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REQUIREMENTS OF TOMORROW'S RAIL TRANSPORT INFRASTRUCTURE

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The framework of rail transport in the 21st century[1]

The second half of the 20th century, after World War II, was characterized by intense decline in the railway's share of the transport market. In absolute values (kilometer tons and kilometer passengers) railway volume increased slightly, yet the percentage participation of the railway in the total transportation volume decreased, given the fact that the increase of the total transport volume was much faster. The railway which, in the beginning of the 20th century was the pioneer means of transportation that fully responded to the needs and conditions of the time was left behind by the developments and placed in a disadvantageous position in relation to the other transportation means, especially compared to its competitors in land transports.

The increase of freight and passenger transport, though, which appeared in the European Community was not the same for all types of transport. As shown in figure 1[2], road transports now represent 44% of freight transport, against 41% of sea transport for short distances, 8% of railway and 4% of inland water transport.

The domination of road transports is yet more evident in the sector of passenger transport (figure 2), where they hold a percentage of 79% of the market, while air transports at a percentage of 5% are soon expected to exceed the railways, which represent 6%.

Railway freight transport (8%) tends to be marginalized, as the average speed of an international train reaches 18 kilometers/hour in Europe. As a model example, we should take into consideration the United States of America, where 40% of freight transports is conducted via the railways.

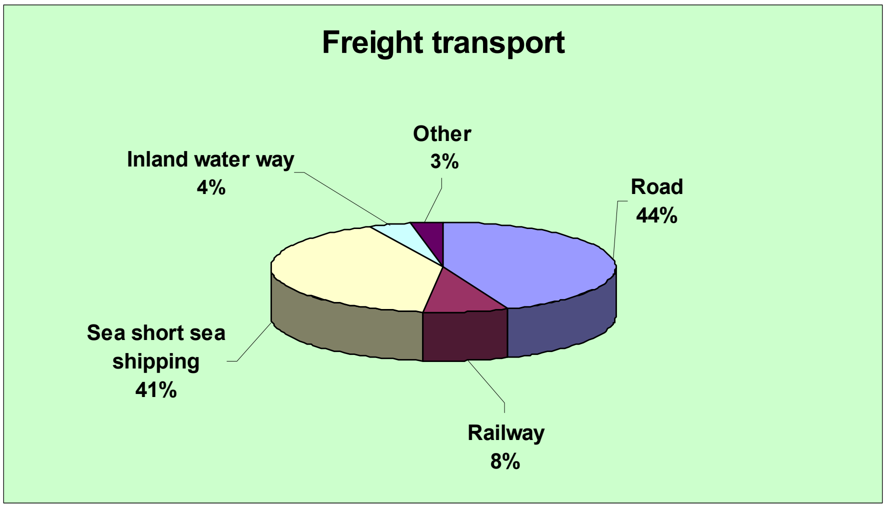

Figure 1 : Market share of the different transport means (freight transport)

[1] Giannakos Konstantinos, "Interoperability in the railway: a development model for Southeast Europe", Doctoral Thesis, A.U.Th., 2000, p. 49

[2] Data from the White Paper on " European transport policy for 2010: time to decide", COM(2001)370, 12.9.2001

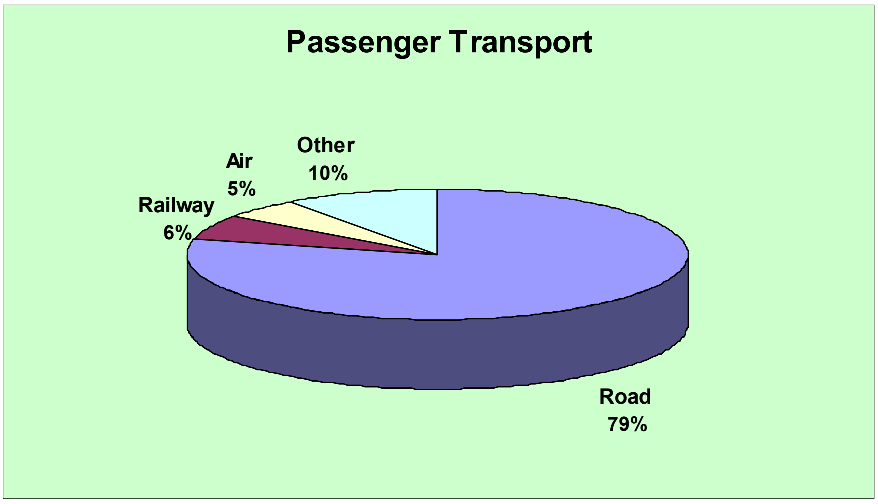

Figure 2 : Market share of the different transport means (passenger transport)

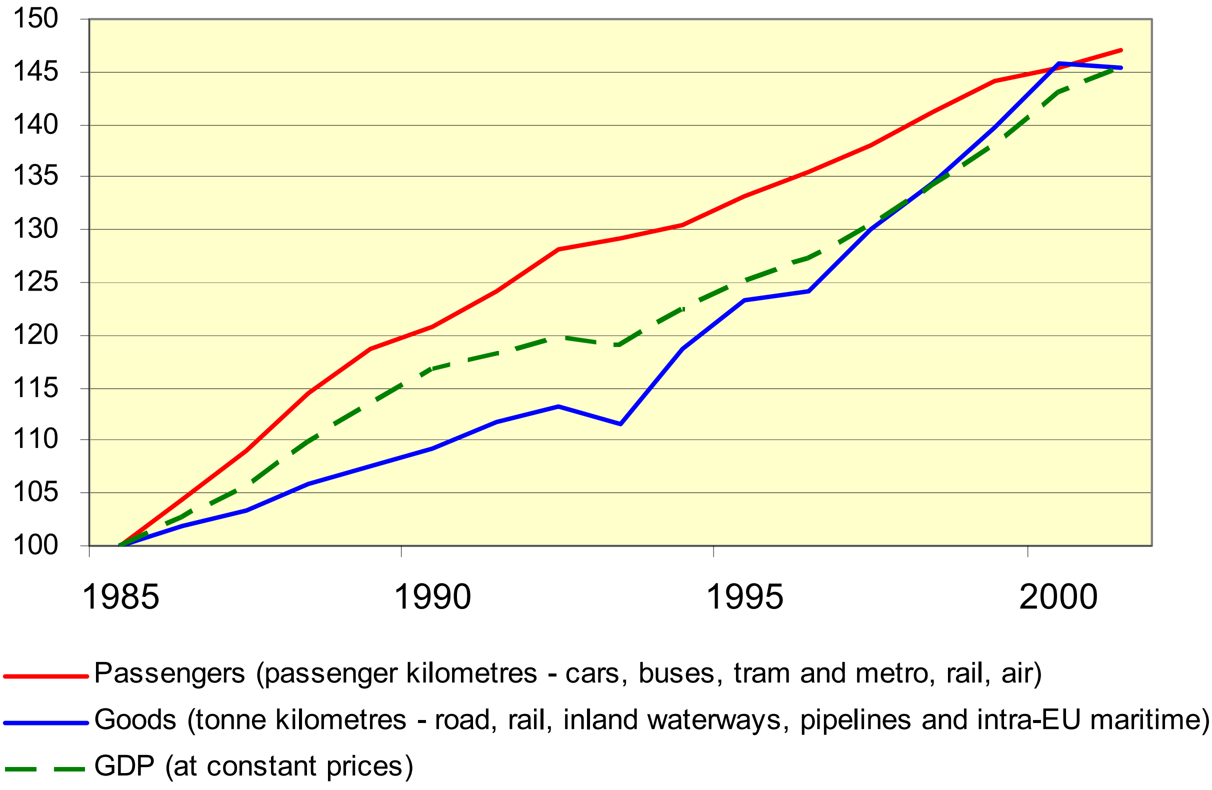

Figure 3: Evolution of transport 1985-2010 (1985=100)

It is imperative that balance is achieved among the means of transport, in the center of the strategy for sustainable development[3].

In the 21st century the frame of rail transport will be defined by the major structural changes that must and will take place in five sectors:

1. The creation of consistent Trans-European Networks, which will cover Europe entirely and ensure interoperability.
2. The promotion of the railway as the core of a combined-transports network in Europe.
3. The reorganizing-restructuring of railway services, with the separation between Infrastructure – Operation at the centre of activities.
4. The reform of the railway enterprises' finances.
5. The creation of high-speed railway axes

The external costs of transport

The main sources for external costs in the transport sector are accidents, congestion, air pollution, noise and climate change.

In the White Paper[4] there is extensive reference to the need to integrate external cost to the cost of transport, by charging each transportation means according to the burden that this causes. Below are extracts from the White Paper which demonstrate the emphasis placed by the Community to this integration:

> "**Adopting a policy on effective charging for transport**
> It is generally acknowledged that not always and not everywhere do the individual modes of transport pay for the costs they generate. The situation differs enormously from one Member State and mode to another. This leads to dysfunctioning of the internal market and distorts competition within the transport system. As a result, there is no real incentive to use the cleanest modes or the least congested networks.
>
> The White Paper develops the following guidelines:
> – **harmonisation of fuel taxation for commercial users, particularly in road transport.**
> – **alignment of the principles for charging for infrastructure use; the integration of external costs** must also encourage the use of modes of lesser environmental impact and, using the revenue raised in the process, allow investment in new infrastructure, as proposed by the European Parliament in the Costa report. The current Community rules, for instance Directive 62/99 on the "Eurovignette", therefore need to be replaced by a modern framework for infrastructure-use charging systems so as to encourage advances such as these while ensuring fair competition between modes of transport and more effective charging, and ensuring that service quality is maintained. This kind of reform requires equal treatment for operators and between modes of transport.

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[3] This target was introduced by the Amsterdam treaty and confirmed by decision of the European Council in Gothenburg

[4] White Paper "European transport Policy for 2010: time to decide", COM(2001)370, 12.9.2001.

Whether for airports, ports, roads, railways or waterways, the price for using infrastructure should vary in the same manner according to category of infrastructure used, time of day, distance, size and weight of vehicle, and any other factor that affects congestion and damages the infrastructure or the environment.
In a good many cases, taking external costs into account will produce more revenue than is needed to cover the costs of the infrastructure used. To produce maximum benefit for the transport sector, it is essential that available revenue be channelled into specific national or regional funds in order to finance measures to lessen or offset external costs (double dividend). Priority would be given to building infrastructure that encourages intermodality, especially railway lines, and offers a more environmentally friendly alternative. In certain sensitive areas there might be insufficient surplus revenue where, for example, infrastructure has to be built across natural barriers. It should therefore be made possible for new infrastructure to receive an "income" even before it generates its first operating revenue. In other words, tolls or fees would be levied on an entire area in order to finance future infrastructure.
One final point for consideration is that different levels of taxation apply to the energy used by different modes, e.g. rail and air, and that this can distort competition on certain routes served by both modes."[5]

"The Gothenburg European Council, too, pointed out that *"a sustainable policy should tackle ... the full internalisation of social and environmental costs. Action is needed to bring about a significant decoupling of transport growth and GDP growth, in particular by a shift from road to rail, water and public passenger transport."*
The thrust of Community action should therefore be gradually to replace existing transport system taxes with more effective instruments for integrating infrastructure costs and external costs. These instruments are, firstly, charging for infrastructure use, which is a particularly effective means of managing congestion and reducing other environmental impacts, and, secondly, fuel tax, which lends itself well to controlling carbon dioxide emissions. The introduction of these two instruments, which will allow greater differentiation and modulation of taxes and rights of use, needs to be coordinated, with the first being backed up by the second"[6].

"The fundamental principle of infrastructure charging is that the charge for using infrastructure must cover not only infrastructure costs, but also external costs, i.e. costs connected with accidents, air pollution, noise and congestion.
This goes for all modes of transport and all categories of user, both private and commercial."[7]

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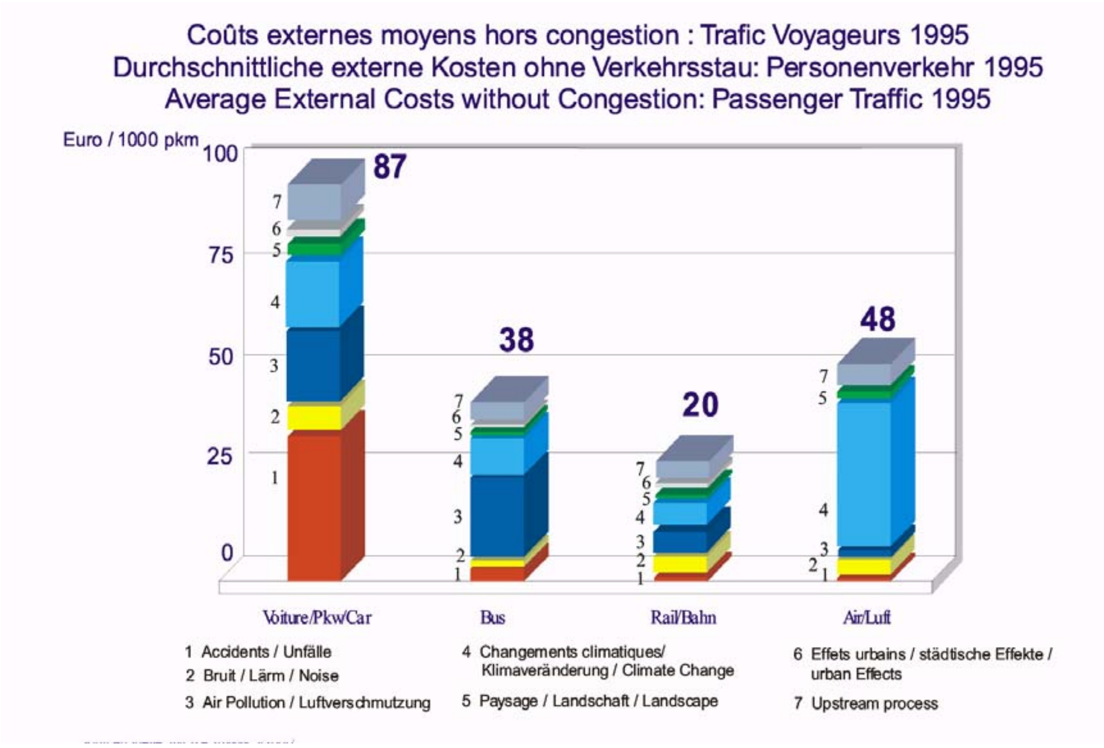
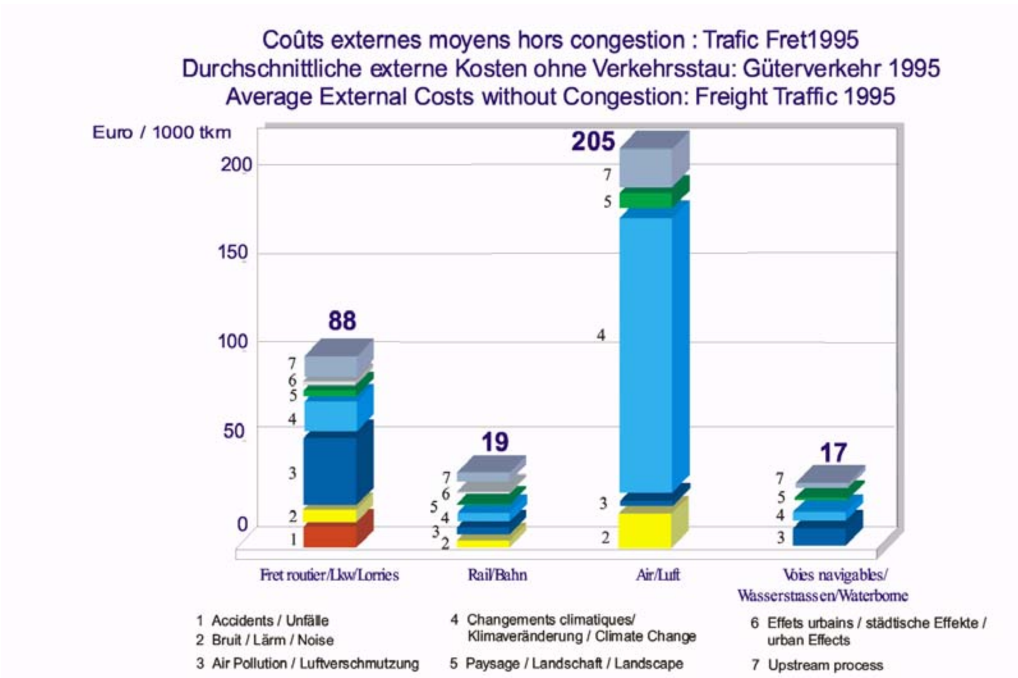
[5] White Paper "European transport policy for 2010: time to decide", COM(2001)370, 12.9.2001, p. 16
[6] White Paper "European transport policy for 2010: time to decide", COM(2001)370, 12.9.2001, p. 78
[7] White Paper "European transport policy for 2010: time to decide", COM(2001)370, 12.9.2001, p. 78





Source: INFRAS/IWW 3/2000[8]

[8] IWW/Infras, "External Costs of Transport, Accident, Environmental and Congestion Costs in Western Europe", 2000

Transport planning: the railways as the core of the future network of combined transports[9]

Road-railway and railway-through-waterways Combined transports are often considered a panacea. Combined Transports can combine the capabilities of diverse methods of transport in an ideal way, assigning the appropriate role to each means; railway and barges for long-distance transports, road transport for local distribution. The different ways of transportation are linked with standard units for combined transports (containers, swap bodies, trailers) and specific transshipment techniques.

Obviously, the railway can only benefit from the development of combined transports and, on the whole, it must play the leading role in their development. This is particularly important, given the fact that railway-infrastructure development programs depend on the exact forecasts of the freight volume expected to be transported through the new transport connections. This holds for railway lines as well as terminal stations, coaches and locomotives.

In future, it is also expected that an important role will be played by the combined transport of railway and airplane, and thus the appropriate infrastructures will have to be developed for the accommodation of this mode of transport[10].

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[9] Giannakos Konstantinos, "Interoperability in the railway: a development model for Southeast Europe", Doctoral Thesis, A.U.Th., 2000

[10] The Commission launched the RAIFF, Rail Air Intermodality Facilitation Forum, an initiative to stimulate a debate on the ways to develop combined use of rail, in particular high speed services, and air.

In order to determine the desirable priority improvements, the Commission has turned to professionals of the industry : airlines (Air France, KM, Lufthansa), rail operators (DB, Eurostar, SBB/CFF, SNCF, Thalys), airport operators (Paris, Brussels, Frankfurt, Schiphol, Leipzig), global distribution systems (Amadeus, Galileo, Worldspan), air (ACI, ATAG/IATA, Eurocontrol, OAG), and rail (UIC) professional bodies, other professionals from the sectors involved (UITP,….)

In the framework of RAIFF, these professionals, with the Commission's technical support, from September 2003 to June 2004, tried to answer questions such as :

- What has to be done so that air-rail trips can be organised and sold by the complete sales system: global distribution systems, internet portals, travel agencies, operators' distribution networks…
- What has to be done so that sales agents and passengers have ready access to air-rail possibilities.
- How to make the trip as seamless as possible for the passenger: automated check-in, remote check-in, luggage handling, standardisation of information…
- How to protect passengers in case of problems, at least as well as if they were travelling either by air or by train only.
- How to prompt air and rail operators to develop air-rail products...

and, of course,

- How the European Union could contribute to fulfilling these recommendations: financial support, adaptation of the legal framework, …

Towards a High-Speed Railway Network[11]

The quality of the offer made by a transportation system can be summarized in four elements:

- The speed (customers' view, suggested journey time)
- The frequency of services
- The line's capacity
- The price

By this rationale, it can be immediately concluded that the optimum use of high-speed railways is the connection of major cities that are several hundred kilometers far, if possible, with no intermediate stop. Within the competition of high-speed railways, on one hand, and the airplane and car, on the other, high-speed railway – in various European cities – constituted the means of attracting new customers, mainly from airline companies[12] (high speed trains can compete effectively with air transport over average distances, as they tend to be cheaper, more comfortable but also overall faster. Travel time to the airport, check in and check out times must also be considered in the total amount of time for air transport. As airports tend to be located at the periphery of cities a significant amount of time must be spend to access them. Train stations tend to be located in central areas and they are therefore generally more accessible).

A European high-speed network cannot be viewed only in the frame of the European Union but it must also foresee the integration of all the countries of the Continent, taking into consideration the procedure for its homogenization and integration, which results from the recent political developments. This Paneuropean network will constitute a strong, consistent and structural element of borderless Europe and a fundamental factor for the economical and social cohesion of Europe.

The future high-speed network in Europe (see maps in the following pages) will connect the major urban centers, in prices that will antagonize airfares for distances up to 1500 km, and, in the case of night travel for longer distances as well. The new generations of high-speed trains will allow speeds of 350-km/h, while lines for such speeds are already under construction (Madrid –Barcelona). Figures 6[13] και 7[14] depict the success of the services offered by high-speed trains.

Interoperability in rail transport should be assured, e.g. from Munich to Thessaloniki, at great speed and without delays, because of changes of traction units or rolling stock in general in different countries, in journey-time that will meet the needs of Europe's citizens in this century. Delays due to technical reasons (e.g signaling incompatibility) as well as administrative ones (e.g. police controls at the borders) should not be minimized but eliminated. Only in this way will the railway become competitive in relation to the other transportation means, for the above-mentioned distances. The Trans-European Networks (TEN) that will be created with these characteristics will cover Europe entirely, they will need to be consistent, and operate, if possible, as an integrated network. These TENs must concern

[11] Giannakos Konstantinos, "Interoperability in the railway: a development model for Southeast Europe", Doctoral Thesis, A.U.Th., 2000, p. 87
[12] as above, p. 23
[13] UIC, High Speed Trains around the world, 10/2002
[14] UIC, High Speed Trains around the world, 10/2002

certain high-speed ''railway corridors'' that will link the major cities/capitals of Europe and constitute the core of the railway network.

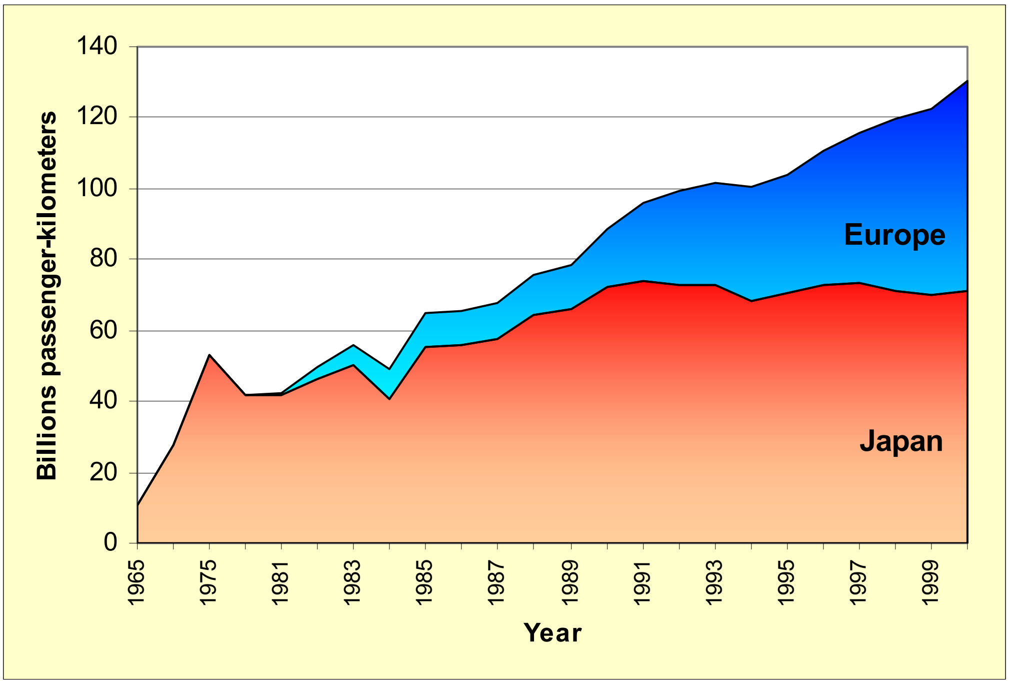
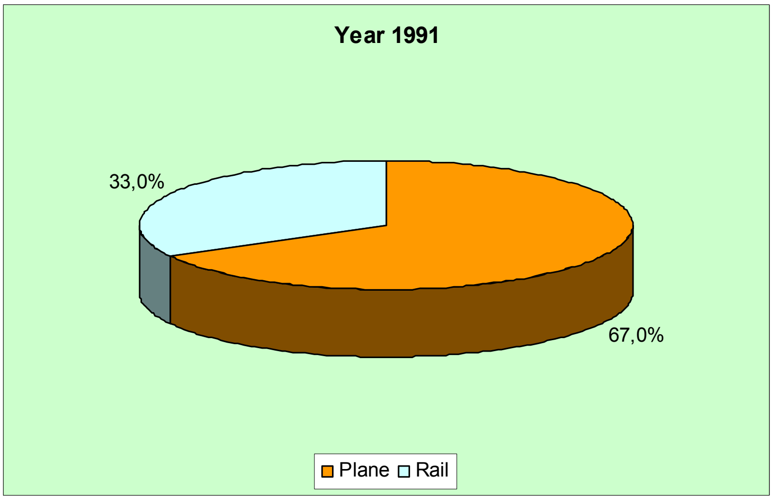


Figure 4 : Development of high speed rail traffic in Japan and Europe



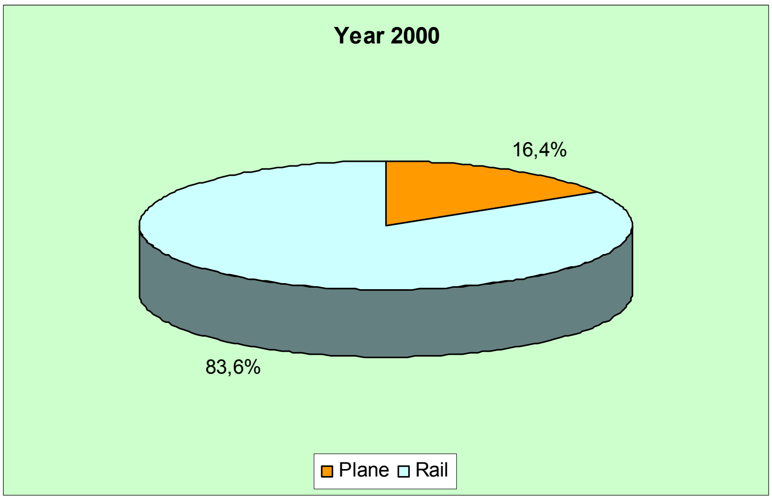


Figure 5: Market share Madrid-Sevilla (471 km) before and after introduction of AVE

The high-speed network must be combined with measures that will assure interoperability with no journey delays for passengers and freight.

In future, the circulation of freight high-speed trains should also be considered.

The high-speed lines that will be constructed will have to be designed for mixed operation (passenger/freight), in order to be economically viable.

The railway network of the EU of 25 has a total length of 197.000 km[15]. The target in the guidelines for the Trans-European Networks – Transport (TEN-T) defines a network to be composed, by 2010, of 1/3 high speed lines (app. by 16% new high-speed lines and 21% by lines upgraded for high speeds) and 2/3 conventional lines.

[15] UIC statistics

Progress has already been made in the construction of high-speed lines. The total length of these lines increased from 6.800 km in 1996 to 10.000 in 2001.

Also the increase of the transportation volume between 1991 and 2001 was great, as it tripled from 21.6 million passenger kilometers to 65.4 million passenger kilometers. Between 1998 and 2001 there was an increase of 35% (from 48,5 to 65,4 million passenger kilometers)[16].

The amount of necessary investments for the realization of all these priority schemes (the incomplete priority schemes of 2001 and the new ones) is estimated to be 220 billion euros approximately. The total cost of the network until 2020, at least, will reach 600 billion euros.

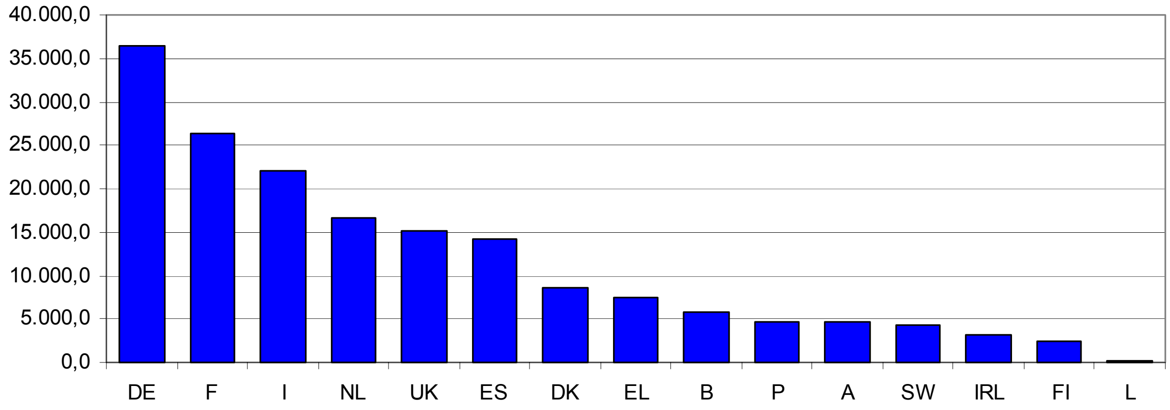


Figure 6: Investment in TEN-T network by country in 1996-2001 (million Euro)

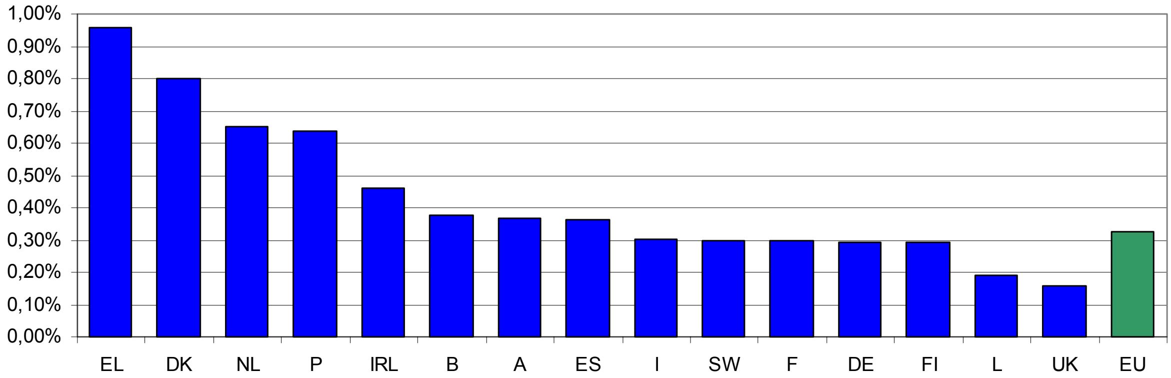


Figure 7: Investment in TEN-T network by country in 1996-2001 (average investment per year/GDP in 2001 in %)

[16] Source: "High Speed trains in Europe" UIC – High Speed division, October 2002

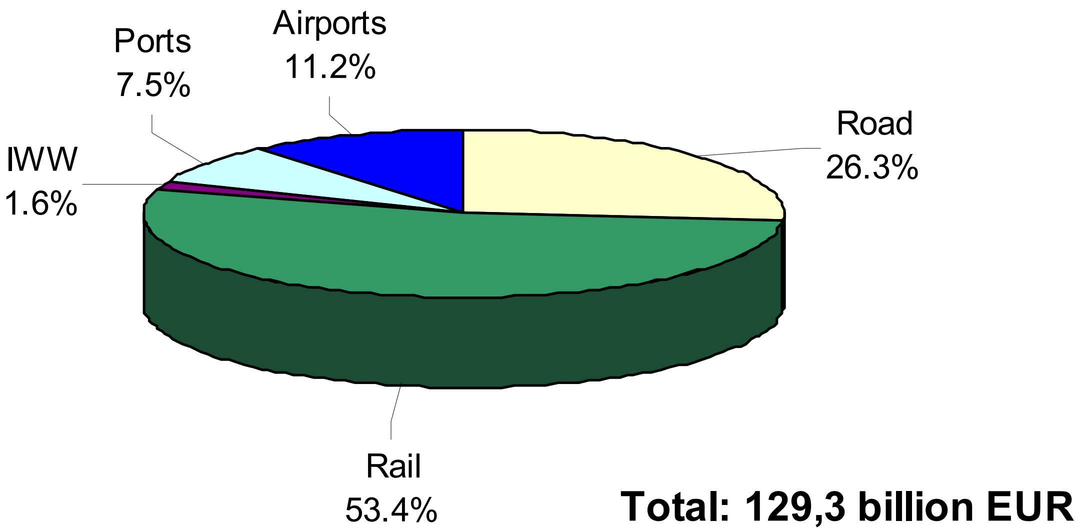


Figure 8: Share of the total investment per means during 1998-2001 [%]

Improvements on the conventional network of TEN particularly concern the following:

- electrification
- alignment improvement and construction of double-track lines
- improvement of the loading gauge, so that combined transports will be favored
- improvement of the weight per axis (especially in the Scandinavian countries, so that the use of longer and heavier freight trains will become possible)
- signaling and traffic control systems

The following maps depict the European, high-speed railway network in 2002, 2010, and 2020.

2002

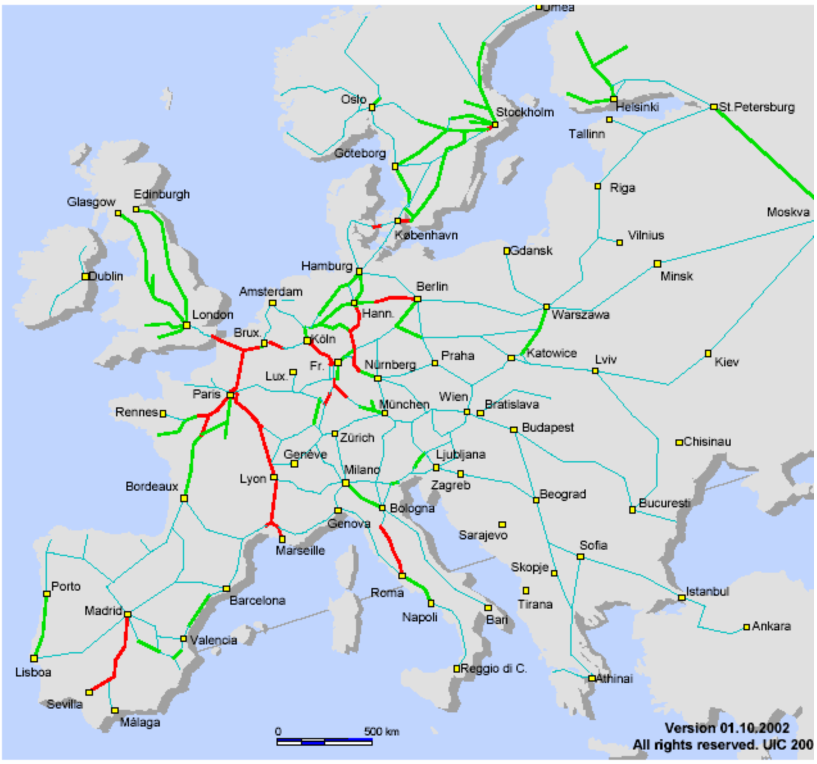
European High-Speed Network

Réseau Européen à Grande Vitesse

Europäisches Hochgeschwindigkeitsnetz

new lines (red)	new lines lignes nouvelles Neubaustrecken
upgraded lines (green)	upgraded lines lignes aménagées Ausbaustrecken
HS Network 2020 (blue)	HS Network 2020 Réseau GV 2020 HG-Netz 2020

High-Speed Division



2010

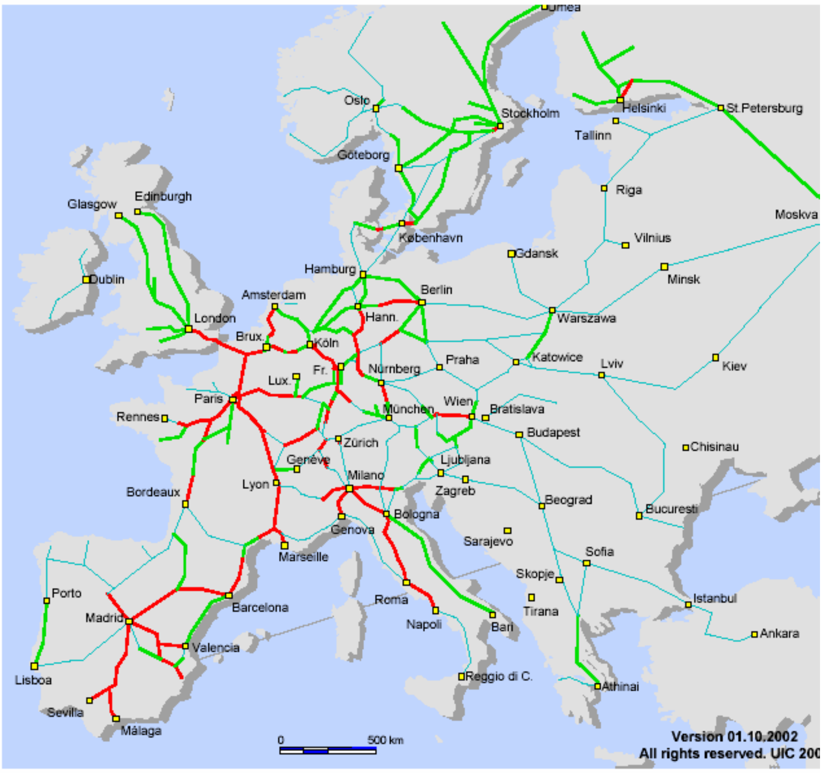
European High-Speed Network

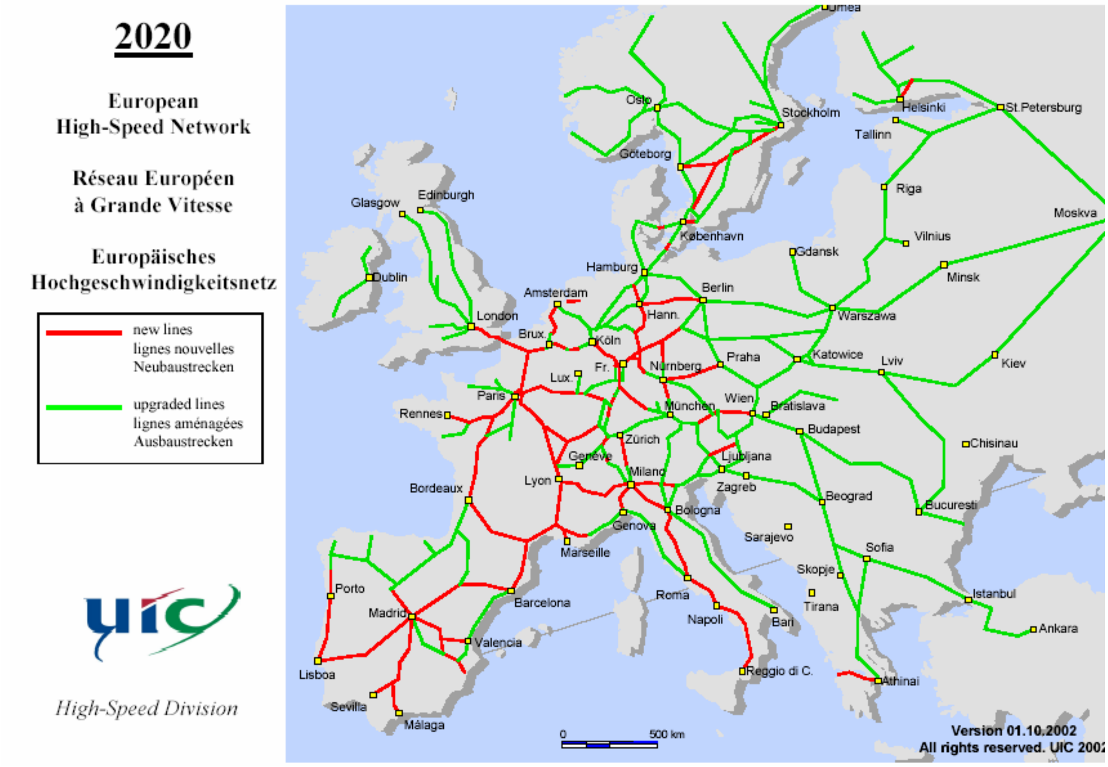
Réseau Européen à Grande Vitesse

Europäisches Hochgeschwindigkeitsnetz

new lines (red)	new lines lignes nouvelles Neubaustrecken
upgraded lines (green)	upgraded lines lignes aménagées Ausbaustrecken
HS Network 2020 (blue)	HS Network 2020 Réseau GV 2020 HG-Netz 2020

High-Speed Division





Freight Villages[17]

The establishment of the so-called Freight Villages[18] supports the transport of products, especially in major cities and capitals. A Freight Transportation Village[19] is a designated area, in which several operators handle all the activities related to transports, logistics and product distribution in national and international transports. Freight Villages are open centers, which connect various modes of transport, provide access to transport corridors, include transportation companies and offer telematics services. In addition, emphasis is paid to strategic areas, e.g. outside key-cities, near ports and airports, with easy access and connections. The reason for this, is to free the major cities from considerable truck circulation and thus control the traffic. Freight Villages offer all the facilities for the settlement of the products, the means of transport and their personnel. The companies that are related with the Freight Villages have offices of advanced technology and facilities in these centers.

[17] Giannakos Konstantinos, "Interoperability in the railway: a development model for Southeast Europe", Doctoral Thesis, A.U.Th., 2000, p. 243

[18] For Freight Transportation Villages in Greece, see European Commission's Directorate General XVI, Cohesion Fund, "Study of Hellenic Network of Freight Villages", January 1997

[19] Efstathiadis Stelios, «Cooperating freight transportation villages and small or medium companies", 2nd Conference on Combined Transports and Transits in Southeast Europe, A.U.Th. , 4-6 June 1998, Minutes Volume, p 201-210

The Freight Villages must offer efficient logistic systems and the necessary railway infrastructure and facilities (warehouses, break-bulk centres, storage areas, offices, car parks, etc...), for a high performance railway transport.

Port Connections

Railway infrastructures that serve ports should be designed and implemented in such a way that the target of fast and with minimum cost realization of transport is fulfilled (unloading form the boat directly to the train, without intermediate placement).

The necessary infrastructures for the servicing of the sea-motorways must been foreseen (discussions / research is still ongoing about the definition of the appropriate infrastructures).

Rail Freight Freeways (RFF) [20]

Support for the creation of new infrastructure, and in particular rail freight freeways is provided in the White Paper "European transport policy for 2010: time to decide", for the revitalizing of the railways[21].

One of the most basic elements that will improve offer in the sector of rail freight transports is the "One-Stop-Shop (OSS)". In order to be effective they have to be operated by personnel who have excellent knowledge of the demands of operation companies and the system's restrictions[22].

In February 1998 the first Freight Freeways began operating:

- The North South Freight Freeway (Denmark, Germany , Finland ,Italy ,The Nederlands , Norway , Sweden and Switzerland), incorporating Scanways
- The Belifret Freightway (Belgium, France, Italy, Spain).
- A third was designated, the East West Freightway (Hungary, Austria, Germany, France and Great Brain), but it is not in use as such.

The required infrastructures for the realization of Freeways are:

- Infrastructures for the reduction or removal of border delays
- Infrastructures for the elimination of bottlenecks (new infrastructures or increase of the performance of the existing infrastructures).

[20] Giannakos Konstantinos, "Interoperability in the railway: a development model for Southeast Europe", Doctoral Thesis, A.U.Th., 2000, p. 175
[21] page 105
[22] As above, p. 11

Exploitation of peripheral lines

As for the peripheral lines of today's networks, there is often a tendency to pause their operation, if they are considered non viable and the State is not willing to pay "Public Service Obligations" (PSO).

In many cases it has been demonstrated that, a change of their operation mode (e.g. via local bodies) may render them viable. Additionally, pausing their operation may result in reduction of the transportation volume, also on the main axes, which the clients cease to use when the operation of the peripheral lines has been paused. Therefore, every effort must be made in order to retain peripheral lines, by making them more attractive and taking into consideration their contribution to the transportation volume of a railway network.

Design and construction of tomorrow's railway infrastructure

Superstructure

Requirements for a modern ballast track[23]

The components of the modern ballasted track are[24]:

- Concrete monoblock sleepers of wide seating surface
- Heavy rail (UIC 60)
- Fastening with high elasticity (e.g. Vossloh SKL 14)
- Elastic pad with low stiffness (c_{stat} < 80 kN/mm)
- Hard ballast [25] [26] [27]

The selection of superstructure materials plays an important role in the stress of the ballast bed, and as a result, the maintainability of the geometry of the track. The relation between the stress of the track by vertical loads and the deterioration in the quality of the track's geometry is given by the relation[28]:

Deterioration in the quality of the track's geometry = (Increase in stress on the ballast bed)^m	where m = 3 to 4

If, for example, the stress on the ballast bed increases by 10%, the quality of the track deteriorates by 30% to 50% and, therefore, a corresponding increased level of maintenance is required.

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[23] Giannakos Konstantinos, "Interoperability in the railway: a development model for Southeast Europe", Doctoral Thesis, A.U.Th., 2000, p. 241

[24] Giannakos Konstantinos, "Actions on the Railway track" (Greek version 2002, English version soon to be published

[25] Giannakos Konstantinos, "Actions on the Railway track" (Greek version 2002, English version soon to be published

[26] Giannakos K., Vlassopoulou I., "Study on the stress on the ballast and the superstructure's performance in relation to the type of sleepers used". OSE/Track Directorate, Athens 1990

[27] Giannakos K., Vlassopoulou I., "Study on the sleeper - ballast system". OSE/Track Directorate, Athens 1990

[28] C. Esveld, "Modern Railway Track, 2001, p. 93

OSE, after years of research into the use of different track materials and the examination of failures in the track's structural elements[29] [30] [31], concluded in the use of B70 monoblock sleepers, Skl-14 (Vossloh) fastenings, soft pads and hard ballast[32] [33]. We should note that for high and very high speeds, advanced technology in civil engineering works consists of the fastening and, especially, the clip and elastic pad (which must be compatible[34]). The compatibility of the elastic pad and clip is defined by the response curves of these two particular elements of the fastening[35].

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[29]In the beginning of the 1970s, OSE adopted heavy-type track superstructure, with heavier rails (UIC 50, UIC 54 for the open track, and UIC 54 and UIC 60 respectively for the switches), biblock, concrete sleepers of Vagneux U2 and U3 type, RN fastenings and 4.5 mm thick, elastic pads. Also at that time, laying of the first tracks with CWR began, with heavy-type superstructure that consists, as mentioned earlier, of UIC 54 or UIC 50 rails and biblock, concrete sleepers with RN fastenings.

In 1986 approximately, following regular inspections for maintenance reasons, it was discovered that the bi-block concrete sleepers began to exhibit cracks, from the sleepers' foot and vertically onwards, to the section under the rail's seat on the sleeper. The appearance of cracks was systematic and reached 60% of the sleepers.

For this reason, a team of diplom engineers was set up – with Mrs. Isavella Vlassopoulou, Mr Pavlos Iordanidis (a member until 1989) and the writer – which began the study and concluded all the work. The research was carried out in cooperation with The Laboratory of Reinforced Concrete and the chair of Railway of the NTUA, the sector of Geotechnic Engineering of the A.U.Th. and the research department "Track" of the French Railways (S.N.C.F.) and lasted – including data processing- until 1993 inclusive.

[30] Giannakos K., Vlassopoulou I., "Stress on concrete sleepers and application for bi-block sleepers". Technical Chronicle, Volume 14, 2/ 1994

[31] Giannakos Konstantinos, "Actions on the Railway track" (Greek version 2002, English version soon to be published

[32] Giannakos K., Vlassopoulou I., "Problems and solutions for the "sleeper-ballast" system in OSE". OSE/Track Directorate, Athens 1991, but also, Giannakos K., Vlassopoulou I., "Research for the definition of the type of sleeper to be adopted by OSE – Comparative Presentation of the various types of ballast – Research evaluation by Prof. K. Riessberger" OSE/Track Directorate, Athens 1992

[33] Giannakos K., Iordanidis P., Vlassopoulou I., "Report of the OSE Committe of Experts on their visit to the SNCF, from 15.5.1988-11.6.1988". OSE/Track Directorate, Athens 1991. Giannakos K., Vlassopoulou I., "Problems and solutions for the "sleeper-ballast" system in OSE". OSE/Track Directorate, Athens 1991. OSE/SNCF Cooperation: 6/1988, "Comportement des traverses en relation avec les charges dynamigues", but also OSE/SNCF Cooperation: 3/1989, " Programme d' essays realize au cetre d ' essays de la Direction de L' Equipement", which includes experimental results from the use of OSE materials in the SNCF laboratories.

[34] Giannakos K., "Management of the railway infrastructure", Athens/Thessaloniki 1999, Giannakos K., "Railway track – fastenings", Athens 1999 and Giannakos K., "Rails, sleepers, fastenings, rail joints, CWR, ballast, track laying", OSE, Athens, October 1985

[35] Giannakos Konstantinos, "Actions on the Railway track" (Greek version 2002, English version soon to be published

Slab Track[36] (Feste Fahrbahn)

After several years of international experience (e.g. Japan, Germany, France, etc) in high speeds, considerable wear was observed on the ballast, which, due to the dynamic loads, brakings, etc, crushed and shrinked, and the results are loss of its elasticity, difficulty in the outflow of rain water, etc. Under these circumstances the preservation of the track's geometry demands very frequent and costly interventions. As for the superstructure elements (sleepers, rails, fastening materials, etc), they suffer unacceptable wear and also require replacement much earlier than their expected life span. Costly interventions on the infrastructure cannot be avoided either.

The slab track consists basically of a rigid bearing concrete structure and appropriately-shaped fastenings, which are affixed to it and hold the rails in the appropriate position. A typical slab track cross-section is shown in Figure 7 concrete construction and the fastenings that are suitably shaped and fixed on it in order to hold the rails (figures 7, 8, 9[37]).

The slab track method (S.T.) actually eliminates (as was proven, in practice, by its application for over 30 years) the disadvantages of the "ballasted track", since the ballast is completely replaced by reinforced concrete bearing slab on suitably shaped subgrade (Figure 7).

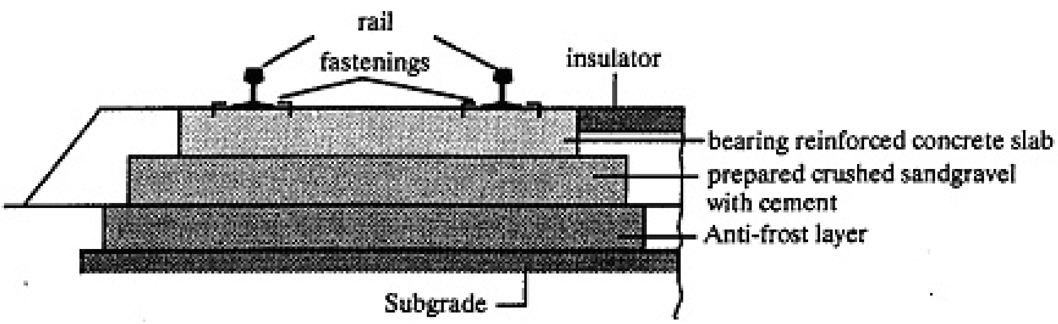

Figure 9: A typical slab track cross-section

[36] Tsoukandas S., Tsitouras H., Giannakos K., Palierakis A., Talambekos G., « Slab Track – The new, concrete-based technology based on the shaping of the railway track", HRF – Hellenic Concrete Department (FIB – RI-LEM Member), 13th Conference on Concrete, Rethymno, 25-27 October 1999, Minutes Volume III, p. 411-425. Giannakos Konstantinos, Interoperability on the railway: a development model for southeast Europe, Doctoral Thesis at the A.U.Th., 2000

[37] Slab Track Monitoring Committee of OSE-ERGOSE, Tsoukantas S. G. ''Examination of the problems that concern the Application of the ''Slab Track'' in Greece, on tunnels, open track and bridges'', Athens, July 2000

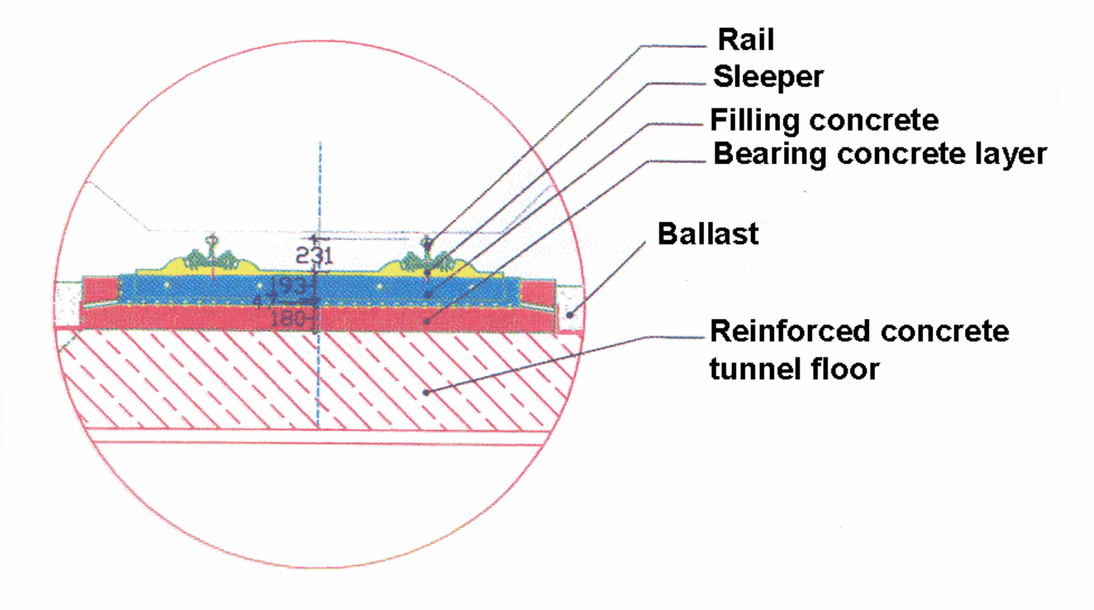

Figure 10: Type Rheda Slab Track detail[38]

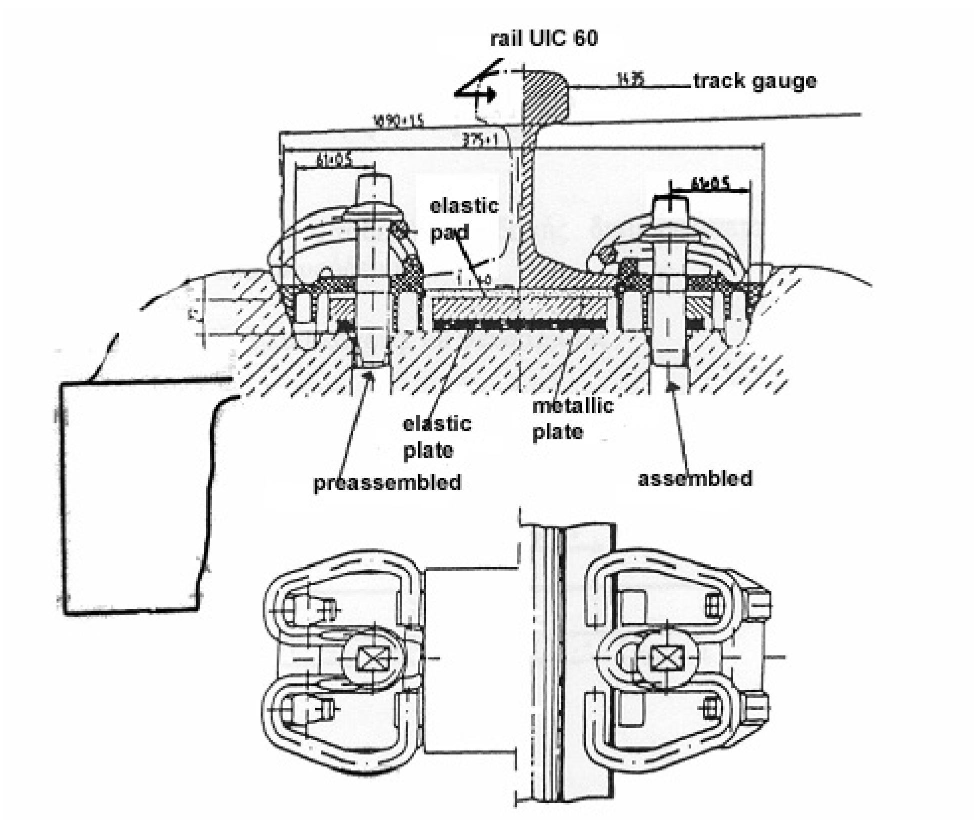

Figure 11: Fastening Skl-300 for slab track

[38] Giannakos Konstantinos, "Actions on the Railway track" (Greek version 2002, English version soon to be published

Selection of track construction with ballasted or slab track

The main advantages of the slab track method are:

- the passenger comfort provided
- the long life cycle, and
- minimized maintenance over time, in relation to the ballasted track, which renders it the most appropriate method for the construction of High-Speed Lines of mixed circulation (see also figures 10, 11)

It should be stressed that the slab track on new tunnels allows the reduction of the tunnel's cross section, thus resulting in the reduction of the project's total cost.

The *disadvantages* of the slab track, always in comparison to the ballasted track are:

- Initially higher construction cost, which is depreciated in time, though, considering the almost zero maintenance cost. Yet, if we take into consideration the experience from the German network, the total cost of the slab-track applications tends to become lower (today it is between 20%-40% more expensive[39] than the cost of the ballasted track, which amounts to 6% of the project's total cost)[40].
- The noise increase by about 3db by running of the trains on a slab track.
  In cases, though, that this noise increase has a substantial environmental impact, measures can be taken for noise reduction, e.g. covering of the slab at railway stations, or addition of sound barriers along the lines, where trains pass though residential areas.
  Today, coordinated, international research is being carried out on the issue of noise reduction on slab tracks and it is expected that soon this issue, too, will be sufficiently dealt with for the years to come.

For the selection of the type of track to be constructed (ballasted track / slab track) various factors are considered, such as:

- life cycle cost (initial investment, service life, maintenance cost)
- construction time
- availability and durability

In the past, the selection of the construction mode was based on the initial investment cost, while today the life cycle cost should be taken into consideration. This will result in the selection of slab track systems. This selection has additional economic advantages in the cases of tunnels.

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[39] It should be noted, that the installation cost of the first application of the Slab Track on an open line in Germany costed approximately 80% more than the classic ballasted track, and today it fluctuates between 20%-40% with a tendency for further reduction.

[40] OSE, Genaral Directorate of Infrastructure, proposal of OSE's Administrative Board for the ''Approval of the feasibility, characteristics, and quality elements of the study for the construction - using the ''Slab Track'' method - of superstructure for the new, double, railway line between k.p. 374+625 and k.p. 381+547 of the Athens-Thessaloniki line (the area of the Tempi tunnel), Athens, 2000

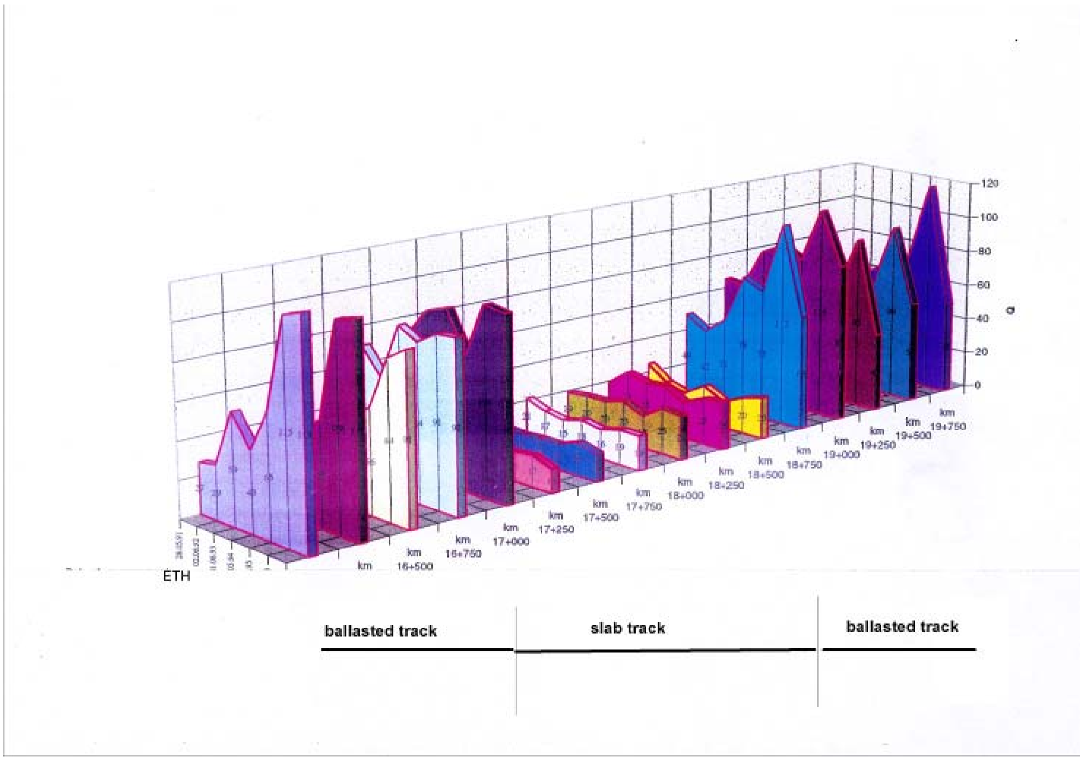

Figure 12 : Characteristic quality index value (Q) in slab track RHEDA type, and the ballasted track on both sides on the high speed line Köln - Leverkusen

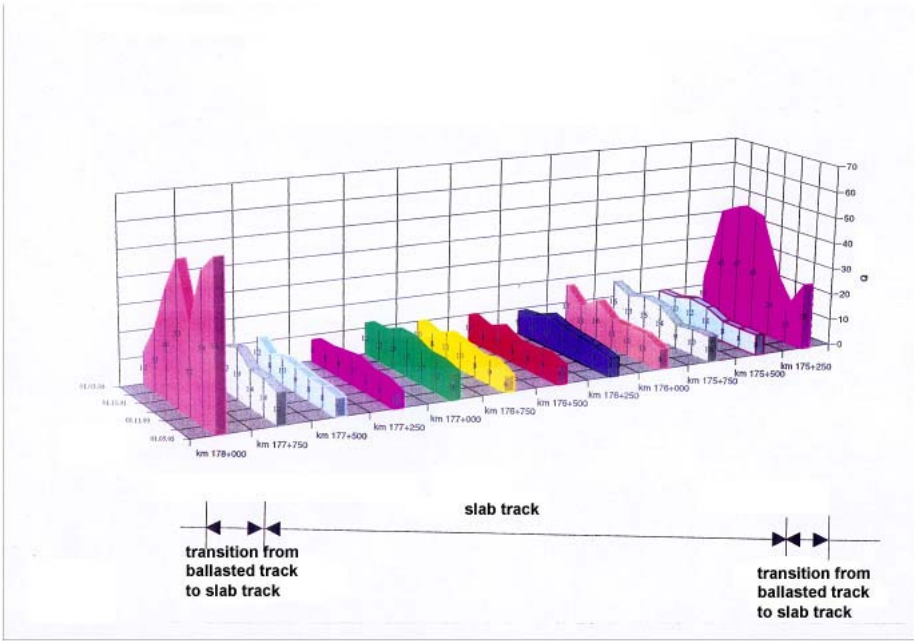

Figure 13: Characteristic quality index value (Q) in slab track RHEDA type, and the the ballasted track on both sides on the high speed line Hannover - Würzburg

Requirements for efficient track maintenance

Efficient track maintenance requires inspection of the track and execution of measurements (recording). Most railway networks (infrastructure managers) today use recording cars to measure track geometry and ultrasonic inspection systems. The recordings and inspections dictate whether there is a necessity or not for track renewal, for reasons of safety and speed increase.

Speed increase and loads are imposing ever-tighter restrictions on the permissible tolerances in track geometry. The measurements have to be highly accurate. So, it is very important to formulate the specifications for the track structure in a way, by which the relative parameters can readily be measured and verified. This applies not only to the construction tolerances but also to the maintenance standards.

The use of new technologies, new inspection methods (e.g. automatic video inspections), and the use of informatics and decision support systems, could increase the efficiency of track maintenance and reduce maintenance costs.

Optimization of the existing infrastructure[41]

Construction of a new line is expensive (10 - 25 Mio €/km) and in general can only be justified if the available capacity on the existing line has been exhausted and/or journey times are far from satisfactory. Competition from the road and air modes should also be taken into account.

Where for quantitative and qualitative reasons a new line is not required, ways are often sought to bring about improvements at a low cost.

The permissible speed and as a result the journey time of a train is contingent on:

- the vehicle design type
- the type and length of train
- the braking conditions
- the line conditions
- the operating conditions.

When it comes to line conditions, the curves and gradients are of decisive importance. A good track alignment should allow shorter journey times to be achieved and, with energy consumption and braking efficiency in mind, should keep breaks in speed to the strict minimum.

In curves, the speed is determined in particular by:

- running conditions
- lateral forces exerted on the track
- stability of goods
- comfort thresholds for passengers

The centrifugal force in the curves can be partially or wholly compensated by track cant.

We can achieve increase in speed on conventional lines by using tilting trains.The profile of the track in principle does not require, or hardly requires, any special

[41] UIC, High Speed Division, Seminar "Reducing journey times on conventional lines", Paris, 28.01.2002

conditions to be satisfied other than the basic conditions to be fulfilled for conventional trains operation.

The track equipment to be used as a reference for tilting trains is the same as that used for conventional trains.

The UIC leaflet 518-1 is dealing with the approval of tilting trains[42].

Noise reduction

Since the construction of high-speed lines, environmental problems such as noise have become more and more important.

The impact of noise produced by railway infrastructure needs to be controlled, especially when located close to urban areas. Both the source of noise, e.g. rail vehicles and tracks, and noise propagation contribute to the total noise emissions.

The requirements of the infrastructure of tomorrow are the design of noise reduction measures. Possible options include[43]:

- control of rail roughness by means of track design and maintenance
- improvement and development of track design[44] to reduce noise emission, including add-on components such as rail dampers, absorption and low track-side barriers, but also novel track structures as they are developed[45].

Towards a Framework for the Improvement of Technical Interoperability[46]

Train circulation on tracks of different gauge

Railways which have the problem of more than one track gauges, can improve the conditions for passenger traffic in one or two ways: either convert all their superstructures to the same track-gauge value, which in most cases is prohibitively expensive, or adjust their trains so that they operate on lines of different track-gauge values[47].

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[42] UIC Leaflet 518 comprises a whole series of regulations covering the running of line tests and the analysis of their findings but only applies to vehicles fitted with a cant deficiency compensation system and thus an extension to the leaflet is needed, in the form of UIC Leaflet 518-1. Tests and approval of railway vehicles from the point of view of dynamic behaviour safety – track fatigue - ride quality
Supplement: application to vehicles equipped with a cant deficiency compensation system and/or to vehicles designed to operate with a higher cant deficiency than stated for Categories I to III defined in Appendix C of UIC Leaflet 518.

[43] Position Paper on the European strategies and priorities for railway noise abatement, EU

[44] Slab-track can reduce maintenance work, but compared with ballast track, slab track has higher noise level. Ballast track can absorb the wheel/rail noise, but concrete surface on slab track reflects the wheel/rail noise and doesn't absorb it.

[45] Thompson D., Jones C., "Low noise track meets environmental concerns", Railway Gazette, July 2002

[46] Giannakos Konstantinos, Interoperability on the railway: a development model for southeast Europe, Doctoral Thesis at the A.U.Th., 2000

[47] International Railway Journal, "Gauge-Changing, Japanese develop First Gauge-Adaptable Emu", January 1999, p. 31

It is more effective for a vehicle to switch from one gauge to the other than to tranship its load, and today there are many solutions towards this end. The possibilities available are:

A) Wagons or carrier bogies

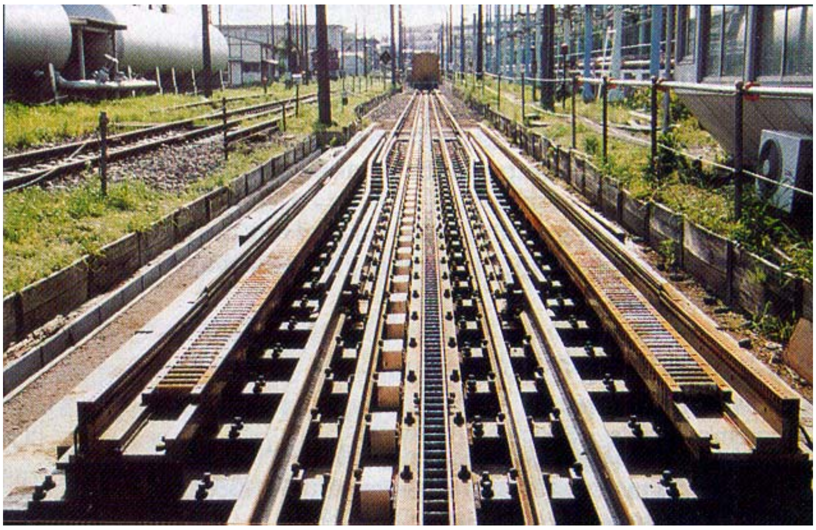
They are small, carrier bogies, which are placed underneath the axles of a vehicle of different gauge or very low carrier platforms equipped with rails on them, in order to carry different-gauge wagons. These formations allow continuity of movement, on narrow-gauge tracks, for vehicles of normal gauge, under the condition, of course, that the cinematic (dynamic, loading) gauge allows it.

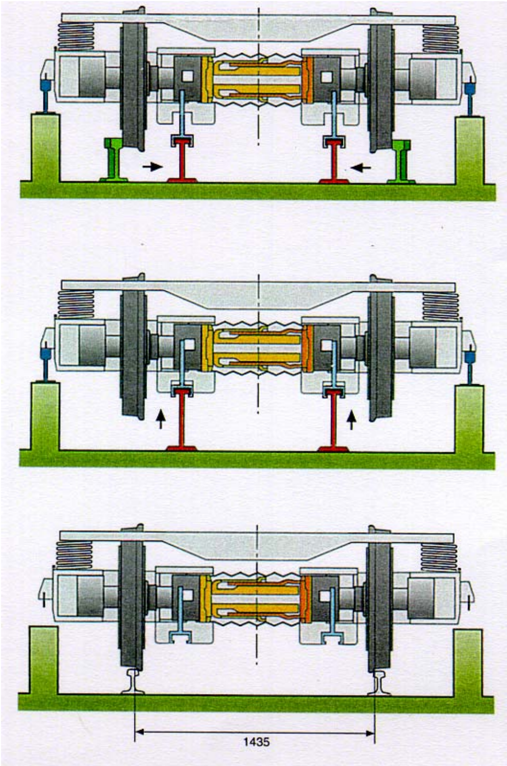
B) Change of rolling elements

Here, the rolling instruments, single axes or bogies, are changed at the borders of the two networks of different track gauge. The vehicle continues its course on the other side, after the change of its rolling elements.

C) Variable-gauge axes

Variable-gauge axes constitute the ideal solution to the problem. Their wheels, assembled on the axis of the axles, can be moved along their axis, and immobilized at the position that corresponds to the desired gauge.





Existing technology should be improved, and new technology should be developed, to accelerate the performance of the gauge change procedure, in order to avoid a competition disadvantage for the railways to the other means of transport (and specially the road).

Promotion of the compatibility between Signaling and Traffic Control – Management Systems [48]

To this day, each of the railway networks in Europe has adopted a national approach. This is particularly evident in the train signaling and control sector. The various systems used to this day are not at all compatible with each other. The continuous growth of circulation throughout Europe alters this way of thinking considerably, towards the improvement of their interoperability, at the levels of system and standardization.

The European Rail Traffic Management System ERTMS

The ERTMS was established in 1995 by initiative of the European Commission. The core of the ERTMS is its management control system (ERTMS/ETCS[49])[50].

The targets of the ERTMS/ETCS are[51]:

- To achieve interoperability among the various European networks (today there exist many different signaling systems which are not interoperable)
- To enhance performance through high speeds and shorter headways.

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[48] Giannakos Konstantinos, Interoperability on the railway: a development model for southeast Europe, Doctoral Thesis at the A.U.Th., 2000, p. 203

[49] *European Train Control System*

[50] Wojanowski Erich, "Development, testing and validation of new train control systems – The ERTMS project", Tokyo Seminar – "Railway Signaling & Telecommunication Technology", Rail International, June 1998, p. 45

[51] as above, p. 45

- To reduce investment on the network's infrastructure, by eliminating the need for side-track signaling and deregulation of equipment
- To stimulate competition within the European market, using common European standards.

ERTMS consists of ETCS, the new control-command system and GSM-R, the new radio system for voice and data.

The new ETCS[52] system

Nowadays, a new European train control system has been designated, called the ETCS, which allows full interoperability among the European networks for future lines, as well as increased circulation, improvement of the safety of the entire system and reduced investment cost.

The new system will facilitate the creation of international, high-speed corridors by reducing or eliminating border delays for passenger and freight trains. The system will also reduce headways and improve the circulation capacity.

This new system foresees three operational levels[53]:

ETCS level 1

The lowest ETCS level is defined as addition to existing national signal systems and is aimed at an increase of safety. Existing signal information and all necessary track data at the existing signal locations are punctually transmitted via electromagnetic transponders (Eurobalises) to the train. The balises are powered by the passing train with a 27MHz electromagnetic field and respond via sending track to train information at 4.3 MHz with a data rate of approx. 564kbit/s. The train's on-board unit (OBU) continuously monitors the allowed train speed and warns the train driver in the case of speeding. If the warning is not recognized and the speed not reduced accordingly within a certain time period, the brakes are applied by the OBU or even a train trip is triggered. An additional transmission of so called infill information in front of the signals via radio, leaky cable or additional balises can reduce the disadvantage of punctual information transmission and provide operational improvements of the line capacity.

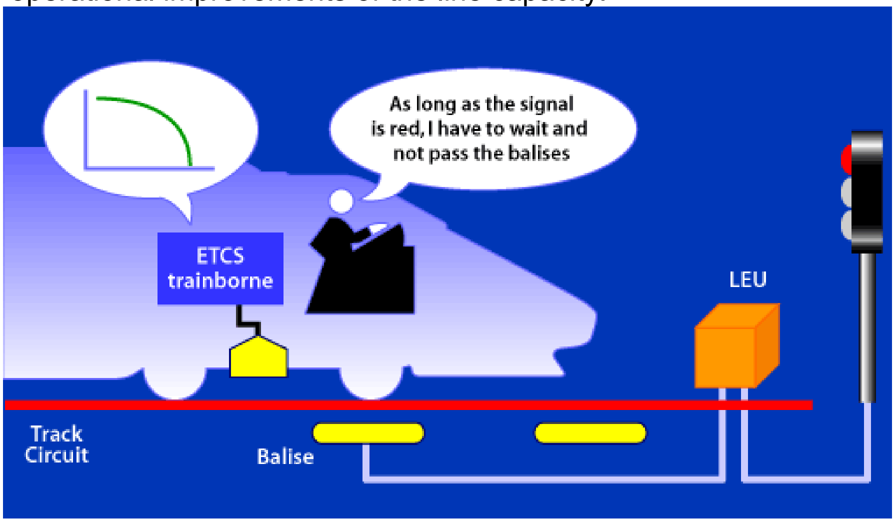

Figure 14: ETCS Level 1

[52] European Train Control System

[53] Rhein D., Ziering F., "ETCS Level 1 now goes from tests to implementation" Computers in Railways VIII, 2002

ETCS level 2

A continuous data transmission to and from the train is performed via digital radio GSM-R, which allows to replace the existing way-side signaling. With this application level the way-side signals can be replaced by cab signaling, but the train movement is still limited by the fixed blocks of the conventional signaling system with its track-side occupation detection systems.

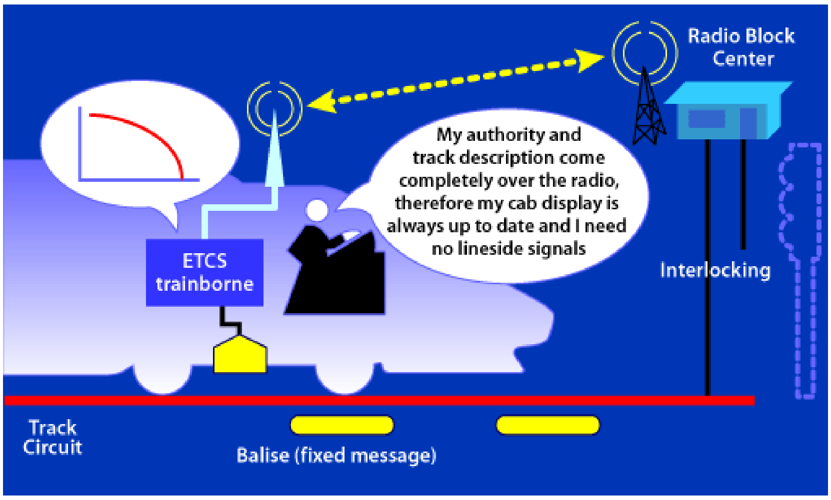

Figure 15: ETCS Level 2

ETCS level 3

As in level 2, a continuous data transmission to and from the train is performed via digital radio GSM-R, which can replace the conventional signaling. Furthermore, the train movement is no longer limited by the fixed blocks of the conventional signaling system. Instead a moving block operation is feasible where the train integrity is monitored on board and axle counters or track circuits are no longer required.

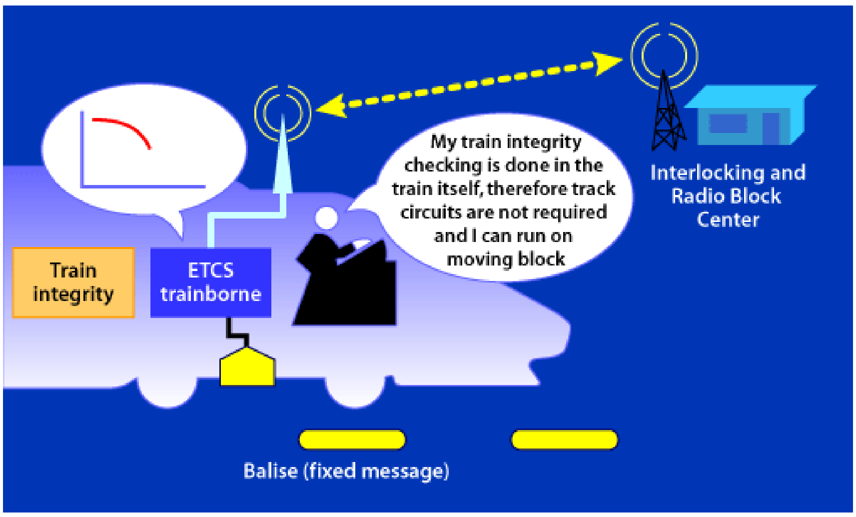

Figure 16: ETCS Level 3

Within the time horizon of 2008, ETCS will be in operation on new lines in Spain, Belgium, France, Germany, Italy, the Netherlands, Spain, Sweden and Switzerland[54].

Promotion of Radio-communication Systems Compatibility
(GSM-R, Global system for mobile radio-communication – a solution for the integration of railway communications)

The GSM-R system was set by the UIC[55] (EIRENE project) in order to integrate and replace some or all of the existing mobile applications, while it provides global interoperability for mobile phones. Such a modern communications infrastructure is expected to be used as the cornerstone that will help railway companies reduce their operational costs drastically and increase their operational efficiency[56].

Traffic management systems for low density lines

Existing command-control systems adapted for medium traffic density lines or the future ERTMS/ETCS system dedicated to high speed and/or high-density traffic railway lines remain too expensive to allow their use on railway lines with low and very low traffic density. As a consequence, many Low Density Traffic Lines (LDTL) in the EU, in Eastern Europe, in the USA, and in developing countries all over the world are still equipped with over-aged safety equipment with high maintenance costs, keeping the capacity of these lines to a very low threshold.
In this context, there is a need for the development of an innovative and cost effective system for Low Density Traffic Lines based on new available technologies. Thus offering the same level of safety than on high-density lines and enhancing the efficiency of these lines in order for rail transport to become more attractive.

There are two approaches: the ETCS-LC project and the LOCOPROL project:

The ETCS-LC project[57]
The International Union of Railways, UIC Infrastructure Commission has launched the Low-Cost Train Control, ETCS-LC project. The aim of this project is to continue developing the ETCS specifications as described in the project declaration. Hereby, the EU Com-mission's plans for extending the technical interoperability of international trains working on high-speed TEN lines to conventional lines can be realised. An additional EU directive on the subject of these plans has been prepared in draft form, and gives top priority to using ERTMS/ETCS.

The LOCOPROL project[58]:
The LOCOPROL project intends to develop an innovative cost-effective satellite based vital fail-safe train location system as the core of a train protection, control and command system.

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[54] UIC, "Implementing the European Train Control System ETCS – Oportunities for European Rail Corridors", 31.12.03
[55] as above
[56] Robillard Christophe, "A solution for the integration of Railway Networks – GSM-R", "Tokyo Seminar – Railway Signaling & Telecommunication Technology", Rail International, June 1999, p. 58
[57] http://etcs.uic.asso.fr
[58] See http://www.locoprol.org/index.htm

The proposed innovations will achieve a significant reduction of the costs aiming to short term applications for low density traffic railway lines.

The four main objectives of the project are strongly interconnected:
- to define a new multi-technology location system
- to study and prove its applicability in LDTL lines
- to study its application to ERTMS/ETCS
- to study and prove its application for workers protection

Various other factors influencing Technical Interoperability (loading gauge, axle load)[59]

In addition to all that has been mentioned above earlier, there are other factors as well, of lesser importance, which influence technical interoperability, such as loading gauges and maximum load per axle.

The issue of axle load today is covered almost all over Europe by the 20-ton load per axle, with the tendency to accept, in all European networks, an axial load of 22,5 tons. These general rules should be adopted, as it is promoted by the UIC, so that freight transports, mainly, will gain benefits.

Organizational and administrative problems during border crossing[60]

The crossing of borders is a great problem for transports. It is obvious that the design of border stations, as their operation, must be approached anew on the whole, especially since the road transportation means face no such problem.

This is not a new problem, yet it has become greater since the former Soviet Union and Yugoslavia were separated, as well as the Czech Republic and Slovakia. The railways are facing the problem of funding in order to increase speeds and make profit (hundreds of millions of dollars, for a few minutes in journey time), while hours are still being lost at the borders.

The problems are more complicated and at a completely different scale in the case of borders with gauge change. The average transit time for freight is 2,5 days. At the same period of time a truck can cross the European continent from one end to the other. The loss of time, for the railway, at a border crossing alone, equals, on average, a truck journey from the origin to the destination station, which could be on the opposite side of Europe. In addition, there are several border crossings where different gauges meet, and gauge change technique is needed, with relevant time loss.

Unfortunately, not all kind of the border controls operate at all the border crossing points and the international rail freight circulation has the disadvantage of excessively long stops, due to veterinarian inspections, measures for agricultural

[59] Giannakos Konstantinos, Interoperability on the railway: a development model for southeast Europe, Doctoral Thesis at the A.U.Th., 2000

[60] Giannakos Konstantinos, Interoperability on the railway: a development model for southeast Europe, Doctoral Thesis at the A.U.Th., 2000

protection, etc. These delays particularly occur at the exterior borders of the countries that succeeded the former Soviet Union[61].

When a train has to cross many borderlines, the total delay considerably reduces competition in rail transport. A swiss study presented the economic dimensions of these prolonged delays at the borders. According to the study, the railways need to invest 25 million Swiss francs to line upgrading, in order to reduce journey time by one minute. In contrast to this, a systematic effort for the reduction of time delays at the borders is by far the most economical alternative solution. This would lead to the saving of journey time, at a scale that can only be achieved by spending billions of Swiss francs on line upgrading.

What concerns the infrastructure, there are different ways to accelerate the border crossing:

1. All the facilities on both sides of the borders must be dealt with as one entity. In cases where the two transhipment stations work for the same kind of transported freight on both sides of the borders, the most efficient station must be retained and the remaining stations must manage the rest of imported and exported freights, as for example, is the case in Ukraine and Hungary concerning bogie change[62].
   To create, in practice, a common station puts an end to time losses between two stations on the sides of the borders. It abolishes the time losses required for the transferring of one station to the other. It considerably simplifies the exchange of empty trains. It forces the customs authorities of the two countries to perform as many controls as possible together. Finally, it simplifies the exchange of documents between two railway companies. Another very important point: unnecessary maneuvers at the borders must be abolished. This means that the concept of an integrated station will abolish one of the two parallel maneuver procedures, one for import and the other for export[63].
2. Marshalling yards will make maneuvers at a higher degree of detail than today.
3. Development of electronic message exchange systems. Electronic messages such as the H30 (train pre-announcement) demonstrate several advantages[64]:

Market orientation of the infrastructure companies

Infrastructure companies will have to develop an orientation for the market, proceeding, on the one hand, to thorough exploitation of the railway infrastructures that constitute the core activities, and, on the other hand, the exploitation of non–core activities, such as exploitation of real estate, telecommunications infrastructure, etc. We should also note that various railway networks, e.g. that of

[61] Ebeling Klaus, " The Pan-European Traffic Networks – An Opportunity for Europe's Railways ", Railway Technical Review, January/February/March 1999, p. 7.
[62] as above
[63] Boutte Claude, "Freight transport – Accelerating border crossing involving gauge change", Rail International, 05/1998, p. 13
[64] Fenyves Laszlo, "Franchissement des frontieres: Taches et activites", Rail International, Mars 2000, p 14-17

the Japanese railways, have great incomings from the exploitation of these parallel activities.

Conclusion

The railway infrastructure of tomorrow consists of:

At planning level:

- Infrastructures for combined transports – Efficient interfaces with the different transport means (rail-road / ship / aviation)
- Connections with freight-villages
- Efficient port – connections with infrastructure for the sea motorways
- Efficient logistic systems
- Creation of rail – freight freeways, with one-stop-shop services
- Design and construction of high speed lines

At design and construction level:

- Modern superstructure
  - Interoperable
  - use of ballasted track with elastic fastenings like Skl-14 (Vossloh) and elastic pads with low stiffness
  - use of slab track (possibly with prefabricated elements)
  - reduce of maintenance cost (with use of new technology materials or constructions, as mentioned before, use of informatics for the maintenance management)
  - noise reduction
- Optimal use of the existing infrastructure (speed increase on existing lines)
- Efficient railway traffic management (use of ERTMS)
- Electrification
- Development - application of innovative solutions for circulation among tracks of different gauge, with the minimum possible delay, at a minimum cost and without transshipment
- Efficient infrastructure on cross-borders
- Increase of axle load for lines of high freight transport volume

The railway infrastructure of tomorrow should be:

- **efficient and of high performance**, with
- **reliability, availability, maintainability and safety (RAMS)**
- **to an acceptable price**

and allow

- the highest level of interoperability
- simplicity and safety by crossing the borders

The infrastructure with the properties described is attractive to PPP financing, given that it has a low Life Cycle Cost (LCC).

Aiming at those targets, the Greek Minister of Transport and Telecommunications Mr. Michalis Liapis, initiated an agreement with Turkey, starting in December of 2004 a new railway connection from Thessaloniki to Istanbul (night train with a travel time of 11 hours) and is working towards another similar agreement with Bulgaria for a new railway connection from Thessaloniki to Sofia (with a travel time of 5,5 hours, instead of 7 hours and 36 minutes today).

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