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Authors: Riccardo Enei (ISIS), Gianluca Leone (ISIS),
Stephan Schmid (IER), Peter Bickel (IER)

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9H 0. EXECUTIVE SUMMARY

- The Italian rail-road inter-urban environmental marginal external costs case studies focus on two corridors: Milano-Chiasso and Bologna-Brennero, with significant shares in terms of overall movements of passengers and freight involved. In 1998, the routes Milano-Chiasso and Bologna-Brennero showed the circulating average daily number of vehicles higher than the average national values, both for freight and passenger cars traffic along the Milano-Chiasso, and for freight traffic along the Bologna-Brennero.

AVERAGE DAILY NUMBER OF VEHICLES IN 1998 - ROAD -		
	Passenger	Freight
A8/A9 Milano-Chiasso	56,188	11,068
A22 Verona-Modena	24,797	10,032
A22 Verona-Brennero	21,985	8,140
Average National Value	25,882	7,827

- Concerning rail traffic, freight movements (train km) along the routes in 1998 showed clear reversal trends with reference to the national average: +3.2% for the Milano-Chiasso and +1.0% for the Bologna-Brennero, compared to the decreasing national average of –4.9%. Conversely, passenger movements showed two different trends: increasing for the Milano-Chiasso (+1.6%) and decreasing for the Bologna-Brennero (-1.6%), which followed the national average (–0.8%).

NUMBER OF PASSENGERS TRAVELLED AND TRAIN KM IN 1998 - RAIL - - % Var.98-97 -		
	Passenger	Freight
Milano-Chiasso	+1.6%	+3.2%
Bologna-Brennero	-1.6%	+1.0%
Average National Value	-0.8%	-4.9%

- Road environmental marginal external costs (air pollution and global warming) in 1998 per vehicle kilometre showed on average higher values on the route crossing the most densely populated areas, i.e. along the Milano-Chiasso. The analysis by vehicle types indicates that HGV, coaches and LGV exhibited higher external costs than gasoline and diesel cars.

Road environmental marginal external costs (air pollution and global warming) cent/vkm, 1998		
VEHICLE TYPE	MILANO-CHIASSO	BOLOGNA-BRENNERO
Car Diesel	2.271	1.089
Car Gasoline	0.606	0.551
Coach	6.207	5.241
LGV	3.022	1.582
HGV	8.878	7.230

- Rail environmental marginal external costs per vehicle kilometer (air pollution and global warming), showed the high incidence of the air pollution external costs arising from power plant emissions (including fuel extraction, transport and refinery).

Rail environmental marginal external costs (cent/train km) 1998			
	AIR POLLUTION	GLOBAL WARMING	TOTAL IMPACT
FREIGHT TRAIN			
MILANO-CHIASSO	14.758	0.149	14.907
BOLOGNA-BRENNERO	18.334	0.185	18.520
PASSENGER TRAIN			
High Speed Train	41.756	0.731	38.691
Intercity	31.650	0.554	29.327
Local train	23.261	0.407	21.553

- Concerning noise marginal external costs, striking differences on the two routes can be observed. Road marginal external costs on the Milano-Chiasso outnumbered of a factor ten the external costs on the Bologna-Brennero, due to the different density of exposed population.

MILANO-CHIASSO

Cent/vkm	day	evening	night
Passenger car	0.01	0.02	0.04
LGV	0.03	0.05	0.12
HGV	0.09	0.13	0.35

BOLOGNA-BRENNERO

Cent/vkm	day	evening	night
Passenger car	0.001	0.001	0.002
LGV	0.001	0.002	0.005
HGV	0.006	0.008	0.021

- Rail marginal external costs confirmed the differences between the two routes. In order to explain the differences, a possible underestimation of the exposure level on the route Bologna-Brennero should be also taken into account. In fact, due to the long distance along the route, i.e. about 362 km, it has not been possible to provide a sufficient level of detailed information along the entire routes length, in particular for specific segments of the northern section of the route.

MILANO-CHIASSO

Cent/ train km	day	evening	night
Goods train	13.2	14.1	10.0
Inter city	1.4	1.7	4.1
Local train	1.2	1.4	1.2

BOLOGNA-BRENNERO

Cent/ train km	day	evening	night
Goods train	0.3	0.37	0.59
Inter city	0.04		0.03
Local train	0.19	0.20	0.25

- In spite of considerable progress made in recent years the quantification and valuation of environmental damage still suffers from significant uncertainties. This is the case for the Impact Pathway Methodology as well as for any other approach. An indication of the main fields of uncertainties is given below:

  - Effects of particles on human health

  - Effects of nitrate aerosols on health

  - Valuation of mortality

  - Impacts from ozone

  - Omission of effects

9H 1. INTRODUCTION

The aim of these case studies is to provide an assessment of the environmental marginal external costs with reference to road and rail transport modes on two important Italian routes: Milano-Chiasso and Bologna-Brennero.

The following table shows the categories of environmental marginal external costs analysed in the case studies, compared to the ideal framework, as presented in the Unite D3[1].

Table 1: Environmental marginal external costs categories analysed in Italian inter-urban case studies

Ideal Framework	Italian Inter-urban Case Studies
Air pollution	√
-human health	√
-natural environment	√
-building materials	√
Global warming	√
-damage costs (agriculture, health, energy use, water availability, coastal impacts)	
-avoidance costs	√
Noise	
-human health	√
-amenity losses	√
Soil and water pollution	
-heavy metals, oil	
-de-icing salts	
Nuclear risks	
-operation of power plants	
-accident risks	

The significant environmental categories of global warming, air pollution and noises are analysed, in particular considering their impacts on human health.

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[1] UNITE Project, D3 “Marginal Cost Methodology”

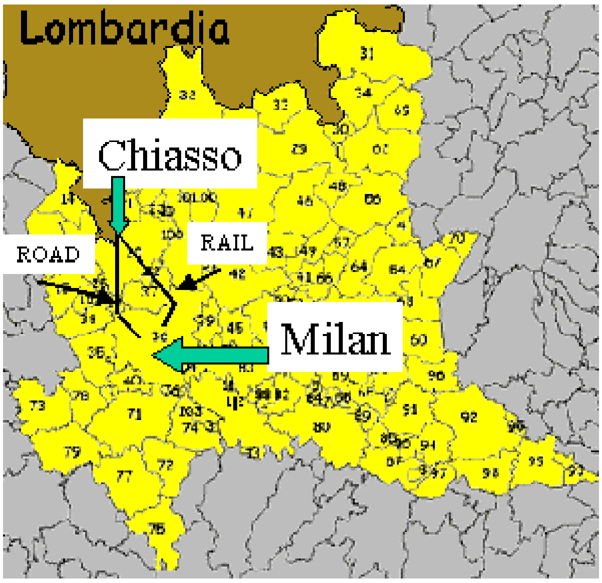
9H 2 CASE STUDY DESCRIPTION

2.1 MILANO-CHIASSO

2.1.1 SOCIO-ECONOMIC CONTEXT

In order to characterise the socio-economic context of the area between Milan and Chiasso, a useful approach is to adopt the territorial aggregation in “local labour systems” (LLS)[2]. In Italy the application of the concepts of LLS has led to the delimitation of 784 homogeneous areas with reference to the economic activities and commuting flows, covering all the country.

The territorial delimitation through homogeneous zones (LLS) provides a solid background for socio-economic analysis.



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[2] That is, the delimitation of a territorial area on the basis of economic and functional relationships. The Standard Metropolitan Statistical Areas (SMSAs), defined by the United States Bureau of the Census since 1940 and the Daily Urban System (DUS), represented the first experiences in the field of territorial functional delimitation. SMSAs were derived from US county-level data on the basis of a two-step procedure: firstly, a 'central city' of at least 50,000 inhabitants was identified. Secondly, contiguous counties showing socio-economic integration with the 'central city' - at least 15% of the resident workers commuting to the 'central city' - and a 'metropolitan character' - at least 75% of total employment was non-agriculture and population density was at least 150 persons per square mile - were added to the 'central city'. The Daily Urban System (DUS) adopted by Berry (1973) in his analysis of the changes in the US urban system during the 1960s, was slightly different. On the one hand, the concept of DUS extended even further the emphasis placed on daily commuting. On the other hand, “it overcame the strict core-hinterland distinction of SMSAs for a more complex notion of self-containment with regard to labour and housing markets” (Chesire, 1997).

The figure shows the localisation of LLS along the Lombardia Region territory, where the routes Milano-Chiasso passes through, considering both the road and rail infrastructures.

The road and rail routes cross mainly through three LSS:

- Milan, number 36 on the figure;
- Desio, number 37;
- Como, number 20.

For each LSS the graphs below show two socio-economic indicators at 1998 compared with the regional and the national average values. The first one is the population density (resident population per km^2) the second one is the enterprises density (the number of enterprises per 1,000 inhabitants), which represents a proxy of economic activity.

Figure 1: Population density in Milano-Chiasso area

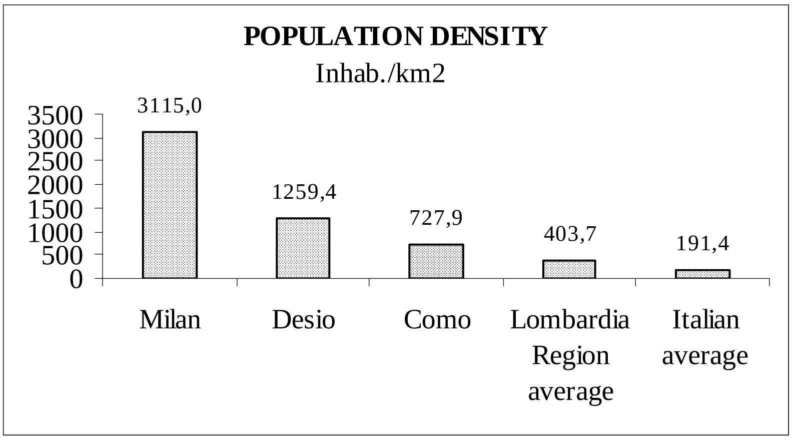
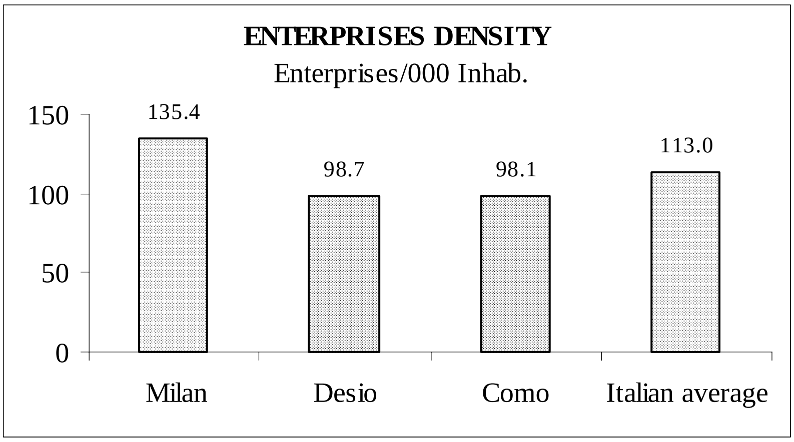


Figure 2: Enterprises density in Milano-Chiasso area



It can be observed that the population density of the three LSS pronouncedly exceed the regional and national averages. In Milan LSS the population density is about 17 points above the average national level and 7 points above the regional one. The population densities of Desio and Como LSS, though lower than in Milan, are above the average national level, respectively by 6 and 3 points.

The enterprises densities, even confirming greater values comparing to the national and regional ones, denote more equilibrium: in Milan LSS the enterprises density is above the national average by 19%, while in Como and Desio is below, i.e. about by 13%.

The high density of economic activities in the LSS generates as consequence high concentration of employees; the Milan LSS (887 square kilometres), for instance, accounts for about 80% of total employees of the Milan Province (1,882 square kilometres).

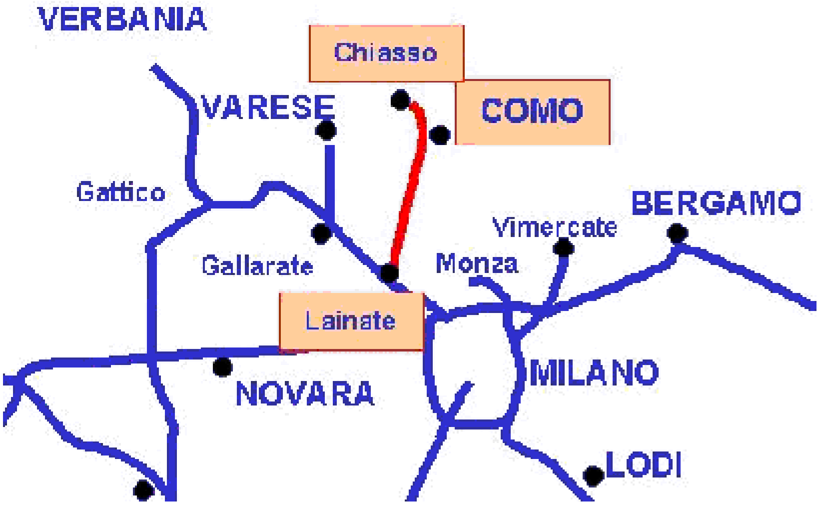
In conclusion, the route Milano-Chiasso crosses through one of the most densely populated and industrialised area of the North of Italy, in particular along the first 30 km, in the Milan LSS territory.

2.1.2 TRANSPORT INFRASTRUCTURE CHARACTERISTICS

2.1.2.1 Road

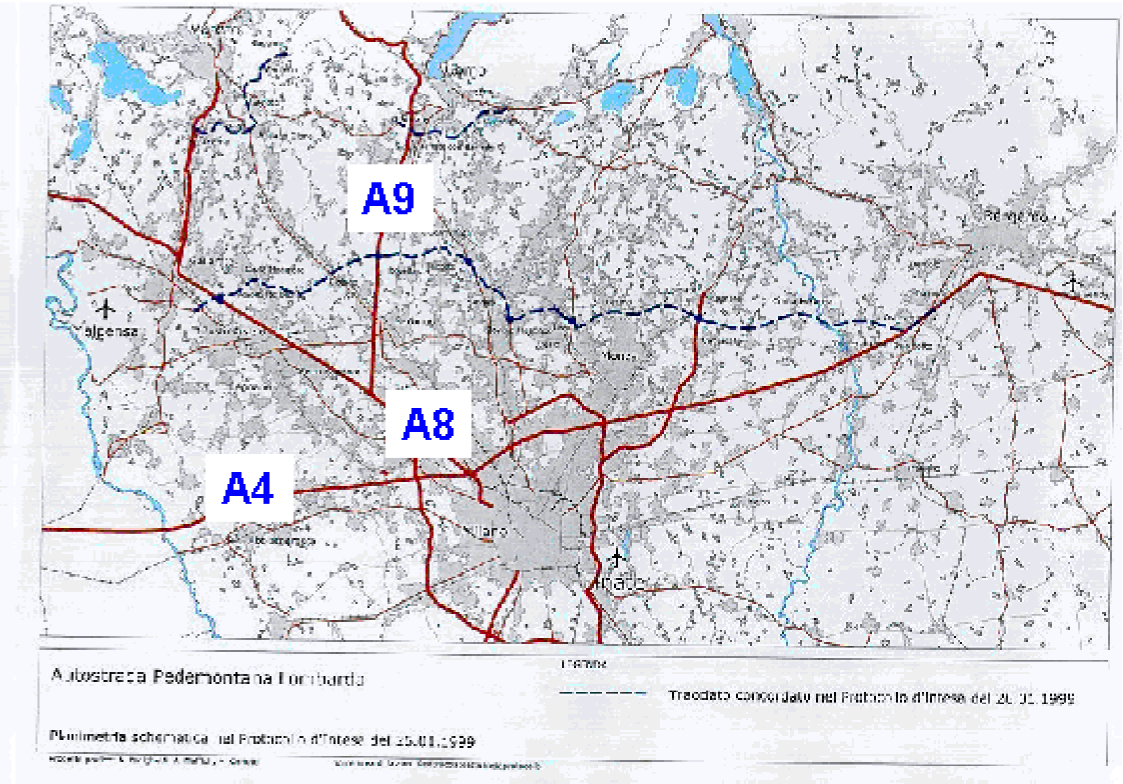
The route Milano-Chiasso, 43 km by road, can be separated in two sections; the first lies on a segment of 11 km along the highway A8 Milano-Varese, the second one coincides with the highway A9 Lainate-Como-Chiasso for the remaining 32 km. The segment of the highway A8, which crosses through the densely populated area of Milan hinterland, up to Lainate, has four lanes in both directions. The highway A9, starting from Lainate, has two lanes in both directions, except for 18 km, from Lainate up to Gallarate, with three lanes in both directions.

The route Milano-Chiasso is prevailingly flat, with long segments without tunnels or viaducts, with the exception on the section Como-Grandate, where three short galleries pass under the Monte Olimpino.



In order to allow the users to take alternative routes to the congested roads around the north of Milan towards Como, Varese and Bergamo, in particular along the A4-A8-A9 highway network system, a project of new infrastructure supply has been formulate.

The project, named “Pedemontana Lombarda highway”, aims at connecting with a new highway the axis East-West in the north area of Milan, including the connection to the new international hub “Milan-Malpensa”. The picture above shows with a dash line the paths of the new highway.

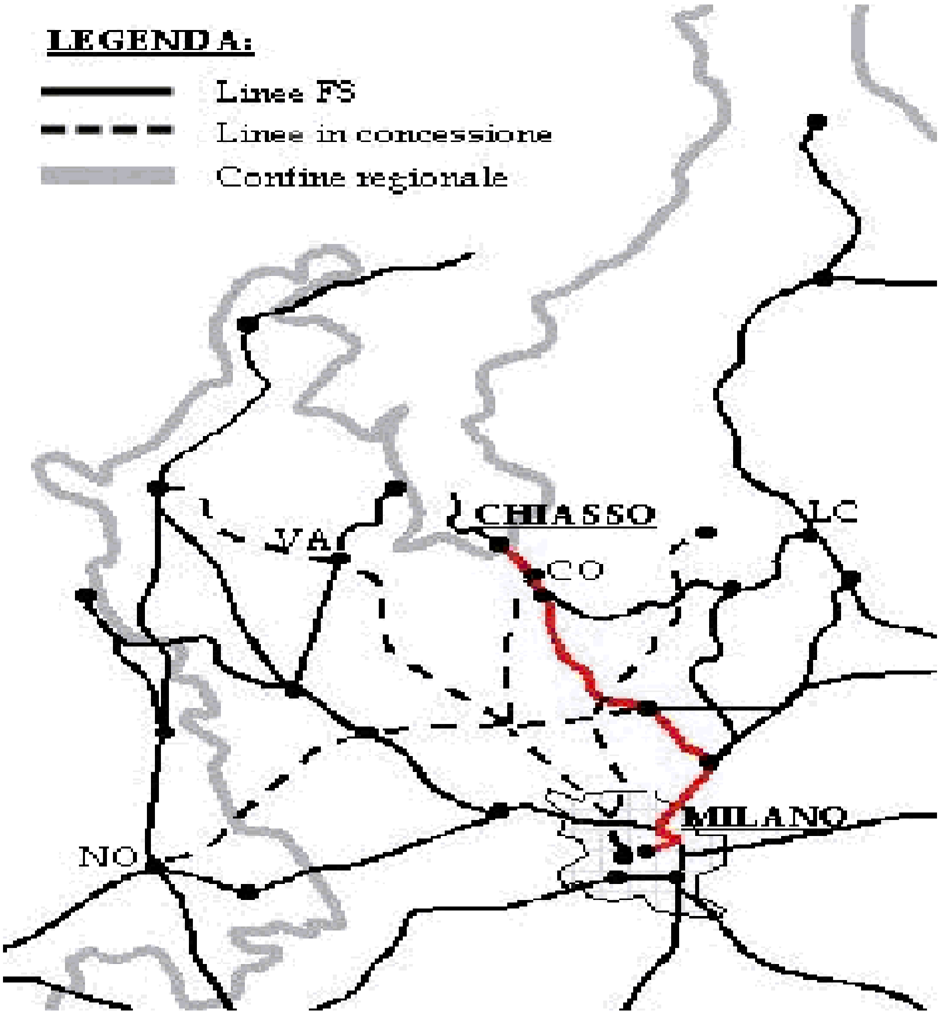


The traffic flows from East to West should be directed towards alternatives paths, connecting several municipalities located at north of Milan, without gravitating on the urban segment of A4 (Milan hinterland).

2.1.2.2 Rail

The route Milano-Chiasso represents the more rapid way connecting Milan, the Switzerland and North Europe through the directions Zurich-Stuttgart-Cologne, Dortmund and Basilea-Strasbourg-Bruxelles.

The railway route Milano-Chiasso, 51 km, is equipped with four trucks in both directions, with the exception of segment Monza-Bivio Rosales, with one truck for direction. The maximum value of slope is 14/1000, upward, and 10/1000 downward.



Due to the crucial role of the route for the transalpine freight traffic between Italy and Switzerland, several projects of technical improvements have been formulated:

1. technical enhancement of rail capacity, aiming at allow the transport by train of trucks up to four meters height and facilitate the loading of containers;

2. freight platform settlement in the area of Como, in order to meet the growth demand of intermodal services. The freight platform could promote synergies with the already existing seven terminals operating in this area[3].

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[3] The main terminals between Milano and Chiasso are located in Milano Smistamento, Milano Greco Pirelli, Busto Arsizio, Gallarate, Oleggio, Desio and Chiasso, providing unaccompanied transport and rolling highway intermodal services.

2.1.3 TRAFFIC VOLUME

2.1.3.1. Road

The yearly traffic volume along the route is intensive, with seasonal peaks in correspondence of holidays and weekends. In 1998 the theoretical average daily number of vehicles travelling along the route[4] was 67,256, a value which doubles the average national value[5] and one of the higher along the overall segments of the Italian highways network. The table below shows, according to a decreasing order, the first most congested segments of Italian highways network; the route Milano-Chiasso follows three A4 highway segments, which connect the axis West-East of the north of Italy, including the most populated and developed area between Milan and Venice.

Table 2:Milano-Chiasso road traffic volume (number of vehicles, 1998)

HIGHWAY	AVERAGE DAILY NUMBER OF VEHICLES IN 1998
A4 Milan-Brescia	90,747
A4 Brescia-Padova	72,334
A4 Padova-Venice	71,328
A8/A9 Milano-Chiasso	67,256
Average National Value	33,709

Freight traffic volume accounts for about 19% of the total traffic volume, which in terms of theoretical average daily number corresponds to more than 11,000 heavy vehicles. This value, as well as for the passenger case, is well above the national average. The average daily number of vehicles travelling along the route Milano-Chiasso was in fact by 29% higher than the average national values for freight case and by 54% for the passenger one.

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[4] The theoretical average daily number of vehicles corresponds to the number of vehicles which travelling along the overall distance of the route (in both directions). It is calculated as the ratio between the vehicle kilometres and the length of the route

[5] The average national value is calculated with reference to the 86% of Italian highways network

Table 3:Milano-Chiasso road passengers and freights traffic volume (number of vehicles, 1998)

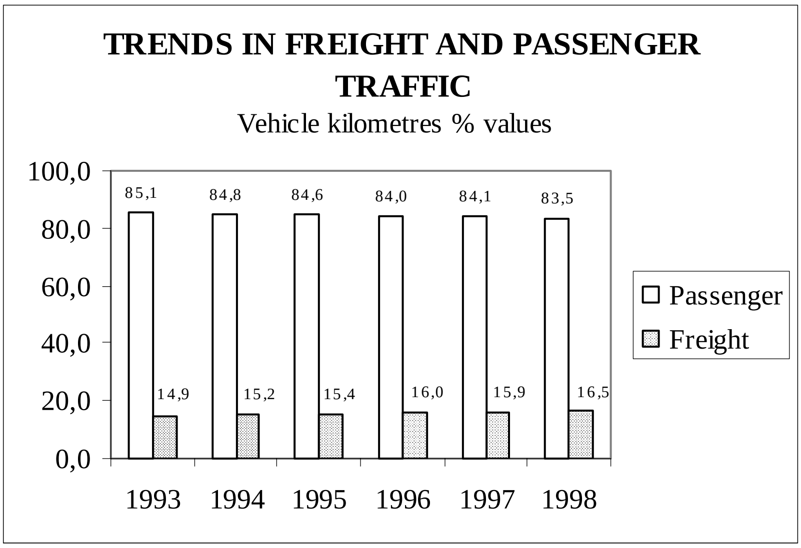
AVERAGE DAILY NUMBER OF VEHICLES IN 1998		
	Passenger	Freight
A8/A9 Milano-Chiasso	56,188	11,068
Average National Value	25,882	7,827

In terms of vehicle kilometres, over the past six years, from 1993 to 1998, the table below shows increasing trends both in the passenger and freight transport cases. The total amount of vehicle kilometres increased by 21%, from 1993 to 1998 (+34% for freight and +19% for passenger transport cases).

Table 4: Milano-Chiasso road traffic volume trend (mil. vehicle kilometres)

VEHICLE-KM (mil.)	1993	1994	1995	1996	1997	1998
Passenger	1,337.9	1,373	1,402.9	1,440,5	1,522.7	1,593.5
Freight	233.6	246.4	256.3	273.8	288.6	313.9
Total	1,571.5	1,619.4	1,659.2	1,714.3	1,811.3	1,907.4

In terms of yearly trends, the graph shows that during the period 1993-1998 the freight traffic (vehicle*kilometre) increased at yearly average rate of 2%, while passenger traffic slightly reduced by -0,3% average yearly rate.



Assuming a rate of occupancy of 1.7 for passenger vehicles and a payload of 9 tonnes for freight vehicles[6], the values of passenger kilometres and tonne kilometres (in million) are the following:

Table 5: Milano-Chiasso road traffic volume trend (mil. passenger kilometer and tonne kilometre)

		1995	1996	1997	1998
A8/A9 Milano-Chiasso	Passenger kilometres	2,385	2,449	2,589	2,709
	Tonne kilometres	2,307	2,464	2,597	2,825
Average National Value	Passenger kilometres	78,573	80,020	82,910	86,404
	Tonne kilometres	121,567	123,558	129,855	136,419

In practice, about 2% of national average freight tonne kilometres and 3% of passengers kilometres travelled along the route Milano-Chiasso in 1998.

2.1.3.2 Rail

The rail route, due to the north of Milan densely populated hinterland, is interested by intense local passengers traffic, both regional and metropolitan, as well as by long-distance, international trains (freight and passengers).

With reference to the passenger transport, the significant weight of local transport can be observed in the table below, which shows the supply of local and long distance passenger trains on the route Milano-Chiasso.

Table 6: Milano-Chiasso rail passengers traffic volume (train kilometer and passenger kilometer, 1998)

TRAINS-KM AND PASSENGERS-KM IN 1998		
	Train * kilometres	Passenger * kilometres
Long distance trains	793,699	144,247,750
Local trains	998,678	121,320,450
Total	1,792,377	265,568,290

The number of trains-km travelling along the route indicates the supply of transport service. Local passengers train-km account for 53% of the train-km in service and for 46% of passenger-km.

The intensive use of local passengers train for short distance travels is confirmed by the breakdown of local trains traffic statistics; the trains-km performed around the metropolitan area, prevailing by commuters, account for about 99%, while only 1% are assigned to medium distance, inter-regional travels.

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[6] National Transportation Account (1999), pag.180

Table 7: Milano-Chiasso rail passengers traffic volume (short and long distance, 1998)

SHORT DISTANCE TRAFFIC – BREAKDOWN OF TRAIN-KM AND PASSENGER-KM- YEAR 1998		
	Train * kilometres	Passenger * kilometres
Metropolitan	989,380	120,357,040
Inter-regional	9,298	963,500
Total	998,678	121,320,540

LONG DISTANCE TRAFFIC – BREAKDOWN OF TRAIN-KM AND PASSENGER-KM- YEAR 1998		
	Train * kilometres	Passenger * kilometres
International	654,416	124,413,500
Internal	139,283	19,834,250
Total	793,699	144,247,750

The vocation of the route Milano-Chiasso as international traffic node can be valuated by the analysis of the table below, which shows the breakdown of long distance passengers traffic in two classes: international and internal[7].

International traffic accounts for about 83% of trains-km and 86% of passengers-km.

The trend over the period 1995-1998 showed a general alignment to the national averages, i.e. a reduction in the passenger kilometres associated with the increasing level of service provided, in particular on the long distance traffic.

Over the past three years, from 1995 to 1998, the train kilometres on long distances rose on average yearly by 2,7% at national level and by 1,6% on the route Milano-Chiasso. An opposite trend can be observed with reference to the short distance traffic, where the train kilometres along the route Milano-Chiasso grew by 1.1% compared with a decreasing national value by –1,8%.

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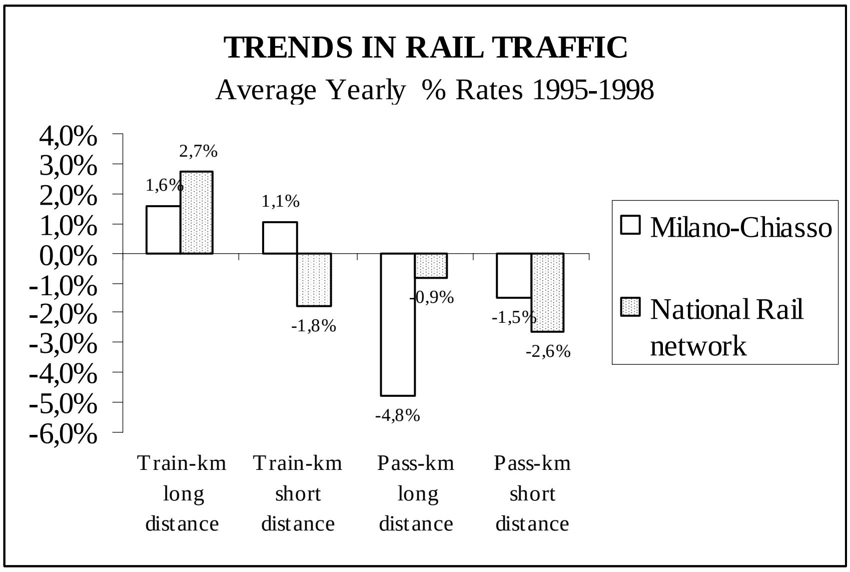
[7] The international and internal traffic include all trains travelling respectively out and inside the national border

Figure 3: Milano-Chiasso rail traffic volume trend (% values)



The rail freight traffic on the route Milano-Chiasso in 1998 amounts to 333 million of tonn kilometres and 935 thousand of train kilometres. Over the past two years (1997/1998) the trend in freight traffic volume on the route grew more than the national average, with an increase respects to the 1997 level (by 3.2%) in terms of train km, against the average national decrease by –4.9%.

2.2 BOLOGNA-BRENNERO

2.2.1 Socio-economic context

The routes Bologna-Brennero, road as well as rail, cross through three Regions, Emilia Romagna, Veneto, Trentino Alto Adige, belonging to one of the richest territorial area of Italy, i.e. the North-East.

BOLOGNA-VERONA

VERONA-BRENNERO

Over the past five years, from 1995 to 2000, the North-East regional economic performance systematically rose above the national averages, in terms of yearly real GDP growth rates (at 1995 prices).

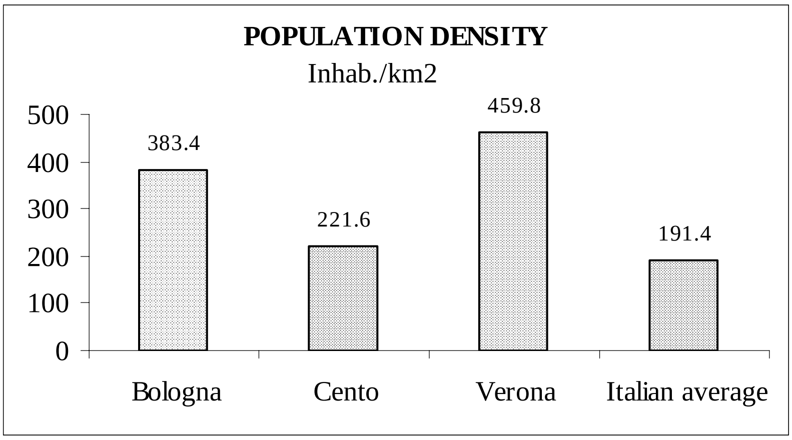
YEAR	NORTH –EAST	NATIONAL AVERAGE
1995-1996	+1.65%	+1.12%
1996-1997	+1.96%	+1.90%
1997-1998	+1.99%	+1.72%
1998-1999	+1.56%	+1.36%
1999-2000	+3.25%	+2.91%

The area between Bologna and Verona includes several “urban local systems (LLS)”[8] with population densities higher than the national average. In particular the following:

Bologna, number 259, in the above figure
Cento, number 263
Verona, number 185

In other cases, i.e. Mirandola, number 252, the population density is approximately the same, i.e. 168.6 inhabitants per kmq against 191.4 at national level.

Figure 4: Population density in Bologna-Brennero area



Along the segment Verona-Brennero, the values of population densities in LSS decline below the national average, i.e. Rovereto, number 172 (110.7 inh./kmq), Egna, number 147 (87 inh./kmq), Vipiteno, number 156 (28.7 inh./kmq), due to the presence of mountain areas.

The presence of a significant network of economic activity is confirmed by the proxy variable of enterprise density (number of enterprises per 1,000 inhabitants). Values of

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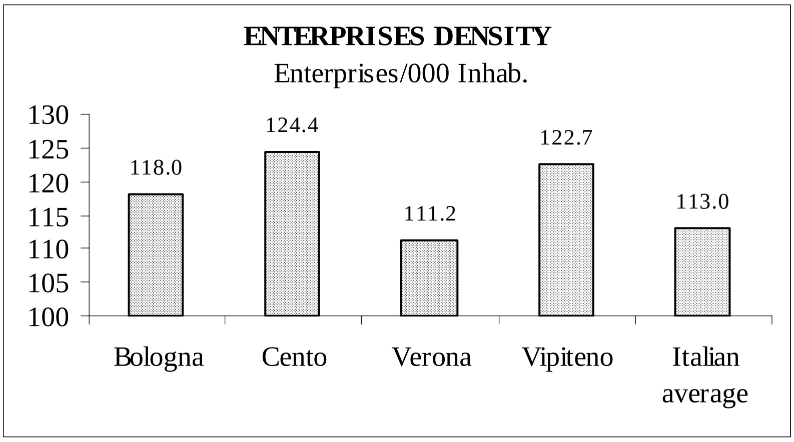
[8] Concerning the concept of LLS, see par. 2.1.1 for details

enterprise densities above the national average can be observed in the urban areas (Bologna, Cento), and, in some cases, in the mountain areas, i.e. Vipiteno.

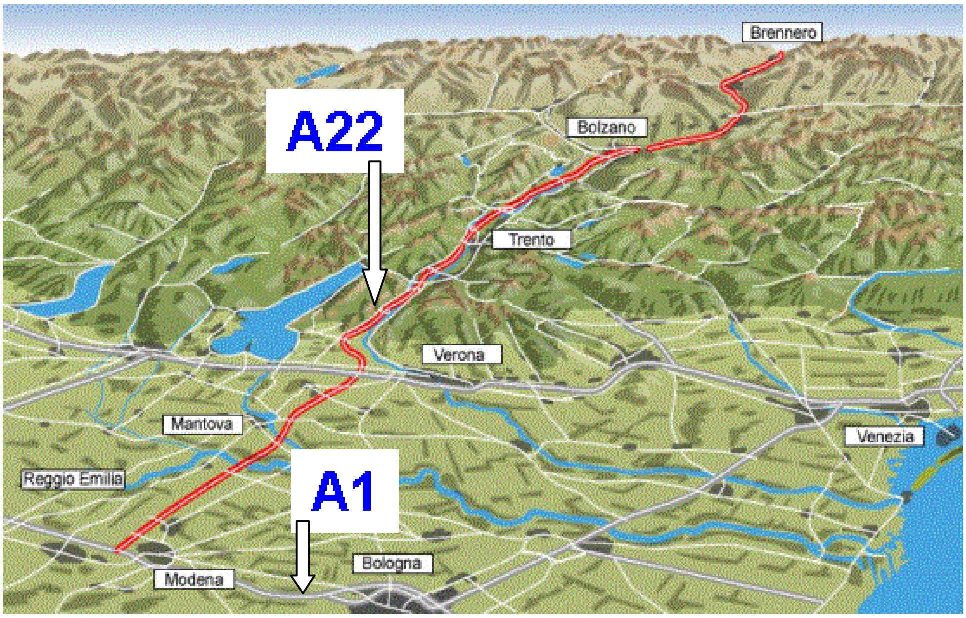
Figure 5:Enterprises density in Bologna-Brennero area



2.2.2 Transport infrastructure characteristics

2.2.2.1 Road

The route Bologna-Brennero (361 km) can be divided in two main sections: the segment Bologna-Modena, 47 km along the A1 motorway, and the segment Modena-Brennero, 314 km along the motorway A22.



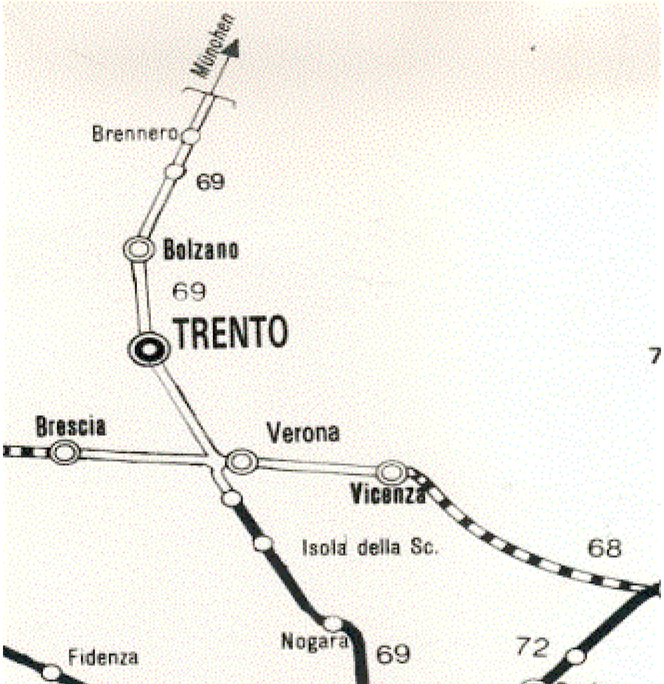
The lengthiest segment, the Modena-Brennero (A22), starts from the border with Austria (Brennerpasse), crossing longitudinally the Trentino-alto Adige region and the Pianura Padana area. Along its path, the A22 meets two important motorways, the A4 near Verona and the A1 near Modena.

The path is rich of slopes and curves, with numerous tunnels and viaducts, in particular from the Austrian border and Bolzano. Conversely, from Bolzano to Modena, the path becomes smooth, with a short tunnel near Trento.

The A22 motorway is equipped with two lanes by each direction. The segment Modena-Bologna, along the A1, is equipped with three lanes by each direction; with a path generally smooth, without tunnels.

2.2.2.2 Rail

The route Bologna-Brennero, 354 km, is part of the greater European South-North conjunction, via Monaco-Innsbruck-Brennero-Bolzano-Verona-Bologna-Roma.



The maximum ascent slope is 9‰ between Bologna and Verona, 8‰ between Verona and Bolzano and 23‰ between Bozano and Brennero.

The segment Bologna-Verona, 114 km, interested both by local and international traffic, represents a weak point along the route, that undermined the overall potentiality of the route Bologna-Brennero due to the only one track allowed for the circulation of trains.

In order to overcome the drawbacks, by 2004 improvement of infrastructure endowment through the doubling of the tracks and investments for intermodal transport equipments have been planned. The capacity of the route should be improved from 90 to 220 train/days, with an average time reduction from 85 to 54 minutes.

2.2.3 TRAFFIC VOLUME

2.2.3.1.Road

The traffic volume between Bologna and Brennero, along the A1 and A22 segments, is particularly intense during all the year, with relevant peak during seasonal period, due to the significant touristic flows between Austria and Italy.

Table 8: Modena –Brennero road traffic volume (number of vehicles, 1998)

HIGHWAY	AVERAGE DAILY NUMBER OF VEHICLES IN 1998
A22 Brennero-Vipiteno	19,606
A22 Vipiteno - Bressanone	21,383
A22 Bressanone -Chiusa	24,279
A22 Chiusa – Bolzano	26,852
A22 Bolzano Sud- Egna	32,899
A22 Egna – S.Michele	32,737
A22 Brennero-Verona	30,125
A22 Verona - Modena	34,829
Average National Value	33,709

The table above shows the traffic volume[9] along the route A22 Modena –Brennero (which accounts for about 87% of the Bologna-Brennero length) in 1998 by segments, compared with the national average value.

It can be observed that along the segment between Verona and Modena (90 km) the traffic volume was slightly above the national average. Other segments, i.e. Bolzano Sud – Egna and Egna- S.Michele, showed high traffic volumes, while the segments towards Brennero (i.e., Brennero-Vipiteno) indicated a reduction in traffic volumes.

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[9] The daily number of vehicles travelling along the route, see paragraph 2.1.3.1 for details.

Table 9: Modena –Brennero road passengers and freight traffic volume (number of vehicles, 1998)

AVERAGE DAILY NUMBER OF VEHICLES IN 1998			
	Passenger	Freight	
		Abs. val.	% val.
A22 Brennero-Vipiteno	13,071	6,535	33.3
A22 Vipiteno - Bressanone	15,175	6,207	29.0
A22 Bressanone -Chiusa	17,342	6,936	28.5
A22 Chiusa – Bolzano	19,967	6,885	25.6
A22 Bolzano Sud- Egna	24,332	8,567	26.0
A22 Egna – S.Michele	23,777	8,959	27.3
A22 Brennero-Verona	21,985	8,140	27.0
A22 Verona - Modena	24,797	10.032	28.8
Average National Value	25,882	7,827	30.2

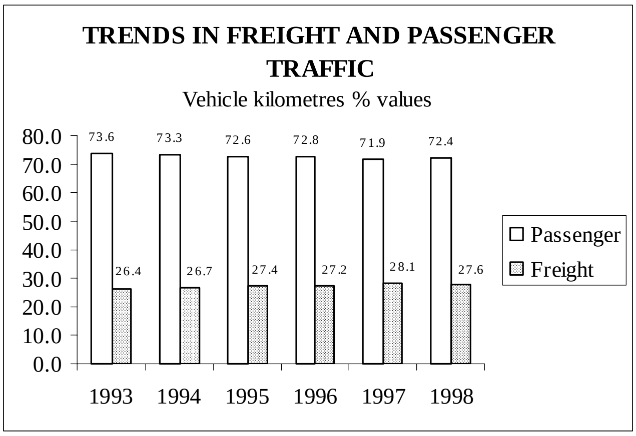
On average, in 1998 the value of freight traffic volume on the route was above the national average (about 8,000 vehicles). In percentage terms, the freight traffic on the segment Brennero –Vipiteno accounted for about 33% of the total traffic volume.

In terms of vehicle kilometre, the freight traffic represented the most dynamic component: between 1993 and 1998 the vehicles kilometres by trucks increased by 28%, compared with 21% for passenger cars.

Table 10: Modena-Brennero road traffic volume trend (mil. vehicle kilometres)

VEHICLE-KM (mil.)	1993	1994	1995	1996	1997	1998
Passenger	2,165.1	2,275.9	2,364.8	2,413,0	2,418.4	2,612.5
Freight	755.7	829.5	893.3	901.4	946.8	995
Total	2,940.8	3,105.4	3,258.1	3,314.4	3,365.2	3,607

The yearly share of passenger traffic volume, in vehicle kilometres, slightly decreased on average by –0.3%, compared with a growing trend by 0.9% for freight transport.



Assuming a rate of occupancy of 1.7 passengers vehicles and a payload of 9 tonnes for trucks, the amounts of passenger kilometres and tonne kilometres on the route Modena-Brennero were the following:

Table 11: Modena-Brennero road traffic volume trend (mil. passenger kilometre and tonne kilomretre)

		1995	1996	1997	1998
A22 Modena-Brennero	Passenger kilometres	4,020	4,102	4,111	4,440
	Tonne kilometres	8,040	8,114	8,523	8,956
Average National Value	Passenger kilometres	78,573	80,020	82,910	86,404
	Tonne kilometres	121,567	123,558	129,855	136,419

About 7% of tonne kilometres, with reference to the national average, have been hauled along the route Modena-Brennero.

2.2.3.2 Rail

In 1998 a relevant traffic volume, affecting both local, i.e. around the cities of Bologna and Verona, and international level, connecting South and North of Europe, interested the rail route Bologna-Brennero.

With reference to the passenger traffic, the following table shows the volumes in terms of train kilometres and passengers kilometres related both to local and international traffic.

Table 12: Bologna-Brennero rail passengers traffic volume (train km and passenger km, 1998)

TRAINS-KM AND PASSENGERS-KM IN 1998		
	Train * kilometres	Passenger * kilometres
Long distance trains	2,518,048	655,088,390
Local trains	3,531,950	399,081,760
Total	6,049,998	1,054,170,150

The table allows to assess a quite equilibrate weight between local and long distance traffic component in terms of vehicle kilometres (local trains accounted in fact for about 58% of total vehicle kilometres). On the other hand, in terms of passenger kilometres, the long distance trains showed a most significant share, i.e. 62% of total passenger kilometres.

The breakdown of short and long distance by metropolitan and inter-regional services (short distance) and international and internal services (long distance) shows higher value for metropolitan transport, in terms of passenger kilometres and for inter-regional services, in terms of passengers kilometres.

Table 13: Bologna-Brennero rail passengers traffic volume (short and long distance, 1998)

SHORT DISTANCE TRAFFIC – BREAKDOWN OF TRAIN-KM AND PASSENGER-KM- YEAR 1998		
	Train * kilometres	Passenger * kilometres
Metropolitan	1,817,639	131,410,760
Inter-regional	1,714,311	267,671,000
Total	3,531,950	399,081,760

LONG DISTANCE TRAFFIC – BREAKDOWN OF TRAIN-KM AND PASSENGER-KM- YEAR 1998		
	Train * kilometres	Passenger * kilometres
International	1,659,761	483,880,150
Internal	858,287	171,208,240
Total	2,518,048	655,088,390

The long distance traffic on the route was clearly dominated by international services, i.e. about 74% of passenger kilometres and 66% of train kilometres.

Concerning rail freight traffic, in 1998 on the route Bologna-Brennero was hauled 1,733 million of tonn kilometres and circulated 3,951 thousand of train kilometres. Over the past two years (1997/1998) the trend in freight traffic volume on the route slightly grew more than the national average, with an increase respects to the 1997 level by 1.0% in terms of train km, against the average national decrease by –4.9%.

2.3 METHODOLOGY

Marginal costs in this case study means the environmental costs caused by an additional vehicle driving on a certain route. For noise costs the time of day is relevant as well, due to the sensitivity of the receptors (which is different at night than during the day) and the high importance of the background noise level for the results.

This approach of looking at the impacts of one additional vehicle requires a detailed bottom-up approach as it has been developed in the ExternE project series. The methodology follows as far as possible this Impact Pathway Approach, which is described in the following sections. For more detailed information see European Commission (1999a,b), Friedrich and Bickel (2001).

2.3.1 AIR POLLUTION

The starting point for the bottom-up approach for quantification of marginal costs is the micro level, i.e. the traffic flow on a particular route segment. Then, the marginal external costs of one additional vehicle are calculated for a single trip on this route segment. This is done by modelling the path from emissions to impacts and costs.

Results of recent bottom-up calculations (see e.g. Friedrich and Bickel, 2001) have shown that the value of externalities may differ substantially from one transport route to another.

For quantifying the costs due to airborne pollutants the Impact Pathway Approach was applied. It comprises the steps:

– emission calculation

– dispersion and chemical conversion modelling

– calculation of physical impacts, and

– monetary valuation of these impacts.

These steps are described in more detail in the following sections.

Emissions/burdens

In the first step the emissions from an additional vehicle on a specific route are calculated.

For comparisons between modes, the system boundaries considered are very important. For instance, when comparing externalities of goods transport by electric trains and heavy duty road vehicles, the complete chain of fuel provision has to be considered for both modes. Obviously, it makes no sense to treat electric trains as having no airborne emissions from operation. Instead, the complete chain from coal, crude oil, etc. extraction up to the fuel or electricity consumption has to be taken into account.

Concentrations

To obtain marginal external costs, the changes in the concentration and deposition of primary and secondary pollutants due to the additional emissions caused by the additional vehicle have to be calculated. The relation between emission and concentration of pollutants are highly non-linear for some species (e.g. primary particles). So, air quality models that simulate the transport as well as the chemical transformation of pollutants in the atmosphere are used.

Depending on the range and type of pollutant considered different models are applied:

- the Gaussian dispersion model ROADPOL for calculation of pollutant concentrations from line sources on the local scale up to 25 km from the road (Vossiniotis et al., 1996)

- the Wind rose Trajectory Model (WTM) is used to quantify the concentration and deposition of non-reactive pollutants and acid species on a European scale (Trukenmüller and Friedrich, 1995)

- the Source-Receptor Ozone Model (SROM), which is based on source-receptor (S-R) relationships from the EMEP MSC-W oxidant model for five years of meteorology (Simpson et al., 1997), is used to estimate changes in ozone concentrations on a European scale.

The consistent use of the same impact model to calculate airborne emissions from all transport modes ensures the comparability of the results across modes. This is especially important when comparing road transport with electrified rail transport, where the latter only produces air emissions from power plants as a point source. Thus the country specific fuel mix used to generate the electricity for the railway system or the railway company specific fuel mix has to be considered.

The modelling approach for rail traffic emissions is consequently similar to the energy sector. Impacts due to diesel trains can be quantified with the same approach as road transport vehicles with internal combustion engine by making adjustments as necessary, e.g. emission height.

Impacts

Concentrations then translate into impacts through the application of exposure-response functions, which relate changes in human health, material corrosion, crop yields etc. to unit changes in ambient concentrations of pollutants.

Exposure-response functions come in a variety of functional forms. They may be linear or non-linear and contain thresholds (e.g. critical loads) or not. Those describing effects of various air pollutants on agriculture have proved to be particularly complex, incorporating both positive and negative effects, because of the potential for certain pollutants, e. g. those containing sulphur and nitrogen, to act as fertilisers.

The dose-response functions used within UNITE are the final recommendations of the expert groups in the final phase of the ExternE Core/Transport project (Friedrich and Bickel 2001). The following table gives a summary of the dose-response functions as they are implemented in the EcoSense version used for this study.

Table 14: Health and environmental effects included in the analysis of air pollution costs

Impact category	Pollutant	Effects included
Public health – mortality	$PM_{2.5}$, PM_{10} 1)	Reduction in life expectancy due to acute and chronic mortality
	SO_2, O_3	Reduction in life expectancy due to acute mortality
Public health – morbidity	$PM_{2.5}$, PM_{10}, O_3	respiratory hospital admissions
		restricted activity days
	$PM_{2.5}$, PM_{10} only	cerebrovascular hospital admissions
		congestive heart failure
		cases of bronchodilator usage
		cases of chronic bronchitis
		cases of chronic cough in children
		cough in asthmatics
		lower respiratory symptoms
	O_3 only	asthma attacks
		symptom days
Material damage	SO_2, acid deposition	Ageing of galvanised steel, limestone, natural stone, mortar, sandstone, paint, rendering, zinc
Crops	SO_2	Yield change for wheat, barley, rye, oats, potato, sugar beet
	O_3	Yield loss for wheat, potato, rice, rye, oats, tobacco, barley, wheat
	Acid deposition	increased need for liming
	N, S	fertiliser effects

1) including secondary particles (sulphate and nitrate aerosols).

Source: IER.

Impacts on human health

The table below lists the exposure response functions used for the assessment of health effects. The exposure response functions are taken from the 2nd edition of the ExternE Methodology report (European Commission 1999a), with some modifications resulting from recent recommendations of the health experts in the final phase of the ExternE Core/ Transport project (Friedrich and Bickel 2001).

Table 15: Quantification of human health impacts due to air pollution[1]

Receptor	Impact Category	Reference	Pollutant	f_{er}
ASTHMATICS (3.5% of population)				
Adults	Bronchodilator usage	Dusseldorp et al., 1995	PM_{10} Nitrates $PM_{2.5}$ Sulphates	0.163 0.163 0.272 0.272
	Cough	Dusseldorp et al., 1995	$PM_{10,}$ Nitrates $PM_{2.5}$ Sulphates	0.168 0.168 0.280 0.280
	Lower respiratory symptoms (wheeze)	Dusseldorp et al., 1995	PM_{10} Nitrates $PM_{2.5}$ Sulphates	0.061 0.061 0.101 0.101
Children	Bronchodilator usage	Roemer et al., 1993	PM_{10} Nitrates $PM_{2.5}$ Sulphates	0.078 0.078 0.129 0.129
	Cough	Pope and Dockery, 1992	PM_{10} Nitrates $PM_{2.5}$ Sulphates	0.133 0.133 0.223 0.223
	Lower respiratory symptoms (wheeze)	Roemer et al., 1993	PM_{10} Nitrates $PM_{2.5}$ Sulphates	0.103 0.103 0.172 0.172
All	Asthma attacks (AA)	Whittemore and Korn, 1980	O_3	4.29E-3
ELDERLY 65+ (14% of population)				
	Congestive heart failure	Schwartz and Morris, 1995	PM_{10} Nitrates $PM_{2.5}$ Sulphates CO	1.85E-5 1.85E-5 3.09E-5 3.09E-5 5.55E-7
CHILDREN (20% of population)				
	Chronic cough	Dockery et al., 1989	PM_{10} Nitrates $PM_{2.5}$ Sulphates	2.07E-3 2.07E-3 3.46E-3 3.46E-3
ADULTS (80% of population)				
	Restricted activity days (RAD)	Ostro, 1987	PM_{10} Nitrates $PM_{2.5}$ Sulphates	0.025 0.025 0.042 0.042
	Minor restricted activity days (MRAD)	Ostro and Rothschild, 1989	O_3	9.76E-3
	Chronic bronchitis	Abbey et al., 1995	PM_{10} Nitrates $PM_{2.5}$ Sulphates	2.45E-5 2.45E-5 3.9E-5 3.9E-5
ENTIRE POPULATION				
	Chronic Mortality (CM)	Pope et al., 1995	PM_{10} Nitrates $PM_{2.5}$ Sulphates	0.129% 0.129% 0.214% 0.214%
	Respiratory hospital admissions (RHA)	Dab et al., 1996	PM_{10} Nitrates $PM_{2.5}$ Sulphates	2.07E-6 2.07E-6 3.46E-6 3.46E-6
		Ponce de Leon, 1996	SO_2 O_3	2.04E-6 3.54E-6
	Cerebrovascular hospital admissions	Wordley et al., 1997	PM_{10} Nitrates $PM_{2.5}$ Sulphates	5.04E-6 5.04E-6 8.42E-6 8.42E-6
	Symptom days	Krupnick et al., 1990	O_3	0.033
	Cancer risk estimates	Pilkington et al., 1997; based on US EPA evaluations	Benzene Benzo-[a]-Pyrene 1,3-buta-diene Diesel particles	1.14E-7 1.43E-3 4.29E-6 4.86E-7
	Acute Mortality (AM)	Spix et al. / Verhoeff et al.,1996	PM_{10} Nitrates $PM_{2.5}$ Sulphates	0.040% 0.040% 0.068% 0.068%
		Anderson et al. / Touloumi et al., 1996	SO_2	0.072%
		Sunyer et al., 1996	O_3	0.059%

[1] The exposure response slope, f_{er}, has units of [cases/(yr-person-µg/m^3)] for morbidity, and [%change in annual mortality rate/(µg/m^3)] for mortality. Concentrations of SO_2, PM_{10} , PM_{10}, sulphates and nitrates as annual mean concentration, concentration of ozone as seasonal 6-h average concentration.

Source: Friedrich and Bickel 2001.

Impacts on building materials

Impacts on building material were assessed using the most recent exposure-response functions developed in the last phase of the ExternE Core/Transport project (Friedrich and Bickel, 2001). This work includes the latest results of the UN ECE International Co-operative Programme on Effects on Materials (ICP Materials) for degradation of materials, based on the results of an extensive 8-year field exposure programme that involved 39 exposure sites in 12 European countries, the United States and Canada (Tidblad et al., 1998).

Limestone:
maintenance frequency: $1/t = [\ (2.7[SO_2]^{0.48}e^{-0.018T} + 0.019Rain[H^+])/R\ ]^{1/0.96}$

Sandstone, natural stone, mortar, rendering:
maintenance frequency: $1/t = [\ (2.0[SO_2]^{0.52}e^{f(T)} + 0.028Rain[H^+])/R\ ]^{1/0.91}$
f(T) $f(T) = 0$ if $T < 10\ ^oC$; $f(T) = -0.013(T-10)$ if $T \geq 10\ ^oC$

Zinc and galvanised steel:
maintenance frequency: $1/t = 0.14[SO_2]^{0.26}e^{0.021Rh}e^{f(T)}/R^{1.18} + 0.0041Rain[H^+]/R$
f(T) $f(T) = 0.073(T-10)$ if $T < 10\ ^oC$; $f(T) = -0.025(T-10)$ if $T \geq 10\ ^oC$

Paint on steel:
maintenance frequency: $1/t = [\ (0.033[SO_2] + 0.013Rh + f(T) + 0.0013Rain[H^+])/5\ ]^{1/0.41}$
f(T) $f(T) = 0.015(T-10)$ if $T < 10\ ^oC$; $f(T) = -0.15(T-10)$ if $T > 10\ ^oC$

Paint on galvanised steel:
maintenance frequency:
$1/t = [\ (0.0084[SO_2] + 0.015Rh + f(T) + 0.00082Rain[H^+])/5\ ]^{1/0.43}$
f(T) $f(T) = 0.04(T-10)$ if $T < 10\ ^oC$; $f(T) = -0.064(T-10)$ if $T \geq 10\ ^oC$

Carbonate paint:
maintenance frequency: $$1/t = \left. 0.12\cdot\left(1-e^{\frac{-0.121\cdot Rh}{100-Rh}}\right)\cdot[SO_2]+0.0174\cdot[H^+]\right/ R$$

with

1/t	maintenance frequency in 1/a
$[SO_2]$	SO_2 concentration in µg/m^3
T	temperature in ^oC
Rain	precipitation in mm/a
[H+]	hydrogen ion concentration in precipitation in mg/l
R	surface recession in µm
Rh	relative humidity in %

Impacts on crops

Effects from SO2

For the assessment of effects from SO_2 on crops, an adapted function from the one suggested by Baker et al. (1986) is used as recommended in ExternE (European Commission, 1999c). The function assumes that yield will increase with SO_2 from 0 to 6.8 ppb, and decline thereafter. The function is used to quantify changes in crop yield for wheat, barley, potato, sugar beet, and oats. The function is defined as

$$y = 0.74 \cdot C_{SO2} - 0.55 \cdot (C_{SO2})^2 \qquad \text{for } 0 < C_{SO2} < 13.6 \text{ ppb}$$

$y = -0.69 \cdot C_{SO2} + 9.35$ for $C_{SO2} > 13.6$ ppb

with y = relative yield change

C_{SO2} = SO_2-concentration in ppb

Effects from ozone

For the assessment of ozone impacts, a linear relation between yield loss and the AOT 40 value (Accumulated Ozone concentration above Threshold 40 ppb) is assumed. The relative yield loss is calculated by using the following equation, and the sensitivity factors given in Table 16:

$y = 99.7 - \alpha \cdot C_{O3}$

with y = relative yield change

α = sensitivity factors

C_{O3} = AOT 40 in ppmh

Table 16: Sensitivity factors for different crop species

Sensitivity	α	Crop species
Slightly sensitive	0.85	rye, oats, rice
Sensitive	1.7	wheat, barley, potato, sunflower
Very sensitive	3.4	tobacco

Acidification of agricultural soils

The amount of lime required to balance acid inputs on agricultural soils across Europe will be assessed. The analysis of liming needs should be restricted to non-calcareous soils. The additional lime requirement is calculated as:

$\Delta L = 50 \cdot A \cdot \Delta D_A$

with ΔL = additional lime requirement in kg/year

A = agricultural area in ha

ΔD_A = annual acid deposition in meq/m^2/year

Fertilisational effects of nitrogen deposition

Nitrogen is an essential plant nutrient, applied by farmers in large quantity to their crops. The deposition of oxidised nitrogen to agricultural soils is thus beneficial (assuming that the dosage of any fertiliser applied by the farmer is not excessive). The reduction in fertiliser requirement is calculated as:

$\Delta F = 14.0067 \cdot A \cdot \Delta D_N$

with ΔF = reduction in fertiliser requirement in kg/year

A = agricultural area in ha

ΔD_N = annual nitrogen deposition in meq/m^2/year

Monetary Valuation

Table 17 summarises the monetary values of health impacts used for valuation of transboundary air pollution. According to Nellthorp et al. (2001) average European values were used for transboundary air pollution costs, except for the source country, where country specific values were used. These were calculated according to the benefit transfer rules given in Nellthorp et al. (2001).

Table 17: Monetary values (factor costs, rounded) for health impacts ($€_{1998}$)

Impact	European average	Italy	
Year of life lost (chronic effects)	74 700	75,400	€ per YOLL
Year of life lost (acute effects)	128 500	129,700	€ per YOLL
Chronic bronchitis	137 600	138,900	€ per new case
Cerebrovascular hospital admission	13 900	14,030	€ per case
Respiratory hospital admission	3 610	3,650	€ per case
Congestive heart failure	2 730	2,760	€ per case
Chronic cough in children	200	200	€ per episode
Restricted activity day	100	100	€ per day
Asthma attack	69	70	€ per day
Cough	34	34	€ per day
Minor restricted activity day	34	34	€ per day
Symptom day	34	34	€ per day
Bronchodilator usage	32	32	€ per day
Lower respiratory symptoms	7	7	€ per day

Source: Own calculations based on Friedrich and Bickel (2001) and Nellthorp et al. (2001).

2.3.2 GLOBAL WARMING

The method of calculating costs of CO_2 emissions basically consists of multiplying the amount of CO_2 emitted by a cost factor. Due to the global scale of the damage caused, there is no difference how and where the emissions take place.

A European average shadow value of €20 per tonne of CO_2 emitted was used for valuing CO_2 emissions. This value represents a central estimate of the range of values for meeting the Kyoto targets in 2010 in the EU based on estimates by Capros and Mantzos (2000). They report a value of €5 per tonne of CO_2 avoided for reaching the Kyoto targets for the EU, assuming a full trade flexibility scheme involving all regions of the world. For the case that no trading of CO_2 emissions with countries outside the EU is permitted, they calculate a value of €38 per tonne of CO_2 avoided. It is assumed that measures for a reduction in CO2 emissions are taken in a cost effective way. This implies that reduction targets are not set per sector, but that the cheapest measures are implemented, no matter in which sector.

Looking further into the future, more stringent reductions than the Kyoto aims are assumed to be necessary to reach sustainability. Based on a reduction target of 50% in 2030 compared to 1990, INFRAS/IWW (2000) use avoidance costs of € 135 per t of CO_2; however one could argue that this reduction target has not yet been accepted.

A valuation based on the damage cost approach, as e.g. presented by ExternE (Friedrich and Bickel 2001), would result in substantially lower costs. Due to the enormous uncertainties involved in the estimation process, such values have to be used very cautiously.

2.2.3 Noise

Noise costs were quantified for a number of health impacts calculated with new exposure-response functions, plus amenity losses estimated by the Italian annual average rent per person in 1998. According to the UNITE valuation conventions this value corresponds to factor costs of 811 Euro/year. This leads to a WTP of 8 Euro/dB (A)/pp/pa for amenity losses[10].

The methodology for quantifying noise costs was extended to the calculation of physical impacts. Costs for the following endpoints were quantified:

- Myocardial infarction (fatal, non-fatal)
- Angina pectoris
- Hypertension
- Subjective sleep quality

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[10] For night-time, only health effects and sleep disturbance are reported as amenity losses are included to a large extent in sleep quality costs.

Table 18: Monetary values (factor costs, rounded) for impacts due to noise in Italy (€$_{1998}$)

Impact	Italy
Myocardial infarction (fatal, 7 YOLL)	
Total per case	**528,000**
Myocardial infarction (non-fatal, 8 days in hospital, 24 days at home)	
Medical costs	3,740
Absentee costs	2,720
WTP	12,910
Total per case	**19,370**
Angina pectoris (severe, non-fatal, 5 days in hospital, 15 days at home)	
Medical costs	2,340
Absentee costs	1,700
WTP	8,080
Total per case	**12,130**
Hypertension (hospital treatment, 6 days in hospital, 12 days at home)	
Medical costs	1,450
Absentee costs	1,530
WTP	550
Total per case	**3,530**
Medical costs due to sleep disturbance (per year)	199
Average (net) rent per person per year (basis of calculation of WTP for avoiding amenity losses)	811
Source: Own calculations based on Metroeconomica (2001) and Nellthorp et al. (2001), except average rent	

As railway noise is perceived as less annoying than road noise, a bonus of 5 dB(A) was applied. This is in line with noise regulations in a number of European countries (e.g. Switzerland, France, Denmark, Germany; see INFRAS/IWW 2000).

2.3.4 Other effects

Air pollution, global warming and noise represent the most important and relevant cost categories for marginal environmental costs. Costs due to “habitat losses and biodiversity” represent the economic assessment of damages the presence traffic infrastructure and its use is causing to the habitats of rare species, and thus to biodiversity. The costs are mostly related to the separation effects due to the existence of roads, rail tracks, airports and artificial waterways and thus are fixed in the short run. They are not marginal and therefore not relevant for the quantification of marginal costs. The same is true for visual intrusion in urban areas.

Most of the damages to soil and water are expected to be small or not relevant for marginal cost estimation. For instance, solid emissions by tyre, brake and wheels (emission of Cd, Zn, Cu) and infrastructure (PAH, heavy metals) abrasion can be expected to cause only small marginal costs as well as de-icing agents. For practical reasons these impacts are only considered in the accounts approach, assuming that additional contamination of one car or train takes place within a certain range along road and railway infrastructure and is not important with concern to marginal costs. It is assumed that soil is already contaminated within a certain reach along frequently used roads/railways. The effect of the use of an additional vehicle can therefore be neglected.

Airborne exhaust emissions and their impacts on soil and water (acidification, eutrophication) are relevant, but currently cannot be quantified in monetary terms consistently. The emissions of sulphur dioxide are small from the (diesel) fuels used in motor transport and trains and unlikely to have a significant impact even adjacent to the highest density traffic routes (Friedrich and Bickel 2001). Nitrogen oxides emissions could to some extent contribute to acidification. Particulate nitrogen deposition could act as a fertiliser and contribute to eutrophication. For practical reasons these minor impacts are not considered for the marginal costs approach.

Solid non-recyclable waste resulting from vehicle and infrastructure disposal could be considered in the ideal approach. Yet, large part of the solid waste is recyclable (e.g. metals). Non-recyclable waste is either deposited or burnt in incineration plants. Only deposited waste products (waste not being burnt) has finally an impact on soil (soil sealing and possible contamination) or on groundwater (leaking of the disposal sites). The quantification of these costs is beyond the scope of UNITE and was therefore neglected.

Costs due to nuclear risks are considered in the costs due to electricity production for electric traction of rail transport.

2.3.5 Conclusion

In spite of considerable progress made in recent years the quantification and valuation of environmental damage is still linked to significant uncertainty. This is the case for the Impact Pathway Methodology as well as for any other approach. While the basic assumptions underlying the work in ExternE are discussed in detail in (European Commission 1999a), below an indication of the uncertainty of the results is given as well as the sensitivity to some of the key assumptions.

Within ExternE, Rabl and Spadaro (1999) made an attempt to quantify the statistical uncertainty of the damage estimates, taking into account uncertainties resulting from all steps of the impact pathway, i.e. the quantification of emissions, air quality modelling, dose-effect modelling, and valuation. Rabl and Spadaro show that - due to the multiplicative nature of the impact pathway analysis - the distribution of results is likely to be approximately lognormal, thus it is determined by its geometric mean and the geometric standard deviation σ_g. In ExternE, uncertainties are reported by using uncertainty labels, which can be used to make a meaningful distinction between different levels of confidence, but at the same time do not give a false sense of precision, which seems to be unjustified in view of the need to use subjective judgement to compensate the lack of information about sources of uncertainty and probability distributions (Rabl and Spadaro 1999). The uncertainty labels are:

A = high confidence, corresponding to σ_g = 2.5 to 4;
B = medium confidence, corresponding to σ_g = 4 to 6;
C = low confidence, corresponding to σ_g = 6 to 12.

According to ExternE recommendations, the following uncertainty labels are used to characterise the impact categories addressed in this report:

Mortality:	B
Morbidity:	A
Crop losses:	A
Material damage:	B.

Beside the statistical uncertainty indicated by these uncertainty labels, there is however a remaining systematic uncertainty arising from a lack of knowledge, and value choices that influence the results. Some of the most important assumptions and their implications for the results are briefly discussed in the following.

Effects of particles on human health

The dose-response models used in the analysis are based on results from epidemiological studies which have established a statistical relationship between the mass concentration of particles and various health effects. However, at present it is still not known whether it is the number of particles, their mass concentration or their chemical composition which is the driving force. The uncertainty resulting from this lack of knowledge is difficult to estimate.

Effects of nitrate aerosols on health

We treat nitrate aerosols as a component of particulate matter, which we know cause damage to human health. However, in contrast to sulphate aerosol (but similar to many other particulate matter compounds) there is no direct epidemiological evidence supporting the harmfulness of nitrate aerosols, which partly are neutral and soluble.

Valuation of mortality

While ExternE recommends to use the *Value of a Life Year Lost* rather than the *Value of Statistical Life* for the valuation of increased mortality risks from air pollution (see European Commission, (1999a) for a detailed discussion), this approach is still controversially discussed in the literature. The main problem for the *Value of a Life Year Lost* approach is that up to now there is a lack of empirical studies supporting this valuation approach.

Impacts from ozone

As the EMEP ozone model, which is the basis for the Source-Receptor Ozone Model (SROM) included in EcoSense does not cover the full EcoSense modelling domain, some of the ozone effects in Eastern Europe are omitted. As effects from ozone are small compared to those from other pollutants, the resulting error is expected to be small compared to the overall uncertainties.

Omission of effects

The present report is limited to the analysis of impacts that have shown to result in major damage costs in previous ExternE studies. Impacts on e.g. change in biodiversity, potential effects of chronic exposure to ozone, cultural monuments, direct and indirect economic effects of change in forest productivity, fishery performance, and so forth, are omitted because they currently cannot be quantified.

2.4 DATA

2.4.1 Vehicles used

Concerning road, collected data are expressed in terms of theoretical annual average daily traffic (all vehicles travelling on the motorways, or specific segments, along the overall length) with distinction between light and heavy traffic. The former includes motorcycles and vehicles with two axes and height less than 1.3 meters; the latter includes vehicles with three and more axes and height more 1.3 meters. When possible, data have been presented according to the maximum level of detail, i.e. the distance between to consecutive gates on the motorway.

Concerning rail, passengers and freight, local and international trains have been taken into account, associated with technical characteristics of the representative type of train, i.e. electricity consumption, year of construction, max. speed, etc.

2.4.2.General data for the calculation of costs due to air pollution

Besides the emissions of the transport modes in the different countries, a large number of additional information was required for the cost calculations. This includes data on the receptor distribution, meteorology, and on the background emissions from all sources in all European countries. Such data is available in the computer tool EcoSense's database and is briefly described in the following.

Table 19: Environmental data in the EcoSense database

	Resolution	Source
Receptor distribution		
Population	administrative units, EMEP 50 grid	EUROSTAT REGIO Database, The Global Demography Project
Production of wheat, barley, sugar beat, potato, oats, rye, rice, tobacco, sunflower	administrative units, EMEP 50 grid	EUROSTAT REGIO Database, FAO Statistical Database
Inventory of natural stone, zinc, galvanized steel, mortar, rendering, paint	administrative units, EMEP 50 grid	Extrapolation based on inventories of some European cities
Meteorological data		
Wind speed	EMEP 50 grid	European Monitoring and Evaluation Programme (EMEP)
Wind direction	EMEP 50 grid	European Monitoring and Evaluation Programme (EMEP)
Precipitation	EMEP 50 grid	European Monitoring and Evaluation Programme (EMEP)
Emissions		
SO_2, NO_x, NH_3, NMVOC, particles	administrative units, EMEP 50 grid	CORINAIR 1994/1990, EMEP 1998 TNO particulate matter inventory (Berdowski et al., 1997)

Source: IER.

Receptor data

Population data

Population data was taken from the EUROSTAT REGIO database (base year 1996), which provides data on administrative units (NUTS categories). For impact assessment, the receptor data is required in a format compatible with the output of the air quality models. Thus, population data was transferred from the respective administrative units to the 50 x 50 km^2 EMEP grid by using the transfer routine implemented in EcoSense.

Crop production

The following crop species were considered for impact assessment: barley, oats, potato, rice, rye, sunflower seed, tobacco, and wheat. Data on crop production were again taken from the EUROSTAT REGIO database (base year 1996). For impact assessment, crop production data were transferred from the administrative units to the EMEP 50 x 50 km^2 grid.

Material inventory

The following types of materials are considered for impact assessment: galvanised steel; limestone; mortar; natural stone; paint; rendering; sandstone; and, zinc. As there is no database available that provides a full inventory of materials, the stock at risk was extrapolated in ExternE from detailed studies carried out in several European cities.

Emission data

As the formation of secondary pollutants such as ozone or secondary particles depends heavily on the availability of precursors in the atmosphere, the EcoSense database provides a European wide emission inventory for SO_2, NO_x, NH_3, NMVOC, and particles as an input to air quality modelling. The emission data are disaggregated both sectorally ('Selected Nomenclature for Air Pollution' - SNAP categories) and geographically ('Nomenclature of Territorial Units for Statistics' - NUTS categories). As far as available, EcoSense uses data from the EMEP 1998 emission inventory (Richardson 2000, Vestreng 2000, Vestreng and Støren 2000). Where required, data from the CORINAIR 1994 inventory. (http://www.aeat.co.uk/netcen/corinair/94/) and the CORINAIR 1990 inventory (McInnes 1996) are used. For Russia, national average emission data from the LOTOS inventory (Builtjes 1992) were included. Emission data for fine particles are taken from the European particle emission inventory established by Berdowski et al. (1997).

Meteorological data

The Windrose Trajectory Model requires annual average data on wind speed, wind direction, and precipitation as an input. The EcoSense database provides data from the European Monitoring and Evaluation Programme (EMEP) for the base year 1998.

2.4.3 Emissions road vehicles

Emissions from vehicles are based on German Handbook of Emissionfactors (HBEFA), assuming as average speed, the speed related to the average traffic situation on motorway.

Beside the emissions from vehicle operation the emissions due to fuel provision was considered. The emission factors for crude oil extraction, refining and transport of petrol, diesel and kerosene are given in table 19.

Table 20: Emissions caused by fuel production processes in g/kg fuel

Type of fuel	CO_2	PM_{10}	NO_x	SO_2	NMVOC
Petrol	560	0.105	1.10	1.90	1.80
Diesel; Kerosene	400	0.047	0.96	1.40	0.62

Source: PM_{10}: Friedrich and Bickel (2001); other pollutants: IFEU (1999)

2.4.4 Costs due to electricity production

The costs due to power plant emissions (including fuel extraction, transport and refinery) were calculated with EcoSense. For costs from other effects than emissions from combustion processes, mainly due to hydro and nuclear power plants were detailed calculations performed in ExternE were used. So, the methodology is compatible with the calculations for road transport vehicles, monetary values were adjusted according to the UNITE valuation conventions. Costs per kWh of electricity were calculated, using the relevant electricity production mix.

The following tables show the electricity production mix for Italy and specific train consumption (kWh/train km) - passengers and freight -.

Electricity production mix	**1998**
railways	share (%)
Coal	9.15%
Lignite	0.04%
Oil	40.76%
Natural Gas	27.68%
Nuclear	0.00%
Hydro	16.25%
other	6.12%
Total	100%

	Train type	kwh/trainkm
Passenger	ICE	21.9
Passenger	Intercity	16.6
Passenger	Local Train	12.2

	Train type	kwh/trainkm
Freight train	Bologna-Brennero	8.5
Freight train	Milano-Chiasso	10.6

2.4.5.General data for the calculation of costs due to the noise level

Basic data taken in consideration for the calculation of costs due to the noise level are related to the estimation of exposed people and traffic data.

The estimation of exposed people has required detailed data on people living near the noise sources, i.e. 250 metres from motorway or rail tracks, associated with information on the distances from noise sources and building characteristics. High-resolution maps for the areas interested by the selected corridors have been used for collecting information.

Traffic data have been collected with reference to the number of vehicles, i.e. trains and average car traffic volume, by daytime and traffic conditions, i.e. average speed.

9H 3. RESULTS

3.1 AIR POLLUTION AND GLOBAL WARMING

3.1.1 Road

The following tables show the marginal external costs of air pollution for road along the selected routes. Marginal costs estimates have been carried out according to the following breakdowns:

3. vehicle types (car, diesel and gasoline, coach, LGV and HGV)

4. range of impacts (local, regional and global)

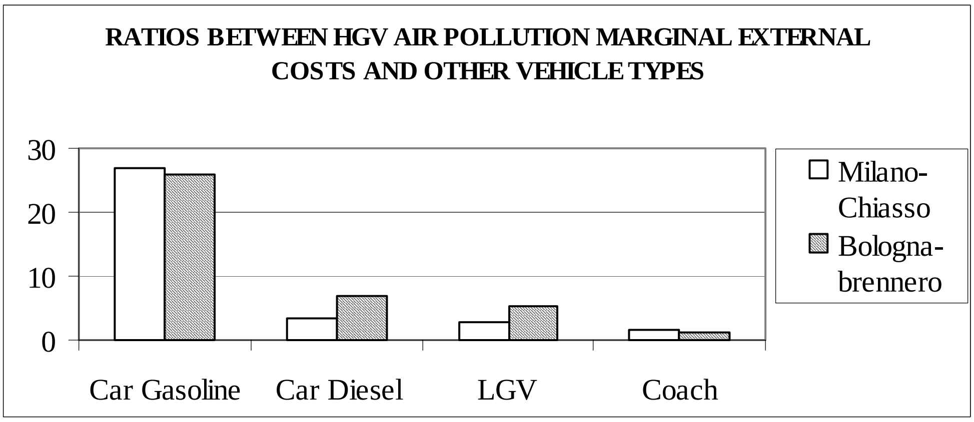
5. type of pollutants (CO, CO_2 , $PM_{2.5}$, NO_3, SO_4, O_3)

The analysis by vehicle type clearly shows the high external costs of HGV compared to the other vehicle types.

Table 21: Road air pollution marginal costs by vehicle type, 1998 (cent/vkm)

VEHICLE TYPE	MILANO-CHIASSO	BOLOGNA-BRENNERO
Car Diesel	1.912	0.730
Car Gasoline	0.250	0.195
Coach	4.667	3.701
LGV	2.411	0.971
HGV	6.716	5.068

As indicated by the graph below, the HGV marginal external costs outnumber by a factor of about thirty the marginal external costs for passengers cars fuelled by gasoline, i.e. about 27 times on the route Milano-Chiasso and 26 times on the route Bologna-Brennero.



Comparing to the passenger cars fuelled by diesel, the HGV air pollution external costs ratios lower towards about a factor of 7 on the route Bologna-Brennero, i.e. 5.068 cent/vkm against 0.730 cent/vkm, and about a factor of 4 on the route Milano-Chiasso, i.e. 6.716 cent/vkm against 1.912.

HGV external costs on average outnumber by a factor of 5 the air pollution external costs of LGV, while, with reference to coaches, the HGV marginal external costs are about 30% higher.

Where detailed data are available at segment level, as for Bologna-Brennero route, it’s interesting to note that the higher external costs by pollutants have been estimated in correspondence with the most populated areas. The table below in fact shows on average decreasing marginal costs to the extent that the road segments cross from highly populated areas, i.e. from Bologna to Verona, towards mountains areas, i.e. from Trento to Brennero.

Table 22: Road air pollution marginal costs by vehicle type and route segment (Bologna-Brennero) 1998 (cent/vkm)

VEHICLE TYPE	BOLOGNA-BRENNERO	Cent/vkm
Car Diesel	Bologna to Modena	0.802
Car Gasoline	Bologna to Modena	0.230
Coach	Bologna to Modena	4.388
LGV	Bologna to Modena	1.077
HGV	Bologna to Modena	5.991
Car Diesel	Modena to Verona Nord	1.075
Car Gasoline	Modena to Verona Nord	0.243
Coach	Modena to Verona Nord	4.608
LGV	Modena to Verona Nord	1.409
HGV	Modena to Verona Nord	6.367
Car Diesel	Verona Nord to Trento	0.573
Car Gasoline	Verona Nord to Trento	0.160
Coach	Verona Nord to Trento	3.212
LGV	Verona Nord to Trento	0.770
HGV	Verona Nord to Trento	4.376
Car Diesel	Trento to Brennero	0.446
Car Gasoline	Trento to Brennero	0.146
Coach	Trento to Brennero	2.753
LGV	Trento to Brennero	0.607
HGV	Trento to Brennero	3.733

The breakdown of air pollution marginal external costs by vehicle type and range of impacts allows estimating the incidence by vehicle type of marginal external costs according to the following range of impacts:

6. local scale
7. regional (European scale)
8. global (greenhouse gases emissions)

Concerning local impacts, high external costs can be observed in particular along the most densely populated route Milano-Chiasso, in particular for passenger diesel cars (1.555 cent/vkm against 0.329 cent/vkm on the route Bologna-Brennero), LGV (1.905 cent/vkm against 0.403 cent/vkm on the route Bologna-Brennero) and HGV (2.837 cent/vkm against 0.600 cent/vkm on the route Bologna-Brennero).

Table 23: Road air pollution and global warming marginal costs by vehicle type and range of impacts 1998 (cent/vkm)

VEHICLE TYPE	RANGE	MILANO-CHIASSO	BOLOGNA-BRENNERO
Car Diesel	Global warming	0.359	0.359
	Regional impacts	0.357	0.400
	Local impacts	1.555	0.329
	Total	2.271	1.089
Car gasoline	Global warming	0.356	0.356
	Regional impacts	0.153	0.175
	Local impacts	0.097	0.020
	Total	0.606	0.551
Coach	Global warming	1.540	1.540
	Regional impacts	2.886	3.325
	Local impacts	1.782	0.377
	Total	6.207	5.241
LGV	Global warming	0.611	0.611
	Regional impacts	0.505	0.568
	Local impacts	1.905	0.403
	Total	3.022	1.582
HGV	Global warming	2.162	2.162
	Regional impacts	3.879	4.468
	Local impacts	2.837	0.600
	Total	8.878	7.230

High regional impacts can be observed for coach and HGV vehicles, in particular along the route Bologna-Brennero, i.e. 4.468 cent/vkm (in absolute terms, the most relevant impacts per vehicle kilometre).

Global warming

The analysis by type of pollutant confirms the most significant incidence of typical local impact pollutants, i.e. PM $_{2.5}$, in proximity of the most densely populated areas along the Milano-Chiasso route.

Table 24:Road air pollution marginal costs by vehicle type and pollutant, 1998 (cent/vkm)

VEHICLE TYPE	POLLUTANT	MILANO-CHIASSO	BOLOGNA-BRENNERO
Car Diesel	$PM_{2.5}$	1.684	0.484
	NO^3	0.270	0.239
	CO^2	0.360	0.359
Car gasoline	$PM_{2.5}$	0.097	0.028
	NO^3	0.140	0.161
	CO^2	0.360	0.356
Coach	$PM_{2.5}$	1.708	0.462
	NO^3	2.812	3.239
	CO^2	1.540	1.540
LGV	$PM_{2.5}$	2.058	0.591
	NO^3	0.321	0.370
	CO^2	0.610	0.610
HGV	$PM_{2.5}$	2.783	0.750
	NO^3	3.751	4.320
	CO^2	2.160	2.160

3.1.2 Rail

Marginal external costs of air pollution and global warming for rail operations (passengers and freight transport) are calculated as the costs per kWh/train km due to power plant emissions (including fuel extraction, transport and refinery). The calculations are based on the costs per kWh of electricity due to the country-specific electricity production mix multiplied by the energy consumption per train/km on specific routes.

Table 25: Rail air pollution and global warming marginal costs – freight transport - , 1998 (cent/train km)

ROUTES	AIR POLLUTION	GLOBAL WARMING	TOTAL IMPACT
MILANO-CHIASSO	14.758	0.149	14.907
BOLOGNA-BRENNERO	18.334	0.185	18.520

The costs per kWh of electricity due to the country-specific electricity production mix for Italy is 1.73 Cent/kWh for air pollution[11]. Global warming estimation takes as reference the value 20 Euro/t CO2.

Significant technical data, i.e. number of stops, average speed, average load, etc, for the calculation of energy consumption at corridor level are based on detailed data collection carried out in RECORDIT Project[12].

Concerning the impacts of passenger trains, air pollution and global warming marginal external costs have been calculated with reference to the three types of representative trains along the routes[13].

Table 26:Rail air pollution and global warming marginal costs – passenger transport - , 1998 (cent/train km)

TYPE OF TRAIN	AIR POLLUTION	GLOBAL WARMING	TOTAL IMPACT
High Speed Train	41.756	0.731	38.691
Intercity	31.650	0.554	29.327
Local train	23.261	0.407	21.553

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[11] Bilancio Energetico Nazionale (1998)

[12] In particular, D2 “Methodology for the analysis of mechanisms of cost and price formation at corridor level”, Sub-task 2 “The tri-modal chain on the corridor between Genova, Basel, Rotterdam and Manchester (southern part)” for Milano-Chiasso and Sub- Task 1 “Freight freeway case study between Patras - Brindisi - Verona - Munich – Hamburg – Gotheborg” for Bologna-Brennero

[13] Including 10% for transmission losses to power stations. Technical references in Prognos (1995), quoted by Friedrich, R. and Bickel, P. (Eds.) (2001)

3.2 NOISE

3.2.1 Road

The following tables show the marginal external costs of noises for road along the selected routes. Marginal external costs have been carried out according to the following breakdowns:

9. type of vehicle (passenger car, LGV and HGV)
10. daytime (day, evening and night)

Table 27: Road marginal external noise costs due to one additional vehicle on selected routes , 1998 (cent/vkm)

MILANO-CHIASSO

Cent/vkm	day	evening	night
Passenger car	0.01	0.02	0.04
LGV	0.03	0.05	0.12
HGV	0.09	0.13	0.35

BOLOGNA-BRENNERO

Cent/vkm	day	evening	night
Passenger car	0.001	0.001	0.002
LGV	0.001	0.002	0.005
HGV	0.006	0.008	0.021

The striking differences on the two routes, a factor of ten outnumber the external costs on Milano-Chiasso route respect to Bologna-Brennero, depends on the different density of exposed population.

On the Milano-Chiasso route, 76 person per km have been taken into account; corresponding, in total, to 3595. The buildings of 2617 persons are exposed to noise levels above 70 dB(A) LAeq 7-23 hours.

On the Bologna-Brennero route, on average, 6 persons per km are considered at risk per km along this route (exposed people 2273 along the 380 km motorway).

In order to explain the differences, a possible underestimation of the exposure level on the route Bologna-Brennero should be also taken into account. In fact, due to the long distance along the route, i.e. about 362 km, a sufficient level of information along the overall lengths of the routes has not been possible to provide, in particular for specific segments of the northern section of the route, Verona-Brennero.

3.2.2 Rail

The table below shows the rail marginal external noise costs on the selected routes:

Table 28: Rail marginal external noise costs due to one additional vehicle on selected routes , 1998 (cent/vkm)

MILANO-CHIASSO

Cent/ train km	day	evening	night
Goods train	13.2	14.1	10.0
Inter city	1.4	1.7	4.1
Local train	1.2	1.4	1.2

BOLOGNA-BRENNERO

Cent/ train km	day	evening	night
Goods train	0.3	0.37	0.59
Inter city	0.04		0.03
Local train	0.19	0.20	0.25

The analysis of rail marginal noises costs by type of train and daytime on the selected routes show the same characteristics of the road case: lower marginal costs on the Bologna-Brennero route.

On this route, the marginal external costs due to amenity losses of one additional passenger train (Inter city or local) are calculated to below 1 cent/Euro per train and for the total segment.

Health effects are also calculated, but as the noise levels are very low, the results are negligible.

The low results are caused by the very low number of residents exposed to rail noise along this line. As also for about 2/3 of all exposed people, the houses are located at least 100 metres from the track, so that the noise levels at the housing fronts are very low.

On the other hand, the marginal noise external costs on the route Milano-Chiasso show values on average higher than 10 cent/train km for good trains and lower than 2 cent/train km for passenger trains.

9H 4. DISCUSSION AND CONCLUSIONS

Analysing the results of the Italian environmental inter-urban case studies, the following two main issues can be emphasized:

1. the extreme variability of environmental marginal costs
2. the difficulty in providing basic data for calculation

The variability of receptors density clearly plays a significant role in explaining the different environmental marginal external costs, both air pollution and noise, between the two selected routes.

Along the route Milano-Chiasso, densely populated, the environmental marginal external costs are generally higher than on the route Bologna-Brennero, characterised by mountains areas and lower population density level.

However, while in the case of air pollution marginal external costs the difference between the two routes is on acceptable scale, i.e. on average +25% on the route Milano-Chiasso, depending on vehicle type, the case of noise marginal external costs exhibits a quite different order of magnitude.

In fact, noise marginal external costs on the route Milano-Chiasso outnumber by a factor 10 the external costs estimated on the route Bologna-Brennero. The reason behind such a wide gap can be only partially explained by the different density of receptors.

Other factors have to be considered, in particular the detailed information required for the estimation of noise marginal external costs, that, if not totally available, could have lead to an underestimation of the impacts.

In particular on the longer route, i.e. Bologna-Brennero, about 362 km, compared to the Milano-Chiasso, about 44km, crossing over different geo-morphological areas, has been difficult to collected accurately data for noise marginal costs estimation, i.e. the number of receptors up to a distance of 250 meters from the noise source, information on surface material and receptor height, etc.

In view of the possible generalisation of the bottom-up methodology in an inter-urban context, the required bulk of detailed information over long distance routes and areas could represent a serious drawback that should be carefully taken into account.

New technologies, i.e. GIS representations, which will be presumably available more easily in a near future, could overcome the difficulties, providing the researcher with detailed information at the required scale.

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