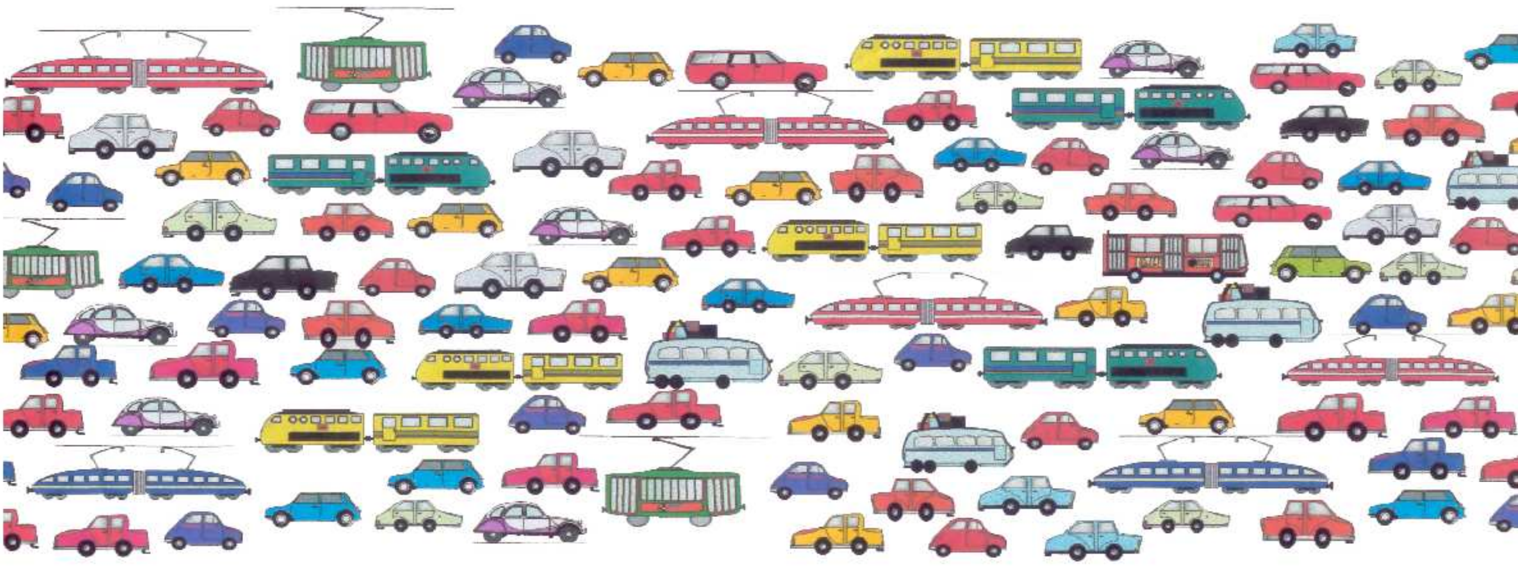
SUSTAINABLE DEVELOPMENT FOUNDATION
Fondazione per lo Sviluppo Sostenibile

Co2 emission reduction from modal shift to railways (Pre-Study)



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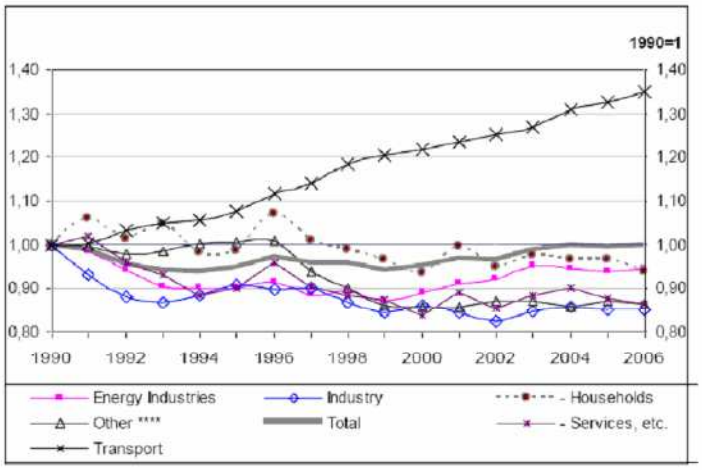
1 Topic of the study

Transport's carbon footprint is *the* issue to be solved if Europe wishes to realize its ambitious targets of Co2 reductions for 2020.

Volumes in Europe are constantly increasing and transport demand scenarios for the next decades confirm this trend. The split of the transport volumes (and market shares) betwe\en transport modes is still unbalanced: road, in particular, is predominant in both passengers and freight. This unbalanced situation determines heavy environmental effects, in particular on GHG emissions.

As clearly visible in Figure, in the last 20 years transport sector CO_2 emissions increased by nearly 40% in Europe, while in all other sectors the "Kyoto" targets have been more or less achieved.

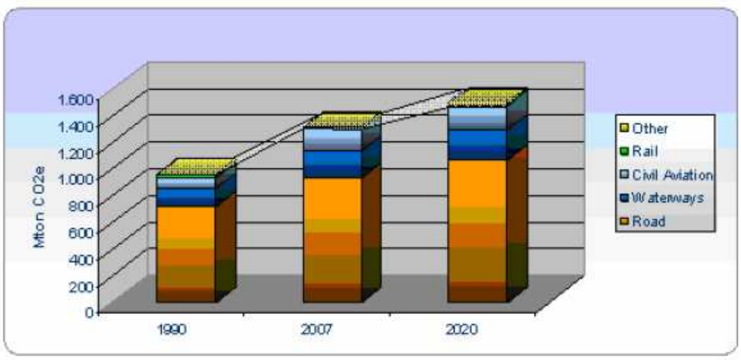
Graph 1 – CO_2 emissions by Sector, EU-27



Source: EU 20-50 GHG Routes study (2009)

The 2008-2009 financial and economic crisis has reduced this negative trend, but still comparably less than in other sectors. The emissions may continue to grow until 2020 within a range of up to 1.400 CO_2 Mton.

Graphs 2 – CO_2 transport emission 1990-2020 without modal shift

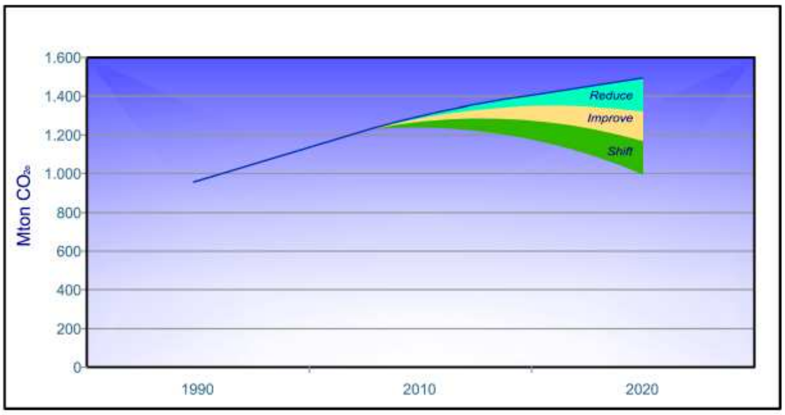


Source: Transport emissions data EU27 1990-2007: EEA (2007) and reported in DGTREN (2008) Transport emissions data EU27 2020: elaboration Fondazione Sviluppo Sostenibile

EEA showed recently that transport emissions projected at 2050 will higher than the total emission targets for all sectors, and a CER/UIC recent paper analyzed that, based on current trends, a major "emissions gap" will most probably occur in transport in 2020 already. This gap could range from 13% to 23% .

Action is needed, and only a strong policy based on the threefold strategy "avoid, shift, improve"could be effective in the medium term.

Graphs 3 – CO_2 emissions from transport sector



Some initiatives have been realized in order to implement the *"improve"* principle, in particular within vehicle emission targets legislation and Intelligent transport systems dissemination and EEA recently raised awareness on how *reducing* transport demand is important.

The aim of this study, thus, is to focus the investigation on the possible "*shift* " to railways and on its potential of reducing CO_2 emissions from transport.

It is generally known that shifting people and goods from road and air transport to railways can lead to substantial reductions in CO_2 emissions, as many EU analyses, good practice examples and some member's state policy can already prove. Can we assess the modal shift potential contribution to the achievement of EU 2020 targets in terms of CO_2 Mton reduction, with a reasonable and sound approach?

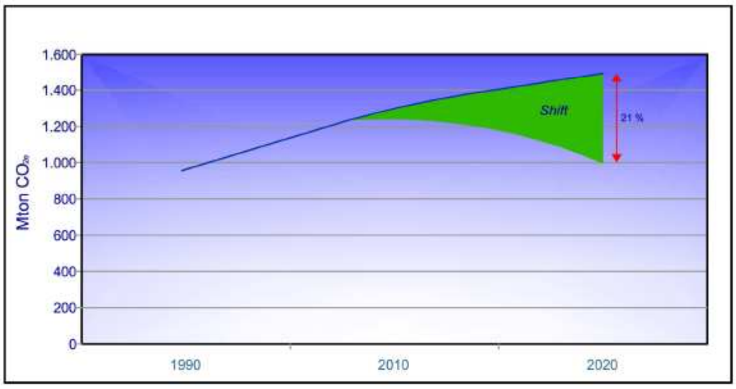
Can we scientifically determine how much CO_2 reduction European railways could technically realize in freight and passenger services?

A proven 10% possible reduction of transport emissions by modal shift alone in 2020, for example, could be a significant input for transport planners and policy makers.

The EU commission recently launched the study "EU Transport GHG: Routes to 2050", a major piece of work which led to a number of draft reports produced in September-December 2009 . The draft chapter of this study dedicated to modal split and decoupling options states that " *there are no reliable estimates available for the overall GHG reduction potential of modal shift*". Nevertheless the study shows that there might be a potential CO_2 reduction from modal shift to railways in a range from 2 to 16% in passenger transport and from 4 to 23% in freight transport, depending on different cases and scenario.

A first theoretical analysis shown in the context of Copenhagen COP15 indicates that the shift of 25% of transport units from air and road to rail would directly reduce CO_2 emissions in 2020 by 21%, i.e. more than the EU target for non-ETS sectors[1].

Graphs 4 – CO_2 emissions from transport sector



In order to investigate more deeply the issue, this scoping study would aim to analyse on a Europe-wide basis the potential railway capacity in medium-term scenario and therefore calculate the CO_2 reduction deriving from shifting reasonably achievable transport units from road and air to rail.

Considering the statement in the EU "2050 GHG study" related to the idea that high investments needed to improve the network can be barriers to modal shift, this study will consider in the first instance *only existing or planned infrastructure (available in 2020)* rather than stressing the need for major new investments.

It will be based on the railway supply potential of the infrastructure in major corridors and passenger routes in Europe that are able to shift traffic units from air and road.

2 Methodology

In order to analyze the modal shift *potential* it is very important to define in which cases railway transport may be considered as a feasible *alternative* to road and air, excluding the other cases from the analysis.

This study considers *time, speed, and distance* as the indicators driving the identification of all possible relations where a shift to rail could be realized.

It will be based upon the technical analysis of potential *transport offer* and will not discuss the policy options that may affect the transport demand: its aim is to set the grounds for possible policy conclusions.

The main methodological pillars of the study are:

- Transport demand scenario (Chapter 3):

The trend 2010-2020 will be investigated, using the main European tools available and a specific evaluation of air transport growth.

[1] Sustainable Development Foundation, based on EU DG TREN 2030 trends

- Assessment of railway capacity (Chapter 4):

In order to analyze the maximum level of potential CO_2 reduction deriving from modal shift to railways, the most important factor to be considered is the possible saturation of railway capacity.

The study will analyze the existing and planned capacity (meaning existing lines or *financed* lines under construction) . The basic reference for this analysis will be the European Rail Infrastructure Masterplan (ERIM) developed by UIC.

- CO_2 emissions allocation (Chapter 5)

Calculation of GHG emissions from transport modes will be based on the Ecopassenger and Ecotransit methodology, adapted to modal shift scenario. The effects of the shift in terms of saved CO_2 will keep track also of the technical improvements of vehicles and services from 2010 to 2020.

- Modal shift scenario (Chapter 6):

– From car to intercity regional and, for specific relations, high-speed train

– From plane to high speed train

– From lorry to freight train

– From ship to freight train

3 Transport demand scenario

Transport flows forecasts at medium term time horizon (2020) represent the basis upon which effective modal shift scenarios can be built. In fact, in terms of CO_2 emission reduction scenarios, the medium term horizon is the background against which to evaluate the effectiveness of modal shift.

The reference here is to the recent literature and scientific evidence on the long term forecasts on GhG emissions; notably, the Intergovernmental Panel on Climate Change (IPCC, 2007) and the seminal report on the economics of global change (Stern, 2006), setting compelling targets to the next 20/30 years to stabilise CO_2 emissions at levels considered acceptable. In fact, if nothing is done, global GHG emissions are projected to increase by 52% by 2050 and this would raise mean temperature by 1.7° C – 2.4° C, compared to pre-industrial levels, in 2050. The consequence is a risk of a "snowball" effect, e.g. factors like reduced sea ice cover, which would change the regional albedo (reflectivity of the Earth's surface) and increased methane emissions from melting permafrost soil, that could accelerate climate change even more.

The European transport policy has proactively been ready to shape its targets over a medium long period. For example, approaching the end of the ten-year period covered by the 2001 White Paper, the European Commission (2009) has embarked in a long term strategy for the sustainable mobility of people and goods, which must be able to take account of structural policies that take long time to implement and must be planned well in advance.

The identification of low-carbon transport scenarios, and the corresponding transport policies, must be rooted in such a long term strategy, and "that is why transport policies for the next ten years must be based on a reflection on the future of the transport system that embraces also the following decades" (EC, 2009). The Commission has launched such a reflection, comprising by the other things, an evaluation study on the possible low-carbon scenarios for transport that can be envisaged on the basis of the future challenges and trends (TRANSvisions, 2009).

In the context of the modal shift study, the room for modal shift of transport demand in Europe from the less environmental friendly transport modes (road, air and shipping) to rail, relies on the pillar of the estimation of the future transport demand, on the one hand, as described in the present chapter. The other pillar is the assessment of the rail capacity, which will be described in chapter III.

The methodology to estimate transport demand for rail (passenger and freight) and for the competing modes (road, air and maritime) will be based on the review of the most recent demand forecasts and transport scenarios at EU 29 level (including Norway and Switzerland), as developed in a recent stream of European Commission funded projects, described in the following sections.. Furthermore, the assessment of transport demand and capacity of the rail sector will also benefit of the scenario to 2020 carried out by the UIC project ERIM (ERIM, 2008).

The forecasts of traffic growth in the EU research projects to 2020 have been estimated according to a Business As Usual perspective, in which there will be the completion of the major TEN-T priority projects to 2020 as planned according to the most recent updating of the implementation process (TEN-T, 2008). As far as the UIC scenario is concerned, the forecasts of rail growth assume the completion of the national railways investment plans up to 2020.

From the methodological point of view, it is important to take into account the differences in scale and in the degree of coverage of transport flows, that are characterising the current development of transport model outcomes.

Concerning the difference in scale, it should be considered that the medium /short (below 500 km) and the long distance (higher than 500 km) rail transport flows suffer of different levels of accuracy.

The long distance forecasts of pan European rail transport flows are assigned to the main, TEN-T network according to the algorithms of transport models, with a good coverage of the European geographical landscape, extended in such a case to the neighbouring countries. For example, the on going EC funded project ETIS-PLUS (2009) is set out to collect more data for the newest member states, neighbouring countries as well as the relations with the rest of the world. The project will in fact endeavour to include accession countries, neighbouring countries participating in initiatives such as TACIS, MEDA and TRACECA. In general, it can be said that the long distance transport assigned on the TEN-T network benefits from a consistent methodology, i.e. robust and tested procedures of assignment and a good geographical coverage, even if data gaps and room for improvement still exists.

On the contrary, the forecasts of pan European short distance transport flows suffer from a lack of data; in particular for rail, for which regional and local lines are often missing, and therefore, short distance rail passengers and time distributions are not included in the assignment of rail passengers on the network.

The implication in terms of modal shift assessment is that for the long distance, transport data availability on O/D pairs make possible the evaluation of the room for competition between rail and air passenger transport market, on the one hand, and for rail and road (freight) market, on the other. On the contrary, the potential for modal shift between rail and road for the short distance transport flows can only be evaluated according to rough hypothesis, and tested through sensitivity analysis., as described in the next sections.

Concerning the coverage of transport flows by transport mode, it can be said that it is good for road and rail (leaving aside the lack of intra regional network allocation flows). In particular, data availability allows to identify mode-specific sub-segments, by technology and type of good, e.g.

- Road passenger cars (diesel, gasoline, other)
- Road freight (LGV, HDV > 32 ton, between 16 ton and 32 ton, < 16 ton)
- Rail passenger (High Speed Rail and other)
- Rail freight (bulk, unitised, general cargo)

Concerning the air sector, since data availability on the air transport routes is lacking, transport volumes are measured at a matrix level. In order to fill the gaps, the University of Bologna has developed its own database on air transport movements across Europe.

Concerning maritime, as for the air sector, detailed traffic data at route level are lacking (short sea shipping). In the current transport models, given that the number of main ports is limited, the main relations are connected manually, if no sea route network exists.

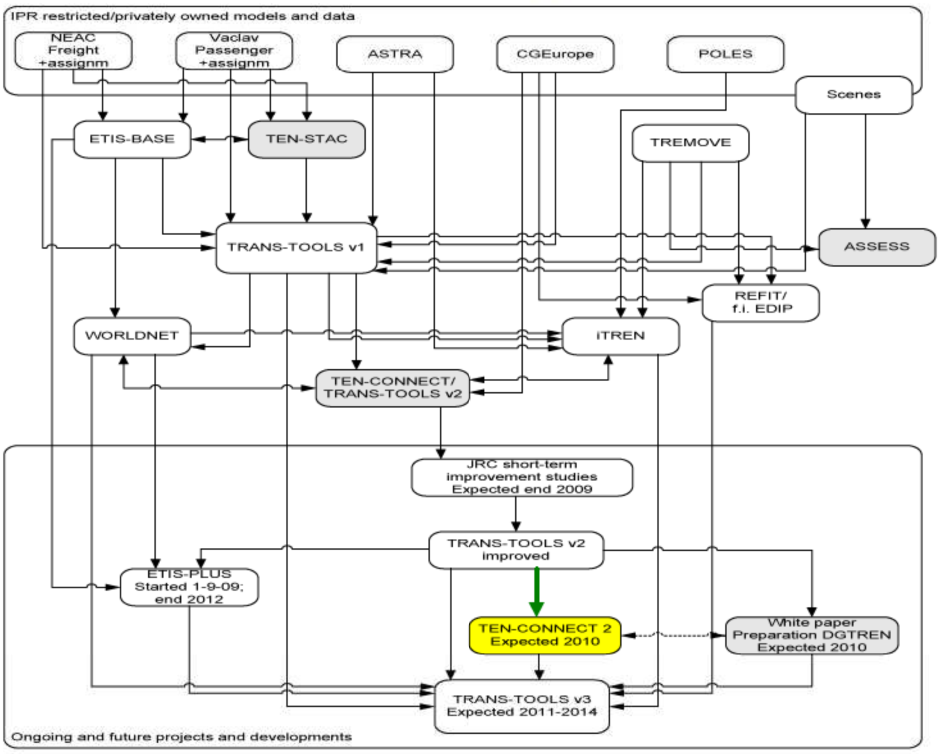
However, in the context of the present study, it should be considered that the room for competition between air (mainly passenger) and maritime (freight) services will be analysed on the long distance transport and for a limited sample of routes.

3.1 Long distance transport forecasts in EU funded research projects

This section describes the methodology for analysing traffic flows and transport forecasts in the medium term (2020). The transport flows, in the form of actual observations or forecasted values, represent the basis upon which the modal shift can be realistically evaluated.

The figure below shows the available models which have been used in different studies on traffic flows and traffic forecasts funded by the European Commission DG TREN over the past years, such as TEN-STAC (2000), TRANS-TOOLS (2005), ASSESS (2005), TEN-CONNECT (2009) and iTREN2030 (2010).

Figure 1: The chain of transport models



The figure shows the inter-linkage of the different models and projects; in fact several projects and models have been input for the development of a new model and this model has been processed further in other projects. The process towards the progressive improvements of the estimates is not yet complete, for, as showed in the figure, the new version of TRANS-TOOLS 3 is projected to be delivered in 2014.

The modal shift study intends to analyse the results of the following models.

3.1.1 TEN-STAC "Scenarios, Traffic Forecasts, and Analyses of Corridors on the Trans-European Transport Network" 2020

The project tested different alternatives of development and realization of TEN-T policies for the European Community. This objective has required the specification of several scenarios, depending on the different implementation of the accompanying measures of the TEN-T policy packages.

The TEN STAC baseline scenario at 2020 assumes a normal economic development in all EU 27 (the EU 15 + the 10 new member states), incorporating the so called consensus values for the key relevant national and international transport generation indicators. The next table shows the results at 2020 of the transport forecasts in billion pkm and tkm in the baseline scenario (TREND) compared to the base year (2000).

Table 1: TEN STAC transport forecasts (2020)

EU15	Base year 2000				TREND+ 2020			
	Total	% m-s	Int'l	% m-s	Total	% m-s	Int'l	% m-s
Passenger transport								
Car & coach	4,351	87%	290	53%	5,394	85%	363	44%
Railway	356	7%	28	5%	426	7%	38	5%
Air	281	6%	226	42%	528	8%	424	51%
Total passengers	4,988	100%	544	100%	6,348	100%	825	100%
Growth 2000 – 2020						27%		52%
Freight transport[6]								
Road	987	74%	367	66%	1,647	72%	667	68%
Railway	210	16%	81	15%	392	17%	146	15%
Inland waterways	145	11%	105	19%	242	11%	170	17%
Total goods	1,342	100%	553	100%	2,281	100%	983	100%
Growth goods 2000 – 2020						70%		78%
Growth in GDP 2000 – 2020						60%		60%

All the traffic flows have been presented through network assignments.

3.1.2 TRANS-TOOLS "TOOLS for Transport forecasting And Scenario testing"

The TRANSTOOLS reference scenario is a 'Business as usual' scenario: i.e. it will assume that the evolution of the transport system is an extension of the current trends. Therefore, the definition of the reference scenario will include:

- projections concerning the population (which is a relevant element for the generation of passengers trips);
- projections concerning the GDP (which is a relevant element for the generation of freight trips);
- autonomous changes in transport costs (i.e. due to more expensive oil price);

- transport network changes due to completed TEN projects. Additional network changes not due to the Trans-European transport network could also be part of the reference scenario according to available data (e.g. from national infrastructure plans).

The following table shows the modal split for the reference scenario compared to the modal split in the base year (EU 27).

Table 2:The TRANS-TOOLS transport scenario (2020)

Country	Volume (tonnes)		Road (%)		Rail (%)		Inlww (%)		Sea (%)	
	Baseyear	Reference	Baseyear	Reference	Baseyear	Reference	Baseyear	Reference	Baseyear	Reference
Austria	335.432.537	544.977.959	85,0%	82,3%	13,7%	16,0%	1,4%	1,7%	0,0%	0,0%
Belgium	944.388.121	1.380.142.514	62,8%	60,0%	10,3%	10,1%	12,3%	12,4%	14,6%	17,6%
Denmark	351.325.201	494.916.355	60,8%	58,5%	2,0%	2,1%	0,6%	0,7%	36,6%	38,6%
Finland	510.631.944	696.487.567	82,0%	80,3%	6,3%	6,3%	0,0%	0,0%	11,7%	13,4%
France	2.545.080.731	3.236.230.509	83,7%	83,4%	5,9%	6,2%	2,4%	2,5%	8,0%	8,0%
Germany	3.909.429.285	4.884.057.252	85,2%	82,7%	7,6%	8,5%	3,7%	4,2%	3,5%	4,7%
Greece	348.771.922	635.652.342	77,9%	53,3%	1,0%	5,0%	0,0%	0,0%	21,1%	41,7%
Ireland	217.904.126	505.117.292	83,9%	86,3%	4,0%	4,3%	0,0%	0,0%	12,1%	9,5%
Italy	1.716.297.662	2.298.783.186	79,4%	77,6%	4,9%	5,5%	0,0%	0,0%	15,8%	16,9%
Luxembourg	109.129.221	237.348.338	92,5%	94,4%	4,5%	3,2%	3,0%	2,4%	0,0%	0,0%
Netherlands	1.245.155.918	1.669.977.765	52,4%	49,8%	4,7%	5,4%	24,6%	24,0%	18,3%	20,7%
Portugal	339.028.921	424.647.102	86,3%	85,5%	2,8%	3,1%	0,0%	0,0%	10,9%	11,4%
Spain	1.268.892.322	2.003.576.080	80,4%	80,8%	3,7%	3,9%	0,0%	0,0%	15,9%	15,3%
Sweden	485.595.869	777.019.918	71,9%	70,8%	5,2%	5,1%	0,0%	0,0%	22,9%	24,1%
United Kingdom	2.403.881.728	3.421.117.406	81,2%	82,3%	5,0%	5,2%	0,1%	0,1%	13,8%	12,3%
Cyprus	1.428.526	3.790.350	3,4%	3,1%	3,1%	2,7%	0,0%	0,0%	93,6%	94,3%
Czech Republic	497.688.630	963.706.270	83,5%	80,2%	16,1%	19,3%	0,4%	0,5%	0,0%	0,0%
Estonia	70.201.430	142.580.839	20,4%	19,4%	21,6%	25,9%	0,0%	0,0%	58,0%	54,7%
Hungary	358.111.823	835.156.637	88,4%	88,5%	10,8%	10,4%	0,8%	1,1%	0,0%	0,0%
Latvia	90.550.878	258.493.739	36,6%	35,8%	5,7%	6,4%	0,0%	0,0%	57,7%	57,7%
Lithuania	73.654.066	190.557.629	56,0%	51,0%	15,9%	15,5%	0,0%	0,0%	28,1%	33,5%
Malta	606.475	1.576.692	1,8%	2,7%	0,1%	0,1%	0,0%	0,0%	98,1%	97,2%
Poland	964.012.020	2.127.046.336	80,3%	74,8%	16,8%	21,2%	0,6%	0,8%	2,4%	3,2%
Slovak Republic	129.917.676	325.469.681	71,5%	67,6%	27,6%	31,6%	0,8%	0,8%	0,0%	0,0%
Slovenia	65.302.835	123.659.076	90,3%	85,3%	8,3%	11,4%	0,0%	0,0%	1,4%	3,4%
Bulgaria	4.038.065	17.219.464	35,3%	47,7%	33,7%	31,5%	2,7%	1,2%	28,4%	19,6%
Romania	6.024.151	29.771.068	31,6%	51,3%	17,8%	10,9%	1,0%	0,7%	49,7%	37,1%
EU27	18.992.482.083	28.229.079.366	78,5%	76,2%	7,1%	8,5%	3,4%	3,2%	11,0%	12,1%

All the traffic flows have been presented through network assignments.

3.1.3 ASSESS Assessment of the contribution of the TEN and other transport policy measures to the midterm implementation of the White Paper on the European Transport Policy for 2010

The White Paper was published in 2001 and presented a number of objectives to be achieved in 2010. The mid term evaluation had two objectives. Firstly, it is assessed to what extent the implementation activities in the period 2001-2005 are in conformance with what has been proposed in the White Paper and secondly, it is assessed whether the objectives are still feasible, taking into account the policy and trend developments in the past period.

To comply with these objectives, the ASSESS study developed four scenarios, as described below in increasing level of ambition:

(i) Null scenario (N-scenario): assumes that none of the White Paper measures has been implemented.

(ii) Partial implementation scenario (P-scenario): includes only measures that will most likely be implemented before 2010. This scenario is what – under current conditions – will actually happen in the future.

(iii) Full implementation scenario (F-scenario): includes all White Paper measures.

(iv) Extended scenario (E-scenario): for most measures the extended scenario follows the full scenario while for some measures the partial scenario is followed because there is no indication that the full implementation is feasible. Additional to this two policy changes have been introduced.

the Partial A Scenario to 2010, with projections to 2020 is considered the most likely scenario and can be considered a sort of Business As Usual scenario.

Table 3:Assess scenario – freight transport demand, billion tonne / Km x year

Region	Mode	Observed 2000	Partial A scenario 2010	Partial A scenario 2020	% change over period 2000-2010	% change over period 2000-2020
EU15	Road	1 319	1 523	1 753	15%	33%
	Rail	250	254	273	2%	9%
	Inland waterway	127	139	157	9%	24%
	All	**1 696**	**1 916**	**2 183**	**13%**	**29%**
NMS10	Road	175	280	387	60%	120%
	Rail	124	130	142	5%	14%
	Inland waterway	4	4	5	-1%	7%
	All	**304**	**415**	**533**	**36%**	**75%**
EU25	Road	1 495	1 803	2 139	21%	43%
	Rail	374	384	414	3%	11%
	Inland waterway	131	143	162	9%	23%
	All	**2 000**	**2 331**	**2 715**	**17%**	**36%**

Table 4:Assess scenario – passenger travel demand, billion passenger / Km x year

Region	Mode	observed 2000	Partial scenario 2010	Partial scenario 2020	% change over period 2000-2010	% change over period 2000-2020
EU15	Car	4 094	4 704	5 388	15%	32%
	Bus/coach	402	422	413	5%	3%
	Train/metro	351	398	429	13%	22%
	Air	284	427	586	50%	106%
	Walk/cycle	215	244	256	13%	19%
	All	**5 345**	**6 195**	**7 071**	**16%**	**32%**
NMS10	Car	325	468	607	44%	87%
	Bus/coach	78	73	66	-7%	-15%
	Train/metro	51	50	49	-2%	-4%
	Air	14	23	34	61%	136%
	Walk/cycle	19	23	24	19%	29%
	All	**488**	**637**	**781**	**30%**	**60%**
EU25	Car	4 419	5 172	5 995	17%	36%
	Bus/coach	480	495	479	3%	0%
	Train/metro	403	449	479	11%	19%
	Air	298	450	619	51%	108%
	Walk/cycle	234	266	281	14%	20%
	All	**5 833**	**6 832**	**7 852**	**17%**	**35%**

Source: Assess (2005), final report

3.1.4 TEN-CONNECT (2009) "Traffic flow: Scenario, Traffic Forecast and Analysis of Traffic on the TEN-T

The TEN CONNECT study has improved the TRANS-TOOLS model as follows:

- Update of the TRANS-TOOLS model to base year 2005.
- Spatial refined of zonal system. The number of zones has been extended from 1269 to 1441.

The focus in the scenario analysis is not only on heavily loaded infrastructure, but also on infrastructure which – if improved – could boost the Single Market, Cohesion and connections to Neighbouring countries. The forecasts are related to 2020/2030 time horizon. The Baseline scenario includes specific assumptions on GDP development, operating transport costs, population development and infrastructure development

Table 5: TEN CONNECT transport forecasts (2030)

Mode		Model 2005	Model 2030 Baseline	Diff. 2030/2005 (%)	Model 2030 SED	Diff. SED/Baseline (%)
Passenger	Passenger car, 1000 m. pkm	4507	6076	35%	6763	11%
	Railway, 1000 m. pkm (excl. Tram and Metro)	375	659	76%	787	19%
Freight	Truck, 1000 m. tonne km	1712	2442	43%	2596	6%
	Railway, 1000 m. tonne km	447	797	78%	894	12%
	IWW, 1000 m. tonne km	130	181	39%	207	15%

All the traffic flows have been presented through network assignments.

3.1.5 iTREN2030 (2009) "Integrated transport and energy baseline until 2030"

The basic objective of iTREN-2030 is to extend the forecasting and assessment capabilities of the TRANS-TOOLS transport model to the new policy issues arising from the technology, environment and energy fields. In this project TRANS-TOOLS (transport), TREMOVE (environment), POLES (energy) and ASTRA (economy) have been combined into one model framework.

The iTREN-2030 baseline uses some assumptions on fundamental socio-economic variables that are among the main determinants of transport demand, energy consumption, etc. Three main elements have to be mentioned: population growth, GDP growth and fuel prices.

The below results show the annual increase up to 2030.

Table 6: iTREN2030 transport forecasts (2030)

Passenger

Mode	iTREN-2030
Road	0.7%
Rail	1.5%
Air	1.4%
Total	*0.8%*

Freight

Mode	iTREN-2030
Road	1.3%
Rail	2.3%
Inland Navigation	1.3%
Maritime	1.5%
Total	*1.5%*

3.1.6 Air transport air transport scenarios to 2020

The competition between aircraft and railway services has started with the opening of the air market; as a result air traffic increased significantly because of the larger amount of routes risen and because of the increased frequencies. However more recently railways have recaptured some shares of traffic thanks to the introduction of high-speed railway services.

The harsh competition between railways and aircraft could probably evolve, as it has been fostered in EU Transport White Papers (2001), towards an integration between the two modes of transport where the aircraft will be substituted by high-speed trains starting from the airports themselves and the railway services will be integrated with flights.

The potential for shifting traffic from aircraft to high-speed railways is related to the generalised transport cost associated to the competing alternatives. The most significant component of this cost is represented by travel time. Experts typically state that railways could substitute aircraft on routes of about 600-800 km or 1 hour flight, because railways can offer comparable or shorter travel times. On the other hand, on routes of less than 400 km, high-speed rails are by far regarded as the fastest transport modes, with almost no competition with point to point air services.

The first step for the estimation of the potential modal shift from aircraft to railways in the EU, with reference to 2020 scenarios, is the individuation of the O/D pairs where flights can be substituted by rail. The O/D pairs will be chosen among the ones that are, or will be, connected by high-speed railways services. In Figure 2 the actual and future EU high-speed network is shown. This network is part of the Trans-European Transport Network that the EU is funding to create an efficient and environmental-friendly transport system. These high-speed rail axes are quickly expanding and the initial scattered pattern is evolving towards an European-wide integrated network. In addition, Figure 3 shows the O/D pairs included in this network that are considered competitive with regard to air transport by Eurocontrol.

In Europe, there will be about 100 city pairs linked by high-speed rail by 2030. The main improvements in the European high-speed rail network will regard: a further development of Spanish and French networks with more international connections; extension of the railway lines to Portugal; construction of new trans-Alpine tunnels connecting Switzerland and Italy; new lines connecting Germany to Austria and Sweden to Denmark

Figure 2: High speed railways network in EU (Source: Committee on Climate Change 2009 – Chapter 3)

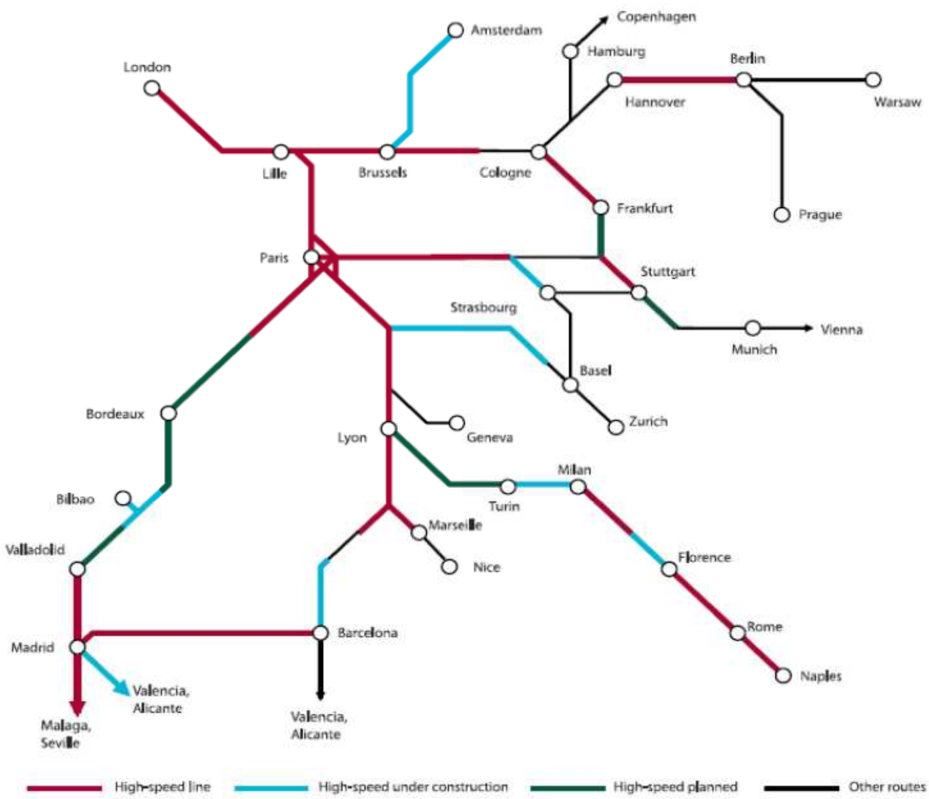
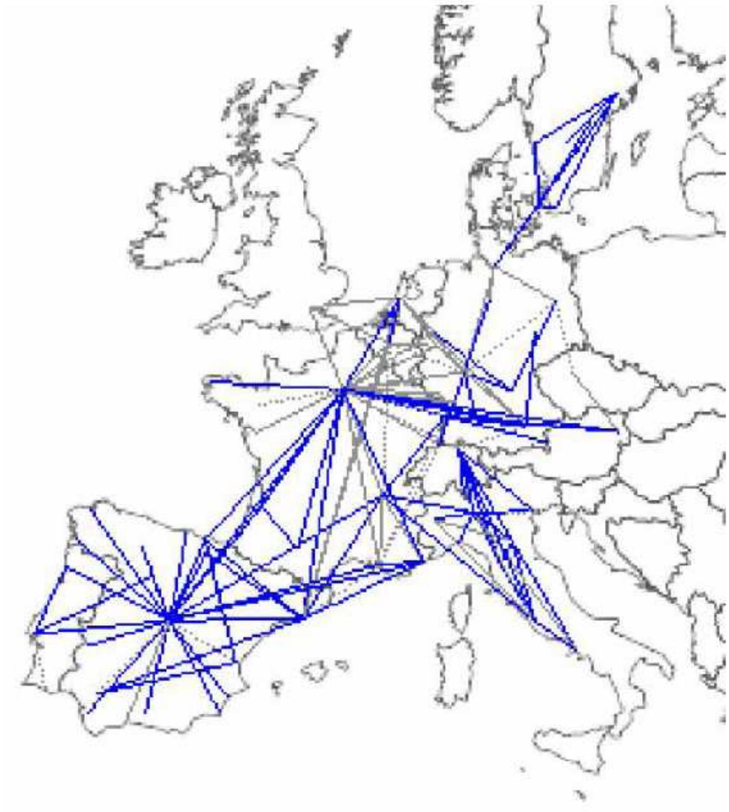


Figure 3: O/D pairs network in EU with possible competition between aircraft and railways (Source: "Long term forecasts 2008-2028" – Eurocontrol)



In Table 5 the main intra-EU airport pairs in passenger transport are presented. A subset of these O/D pairs will be taken into consideration, which excludes connections with no expected modal shift according to suitable criteria.

Table 7: Top 25 intra-EU O/D airport pairs; total passengers carried in thousands

Airport pairs	*2005*	*2006*	*2007*
Madrid – Barcelona	4358,3	4442,4	4627,4
Milano – Roma	2414,6	2387	2510,1
Paris – Toulouse	2328,1	2350,9	2327,2
Nice – Paris	2262,9	2318,9	2311,9
London Heathrow – Dublin	2089,4	1991,1	1974,4
London Heathrow – Amsterdam	1895	1846,4	1799,1
London Heathrow – Paris	2011,1	1970,8	1790
Munchen – Hamburg	1450,5	1582,9	1756,9
Frankfurt – Berlin	1545,6	1541,1	1647,9
Catania – Roma	1368,7	1371,6	1534,2
Munchen – Dusseldorf	1381,5	1362,2	1528,9
Munchen – Berlin	1419,2	1424,7	1509,9
Madrid – Malaga	1399,8	1423,9	1502,4
London – Frankfurt	1530,4	1513,3	1450,1
London – Edinburgh	1659,9	1495	1436,5
Paris – Milano	1064,8	1201,7	1400,6

Airport pairs	*2005*	*2006*	*2007*
Roma – Paris	1240,4	1262,1	1351,8
Hamburg – Frankfurt	1288,3	1289,7	1297,4
Amsterdam – Barcelona	1103,9	1235,2	1271,7
Roma – Palermo	1111,2	1134,8	1244,2
Paris – Madrid	869,7	1086	1236,1
Munchen – Koln	1165,3	1209,3	1235

Source: Eurostat

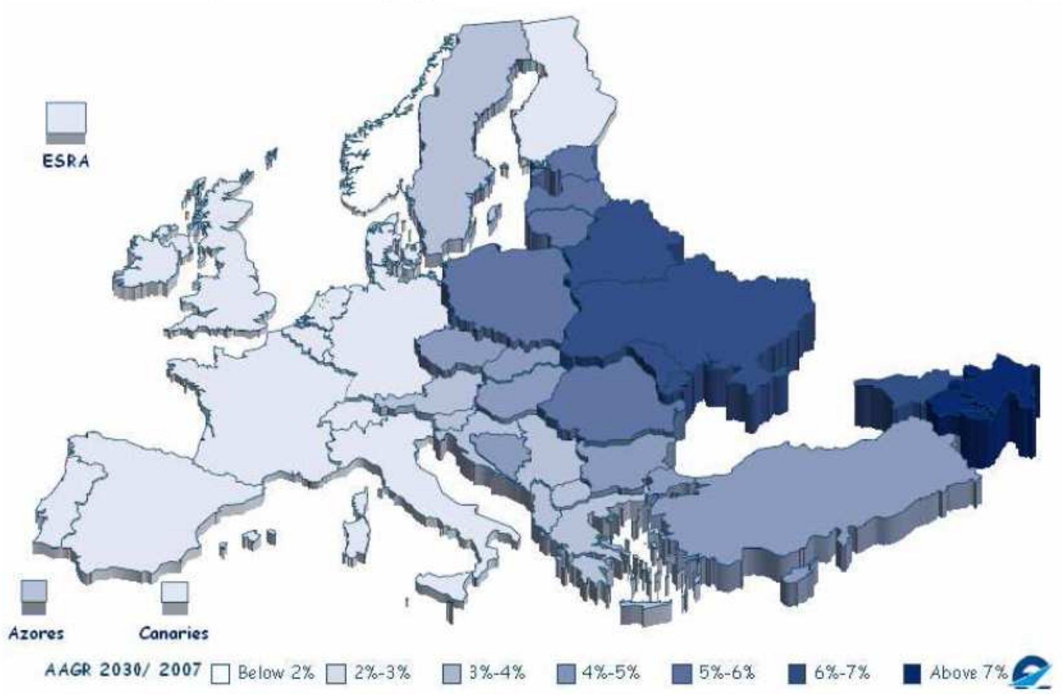
The scope for modal shift from air to rail transport is determined by the level-of-service attributes and the capacity constraints as well. Actually, transport systems are characterised by capacity limits, which prevent nodes and links from processing an unlimited traffic volume. Furthermore, it is not sufficient to estimate only air and rail market shares but also the total number of trips that shift from air to rail. In this respect, forecasts are needed regarding the trends in intra-EU transport demand. What could make these forecasts particularly uncertain is the deep crisis that the global economy is undergoing nowadays since transport demand is strongly linked to the Gross Domestic Product of the region.

Table 6 reports the forecasts of air transport demand in the intra-EU market. These future trends have been elaborated by aircraft manufacturers (Airbus and Boeing). However, some differences can be observed among the various European countries, as shown in Figure 4

Table 8: Forecast at 2030 of annual intra-EU air passenger traffic growth rate

Air Passenger Traffic growth rate (2030)	
Boeing	+3,4 % / year
Airbus	+3,9 % / year

Figure 4:– Average annual instrumental air-traffic growth 2007-2030 for each EU State in a scenario characterized by moderate economic growth and strong regulator's intervention in order to address environmental targets



(Source:Eurocontrol Statistic Reference Area, 2008)

More detailed and specific forecasts may be derived with the implementation of time-series projections techniques. Either linear or non-linear curves (i.e. exponential functions) may be adopted in the estimation process.

Air transport emissions represent undoubtedly a hot topic in the current political debate at the EU level. Today air transport industry represents only about the 2% of global carbon dioxide emissions and the 12% of CO_2 emissions from all transport sources or rather, in global terms, aviation is responsible for the 3% of the total man-made climate change (source IATA). However what concerns the most regulators is the expected growth of air transport industry over the next decades which is supposed to increase the percentage of contribution of air transport to climate change up to the 5%.

The air transport industry has adopted a proactive path in order to avoid possible constraints or increases in the operative cost due to the implementation of policies aimed at reducing emission, and trough the IATA (International Air Transport Association) the industry has set voluntary targets for reducing the impact of aviation on Climate Change.

These objectives have been formalized in the Global Declaration on Aviation Climate Change signed by the major air transport players during the third Aviation and Environmental Summit held by IATA in 2008 in Geneva. The air transport players which signed the declaration which are the aircraft producers, the airlines trough the IATA and the airports trough the ACI, commit themselves into a four pillars strategy in order to tackle the problem of Climate Change. The strategy is built on four pillars:

- Technology improvements (improve the aircraft fuel efficiency, develop alternative fuels and adopt more advanced air traffic management technologies);
- More efficient air transport operations;
- Infrastructure improvements;
- Economic measures.

3.2 Long distance transport forecasts in the UIC project ERIM

The ERIM projects was carried out in 2003, by the Market & Development Sector of the UIC. The projects addressed several important issues:

- Assessing the infrastructure needs in 2020, developing a detailed database in collaboration with the Member Railways for which the main infrastructure parameters and investment up to 2020 across the ERIM rail network have been collected. The ERIM corridors represent only 21% of the total route length in the countries covered, but carry 47% of all passengers-kms and 63% of all tonne-kms of the 32 countries.
- Evaluating capacity constraints and bottlenecks to 2020 on the ERIM rail network (showed in the ERIM ATLAS report, 2007), preparing the background information for evaluating the necessary investment to overcome the capacity constraints
- Providing an estimation of the traffic growth to 2020. The ERIM traffic growth forecast for the period 2006-2020 is 34% for passenger traffic and 56% for freight traffic.

The ERIM estimates have been compared to the outcomes of a sample of transport forecasts of European and United Nation research projects (ASSES, TEN-STAC and TER), finding an overall consistency.

The following table shows the estimated rail passenger and freight growth along the 2005-2020 period on the ERIM rail network.

Table 9: ERIM forecasts of rail growth (in millions pkm and tkm) 2005-2020

	Passengers			Freight		
	Total	Domestic	International	Total	Domestic	International
Overall Total ERIM 2005	178 659	167 384	11 276	255 240	116 273	138 967
Overall Total ERIM 2020	240 255	223 647	16 609	398 075	175 353	222 723
growth 2020/2005	34%	34%	47%	56%	51%	60%

3.3 Short/medium distance transport forecasts

The methodology to estimate medium/short distance transport flows in Europe must be different from the long distance traffic. While the long distance transport can benefit of data availability, consistent and continuously improved research studies and transport models, the intra-regional transport suffers of comparable data availability at network level at the European level.

However, it is likely that modal shifts road/rail may occur even at short/medium distance, in particular for commuting trips at intra-regional level.

In order to gauge this opportunity, it is necessary firstly to estimate the long term traffic forecasts at EU level for short/medium distance for passenger rail and road (below 500 km). This can be done using the TREMOVE (2007) transport database, developed for the European Commission.

The TREMOVE database is designed to study the effects of different transport and environment policies on the emissions of the transport sector. All relevant transport modes are modelled, including air transport. Maritime transport is treated in a separate model. TREMOVE covers the 1995-2030 period, with five yearly intervals.

Data are available in aggregated form at country level, not at network level, for trips below and higher 500 km, with a geographical zoning classified in urban, non urban and metropolitan areas.

The following table shows the 2005 value (EU 15 + CH and NO) of the road car pkm on the short/medium distance (below 500 km) according to the TREMOVE estimates.

Table 10: Road (car) passenger transport in billion pkm (2005): short medium distance (TREMOVE model)

TREMOVE (EU 15 + CH and NO)	
Non urban	2409
Motorways	770
Urban	1083
Total	4261

The table shows that 770 billion pkm travelled by road (car) in 2005 at EU 15 level using motorways along a distance below 500 km.

Leaving aside the short/medium distance road transport occurring in the urban areas (1083 billions of pkm), for which no competition along the rail main network is supposed to happen (excluding metro and tram), it can be concluded that the potential competitive market for rail is located in the motorways and non urban segment below 500 km (3492 billions of pkm).

3.4 Expected results

The analysis of transport forecasts to 2020 will provide an assessment of the future growth of transport volume and flows for rail and the competing transport modes, in order to estimate the potential of traffic flows that can be shifted to rail, according to the most likely business as usual scenarios. A comparison with the estimates to 2020 (DG TREN, 2008) will be provided for ensuring consistency.

- The traffic volume will be primarily expressed in pkm and tkm. Traffic flows in vkm could also be estimated through the use of specific load factors
- The evaluation will be carried out by the relevant market segments, i.e.

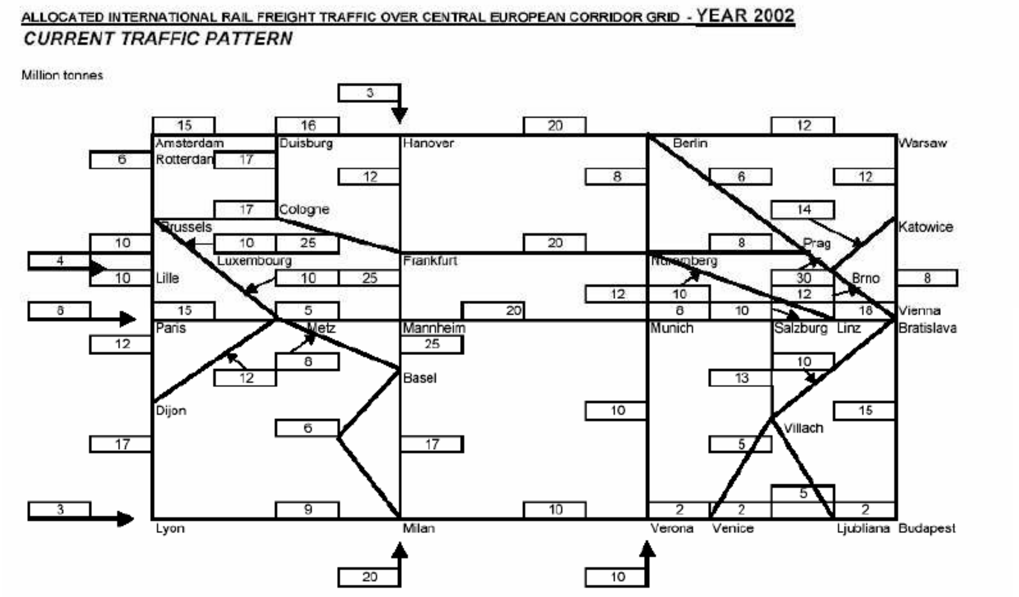
  – High Speed Rail – Air

  – Passenger Rail - Road (below 500 km)

  – Freight Rail – Road (unitised transport)

  – Freight Rail – Maritime
- This will form the basis for the assessment of the traffic flows potentially to be shifted towards more environmental friendly transport modes.
- In case of the road passenger traffic, given that it is not possible to guess how much traffic could be potentially shifted to rail in the medium/short distance, a sensitivity analysis will be carried out through several hypothesis of modal shift, also taking into account of the residual capacity after taking into account of the air, airline and road (freight) modal shifts.
- When possible, forecasts and market share by the type of commodity will also be provided
- The geographical scope of the analysis will be the pan European corridors for the long distance transport (rail, road, air, maritime – passenger and freight -) and the aggregated flows at country level and EU 27 in total for the short distance (road, rail – passenger -).
- As a by-product of the study, based on the available information, an estimation to 2020 of the traffic flows along the main corridors will be carried out. The resulting outcome could be similar to the assessment carried out by UIC in the past years, i.e. the so-called rail Grid in central Europe, as identified in 2002 and shown in the next figure. The basis for this assessment will be derived from the analysis of the long distance traffic flows forecasts assigned to the TEN-T network. No new traffic allocation to the main network will be carried out in this study

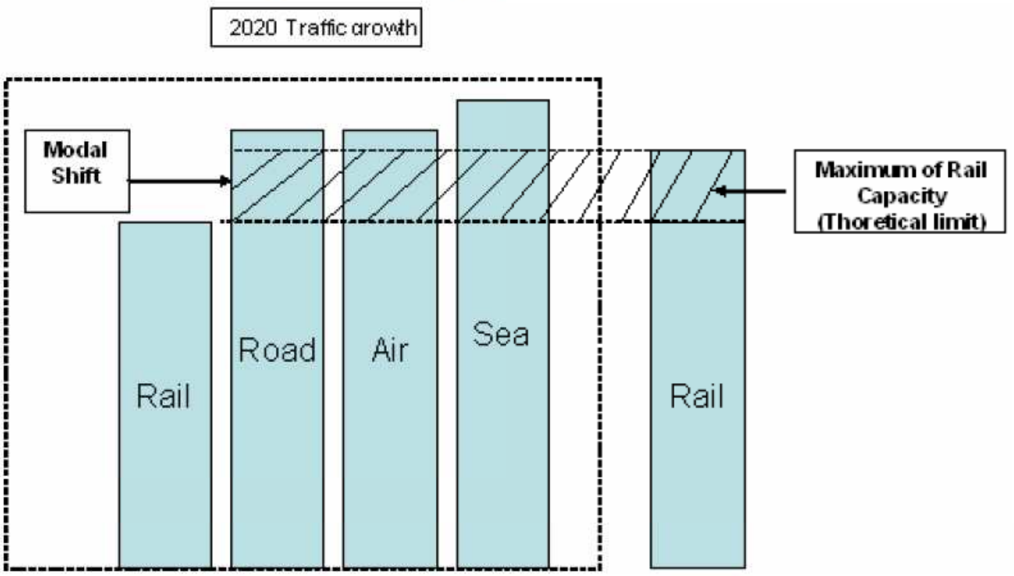
Figure 5: The Rail freight grid (Central Europe) year 2002



4 The assessment of rail capacity

The assessment of rail capacity represents an important methodological aspect of the study. The room for modal shift is in fact evaluated, on the one hand, through the expected traffic volumes to 2020/2030 for rail and the competing transport modes, and, on the other, through the assessment of how much of the projected traffic of the competing modes could be shifted to the rail network through the assessment of the theoretical maximum limit of rail capacity. The figure below shows the overall approach.

Figure 6: Rail capacity: The methodological approach



The assessment of rail capacity is not easy to carry out. Previous research project (e.g. EURAILINFRA, 2004) have shown the intrinsic complexity of the task. The UIC Working Group 'Capacity Leaflet' was mandated in 2000 to comprehensively define capacity and use of capacity and to present the results in the form of a UIC Leaflet (405-1). This working group has come to the conclusion that a one-time, genuine definition of capacity is not possible, but a requirement-specific methodology was worked out, whereby a uniform procedure of capacity calculation could be applied at corridor level.

However, the EURAILINFRA project has shown that the procedure for the assessment of capacity at corridor level is complex, since it involves the following steps:

- Analysis of the current technical infrastructure data
- Assessment of the present capacity
- Analysis of already planned infrastructure investments
- Assessment of the bottlenecks that will still exist after the infrastructure investment, and proposed measures to solve them

The EURIALINFRA approach implies a) the capacity assessment at corridor level, b) the evaluation of future investment, c) the analysis of the already planned and financed infrastructure measures, d) the analysis of the technical data has served to support the capacity assessment, indicating how the infrastructure will be further developed in the period under review.

It can be said that each track section between two nodes has its unique capacity, due to three specific factors: 1) areal limitations, 2) sectoral limitations, and 3) network limitations.

Areal limitations. Where infrastructure constraints are occurring on physically separated sections of the network (links and nodes) and can be resolved by specific measures at these locations

Sectoral limitations. Under certain circumstances, the areal limitations cannot be allo-cated to a specific link or node, e.g. if a voltage change on the network is located be-tween two nodes. In this case, the type of limitation is referred to as sectoral.

Network limitations. Other bottlenecks are not only covering physically separated sec-tions but have effects on the whole part or the entire network of a country. The limitations occurring due to these constraints do not have direct effect on the partial capacity of the major axes but are affecting the accessibility of the network.

The application to the present study of the assessment of rail capacity at corridor level is considered not feasible. A top-down approach is proposed for the overall main network /the TEN-T rail network, while no assessment is carried out for the secondary rail network

4.1 Capacity assessment on the main rail network

On the main rail network, an example of top-down approach leading to the assessment of a theoretical maximum limit of capacity for the overall rail network has been provided in the UIC-GTC (2004) capacity assessment study, carried out by by Kessel + Partner Transport Consultants, and KombiConsult GmbH.

The study has identified in +20% the improvement of rail capacity on double tracked electrified lines related to the average of the rail network by 2015, compared to the 2002 level.

This improvement, expressed in number of trains (movement) per day and direction, represents a 100% use of capacity according to the adoption of a package of measures to adjust capacity, namely

- "soft measures", e.g. longer trains,
- better operational/signalling systems,
- bi-directional traffic

A similar approach has been followed in the UIC study ERIM (2008), in which, on the basis of the information derived from the ERIM database, including the inventory of the 2007 infrastructure and the national upgrading plans up to 2020, it has been possible to derive an average theoretical maximum capacity of double track and single track lines.

The quantification of the maximum capacity in number of trains per day has been estimated assuming the 70% - 80% utilisation threshold, above that the prospect of instability in the timetable may arise to a greater degree.

In the present study the assessment of rail capacity will use the ERIM approach.

Expected results

- At the level of the European main network (TEN-T), hypothesis of the maximum achievable modal shift (in terms of volume and flows) to 2020 from the competing transport modes to rail, in consideration of an assessment of the maximum rail capacity which is attainable at 2020
- The rail capacity will be estimated in relation to
- Air passenger market (high speed rail)
- Road passenger market (main rail network below 500 km)

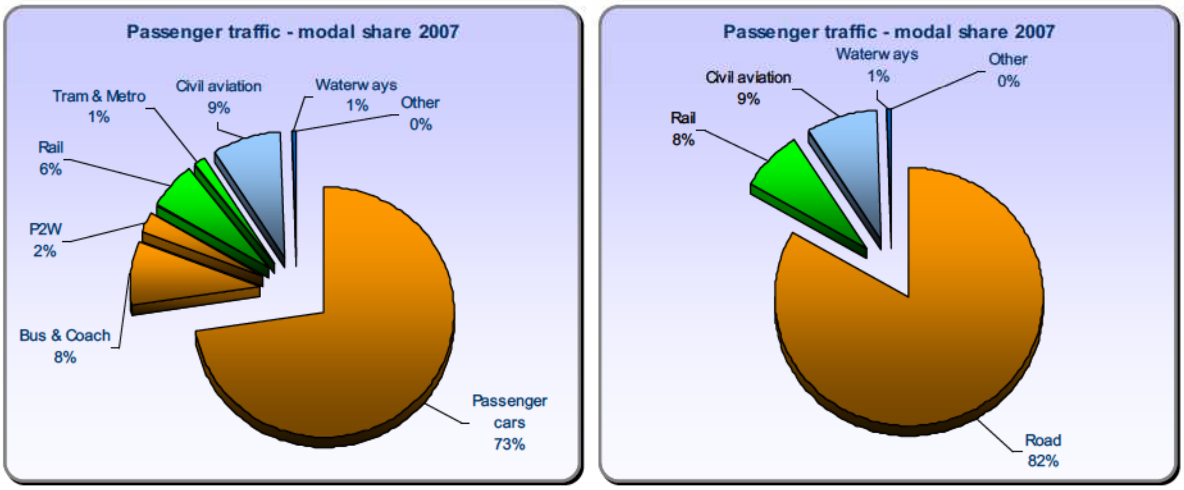
- Road freight market (pan European corridors)
- Maritime and short sea shipping market (pan European corridors – freight -)
- The geographical scale of the results (modal shifts) is the overall network. Since node or line capacities are not taken into account, the potential of modal shifts at corridor level can not be evaluated.
- It is important to consider that the actual application of the modal shifts to the average rail network level could also exceed the rail capacity on saturated and unsaturated line sections at certain times in the day timeline. Furthermore, even with enough theoretical capacity available, bottlenecks might still occur due to problems with insufficient interoperability and other constraints

5 CO_2 emissions allocation

In this chapter, referring to the time scenario 2007-2020, it will be calculated the CO_2 emissions reduction due to the shift of passengers and goods form the more polluting transport modes towards railways, within the EU 27 Nations.

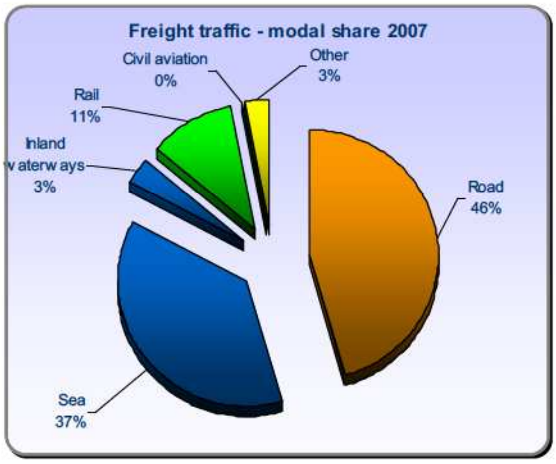
The starting point of this process will be the analysis of the distribution, in year 2007, of passengers and goods traffic between the different transport modes:

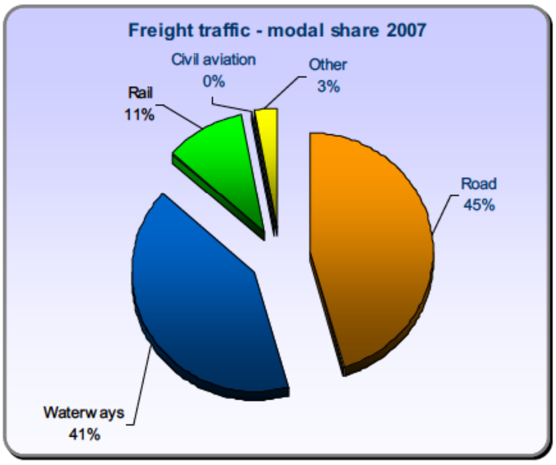
Graphs 5 and 6 – Distribution of passenger traffic, in year 2007, between the different transport modes



Source: Air and Sea: only domestic and intra-EU-27 transport; provisional estimates - European Commission DG TREN (2009)

Graphs 7 and 8 – Distribution of freight traffic, in year 2007, between the different transport modes





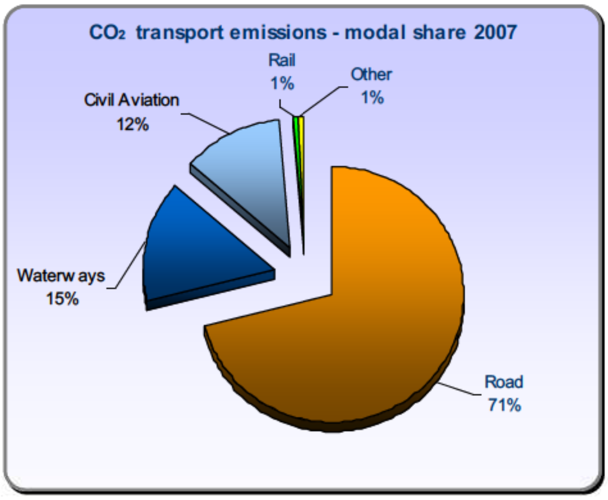
Notes:

Air and Sea: only domestic and intra-EU-27 transport; provisional estimates Road: national and international haulage by vehicles registered in the EU-27

Source: European Commission DG TREN (2009)

Always referring to year 2007, the next step will be to carry out the emission analysis of the overall transport sector, with the related distribution between the different modes

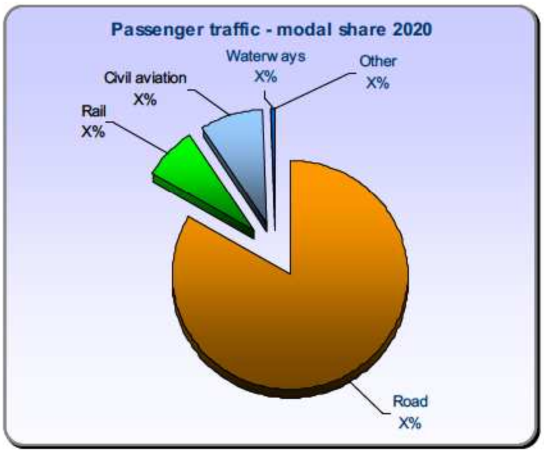
Graph 9 – Distribution of CO_2 emissions, in year 2007, between the different transport modes

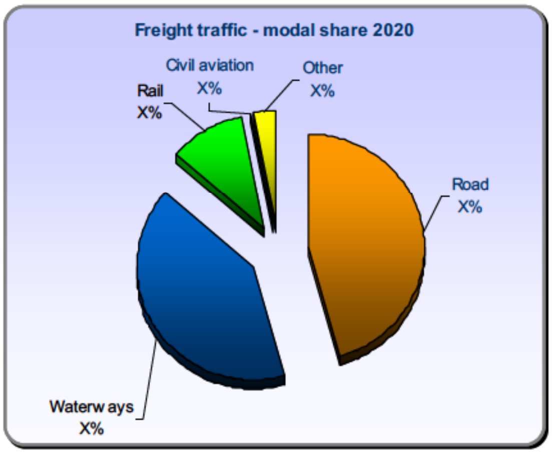


Source: Transport emissions data for the EU27 1990-2006: EEA (2007) and reported in DGTREN (2008)

Afterwards it will be considered the passenger and freight traffic possible distribution in 2020, with the related estimation of the transport demand trends, taken from the results of chapter 5.

Graphs 10 and 11 – Estimation of the passenger and freight traffic distribution in 2020 between the different modes





Notes:Air and Sea: only domestic and intra-EU-27 transport; Road: national and international haulage by vehicles registered in the EU-27

Source: elaboration Fondazione Sviluppo Sostenibile

Next step will be the calculation of the consequent CO_2 emissions for year 2020.

The methodology of reference for the calculation of CO_2 emissions is the one developed by IFEU within the Ecopassenger and EcoTransIT projects.

This methodology doesn't take into account only the CO_2 emissions directly caused by the final energy consumption (fuels or electricity used in the operation of vehicles), but also all the CO_2 emissions due to the energy consumption for the generation of final energy.

In other terms, to evaluate the overall CO_2 production caused by a certain transport mode, and therefore the possible effects of a certain modal shift, it has to be considered the total energy chain.

For the calculation of CO_2 emissions directly caused by the final energy consumption – for all main types and classes of vehicles – values are taken from the most reliable international studies such as:

- COPERT 4 for passenger cars,
- UIC energy and CO2 database 2007 for electric trains,
- UIC Rail Diesel Project 2006 for diesel trains,
- UmweltMobilCheck 2006 and TREMOD 2005 for planes,
- HBEFA 2.1 and COPERT 4 for lorries
- Borken 1999 for sea transport.

The calculation of the previous energy chain of fuel production (used by planes, cars, lorries, diesel trains and ferries) includes:

- exploration and extraction of primary energy (crude oil, gas) and transport to the entrance of the refinery
- conversion within the refinery (including construction and deposal of refineries)
- energy distribution (transport to petrol station, filling losses).

The emission factors and energy demand for the construction and disposal of refineries, exploration and preparation of different input fuels; the transport to the refineries; the conversion in the refinery and transport to the filling station are taken from Ecoinvent 2006.

The calculation of the previous energy chain of electricity production (used by trains) includes:

- Exploration and extraction of the primary energy carrier (coal, oil, gas, nuclear etc.) and transport to the entrance of the power plant
- Conversion within the power plant (including construction and deposal of power stations)
- Energy distribution (transforming and cable losses)

The emission factors of electricity production depend mainly on the mix of energy carriers and the efficiency of the production. The values for the Energy mix of the electricity production are taken from "UIC energy and CO_2 database 2007", where no values are available, data are taken from EU-statistics /Eurostat 2007. The emissions factors for the electricity generation in all countries are estimated on basis of Ecoinvent 2006.

Outside the boundaries considered in the calculations are:

- the production and maintenance of vehicles;
- the construction and maintenance of transport infrastructure;
- additional resource consumption like administration buildings, stations, airports, etc..

As it regards the length of the route on which apply the energy and CO_2 calculation, the study will consider the specific route available for each transport mode between the origin and destination defined.

Finally, for passenger air transport, the different flight phases are taken into consideration:

- taxi (rolling traffic);
- take-off and climb;
- cruise;
- dive and landing;

and the RFI (Radiative Forcing Index) that takes into account the climate effects of other GHG emissions (in particular nitrogen oxides, ozone, water, soot, sulphur) may be considered as well.

In calculating the emissions at 2020 it will be necessary to make some estimations concerning the following parameters:

- load factor;
- specific consumption for the different transport modes;
- emission factors due to final energy consumption and efficiency for fuel and electricity production.

Concerning the load factor, for passenger traffic it is considered:

- the European average value for the cars and planes
- the average country load factors for train types, where available.

For freight transport, standard modes of three types of cargo are considered: bulk goods (coal, ore, oil, fertilizer etc.), average good and volume goods (industrial parts, shopping goods such as furniture, clothes, etc.). The cargo specification is defined due to the typical load factor including all empty trips.

In all cases average load factor values can be changed with more specific settings to perform different modal shift scenarios.

Starting from year 2007 load factor values, evaluated according to the above mentioned principles, the 2020 load factors values will be estimated, on the basis of the specific sector commitments established for the different transport modes.

As it regards the specific consumptions, the corresponding values for the different transport modes will be estimated, for year 2020, on the basis of the analysis of the 1990-2020 values trend and taking into account the targets for specific energy consumption reduction established with National and European laws for the automotive sector and the voluntary targets for shipping and railway sectors.

As it concerns the CO_2 emission factors and the energy efficiency of electricity and fuels production, the related values will be estimated, for the different kind of production, for year 2020, on the basis of the analysis of the 1990-2020 values trend and taking into account the targets for emissions reduction established with National and European laws.

The possible CO_2 emissions reduction will be calculated with the same methodology described above, according to the following passengers and goods modal shift, as mentioned in chapter 5:

- $\Delta pkm_{airplane \rightarrow highspeed\ train}$ from plane to high speed train;
- $\Delta pkm_{car \rightarrow IC/Regional\ train}$ from car to Intercity/Regional train;
- $\Delta tkm_{truck \rightarrow train}$ from truck to train;
- $\Delta tkm_{ship \rightarrow train}$ from ship to train.

$$\Delta \mathbf{CO_2}_{\ airplane \rightarrow highspeed\ train} = (FC2007_{airplane} * A_{FCairplane} * \Delta pkm_{airplane \rightarrow highspeed\ train} / LF2007_{airplane} * C_{LFairplane} * EF2007_{kerosene} * e_{kerosene} * D_{EFkerosene}) - (EC2007_{highspeed\ train} * A_{EC\ highspeed\ train} * \Delta pkm_{airplane \rightarrow highspeed\ train} / LF2007_{highspeed\ train} * E_{LFhighspeed\ train} * B_{route\ airplane \rightarrow highspeed\ train} * EF2007_{electricity} * e_{electricity} * F_{EFelectricity})$$

where:

$\Delta pkm_{airplane \rightarrow highspeed\ train}$ [pkm] = pkm shifted from plane to high speed train;

$FC2007_{airplane}$ [g kerosene/seat km] = fuel consumption;

$A_{FCairplane}$ = correction factor for airplane fuel consumption to take into account the sector technological evolution from 2007 to 2020;

$LF2007_{airplane}$ [%] = load factor;

$C_{LFairplane}$ = correction factor for airplane load factor to take into account the sector traffic increase from 2007 to 2020;

$EF2007_{kerosene}$ [gCO_2/g kerosene] = emission factor for kerosene;

$e_{kerosene}$ = efficiency of kerosene;

$D_{EFkerosene}$ = correction factor for kerosene emission factor due to its production and consumption to take into account the technological evolution from 2007 to 2020;

$EC2007_{highspeed\ train}$ [Wh/seat km] = electricity consumption;

$A_{EC\ highspeed\ train}$ = correction factor for train consumption to take into account the sector technological evolution from 2007 to 2020;

$LF2007_{highspeed\ train}$ [%] = load factor;

$E_{LFhighspeed\ train}$ = correction factor for train load factor to take into account the sector traffic increase from 2007 to 2020;

$B_{route\ airplane \rightarrow highspeed\ train}$ = correction factor to take into account the different routes followed from train and airplane to reach the same destination;

$EF2007_{electricity}$ [gCO_2/Wh] = emission factor for electricity;

$e_{electricity}$ = efficiency of electricity;

$F_{EFelectricity}$ = correction factor for electricity emission factor due to its production and consumption to take into account the technological evolution from 2007 to 2020.

$\Delta \mathbf{CO_2}_{\ car \rightarrow IC/Regional\ train} = (FC2007_{car} * A_{FCcar} * \Delta pkm_{car \rightarrow IC/Regional\ train} / LF2007_{car} * G_{LFcar} * EF2007_{gasoline} * e_{gasoline} * H_{EFgasoline}) - (EC2007_{IC/Regional\ train} * A_{EC\ IC/Regional\ train} * \Delta pkm_{car \rightarrow IC/Regional\ train} / LF2007_{IC/Regional\ train} * I_{LFIC/Regional\ train} * B_{route\ car \rightarrow IC/Regional\ train} * EF2007_{electricity} * e_{electricity} * F_{EFelectricity})$

where:

$\Delta pkm_{\ car \rightarrow IC/Regional\ train}$ [pkm] = pkm shifted from car to IC/R train;

$FC2007_{car}$ [g gasoline/seat km] = fuel consumption;

A_{FCcar} = correction factor for car fuel consumption to take into account the sector technological evolution from 2007 to 2020;

$LF2007_{car}$ [%] = load factor;

G_{LFcar} = correction factor for car load factor to take into account the sector traffic variations from 2007 to 2020;

$EF2007_{gasoline}$ [gCO_2/g gasoline] = emission factor for gasoline;

$e_{gasoline}$ = efficiency of gasoline;

$H_{EFgasoline}$ = correction factor for gasoline emission factor due to its production and consumption to take into account the technological evolution from 2007 to 2020;

$EC2007_{IC/Regional\ train}$ [Wh/seat km] = electricity consumption;

$A_{EC\ IC/Regional\ train}$ = correction factor for train consumption to take into account the sector technological evolution from 2007 to 2020;

$LF2007_{IC/Regional\ train}$ [%] = load factor;

$I_{LFIC/Regional\ train}$ = correction factor for train load factor to take into account the sector traffic increase from 2007 to 2020;

$B_{route\ airplane \rightarrow highspeed\ train}$ = correction factor to take into account the different routes followed from train and car to reach the same destination;

$EF2007_{electricity}$ [gCO_2/Wh] = emission factor for electricity;

$e_{electricity}$ = efficiency of electricity;

$F_{EFelectricity}$ = correction factor for electricity emission factor due to its production and consumption to take into account the technological evolution from 2007 to 2020.

$\Delta \mathbf{CO_2}_{\ \mathbf{truck \rightarrow train}} = (FC2007_{truck} * A_{FCtruck} * \Delta tkm_{truck \rightarrow train} * EF2007_{diesel} * e_{diesel} * L_{EFdiesel}) - (EC2007_{train} * A_{EC\ train} * \Delta tkm_{truck \rightarrow train} * B_{route\ truck \rightarrow train} * EF2007_{electricity} * e_{electricity} * F_{EFelectricity})$

where:

$\Delta tkm_{truck \rightarrow train}$ [tkm] = tkm shifted from truck to train;

$FC2007_{truck}$ [g diesel/tkm] = fuel consumption;

$A_{FCtruck}$ = correction factor for truck fuel consumption to take into account the sector technological evolution from 2007 to 2020;

$EF2007_{diesel}$ [gCO_2/g diesel] = emission factor for diesel;

e_{diesel} = efficiency of diesel;

$L_{EFdiesel}$ = correction factor for diesel emission factor due to its production and consumption to take into account the technological evolution from 2007 to 2020;

$EC2007_{train}$ [Wh/tkm] = electricity consumption;

$A_{EC\ train}$ = correction factor for train consumption to take into account the sector technological evolution from 2007 to 2020;

$B_{route\ truck \rightarrow train}$ = correction factor to take into account the different routes followed from train and truck to reach the same destination;

$EF2007_{electricity}$ [gCO_2/Wh] = emission factor for electricity;

$e_{electricity}$ = efficiency of electricity;

$F_{EFelectricity}$ = correction factor for electricity emission factor due to its production and consumption to take into account the technological evolution from 2007 to 2020.

$\Delta \mathbf{CO_2}_{\ \mathbf{ship \rightarrow train}} = (FC2007_{ship} * A_{FCship} * \Delta tkm_{ship \rightarrow train} * EF2007_{diesel} * e_{diesel} * L_{EFdiesel}) - (EC2007_{\ train} * A_{EC\ train} * \Delta tkm_{ship \rightarrow train} * B_{route\ ship \rightarrow train} * EF_{electricity} * e_{electricity} * F_{EFelectricity})$

where:

$\Delta tkm_{ship \rightarrow train}$ [tkm] = tkm shifted from ship to train;

$FC2007_{ship}$ [g diesel/tkm] = fuel consumption;

A_{FCship} = correction factor for ship fuel consumption to take into account the sector technological evolution from 2007 to 2020;

$EF2007_{diesel}$ [gCO_2/g diesel] = emission factor for diesel;

e_{diesel} = efficiency of diesel;

$L_{EFdiesel}$ = correction factor for diesel emission factor due to its production and consumption to take into account the technological evolution from 2007 to 2020;

$EC2007_{train}$ [Wh/tkm] = electricity consumption;

$A_{EC\ train}$ = correction factor for train consumption to take into account the sector technological evolution from 2007 to 2020;

$B_{route\ ship \rightarrow train}$ = correction factor to take into account the different routes followed from train and ship to reach the same destination;

$EF_{electricity}$ [gCO_2/Wh] = emission factor for electricity;

$e_{electricity}$ = efficiency of electricity;

$F_{EFelectricity}$ = correction factor for electricity emission factor due to its production and consumption to take into account the technological evolution from 2007 to 2020.

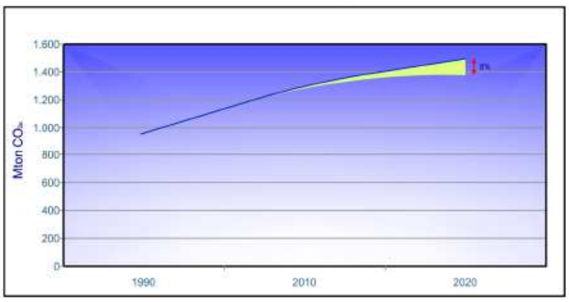
The CO_2 emissions of the transport sector at 2020, recalculated taking into account the above mentioned passengers and goods modal shifts, are:

$$\mathbf{CO_2\ 2020}_{\ \mathbf{modal\ shift}} = CO_2\ 2020 - \Delta pkm_{\ airplane \rightarrow highspeed\ train} - \Delta pkm_{\ car \rightarrow IC/Regional\ train} - \Delta tkm_{\ truck \rightarrow train} - \Delta tkm_{\ ship \rightarrow train}$$

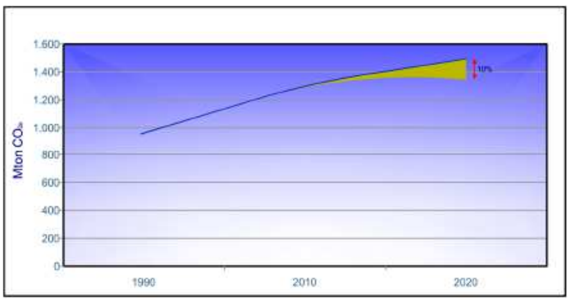
6 Modal shift scenario

Different and possible modal shift scenario will be analyzed and matched with the railway capacity assessment results. All different scenario will share the same assumption: railway 2020 capacity will be the limit. The study will be able to show the best possible modal combination (*due to sensitivity analysis*) that will lead to highest CO_2 reduction levels.

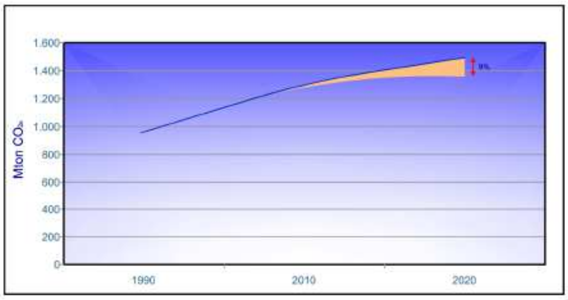
Graph 12 – Results: Passengers from road to rail



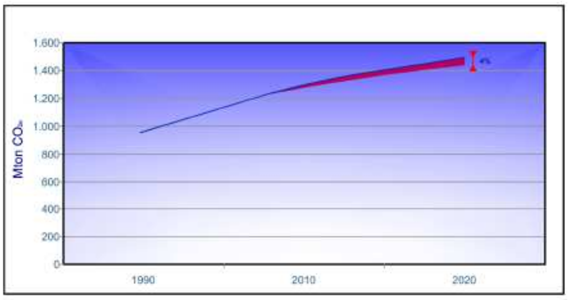
Graph 13 – Results: Passengers from air to rail



Graph 14 – Results: Freights from road to rail



Graph 15 – Results: Freights from ship to rail

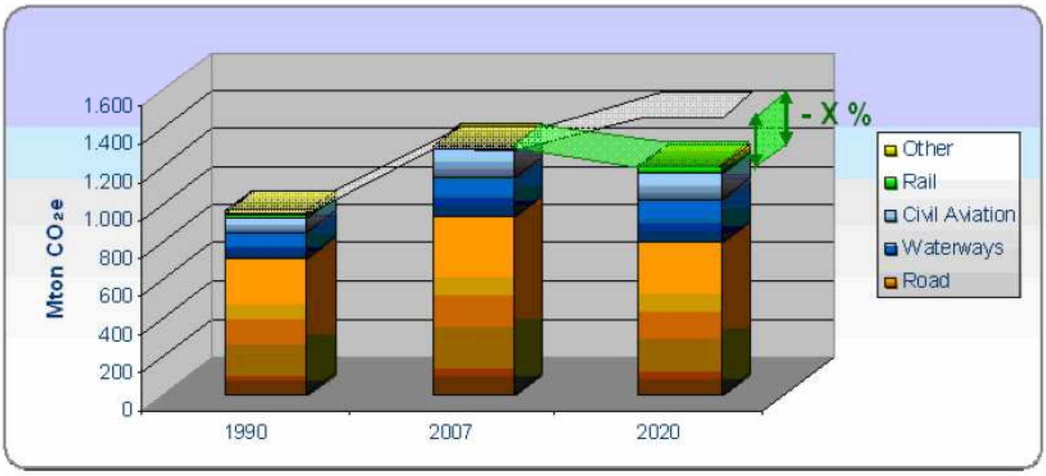


7 Conclusions

The study aims at giving technical support to political decisions. By matching different modal shift options with corresponding results in terms of possible CO_2 savings it will help decision makers to set priorities and policies.

Using the principle of *reductio ad absurdum*, **the technical demonstration** that modal shift to railways may significantly reduce CO_2 emissions until 2020, could lead to the conclusion that promoting railway transport for passenger and goods in the next decade may be a key strategy to obtain CO_2 reduction.

Graphs 16 – CO2 emissions from transport sector



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The Sustainable Development Foundation, based in Rome and established in September 2008, is a network formed by private companies and single members engaged in the green economy (energy efficiency, renewables, sustainable mobility, waste reduction and recycling, etc) chaired by Edo Ronchi, a former Italian minister of environment (1996-2000). It cooperates with international bodies like EEA and CEN on sustainable mobility issues. It is based on a network of 50 experts on sustainability issues and published a number of technical reports on energy and GHG emissions.

The Institute of integrated studies (ISIS), based in Rome, has produced a number of studies financed by EU Commission on transport and environment issues, like "Comparative International Review of third country measures to reduce the climate impact of transport"- DG ENV 2009-, "EU Transport GHG: routes to 2050?" -DG ENV 2009, and GRACE: "Generalisation of Research on Accounts and Cost Estimation"-DG TREN 2008. In 2005 it has realized for UIC the project ERIM: "European Rail Infrastructure Masterplan"

The DISTART Department of Bologna University is active mainly in the transport scenarios analysis and feasibility studies, like the development of the EASTWAY-ITHACA project ("Linking Motorways of the Sea and of the Road in the Southern Mediterranean Region") Coordination and development of the Italian National Project "Methods and Models for Planning the Development of Regional Airports".