurt to Paris the following comparison is made for the journey by car, plane and rail using Ecopassenger.org[rr]:

- **Car:** Total journey time = 5h03. Estimated disposable time for work or rest = 0h00 (when driving yourself). Share of usable time compared to total journey time = 0%.
- **Plane:** Total journey time* = 3h00. Estimated usable time for work or rest = 1h00. This estimate is based on a minimum uninterrupted disposable period of 30 minutes. This depends strongly on personal preferences for uninterrupted usable time. Some people might prefer (or are under pressure) to work, even in short sections of 5-10 minutes at a time. Perhaps talking on the mobile, reading or taking notes without electronic devices could enlarge the usable time during the journey. The share of usable time compared to total journey time = 35%.
- **HSR:** Total journey time = 3h49. Estimated usable time for work or rest: 3h49. The time to find a seat and checking tickets is not subtracted from the total as this takes place before or is insignificant. Share of usable time compared to total journey time = 100%. This figure only takes in to account travel time and does not assess the access to the train station. This time is dependent on starting distance from the train station and ease of access. This time could reduce the amount of useable time although once on HSR useable time is still optimal.

* including feeder services by rail or car, NOT including the different journey components like check-in, security check, boarding, baggage retrieval. Thus the less interrupted nature of HSR journeys is likely to facilitate improved productivity for business travellers and a less stressful journey for both business and leisure travellers.

## 5.2 HSR provides reliable and comfort mobility

In business and private life people need reliability to plan their time effectively. A reliable railway is one of the most important requirements of passengers. Travelling by rail supports this goal by being more reliable than other transport modes. Improved reliability can also help increase capacity. More services can be run on a given line if all trains run precisely to their allotted timetables. This will be facilitated by new radio-based signalling technology, which has the additional benefit of reducing the disruption caused by maintenance works on the infrastructure. Passenger expectations of reliability are likely to increase as personal incomes grow and people value their time higher. HSR is ready for a future in which people are less tolerant of delays and unproductive use of their time and place more importance on the end-to-end journey, interchange at stations, ease of ticket purchase and the quality of "on the spot" real-time information.

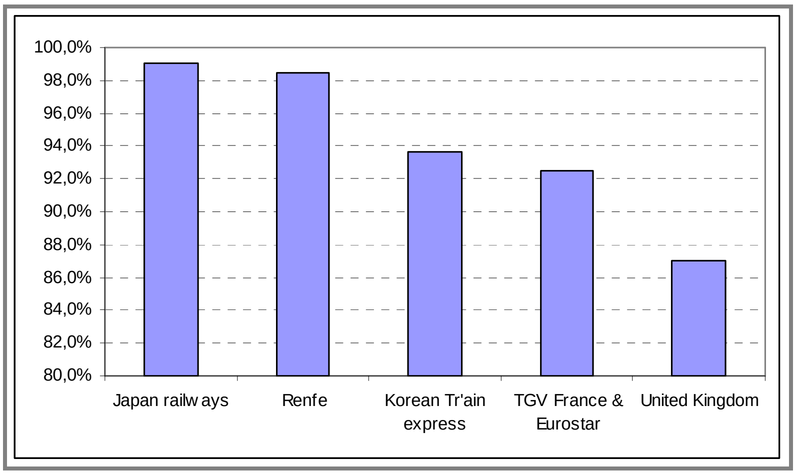
### HSR IS A RELIABLE MEANS OF TRANSPORT

According to UIC punctuality is defined as percentage of trains arriving on time or within 5 minutes from schedule. The punctuality rate of several HSR companies throughout the world shows a very high quality level of service as shown in

Figure 32 below.

[rr] www.ecopassenger.org. Journey times are for a mid week off peak journey and may vary during peak hours

**Figure 32** Punctuality worlds ranking of HSR[ss] trains




Source: Renfe, 2009[43]

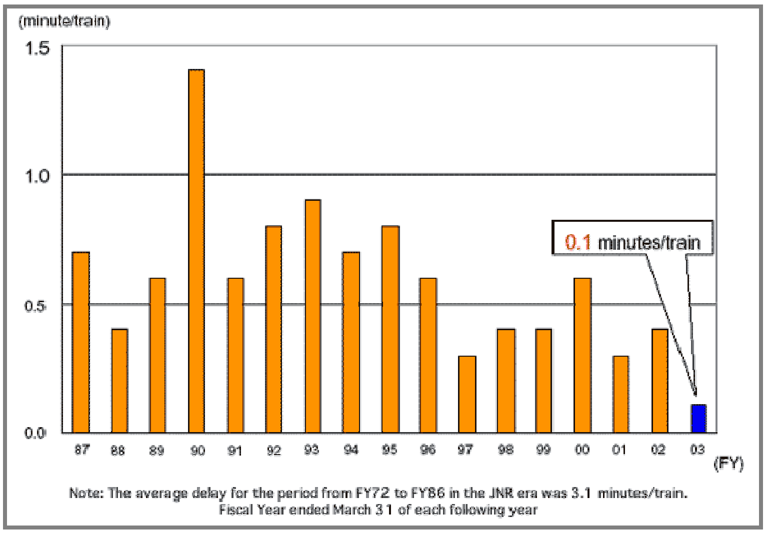
Just like cars or planes, trains also have to cope with delays - for a variety of reasons. Despite all efforts, disruptions to rail operations are not always avoidable, such as those resulting from adverse weather conditions and technical problems. In many cases, a delayed train can still make up for lost time on its way, but sometimes this is impossible. See Figure 33 for an example from Japan of how delays can be managed.

[ss] The UK figure includes conventional rail journeys.

**Good Practice Example – Japan's almost always punctual network**

In 2004, the Central Japan Railway Company (JR Central) has set an average delay[tt] of only 0.1 minute per train. The company has led a real policy of delay reduction since its creation in 1987 in order to meet this figure. Before, during the period running from 1972 and 1986, the average delay was of 3.1 minute per train[uu].

**Figure 33** Average delay for the Tokaido Shinkansen for the period 1987-2003




Source: [Central Japan railway Company](), 2009[44]

The main measures set up in order to cut down for example the delays due to bad weather conditions were:

- Improving civil engineering facilities (embankments, cuttings, etc.), which results in relaxing the operation restrictions during rainfall
- Improving snow-removing works for rolling stock, such as the installation of sprinklers and snow detectors on the ground, the use of rotary brushing snow blowers, and the increase in the number of staff for undertaking the work at stations
- Improving skills through simulation training in the operation control room that manages the occurrence of train delays
- Achieving the common utilization of rolling stock by replacing all Shinkansen rolling stock with Series 300 and Series 700; both of which have standardized operating performance (a top speed of 270 km/h) and seating layout for a 16-car train set.

**Good Practice Example – Madrid-Seville Renfe Punctuality Commitment**

Renfe have kept up punctuality levels over 98% in the last years, recording a top rate of 99.6% in 2006. These numbers represent the quality of a service characterized by the Punctuality Commitment that was established in September 1994. The obligation that Renfe undertook for Ave passengers on that date is unprecedented in any railway company worldwide and even in other modes of transport: if a train arrives at its destination more than five minutes late, the passenger is refunded the full ticket price, in cash, as long as the cause of the delay can be attributed to Renfe. Out of the 14,044 trains that provided a service between Madrid and Seville in 2006, just 56, i.e. 0.3%, arrived more than five minutes late. These punctuality levels have allowed Renfe to guarantee competitive travel times that have turned the AVE into a first-rate transport method of the corridor.

[tt] Average of all late departures and arrivals of one minute or more from/to Tokyo and Shin-Osaka stations, including delays caused by natural disasters such as heavy rain, typhoons, and heavy snowfall
[uu] http://english.jr-central.co.jp/news/n20040408/index.html, viewed the 29/10/2009 keep it in French

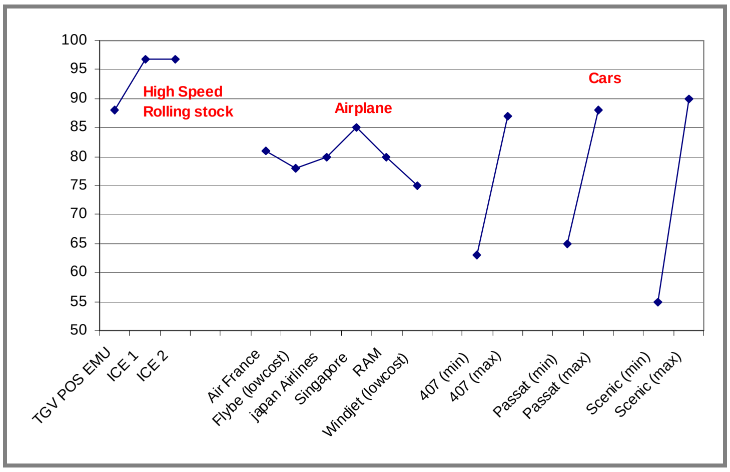
Trains, and especially HSR, provide comfort for the passenger which is not always available on other modes. For example, booked seats give each passenger their own space and the limited number of stops compared to conventional train travel mean that passenger turnover is low and journeys are less interrupted. Space to walk around in the train also enhances the quality of travel in comparison to other modes.

The following five indicators can be taken into account for intermodal comparisons:

- Distance between seats[vv] (see Figure 34)
- Mobility within coaches (see Figure 35)
- Services on board
- Potential impacts on health during travel time
- Exposure to noise disturbances onboard.

As shown in the Figure 35 below, HSR provides the best conditions concerning the "distance between seats". Besides, it is necessary to note that distances for HSR rolling stock are fixed whereas they are variable for cars and rarely reach the maximum desirable measures.

**Figure 34** Distance between seats – a multimodal comparison




Source: Air Valid[45]

**Figure 35** Interior of the Spanish AVE 100R

Source: Renfe 2010 [ww]

[vv] Comparison established on the basis of constructor data (Passat VW, Peugeot 407), TGV Duplex and several Airline companies
[ww] HSR Summit: Global Insights on High-Speed Rail, Capturing the Value of High-Speed Rail

**Mobility within coaches** is also an important indicator of comfort. When comparing air, car and high speed, HSR rolling stock characteristics enable the most mobility. During HSR journeys it is not necessary to fasten any seat belt, unlike for plane and car trips. Thus, HSR users benefit from more freedom of movement and can easily go from one coach to another without hindrance. On airplanes, this mobility is largely hindered, first during the take-off and landing phases, on board service and air turbulence. Within a car, this mobility is completely hindered.

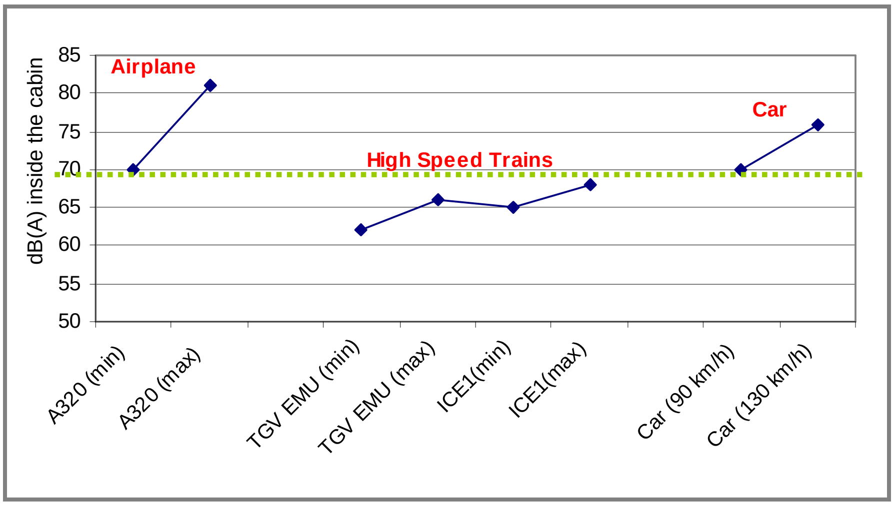
When **onboard services** are considered, the comparison is slightly more balanced. Indeed, all constructors and operators in case of HSR and air transportation have developed new possibilities for on-board services. Thus, the possibilities of service are different for each mode and for each commercial profile. In cars, as an individual mode, services are limited to car options, such as GPS or on-board video. For HSR and air transportation on-board services are both facilitated by construction options and commercial offers:

- Access to the Internet is now spreading especially on HSR trains (e.g. Thalys). For airplanes, access to the Internet is possible but still with the same constraints linked to the take-off and landing phases.
- Catering (requiring payment on HSR trains and low cost air flights, but free on regular airplanes)
- Video on board (only on medium and long distance flights, some HSR companies are proposing such a service as an option).

Once more, HSR proves to be the best on the indicator "**Potential impacts on health**". Impacts on health can be significant on airplanes due to stress, possible injuries due to air turbulence, and side effects due to the modification of the barometric pressure and lack of personal movement (e.g. deep vein thrombosis). By contrast the impacts on health are very limited on HSR trains. For cars, the main side effects and inconvenience is due to the lack of personal movement.

When considering "**noise disturbances on-board**" HSR also offers an advantage as shown in Figure 36 below. Minimum measures of on-board noise in airplanes and cars at a comparable speed are above the maximum noise measured in HSR trains.

**Figure 36** Noise measures onboard – a multimodal comparison

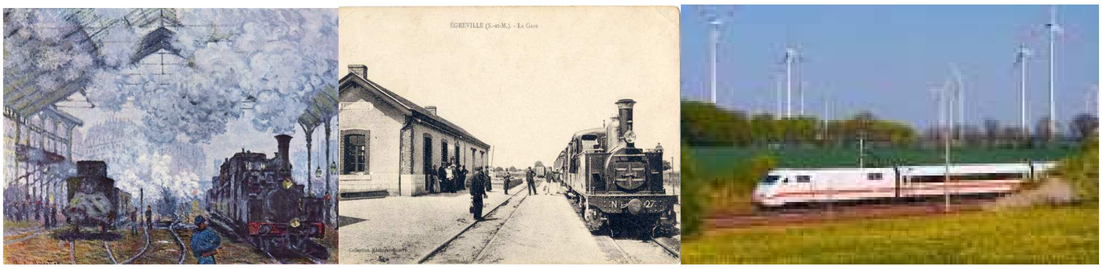



Source: SYSTRA, 2006[46]

## 5.3 HSR improves access to mobility

A short look into history shows that the introduction of mechanical modes of transportation has completely changed the relation of humans to their environment and territory (see Figure 37).

**Figure 37** Railways at the end of the 19th, beginning of the 20th century and today

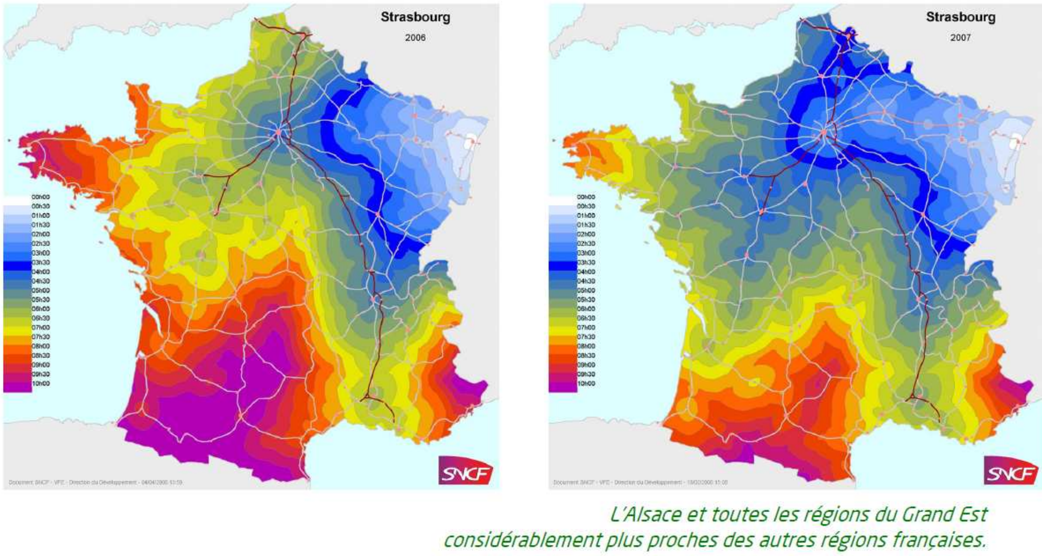


Source: MONET Claude, La Gare Saint-Lazare, 1877; Une machine à vapeur, Gare d'Egreville, Paris, 1936, ICE xxx

### HSR CONNECTS CITIES AND PEOPLE AND IMPROVES ACCESSIBILITY

HSR enables links between the main political and economic centres and facilitates exchange. HSR networks open up new opportunities for interoperability and interconnectivity. HSR strengthens the transportation system and improves related infrastructures. The entire organization of other, related, transport networks is modernized, updated and has higher efficiency. A good example is in France, where the arrival of TGV East has been anticipated and accompanied by a reorganization of the regional train services. The regional train supply has been augmented up to +17% in the concerned regions (630 trains a day for weekdays, previously 550) to "diffuse" the effect of the TGV. The introduction of TGV considerably improved the accessibility of the Alsace Region to the rest of France as shown in Figure 38 below.

**Figure 38** Accessibility changed in France from the TGV




Source: SNCF[47]

In Spain the improvement in accessibility according to the national infrastructure master plan[xx] will provide the following results: In 2009 40% of the population has a HSR station within a 50 km radius; in 2012 it will be 55% and in 2030 90%.

When HSR is associated with the reinforcement of regional conventional rail services, the effect of it is then spread more thoroughly, through a diffusion of time travel savings. The creation of transport hubs and the improvement of rail connections with other transport modes, for example air travel, are vital for its efficiency. Several aspects are to be considered here: integrated pricing, through booking, physical integration (e.g hubs), information (e.g ITS), etc.

To support such forms of urban dynamics, HSR should not be developed at the expense of the existing transport services but in addition to improvements to the local, regional and conventional inter-city networks: well connected multimodal transport systems need to be offered. International (air transport and HSR), national (heavy rail and highways) and

[xx] Source: Spanish Strategic Infrastructure and Transport Plan 2005-2020

regional/local (light rail, car and public transport) transport networks should offer interconnectivity. The North European HSR Network is a good example as being the most developed network of HSR connections in Europe, linking Paris, Brussels, Köln, Amsterdam and London, with direct onward linkages to Frankfurt and via the Paris Centre to the rest of the French TGV network. More than 200 train stations benefit directly from HSR with TGV trains connecting them directly.[yy]

In late 2005 a joint venture between Eurostar and Thalys was established to further the aim of modal shift by through booking and easier connections. This was joined in 2006 by various national rail companies and the Dutch High Speed Alliance (operator of the HSL Zuid) with the aim of delivering more seamless high speed travel over a wide area of Northern Europe.

### HSR OFFERS EASY ACCESS TO MOBILITY

Mobility is essential for participating actively in life. HSR enables people to travel independently and offers them a wide range of services, e.g. for elderly people or for those with disabilities/ with reduced mobility?. Along with interconnections with other public modes HSR enables maximum autonomy for everyone. By comparison, travelling by plane generally requires systematic human intervention several times during the trip. Travelling by car requires the possession of a vehicle and driver's license or at least of someone able to drive.

Easy access to mobility can be divided into three main parts:

- Access to **travel information**, tickets and other services before, during and after travel
- **Physical access** to stations linking to other transport modes (by foot, bike, public transport, car or plane) with emphasis on the qualities of barrier free travel directly to and from work, leisure activities, holidays, as well as between city centres etc.
- **Services** for dedicated groups with special needs, e.g. business people, commuters, students, children/families, elderly people, the disabled/ with reduced mobility?.

There will be a significant increase in pressure to make the transport system more accessible to those with mobility impairments, both as a result of changing attitudes to disability and as a result of the ageing population. For instance, around one in ten of the UK working population is estimated to have a disability, a figure typical for many other European countries. Although age is not a perfect predictor of mobility problems, on average mobility problems increase with age as a result of declining levels of physical function.[zz]

Physical accessibility is facilitated today by programs e.g. "Acces plus" launched by the French SNCF for people with disabilities or the German DB's program "barrier-free travel". These programs not only mean installing elevators, moving stairways or tactile guidance systems (see Figure 39). It is also about offering assistance e.g. when entering the train or being in dialogue with institutions, e. g. disability organizations. In 2009 Renfe and Adif, extended the coverage of customer care services to disabled persons, called Atendo, to more than 240 stations. During the year, assistance was provided on 235,571 occasions, an increase of 109.2% compared to the previous year.

**Figure 39** Disabled person entering a train

Source: Dan Pepion SYSTRA, 2008

[yy] http://multimedia.sncf.com/30anstgv/dp_versionpdf.pdf , page 22
zz International Transport Forum 2010, Urban Transport and Mobility → Systra

The ageing of the population in industrialized countries is a big challenge for mobility providers and will have non-negligible consequences in terms of mobility. In Europe, the proportion of people aged 65 or more will increase from 17% in 2008 to 30% in 2060, with those aged 80 and over rising from 4.4% to 12.1% over the same period[aaa]. In Japan, the proportion of people over 65 years old was 19.73% in 2005 and this could increase to 40.5% by 2055 in a business-as-usual scenario. The so called “silver generation”, or over-50s, is an important target group for HSR as they are very comfort oriented. HSR, with its advantages in comfort, offers a very good choice of travelling.

Offering mobility for everyone also means offering fair ticket prices. Any comparison of prices is very dependent on the context as regulation, taxes, pricing management and other influencing factors that can change according to the country and the companies involved. Nevertheless, HSR can compete, or even be cheaper than travelling as one single person by car. With more than one passenger the results are more uncertain depending on the level of charging. If trips involve more people, the road transport advantage becomes more significant. Nevertheless, it can be noted that the costs of using cars has risen significantly over the past decades and will increase in the future (due to increases in oil prices, the introduction of road charges, etc.).

HSR is, in many cases, less expensive than air transport according to several examples in France, South Korea and Japan. Nevertheless low cost airline companies can compete with HSR in terms of fares by proposing “loss-leader”[bbb] prices. These loss-leader prices do not reflect the average cost that is perceived by passengers. As “yield management”[ccc] is used both by air and railway companies, the calculation of average prices has become very difficult. Ranges of prices reveal air transport fares are more variable and can be higher, even for a low cost company.

**Example – Frankfurt (Main) to Paris Est[ddd]**

| | **Rail** | **Car** |
|---|---|---|
| Duration | 03:49h | 05:03h |
| Fare/Distance | 106,00 EUR (incl. Res.) | approx. 132 EUR, 573 km*<br>approx. 332 EUR, 573 km** |

* Variable costs calculated for middle class (Mileage: Ø 15.000 km per annum) with 23 CENT%? per km - simple route (ADAC[eee]).

** Full costs calculated for middle class (Mileage: Ø 15.000 km per annum) with 58 CENT %? per km - simple route (ADAC).

aaa EUROSTAT 2008 http://epp.eurostat.ec.europa.eu

bbb Loss-leaders are goods or services offered at steep discounts in order to attract new customers

ccc Yield management is the process of understanding, anticipating and influencing consumer behavior in order to maximize yield or profits from a fixed or perishable resource such as tickets.

ddd Mobility Check by Deutsche Bahn, http://www.bahn.de/i/view/DEU/en/services/overview/environmental-mobility-check.shtml

eee The car cost calculation is based on ADAC data, The ADAC has calculated the average total cost per car kilometre. Almost all car models available in Germany were considered in the process. One can even adjust these individually to match its data.

# 6 High Speed Rail contributes to sustainable economic development

Wealth and development have for long been reduced only to the GDP indicator. Social welfare or environmental aspects didn't play a role. But things are changing; the United Nations Development Program (UNDP) has introduced the Human Development Index (HDI) in order to take into account larger criteria such as education, health and life expectancy or standard of living. Also Joseph Stiglitz, the 2001 Nobel Prize winner in economics, has recently highlighted the necessity of taking into account extra criteria reflecting individual well-being and social welfare. In economic calculations the so-called externalities (costs or benefits that are not transmitted through prices) become more important. In the case of Europe there exists a strategy for revitalizing the railways as a means of encouraging modal shift against the current dominance of road transport. This is justified in terms of the lower external costs of rail transport when compared to road transport with respect to congestion, safety and pollution.

Sustainable economic development requires a stable and healthy economy but also a healthy environment and social welfare. The benefits HSR brings to society, the environment as well as individuals were widely illustrated in chapters 3 and 4. Moreover HSR contributes to sustainable economic development by improving inter-regional connectivity, labour mobility, business efficiency and local attractiveness. Certainly, investments in the transport system support the economy in general; however, HSR supports a more efficient economic system thanks to lower external costs compared to its competitors.

## 6.1 HSR provides macro economic advantages despite its high investment costs

HSR provides numerous benefits for the environment, society as well as individuals as shown in the previous chapters. Yet, there is a financial counterpart in terms of the high investment cost (i.e. construction, maintenance and operation). However, this should be seen in a positive relation to the numerous advantages of HSR.

Building new HSR infrastructure involves three major types of costs:

- Planning and land costs (e.g. feasibility studies, technical design, land acquisition etc.)
- Infrastructure construction costs (e.g. terrain preparation and platform building)
- Superstructure costs (e.g. tracks and sidings along the line, signalling systems, catenary and electrification mechanisms, communications and safety installations).

The **infrastructure construction costs** are the most important costs for a HSR project. A deeper analysis of HSR experiences over the world reveals that they are extremely variable depending on many factors such as:

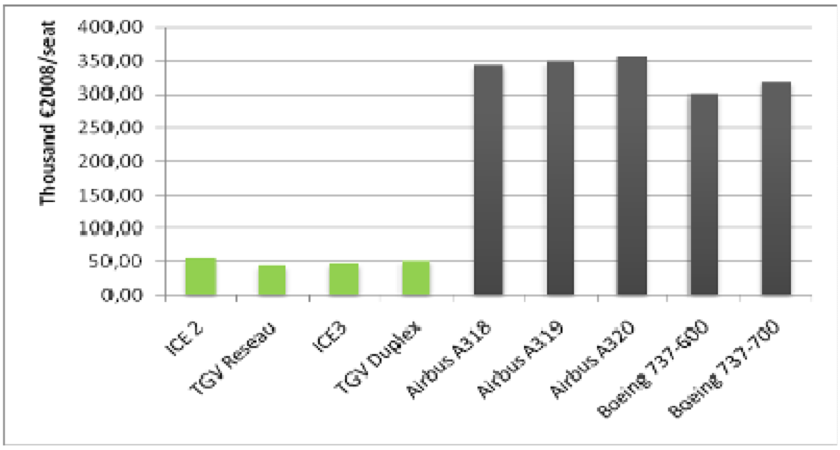
- Radius of sharpest bends that influence the maximum speed
- Geographic obstacles (need of singular solutions such as viaducts, bridges or tunnels)
- Length of route
- Number of stations to construct, and so on.

The costs of building HSR lines do vary from country to country. Where lines are built in densely populated areas it tends to be more expensive. In addition construction procedures are often different. Therefore caution must be used when comparing construction costs between countries.

Furthermore, HSR seems to have higher average construction costs than motorways. This can be explained by the higher costs of equipment for railways and the more relevant constraint of gradients that leads to more civil engineering structures. Nevertheless, many constraints for HSR lines can also be applied to motorways which partly explain why the costs of both are increasing over time.

**Construction of rolling stock** represents a further significant part of the total investment costs. Differences in HSR development across the world led to differences in technologies used for the rolling stock in terms of length, composition, mass, weight, power traction, tilting features, etc. The cost for the rolling stock can vary according to these characteristics. However, a comparison reveals higher investment costs for the acquisition of planes. Estimated costs per seat for an Airbus A320 are more than 6 times higher than for a TGV (see Figure 40). It must be noted that HSR trains as well as planes have to be replaced or retrofitted. Retrofitting can have an important impact on the lifespan of rolling stock. The expected lifespan for HSR trains or planes generally lasts from 30 to 40 years (without retrofitting).

**Figure 40** Comparison between HSR trains and airplanes regarding construction of rolling stock



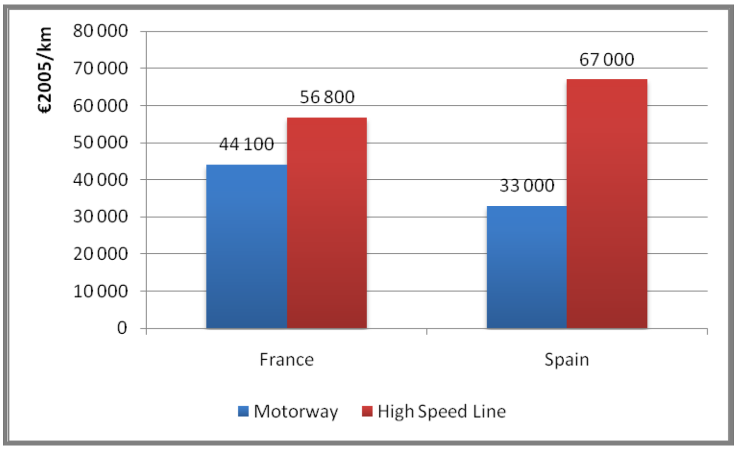

Source: Fundacion BBVA, 2009[48fff] / UIC / calculation by Systra

Once the infrastructure and the rolling stock for HSR have been constructed, their **operation and maintenance** still represent an important expense (see Figure 41). They can be divided into four main categories:[49]

- Shunting and train operations (mainly labour costs)
- Maintenance of rolling stock and equipment
- Maintenance of infrastructure
- Energy
- Sales and administration.

Total operating costs depend on the operator's practices, the technology that is used as well as the local context and traffic levels. Figure 41 gives an assessment of operating and maintenance costs in France and Spain in a comparison with motorways' operating costs.

**Figure 41** Infrastructure operating and maintenance costs in France and Spain




Source: CGPC, 2006[50], Fundacion BBVA, 2009[51]

Both, rail infrastructure as well as motorway infrastructure depends on government investment and public funding. As investments, and particularly investments using public funds, they should always be sustainable; construction and operation costs should not be the only costs

[fff] For planes, catalogue prices are given by the constructors. For this calculation prices for Airbus and Boing were used, URL: http://www.airbus.com/store/mm_repository/pdf/att00011726/media_object_file_ListPrices2008.pdf

considered in the decision-making processes, as explained in chapter 6.2 regarding external costs.

## 6.2 Rail and HSR has lower external costs than competitive modes

External costs related to transport are costs generated by transport users and not paid by them but by society as a whole, such as congestion, air pollution, climate change, accidents, noise but also costs for nature and landscape damage. For a long time, external effects, related to the impact of economic development on the environment and society in general, have been neglected. For instance, the price for energy from non-renewable resources hasn't reflected the drain on these sources (see Figure 42). Likewise congestion which generates delays that have an effect on economic activity is also ignored. Moreover the negative impacts of economic activities such as the pollution of soils and air are still not totally mitigated. A real and generalized internalization of external costs is therefore crucial.

**Figure 42** Who is paying for external costs?

| Costs Categories | Who's paying | |
|---|---|---|
| | Transport users | Non transport users |
| **Climate Change:**<br>• **Natural hazard**<br>• **Reduced harvest** | Users do not pay | • Insurance (covered people)<br>• Public authorities Individuals<br>• Future generations |
| **Air Pollution:**<br>• **Human health**<br>• **Animals health** | Users do not pay | • Insurance (covered people)<br>• Public authorities Individuals |
| **Accidents:**<br>• **Body Injuries**<br>• **damages** | Partially, through insurance | • Insurance (covered people)<br>• Public authorities<br>• Individuals |
| **Congestion:**<br>• **Stress**<br>• **Decrease in productivity** | Partially, through decrease in productivity | • Companies<br>• Individuals<br>• Health Insurance (covered people) |
| **Noise:**<br>• **Stress** | Users do not pay | • Individuals<br>• Health Insurance (covered people) |

Source: CER, 2008[52]

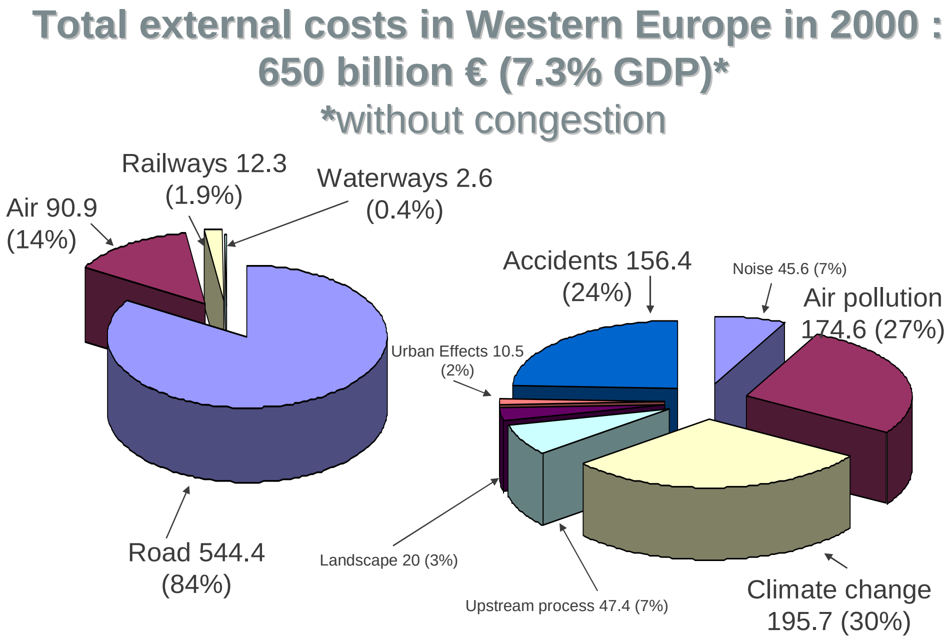
Indeed, markets are not able to include all economic effects in contracts which imply that they do not really reflect the real costs or benefits related to the production or consumption of goods and services. In particular transport causes many effects on society that are not reflected in the market price so users make their transport choice using a misleading price signal; this is a market failure.

As transport and mobility provide an important stimulus to the economy an important issue is to know whether it is relevant to "internalise" external costs, or not, and how to implement this since the assessment of externalities seems difficult to establish. A first approach to answer this question is to look at the amount of those external costs to the economy.

In order to make an assessment of the external effects of transport, costs have to be defined. Calculations of costs have been underestimated most of the time, reflecting relatively timid political approaches. Thus it is important to note that those costs could increase with raising public awareness.

A study carried out in 2004 by INFRAS/IWW[ggg] showed that total externalities cost €650 billion (for 2000) to society in EU15 (plus Norway and Switzerland), representing about 7.3% of its GDP excluding congestion, and about 10% including it. Road transport is responsible for most of this cost (84%), followed by air transport (14%) and rail transport with less than 2% of total external costs. Thus, it would be unfair to continue letting society as a whole assume the responsibility of those costs (see Figure 43).

**Figure 43** Total external effects of transport




Source: UIC 2000[53]

It is necessary to internalise external costs and include them in transport prices and achieve a level playing field between the different modes. Reasoning based on economic efficiency leads to similar conclusions. Indeed, externalities cause major market distortions. If activities that generate negative external effects do not support all the costs they generate, they will be prone to produce more and more and those that bear those costs would be penalized and limited, leading to inefficient resource allocation. In other words, social benefits from additional activity generated by transport activities will not compensate for the cost it represents to society which will hamper the development of other activities.

### RAIL IS EFFICIENT IN TERMS OF ECONOMY

Results from the INFRAS/IWW (2004) study show that rail transport represents the lowest average external cost per pkm for the economy (environmental and safety costs, except congestion costs) (see Figure 44). These figures cover all rail journeys, including HSR, as there is no data currently available which distinguishes between different types trains.

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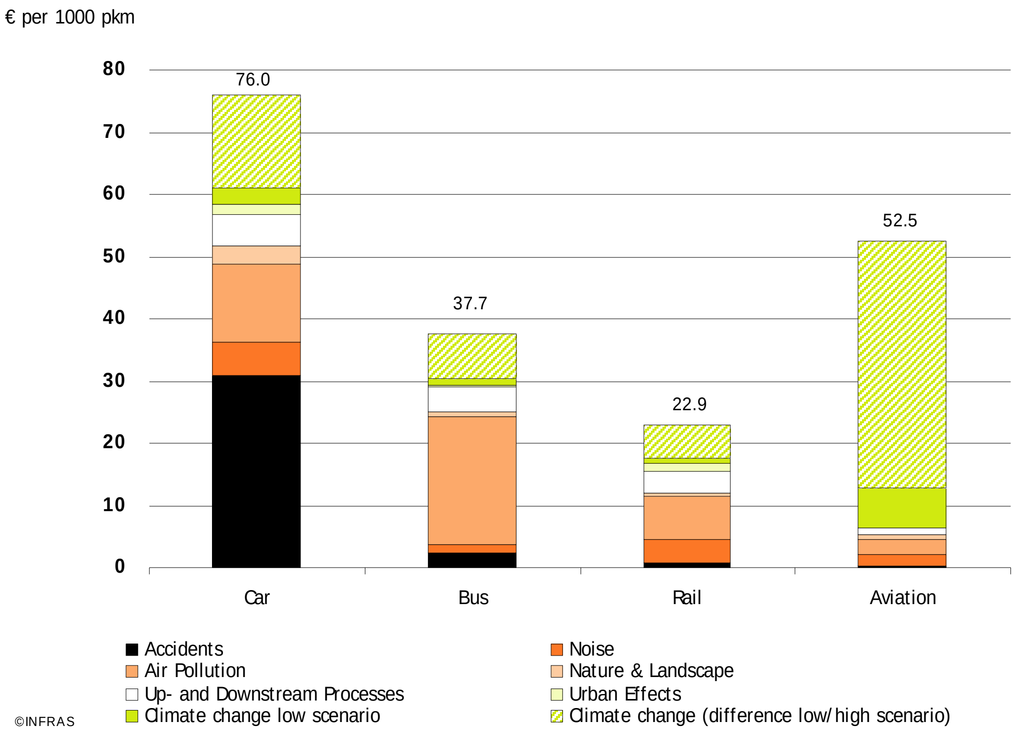
[ggg] The study carried out by INFRAS/IWW assesses external costs of transports in Europe (UE 17) by mode of transportation and by category of costs. It refers to rail in general, but not specially to High Speed Rail.

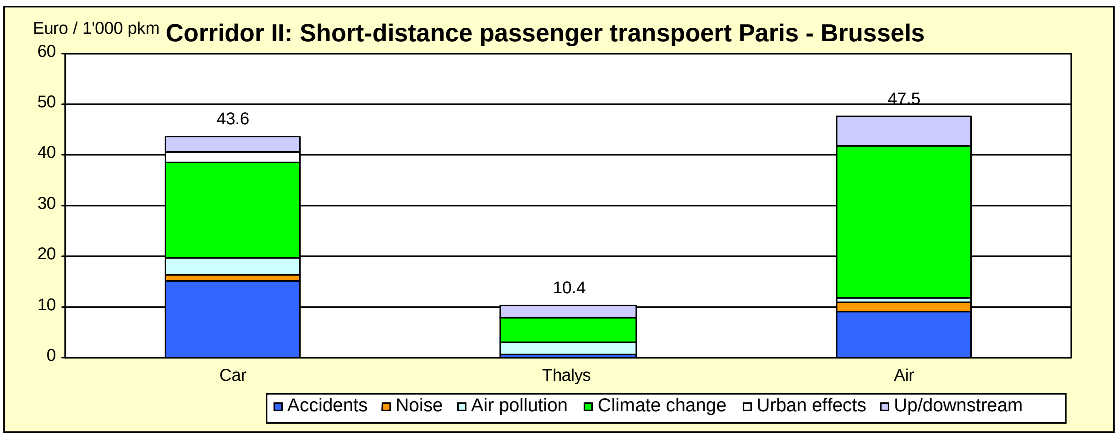
**Figure 44** Average external costs: passenger transport 2000 (excluding congestion)[hhh]




Source: INFRAS/IWW, 2004[54]

An earlier study (IWW/INFRAS 2000) showed that the external costs of HSR services between Brussels and Paris only represent ¼ of air and road transport. The external costs for 1,000 pkm on this line are equivalent to €10.4 while it reaches €43.6 for road transport and €47.5 for air transport. It is crucial to note though that these costs are very closely linked to load factors. (see Figure 45 Marginal costs in Euro per Pkm IWW/INFRAS 2000 )

**Figure 45 Marginal costs in Euro per Pkm IWW/INFRAS 2000**




Source: IWW/INFRAS, 2000 [53]

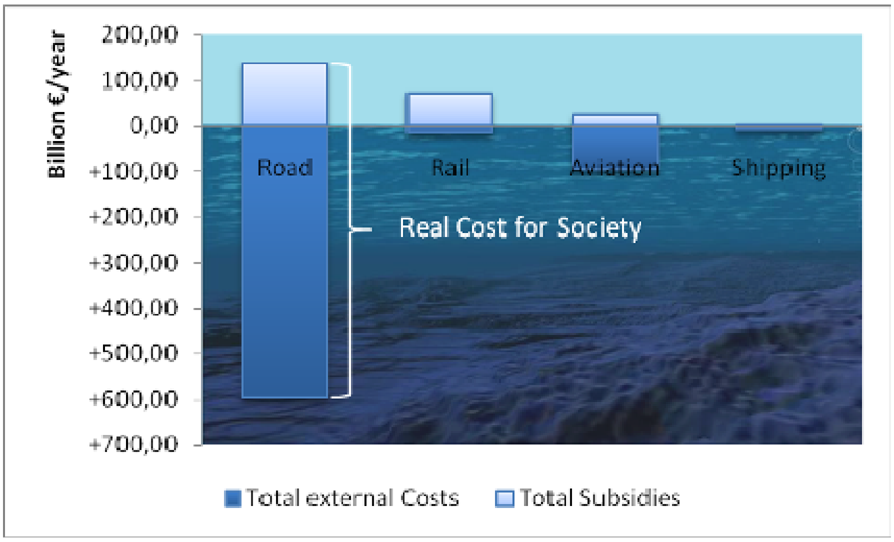
According to the European Environmental Agency (EEA), external costs exceed the amount of subsidies[iii] for the main transportation systems[jjj]. This is particularly true for road transport.

[hhh] The high value of climate change costs in aviation is due to the higher global warming effect of aviation's $CO_2$ emissions at high altitude during flight (factor 2.5 used compared to the impact of $CO_2$ emissions on the earth surface, based on IPCC.

[iii] According to EEA: "The numbers for subsidies comprise on-budget subsidies, annual public funding of infrastructure and exemptions from or reductions to fuel tax and VAT. The numbers for external costs include costs of accidents,

Moreover, it is important to note that the external costs of rail transport are less than its subsidies – contrary to other modes. Subsidies introduce distortions into the transportation market and lead to sub-optimal decisions based on limited knowledge regarding the impact of actions on the environment and welfare for the society. Hence there is a need to internalise costs (see Figure 46).

**Figure 46** Subsidies and external costs in the EU-15




Source: EEA, 2007[55]

Policies to internalise externalities already exist in some cases. One of the most famous examples is given by congestion charge experiences in some cities, for example in London, to limit congestion and pollution. Nevertheless, these schemes are currently very limited and road transport is still the transportation mode that least internalises its externalities. The "polluter pays principle" has proved to be very difficult to set up for road transport which matters as road is the most important contributor to external costs. By contrast, the rail sector, with 80% of traffic with electric traction, internalises many costs associated with electricity since it is fully integrated into the EU emissions trading scheme (ETS). Air transport will be integrated into the ETS in 2011-2012.

Thus, the rail sector represents the most "legible" cost for society since most of it is represented by public spending and the internalisation of external costs is largely applied. On the contrary, road transport generates huge "shadow costs" that largely exceed public spending for the mode.

Considering those facts, public spending for transportation systems should be re-distributed according to the real costs to society. In addition, internalizing costs should enable all economic agents to create incentives for choosing the most sustainable transport mode.

## 6.3 HSR contributes to local development

Different studies have proved that positive impacts on local development were to be expected from HSR projects, even if these impacts are sometimes difficult to isolate and quantify. HSR appears to be a real accelerator of beneficial trends. The positive impacts on local economies are diverse, dealing with employment, tourism, congress and business activities as well as synergies with other transportation networks.

Bringing along an image of modernity and state of the art technology, HSR constitutes a great asset for urban marketing. Indeed, becoming part of the HSR network enables metropolitan areas to be associated with state-of-the-art technology and are therefore attractive for people in the metropolitan area and, as well, for the area to get well-positioned against international competition for investments. HSR contributes to the image of a development vision and

noise, air pollution, climate change, nature and landscape, up- and downstream processes and additional urban costs."

[iii] http://www.eea.europa.eu/data-and-maps/indicators/external-costs-of-transport-3

represents the opportunity to gather social and institutional support, necessary to the success of urban projects.[56]

In Japan for instance, interesting effects have been observed since the launch of the first bullet train in 1964. Population growth was recorded in cities served by a station compared to other, unserved, cities near the track and compared to the national average. More interestingly, Shinkansen seems to have had important economic effects on cities as shown in the following tables (Figure 47 and Figure 48). Cities with Shinkansen stations have experienced significant economic growth compared to cities without[kkk]. It is also interesting to note that Shinkansen seems to have a substantial impact on growth as a comparison with cities only served by motorways.

**Figure 47** Comparison of cities with and without Shinkansen railway stations - 10 years before and 10 years after the opening of the Shinkansen

| Sector | Annual growth percentage before opening Shinkansen | | Annual growth percentage after opening Shinkansen | |
|---|---|---|---|---|
| | Cities with a station | Cities without a station | Cities with a station | Cities without a station |
| Wholesale | 12,9% | 20,8% | 11,6% | 8,7% |
| Retail | 10,1% | 13,5% | 10,0% | 8,6% |
| Industry | 13,7% | 14,2% | 9,5% | 7,8% |
| Construction | 13,8% | 14,9% | 8,0% | 6,4% |
| Population | 2,7% | 3,4% | 1,9% | 1,6% |

Source: Brian D. Sands 1993[57]

**Figure 48** Information exchange industries employment growth in regions with population increase. 1981-1985

| | Shinkansen & expressway (%) | Expressway only (%) |
|---|---|---|
| Business services (total) | 42 | 12 |
| Information, investigation and advertising services | 125 | 63 |
| R&D and higher education | 27 | 21 |
| Political institutes | 20 | 11 |
| Other | 57 | 28 |
| Banking services | 27 | 28 |
| | 21 | 3 |
| **Average** | **22** | **7** |

Source: Nakamura and Ueda (1989) and Hayes (1997)

It seems that the Shinkansen benefited remote areas to a very limited extent, as most of the activity remained in large agglomerations. In this sense, medium-sized cities that benefited from Shinkansen, such as Kakegawa City (72,000 inhabitants), were under the influence of major centres like Tokyo or Osaka. [58]

In 1987 France, Belgium, Holland and Germany decided to jointly develop the TGV network. As initially planned, the Paris-Brussels TGV line would have bypassed Lille, but local authorities considered an inner-city TGV station would stimulate the regeneration of the old industrial and economic capital; the Euralille project evolved from this decision.

Euralille today is a multi-functional complex close to the HSR station combining housing, green spaces, public facilities and leisure such as shopping and conference centres, accommodation for business people, a business school, research centre, concert halls, cultural centre, the Architecture and Urban Development centre, as well as day-care centres and nurseries (see Figure 49).[59]

[kkk] Decrease in growth after the opening is due to the severe economic downturn that occurred in Japan at that time.

**Figure 49** The Euralille business centre


Source: Wikipedia (2009) [72]

Euralille is also a powerful centre of exchange with major French, English and Belgian cities, with over 23 million people a year using the Lille-Flandres and Lille-Europe HSR stations. The two stations are connected to the north-European HSR network but also to motorways, a ring road, a fast urban road, regional express trains, tramways and the longest automatic subway network in the world (VAL).

During the last 10 years, many connections with important cities have been improved with HSR, generating a significant impact on commercial activities and tourism. Over 13 years, the hotel and catering industry capacity has evolved, the number of available rooms rose from 1,300 to 2,100 (see Figure 50 and Figure 51). Usually vacant on week-ends, hotels are filled now. The number of hosts is even more impressive and shows the evolution of tourism activities.

**Figure 50** Development of number of hotels and rooms in Lille 1990 - 2003

| Lille Métropole | 1990 | 1995 | 2000 | 2003 |
|---|---|---|---|---|
| Number of hotels with 3 or 4 * | 16 | 19 | 23 | 27 |
| Number of rooms with 3 or 4 * | 1300 | 1600 | 1800 | 2100 |

Source: CSEF, 2005[60]

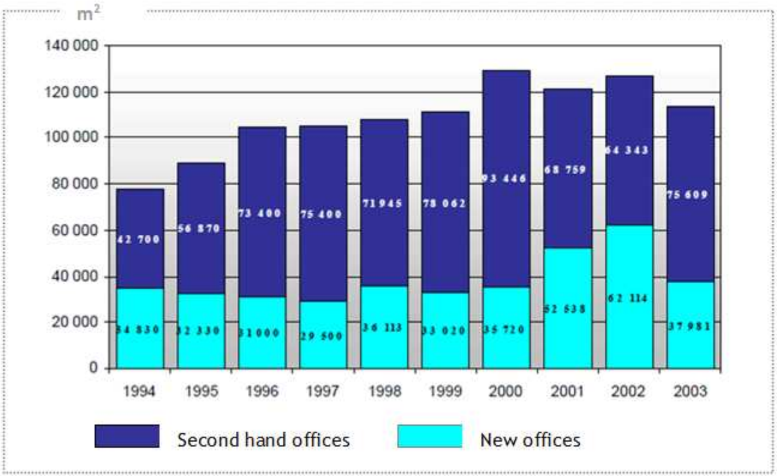
**Figure 51** Evolution of number of tourists in Lille 1990 - 2003

| Lille Métropole | 1990 | 1995 | 2000 | 2003 |
|---|---|---|---|---|
| Number of visitors | 34 000 | 149 000 | 431 000 | 517 000 |
| Number of foreign visitors | 9000 | 41 000 | 133 000 | 186 000 |
| % of foreign visitors | 26% | 28% | 31% | 36% |

Source: CSEF, 2005[61]

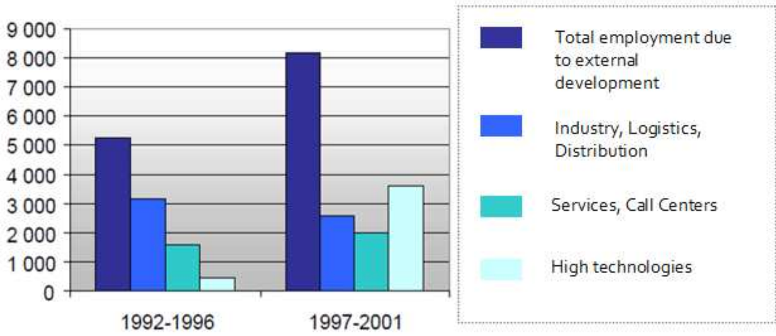
Other indicators show the attraction of Lille centre and its economic development: the office market and employment (see Figure 52 and Figure 53). In Lille the commercial property market is emerging, attracting property investors. In 2004, the price by square metre reached €1,700 and has kept increasing. These figures illustrate office commercialisation and employment growth.

**Figure 52** Annual evolution of office commercialization




Source: CSEF, 2005[62]

**Figure 53** Employment growths with external development

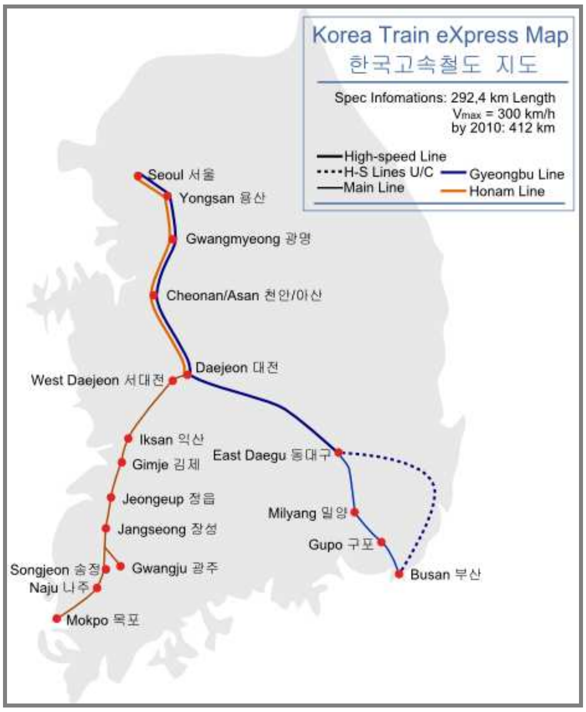



Source: CSEF, 2005[63]

Le Mans, 211 km from Paris, with 150,000 inhabitants, with a station in the city-centre and a journey time to Paris of 54 min, is another good example. Before building the station, the town put in place a development plan to control and reorganize the surrounding area. Consequently the "NOVAXIS technopole" around Le Mans station is considered a great success, with 74 insurance, IT and communication companies employing 2,800 people in 60,000m² of commercial floor space. Köln, Germany, has similarly redeveloped around a new station opposite the old station on the other side of the Rhine. In Belgium, rather than construct a new station at Brussels South, Antwerp and Liège were rebuilt and significant development implemented. Cordoba, Spain, constructed a new station next to the existing station. In Turin, Italy, a major redevelopment of the city centre took place around the new HSR station. In all the cases where new stations have been built, care was taken to ensure that they were well integrated into the public transport network. This was found to ensure that the benefits of HSR were not exclusive to the immediate location of the station, but was spread throughout the city and region. [64]

Another good practice example is the Korea Train Express (KTX) which was introduced in April 2004 to aim to reduce the north-south imbalance and bring about a shift in economic geography (see Figure 54).

**Figure 54** South Korean HSR networks[lll]




Source: Andre Werske, 18 August 2008 (UTC)

Along the corridor of an HSR line, the railway stations can generate considerable business effects as the Yongsan district in South Korea shows. The KTX influenced business activity; many companies have moved their branch offices. Yongsan station (see Figure 55) now is a major rail hub and a starting point for KTX in Seoul to the Gwangju and Mokpo stations (on the Honam line). The construction of the railway station has been a remarkable opportunity for the Yongsan district to develop activities like electronic and computer centre, cultural facilities, a shopping and fashion arcade, restaurants etc.

**Figure 55** Yongsan KTX Station


Source: IURD, UC Berkeley, 2005[65]

The district has been totally transformed: previously in decline, it is today more dynamic and modern, it has even become a model for district development in Seoul. One can notice in the Korean case that among cities with HSR stations, those that grew better have received a greater level of support from the central government and had the potential, before the HSR project, to absorb the new growth. HSR can be considered as a catalyst to simulate city

lll The red through line indicates a HSR line in operation, the dotted red line a HSR line under construction and the black one a main line.

growth, promoting development of areas adjacent to HSR stations and the development of service industries and tourism along HSR corridors.

## 6.4 HSR provides green jobs

As economies are currently unsustainable, transformation of activities are necessary to achieve building a new society model that meets economic, social and environmental requirements. Shifting toward sounder sustainably activities will require strong will and proactive policies in a wide range of areas including the use of renewable resources, increases in efficient technologies, changes in lifestyle, consumption habits and so on.

Such deep changes in production systems have necessarily strong implications in employment and labour market organization. This issue seems particularly serious since unemployment and job insecurity is already hitting our resource intensive economies hard.

Nevertheless, a low-carbon economic model could also be an outstanding opportunity to develop a new economic model with new business and employment opportunities. Shifting toward environmentally-sounder economies will have strong implications for employment in all sectors in the forthcoming decades. Within this framework, environmental and social concerns are not only seen as unbearable constraints, but raise awareness among public opinion, entrepreneurs and professionals. The growing interest of young professionals in green jobs demonstrates the need for sectors and activities that have a positive impact on the environment.

Nevertheless, defining green sectors and jobs remains quite a difficult issue since most current activities have a negative impact on the environment. Thus, green sectors have to be addressed as activities that enable to shift to sustainable economies by maintaining, restoring or avoiding further damage to the environment.

### HSR provides environmentally sound and decent jobs

HSR has many characteristics that make it an ideal industry for a new creed in green economics:

- While being far less polluting and resource consuming than current dominant transport modes, HSR has proved over the past decades that it could compete with other mass transit high speed modes.
- As green activities heavily rely on resource efficiency, the domain of green sectors is evolving with technology. HSR has the potential to be even more efficient and be an environmentally proactive sector.
- HSR fits perfectly with the evolution of economies with increasing needs for mobility and the expansion of the service sector.
- HSR is a labour intensive sector that provides environmentally sound jobs.

Regarding the latter point, the railway sector, which is very labour intensive, contributes significantly to employment. According to the European Union, the rail sector represents 11% of employment in European transportation. By comparison, air transport represents 5% and road transport more than 50% of total employment in transportation but represents 95% of all transport routes in Europe. A study carried out by the Worldwatch Institute for UNEP reveals that regarding investments in Europe, the construction of highways generates fewer jobs than any other public infrastructure investment. Investment in HSR generates employment during the whole life cycle of the infrastructure (see Figure 56). These can be permanent or temporary (e.g. during construction phase).[66] A further study stated that 10 new direct rail jobs generate 14 new indirect and induced jobs, while creating 10 direct jobs in the road sector only creates 5 indirect and induced jobs. For every £1.00 invested by the government, the industry invests £1.30. Thus, for £2.3Bn invested, 52,000 jobs could be created.[67]

Once again France is a good example for showing that construction of a new HSR lines requires numerous jobs. According to the rail network manager RFF (Réseau Ferré de France) the number of jobs created or saved for the 6 years of construction for the LGV East (Ligne à Grande Vitesse Est) reaches 63,000, partially due to the demand of civil works enterprises. The Madrid-Valencia HSR line has created more than 100,000 direct jobs during the construction period from 2004-2010 while during the first five years of service even 135,000 permanent jobs were created.

HSR also generates permanent jobs in many sectors. For instance, the SNCF assessed that the LGV East enabled to create or save 3,200 permanent jobs due to rolling stock construction.

**Figure 56** The new LGV East construction which created many jobs

Source: Pandrol Track systems UIC

### No job loss through modal shift

Transition to a new sustainable society requires the transfer of capital and labour resources toward greener activities. In the case of transport, a significant increase in rail transport should also signify a decrease in the importance of the automotive and air industries and an increase in that of the rail sector.

Considering the importance of the two first sectors in the current economy, this really addresses a question whether this would lead to net gains or loss of jobs. Even if no comprehensive study has been carried out that really enables us to answer to this question, some elements can be given to answer to this issue.

Studies in Germany and Great Britain indicate that jobs created by the rail industry could well offset the loss of employment in other sectors. For instance, a study carried out in 1998 by the Öko-Institut in Freiburg, Germany, considering a significant modal split to public transport, stated that if automobile manufacturing lost 130,000 jobs, this would be more than compensated by the creation of 338,000 jobs in other developing transport industries.[68]

## 6.5 Rail companies act responsibly and improve sustainability

A sustainable economic system needs sustainable companies. As for the rail industry the benefits of rail travel, and particularly HSR, towards sustainable economic development were shown in the previous chapters. But also the companies themselves are responsible for a sustainable business and can effect a change toward sustainability. Rail companies all over the world have signed the UIC Declaration on Sustainable Mobility and Transport, which commits to the ten principles of the UN Global Compact with respect for human rights, labour, environment and anti-corruption. With this commitment, the UIC members express their intent to advance these principles within their sphere of influence, and will make a clear statement of this commitment to their stakeholders and the general public.

UIC members companies that signed the Declaration strive to:

- deliver a transport mode with a strong sense of responsibility
- raise the levels of customer satisfaction through meeting the needs and expectations of the end-users
- become an increasingly preferred transportation mode
- improve safety, reliability, punctuality, cleanliness, comfort, and environmental advantage
- enhance technological innovation
- conduct joint research into the best practices and procedures

- contribute towards national and global reductions of $CO_2$ emissions
- provide opportunities for modal shift from other transport modes
- increase the energy efficiency of the railways
- reduce the noise and other impacts - not only from railway operation, but also from all facilities including; stations, factories, back offices, and other activities[69].

# 7 Conclusions

Transition to a more sustainable transport system relies on important efforts and policies from all stakeholders in the transport sector, from public and private entities. Significant efforts are being undertaken by all actors of the railway sector that will lead to important progress in the environmental performance of HSR in the forthcoming years. At the same time, one of the most important assets of HSR is that it can flexibly adapt itself to a more global framework of environmental management through the choices in electricity mixes of countries, which remains the main source for environmental progress for rail.

However current financial flows largely target a road sector based model of development. In developing a new financial framework, it is important to begin by acknowledging the growing consensus on the overall policy paradigm that allows the development of more sustainable forms of transport, such as HSR.

The Avoid, Shift and Improve (ASI)[mmm] approach to climate change mitigation could be the basis of the new paradigm. This approach calls for:

- **Avoid:** Avoiding or reducing trips through e.g. the integration of land use and transportation planning, such as locating new movement generating developments near to railway stations;
- **Shift:** Shifting to more environmentally friendly modes such as public transport, including HSR, and non-motorised transport; and
- **Improve:** Improving vehicle and fuel technology of all modes of transport, including HSR, to improve the environmental efficiency from each kilometre travelled.

The implementation of an "Avoid-Shift-Improve" approach would initially reduce the growth of GHG emissions and ultimately work to reverse it. This approach will contribute to the overall sustainability of the transport system by, for example, improving air quality, enhancing accessibility, reducing accidents and curbing traffic congestion. Adopting such a co-benefit strategy rather than pursuing these objectives in isolation is likely to be highly cost effective, especially where resources are scarce.

In pursuit of this vision, the design of the financing framework[nnn] needs to be fully integrated and made to support the Avoid-Shift-Improve paradigm. Four closely related actions are required;

- ANALYSE the impacts of financing decisions taken by relevant stakeholders on sustainability;
- SHIFT existing resources towards a sustainable direction e.g. HSR;
- ADD / increase funding for those areas where resources are lacking; and
- PAY for the full costs of transport including environmental depreciation.

Pricing directly affects the way financing of HSR systems translate into actual benefits, mainly through:

- Incentivising behavioural change of individuals and allowing sustainable patterns of transport to become more financially attractive relative to one based on private motorised transport.
- Providing a strong signal to the private sector to invest and innovate in HSR.
- Raising the revenue required for additional investments to be made in HSR.

Resources targeted at sustainable transport are generally a small fraction of those allocated for traditional (unsustainable) transport. A wide range of transport–relevant financial flows need to be reoriented towards sustainable transport to achieve the required paradigm shift and ensure that HSR is rightfully seen as a core element of transport provision.

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