INTERNATIONAL UNION
OF RAILWAYS

UIC Low Carbon Rail Challenge

Technical Report

This document has been elaborated by UIC (International Union of Railways), Fundamental Values Department.

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1.1 Targets for energy consumption and CO_2 emissions: framework, description and methodology

1.1.1 Framework

UIC, the International Railway Association, is proposing a transport sector challenge in the framework of the green growth agenda and climate change perspective for 2030 and 2050. This challenge sets out ambitious but achievable targets for improvement of rail sector energy efficiency, reductions in greenhouse gas (GHG) emissions and a more sustainable balance between transport modes. These targets have been voted unanimously by UIC worldwide members in UIC General Assembly, held in Paris on June 27th 2014.

These worldwide voluntary reduction objectives follow what has already been put into practice at the European level by UIC and CER with the "European Rail Sector Sustainable Mobility Strategy" that envisages specific targets for energy efficiency, CO_2 emissions reduction, PM/NOx emissions reduction and noise reduction to be met by the EU railway sector in 2030 and 2050[1].

In order to monitor the environmental performance of the European Railway Sector, the UIC Environmental Strategy Reporting System (ESRS)[2] has been created as a comprehensive instrument which allows the overall procedure of construction of indicators, data collection, analysis, reporting and data sharing to be regulated in a clear and transparent structure. Results will be published on yearly basis on a dedicated internet site (www.co2-data.org).

1.1.2 Description

As a first step of the challenge, the world railway sector has set for itself ambitious 2030 and 2050 targets for energy consumption and CO_2 emissions:

- Reduction in specific average final energy consumption from train operations:
  - 50% reduction by 2030 (relative to a 1990 baseline)
  - 60% reduction by 2050 (relative to a 1990 baseline)
- Reduction in specific average CO_2 emissions from train operations:
  - 50% reduction by 2030 (relative to a 1990 baseline)
  - 75% reduction by 2050 (relative to a 1990 baseline)

These targets will be achieved by railway companies across the world, in aggregate terms.

1.1.3 Methodology

Sources

For the definition and the calculation of the energy consumption and CO_2 emissions reduction targets, this work mainly references the following sources:

- UIC Statistics data (which are collected directly from railway companies throughout the world), related to passenger and freight production, energy consumption, etc.;
- The elaborations made by UIC in collaboration with IEA in the production of the annual Railway Handbook on Energy Consumption and CO_2 emissions (editions 2012,2013 and 2014);
- The ESRS monitoring system and the evaluation of the reduction drivers in a European context;

[1] European railways committed to a 30% specific CO_2 reduction in 2020 and 50% in 2030, baseline year 1990. The 2020 target has been reached in 2011 already.

[2] The ESRS is ruled by a specific methodology as a guideline to collect, account and report the environmental Key Performance Indicators (KPI) of UIC/CER railway members. The ESRS is an evolution of the UIC Energy & CO_2 Database, which was started in 2005 to collect and analyse the railway sector's energy and CO_2 performance values, and has been updated on an annual basis. The database takes into account figures regarding both passenger and freight service, and has been used to show the picture of full energy/CO_2 performance data from the year 1990.

- The estimates made by the IEA Mobility Model (MoMo), published in the IEA Energy Technology Perspectives (ETP), editions 2012 and 2014.

In the absence of statistical data built with homogeneous methodologies and systematically available for all the world regions, the IEA Mobility Model (MoMo) contains historical data and projections to 2030 and 2050 on all transport modes and vehicle types. MoMo is the main instrument used by IEA in the ETP regarding the transport sector. MoMo is a spreadsheet model of global transport, energy use, emissions, safety and materials use that can analyse a set of scenarios and projections to 2050, based on hypotheses on GDP and population growth, vehicle fuel economy, fuel costs, travel demand, vehicle and fuel market shares. For rail, total travel activity, energy intensities, energy use and emissions are tracked.

In order to ensure data quality, MoMo energy use is compared to official IEA energy balance statistics. For the railway sector, one of the main sources of IEA is the data collected by UIC from its member companies.

Furthermore, IEA and UIC have an on-going collaboration since 2012 for the production of an annual *Railway Handbook on Energy Consumption and* CO_2 *Emissions*. The *Handbook* is a data compendium on the environmental performances of the railway sector, which is at its third edition in 2014. Currently, MoMo data is aligned with the *Handbook* and the UIC historical data. The availability of this data allows for a critical statistical analysis of the past trends, which can support the interpretation of the scenarios compiled by IEA.

In the framework of the UIC/CER EES Strategy Energy and CO_2 Targets, the UIC has examined yearly the progress towards the 2020-2030 European targets for energy consumption and CO_2 emissions with the data sent to UIC by all members, set a transparent methodology paper for calculation and published a yearly Report.

Definition and verification of the targets

The IEA has defined three scenarios at a world level, which have been declined sector by sector. Those scenarios (called *6DS*, *4DS* and *2DS*) are referred to the potential increase of average world temperature in 2050: 6, 4 and 2 degrees Celsius.

In the transport sector, the 6DS scenario makes a simulation of what could happen in case the current policies (in particular the standards related to the containment of energy consumption and CO_2 emissions of road vehicles) are not implemented in the future. The scenario basically implies a failure in the penetration of cars powered by alternative fuels (electric, hybrids, second-generation biofuels, natural gas etc.).

The 4DS scenario projects a *business-as-usual* (BAU) trajectory, where existing policies are developed and implemented: more stringent emission and fuel standards are implemented in OECD countries, energy efficiency standards in navigation start to generate real effects and ETS comes into play for aviation in EU. In this case the penetration of electric vehicles would be slow, similarly to what is currently happening for hybrid vehicles.

The 2DS scenario in the transport sector includes two sub-scenarios: *Improve* and *Avoid/Shift*. A combination of these two sub-scenarios leads to a significant reduction of greenhouse gas emissions by 2050.

For the three basic scenarios (6DS, 4DS and 2DS), IEA estimates through MoMo the following indicators by 2030 and 2050 (with 2010 considered as the baseline year):

- Transport demand;
- Modal split;
- Energy consumption by mode;
- CO_2 emissions by mode.

These elaborations are built at a world level as an integration of estimates made in 29 regions, including several specific countries (USA, Canada, Mexico, Brazil, France, Germany, Italy, United Kingdom, Japan, Korea, China, India…)[3].

On the basis of these estimates it was possible to reconstruct the trends of **energy and carbon intensity of the railway sector** expected by IEA in the different scenarios. The focus was on the 2DS scenario, in order to take into account the best technological evolutions and the hypotheses for a greater expansion of the railway network assumed in the 2DS *Avoid/Shift* scenario. The goal was to have estimates compatible with the *modal shift challenge* described in the next chapter.

The future projections have then been evaluated with the following factors in mind:

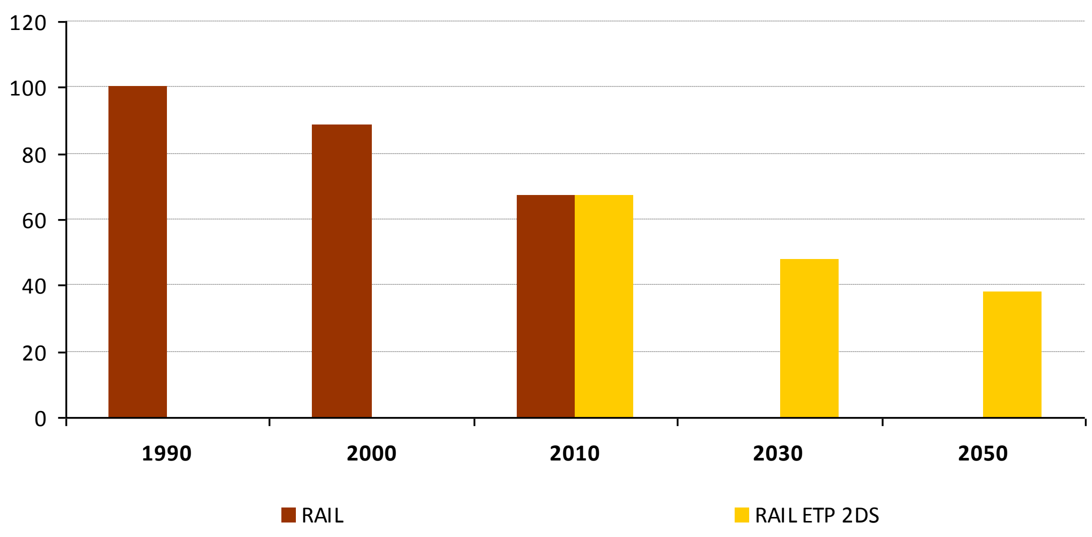
- The historical trends of energy and carbon performance of rail, globally and in the different regions examined;
- The key drivers of energy efficiency and decarbonisation, which have determined past evolutions and will play an important role in the future as well;
- The possible evolution of some of these key factors.

After this critical evaluation, the challenge targets have been determined using IEA estimates as a basis, and the potential reductions compared to the scenario BAU Energy Consumption have been assessed.

1.1.4 Energy consumption intensity reduction based on IEA 2DS scenario

The IEA 2DS scenario estimates the final consumption of energy and the volumes transported by 2030 and 2050 in the world railway sector. These estimates are founded on the reconstruction of historical trends which are aligned with the data autonomously collected by UIC.

Fig. 1-1 Rail energy consumption intensity reduction (1990=100)



Source: Susdef Elaboration on data from UIC/IEA Handbook 2014 and ETP 2012

Compared to 1990, considered as the baseline year for the challenge, **the energy intensity of the railway sector (final energy consumption/traffic unit) decreased by 33% worldwide**. By projecting the data to 2030 and 2050, IEA estimates in the 2DS scenario that there will be a further reduction of energy intensity to 52% in 2030 and 62% in 2050, compared to 1990 values.

The targets declared seem thus to be in line with IEA findings.

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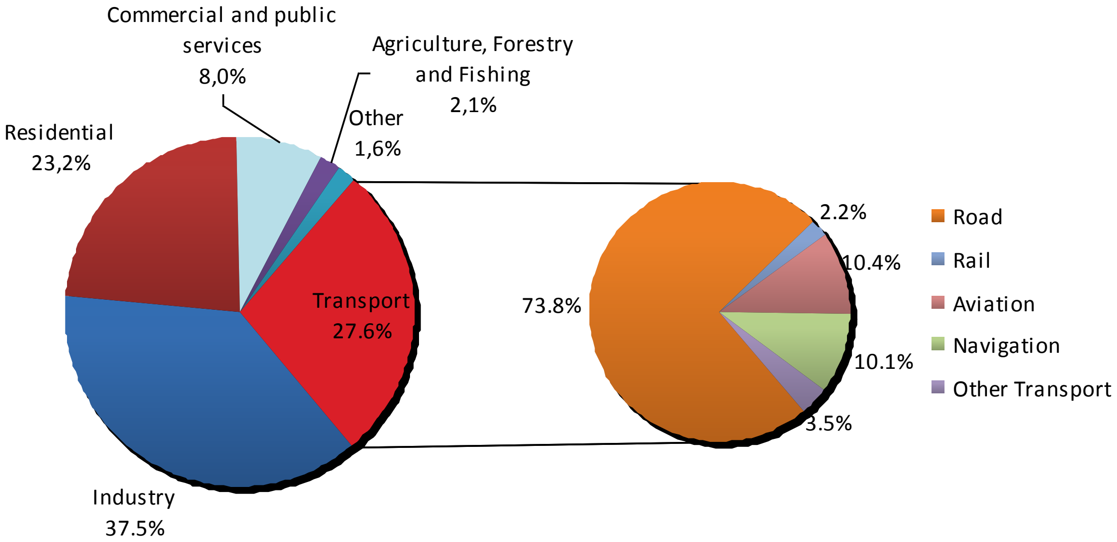
[3] IEA has provided elaborations to UIC on several countries that are key for railway production: USA; EU, Russia, China, India, Japan, Brazil and South Africa.

1.1.5 Trend analysis

As is well known, railways contribute with a very low share (2.2%) to the energy consumption of the transport sector. This share is much lower than the weight of railways in the modal split, thanks to a lower specific consumption compared to other modes.

Fig. 1-2 Share of final energy consumption by sector, 2011



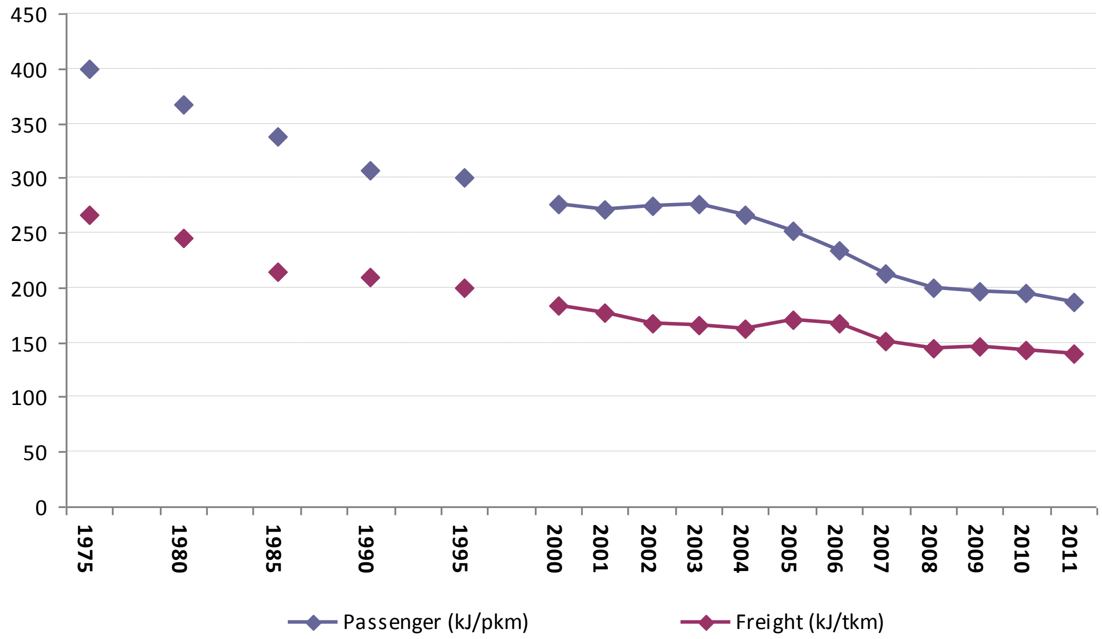
Source: IEA/UIC Railway Handbook 2014

On top of that, railways are the transport mode which is less dependent from the use of fossil fuels, due to their high rate of electrification.

From the MoMo and the UIC databases, it is possible to trace the trends of specific energy consumption in the railway sector between 1975 and 2011. Compared to 1975, it is possible to observe in 2010[4] a reduction of energy intensity by around 51% for passenger and 47% for freight. This trend indicates a decoupling between energy consumption and transport activity, with the volumes on rail constantly growing and the energy consumption remaining basically stable.

[4] All the elaborations in this report use 2010 and 1990 as baselines for calculations and for the definition of targets.

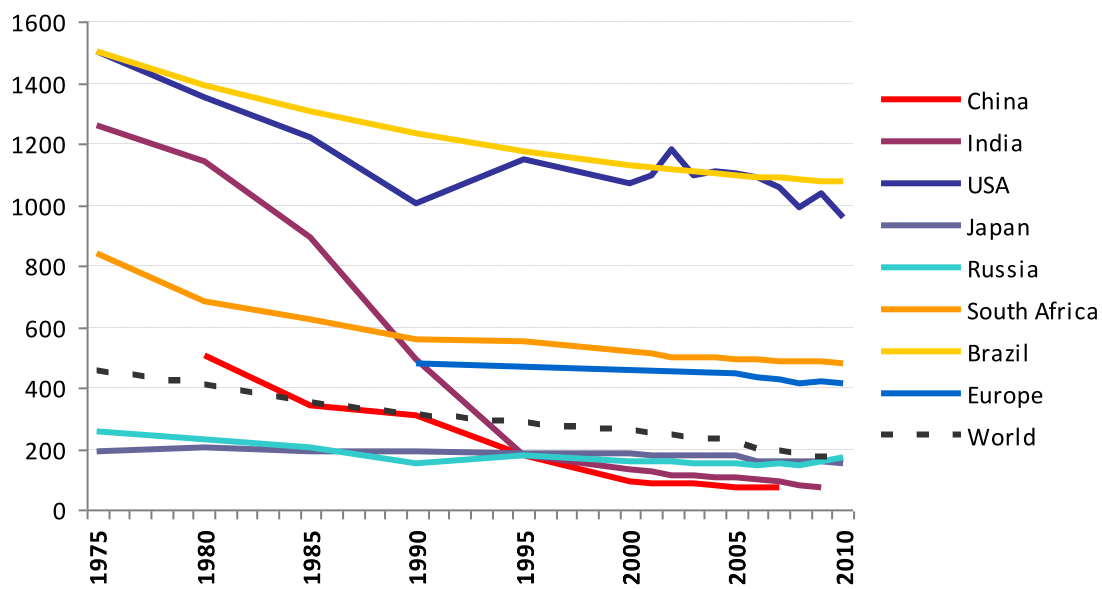
Fig. 1-3 Evolution of energy intensity of the world railway sector, 1975-2011



Source: IEA/UIC Railway Handbook 2014

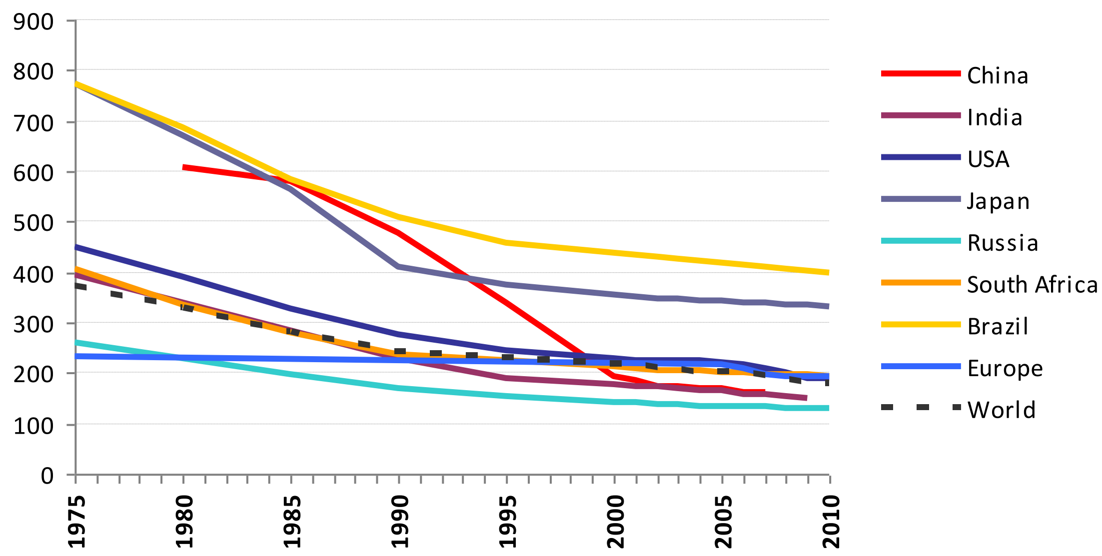
By observing the same indicator in different regions of the globe, a diversified picture emerges. The **European** railway sector has low to mid rates of energy intensity reduction, both in passenger and in freight transport. In the European passenger sector, energy intensity values are higher than world averages, while in the freight sector those values are in line with the world. **Chinese**, **Indian** and **Russian** railways are distinguished by values lower than the world average both in passenger and in freight. **Japan** has a very favourable energy intensity in passenger transport, not so much in freight; the opposite holds in the **USA**. Among the regions selected, the Brazilian railways have the worst figures for energy intensity but they have higher improvement rates than the others.

Fig. 1-4 Railway passenger specific energy consumption in selected countries, 1975-2010 (kJ/pkm)



Source: IEA/UIC Railway Handbook 2013

Fig. 1-5 Railway freight specific energy consumption in selected countries, 1975-2010 (kJ/tkm)



Source: IEA/UIC Railway Handbook 2013

1.1.6 Factors influencing energy intensity

The energy intensity is the most significant indicator for average specific consumption in the railway sector. The energy intensity is the ratio between the energy consumption of the railway sector[5] and the demand for units of product, expressed in passengers-km and tonnes-km[6]. A notable aspect of this indicator is that the denominator contains the demand for transport, and not the supply. In this sense the strategies that the railway sector can adopt are both technical/organizational and systemic, that is they can be turned on the transport demand, on the transport supply and on their interaction.

The main factors that can have an impact on energy intensity can be differentiated between those related to supply and those related to demand.

Table 1-1Energy intensity reduction strategies

Supply factors	Demand factors
Traction concepts and energy sources	Space utilisation
Mass reduction	Load factor
Areodynamic and friction	Reduction empty trips
Reducing conversion lossess	Flexible trains
Regenerative braking and energy storage	Marketing strategies to increase demand
Reducing energy consumption for confort function	
Energy efficient driving	
Procurement strategies	
Awareness of personal and incentives	

Source: UIC EVENT

The supply-side factors, in summary, are connected to new technologies and technology improvements. A typical example of energy efficiency is the modification of the *traction concept*: from diesel to electric, as it once went from steam to diesel. Given a technology, it is also possible to improve its use, for instance with

[5] See the UIC ESRS Methodology for details.

[6] The energy intensity is also an essential instrument to compare different modes of transport.

“intelligent driving” which can be put in practice both through training of the train drivers and through an efficient planning of the schedule[7].

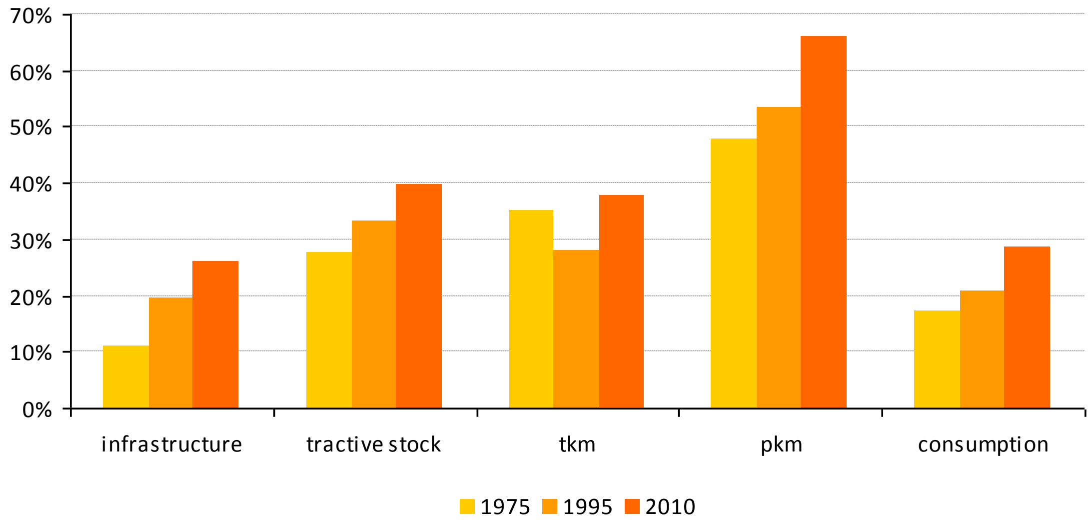
The demand-side factors act on the denominator of energy intensity: when more passengers and freight are transported with the same amount of energy consumption, the intensity decreases. Consequently the demand-side strategies are concentrated on increasing the load factor of trains. This objective can be reached by reducing the offer of trains with the same amount of passengers transported (e.g. trains with more capacity or with a more flexible composition) or by increasing the amount of passenger/freight transported with the service already in place. The increase of passengers and freight transported are not only a direct consequence of the actions of railway companies: in the next chapter, some enabling conditions for the increase of market share of railways will be analysed.

1.1.7 Key indicators

As mentioned above, one of the crucial factors for the reduction of energy consumption is the adoption of traction systems with better energy performance. A key indicator for this is the fuel mix of railways, and in particular the electrification.

The process of electrification of world railways is in continuous expansion: since 1975 to 2010, there has been an increase of electric railway lines and traction material, of passenger and freight traffic on electric lines and of the share of electric energy on total energy consumed by railways.

Fig. 1-6 Electrification evolution of the worldwide railway sector



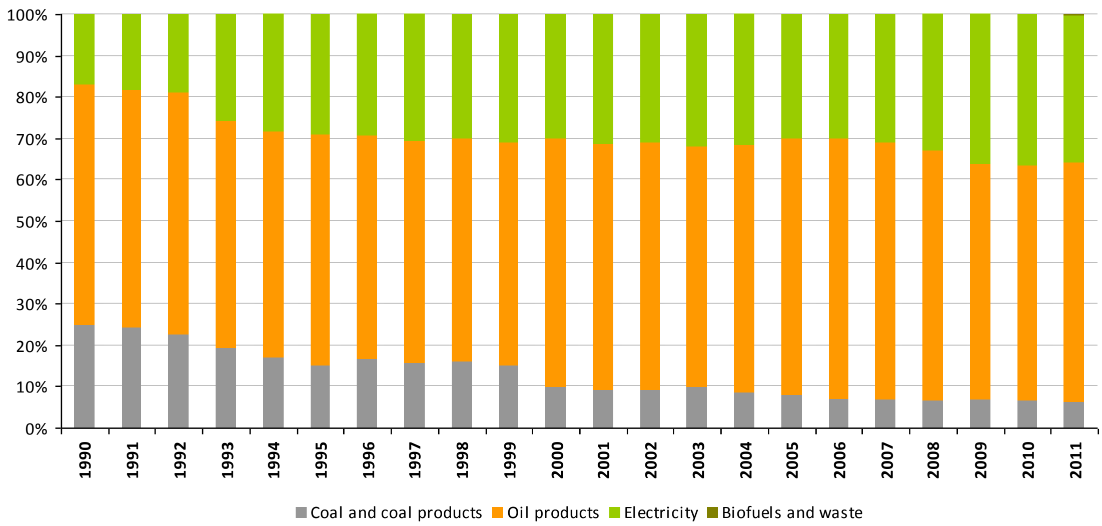
Source: IEA ETP 2014

Among the different modes of transport, railways are those with the highest share of electrification. Electricity represents around one-third of the energy used globally by the railway sector, with 40% of rolling stock powered by electric traction and electrified lines representing 25% of total.

The use of electricity in railways worldwide went from 17% to 37% (measured as share of final energy consumption) between 1990 and 2010. The diesel consumption is stable, close to 60%. The use of coal is dropping, with a share of 6%. The penetration of biofuels is very low, but the increase rate in the last 5 years is quite interesting (9 MJ in 2011 from 0.1 MJ in 2006).

[7] The use of energy meters and economic incentives to drivers has produced excellent results in DB. The Driver Advisory Systems (DAS) are the current cutting-edge technology for an optimal use of energy in relation with the driving style. The schedule planning can also include energy-efficient driving among the factors to keep under control.

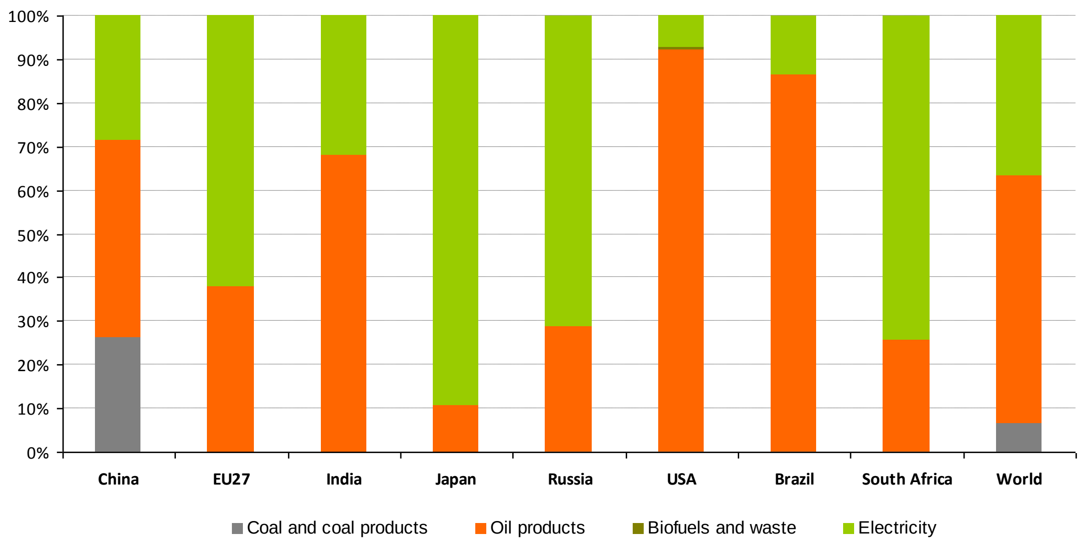
Fig. 1-7 Railway final energy consumption by fuel



Source: IEA/UIC Handbook 2014

A comparison between the current situation in some key railway systems and the 1990-2010 trends, the margins of improvement are clear. In **China** for example, the penetration of electric traction went from 4% in 1990 to 28% of energy consumption in 2010: however, we are far from the percentage found in **Russia** (71%) or **EU** (62%). The same holds in **India**: these are two the largest railway systems, where the railways have an important market share both in passenger and in freight. With electrification, those railways can reach huge reductions of specific consumption, pulling the whole world railway sector.

Fig. 1-8 Railway final energy consumption by fuel in select countries (2010)



Source: IEA/UIC Handbook 2014

Where the introduction of electric traction is not economically feasible, there are still ample margins of improvement of energy efficiency thanks to the combination of hybrid traction, associated with energy storage systems to recover energy from braking. Diesel-hybrid locomotives demonstrated in the UK and advanced types of hybrid drive-trains under development in the United States and Japan, could save 10-20% of diesel fuel. The low share of electrification in USA, where there is almost exclusively freight traffic, can very well benefit from these innovations.

As noted earlier, the energy intensity can be influenced by the load factor of trains, i.e. by the productivity[8], expressed as the ratio of satisfied demand (output) and production (input).

It is possible to compare the improvement of:

- Energy intensity (ratio between final energy consumption and demand);
- Energy efficiency (ratio between final energy consumption and railway production in train-km);
- Productivity (ratio between demand in Traffic Units and supply in train-km).

From this comparison, it appears that the energy intensity is more sensitive to variation of productivity (23% of variation in the 1990-2010 period) than to energy efficiency (16% of variation 1990-2010). This means that load factor improvement has played a more important role than technology improvement.

This aspect is confirmed by the analysis of the European case. European specific energy consumption has been reduced from 1990 to 2012 by 16.5% for passenger and 23% for freight. The monitoring activities of UIC/CER with the ESRS have clearly shown that the load factor, both for passenger and freight, is one of the most effective drivers of energy intensity reduction for railway sector as a whole.

1.1.8 Energy intensity and high speed rail

Railways in the near future will see an increase and expansion of high speed rail. This kind of railway service may on first inspection appear to lead to an increase in energy consumption. It is true that the energy required to overcome aerodynamic drag increases exponentially with the speed of the train. However, high speed rail systems typically achieve energy savings in a number of other areas (eg lower mechanical resistance, energy lost in braking, electrical losses, etc). When the performance of the whole system is analysed it is clear that high speed rail services can consume lower quantities of energy when compared to conventional rail[9].

Empirical data from the European experience confirms the hypothesis that high speed trains have a lower energy intensity compared to intercity and regional trains.

As an example, a comparison between specific consumption of different train types of Spanish company RENFE- in normal operating environment -shows that energy intensity per pkm is inversely proportional to the speed of different train types.

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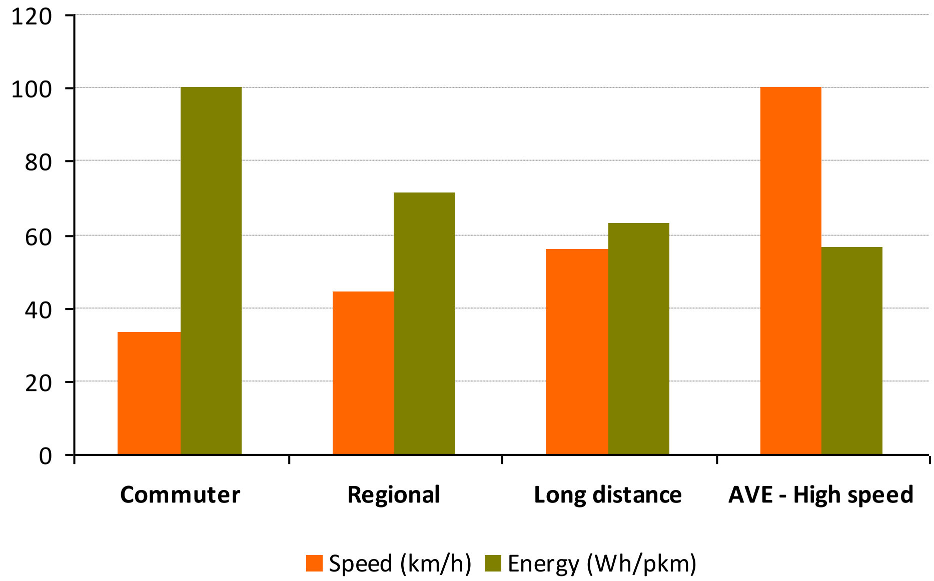
[8] The load factor is the best productivity indicator. However, it is not always possible to have data on seat-km offered. In this case the productivity is measured as the ratio of the traffic units transported and the production in train-km.

[9] Alberto GARCIA, High speed, energy consumption and emissions: study and research group for railway energy and emissions, Paris 2010

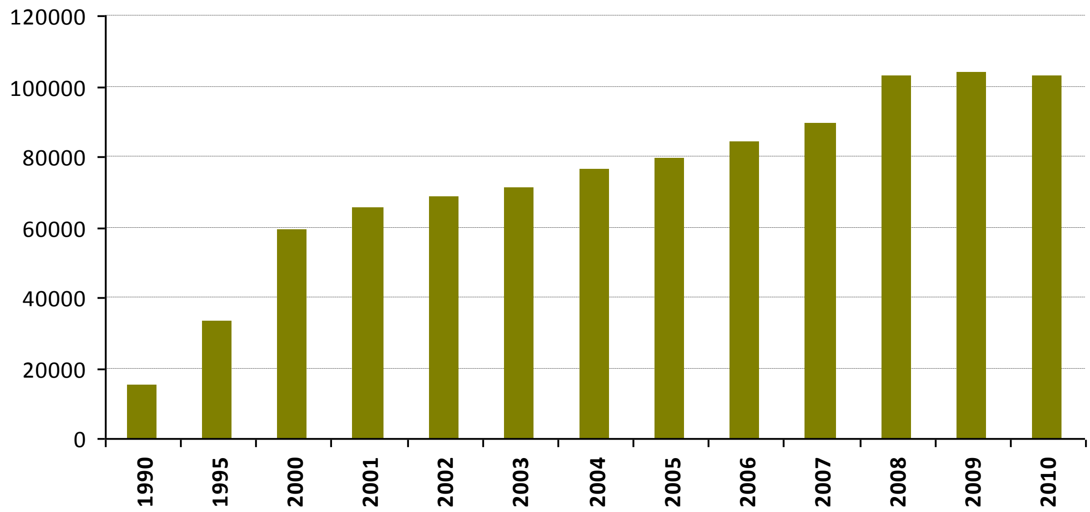
Fig. 1-9 Comparison of energy consumption per passenger-kilometer in various types of trains (energy 100= 140 Wh and speed 100= 160 km/h



Source: UIC/RENFE

This is confirmed also by the fact that while high speed rail has grown in Europe from 1990 to 2010 (with number of passengers increased by a factor 7), the energy intensity of the railway sector per pkm in Europe has decreased by 15% in the same period.

Fig. 1-10 Passenger-km (million) transported by high-speed railway in Europe



Source: UIC

It is essential also to stress that the proposed targets are not focused on total energy consumption or on different train types or services. The targets are focused on energy intensity **per traffic unit.** To this goal, high speed rail generates the best performances thanks to the higher load factor and the improvement of energy intensity of railway system as a whole.

1.1.9 Final considerations on the feasibility of targets

As previously said, according to the UIC and IEA data elaborations, from 1990 to 2010 there has already been a 33% reduction of energy intensity worldwide.

The progressive alignment of world railways to the standards of more advanced companies would hold considerable improvements of technical and organizational efficiency in the energy field. Even though railways are already enjoying the lowest specific consumption compared to other transport modes, **the increasing weight of the energy bill in the budgets of railway companies** is creating the conditions for investments in energy efficiency as one of the keys for increasing profitability.

Some railway companies in Europe and in the world have officially published energy efficiency strategies, with targets for 2020 and 2030 and all relevant train operators and infrastructure managers have on-going projects related to energy recovery from braking, renewable of rolling stock, energy efficient time-tabling, load factor management, etc.

A UIC questionnaire determined the main drivers for energy intensity reduction to be the following:

- Load factor/empty trips management;
- More efficient rolling stock;
- Increase of regenerative braking;
- Infrastructure energy efficiency management;
- Eco-driving programs/Use of DAS;
- Heating, cooling and “train hotel loads” management.

Furthermore, there is a strong correlation between the high rates of growth for railway demand, such as in India and China, and increases in productivity[10]; and productivity is a crucial factor for the reduction of energy intensity. The performances of two of the largest railway systems in the planet, thus, will progressively improve and generate a reduction of the global specific consumption of railways.

It is realistic to assume that in the near future, the tendency towards reduction of energy intensity noticed for the world railway sector in the 1990-2010 timeframe will continue: this makes the energy intensity targets of the Challenge ambitious, but feasible.

The experience of the UIC *Environmental Strategy Reporting System* allows the transfer to a world level the methodological and organizational structure set up to monitor the European targets, guaranteeing an official, reliable and homogeneous data collection for the global railway sector.

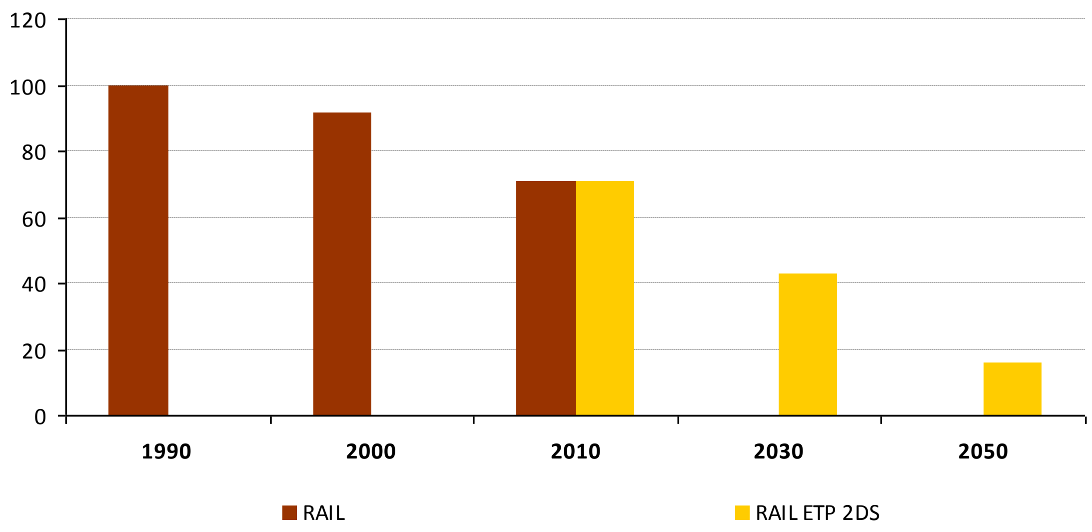
1.2 Carbon Intensity

1.2.1 CO_2 emissions intensity reduction based on IEA 2DS scenario

The IEA 2DS scenario forecasts a reduction of CO_{2eq} emissions for the railway sector of 57.3% and 84.1% by 2030 and 2050 respectively, compared to base year 1990 (see Fig. 1-11).

[10] In its simplest form, the law of Verdoorn states that there is a close relationship between the long run growth of manufacturing productivity and that of output. The importance of the law is that it suggests that a substantial part of productivity growth is endogenous to the growth process, being determined by the rate of expansion of output through the effect of economies of scale.

Fig. 1-11 Rail energy emissions intensity reduction (100=1990)



Source: Elaboration by Susdef from UIC/IEA Railway Handbook on Energy Consumption and CO_2 Emissions (2014 edition) and IEA ETP 2012

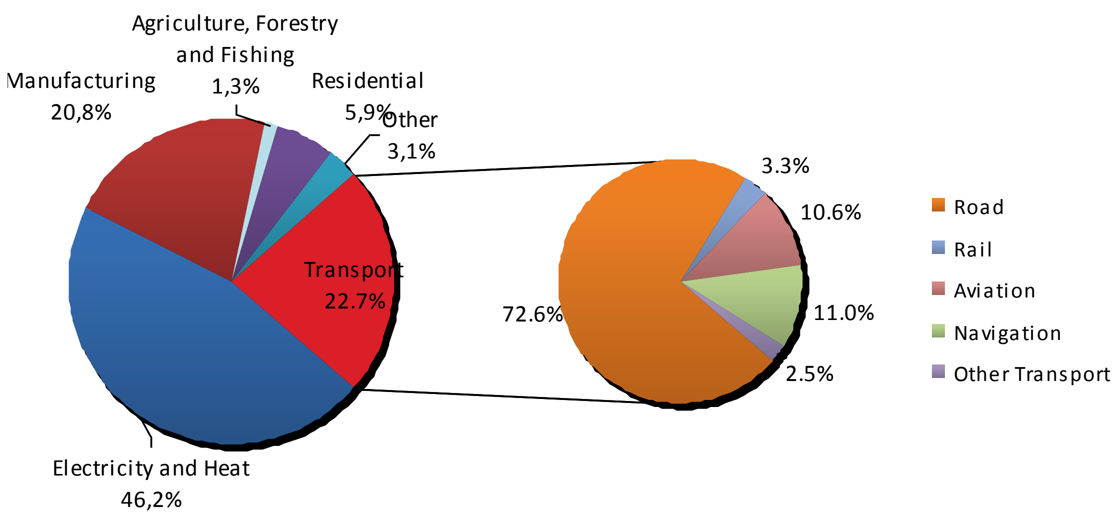
In 2010, the world carbon intensity of the railway sector decreased by **29.2%** with respect to the year 1990, which is the baseline year of the challenge.

The target of the UIC challenge is thus slightly more prudent than the IEA forecasts.

1.2.2 Trend analysis

The greenhouse gas emissions of the transport sector have doubled from 1970, growing at a stronger pace than other sectors. Around 80% of this growth can be attributed to road transport. Railways only contribute for 3.3% of the transport sector CO_2 emissions (see Fig. 1-12).

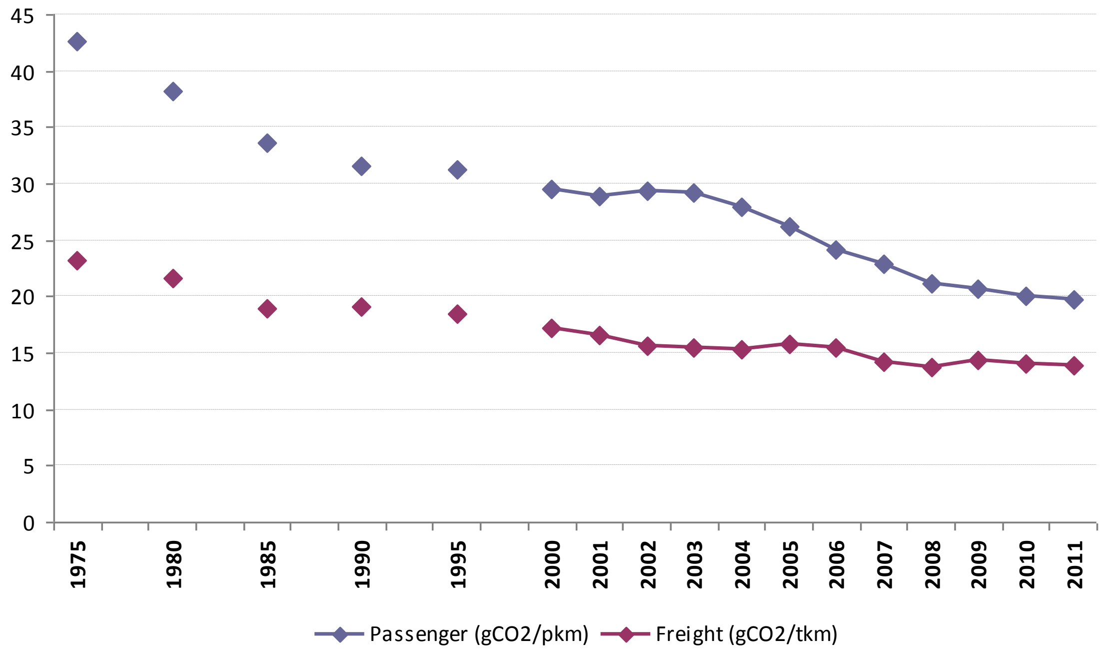
Fig. 1-12 Share of CO_2 emissions from fuel combustion by sector, 2011



Source: UIC/IEA Railway Handbook on Energy Consumption and CO_2 Emissions (2014 edition)

From the databases of the IEA Mobility Model and of the UIC, it is possible to reconstruct the trend of specific CO_2 emissions of the railway sector between 1975 and 2011. Compared to 1975, in 2010 the carbon intensity is reduced by around 53% for passenger transport and 40% for freight transport (see Fig. 1-13).

Fig. 1-13 Evolution of carbon intensity in the world railway sector, 1975-2011



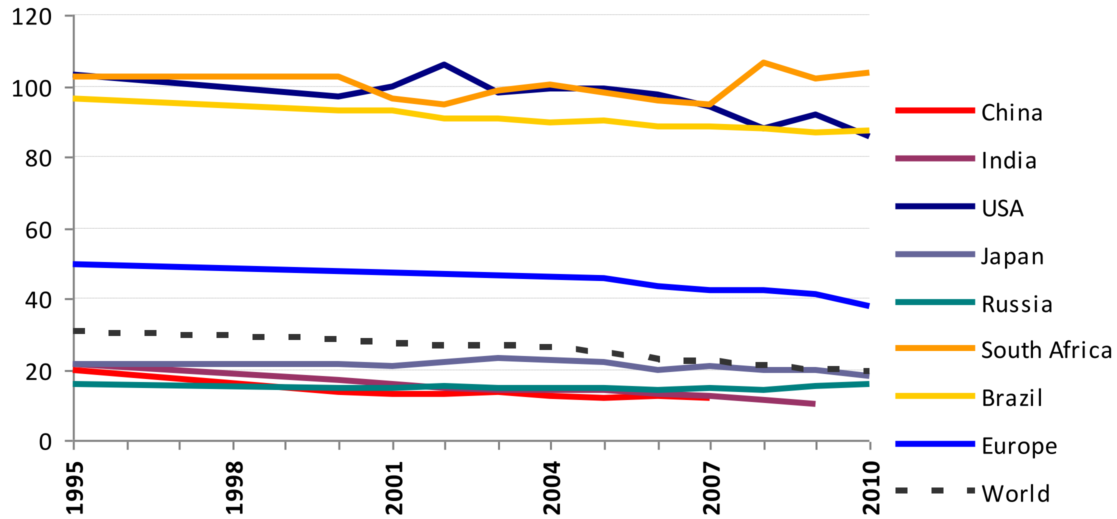
Source: UIC/IEA Railway Handbook on Energy Consumption and CO_2 Emissions (2014 edition)

One of the main factors in the reduction of carbon emissions intensity is the reduction in energy intensity: if the emission factor of the energy used remains constant over time, a reduction in energy intensity generates a proportional reduction in carbon intensity.

However, when the emission factor deteriorates this does not happen and the carbon intensity trend differs from the energy intensity trend. Since the indicator of the intensity is established for the rail sector as a whole, the reasons for an increase of the emission intensity may depend on the different country emission factors. Some countries weigh more in the total railway traffic demand, and some have a different weight for passenger or for freight service. In particular, the stagnant performance of the carbon intensity of freight railway shown here is due to the deterioration of the energy mix of some countries with significant weight in terms of freight traffic such as India and China. It is in fact well known that freight traffic has a larger share of diesel traction compared to electric.

The trend of specific CO_2 emissions in a few select countries shows a diversified picture, similar to what has been seen for energy intensity in the same countries. In passenger transport (Fig. 1-14), the European railway sector displays higher specific emissions compared to the world average; the same consideration does not hold for freight transport. In passenger transport, the railways well above average specific emissions are Brazil, USA and South Africa: countries in which the modal share of railways in absolute terms and compared to other forms of passenger transport is very low. Below world average are Russia, China, India and Japan.

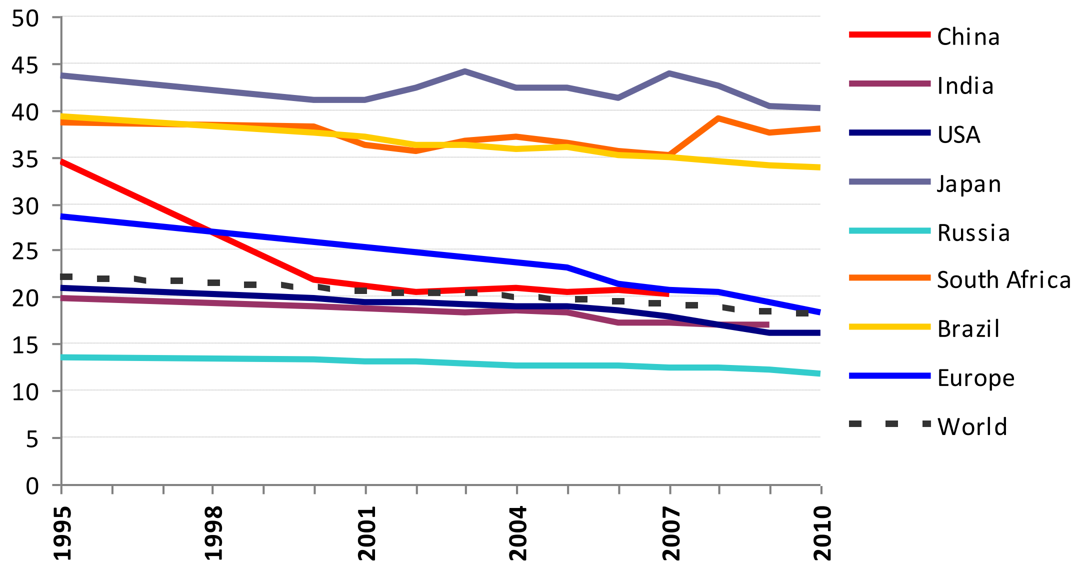
Fig. 1-14 Railway passenger specific CO_2 emissions in select countries, 1995-2010 (gCO_2/pkm)



Source: UIC/IEA Railway Handbook on Energy Consumption and CO_2 Emissions (2013 edition)

In freight transport (Fig. 1-15), Japan and USA switch places, as it happened for specific energy consumption. Together with Brazil and South Africa, Japan shows higher specific emissions compared to world average. The Russian, Indian and American railways seem to be the best-performing. Starting from 2000, the trend for Chinese railways is in line with the world average.

Fig. 1-15 Railway freight specific CO_2 emissions in select countries, 1995-2010 (gCO_2/tkm)



Source: UIC/IEA Railway Handbook on Energy Consumption and CO_2 Emissions (2013 edition)

1.2.3 Factors influencing carbon intensity

Carbon intensity is expressed as the ratio between the CO_2 emissions of the railway sector and the transport demand, expressed in passenger-km and tonnes-km. As in energy intensity, the transport demand is the denominator of the ratio. Here as well, the strategies that the railway sector can adopt concern both the technology and the system. The main reduction factor for specific CO_2 emissions is the reduction of energy intensity; this can be coupled with actions directly aimed at the reduction of the emissions intensity of the energy used, such as the **use of biodiesel** or the **greening of the electricity mix**.

As previously stated, an improvement in energy intensity – for example due to an increase in the load factor – coupled with a worsening carbon intensity of the electricity used in rail transport can hinder a good performance in terms of specific CO_2 emissions.

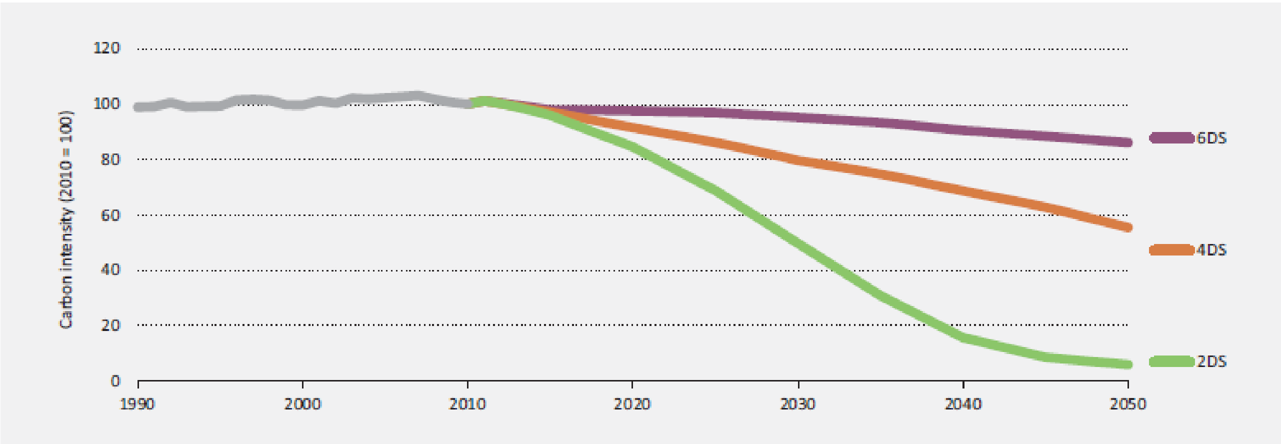
Conversely, the **electrification of railway transport** can have a double impact on carbon intensity: it increases the energy efficiency if matched by the reduction of the electric emission factor in order to improve the railways' specific emissions. The electrification of traction is a major driver in the reduction of CO_2 emissions by railway undertakings: by having trains run on electric power, it is possible to reduce the environmental impact of traction by acting on the emission factor of electricity (which can potentially go all the way down to zero if the electricity is entirely produced with renewable sources). In Europe, for instance, the reduction of specific emissions goes hand-to-hand with the increase in electrification (calculated by dividing the train-km of electric traction divided by total train-km).

1.2.4 Key indicators

As mentioned in the previous section, one of the key factors to reduce energy consumption is the improvement of the electricity mix.

Since 1990, the intensity of emissions from electricity generation has been stable. Despite significant growth in their deployment, the positive effects of low-carbon generation technologies have been muted by the fact that fossil fuels have accounted for the majority of new generation capacity. According to the IEA 2DS scenario, in 2050 the electricity will be significantly decarbonised, reaching a world average emission factor of 37 gCO_2/kWh. This would be a reduction of more than 90% compared to the emission factor of 529 gCO_2/kWh estimated for 2013 (see Fig. 1-16).

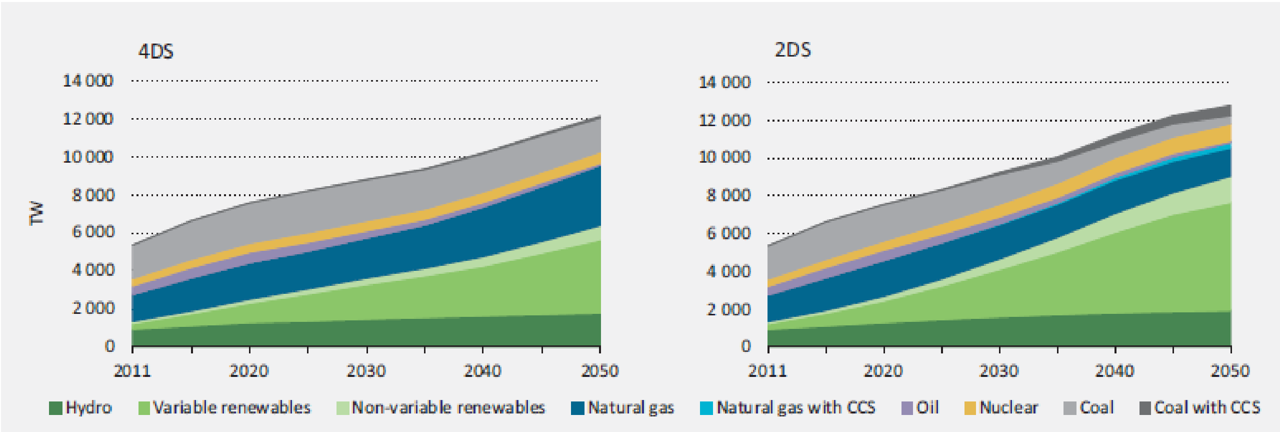
Fig. 1-16 Carbon Intensity of the Electricity Generation Sector



Source: IEA ETP 2014

To reach 2DS targets by 2050, the share of renewables has to be more than 70% (Fig. 1-17) and fossils reach just over 20%, coupled with nuclear maintaining its current share (7%). In the 4DS scenario, some emissions reduction is seen, largely due to efficiency improvements in fossil generation, fuel switching from coal to gas and some renewables becoming increasingly competitive in good locations. The average CO_2 intensity in the 4DS scenario in 2050, however, is only slightly lower than a very efficient gas plant by current standards.

Fig. 1-17 Global electricity generation capacity by technology

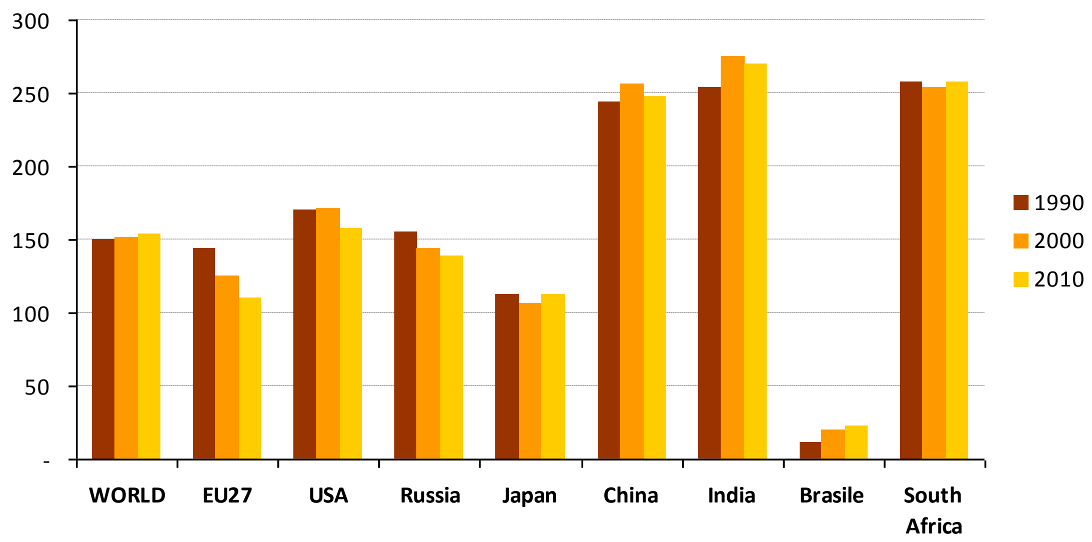


Source: IEA ETP 2014

According to IEA estimates, the electricity mixes that power the networks of the various railway systems offer a much diversified picture. The carbon intensities vary widely, and there has been no consistent evolution between 1990 and 2010 throughout the world (see Fig. 1-18). Significant improvements in the emission factor can be seen only for USA, European Union and Russia. In other countries, the carbon intensity of electricity is substantially stable.

There are also several differences in the comparison between countries: in 2010, with a world average of 154.18 gCO_2/MJ, there are much higher emission factors such as in China (247.14 gCO_2/MJ) and India (270.08 gCO_2/MJ) and much lower emission factors such as in EU, Japan and Brazil. In Brazil specifically, the share of renewables in electricity generation is close to 90%, causing a carbon intensity of the electricity mix seven times lower than the world average (22.14 gCO_2/MJ).

Fig. 1-18 Carbon intensity of electricity mixes in select railway systems (gCO_2/MJ)



Source: UIC/IEA Railway Handbook on Energy Consumption and CO_2 Emissions (2013 edition)

It is then clear how a progressive electrification, coupled with a reduction of the emission factor for electricity generation, can deeply improve the carbon intensity of the world railway sector. It is worth noting that one of these factors is "internal" to the railway sector (electrification) and one is "external" (the electric emission factor), i.e. railways have no control over it.

It is possible to estimate the *elasticity* of these two reduction factors (electrification rate and emission factor of electricity) with respect to the carbon intensity of railways, i.e. in what measure the variation of each factor can influence the variation of the carbon intensity. On a world level, the improvement obtained by the railway sector between 1990 and 2010 can be attributed mostly to electrification. Only in the EU both drivers have had a comparable impact throughout the years.

It is still worth reminding that there are also other drivers that may have an impact on specific emissions: passenger and freight production (and the respective load factor in particular), and the increase in the use of biodiesel.

1.2.5 Final considerations on the feasibility of targets

As previously said, the IEA elaborations demonstrate that there has been a 29% worldwide reduction of specific emissions for the railway sector between 1990 and 2010.

With the expected increase in electrification and improvement of the electric emission factor, the potential improvements are considerable, even more than for energy intensity; this could confirm the assumptions of the IEA 2DS scenario, on which the targets definition is based.

Railways are already featuring the lowest values of emissions per pkm and tkm among all transport modes, thanks to the high rate of electrification. The railway sector can enjoy without any additional investment the improvements generated by the progressive decarbonisation of electricity.

The UIC Environment Strategy Reporting System (ESRS) methodology collects the energy consumption data from railway companies, then – in order to calculate the corresponding emissions – uses the electricity mixes published by national and international organisations such as IEA and Eurostat and the emission factors established by IPCC.

Furthermore, the recent update to the ESRS methodology adopts a “dual reporting” system, outlined in the GHG Protocol standard, for green electricity instruments such as GOs or RECs. There will thus be a separate view of emissions generated, one which uses the national electricity production mix and the other that takes into account the green electricity instruments. This will guarantee the highest level of transparency.

The reduction of carbon intensity allows the world railway sector to avoid 98 Million tonnes (MT) of CO_2 in the freight sector and 23 MT of CO_2 in the passenger sector, i.e. 121 MT CO_2 in total compared to the 6DS scenario.

2 Modal shift challenge

2.1 Targets for Modal shift: framework, description and methodology

2.1.1 Framework

The current transport system, based mainly on vehicles powered by fossil fuels, generates unsustainable social, environmental and economic impacts. The strategy to pursue a better sustainability is composed of three integrated lines of action, called *Avoid/Shift/Improve* (ASI): *Avoid/Reduce* the demand for mobility, *Improve* the efficiency of the vehicles, and *Shift* to more sustainable modes of transport (or *Maintain* their usage levels). In this last line of action, the role of railways is essential.

On an environmental level, the real challenge of railways is not just to reduce their specific impact on energy consumption or carbon emissions, but to expand their market share. Currently, the energy consumption and CO_2 emissions of railways are substantially lower than other transport modes: therefore, rail is one of the transport modes towards which mobility has to be *shifted*.

2.1.2 What is a modal shift challenge

A modal shift challenge does not entail making forecasts or outline a plan. It means to:

- Define a challenging objective
- Commit to reach the objective with the instruments at hand
- Outline the enabling conditions allowing to reach the objective
- Involve key partners and stakeholders

The targets of the challenge

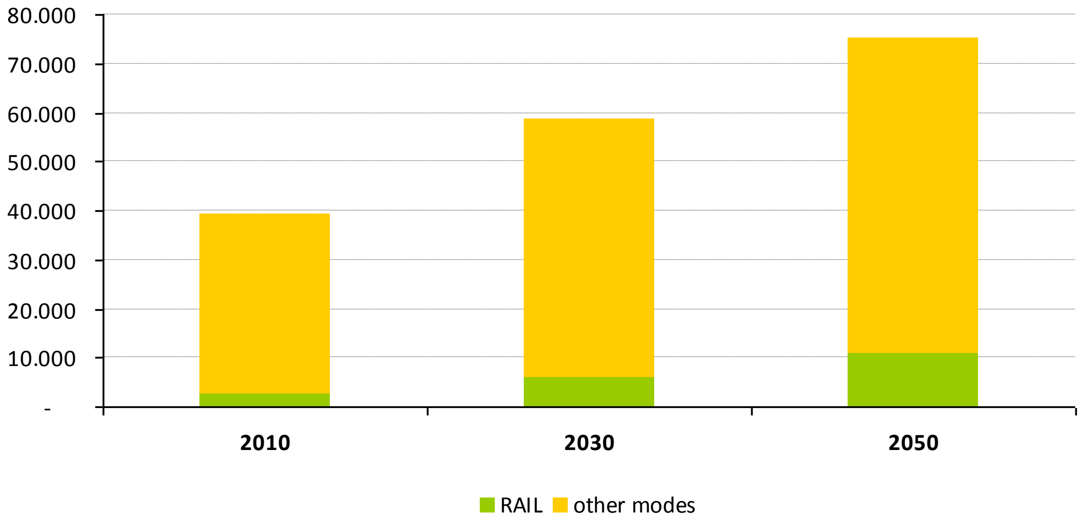
The modal shift challenge is based on the definition of two targets for the railway sector at a worldwide level, both for passenger and for freight transport. The targets are referred to a global scale, i.e. to the whole world railway sector, and are measured respectively in passenger-kilometres (pkm) for passenger transport and tonnes-kilometres (tkm) for freight transport.

The targets are based on the estimates produced by the International Energy Agency (IEA) for the transport sector in the definition of the 2DS scenario, used also in the analysis of the Intergovernmental Panel on Climate Change (IPCC) and mentioned in the previous sections.

In passenger transport the challenge is to increase the passenger modal share of rail by 50% in 2030 and by 100% in 2050 compared to 2010.

The modal share of rail is calculated with respect to all other passenger transport modes, i.e. road, aviation and navigation.

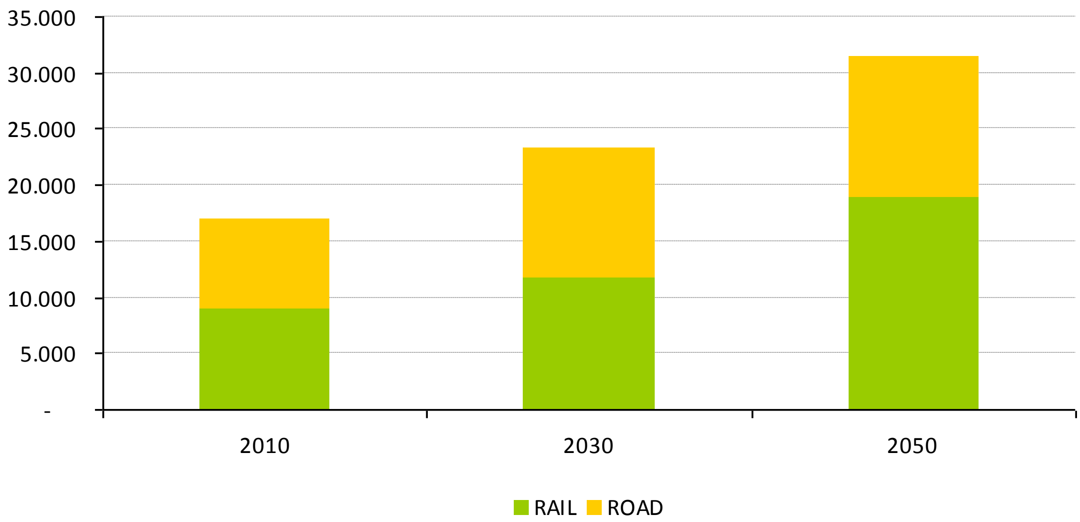
Fig. 2-1 The modal shift challenge for passenger transport (billion pkm)



In freight transport, the challenge is to reach the freight modal share of road in land transport in 2030, and exceed it by 50% in 2050.

In this case, the modal share of rail is calculated with the exclusion of navigation and aviation.

Fig. 2-2 The modal shift challenge for freight transport (billion tkm)



These targets are ambitious and reachable in view of a development of a Green Economy; they set themselves to be an essential requirement to reach the objectives of the IEA 2DS scenario.

Shift to rail/mantain the rail

The term “modal shift” is tied to the evolution in the organisation of transport in OECD countries, where road and air transport have been continuously growing their share. The modal restructuring implies in this case a “shift” from less sustainable modes to more sustainable modes such as railway.

In several other countries and regions, however, the modal share is already favourable to rail. What is happening there today is in fact a shift towards less sustainable transport modes. In this context, the term “modal shift” can be misleading if it is intended to be a shift towards rail. The meaning of the ASI strategy here is to stop the modal shift to less sustainable modes, or in other words “maintain” the modal share of rail when an increased demand for mobility arises.

This is also the perspective for those developing countries in which railways currently have a very limited role or none at all, such as in many African countries. It is forecasted that Africa will be the second most-populated continent by 2050, after Asia[11].

2.1.3 Methodology

Sources

For the definition of the modal shift targets for the world railway sector, the same sources have been used as in the previous sections regarding energy and carbon intensity. More sources used are the quantitative analyses of the IPCC reports, in particular the 2013 report, WGIII AR5 – Mitigation of Climate Change relative to the transport sector, and the ITF Outlook 2012 and 2013.

Definition and verification of the targets

As noted previously, the IEA has defined three fundamental scenarios at a world level: 6DS, 4DS and 2DS, referred to the potential increase of the world average temperature in 2050. In ETP 2012, the IEA has defined two sub-scenarios: "2DS Improve" and "2DS Avoid/Shift". In this last scenario, through its Mobility Model (MoMo), IEA makes some estimates for 2030 and 2050, compared to base year 2010, for:

- Transport demand
- Passenger and freight modal share
- The activity for all modes (except navigation) in pkm and tkm

The IEA has recently published an update of its Energy Technology Perspectives (ETP 2014), focused on the electrification of transports and the elaboration of specific scenarios on the topic.

At the UIC's request, the IEA has also provided elaborations made for ETP 2014 on some key countries for railway production such as USA, EU, Russia, China, India, Japan, Brazil and South Africa, as well as some underlying assumptions for the 2DS Avoid/Shift scenario.

On the basis of these elements it was possible to outline the world modal share for passenger and freight transport projected by IEA in the different scenarios for 2030 and 2050, with a focus on the differences between the 4DS scenario (taken as a "business-as-usual" – BAU – scenario) and the 2DS scenario. Both the reduction of transport demand and the modal shift anticipated by MoMo have been taken into account.

The future trends have then been evaluated in light of:

- The historical evolution, both globally and in the different regions considered separately;
- The key factors that have determined past modal changes and that will play a crucial role in the future as well;
- The evolution of transport demand;
- The probable evolution of some key indicators.

Following this critical evaluation, the targets of the challenge have been determined, and the potential ensuing reductions have been assessed, based on the IEA estimates.

2.2 Modal shift

2.2.1 Long-term scenarios (2030 and 2050) based on IEA 2DS and 4DS scenario

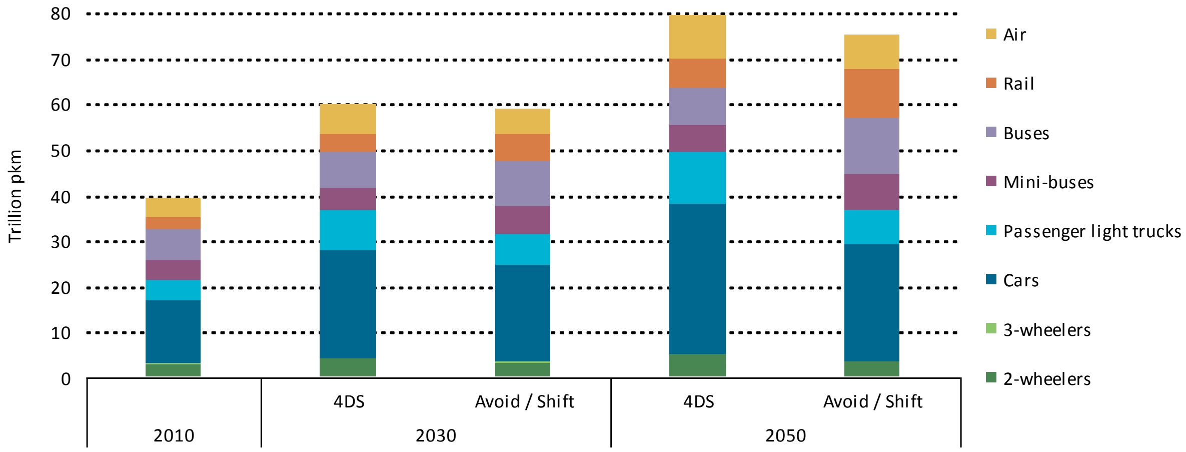
The IEA Avoid/Shift sub-scenario analyses the potential effects of policies oriented to modal shift and to the reduction of transport demand[12]. In the passenger sector, the Avoid and/or Reduce policies are considered

[11] The factors generating an increase in transport demand are several: the most important are considered to be the increase in population, the urbanization and the increase in disposable income.

[12] IEA stresses the important contribution that can come from modal shift particularly in an urban environment, where a higher growth and concentration of population is expected in the next decades. An intelligent growth of the cities can reduce the distance and number of movements, and promote the use of more sustainable transport modes such as public transport, cycling and pedestrian mobility.

to have more significant effects in the long term, while by 2030 the modal shift is expected to have a greater effect on the reduction of the environmental impact of mobility.

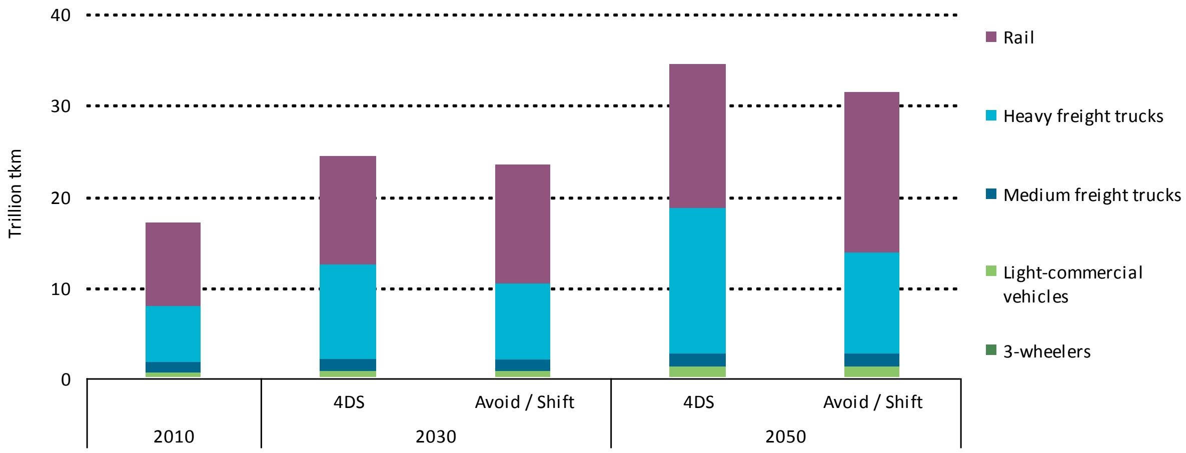
Fig. 2-3 Volumes of passenger traffic and modal share estimated by IEA



Source: IEA ETP 2012

The railway traffic, both on medium-long range and on urban/suburban distances, can increase considerably and reduce the weight of road transport and aviation. In the land freight transport sector as well, the impact of policies oriented to modal shift on rail is relevant and can be up-and-running in the medium term.

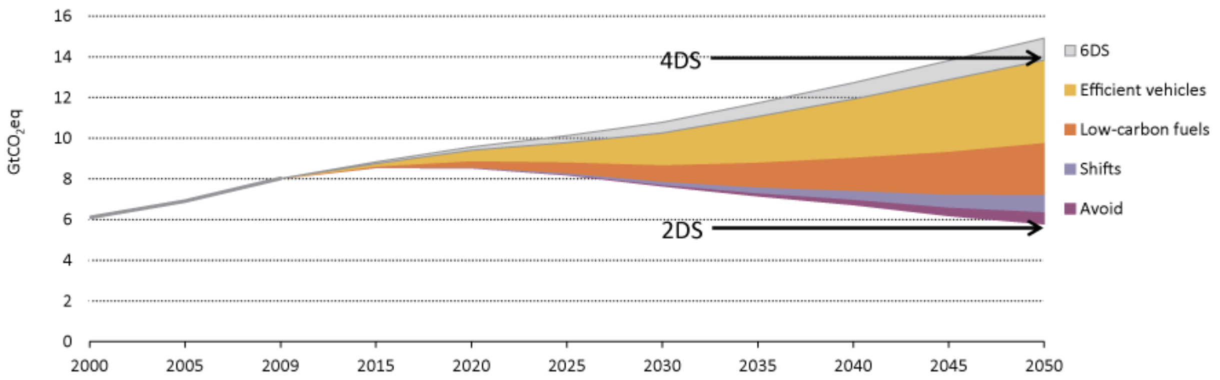
Fig. 2-4 Volumes of freight traffic and modal share estimated by IEA



Source: IEA ETP 2012

The combination of the effects of the scenarios *Avoid/Shift* and *Improve* can trigger a reduction in emissions of the transport sector by around 8 $GtCO_{2eq}$ by 2050 compared to the 4DS scenario, with a contribution of 1.4 and 6.6 $GtCO_{2eq}$ from the Avoid/Shift and the Improve scenario respectively.

Fig. 2-5 Greenhouse gas emissions of the transport sector estimated by IEA



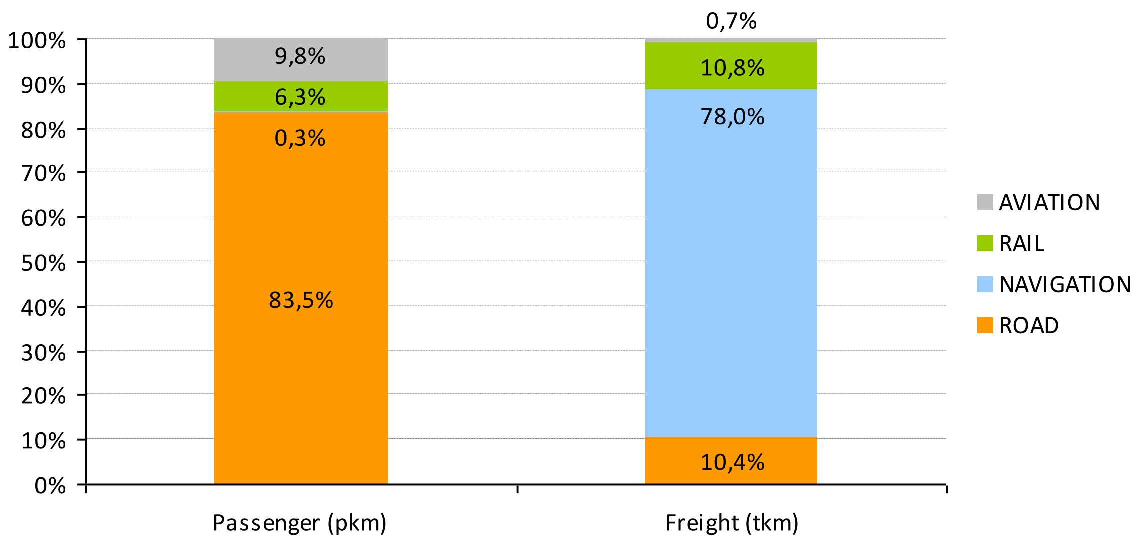
Source: IEA ETP 2012

2.2.2 Trend analysis

The World Today

In the absence of statistical data collected with consistent methodologies and available for all the world's regions, this report usually refers to the estimates of the IEA Mobility Model (MoMo). The MoMo contains historical data and projection to 2050 for all transport modes and vehicle types. XX shows the modal share for the year 2011 according to the MoMo database, updated by IEA in conjunction with ETP 2014[13].

Fig. 2-6 World modal share for passenger (pkm) and freight (tkm) transport



Source: IEA MoMo

The world modal split is a result of the modal splits of different countries, which vary widely. It is possible to understand how deep those differences are by using some of the MoMo estimates for the year 2010 (IEA ETP 2014)[14], associated to some of the larger transport markets in the world.

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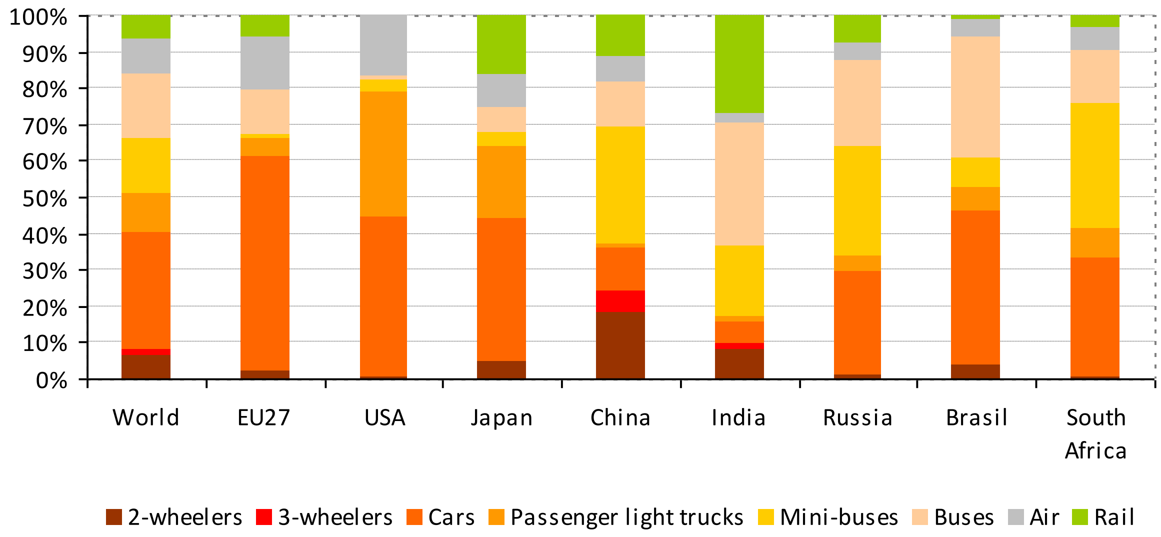
[13] In these estimates, the IEA has excluded the modal share of pipelines.

[14] In the MoMo results used for ETP 2012 and ETP 2014, and used for several elaborations in this publication, the share of navigation and aviation in freight is not available. The freight modal share reported is intended only for land transport.

For instance, the share of passenger road transport is high everywhere, but Brazil has a value higher than the world average (94.3%) together with Russia and South Africa, while India has the lowest value (70.3%). USA, China and EU27 have values that tend to remain close to the world average.

If we increase the segmentation, the high inhomogeneity between transport markets shows even more. In Europe[15] for example, road transport is dominated by cars (59.5%) and public buses (12.8%) with a low penetration of 2-3 wheelers and minibuses; in BRICS countries, the latter vehicles have a much higher share while the proportion of cars is lower. This is likely to be due to the difference of per-capita income between these two areas of the world. In the United States, a high share of road traffic volumes is made by "passenger light trucks", a vehicle little used in Europe. The share of passenger air transport in the USA and EU is higher than the world average. As for passenger railways, two of the BRICS countries (India and China) have values higher than average (26.8% and 11.4% respectively), as does Japan with 16.4%. EU27 has a value of 5.8% slightly lower than the world average, and the USA have nearly zero passenger railway transport.

Fig. 2-7 Passenger modal share for world and for select countries estimated in 2010 (% of pkm)

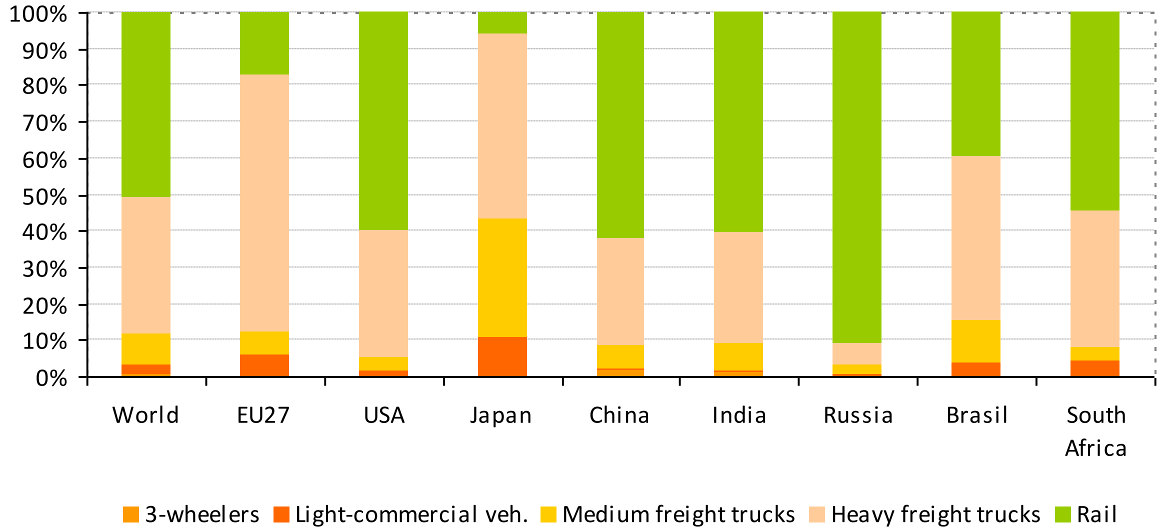


Source: IEA MoMo (ETP 2014)

Similar differences can be registered in freight traffic. The share of road and rail transport and of the different vehicles used is quite diversified, often with radically different tendencies compared to passenger transport. The United States for example, which have barely any railway passenger transport, are one of the largest markets in the world for freight railways (60.1% of share). Russia, pipelines excluded, transports nearly all freight on its railways; China's freight rail has a 62.2% of land freight share and India has 60.4%. Other BRICS countries have also railway performances much higher in freight than in passenger transport. On the other hand, Japan and EU27 have lower performances for freight railways: in particular Europe has one of the lowest market shares in the countries considered in this study.

[15] Even inside the EU27 there are significant differences, in particular between former Communist Bloc countries and the original European Community countries. Lately, there are also some differences between some geographically core countries, such as Germany, and peripheral countries such as Italy, Spain and Greece.

Fig. 2-8 Freight modal share for world and for select countries estimated in 2010 (% of tkm)



Source: IEA MoMo (ETP 2014)

From this quick analysis, it is clear how in the passenger sector it is harder to find some critical factors explaining such different performances; on the other hand, in the freight sector, it can be observed that in countries with an extended and homogeneous territory are more favourable to railway freight transport, while countries or regions which are smaller or fragmented by internal geographic barriers are less auspicious of railways as a means to transport freight.

The selection of the countries mentioned above, which will also come back later on, comes from a consideration: the global railway offer and demandi s concentrated in few countries and regions of the world. When passenger and freight volumes are put together, six railway systems account for around 90% of world rail activity: North America, China, Russia, and India for freight, and India, China, EU15, Japan and Russia for passenger traffic.

The data shows a transport market with different trends:

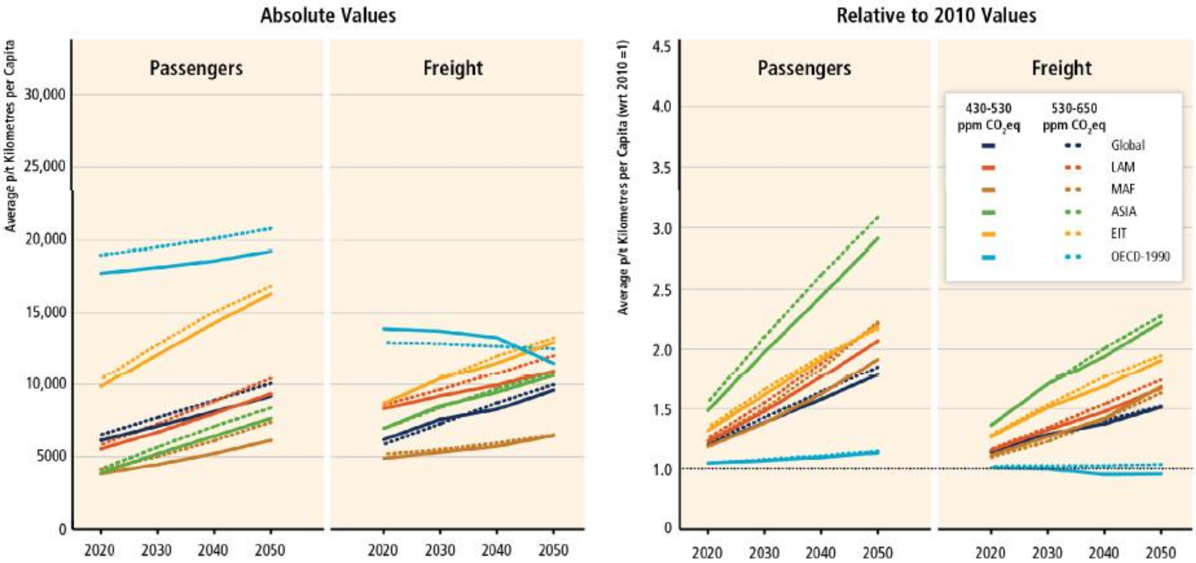
- Europe: railways are losing market share both in passenger and freight transport, even though the transport demand is stable or slightly growing in time.
- North America: railways transport almost exclusively freight. The demand grows since the Eighties both in absolute volumes and in market share.
- Japan: here, railways are almost exclusively for passengers, with a market share currently stable after a noticeable contraction between 1970 and 1990.
- China: in two short decades, the transport demand for all modes has exploded. Railways have held their ground and still keep a significant market share.
- Russia: railways are a dominant mode of transport, particularly for freight. The other transport modes do not grow with higher rates than railway.
- India: the market share of railways is being halved, both in passenger and freight, due to a smaller growth rate for railways compared to other modes in a context of a great increase in transport demand in the last decades.

2.2.3 Transport demand: estimates for 2030 and 2050

The world transport demand in the near future is a crucial challenge for the reduction of the impacts of mobility. It is extremely complex to make predictions and estimates and to build future scenarios.

According to the IPCC WGIII AR5 scenario[16], the transport demand – for both passenger and freight – will grow in the next decades until 2050 (see Fig. 2-9), with most of this growth happening in emerging countries, where higher rates of income and population growth are forecasted. All scenarios analysed by IPCC show how, due to a strong correlation between passenger mobility and disposable income, **the highest rate of growth will be in non-OECD countries**. IPCC estimates that freight demand grows with lower rates than passenger demand, with a decoupling between demand growth and GDP forecasted to happen earlier in the passenger sector.

Fig. 2-9 Per-capita passenger and freight demand in different regions based on scenarios differing by CO_{2eq} concentration levels in 2100 (average pkm and tkm per-capita per year)



Source: IPCC

The IEA[17], in the 6DS and 4DS scenarios, conjectures that the global passenger demand, in a BAU perspective, will double between 2010 (baseline) and 2050, with an average rate of 19.3% in 10 years. In the Avoid/Shift scenario, where some measures to slow the demand growth are evaluated, the 10-year growth rate is reduced to 17.6%. The IEA assumes that the passenger demand will rapidly increase, in particular in non-OECD countries, because of multiple factors: among those, the forecasted growth in population and income[18]. The global growth will be partially mitigated by the stabilization of transport demand in OECD countries. In a BAU scenario, the forecasted growth rates of freight transport demand is not lower than passenger transport demand growth rates, while in the Avoid/Shift scenario the 10-year growth rate goes from 19.5% (BAU) to 16.7%.

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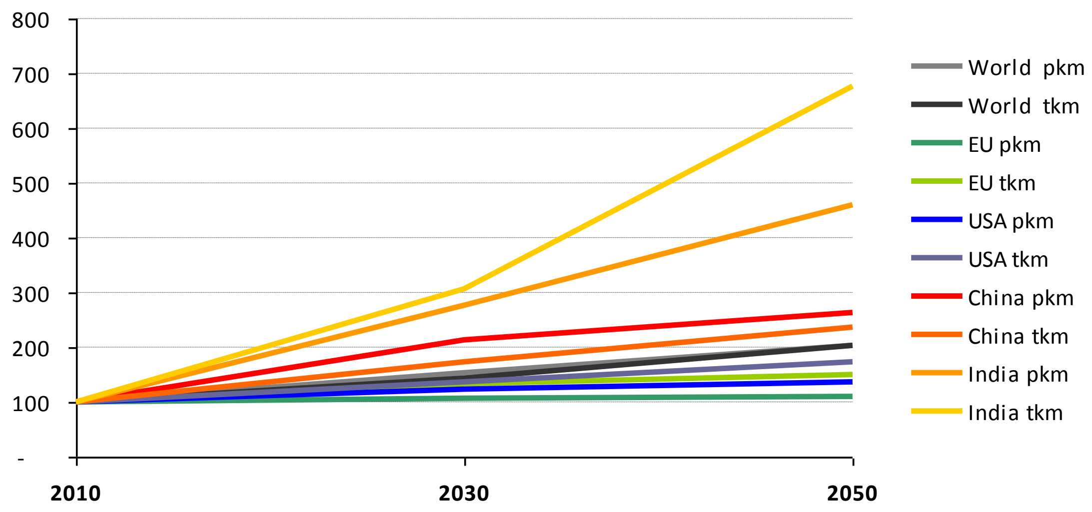
[16] The IPCC WGIII AR5 is based on the analysis of more than 1200 existing scenarios

[17] ETP 2012

[18] The passenger transport demand in 2050 according to IEA will be around 80 trillion pkm. The estimates contained in ETP 2012 are consistent with the estimates made in 2009.

Fig. 2-10 Growth of passenger and freight transport demand according to the IEA 6DS and 4DS scenarios, for World, EU, USA, China and India (2010=100) (100=2010)



The International Transport Forum (ITF) of the OECD has revised its estimates[19] on the growth of transport demand downwards, taking into account the revisions of the forecasts on global economic growth with the medium-long term impacts of the 2008 crisis in the transport sector. The 2013 ITF Outlook focuses its scenarios (2050 horizon) according to different hypotheses of global economic growth, where it is assumed that the 2008 shock had permanent effects on global production and a standard rebound is not possible.

The estimates on 2050 demand are different according to the assumptions of economic growth and the policies chosen: policies favourable to privately owned cars (*Private transport oriented/high roads*) or favourable to public transport *(Public transport oriented/low roads)*. The 2013 ITF Outlook forecasts that the passenger demand[20] in 2050 will evolve in correlation with the growth of GDP, the prices of fuels and the development of urban transport, with a growth factor of 1.9 to 3.7 compared to 2010. In the *central* scenario the growth factor is 2.4, with a low GDP growth, and 2.9 for the *baseline* scenario. ITF confirms that the growth distribution is different for OECD and non-OECD countries according to different growth factors (respectively between 1.3-2 and 2.9-6.5), as are different the modal shares of private cars and 2-wheel vehicles. The growth rates estimated at 2050 by ITF for land freight transport are also quite different for OECD and non-OECD countries: between 42% and 124% for the former, and between 100% and 430% for the latter, compared to 2010.

2.2.4 Factors influencing modal share

Supply-side factors

The railway sector is in measure to intervene on some of the factors which influence the modal share. An increase in productivity, for instance, can encourage a price competition on certain segments of the transport market and promote the choice of rail. Similarly, the introduction of a new product can have positive effects on the rail modal share: e.g. the high-speed rail, which has often conquered a significant portion of market share from aviation.

These are necessary and decisive actions that, however, have to be done in conjunction with investments in infrastructure which are essential for the development of the transport service. The investments in rail

[19] The scenarios are still defined from the IEA Mobility Model

[20] In the 2013 Outlook the estimates are expressed in vehicle-km, and not in passenger-km.

infrastructure, due to their high costs, often have to be connected to the adoption of specific transport policies by public institutions.

The investments in railway networks have also to be evaluated in relation with the investments made on the competing modes. It is often believed that the investments on rail are always new lines and rail corridors needing huge expenses. In fact, the investments needed to increase the efficiency and effectiveness of rail transport[21] can also be smaller: e.g. the reduction of bottlenecks, the modernization of signaling systems, the increase of axial loads and loading gauge in some strategic sections of the network. The investments can also be on building or improving the inter-modal nodes dedicated both to freight (ports, logistic centres) and to passenger traffic (stations, parking facilities, connections with public transport).

Demand-side factors

The modal share is influenced also by demand-side factors such as the generalised perceived cost of travel[22], the disposable income, the underlying needs of travel and the subjective expectations connected to socio-cultural factors.

In the generalized cost of travel factor, for instance, there is a key role played by the accounting of external or hidden costs. **Without a mechanism to internalize the external costs**, the choices of consumers are made in a transport market that doesn't work correctly and hampers the more sustainable modes of transport[23].

An urban planning which does not take into account the social, economic and environmental impacts of mobility will influence – often in an irreversible way – the transport demand and the modal share. The correlation of urban sprawl with the dependency from the use of cars or trucks is well known, for example.

2.2.5 Shift to rail/mantain the rail:what and where

There are technical and economic constraints – always in evolution – that determine the market segments in which railways can be competitive with other less sustainable modes such as cars, light and heavy-duty vehicles and aviation. The necessary condition for the train to be preferred to modal alternatives is that railways are able to offer a **competitive product/service** on a specific mobility segment[24].

Currently, with reference to the experiences collected in different geographic areas and railway systems, the greater potentialities of railways can be seen mainly in some market segments where the train has the technical means to compete for significant market shares with other modes of transport:

- Commuter rail vs. private car;
- High-speed train vs. plane;
- Medium-long range rail (high-speed included) vs. private car;
- Freight rail vs. trucks;

[21] The interventions for the increase of productivity and profitability of the network are generally aimed at the increase in capacity (in terms of number and types of trains going through the network per day), in speed and interoperability.

[22] The generalised cost includes monetary costs and the value of time. In the general supply/demand theory, in case of a perfectly competitive market for goods and services, the price takes the place of the generalized cost.

[23] The current reality sees the presence of subsidies to less sustainable modes of transport, e.g. the tax breaks or incentives for fossil fuels in aviation and in road transport.

[24] One of the more significant segmentations is based on the optimal range of the different transport modes. The optimal range is intended as the range that can be served best by a specific mode of transport in terms of efficiency and effectiveness. The efficiency integrates in the range the optimal use of the "value of time".

- Freight rail vs. cargo ships.

The outcome of this competition, in case the railway prevails, determines a potential reduction of the impacts of transport.

Local/urban mobility: commuter rail vs. private car

Rail can potentially serve very well the great volumes of traffic centered in the metropolitan cities, coming and going from the suburbs and the outskirts of the city. The car congestion of the roadways entering the city are a competitive advantage for rail: many successful examples of commuter train can be quoted from European, North American and Asian cities. An urban development tightly connected to the railway system is a great opportunity for railways and for the livability of large cities.

Medium-long range mobility: high-speed train vs. plane

In countries which were early adopters of High-Speed Rail (HSR), e.g. in France, several studies have shown how its introduction has triggered a direct competition with airlines. HSR is definitely faster and cheaper than a plane when travel time is lower than 2 hours. When the train travel time is more than 4 hours, the plane is faster than the train and has the majority of market shares. When train travel time is between 2 and 4 hours, the competition between rail and aviation is very strong.

Medium-long range mobility: intercity train (including HSR) vs. private car

Both High-Speed Rail and Intercity[25] can compete with the car in the movements above a certain distance. This also depends on certain factors, e.g. the geographic characteristics of a country, the travel time difference between rail and car, the train schedules and the density of train stations. There are countries such as Switzerland, Germany or Japan[26], where well-performing Intercity services on some routes engender modal shares for rail well above the modal shares for road.

There is a very strong correlation between the modal split between rail and road and the travel time needed for each mode: thus, only fast railway networks with frequent connections can compete with road transport. All this is possible on some conditions, e.g. a high population density with an equally high density of railway offer and demand.

Medium-long range mobility: freight train vs. truck

Railway freight traffic is a strategic transport system and plans to keep such a position. In EU27, since the year 2000 rail freight is gaining ground in all railway companies, especially Deutsche Bahn. In Switzerland and Austria, railway transports more than 50% of freight, in a context where railways have been assigned specific environmental objectives. In the USA as well, freight rail has gained market shares since the mid-Eighties.

Railway transport is extremely efficient to transport raw materials for industrial activity (e.g. steel, chemicals, automotive) and for container traffic, tightly integrated with naval and road freight. The main feature of freight rail is to operate on long distance: the challenge for the whole railway sector is to constantly reduce the distance in which rail transport is effective, and gain market shares in commercial sectors which are not using railway transport, or very little. All this is possible, and demonstrated by several

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[25] Generally speaking, Intercity trains connect stations of different cities with a high demand. They differ from local/regional trains on price, commercial speed and fleet used. Depending on railway systems, the distance between terminal stations can vary, as well as the distance between stops (which is usually larger than for local/regional trains).

[26] All the countries mentioned are characterised by a high per-capita income, extremely developed networks of roads and highways, and rates of penetration for private cars much higher than the world average.

success stories, through technological and organizational improvements that increase efficiency, security and reliability of transport.

Medium-long range mobility: freight rail vs.cargo ships
Given a specific distance, freight transport through ships is more efficient than rail. Freight rail – where geographically feasible – can be competitive with navigation when it can significantly reduce the distance travelled by the goods. This is the case of the trans-Asian rail network that connects the markets of China, India and Europe, or the North-South Europe railway corridors which can guarantee access to Central Europe for the merchandise crossing the Suez strait, using the Mediterranean ports and avoiding Gibraltar.

2.2.6 Conclusions

Asia accounts for the majority of the projected growth in transport demand and presents the greatest opportunities for meeting the modal share targets through investments in low carbon rail transport. In countries like China and India, it is necessary to balance the growth of private motorised vehicles and road freight (coupled with economic growth) with strong investments in rail and public transport. Today, China alone represents more than 25% of worldwide rail freight tonne-kms, and India represents one third of worldwide passenger traffic with one of the highest market shares for rail. The challenge lies in moving to low carbon energy sources whilst maintaining and consolidating this strong position for rail, in spite of the growing demand for less sustainable modes.

North America has an established and thriving rail freight system operated mainly by the private sector. However there is enormous potential to further develop urban and inter-urban passenger rail efficiency and coverage (e.g. modal shift from air to High Speed Rail), particularly on the East and West coasts. The challenge requires a move away from “business as usual” (rail passenger share is currently only 1%) so that by 2050 to the modal split is similar to that of leading European countries.

Russia (and former Soviet Union countries) presents today a very high market share for railways, both in freight and in passenger services. It is necessary to consolidate this position through improvements in the railway network capacity, reaching greater efficiency and aiming at more specialized logistic networks.

In Europe, whilst projected increases in transport demand are modest, there is a strong record of year-on-year improvements in efficiency. The extensive rail network has a huge potential for passenger and freight increased capacity (modal share) as highlighted in the EU transport White Paper: 50% freight transport – for distances longer than 300 km – shall be transported by rail or water in 2050; the existing high speed rail network length should be tripled and medium distance passenger transport should be mainly on rail by 2030.

South America has examples of successful freight rail systems. However there is large potential to expand the rail share of transport activity. Brazil, in particular, can aim at reversing the dominance of road transport over rail by developing urban passenger services and high speed connections between cities.

Australia has well-established urban and freight rail networks. There is great potential to develop both of these with the addition of high speed inter urban transport (particularly on the east coast) and more developed commuter trains within the major cities.
In 2050 Africa, the second-most populated continent in the world after Asia, will collect 20% of the world population. Commercial internal exchange between African countries is nowadays not big, but it is rapidly growing. The continent suffers from a low integration of railway systems and widespread scarcity of infrastructure and rolling stock. The challenge consists, for freight transport, in creating railway corridors

interconnected with ports and able to foster multimodality; for passenger services, in sustaining the very ambitious programs that have been launched (e.g. by South Africa and Morocco, where new high-speed lines are being planned).

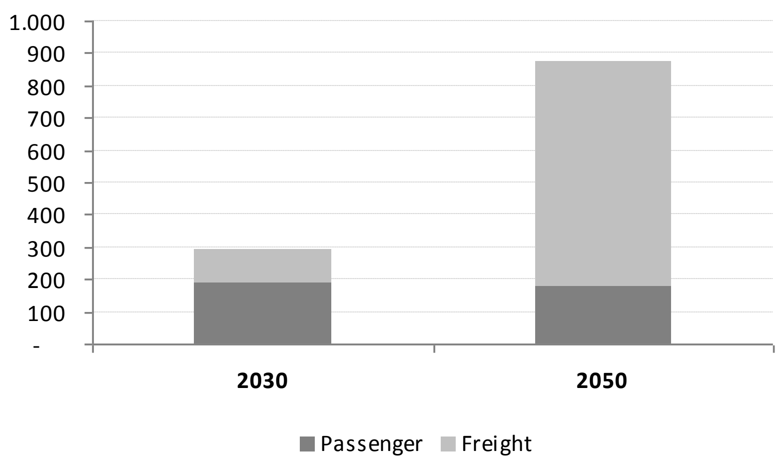
All scenarios on population growth, GDP growth, expansion of big cities and international trade, show Middle East as one of the areas with highest potentialities in future rail transport both in passenger and freight services. Turkey and Iran (who currently own more than 70% or railway infrastructure in the area) have developed important plans of railway business expansion[27], investing both in international freight corridors and in urban and intercity routes for passengers (e.g. in Turkey, where a first leg of the Ankara-Istanbul line is working).

Regarding the flows from other modes to rail, the assumptions taken by the IEA Mobility Model are very complex. They can be summarized as follows for what regards the horizon 2050:

- The passenger modal shift towards more sustainable modes comes about 20% of pkm from passenger cars, 40% pkm from light trucks and SUVs, another 30% from 2-wheel vehicles and 45% from 3-wheeled vehicles. Of these pkm, about 25-30% goes to rail, the rest going to buses and other collective transport.
- An additional shift of about 25% from air pkm in 2050 gets shifted, with about 50% going to rail, the other half "avoided".
- For freight, about 30% of heavy freight tkm is shifted from trucks by 2050 to rail.
- In IEA 2DS scenario, thanks to these modal flows the passenger share of rail is estimated in around 10.1% in 2030 and 14.4% in 2050. The modal share of land freight reaches 49% in 2030 and 46% in 2050.
- Unlike the targets for energy and carbon intensity, the definition of the modal shift targets of this challenge goes beyond the forecast of IEA: some of the assumptions of the IEA 2DS scenario shown in ETP 2012 seem to be exceeded by the enabling conditions mentioned in the previous sections, conditions which are absolutely necessary for a transition of transport towards green growth[28].

Fig. 2-11 shows the estimate of CO_2 emissions that can be avoided by reaching the objectives of the modal shift challenge. To calculate those estimates, the reduced specific consumption and emission targets for 2030 and 2050 has been used for all passengers and freight shifted to rail.

Fig. 2-11 Modal shift challenge GHG reduction ($MtCO_{2eq}$)



[27] According to its 20 year outlook plan, Iran's railway lines are to reach 25,000 kilometres by the year 2025.
[28] As a matter of fact, in the IEA ETP 2014 publication which has just been published, the estimates for modal shift to rail in freight in the 2DS scenario are more optimistic and are in fact in line with the estimates of the Challenge.

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