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A High-Speed Passenger Transport Network to Overcome Peripherality

Case Study Portugal

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- Abstract -

This study is focusing on the problem of connecting peripheral areas to the European passenger transport network. Remote areas are suffering from insufficient inter-regional transport services and missing links to Europe's economic core regions. Transport infrastructure development has therefore been identified as one of the key issues to bring forward the European integration. The case of Portugal reveals some interesting aspects in transport policy and transport planning that without any doubt are of general relevance for the whole area of European cohesion.

The European Commission has contributed a corner stone to the transport planning in Europe with the development of guidelines for a common transport policy and the outlines for a trans-European transport networks. Though in the theoretical framework of the common transport policy interconnection of the European regions with intermodal and interoperable transport networks is a key issue, the first step to realisation, the trans-European networks have been massively criticised for a number of inconsistencies and shortcomings. To sum it up, it can be stated that the trans-European transport networks' design does hardly reflect the necessity of the development of intermodality.

This TEN scenario is also true for the high-speed train connection planned in Portugal, which out of many reasons will never be realised. The study proposes an alternative approach through using a less costly technology - the pendular train system- to improve the performance of Portuguese railway services and interconnect this service to aviation with Lisbon Airport as an efficient interface. The performance potential of a pendular train system is demonstrated through a computer simulation a part of the corridor Lisbon-Porto. For this simulation the software programme *Railway Simulator (RWS)*™ running on an Apple™ Macintosh Iiic, is used which originally was designed to build the time schedules for the national Portuguese train network.

- Kurzfassung -

Diese Studie befaßt sich mit der Anbindung peripherer Räume an das europäische Personenverkehrsnetz. Diese Gebiete leiden an einer Unterversorgung mit Verkehrsdienstleistungen sowohl innerhalb der Region, als auch in Verbindung mit den europäischen Kerngebieten. Die Entwicklung der Verkehrsinfrastrukur gilt als einer der Schlüsselfaktoren zum Vorantreiben der Europäischen Integration. Am Modellfall Portugals lassen sich Problembereiche der Verkehrspolitik und -planung aufzeigen, die für das Gesamtverständnis der Probleme der Peripherie in bezug auf die europäischen Kohäsion relevant sind.

Ein Eckpfeiler der Verkehrsplanung in Europa ist de Gemeinsame Europäische Verkehrspolitik und das Konzept der Trans-Europäischen Netze. Obwohl im theoretischen Rahmen der Gemeinsamen Verkehrspolitik die Verbindung der europäischen Regionen mittels intermodaler und interoperabler Verkehrsnetze eine zentrale Stelle einnimmt, wurden die Trans-Europäischen Netze als erster Realisierungsschritt gerade wegen Mängeln und Widersprüchen in diesem Bereich kritisiert. Kurzgefaßt kann festgestellt werden, daß sich im derzeitigen Konzept der Trans-Europäischen Netze der Gedanke der Intermodalität nur begrenzt widerspiegelt.

Dies zeigt sich auch in der Konzeption der Hochgeschwindigkeitsbahnverbindung in und nach Portugal im Rahmen der TEN, die aus vielen Gründen nicht realisiert werden kann. Diese Studie untersucht die Verwendung einer alternativen Bahntechnologie, der Wagenkastenneigezüge ('Pendolino'), um im konkreten Fall die Leistungsfähigkeit der portugiesischen Bahn zu erhöhen, und gleichzeitig eine leistungsfähige Schnittstelle zwischen Luft- und Bahnverkehr am Flughafen Lissabon zu schaffen. Das Potential der Wagekastenneigetechnik wird in einer Computersimulation für einen Ausschnitt des Korridors Lissabon - Porto dargestellt. Für diese Simulation wurde das Softwarepaket *Railway Simulator (RWS)* ™, das auf einem Apple™ Macintosh Iiic läuft, verwendet, und von der portugiesischen Bahn eigentlich zur Fahrplanerstellung eingesetzt wird.

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0. Introduction

In Title XII of the Maastricht Treaty of the European Communities one of the priority policy objectives stated is the improvement of the European transport systems. The realisation of the internal market relies heavily on a functioning network for the physical distribution of goods within the Community, and furthermore the free movement of citizens between the member states has to be supported by passenger transport systems satisfying the needs of the user.

In the past transport policy has focused on the national level, leading to various different transport systems not compatible across national borders. Apart from spatial interconnectivity also the connection of the different transport modes is a focal point on the future agenda. Transforming the patchwork of transport services into a common network is the challenging task Europe's transport policy has to tackle in the near future.

The transport market consists of two parts: The passenger market and the freight market which are both using common infrastructure. They can be further broken down according to the geographic level into the local and regional market serving citizens' demand for mobility in the neighbourhood of their homes (i.e., local accessibility), and the demand for circulation across Europe in long-distance haulage ,i.e., trans-European networks (CEC, 1994b).

This study is focusing on the problem of connecting peripheral areas to the European passenger transport network. Remote areas are suffering from insufficient inter-regional transport services and missing links to Europe's economic core regions. Particular emphasis will be laid on the case of Portugal, because it reveals some interesting aspects in transport policy and transport planning that without any doubt are of general relevance for the whole of Europe:

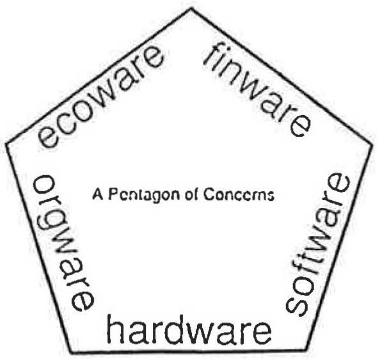
- Portugal is an excellent example to demonstrate the non-existing co-ordination of planning strategies between different transport modes. Though intermodality is a sine non qua in today's transport policy the Portuguese planning practice is ignoring the construction of functional interfaces between the modes. Even between high-speed rail and air transport which are the most appropriate modes to improve Portugal's peripheral situation no co-ordination can be observed.

- Also the European Community's fostering of intermodality, the main political driving force of large-scale transport projects, has difficulties to get beyond the theoretical level and its practical application in passenger transport is neglected. Moreover general conflicts between the framework of the Common Transport Policy and the implementation of projects at the national or regional level are widespread.

- The most promising factor in the transport field is the new concept of high-speed trains which is or was believed to reshape Europe's landscape and transport industry. Not affordable for a peripheral region as Portugal, the high-speed trains seem to have reached its financiability in the core regions of Europe, too. Redesigning the concept on a broad basis will be a necessary step in the future.

The area of transport is a very complex one and the current problems cover a lot of disciplines. This paper is clearly policy oriented and will focus on the organisation and planning of networks during the transition phase, Europe has to go through modifying its current transport systems to an intermodal, interoperable and sustainable network. As in most large-scale planning projects the desirable conditions of an ideal future transport system have been drawn up in numerous publications and maps. The fact that reality is not built by static conditions but dynamic processes is still hardly considered in the theoretical framework. The description of the necessary actions to find interim solutions on the way from the current state to future scenarios usually remains vague. But compromises have to be found, as the realisation of a scenario usually is constrained by available as well as by the indeterminacy of complex systems (Bono, 1967; Grossmann, 1993). According to the Pentagon of Concerns (Nijkamp and Vleugel, 1993), shown in figure 1, this paper will concentrate on hard-, soft-, and orgware issues.

Figure 1. Pentagon of Concerns (Nijkamp and Vleugel, 1993)



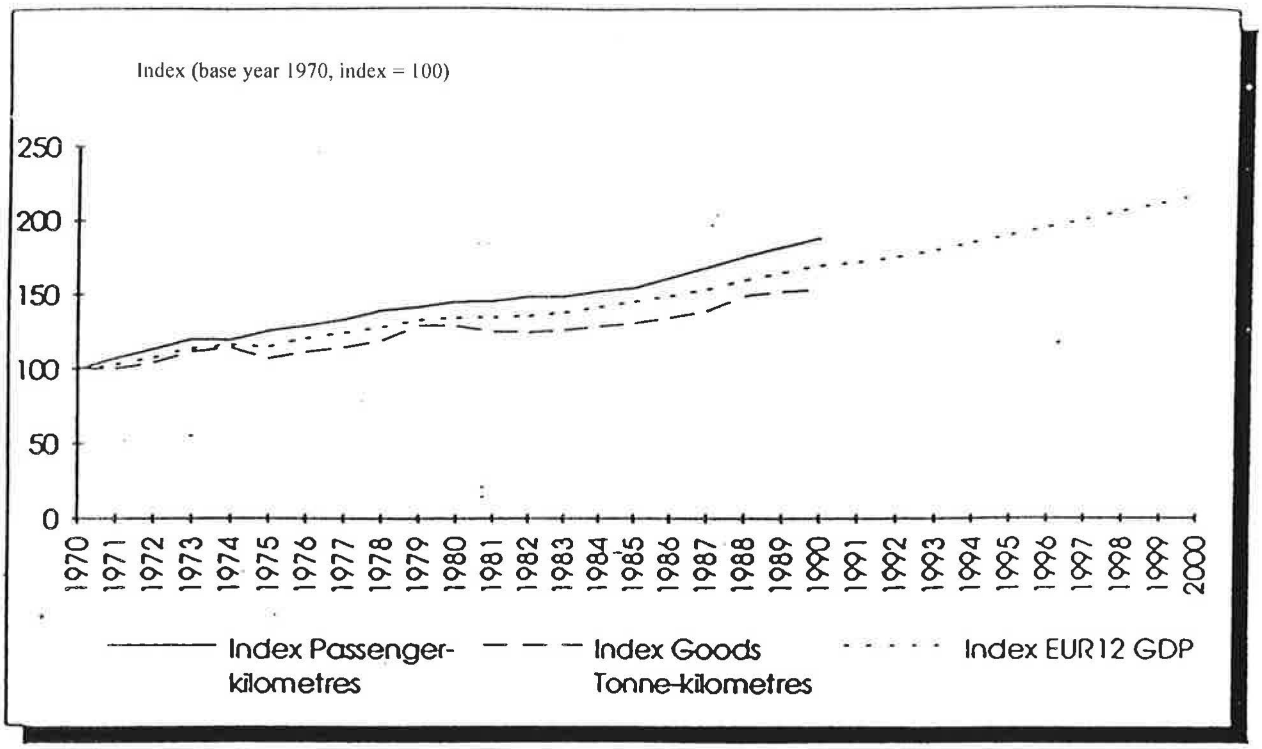
- ***hardware***: refers to the physical technological aspects of transport infrastructure.
- ***software***: refers to information and use of measures that serve to increase efficiency of transport operations.
- ***orgware***: deals with control and organisation of infrastructure.
- ***finware***: is concerned with economic and financing aspects.
- ***ecoware***: refers to environmental conditions to be fulfilled by transport

Planning policy, the identification of corridors in practice, the decision making on construction and realisation of networks is the subject of this paper. Other major areas as the privatisation of capital and services in the transport sector, the realisation of the user-cost principle and the internalisation of the external effects of transport or environmental impacts of transport infrastructure are outside the scope of this study, though all these topics of course are more than relevant to solve the problems the transport sector is facing with today.

1. The Transport Economy: Trends and Tendencies

A human right, pleasure to many people, an economic resource and a servant of economic activities: Transport stands for a lot of things to all people. Logistics and transport have been a back bone of economic development, but the full social, economic and cultural advantages of mobility can only be enjoyed by users and transport service operators if they have access to a quality infrastructure which allows safe, reliable, efficient and environmental friendly transport.

Figure 2. Transport Growth in Europe (CEC, 1994b)



Despite regional variations and different developments in the various transport modes, transport demand has experienced robust and steady growth over several decades, even the successive 'oil shocks' failed to bring a reversal of this trend. In general transport demand, for both goods and passengers, shows a pattern of development parallel to growth in GDP. Since 1970 the average annual economic growth rate in the Community was 2.6%, the growth rates of transport services averaged 2.3% for goods and 3.1% for passengers during the same time period.

Figure 3. Expanding Demand

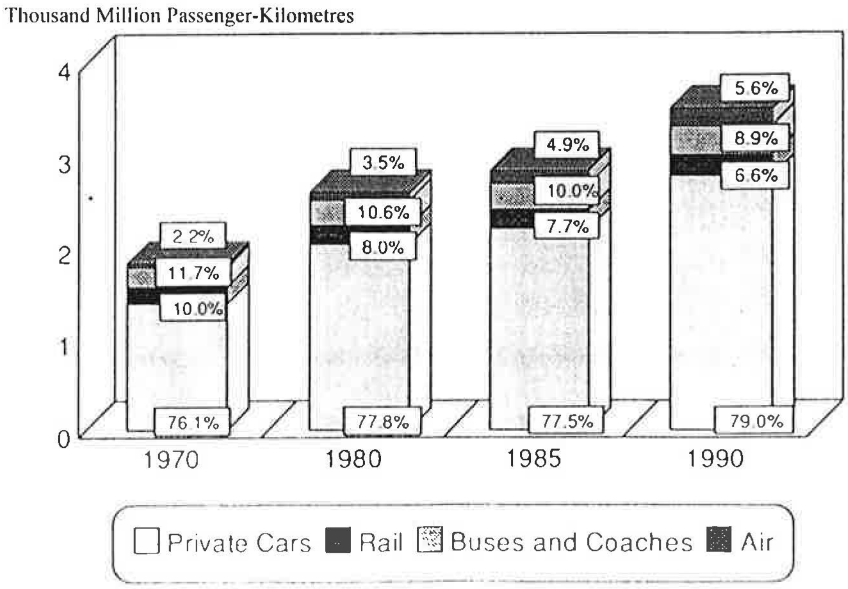
- Shift of production centres and employment from urban agglomerations to more dispersed industrial sites due to changes in the structure of manufacturing industry
- Professional mobility in the service industry over short, medium and long distances
- Holiday and leisure time travelling due to higher incomes (Elasticity of the growth rate of travel to household income is well above 1)

source: CEC, 1994c

While the general tendencies of growing demand are likely to persist, simple extrapolation of past trends not necessarily reflects what is going to happen in the near future. But if the current underlying trends to this growth continue, significant pressure will be put on the Community's transport systems (see figure 3). It is important to note, that transport growth in the Community has not spread evenly between modes. As shown in figure 4 passenger transport activity has increased by more than 85% from 1970 to 1990, most of the increase being attributable to the private car, which has doubled in absolute terms. Though the relative shares of rail and air transport have decreased, the absolute growth of passenger traffic was about 25%, and air passenger transport has the highest growth rate of all modes, as it quadrupled over the period. Air transport is generally expected to grow at rates above the growth rate of GDP, mainly because of increasing commercial links within the Union and changing patterns in holiday travel. Cross-border traffic has been growing by 2-3% a year, since the Internal Market has been established. Transport demand as a whole is forecasted to double by 2010.

As this high level of mobility is seen as a problem by a considerable number of transport experts, reducing traffic volume has become a goal of transport policy, too. Therefore not only forecasting travel demand, but the need for understanding travel behaviour itself has become a prominent research theme (Fischer, 1992).

Figure 4. EC-Passenger Transport in Billion Passenger-Kilometres (source: CEC, 1994b)



While transport demand has grown constantly over the past, investment in transport infrastructure in Europe expressed as a percentage of GDP actually declined until 1980 and then the relative investment share remained at about 1% throughout the decade. In average the importance of investment in all modes in the years 1980 and 1989 shows that road accounted for the main part of all investments (66%, though with a small downward trend). On the other hand rail's share has increased to 23% and aviation benefited most from investments increasing its share from 2.9% to 5.6%. These contradictory trends of increasing demand and declining inland infrastructure investments explain part of today's pressure on transport systems' capacity. One of the consequences is congestion on most of the major European transport corridors. This congestion imposes huge costs on the European economy. Though only rough estimates exist to quantify this loss it is believed that in Britain alone the damage runs to £15 billion a year, or around 2% of GDP. This would imply equivalent figures for Germany of 1.62%, France 0.98%, Italy 2.01%, Spain 1.37% and the Netherlands 1.75% (CEC, 1992; ECMT 1995).

On the one hand inefficiencies, in the form of congestion and negative environmental impacts on society as a whole, are the consequences of a political framework hindering market forces to develop in this sector by not always setting the correct incentives. On the other hand there are crucial missing links between national infrastructure, creating traffic bottlenecks. Often national networks are not at all interoperable. The prime negative example are railways where gauges, power supplies, rolling stock specifications, signalling and safety technology are not compatible throughout Europe. Another example is air traffic control in Europe that uses 22 different technical systems at 42 separate centres.

Regions and Member States at the periphery of the Union often lack quality infrastructure compared to those at the centre. The evident conclusion is that the Union lacks the transport infrastructure necessary to deal with the rising demand for mobility and to fully exploit the opportunities presented by the single market.

1.1 The Common Transport Policy

The Commission's White Paper on "The Future Development of the Common Transport Policy" launched in 1992 was a first step towards defining goals and establishing a work programme to overcome the problems in transport by common effort. It suggested an approach to guarantee both the effective functioning of the Community's transport systems and a general sustainable orientation in mobility. The Maastricht Treaty then marked a new phase for the Common Transport Policy. While maintaining the goal of developing further the Single Market also through improving the quality of its transport services, it underlined the importance of sustainable growth and the protection of the environment.

Efficient, accessible and competitive transport systems are vital to the society and the economy of the Union. They contribute to the well-being and quality of life of its citizens as well as to the prosperity of its businesses. The links provided are essential for the internal cohesion of the Union both in regional and social terms. At the same time transport policy must reconcile the need for mobility with ensuring a high level of safety and environmental protection. Transport efficiency requires that, on the basis of a functioning internal market, the development of trans-European transport networks under the use of the best technology available, citizens and enterprises should have access to means of mobility corresponding as closely as possible to their needs. Clearly user requirements should be one of the main driving forces of a new orientated transport policy (figure 5).

Figure 5: The Seven Pillars of the Common Transport Policy

1. An internal market which works efficiently and facilitates the free movement of goods and people
2. A coherent, integrated transport system using the most appropriate technologies
3. A trans-European transport network that interconnects national networks, makes them interoperable and links the peripheral regions of the Union with the centre
4. Respect for the environment embodied in transport systems which helps resolve major environmental problems
5. Promotion of the highest possible safety standards
6. Social policies to protect and promote the interests of those working in and using transport
7. Developing relations with third countries

source: CEC 1994c

Access to transport facilities should be at a reasonable cost consistent with their long term maintenance and development. At the same time transport services should be safe for the user and they must be provided under conditions that promote the Community's social cohesion and contribute to the protection of the environment. The realisation of all these objectives implies, that as a general rule all transport users should pay the full costs of the service they consume. In particular, internalisation of external costs should be a major element of transport policy.

At least five ambitious tasks confronting the Union can be identified :

- Fill in the many missing trans-border links and connections between national transport systems.
- Create new meeting points between the various transport modes so that the user can choose any combination according to need and convenience.
- Make national infrastructure interoperable by removing those technical and other impediments which impose delays at national borders.
- Enable easy access to the trans-European networks.
- Co-ordination of all the necessary projects.

At the same time, at the implementation level the concept of subsidiarity is explicitly recognised, which requires that decisions should be taken - and as well realised - at the most appropriate level. As to the management and control of Community actions the goal will be a maximum decentralisation compatible with the realisation of the objectives. The European Union has no exclusive powers to plan a trans-European transport infrastructure for its Member States, still less the resources to construct one. Since Member States do their own national transport planning and fix their own financing priorities the Common Transport Policy is meant as a guideline for a European dimension.

1.2. The Trans-European Transport Networks

Obviously some mechanisms are needed to ensure that national plans are coherent with the wider interests of the Union. Based on partnerships between the Commission, the member states and representatives of the transport community (operators, manufacturers, planners, economists, users) a continuous co-operation in planning has been set up.

In order to achieve the goals set out in the Maastricht Treaty in its Article 129b and in the Common Transport Policy, the Community established a series of guidelines covering the objectives, priorities and broad lines of measures envisaged in the field of trans-European networks. These guidelines identify projects of common interest and provide for actions which allow to develop the network concept in the forthcoming decade(s) for all modes of transport and combined transport. The guidelines comprise:

- network schemes for the various transport modes, which illustrate the present status and how the network should develop progressively up to the year 2010.
- Broad lines of measures forming a development process leading to a transport network which is able to respond adequately to the needs of the coming decades.
- Criteria and a procedure for the identification of projects of common interest to implement the envisaged measures.
- The completion of a single trans-European transport market by identifying the way to achieve adequate infrastructures, which promotes efficient and safe transport services under best possible environmental and social conditions.

Figure 6: Trans-European Networks - General Work Content

- *Road*: 58.000 km of roads are deemed to be considered of trans-European nature. Actions foreseen by the Member States include realignment, upgrading and construction of new links mainly in the periphery.
- *Rail*: The European rail network comprises around 70,000 km of lines. 23,000 km of these lines belong to the high-speed rail network, either as new or improved lines for speeds of 200 km/h and more. The other lines are for the use of combined transport services or to give access to regions or ports.
- *Inland waterways* comprise a network of 12,000 km of navigable waterways
- *Combined transport*: Links will consist of corridors and well developed intermodal platforms for efficient transhipment of goods between rail, road and waterborne transport.
- *Maritime transport*: Selected projects to improve the position of ports in the transport chain to foster short sea shipping in the Community.
- *Aviation*: approximately 250 airports have been identified as of Community interest.
- *Traffic management and control systems*: For all modes the improvement of efficiency and safety supported by the latest technology has strategic character.

Source: CEC, 1994d

In a discussion process between the Member States and the Community institutions a master plan has been developed that outlines the corridors of common interest to the Community networks for all the modes. The Commission defines projects of common interest in a rather general way. Any project may be considered as a project of common interest, if it concerns the network indicated in the outlines, shows potential for economic viability and implements at least one of the priorities specified. These priorities take specifically into account the Common Transport Policy (i.e., sustainable mobility, interoperability, intermodality, accessibility, safety, information systems, control and management) and are defined to lead to a complete concept of the network by 1999, which is to be implemented up to 2010 (CEC, 1994d).

In December 1993 the European Council established a group of personal representatives of the Heads of State or Government, the Christophersen Group, named after its chairman the former Commissioner Henning Christophersen, to assist the Commission to move forward the creation of trans-European networks. Lack of synchronisation between national procedures, different priorities and lack of communication between the authorities involved in the planning process has been slowing down the whole working programme. The task of this group was primarily to identify and accelerate projects of priority importance and involves, furthermore, improving conditions for implementation of trans-European networks in the future. Another aspect of the work of the Christophersen Group has been to identify obstacles hampering private-public partnerships in financing infrastructure projects and to propose measures of how to activate private investors. One year later the Essen European Council endorsed the group's recommendations. A list of 11 priority projects was published, where work has already begun or preparation could be accelerated so that work is able to start in about 2 years time and further 13 projects have been considered for more detailed examination (CEC, 1994e). Meanwhile the list of priority projects has been extended to 14 projects across all modes (CEC 1995b).

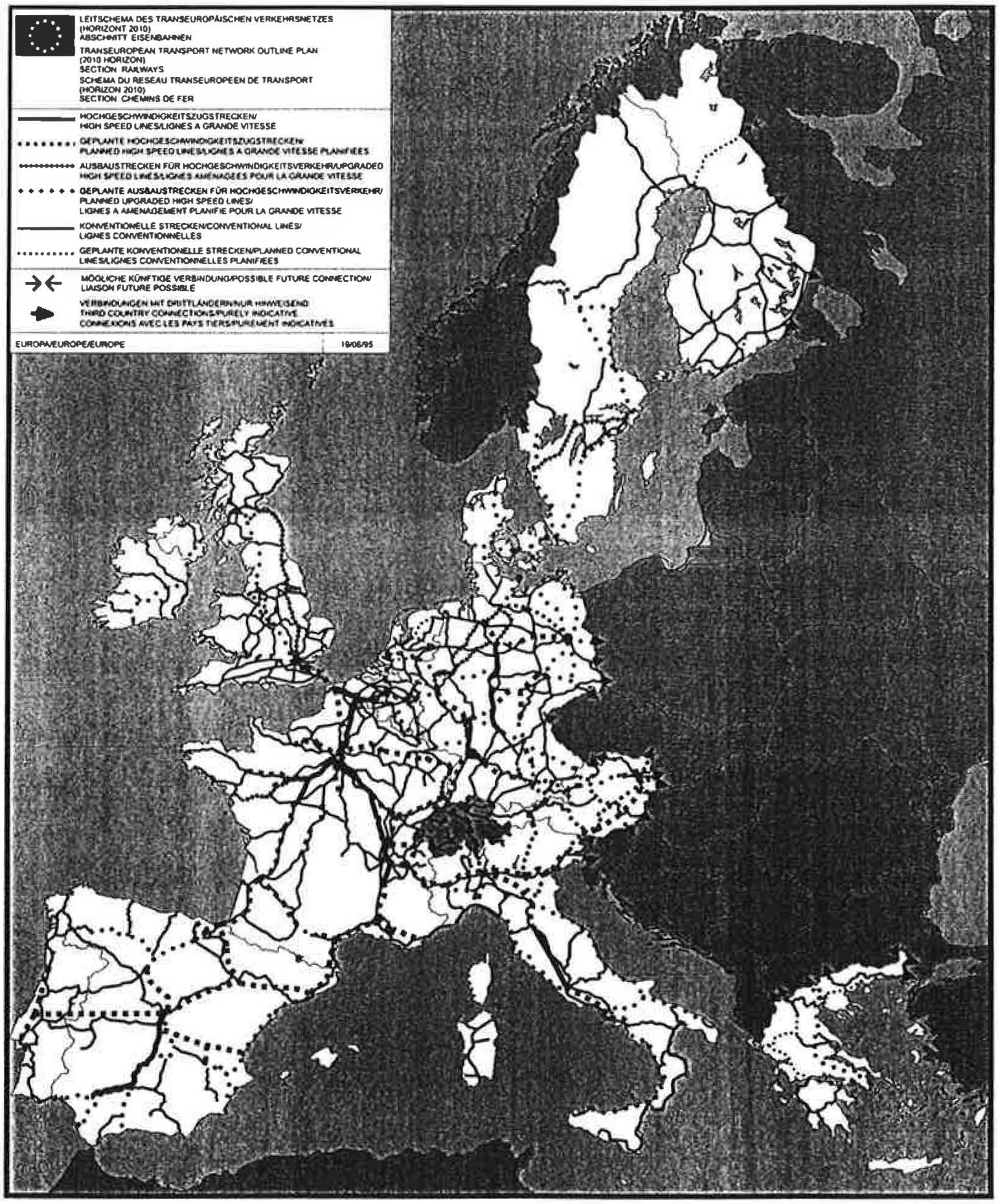
In view of the scope of this study on high-speed modes in passenger transport, a closer description of those networks identified in the TENs will be given in the subsection below.

1.2.1. The Railway Network

Rail services will play an essential part in the multi-modal network for passenger transport. In the future railway companies will be called upon to play a more important part in the transport market according to the EU policy. The railway network therefore has to be adapted to meet present and future needs to allow the companies to operate competitively, especially in those gaps in the market, with rapid, large-capacity transporting of passengers.

The network proposed by the working groups of senior officials on high-speed trains and conventional rail comprises a basic network of approximately 70,000 km of tracks, of which 23.000 km will be used for high-speed passenger services, while the rest are conventional lines mainly used for combined transport and additional lines. The high-speed train network will consist of 10,000 km of newly constructed lines for speeds in excess of 250 km/h and 12,000 km upgraded lines for speeds of about 200 km/h. Furthermore it was specified that the continuity and interoperability by technical harmonisation as well as easy access to urban transport centres, airports, ports, intermodal interchanges and appropriate information systems have to be ensured.

Figure 7: Masterplan of the Trans-European High-Speed Rail Network (CEC, 1994c)



Projects of common interest (figure 8) for this network are those which are sufficiently advanced for immediate action and which enable the network to obtain a European dimension by the year 2000. These projects for the high-speed railway network are shown in figure 8 on the map issued by the Commission, which also shows key links of the network, that deserve special attention within the European framework.

Figure 8: Projects of Common Interest in the Railway Network

1. Brenner axis
2. Paris-Brussels-Cologne-Amsterdam-London (PBCAL) high-speed train lines in Belgium
3. Paris-Brussels-Cologne-Amsterdam-London (PBCAL) high-speed train lines in the Netherlands
4. London-Channel Tunnel high-speed train access (PBCAL)
5. Madrid-Barcelona-Perpignan high-speed train
6. Fehmarn Belt crossways between Denmark and Germany
7. Paris-Strasbourg high-speed train
8. Karlsruhe-Frankfurt/Main-Berlin high-speed train
9. Betuwe line Rotterdam-Cologne-Frankfurt/Main-Karlsruhe-Italy
10. Lyon-Torino high-speed train /combined transport
11. Urban by-pass sections

source: CEC 1994d

In the latest list of priority projects as identified by the Christophersen Group, published in December 1995 - which in fact is a result of presentation of prior findings to the Essen summit in 1994 - The Fehmarn Belt crossways (6) and urban bypass sections (11)are not mentioned any more, while the Øresund fixed link between Denmark and Sweden upgrading of tracks in the UK and Ireland have been added. About more than 80% of the total investment has been earmarked for these new rail links.

1.2.2. The Airport and Air Traffic Management Network

The development of the airport network in the community seeks to safeguard that the airport capacity within the EU is able to meet future demand, taking into account the expected effects of the Third Civil Aviation Package, adopted by the Council of the European Communities in June 1992. Though airport development will contribute to the economic and social cohesion of the community, the Commission states that capacity expansion has to remain compatible with environmental requirements. Particularly it is expressed to take into account the ensuing growth of land-side traffic.

Figure 9: Categories of Trans-European Airports (CEC, 1994d)

Category	Function
Community connecting points	links between the EU and the rest of the world
regional connecting points	links within the Community
accessibility points	access to the core of the network and links to remote areas

The components of the trans-European airport network are airports of common interest, which are defined by the Commission according to their function within the European Union (figure 9).

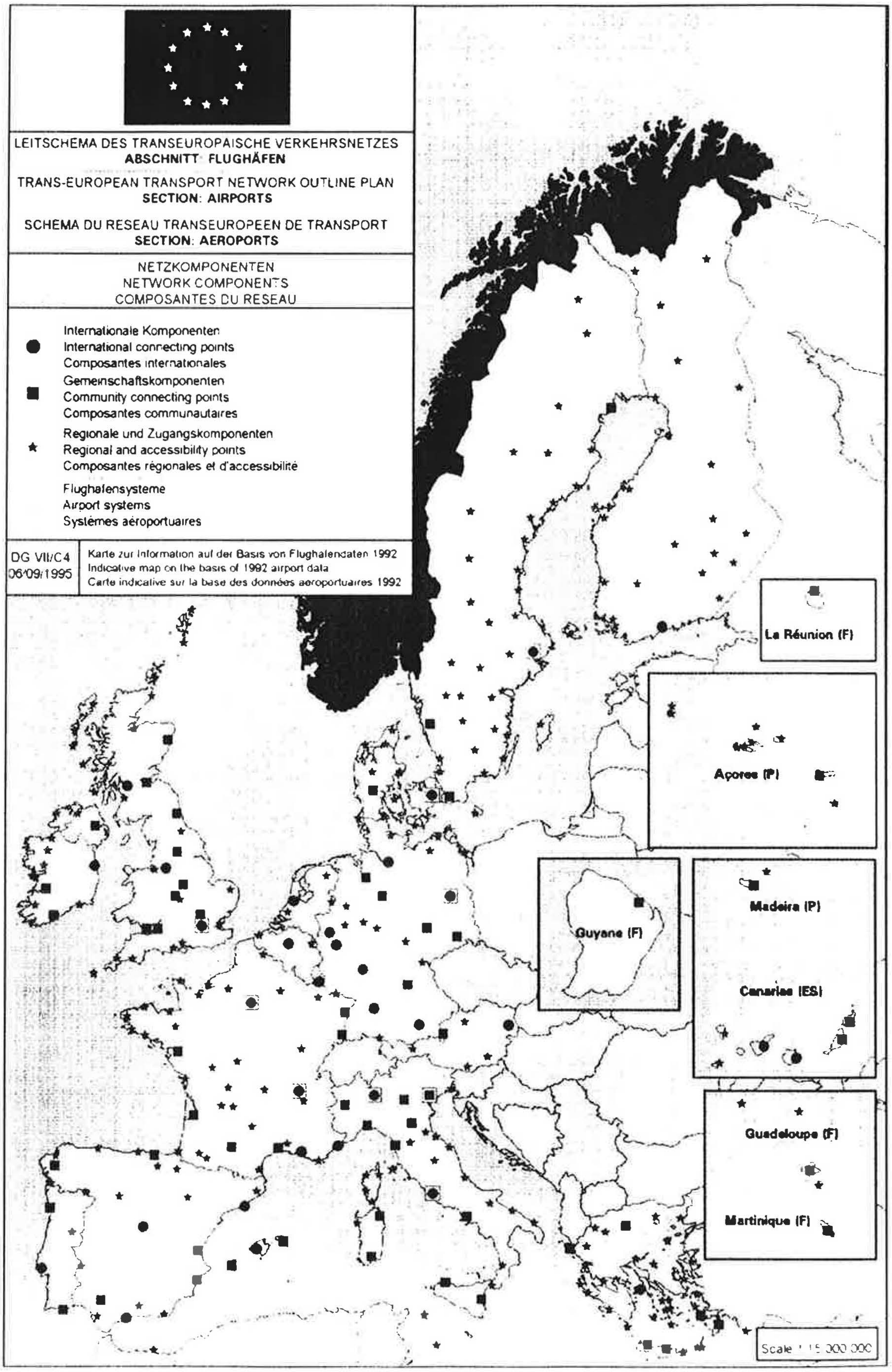
The eligibility criteria for airports of common interest refer to annual commercial aircraft movements and to annual passenger movements (CEC, 1994d). For the exact categorisation of the airports within the Community please refer to the map in figure 11 on the airport network produced by the European Commission.

In order to achieve the objectives under this development framework, the time scale to meet demand is set with 2005, priorities have been identified to contribute to the overall efficiency of the network. The Commission sets one of its priorities as the enhancement of existing airport capacity to meet short-term increase in demand, including improved Air Traffic Control facilities and more efficient approach procedures. A further development of airport capacity will include new and the extension of existing subsystems of airport ground infrastructure, as runways, aprons and terminals to meet medium and long-term demand. At the same time the environmental compatibility of airports shall be improved by reducing disturbances caused by air and ground traffic.

Figure 10: Eligibility Criteria for Airport Projects (CEC, 1994d)

Project Specifications	Type
1. Optimisation of existing airport capacity	
Optimisation of the existing capacity in terms of aircraft, passenger or freight movements, including air navigation equipment depending on the airport	Community connecting point Regional connecting point Accessibility point
Improvement of airport security and safety	Community connecting point Regional connecting point Accessibility point
Adaptation of existing infrastructures made necessary by completion of the internal market and in particular by the measures governing the free movement of persons within the Union	Community connecting point Regional connecting point
2. Development of new airport capacities	
Development of the infrastructure and equipment which determine airport capacity in terms of aircraft, passenger or freight movements, including air navigation equipment depending on the airport	Community connecting point Regional connecting point
Construction of a new airport to replace an existing airport or airport system which cannot be developed further on its existing site	Community connecting point
3. Improvements of protection against nuisance generated by airport activities	
Improvement of environmental compatibility in terms of noise and the treatment of airport effluent	Community connecting point
4. Improvement or development of airport access	
Improvement or development of interfaces between the airport and access infrastructure	Community connecting point Regional connecting point
Improvement and development of interconnections with other transport networks, including the rail network	Community connecting point

Figure 11: The Trans-European Airport Network (CEC, 1995c)



Regarding the air traffic management, already in the late 1980s the sharp deterioration in the punctuality of flights in Europe raised the public awareness of a number of shortcomings in this field. A number of bottlenecks can be identified, but in general they can be summed up as a consequence of the large number of national air management systems, and the lack of co-ordination between the Member States in setting up technical and administrative standards. Within the trans-European networks' framework also projects should be set up to improve the current situation and to help keep pace with booming demand.

In the first phase of the development of the trans-European network no specific projects have been defined yet (CEC, 1994d), but a set of specifications has been drawn up, and all projects will qualify as a project of common interest, if they meet the specifications shown in figure 10. The Christophersen Group then in the same year identified a priority project in air transport. Malpensa airport near Milan is supposed to become a new Community hub in the region of northern Italy.

2. Aspects of Regional Development

The completion of the single market transforms the European regions into a network economy with an open access to, but also a strong competition between the major areas. Some of the regions will gain from this development while others become losers, the regional development issue is going to be a factor of critical importance in Europe. Thus, transport infrastructure is believed to be a major success factor for competitive performance of regional economies, as improving infrastructure leads to higher productivity. Accessibility to the information, labour, capital and consumer market plays an important role in the national and international competition of industries (Nijkamp, 1994). There are several reasons why, on a political level, infrastructure is considered as a useful instrument for regional development. Infrastructure is an investment in the future and not current consumption, and all economic sectors have the opportunity to benefit from this kind of investment (Lian, 1995).

The mostly desired effects (apart from direct effects in construction, operation and maintenance) are long-term indirect changes in income, employment or investment in the private sector which are induced by the new opportunities offered through the improvement of infrastructure. It has to be mentioned that an active strategy, where transport infrastructure should be leading and inducing private investment, often shows insufficient response from the private sector (Rietveld and Nijkamp, 1992). The more common practice is, that infrastructure investments follow private economic development. This is an important fact, as a new connection between two regions will lead to lower transportation costs, and then it depends on which region can use the new situation for its advantage, i.e., exporting goods/services/knowledge to the other region (Pluym and Roosma, 1984).

It can be assumed that the economically more advanced region will increase its production on cost of the less developed region as infrastructure only has a positive impact if the region at hand has already a favourable, existing potential for new development. It was found that an index of sectoral composition of regional economies explains much more of the variance in regional per capita income than infrastructure does (Biehl, 1986). Also the so called typhoon principle supports the view which asserts that when an external force (e.g., the completion of the single market) hits a multi-regional economy, as a consequence richer regions will always be better off and the poorer regions worse off, unless there is public intervention via regional policy (Nijkamp, 1989). Though, of course, it is very difficult to predict the net effects of change in such a complex matter for cross-sector production in the long run.

A study conducted on the distribution effects of regional employment using an ex-ante approach on high-speed railway connections in central Europe, found as a result however that employment relocation induced by high-speed rail would be quite modest (Evers et al., 1987), and another study of the high-speed railway system in France also suggests that, while facilitating development, the overall impact has been small (Bonnafous, 1987).

Summing it up, economic development is , thus, now generally seen as a complex process with transport permitting the exploitation of capital and talents of a region; it is, therefore, necessary but not sufficient for development (Button, 1993).

2.1. Peripheral Regions

It is not the situation on the rim of Europe alone, but also the low density of important economic agglomerations in an area that defines the concept of peripherality. Not so much the geographical position, but the centrality of a city or an urban agglomeration specifies the place it occupies in the international decision and trade network.

The insufficient transport links to the peripheral regions of the Community are one of the major problems. Existing bottlenecks caused by missing links and transport costs on average 5% higher than in central areas are felt to be a serious handicap for companies operating in these regions. Regional cohesion is one of the prime goals of the Maastricht Treaty, as GNP in the central regions of the Community grows two times faster than in the peripheral areas. An even distribution of economic wealth and social welfare also will be influenced by the development of connectivity to transport infrastructure and mobility. For a lot of experts transport is still the ideal measure to create a better cohesion within the Community, others rise serious doubts (see above) whether transport is a good alternative to improve the situation of remote areas (Group transport 2000 plus, 1991).

Also in the opinion of the Commission of the European Communities transport is an important instrument for the cohesion policy of the Community, as it ensures the flows of goods and persons on the links between the regions and the activity centres of Europe (CEC, 1994d). Geographic disadvantages may be exacerbated by insufficient transport resulting in a lack of competitiveness and difficult market contacts of the economies concerned. Therefore, the reduction of disparities and the removal of imbalances in accessibility is expressively stated as a prime goal of the Common Transport Policy (CEC, 1992). A lot of criticism has been risen, that despite of political declarations of intent the European integration in fact is only shifting the problem of strengthening central areas and weakening the periphery from national to a European level, resulting in a quantitative larger dimension and qualitatively new structured reproduction of regional disparities (Hutter, 1995).

The transport problems of the periphery can be considered at different levels:

- The completion of the peripheral country's network of infrastructure,
- Linking up a peripheral country with the centre of Europe.

Peripheral regions can adopt an approach which does not necessarily have to be based on existing national networks, nor does it have to rely exclusively on such networks. Peripheral regions which are afraid of finding themselves in an increasingly less favourable position relatively to the central region can work together either to strengthen links between themselves (through closer economic co-operation) or to ensure that traffic moving towards the centre is moving on the same axis (ECMT, 1995).

2.2. Metropolitan Agglomerations

While high-speed opens up possibilities by considerably reducing transport time, it also introduces the risk of imbalances with respect to more demanding aspects of services: the rationalisation of operations and the need to amortise large-scale infrastructure investment calls for a concentration of flows which is always difficult to reconcile with a finer pattern of services to regions as a whole. In so far high-speed will certainly help to strengthen the position of the European centres. New high-speed rail or airport facilities are often planned in conjunction with new business centres, which attract business activities from less central regions.

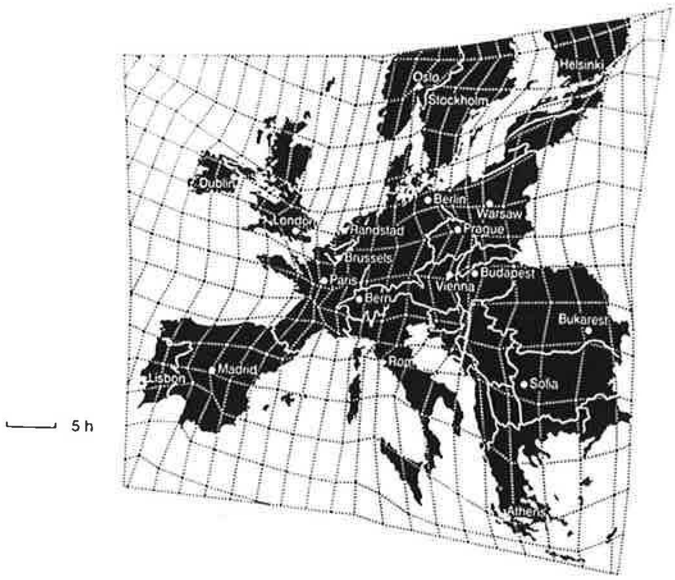
The improvement of high-speed services between major centres can lead to a deterioration in the accessibility of areas located between these centres, thus sacrificing the time saved by speed primarily owing to increased local or regional congestion. Accordingly there is a risk of a dichotomy in the European space whereby nearby areas take a long time to travel to, but transport operations between major centres are carried out in very good conditions (ECMT, 1995). In short the development of high-speed transport services in Europe makes a very limited contribution to the Community's cohesion.

This aspect shows a clear conflict between different European policies, as fostering high-speed transport weakens the relative position of peripheral regions. Though there are critical statements (ECMT, 1995; Fonger, 1994) and these topics are on the agenda for further discussion, there is still little evidence of proposals for practicable solutions.

2.3. The Status-Quo in Portugal

Already a quick glance at a map of Europe reveals the tricky position of Portugal regarding its connection with a supra-national transport network. Being situated at the rim of the Iberian peninsula extremely long distances to the European heartland hamper the exchange of people and goods with Europe's core regions. Apart from the lacking accessibility within the country, Portugal itself is a peripheral region on international level.

Figure 12: Time-Space Map of Rail Connections in 1993 (Spiekermann and Wegener, 1993).



This aspect has recently been visualised in so called time-space maps where the distance between two points in a two-dimensional layer are not by travel time rather than metric distance. This change of scale from spatial to temporal units results in distortions of the map compared to physical maps. In this way reduced travel times by improved transport infrastructure become visible. In figure 12 the travel time on the railway network is mapped, representing the travel time for railways in Europe for 1993 (incorporating all existing high-speed lines). Today's peripheral location in terms of insufficient connections to central Europe is obvious, being improved by the ambitious plans of the high-speed rail network (Spiekermann and Wegener, 1993).

Though the current difficult situation has been recognised by the European Commission the priority areas for infrastructure improvements expressively referred to, are always the even more isolated islands of Greece and Ireland. Portugal is hardly ever specifically mentioned in the Community's policy papers when talking about the transport problems of peripheral areas. This might be a decisive disadvantage, as the Commission's documentation is a prime reference for funding projects, and usually has catalysing effects in speeding up actions. It was not possible to find an explanation for Portugal being neglected in the basic documents on Common Transport Policy concerning the constraints of transport infrastructure in peripheral regions. There seems to be some more need for better aimed lobbying.

Portugal is a small country of 89,000 km² and about 10 million inhabitants. The distribution of the economic activities and the population is concentrated in the coastal areas, with more than one third of the population living in the two urban agglomerations of Porto and Lisbon. These areas have also been the fastest growing areas in Portugal over the last decade. At a lower level important urban areas are Braga, Aveiro, Coimbra, Évora and Faro.

The provision of transport infrastructure is on a very low level, and services generally are not the best performers. The main area of investment has been the construction of motorways so far. Significantly, the only priority project on Portuguese territory selected for funding under the TEN Framework was the motorway Lisbon - Valladolid (CEC, 1994e). The fast and co-ordinated development of other modes in passenger transport, capable of coping with the long distances to the centre of Europe is necessary, if Portugal wants to offer a decent service to support its growing economy. Strategies developed so far have been of rather general quality and mainly remained patchwork (da Silva, 1990).

3. The Development of High-Speed Rail Transport

The first line of a high-speed train, the Shinkansen, was inaugurated in Japan in the year 1964 already. Following this successful example the governments of some European states started initiatives to introduce better performing railway connections on a national basis. The "direttissima between Florence and Rome finished in 1970, made Italy being the first European country with experience in this field, though it has to be annotated, that all the corridor was available to high-speed service by May, 1992 only. In France the TGV connecting Paris with Lyon went into service in 1981. Soon Germany and also Spain followed to provide their first services of high-speed railways.

Already in 1986 the European Community gave a high priority to this new developments in the transport sector and three years later a first proposal for the establishment of a trans-European high-speed railway network was made by the European Commission.

High-speed trains proved the technical viability of wheel-rail systems in commercial service and several speed trials. In fact the term 'high-speed' does not only refer to the maximum speed, generally above 160 km/h up to more than 300 km/h depending on the features of the region, but it is used to describe the new services introduced in rail transport. Other key factors are the ability to handle large volumes of traffic and the improvement in the quality of service, i.e., comfort, safety, new on-board facilities and different marketing. This broad definition means that high-speed is considered a completely new mode of transport geared to the needs of modern European society (CEC, 1990). The step from conventional rail to the high-speed rail system is often compared with the shift from propeller aircraft to jet propulsion in aviation.

One of the prerequisites of a high-speed train service is a specially designed infrastructure, either new purpose-built lines or upgraded existing lines, and a specially designed rolling stock.

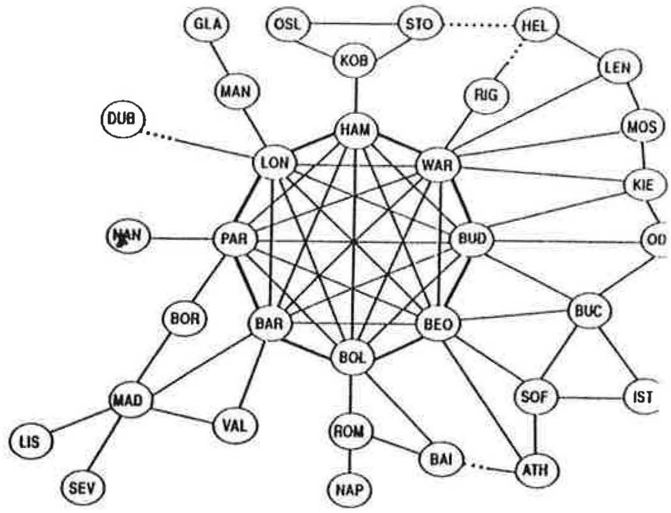
3.1. High-Speed Rail Transport in Europe

The European network (figure 13) is outset to consist of a dense central part, covering the highly populated areas of Europe offering eight gateways to the peripheral regions.

Experience has shown conclusively that the high-speed train can successfully link urban centres between 300 and 500 km (or more) apart.

Figure 13: The European Network (Walrave, 1995)

LIS	Lisbon	GLA	Glasgow
SEV	Seville	MAN	Manchester
MAD	Madrid	OSL	Oslo
VAL	Valencia	KOB	Copenhagen
BOR	Bordeaux	STO	Stockholm
BAR	Barcelona	HEL	Helsinki
NAN	Nantes	RIG	Riga
DUB	Dublin	LEN	Leningrad
PAR	Paris	MOS	Moskva
LON	London	KIE	Kiev
HAM	Hamburg	ODE	Odessa
WAR	Warsaw	BUC	Bucarest
BUD	Budapest	IST	Istanbul
BEO	Belgrad	SOF	Sofia
BOL	Bologna	ATH	Athens
ROM	Rome	BAI	Bari
NAP	Naples		



For passenger services high-speed train is believed to be the way ahead to show a willingness to win back a significant share of the transport market. This might give a halt to the constant decline of rail's market share in a growing market over the last decade. Especially the UIC (Union Internationale de Chemin de Fer) and the CCFE (Community of European Railways) are interested in addressing the various problems arising from the new dimension of rail services.

Financing: Over the last decades a reduction of total investments into the railway sector has been observed in almost all European countries. As the transport volume, both freight and passengers, was growing constantly, it does not surprise that today's infrastructure standards do not come up to the needs of demand any more.

As a consequence today's investments have not only to cover new technology but also the neglect of the last years. Government budgets find themselves in a constraint situation and are not able to bear these investments alone any longer. Due to the fact, private capital has to be attracted, which might be difficult as the returns on investment have a long-term character and in some of the cases do have a high risk profile. In fact; the enormous infrastructure investment costs turn out to be the main impediment to the development of an improved railway network (Smonig, 1996a and b).

If the governments are ready to operate as sponsors of the projects and as an underwriter of some of the risks, namely those related to delays in projects caused by political discussion (e.g. environmental impacts) and economic dangers outside the control of the private companies (e.g. inflation or interest rates), recent planning has proved a more easily appearance of private capital (Viegas, 1993). Besides it has to be borne in mind, that out of the ideas of environmental economy the user-cost principle is due to be introduced also in the transport sector. So far the whole area was heavily subsidised by the government via taxes. This will lead to shifts in the systems financing, that are still hard to estimate.

Technical Components: The historical development of the railways has lead to a co-existence of solutions in infrastructure, power supply, traffic control, train sets and regulation, which makes it difficult to provide fast and efficient international passenger services. The question of compatibility, which is an urgent task after the parallel development of two only partly compatible high-speed train systems in France and Germany, does not only cover tracks and rolling material and traffic control. A convergence of all legal, regulatory and administrative procedures concerning the circulation of high-speed trains, that do not stop at national borders anymore has to be found. Staff training is a further important aspect to be settled, as drivers will not change at the border, they have to be familiar with the different signalling systems of the member states. The probably most important target on a longer term basis (7 up to 11 years) is the definition of a unified European train control and command system (ETCS) that should be adopted on all new trains.

Another rather crucial issue will be the fine-tuning of timetables. As international trains will be more frequent this will create tension with the various inter-city trains, that usually nowadays occupy the preferred time slots.

Marketing: High-speed service asks for a completely new marketing concept. Because of insufficient quality standards, dissatisfying performance of train services and rising incomes of the population, trains were mainly used by those, who could not afford a private car. With the new trend in favour of the train induced by high-speed services, tendencies are towards a "'yuppiesation'" of the train: High quality standards combined with optimal performance. This is also expressed in the price policy followed by railway companies, that is orientated along the prices of air transportation, as this is seen as the main competitor.

3.2. High-Speed Train Services and Regional Development

As mentioned in section 2, the European Commission declared as a major aim to reduce regional disparities within the Union. Whether the construction of a high-speed train network is a measurement to support the economic development in regions lagging back is an issue being discussed throughout Europe. Planning of high-speed lines favours central regions, i.e. agglomerations, and might intensify regional disparities. This point must be considered by all parties involved in Regional Policy, as high-speed railways will be the most unbalanced factor concerning accessibility across European regions.

Figure 14 Employment Created as a Result of the Construction of a High-Speed Railway Network in Europe (High-Level Group, 1995)

	Europe 12, AUT, CH	**Portugal**
Temporary jobs	280,000	7,000
Permanent jobs	711,000	18,000

Figure 14 shows the aggregated results of a study estimating the jobs created in Europe and Portugal by the construction of a high-speed railway network over the period 1990-2010. Of course it is not which regions will be profiting exactly, but it is very likely that it will be urban areas (High-Level Group, 1995).

3.2.1. The Interstitial Regions

One of the major decisions related to high-speed train services is the choice of conurbations to be served. Apart from the routing of the line as such, also the aspect of stopping at intermediate points is of crucial importance as a compromise between accessibility and travel time has to be found. Stopping at intermediate points means extra traffic for the railway company on the one hand, and increase of the travel time on the other hand.

Those areas being passed by the tracks of a high-speed line, but not being served by a station form a special problem in this discussion. As these regions are affected by the negative outputs (environmental impacts) of the high-speed system, it will be hard to convince local communities of the advantages of the installation without appropriate compensation. Money alone for the expropriation of land will not be enough. From a local point of view, high-speed trains are probably the least acceptable transport modes (As aeroplanes do only disturb the vicinity of airports and motorways usually also do offer gains in accessibility).

3.2.2. Feeder Systems

The crucial point is the establishment of appropriate intermediate transport means connecting the interstitial areas to the main network. Usually such transport means are very well developed in urban agglomerations, though in the majority of the cases efficient interfaces between the transport system are missing. In less central areas such feeder systems are poorly developed, if they exist at all. Some promising projects are underway that might lead to a viable solution for less profitable lines. Out of the expressed dissatisfaction of local authorities the French SNCF gave birth to the concept of TER (Transport Express Régional) in 1991. Starting from August 1997 the conventional regional trains in France will be substituted by a new fleet of diesel train sets, that operate on 160 km/h basis to compensate the inability of TGVs to handle intermediate trips. For the future the development of an electrified 200 km/h version is planned, that will partially be able to use the new TGV tracks (Boutonnet, 1995).

Another feeder train concept was engineered by Duewag AG in Germany. The idea elaborated is to use prefabricated and off-the-shelf bus and tram components to assemble a regional train for lines with a low profitability profile. Bus diesel engines conform to emission directive Euro 11 are used as propulsion system. The chassis consists of pre-assembled aluminium sheets filled with structural foam. A reduction in passive safety (light construction) is compensated by higher active safety, such as rapid braking. The life-cycle cost advantage, implying construction and operation costs, is estimated to around 40% in comparison with existing train sets. After only one year of development the first car went into circulation in March 1995 at Dürener Kreisbahn (Jacques, 1995).

3.3. The Present Railway System in Portugal

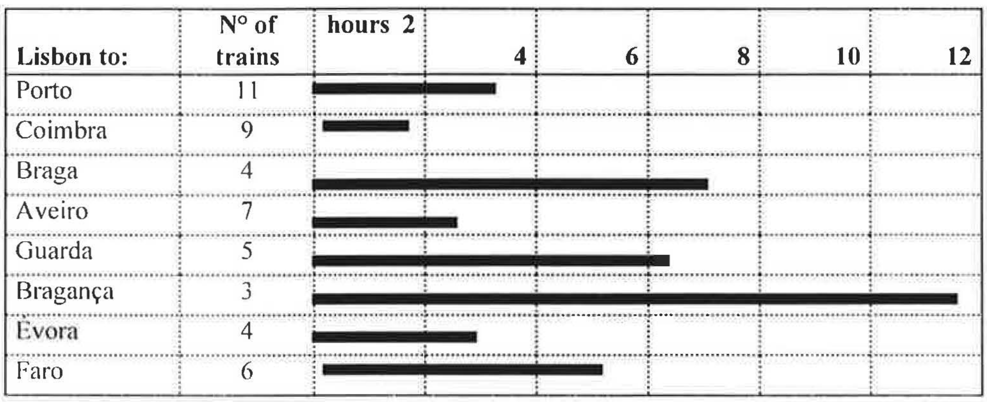
The total length of the current railway network is 3,117 km, of which 420 km are double track or more and 462 km are electrified. Almost 13% of the total lines are narrow track gauge. These basic figures reveal already the huge problems Portugal rail has to cope with. On the main connection between Porto and Lisbon currently regular services of 6 Inter-city trains per day are offered, that cover the track in 3 hrs 35 min. As an innovation there has been introduced the Alfa Club, 5 times per day which mainly introduces new quality standards similar to the aeroplane. Regarding the travel time it does not introduce any improvements, as the journey takes the same time as with the Inter-city. So the average speed on the main line Porto/Lisbon does not exceed 100 km/h. Only two times per day two Alfa train sets are running without any stop between Porto and Lisbon, consequently cutting travel time to exactly 3 hrs. The frequency is not too high. Outside the peak hours in the morning and in the evening there is a train of at least Inter-city standard only every three hours.

Figure 15: Development of Rail Passengers in Portugal (CP, 1992)

(in millions)	Passengers	Passenger-km
1985	**221,5**	**5,725**
1991	**223,6**	**5,688**
Δ%	**+0,9%**	**-0,6%**

The situation on all the other lines connecting the North (Braga, Bragança), the South (Évora, Algarve) and the hinterland is worse. The performance of most trains is poor, on those lines as average speed is less than 70 km/h for passenger transport. Freight trains are significantly slower and due to the vast extent of single track lines one of the major obstacles for passenger trains. The frequency of trains per day is very low, that in the majority of the links between urban centres it is not possible to have a return trip on the same the day for business purposes. Nevertheless passenger transport has remained almost constant over a period of seven years (figure 15). This might be seen as a good sign for the future development of railways in Portugal.

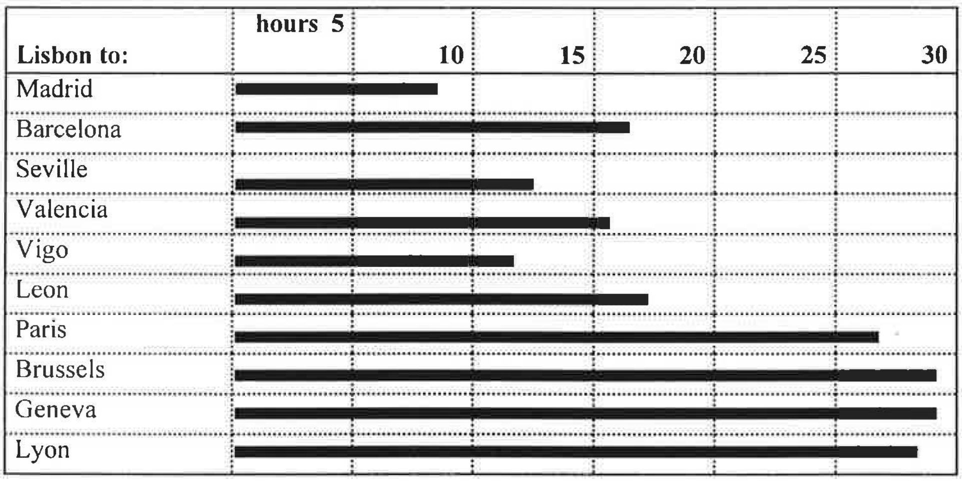
Figure 16: Rail Travel Time to Urban Centres in Portugal in 1993 (Da Silva, 1994)



In figure 16 the journey times from the capital to the most important urban centres in Portugal are given. The enormous travel time to cities not located on the main line are obvious. Only to travel the remaining distance from Porto further North to Braga takes almost as long as the journey between Porto and Lisbon.

The situation for international travel is similar. Here Portugal additionally suffers from the insufficiencies of the Spanish railway system, especially the different track width (1,668 m) Spanish Rail is using in contrast to the European standard (1,435 m). So just to cross the Iberian Peninsula takes more than 15 hours by train. To arrive in the cities of the European core region the travel time is more than 25 hours. Even to reach the closer urban agglomerations in Spain 8 to 15 hours have to be calculated. Moreover delays in time schedules are more than common, and service and comfort are also questionable. Today's only satisfying train service in Portugal is the Alfa connection between Lisbon and Porto.

Figure 17: Rail Travel Time to Urban Centres in Europe in 1993 (Da Silva, 1994)



So the national trips in Portugal have been mainly substituted by car, which even in distances over 200 km still offers advantages or equals railway in travel time, as shown in figure 18. The only positive aspect that can be found in this situation is, that, as an improvement of the public transport in Portugal is inevitable, there is the motivation and the possibility to install the latest technology available in this sector, i.e. preparing the railway infrastructure for a high-speed future. In fact there exist plans and different concepts how Portuguese Rail could get involved into the business of high-speed trains, which will be discussed in the following section.

Figure 18: Isochrones 3 Hours of Travel Time by Car from Lisbon (Viegas, 1993)

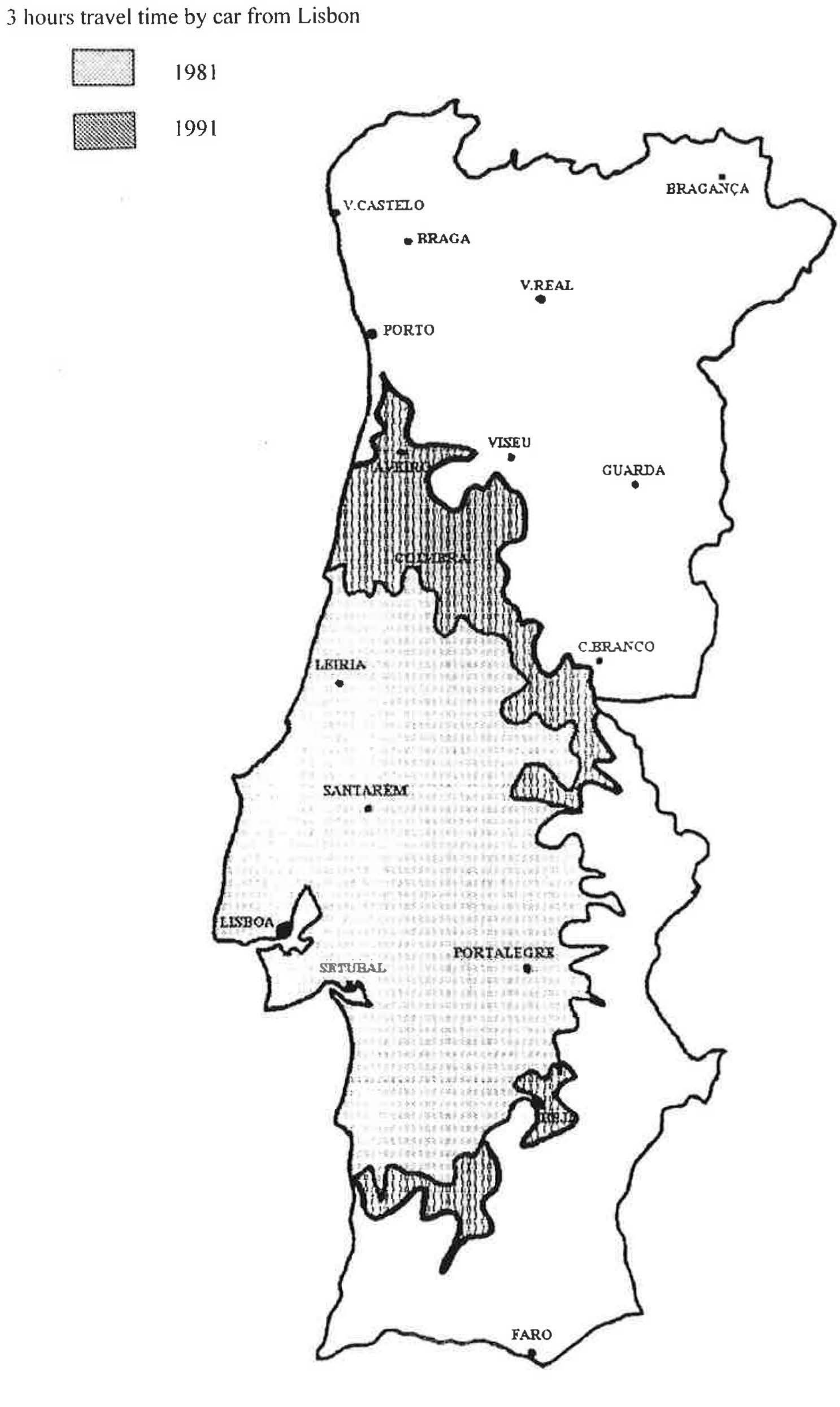
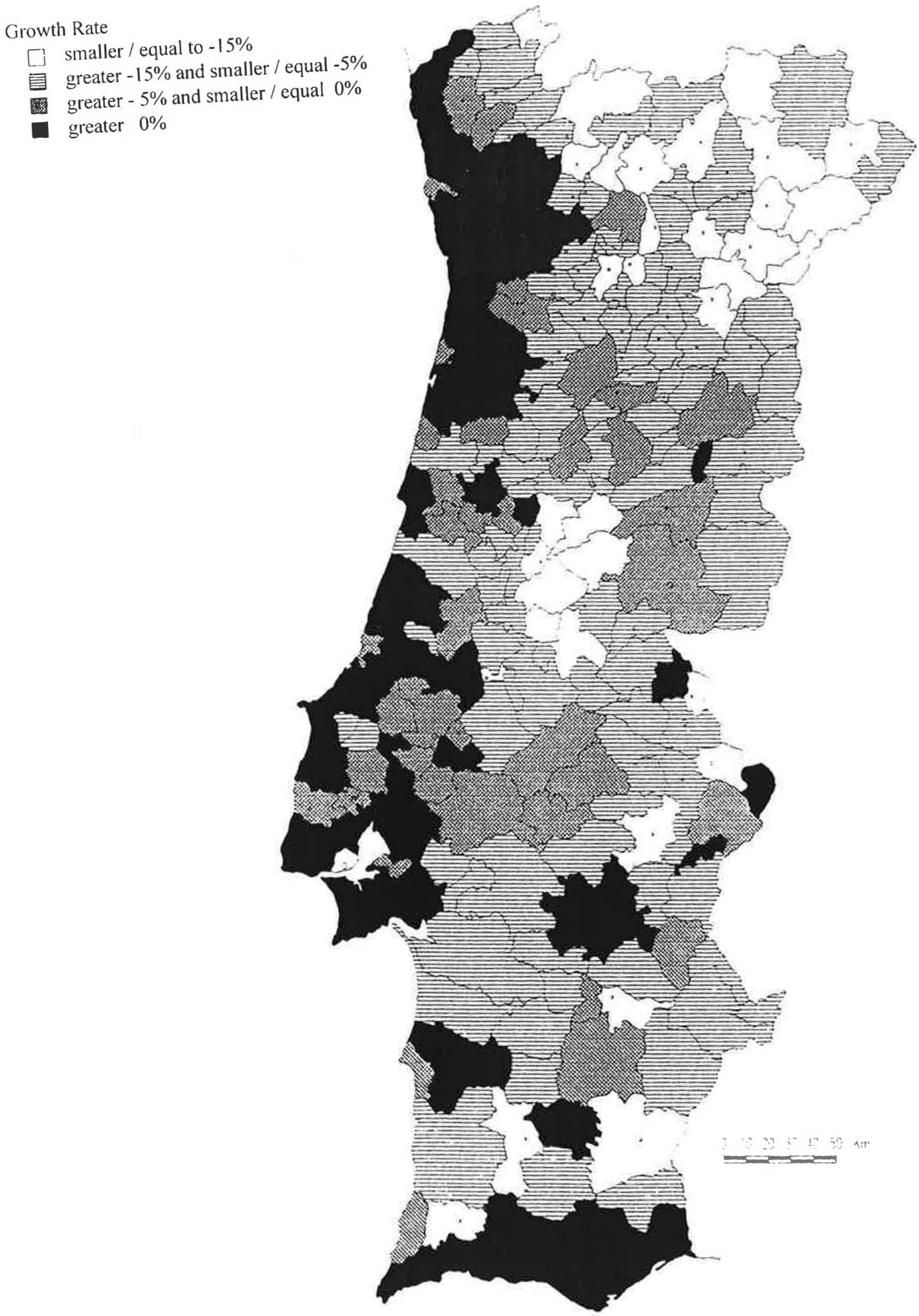


Figure 19: Population Growth in Portugal from 1981/91 (Da Silva, 1994)



3.4. Plans for the Development of a High-Speed Railway Network

The two Portuguese regions that would justify to be connected by high-speed infrastructure are the Area of Greater Lisbon and Porto, where 34% of the Portuguese population lives. The two cities and the coastal area in between is the fastest growing area in Portugal except the two growth poles around Èvora and the Algarve region (Figure 19).

The dependency on the Spanish transport policy is one of the main impediments for Portugal in connecting with the European economic core regions. For Spain, at the moment running the high-speed line between Seville and Madrid only, the connection of Madrid to Barcelona and France is of higher priority, than constructing a new line to Lisbon. And obviously Portugal depends on the investments undertaken on the other side of the border. A market study showing that the demand for trips between Madrid and Lisbon is relatively low, quite in contrast to the demand for trips to Paris for example, will not help to encourage investments either. The corridor between Madrid and Lisbon was identified as one of the first-priority projects by the Commission that should receive financial aid from community funds.

3.4.1. The Mainline Lisbon - Porto

While for Portugal's international gate to Europe via high-speed train various alternatives have been developed, which will be described in the following section, the core line on national territory is always the same: The corridor between the two economic centres Porto and Lisbon is the most important part of the network, and can be completed more rapidly because of national autonomy. The Portuguese government decided to start the planning of a train connection in European standard tracks, that allows a travelling time of 1 hr 30 up to 2 hrs between Porto and Lisbon. For both cities a new terminal infrastructure will be planned (Porto Parkway, Lisbon Central).

A) The Options

Three different alternatives have been set as preconditions to study various route options within the corridor. Option A considers freight services during the day at a speed up to 140 km/h. Each 30 km there will be the possibility for Alfa passenger trains, cruising at a speed of 250 km/h to overtake. In this scenario the Inter Regional trains are running with 200 km/h. Option B does provide a daytime service of Alfa trains at a speed of 300 km/h and Inter Regional trains at 225 km/h. The Inter Regional train will have an 11 minutes stop in Coimbra to allow the next Alfa in the same direction to pass by. Freight trains will be able to use the line during the night only, when one of the tracks is closed due to maintenance. Option C is very similar to option A as the services operated show the same characteristics, only the track will differ in the area of Leiria, as this city will not be served. For all options in addition suburban trains are planned to connect e.g. Vila Franca da Xira to Lisbon in 16 minutes, or Espinho to Porto in 15 minutes only. In figure 20 the main characteristics of the corridors studied for the three options are described.

Figure 20: Alternative High-Speed Rail Corridors between Porto and Lisbon (CP, 1990)

	Option A	Option B	Option C
Travelling speed max. (km/h)	250	300	250
Travelling time (min)*	97	87	97
Track length (km)	304,6	297,1	302,6
Type of traffic	freight & passenger	passenger	freight & passenger
Routing via	Leiria-Coimbra-Aveiro	Leiria-Coimbra-Aveiro	Coimbra-Aveiro
Inclination max. (‰)	12,5	35	12,5
Lines straight (%)	53	57	47
Curves, rad <6.000m (%)	10	10	11
Curves, rad ≥6.000m (%)	37	33	42
Tunnels (%)	9	8	8
Bridges (%)	11	7	13
Land use (ha)	1078	1127	1063
Total costs (billion. esc)^	552	500	552
Costs/km (billion. esc)	1,8	1,7	1,8

* with 1 stop between Lisbon and Porto, ^ in prices of Jan. 92,
% refers to the total length of the line

The most urgent problems to be solved are the crossing of the river Douro and the reduction of the number of tunnels. While the first is an engineering challenge, the second should keep the construction costs low. A major drawback of the project should be revealed right at the beginning. Though various alternatives for tracks have been studied the trains in option B, technical conditions will allow the maximum speed of over 300 km/h in 11 to 15% of the line only. Also the 250 km/h in option A and C will only be reached in approximately 50% of the corridor.

B) The Stops

The route planned, heads from Lisbon via Vila Franca da Xira, Leiria, Pombal, Coimbra B, Aveiro, Espinho to Porto. It is a heavily discussed issue, where the high-speed train should have its stops in this corridor. As the whole corridor has a length of 300 km only and the economic importance of the cities in between Lisbon and Porto actually is too small seen on an international level the alternative of having no stops at all between Lisbon and Porto is discussed. As usual there is a trade-off between travel time and catchment area: The more stops on the line the longer, and less attractive gets the journey for those passengers travelling the whole trip, but the line will be accessible for a larger number of clients living in the cities in between. Local authorities logically all put pressure to be provided with direct access to the new infrastructure.

Figure 21: Travel Time and Stops on the Corridor Porto - Lisbon (CP, 1990)

	Alternatives with stops					
Typology (# of stops)	**1**	**3**	**1**	**3**	7	7
Maximum speed (km/h)	300	300	250	250	225	200
Average Travel time (hrs. min.)	1.27	1.33	1.37	1.48	2.11	2.18

At the moment there are alternatives studied with up to seven stops on the route between Lisbon and Porto. It has been brought forward that from the economic point of view probably non of the cities on the route justifies to be connected to the high-speed railway network, but 1 up to 3 stops are the most plausible solution. Still the problem remains which will be the cities selected to be served by the high-speed train service. In figure 21 the effects of the number of stops on average journey time are described for the different options of maximum travel speed. In the end due to the various interests involved a political decision will (have) to solve this problem.

Another possibility to satisfy local needs is, that successive trains stop in alternative stations, allowing to serve a large number of cities without a tremendous increase in travel time for a specific train. The negative effect of this measure is that there are no constant intervals between successive trains. Because it is impossible then, to create "train families", i.e. trains with the same itinerary, the disadvantage of this solution is larger intervals between the trains due to security requirements, leading to a decrease of capacity on the line for high-speed train sets. The Inter Regional trains, in any case, will stop in all the cities mentioned in the routing above.

C) Market Research, Demand Based

In 1993 8 billion trips have been made on the Lisbon-Porto corridor by passengers using either Alfa or Intercity trains. An extrapolation of passenger data, based on the estimate of Portugal's GNP (growth rate of 4,5% until 2008 and then 2% until 2018) forecast 19 billion rail passengers in 1998, 35 billion in 2008 and reaching 39 billion in 2018 (CP, 1992).

These figures do include the passengers willing to accept a fare 120% above today's prices for the Alfa. The market share in this scenario would be 43% for the train in the year 2018, and it is forecasted, that the train will lose its market leadership only when increasing the fares by 250% of the current Alfa service (CP, 1990). This rather general prospective draws a very optimistic picture, which in fact does not represent the complex nature of consumer behaviour. It also may be doubted that the reaction of the market will be that inelastic. However on the other hand Portugal has, in contrast to most of the Nordic countries, a well established road-pricing system, which firstly makes it easier for the railways to compete with the private car, and secondly allows to calculate relatively exact cost schemes for cars. This will facilitate to attract new clients to change from road to rail. Due to the short distance between Porto and Lisbon the market share of aviation is so small, that it does not come up to a serious competitor.

According to the timetable valid until September 1995, there are 5 Alfa and 6 Inter Regional trains circulating between Lisbon and Porto in one direction per day. This number is projected to increase to 30 Alfa and 25 Inter Regional trains until 2018 according to demand prognosis.

3.4.2. The Connection Madrid - Lisbon

As mentioned before the international character of this project includes some difficulties to be overcome in bilateral negotiations within the Luso-Spanish Technical Commission. The use of European standard tracks for the new high-speed connections all over Europe is a matter of fact. More difficult is to find a route between the two capitals coming up to the need s of both countries.

In the initial stage of planning CP and the Portuguese Ministry of Transport suggested two transversal lines heading from the mainline Porto-Lisbon towards the Spanish border. One in the northern area of Estarreja reaching the border at Almeida, another in the south crossing the river Tejo between Lisbon and Vila Franca da Xira, passing Évora and continuing to the Spanish border at Elvas. During the design of the European Masterplan by the Community the investment prognosis for the two axes lead to abandoning this plan, as two access corridors could financially not be justified.

Alternatively it was searched for one intermediate line with the fundamental character of high-speed service to Madrid only. The first proposal arising was a track from Leiria in direction to Castelo Branco and Plasência. In one of the co-ordinating sessions of the Technical Commission it became evident, that the Spanish government would not be able to discuss the prolongation of the line, as it was by-passing the region of Extremadura and actually Spain could not profit from this corridor. The CP corresponded to the wish of its neighbour country and an alternative line serving the triangle Cáceres - Mérida - Badajoz was selected as the final solution. Two studies were effectuated to give a first survey about specific route options on the Portuguese side.

A) Alternative Solutions: Route Elvas/Badajoz

In this case the crossing of the Tejo is planned in the proximity of Vila Franca da Xira or between Beato and Montijo, both with a newly bridge to be built. The line would pass close to Évora with a station located there. The specifications of the route are given in figure 22, for the geographic location refer to figure 24.

Figure 22: Alternative Solutions: Route Elvas/Badajoz (CP, 1992)

	North	**Évora**	**North-South (Évora)**
Line (km)	183	212	211
Travelling time, Lisbon-border (min)	50	53	59
Costs/km (billion esc)	0,9	1,0	0,9

B) Alternative Solutions: Route Cáceres

Three different tracks with optimal characteristics were identified, where the inclination of always less than the 12 per thousand is considered as favourable (Figure 23, for geographic location refer to figure 25).

Figure 23: Alternative Solutions: Route Cáceres (CP, 1992)

	South	**Medium**	**North**
line (km)	155	149	157
Travelling time, Lisbon-border (min)	43	46	49
costs/km (billion. esc)	1,1	1,0	1,1

Figure 24: Mapped Alternative Solutions: Route Elvas/Badajoz (CP, 1990)

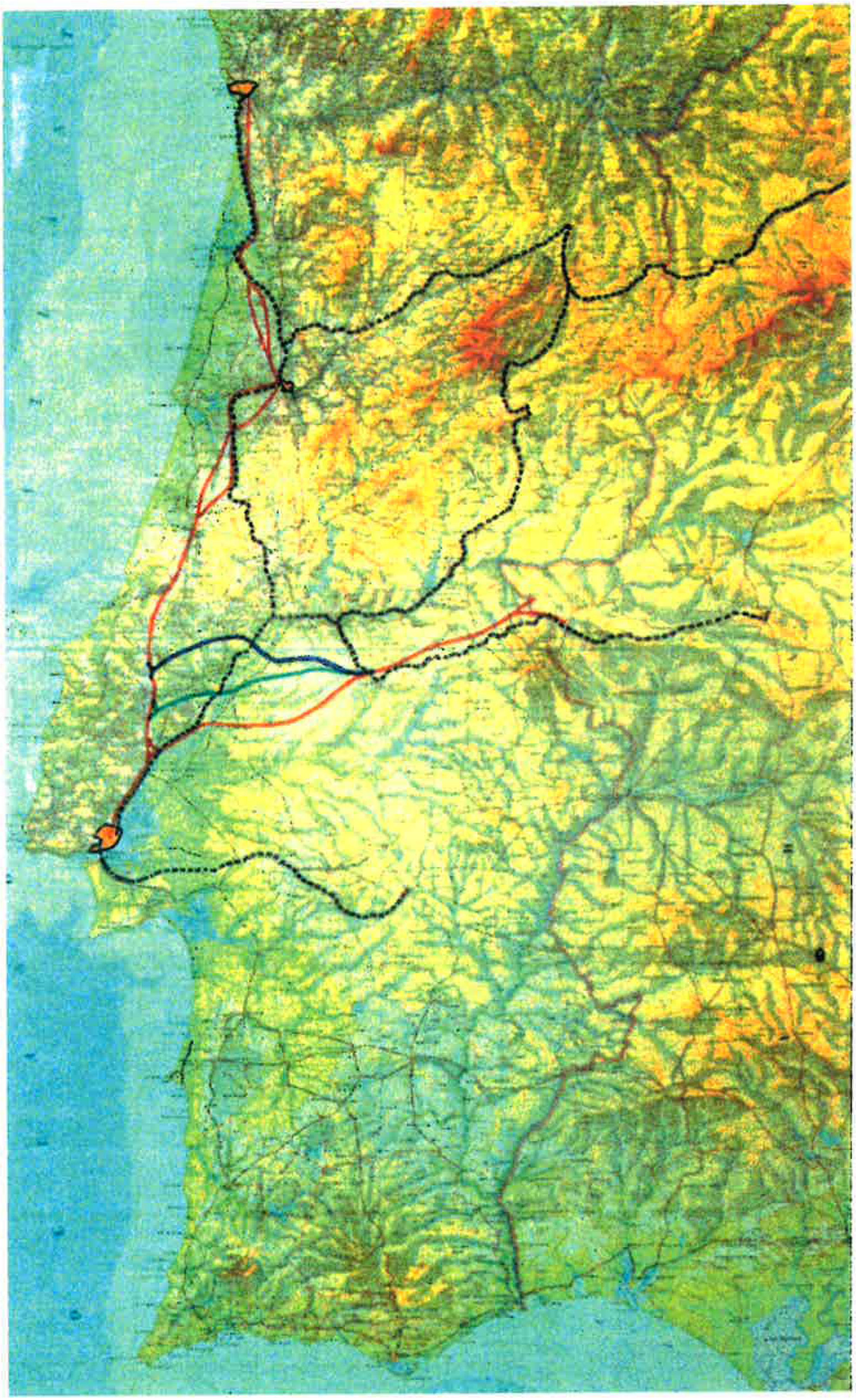


Figure 25: Mapped Alternative Solutions: Route Cáceres (CP, 1992)

So the spatial identification of the new tracks was successfully concluded, but, as mentioned above already, the economic profitability of this connection can be put in question, as the present transport volume between Madrid and Lisbon is rather low , and estimates for new mobility generated by the line itself is difficult. Furthermore the high-speed railway probably will not be able to compete with the aeroplane for destinations in the centre of Europe.

3.4.3. The Realisation

In 1989 the so called France/Atlantic-Spain/Portugal corridor was still one of the priority projects in the outline plan of the European high-speed rail network, as a vital route for the integration of the Basque region, Northeast Spain and Portugal. The route via Èvora, Badajoz and Brazatortas was favoured then. The horizon for starting with implementing the new infrastructure was given with 7½ years in 1992. But a considerable number of problems is hampering progress of this project.

Due to the many problems of Portuguese Rail in all the areas like telematics, signalling, electrification, rolling material and service of conventional rail the ability of investing in new projects is low. Despite guaranteed Community funding CP stopped further activities in the area of high-speed trains, and will concentrate on the improvement of the existing infrastructure due to the lack of financial reserves. Before 2040 it is very unlikely that Portugal will continue with the adoption of high-speed railway technologies like TGV or ICE.

As financial resources are scarce the Commission has given priority to the financing of the Mediterranean link to Spain, consequently the realisation of the Atlantic link had to be postponed. Furthermore Portugal completely depends on the policy of its neighbouring country Spain in connecting its railway network to the rest of Europe. Spain's priority does not lie in connecting up with Portugal, but with France. Additionally the difference between the Spanish gauge and European standard track make Portuguese cross-border initiatives almost impossible.

In the recently published Christophersen Report on trans-European networks the corridor does not appear as a Community priority project anymore (CEC, 1995b). Therefore Portugal is in a very difficult situation, and an aspect that should not be forgotten by the decision makers is that it could be worse being on the waiting list for infrastructure provision, than not being considered at all. Because the regions not selected for the Masterplan of the European High Speed Network are forced to develop other possibilities soon to cope with growing mobility, while places waiting one or more decades for the realisation of a fixed planned solution, might continue lagging back.

Therefore fast action in improving Portugal's transport network is needed. Too many years have been lost already by an indecisive search for solutions to provide an adequate infrastructure.

4. The Air Transportation System

Statistics on the development of air transportation paint a picture of an industry seeing steady growth. Among the world's top 100 ranked airports mere seven airports lost traffic in 1994 compared with twenty-one in 1993, in the top 50 only two recorded decreases. And predictions of the world's forecasters showing inexorable growth in passenger traffic is the situation one should become used to (N.N., 1995).

In contrast to the railway sector, where companies still are running both infrastructure and services - only British Rail has started with the privatisation of operation services - in air transportation there can be found a different structure with two types of actors: The airports, providing the infrastructure and the carriers providing the transport service. This is an important fact because both actors follow different business and planning strategies. Characterising the relationship between those actors it can be said that airlines are the customers of airports.

4.1. Current Air Passenger Transportation in Europe

Two major issues in the current development in aviation can be identified. Congestion on most of the European lines and airports is threatening the performance of air transport, and the adaptation to the deregulation of the European market are the hot topics in near future.

4.1.1. Deregulation of the Air Transport Market

Deregulation is going to open up previously protected markets and to create competition on the basis of price and service. When deregulation is completed in 1997, any EU airline will be able to fly anywhere within the single market. Competition in nearly all service activities, such as ground handling, catering and check-in will be open to independent providers, also non-European players. This means that traditional sources of profit are being eroded, greatly diminishing the ability of an airline to subsidise its flight operations through revenues from other activities. It is not at all clear how this changes will shape the European airline industry, looking to the United States, with its 15-year history of deregulation, provides some clues, but no firm conclusions. Since the 1978 Airline Deregulation Act, consumers in the United States have benefited from real price falls of an average of 20 per cent, and up to 35 per cent on long-haul routes. If European airlines respond to regulatory changes in the same way as their US counterparts - and there is no evidence that they will not - it will lead to growing price and cost pressure (Barton, 1995). Apart from productivity improvements such as splitting off non-core services, reduction of asset intensity and aggressive marketing strategies, a prime issue will be the optimisation of their networks around their hubs.

Not only the airlines are effected by open-sky initiatives, deregulation has also made the airport business more competitive. Airport marketing is coming of age, as most airports are only beginning to discover the benefits of a proper marketing programme aimed at attracting new airlines, new routes and new hub operations. Airports can play an important role in airline route development by helping carriers to find new spokes for their hubs, or high yield point-to-point hub bypass routes. The main principles of airport marketing have been identified as the following (Barron and Whitaker, 1995):

- The airport's customers are the airlines not the passengers, which will only begin to use the airport if the carriers are serving it.
- All the airports are in competition with one another, not only with those 50 to 100 km away. They are competing for any new ordered jet that will be allocated on a certain route across Europe.
- A small or medium-sized airport has to decide whether it can be a hub or whether its role should be as a feeder point into other hubs.
- To an airline market access is more important than facilities.

The issue of an airport's role is a complex one for many medium-sized airports. The correct strategy is a very crucial, aside from hubbing or feeding there is also the option of origin and destination flights between smaller airports, bypassing hubs. In this way a small airport can sometimes steal passengers away from a nearby hub by introducing a spoke to a second hub. An efficient spoke can beat a weak hub. The carriers need airports to help them find connecting niche opportunities, markets with 1,000 to 2,000 passengers a year. A global airline has hundreds of routes it should be studying, but there may only be a handful that it actually looks at in detail. Airports that can concisely and convincingly produce a detailed analysis of the markets they can access will rapidly achieve a high profile with overworked airline planning departments.

Already today a lot of examples among the European airports have proven the feasibility of those concepts, such as Basle, Clermont Ferrand or Manchester, which even use different branding techniques for scheduled and charter market.

Attracting an airline to operate a single service to an airport can be quite a challenge, but getting it to establish a hub requires a marketing effort on a different scale. While the ideal way of establishing a hub is through an airline champion, often the airport has to take the lead, either by attracting the champion in the first place, or by getting the ball rolling on an interline hubbing basis. Most airports have hub potential and they can be grouped according to four categories (Barron and Whitaker, 1995):

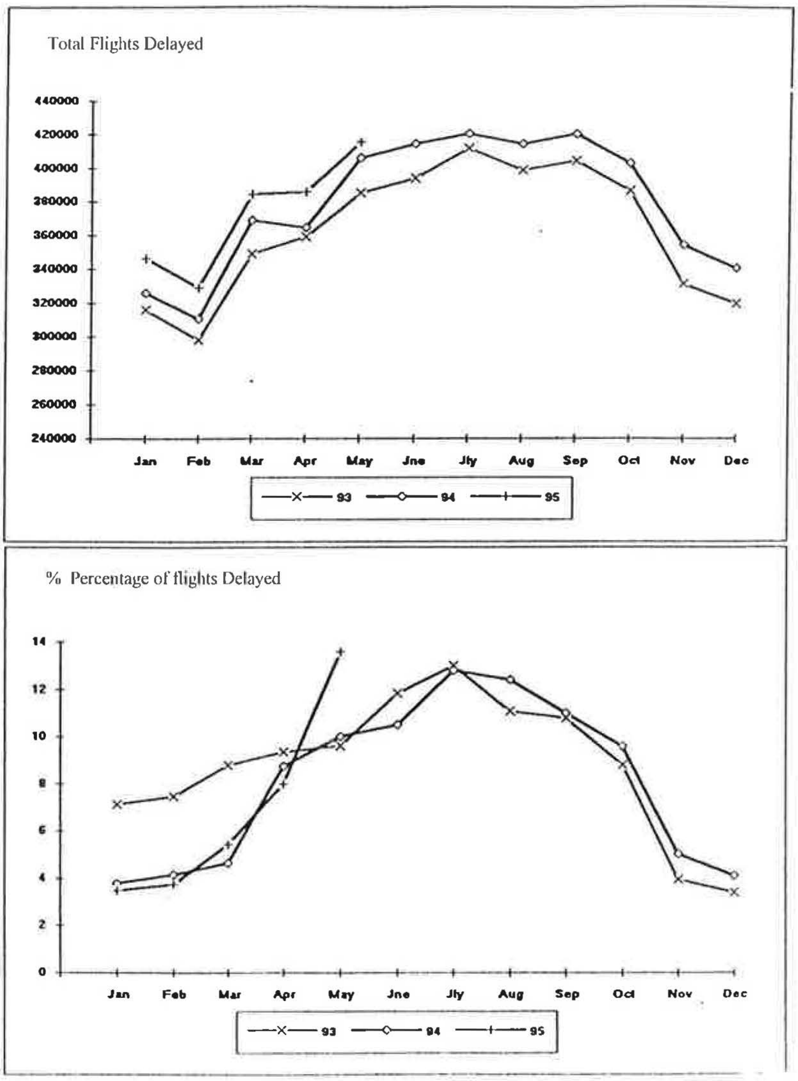
- Major cities that are not hubs already,
- New airports near major cities,
- Airports at secondary cities,
- Niche opportunities for smaller airports.

Every connection in the market attracts passengers - the numbers may be small but they add up.

4.1.2. Congestion of Air Traffic Corridors

Over decades the main emphasis of planning processes in aviation has been concentrated on the capacity of airports and environmentally compatible runways, which were thought to be the only limiting factors to growth. Only in the eighties in Europe was realised that the capacity of air traffic control has major impacts on the development of civil air transportation. In the year 1986 European airlines had to cope with delays of more than fifteen minutes in 12% of total flights, delays being caused by various reasons such as weather and capacity constraints of air traffic control, carriers and airports. By 1988 the percentage of delayed flights had increased to 20% and by 1989 to 25%. The main part of these delays was caused by bottlenecks in the air traffic control system, and annual costs of these delays were estimated of up to 2.5 billion ECU.

Figure 26: Delayed Flights in Europe from 1993-95 by EUROCONTROL (CEC, 1995d)



Due to this rapid decrease of the service level political decision makers have reacted with concerted actions to improve the situation. Under the framework of the European Civil Aviation Conference and EUROCONTROL the European countries started initiatives to introduce common co-ordination, technical standards and regulations in air traffic management. These efforts have led to some promising results as by 1994 the percentage of flights with more than 15 minutes delay could be reduced to the level of 1986. Nevertheless the results achieved did not come up to the expectations because the costs caused by delays are still estimated of lying between 1.2 to 2 billion ECU. Moreover total costs of air traffic control have increased by 50% from 1986 to 1993, and in 1994 5.6% of operational costs on intra-European flights are due to air traffic control (CEC, 1995d). The numbers show that despite of enormous investments, efficiency of air traffic control could not be realised and aviation is hampered by bottlenecks in traffic flow management.

Currently each air traffic control centre is defining the capacity for the routes in its air space based on individual resources, not under the global aspect of traffic volume. Thus, leading to a regular crisis at the Iberian peninsula during the tourist season in summer (see figure 26). In 1995 a first attempt of common preparation was made by all the air traffic management authorities to improve the situation through advanced planning across all airports and corridors.

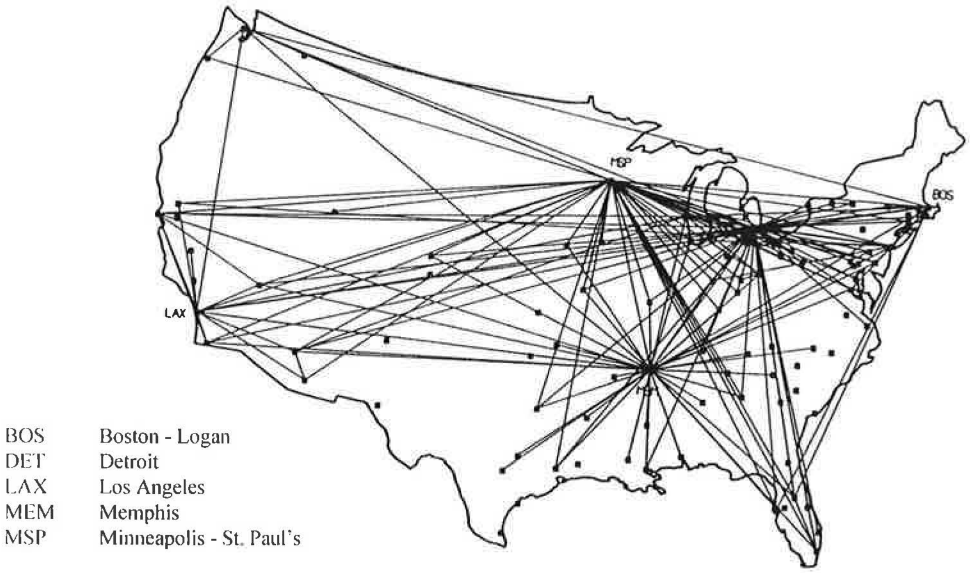
4.2. Air Transportation and Regional Development

Also the spatial structure of air transportation can be described by two functional elements, nodes and lines. The nodes of aviation are the airports, and as aviation is a long distance transport mode it owns relatively few nodes with a strong hierarchy. Not the single airport is of interest, but the whole airport system at a single location, as for instance in Paris or London. The air space is organised in corridors which form the lines of the air transport network. As the corridors do not require any physical infrastructure air transportation has impacts on selective places only. These impacts can be represented by isochron lines representing any kind of factor such as the catchment area or environmental factors.

Air transportation is mainly concentrated in the central urban areas, where the largest airport systems are concentrated (London, Paris, Frankfurt, Amsterdam). The busiest corridors can be found between those centres, with the northern Atlantic route being the most important corridor world-wide. In the peripheral regions only airports in the more important holiday regions reach the traffic volumes of the central regions, due to the high number of non-scheduled flights during the peak season. For Europe Palma de Mallorca would be such an example with more than 14 million passengers in 1994. Most of the routes are connecting the peripheral area to a centre, connections between peripheral areas are usually missing.

Traditionally the nodes of the airport network were bound to large urban agglomerations offering direct connections to other centres. During the deregulation of the market the building of large networks on a hub-and-spokes basis took place when US carriers restructured their routes that flight operations could be more efficient and cost-effective (figure 27). In a hub-and-spoke network, hubs serve as a central node which collect and distribute passengers between a set of locations connected to hubs. The major advantage of a hub network is its savings in the number of direct flights necessary to connect all nodes to the network. To provide direct connection between n places in a network it requires $n(n-1)/2$ linkages. The number of linkages required to connect these n places can be reduced to $n-1$ if a hub is established (Shaw, 1993). A hub network structure allows to achieve economies of scale, as large passenger volumes funnelled through hubs allow carriers to fly larger, hence more economical aircraft to offer more frequent flights and to gain higher load factors. Such hubs then also developed at smaller airports, with a high potential for expansion. The geographic location was of minor importance as these hubs almost exclusively used as interchanges for connecting flights. The hub-and-spokes structure is essentially a supplier-led strategy, its purpose being the maximisation of on-line connections available to the airline. This type of networks has been an outcome of the deregulation process in the US. As Europe hesitantly follows the way of US air transportation economy (only the UK applies a strict deregulation strategy) hubs-and spokes structures did not emerge in such a distinctive form in Europe, yet.

Figure 27: Example for a Hub-and-Spokes Network, Northwest Airlines (Shaw, 1993)



Generally airports are poles for economic growth, not only providing dynamics through the activities directly related to the air traffic but also by attracting businesses to nearby sites. This can clearly be observed at airports located considerably off the urban agglomeration they are serving. It is estimated that an airport creates one job per 1,000 annual passengers.

4.3. The Airport System in Portugal

Portugal has three major continental airports Lisbon Airport, Faro Airport and Sá Carneiro Airport in Porto, which are organised in the public company of ANA - Aeroportos e Navegação Aerea (Airports and Aviation), owned by the Portuguese government by 100%, together with the airfields on the islands of Madeira and the Azores. The busiest airport, Lisbon, does not appear in the world's top-one hundred airports with an annual passenger movement of slightly over 6 mill. passengers in 1995. The second busiest national airport is Faro in the Algarve region with 3,6 mill. passengers followed by Porto with 1,8 mill.

passengers in 1995. All three airports have shown robust growth in passenger volume over the past 15 years (see figure 28). Porto and Lisbon show a similar pattern in their most important destinations which are, with variations in the ranking in time, London, Paris, Funchal, Madrid, Frankfurt, Amsterdam, Brussels and connections between the two cities. Direct intercontinental connections are of relatively minor importance, and only offered to destinations in the former Portuguese colonies and North America. The airport in Faro has a different structure, typical for an airport serving a holiday region. It is one of the major destinations of the intra-European inclusive tours or 'package' model, serving Mediterranean resorts, or such as in this case the Algarve. More than 80% of the total passengers in 1995 have arrived with international charter flights, of which more than half had there origin in the UK.

Figure 28: Total Annual Passengers (ANA, 1996)

	1995	1990	1985	1980
Lisbon	6.010,160	4.976,194	3.203,689	2.799,788
Porto	1.834,634	1.199,095	534,153	404,795
Faro	3.652,758	2.628,870	1.678,406	923,757

Looking into the figures for origin-destination pairs it becomes obvious that the connections to the central regions of Europe are by far more important than flights to Spanish cities. For Lisbon traffic volumes to Paris or London are generally twice as large as to Madrid, for Porto they are three to ten times larger. Passengers going to Barcelona are generally half of those to Madrid. Also air traffic between the two Portuguese cities is approximately as large as to Madrid. The statistics to Faro do not show any aircraft movements with Spanish destinations at all for passenger transport (figure 29).

Figure 29: Percentage of total passengers for selected Origin/Destination Pairs of the Portuguese Airports in 1995(ANA, 1995)

	London	Paris	Brussels	Amsterdam	Frankfurt	Madrid	Lisbon	Porto	Faro
Lisbon	9.9%	10.7%	3.6%	3.1%	4.2%	5.8%	-	5.2%	2.3%
Porto	8.2%	24.1%	4.8%	3.8%	6.3%	3.0%	15.6%	-	-
Faro	22.5%	1.5%	2.0%	7.4%	4.6%	-	4.0%	-	-

Also regarding the structure of air transport passengers both Porto and Lisbon follow the same pattern. Of total passengers an average of 20% is domestic, from the remaining international passengers 70% use scheduled flights 10% charter flights. The seasonal peak in the month from June to September is considerable, as compared with the winter months from December to February there are 40% more passengers. The passenger statistics of the airport of Faro draw a more extreme picture. The percentage of domestic passengers varies between 2-10%, about 10% are international scheduled passengers, while the remaining amount are passengers from non-scheduled flights. As Faro is the typical airport of a holidays region, in summertime there are nine times more passengers arriving by charter flights, than in January or February (figure 30).

Figure 30: Scheduled and Non Scheduled International Passengers at Portuguese Airports in Selected Months in 1995 (ANA, 1995)

		December	January	February	July	August	September
Lisbon	**scheduled**	297,335	282,053	246,483	428,701	452,519	431,705
	non-scheduled	22,285	17,258	9,701	73,731	96,974	68,344
Porto	**scheduled**	99,652	95,210	73,471	136,540	141,754	128,700
	non-scheduled	29,707	24,107	2,428	52,038	71,504	38,657
Faro	**scheduled**	15,086	19,566	22,908	42,390	40,978	40,961
	non-scheduled	68,072	57,236	79,124	446,752	444,174	413,244

Apart from the relatively low number of total annual passengers, the passenger structure also gives evidence that Portuguese airports are not important hubs in the air transportation network for transiting passengers but mainly a origin/destination port (figure 31). As the airports are the main base for the Portuguese flag carrier TAP, which is not a strong player in the business either but has a quasi-monopoly on slots and services the performance of the airport is closely tied to the market performance of its home carrier.

Figure 31: Annual Transiting Passengers at Portuguese Airports in 1995 (ANA, 1995)

	Lisbon	Faro	Porto
Transiting Passengers	233,157	178,982	195,931
Total Passengers	6.010,160	3.652,758	1.834,634

In general it can be observed that all the three airports have reached their capacity limits in transport volume in the peak season already. Though capacity constraints at an airport can be of different nature such as limited runway capacity, terminal capacity or ground handling, the main impediments for the Portuguese airports is runway capacity. The only solution to this bottleneck means the construction of additional runways or moving the whole airport to a new site. In fact it has become clear that nowadays the expansion of an airport in such a way has become politically impossible. Only very few examples, such as Malpensa airport, can be found outside the developing countries (Graham, 1995).

Consequently the current reconstruction of the Lisbon airport, the so called 'Plan ALS 2000' shaping the airport for the world exhibition in 1998 focuses on organisational and non-expansive construction aspects. A new pier with six gates, a new loading bridge and new arrival and check-in area will push the capacity to 12 million passengers a year. This on-site development is realised despite the problematic location of the airport in the middle of residential neighbourhoods in a distance of 5 km only from the city centre.

This unfavourable location naturally causes large negative environmental impacts as a high number of people is exposed to noise emission and air pollution. For years now there has been a project around to move the airport from almost the middle of the city to a new site outside the urban area. So far there is no specific information available on the planning in progress for the New Airport of Lisbon project, but that there are three different sites, Rio Frio, Ota and Montijo studied. Though, according to the airport authorities a political decision on the final location has to be taken, when the traffic volume at the current airport exceeds 7 million passengers a year (ANA, 1996). The strategic plan behind the ongoing development remains unclear, as the question of how to justify such an enormous investment into the current airport if it should be relocated in approximately twenty years time anyhow. Presumably the relocation of the airport, if it ever takes place, will be shifted some more decades back. As the various airports are facing stringent capacity problems the integration of the air transportation network and a modernised railway network to a multi-modal network should be considered as a possible solution. An efficient railway link between the airports could be used as a mechanism for distributing passengers in peak times.

5. Towards a Multi-Modal Network Solution

Transport activities across all modes, using different technologies, in different regions and under a number of regulatory regimes and institutional configurations can be described with the help of networks, which are sets of nodes connected by links. Linking networks together offers synergy effects in various different ways: interoperability, interconnectivity and intermodality. Interconnectivity refers to the linking of networks of different geographical areas, interoperability is in particular concerned with operational and technical uniformity, while intermodality addresses sequential use of different transport modes in a transport chain. All these aspects underline the important role of interfaces between different networks and their layers. Since there is no single network in transport which can serve all needs, a complicated system of partly overlapping, partly complementary network components can be observed. Deregulation and privatisation connected with the declining domain of the public sector have contributed to the growing popularity of network concepts, as they incorporate the flexibility to mirror the market pull of demand conditions (Fischer and Nijkamp, 1993).

Since the beginning of this century transport service and infrastructure supply has mainly been a public government responsibility where planning processes were hardly driven by commercial attitudes. Now many of these institutions try to implement and plan market orientation in network systems. But the lack of a systems' approach for identifying long-term needs and alternative solutions is still a serious deficit in most of today's planning strategies. Decision-making processes can last to some 10 to 12 years already. Plus a construction time of about 20 years are likely to pass from the initial start until the realisation of large infrastructure projects (Nijkamp and Vleugel, 1993). Conventional planning is oriented to find the final solution to an existing or predicted problem and does offer only little freedom to react to changes in the needs during the planning period. Modern planning strategies should be process oriented, i.e. there do not exist final solutions but the permanent development is determining the planning steps. Feed-back and response models need to be integrated into the planning process to offer fast reaction or even proactive planning corresponding to the developing needs. A set of alternatives provided, that does not only include the probable but also all the possible paths, will assure high flexibility and reduce risks after occurrences that have not been considered in the priority scenario (Bono, 1967).

5.1. Network Planning Practice in Europe and Portugal

The European Commission has contributed a corner stone to the transport planning in Europe with the development of guidelines for a common transport policy and the outlines for a trans-European transport networks. Though in the theoretical framework of the common transport policy interconnection of the European region with intermodal and interoperable transport networks is a key issue, the first step to realisation, the trans-European networks have been massively criticised for a number of inconsistencies and shortcomings.

- The selection process of the corridors, and then also of the priority projects was mainly politically motivated and not based on sound analysis, as the selection criteria are of very general nature. The priority projects are all national projects, that would have been built anyway.

- The European dimension of the trans-European networks remains unclear, as also some corridors of only regional importance have been added to the masterplans.

- Some member states have detailed infrastructure development plans beyond the year 2010. There is no evidence whether or how these national measurements are considered.

- Despite having identified intermodality as a key issue, the proposed networks do not reveal through which instruments a stronger connection of the modes will be reached. The published masterplans are only mode based and there is no evidence in passenger transport how and where the networks of the modes will be connected. The only explicit result is a masterplan for combined freight transport, which also refers to the modes separately only.

- The classification of airports in the trans-European networks is the decision criteria for access to instruments of community funding. As the actors in air transportation are participating in a free market, this classification is heavily criticised by airports themselves to foster unfair competition.

To sum it up, it can be stated that the trans-European transport networks' design does not reflect the necessity of the development of intermodality.

The same situation can be found at the national level in Portugal. None of the studies conducted by Portuguese Rail on the improvement of the national railway system even mentions the development of interfaces with air transport. Under the 'Plan ALS 2000' currently underway at Lisbon airport there will be neither a connection to Santa Apolónia train station nor to the future Orient station at the EXPO'98 area. The only transfer possibility between rail and air at Lisbon is the car, taxi or bus. A connection to the underground system is foreseen for the airport in 2003 and for Santa Apolónia even later. From the three locations under discussion for the New Airport Lisbon only one, Ota offers the possibility of linking up with the railway network (ANA, 1996).

Among European airports with a traffic volume higher than 5 million passengers a year only five do not have a urban rail link, and most airports undertake efforts to connect with the inter-city rail services (Rowe, 1995; Pullman, 1995; COST 318, 1995). There is no reason why Portugal should not follow this trend, as it would help to overcome some of the main barriers of connecting to the European transport networks.

5.2. Rail/Air Complementarity

The following section lists some of the prime impediments for the connection of the Portuguese to the European transport network and the same time explain how an improved rail/air complementarity can help to overcome those barriers:

- **Spanish rail infrastructure and priorities**: The rather simple technical aspect of the Spanish gauge being different from the European standard gauge is one of the main barriers as it simply cuts Portugal off the European rail network. As the Spanish development priorities are directed towards France and not Portugal it will take some more decades until fully operable rail connections will be established. In an intermodal network the corridors to central Europe could be covered by aeroplane.

- **Finance**: Portugal depends on the investments funds of the European Union, but these sources are also scarce. No rail or air project has been selected to the priority list, yet. A shift from high-speed rail to the less ambitious pendular technology integrated into an intermodal network could lead to an easier release of funds for the Porto-Lisbon line. At the next revision of the trans-European network masterplan (every five years) probably some more cross-border rail connections could be added to the masterplan, as only those projects mentioned in the masterplan are applicable for money from the cohesion fund.

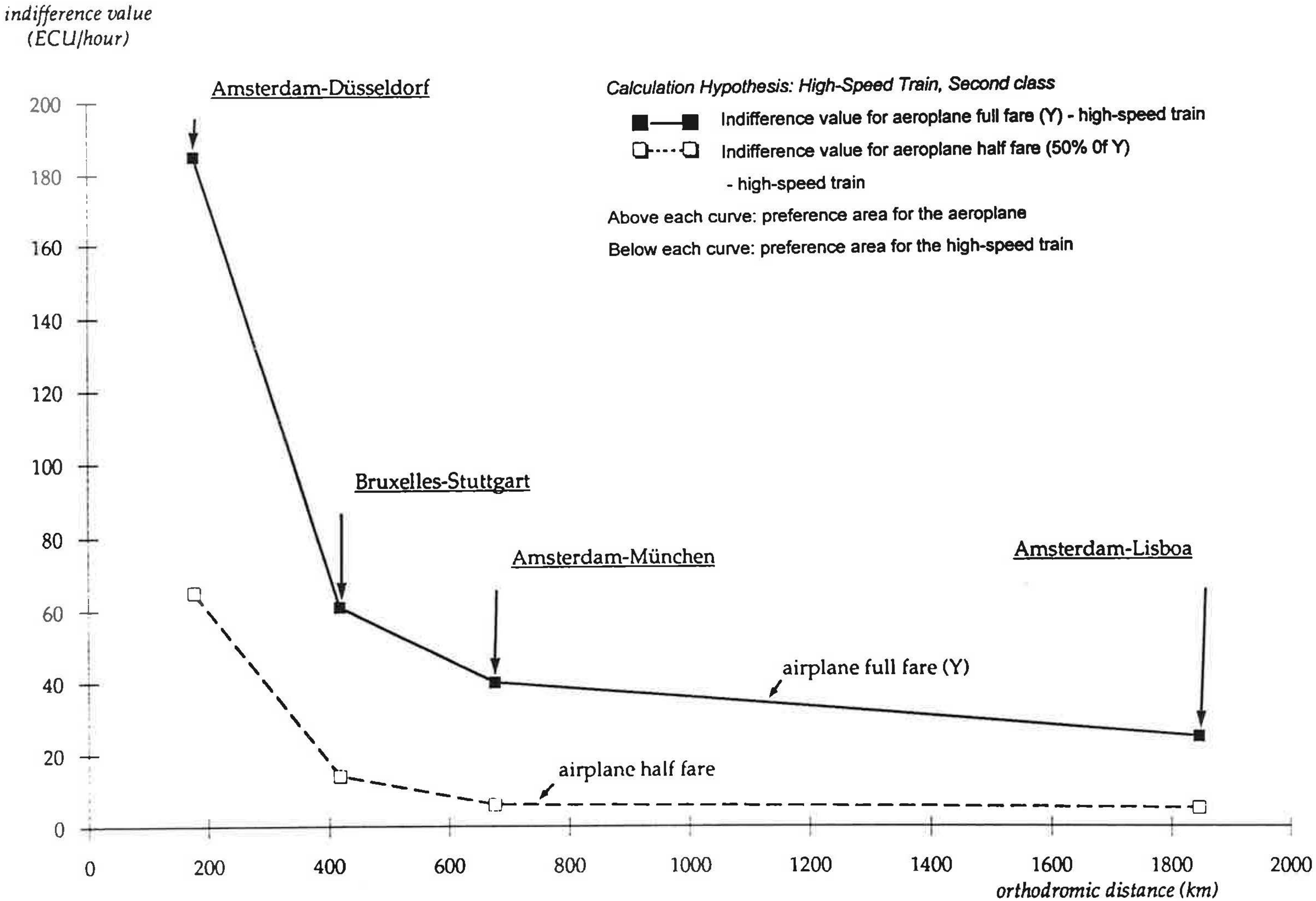
- **National co-ordination**: One should think that this is the easiest problem to solve in the short run, because all partners are state owned. But it seems that mainly market forces are driving efficiency through competition and provider-client relations, as in so many other cases.

The impact of the high-speed train is very great on the short distances, where the journey time by high-speed train is less than 3 hours; this is equivalent to distances of up to 500 km 'as the crow flies' (orthodromic distance). On the other hand , over 1,000 km, the impact of the high speed train on air traffic remains weak even negligible, and the aeroplane continues to control a preponderant share of the market. The range of distance in which competition between the two modes will be most intense is therefore the middle range from 500 to 1,000 km. Obviously this competition will only exist where rail traffic is sufficient to warrant the construction of new high-speed tracks. Journeys made up of two segments on which the respective advantage of the two modes complement each other, i.e., a short segment on which the train is as fast as the aeroplane but less expensive and a long segment on which the aeroplane is faster than the train, show the strength of an intermodal approach. The typical case are medium sized cities in not more than two hours distance from a major hub. Effective train/aeroplane complementarity requires that a number of conditions are satisfied. In particular:

- There must be excellent interfaces between the rail and air networks, i.e., train stations at airports and schedules that are co-ordinated.

- Baggage can be checked from the origin to the final destination.

Figure 32: The Areas of Preference for the Aeroplane and the High-Speed Train (2nd class) as a Function of Air Fares on four major European Routes representative for different distances (ITA, 1991)



- There is commercial co-operation between the railway companies and the airports

The major factor when investigating competition and complementarity of rail and air is travel time and how it is valued by the customer. The concept of generalised costs covers the transport costs of the specific mode plus the value of travel time for each passenger. A cost curve can be calculated for both air (faster and more expensive) and rail (slower but less expensive). An indifference value is found where the generalised costs for both modes are equal. This value gives the equivalent of monetary units a passenger is willing to pay for time savings. This concept of, course is only of use if there is a trade-off between travel time and price. When the faster mode is also the cheaper mode it will attract all the passengers.

For a study the modal choice according to the indifference value has been calculated for destinations in Europe representative for different types of distances (figure 32). It shows that for long distances such as Lisbon-Amsterdam all passengers valuing one hour of travel time higher than 35 ECU would opt for the aeroplane, in case they have to pay the full fare (business travel). If it was to pay a special fare (50% reduction leisure travel, or generally lower air fares due to deregulation) this value would decrease to less than 10 ECU (ITA, 1991). This example illustrates that high-speed rail is going to take a considerably small market share on routes over 1,000 km from aviation. Distances from Lisbon to the central European regions are far beyond this number: Frankfurt 1873 km, Brussels 1717 km, Milan 1683 km. These long routes are considered as natural markets for air transportation, and the introduction of high-speed train service has practically no impact on air traffic (ITA, 1991) This fact should be taken as the most important evidence, that the development of a multi-modal transport network should be a priority for Portugal.

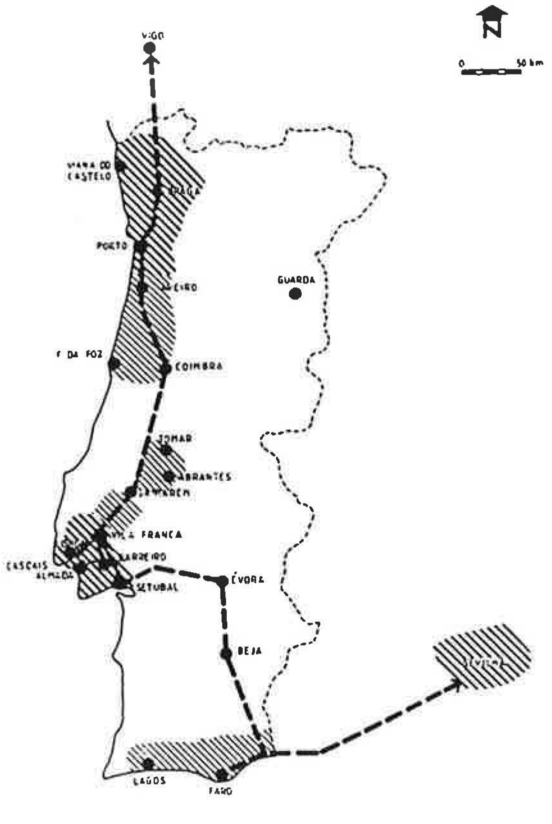
On the other hand it is envisaged that night-time high-speed train services could have a tangible effect on air traffic capturing as much as 10% of the market. In Germany there has been introduced the InterCityNight service using passive tilt technology on two routes between Munich-Berlin, and Berlin-Bonn. A completely new quality concept is applied with highly comfortable sleeper cars. Nevertheless also this new market niche has to be observed closely through the next years, as only the Route to Munich has proven profitable so far and the expansion plans of German Rail have been postponed for the moment (Gough, 1995).

5.3. The South-Corridor

Another advantage of a multi-modal network would be that it does not primarily focus on the long distance connections, but also allows the development of a high quality transport network serving the region as such. As there still does not exist any definitive strategy of developing Portugal's economy and territory, it has been proposed to get out of the position lagging behind the average economic progress in Europe by creating a new European region as a counter-pole to the already congested centre (Da Silva, 1990). An "Atlantic Sunbelt" could be the Community's gateway to the West and to the countries of the Maghreb. A generic dynamic process has to be stimulated to assure and support the innovation force of this region. In this way another centre, complementary to the European core regions in its economic basis, could be established. The drawback, that might prevent such an evolution is the missing "hinterland" to strengthen its position in the long term.

Nevertheless the suggested connection of Portugal's growth poles (Porto, Lisbon, Setúbal, Évora, the Algarve region) via a high-speed train corridor and its completion by Spanish authorities to the North (Vigo, Santiago) and the East (Seville) could be a decisive stimulus to reinforce investments in this peripheral region (figure 33). So far other cross-border connections between Spain and Portugal than the Madrid-Lisbon corridor, have been neglected in the European masterplan and therefore do not appear on any agenda for infrastructure development. Careful research of macro and micro economic parameters and studies in regional development will have to show, whether this option should be given preference to the construction of the Lisbon-Madrid corridor in medium/long term.

Figure 33: The Atlantic High-Speed Railway Corridor for a New European Region (Da Silva, 1990)



Main Urban Metropolis
Secondary Urban Agglomerations
Urban Centres
High-Speed Railway Axis

5.4. Environmental Impacts

Apart from transport related aspects of course the environmental impacts of the various modes are an important issue to be discussed. Though in respect to emissions, and energy consumption the train is more favourable than air transport, in the case of the high-speed railway, however, there can be observed two key problems not being easily accepted by the population affected.

Noise is a traditional problem mainly due to rolling and to aerodynamic pressure (speeds above 300 km/h). Progress has been made, and the ICE trains do now produce the same noise at 300 km/h as conventional trains were producing at 200 km/h (Button, 1993b). But still, the best that can be said in this respect is that the situation did not get worse, only that many people feel disturbed by the current noise level already. Noise is also a problem with air transportation, and again in this field new engine generations have improved the situation. However airports due to there punctual location tend to effect less neighbouring areas negatively than the linear corridors of the high-speed railway.

The splitting of landscape can be identified as a major ecological issue. The matter of separating large areas by a physical barrier, is not only difficult to argue in agricultural regions, but generally affects complex ecosystems like wildlife migration. Still there is only little information about such long-term effects.

Undoubtedly in the reduction of emissions and also in safety, with no fatalities since the introduction of high-speed rail technology, rail has an important advantage over air transportation (CEC, 1994a).

Figure 34: Graphic Outline for a Multi-Modal Network

5.5. Outline of a Possible Solution

As discussed above already the main advantages of multi-modal network solution (a possible outline is shown in figure 34) for Portugal can be summed up as follows. A fast and efficient connection to the European core region by aeroplane and a high-quality rail network as a backbone on the regional level. The performance of the interfaces will be of crucial importance for the functioning of the network.

An efficient rail link not only to the economically important agglomeration Porto but also to the South with a connection to Faro airport could take a lot of pressure from the Portuguese airport system. This link would allow to shift also non-scheduled flights during the peak season in summer between Lisbon and Faro. The rail links will also free capacity for international flights, as much domestic air traffic will be moved to the rail.

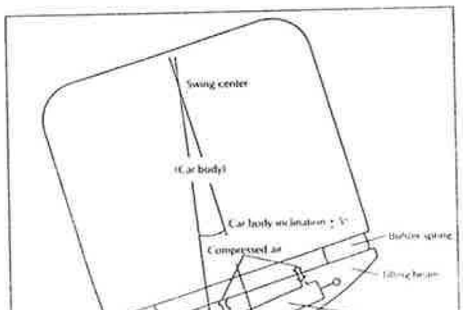
The air transport system for international connections is more or less established already. The missing factor are the efficient rail links between the urban areas and the airports. A possible way to realise these connections even for a country with a low financial profile is shown in the next chapter.

6. Tilt Train - An Existing Alternative

As already discussed above a clear definition of the term high-speed is necessary to discuss the new developments in the railway sector. It has been agreed to refer to high-speed trains only if it concerns newly, purpose built infrastructure and rolling stock, that can be considered a new transport mode, differentiated from conventional rail by speed (270 to 300 km/h) and services offered.

Another technology in rail transport rapidly gaining ground is the pendular system (figure 35). This intermediate speed system is mainly based on the development of a completely new construction mode of the rolling stock. A mobile train body is carried on the bogie on a tilting beam using secondary air springs. The beams run on rollers on the bogie frame, connected to it by horizontally mounted air cylinders. There will be used active tilt trains in the future, where the tilt mechanism is controlled by an on-board computer, using a digital record of track geometry and speed limits for the route. A tilting pantograph support will also ensure good power collection from the overhead line even when the train is at maximum inclination. This allows 2,5°

Figure 35: Pendular System (O´Rourke, 1995)



higher curve gradients in comparison with a passive tilt system (O'Rourke, 1995).

The advantage is obvious: On existing or upgraded tracks with low curve radius speeds of 200 up to 250 km/h can be reached without reducing the safety or the comfort for the passenger. According to ABB, one of the major suppliers in railway infrastructure, an existing track in good condition can be upgraded by costs of 0,2 Mill. U$/km, which is only 5% of the construction of a high-speed line (TGV e.g. 4.0 Mill. U$/km). This means considerably lower construction costs, which is an important factor in introducing new infrastructure, as we remember that this is one of the main obstacles for private investments entering the market. In the case of Portugal with less favourable preconditions the savings would be up to 30 or 40% compared to the preparation of a high-speed service (Viegas, 1993).

Not only Portugal, also Italy and Sweden have decided to leave the high-speed sector in the medium term because of the high costs, and to invest into an intermediate speed system: tilt trains and the comparatively cheap improvement of conventional lines. This trend has been becoming more meaningful only in the beginning of 1996 when it became public that also SNCF is making a break in the development of its TGV, which is assumed having reached the limits of financiability. Though the construction of two more lines (Lyon -Marseilles, TGV-Est) was fixed, start for the work has been postponed several times already. The future expansion of the railway network - the 'French Flyer' - will focus on the pendular technology as well. The reason for this change of policy is that inspite of huge annual investments, no additional passengers have been attracted for five consecutive years now (Smonig, 1996a). Also just this year in the United States the construction of Amtrak's first 'high-speed' corridor between Boston and New York will start. The tender was won by consortium Bombardier/GEC Alsthom (which is also the TGV constructor) offering the tilt technology

In the coming-up improvement of the Northern Line Portuguese Rail plans to remodel the whole corridor allowing speeds of more than 200 km/h, by enlarging curve gradients and renewing tracks not feasible to this technology. This new type of tilt trains will be operating on tracks together with a variety of other conventional trains, like inter-regional, suburban or freight services, which are running on considerably lower speed. Train sets with a wide spectrum of cruising speeds running on the same track will lead to inhomogeneous traffic. This means that all or most trains have a different number of stops and different speeds, which necessitates passing each other. Usually inhomogeneous participants in any type of transport network cause a loss of capacity (Kreutzberger et alt, 1992).

This can be seen as a disadvantage compared with the purpose built high-speed trains, as apart from lower speed, a trade-off between construction costs and capacity occurs. Though it is important to note that the capacity referred to in this case is trains/hour on a specified track, which has its main consequence for the frequency of trains. While the capacity of passengers/hour on a specific track, which is the maximum transport volume, does not only depend on the number of trains, but can be influenced by other factors like the total number of seats.

6.1. Simulation of the Tilt Train's Potential

Upgrading the Alfa to a pendular system is such a step towards an increase in the difference of average speed to the suburban train sets. It is an important issue to compare the potential of the tilting system with the calculated performance of the classic high-speed system. As the pendular train will be running in mixed traffic with suburban trains on upgraded lines their performance might be constrained. The objectives of this simulation are twofold.

- First, there should be shown whether the combination with suburban train sets allows the pendular train set to achieve shorter travel times than today's Alfa trains.
- The second point is to clarify whether there are capacity constraints of trains per hour due to inhomogeneous traffic.

To shed some light on these problems and possibly to find some answers the current performance of trains on the Lisbon -Porto corridor and the calculations for the high-speed alternatives will be compared with the simulated performance potential of a pendular train system on a part of the corridor. For this simulation the software programme *Railway Simulation (RWS)™* running on an Apple™ Macintosh Iiic, is used which originally was designed to build the time schedules for the national Portuguese train network. This program is able to visualise the itinerary of any train in a two dimensional time-space diagram by browsing a database with all features of the cruising train set and the used track network (Giger, 1994).

In a two-dimensional graph the trains are represented as lines in time and space. So it is possible to identify when a train passes a certain point of the corridor. While on one axis the path of the corridor of the network is shown, the other axis represents the journey time. The x-axis: represents the time, and the y-axis: represents the length of the selected corridor. The smallest unit calculated on the time-axis is one second. The starting time of the simulation as such, as well as the entrance time of a train into the corridor can be chosen individually. The absolute time is only important for building time tables, but for simulations on capacity only the time-span between trains travelling through the corridor has to be considered.

The software package does not offer the possibility of automatic analysis of the results, but the printed graph has to be analysed usually. Through distortions in the lines representing a train congestion in a corridor or in a crossing becomes visible. By changing the number of trains or the intervals between two trains entering the corridor the optimal solution has to be approached step by step in an iterative process (Giger, 1994).

The programme allows to create so called 'train families'. This means trains with the same itinerary running through a corridor at different times, need to be specified one time only with all their features, then it is enough to give the frequency (if they run with regular intervals) or the entering time into the system (if they run with irregular intervals). Each 'train family' is represented by lines in the same colour.

A 48,2 km long corridor between Azambuja and Lisbon-St. Apolónia has been chosen for the simulation study carried out. This corridor is part of the Northern line, Portugal's main railway connection between Lisbon and Porto, -St. Apolónia is the most important of Lisbon's four railway stations. Almost the whole corridor selected is constructed with four tracks, but the double-tracked part between Vila Franca da Xira and Averca is causing a bottleneck like the double-tracked entrance to St. Apolónia station.

A description of the features representing the corridor in the database is given below. The database does not only contain the specifications of the infrastructure, but also that of the rolling stock. A graphic representation of the corridor used in the simulation can be found in the annex of this study (It has to be noted that *destination/itinerary*, *train set* and *timetable* are non-graphic data for calculation purpose only).

A) Links

The whole network is represented by links and nodes A link is the smallest unit of the track represented in the programme. Each link can be identified by number. In the database the following criteria is connected to the typology: ID-number, speed limit, length, code for special features (i.e., infrastructure installations except signals) and inclination.

In the graphic representation of the infrastructure the id-numbers of the links are printed in red, the length(in meters) in black.

B) Routes

All consecutive links between two signals form a so called route. These signals are all the installed signals in the network relevant for the train driver. There are three different types of signals, entrance, exit and track signals A route stores the following information: ID-number, signal type (entry, exit, track), signal conditions, visibility distance of signal, speed maximum, the IDs of the links forming the route
and time relation between two trains leaving for different lines.

In the graphic representation the routes are labelled with blue and green numbers at the beginning and the end. Additionally to the features described above there can be found information on inclination, platforms in stations and speed reductions in the graphic representation of the corridor.

C) Destination / Itinerary

The complete itinerary the train is going to pass through is accomplished in this file. The itinerary is built up by all the consecutive routes the train will take. The information contained in the file is: ID-number and IDs of the routes forming the destination

D). Train Sets

In this file the characteristics of the train can be specified. The real features of almost any type of rolling stock are available in the programme. The following characteristics are considered: type of tractor, train type (ordinal: passenger or freight), speed maximum, train length, gross weight and minimum time to complete stand still.

E) Timetable

Before running the simulation the following items for the timetable have to be indicated: ID number, itinerary file (from point *C*), frequency, train file (from point *D*), speed when entering itinerary, time of entering itinerary, stops and stopping time in stations

With a specification of the above mentioned variables it is possible to run the simulation. Before the execution the programme only asks for the simulation time and two ordinal parameters regarding the general conditions of the network and accumulative delays. The execution of the processing programme unites all the data resulting in the graphic presentation of the trains passing through the corridor as coloured lines in a time-space graph (Giger, 1994).

On the examined line a broad variety of trains is in service, like freight trains, suburban and regional trains, and the above mentioned Inter-City and Alfa train sets. To simplify the simulation, without weakening its validity the passenger trains have been summarised in two groups, suburban and Alfa:

- Regional and suburban services are referred to as suburban services and are represented in the diagram by coloured lines.
- Inter-City trains are substituted by Alfa trains. They are represented by the black lines in the diagram.
- Freight trains are not taken into account.

Apart from these adaptations in the first run the current situation was simulated with data sets for the rolling stock and the infrastructure currently in use, as well as the existing time schedule of the selected corridor. The result of performance of suburban and Alfa trains under current conditions is charted in figure 36.

In the following step all the features of the corridor and the rolling stock were modified to serve for a higher speed service. The signalling, the visibility, the time relations and the speed limits in the straight parts of the corridor had to be adopted according to the maximum performance, which is 250 km/h. In the curves the length of the links had to be altered additionally, due to the smoothing of curves with narrow radius. Crossing stations, intersections or in curves the existing speed limits had to be altered accordingly to the technical performance and safety standards of the used tilt-train set.

Instead of the current Alfa the technical characteristics for the tilt train Pendolino, developed by FIAT in Italy, were placed. A ten car set with a maximum speed of 220 km/h was used in the simulation. The result of performance of the suburban and the pendular trains under the modified conditions is charted in figure 37.

6.2. Interpretation of the Simulation Results

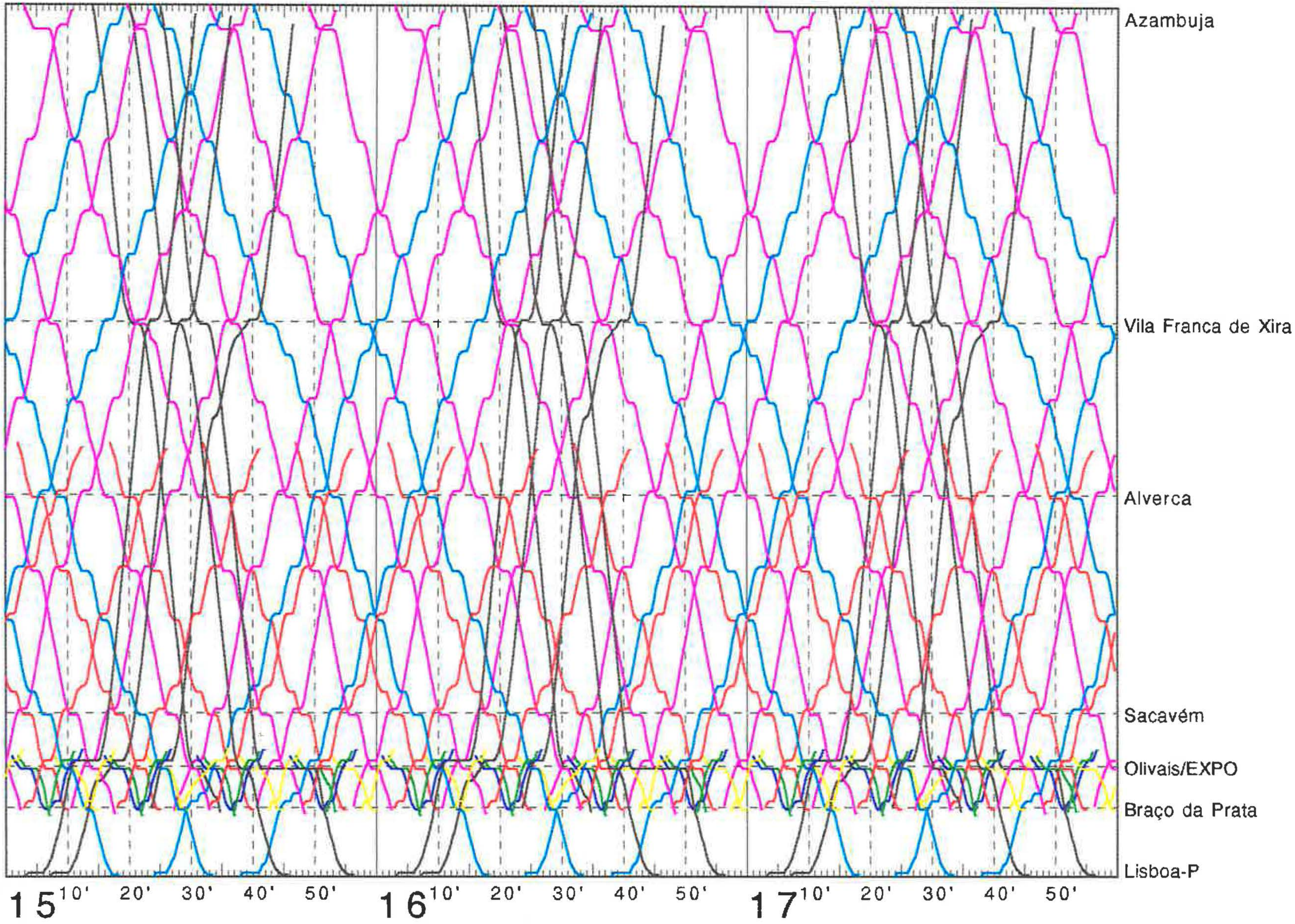
The interpretation refers to the changes in average travel time and the time savings achieved through upgrading the line and using a tilt train car set in comparison with the performance of the current conventional train sets as well as the planned pure high-speed alternatives under point 4.5.

Even with only minor structural changes on the line itself, the tilt-train passed the corridor in 24 minutes, while it took the conventional Alfa train 28 minutes. These are remarkable 4 minutes less travel time on a track of a length of 48,2 km only. This fact underlines the potential of the tilt-train in comparison with the high-speed train, and strengthens the expectations for a sound performance of the pendular technology on the connection Lisbon-Porto. Though it has to be noted that the characteristics of the line, and consequently the needs of reshaping and adaptation, vary enormously and it is definitely not possible to extrapolate the savings of travel time to the total of the corridor Lisbon-Porto. However, evidence is found for a considerable potential of this technology, that needs further research.

The second point to be interpreted is a possible decrease in capacity of trains per hour on an upgraded line due to mixed traffic of train sets with considerable differences in average travel speed (Kreutzberger et alt, 1992).

In fact disturbances of capacity could not be observed in this case when the same number of Pendolinos was operating on the route instead of the Alfas. But the whole corridor is working at its capacity limits. It is not possible to add even one more Pendolino/Alfa per hour in the mixed-traffic scenario with suburban trains. The reason are the two bottlenecks, the double-track sections at the station entrance and between Vila Franca da Xira and Averca. If the whole line was in four tracks, and two of those only reserved for long distance traffic, another simulation showed, that 15 Pendolino/Alfa train sets could operate per hour instead of the 3 in the present situation of mixed traffic. Not surprisingly, this can be interpreted as a prove of the theory, that homogenisation of speed in a transport network leads to a gain in capacity.

It should be borne in mind that this simulation was done for hourly capacity at peak hours. The chosen scenario of three Alfas per hour is only representative for the peak hours between seven and eight o'clock in the morning and in the evening. As mentioned above currently there are only 11 trains (5 Alfas, 6 ICs) operating between Porto and Lisbon per day. So during different day times even the present line has free capacity available.



coloured lines: suburban trains black lines: pendular train sets

Figure 36: Simulation under Current Conditions - Conventional Rail Service

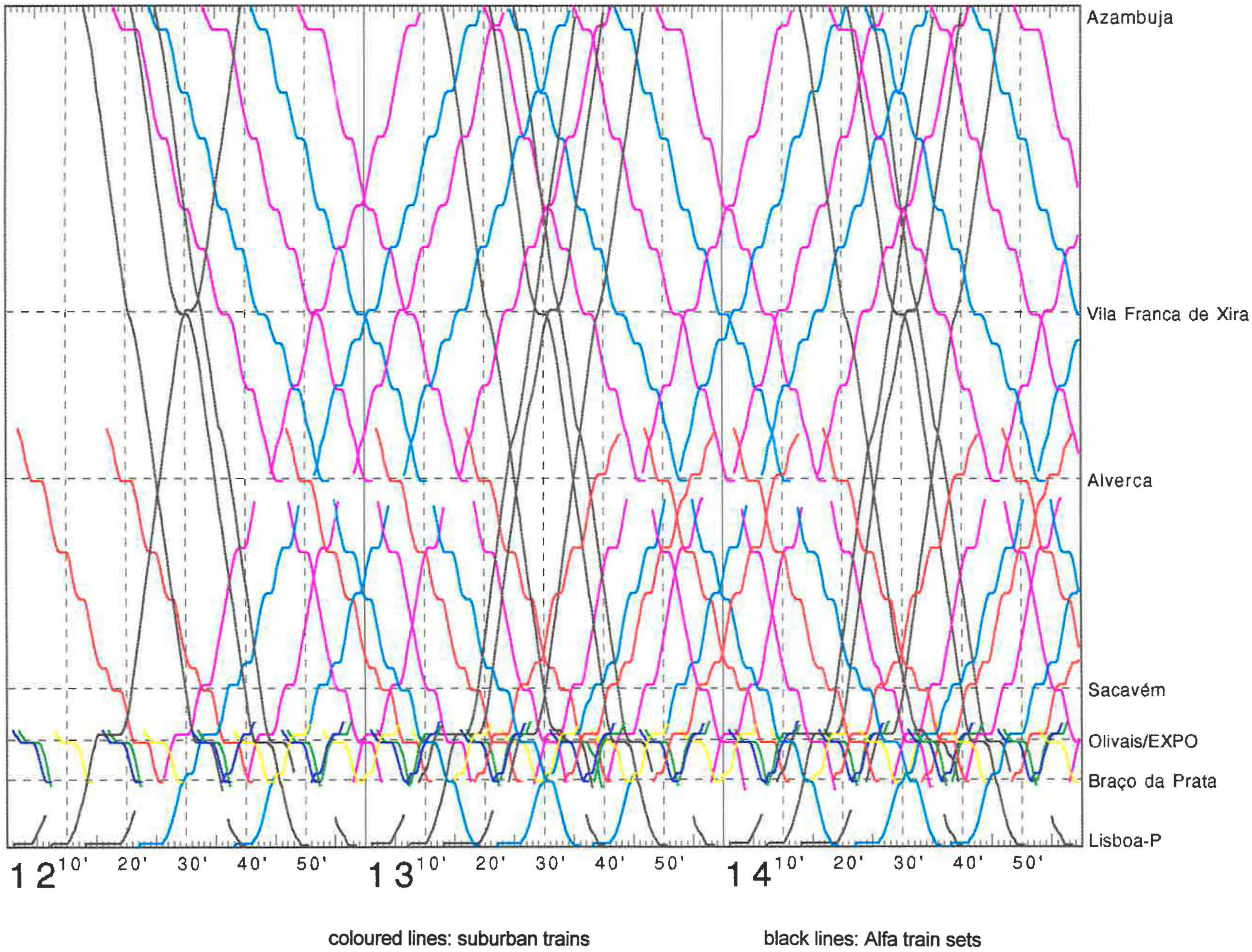


Figure 37: Simulation under the Conditions for the Use of Pendular Train Sets

7. Conclusions and Outlook

Due to its political and economic history in this decade as well as its geographic location Portugal finds itself in a very difficult position. Having been a peripheral area in any sense of the word a lot of effort has currently been put into improving the situation. It is clear that for a country located like Portugal it will be difficult, if not impossible to directly compete with the European core region. Nevertheless there do exist many possibilities to improve the country's position through developing domestic networks and get those networks interconnected with the rest of Europe. Transport infrastructure networks are certainly a key-issue in this respect, as any of the economically high performing regions offers a well functioning infrastructure network, but of course this can only be a (supply-side) facilitator. The region also has to generate the demand making use of these networks.

By joining the European Community in 1986 Portugal hoped to considerably improve its transport infrastructure getting access to various Community funds. In fact a lot of money has been invested, mainly in road infrastructure so far. The negotiation process between national governments and Community authorities to agree on which projects should be selected for Community funding is a lengthy one. Once a decision has been formulated and published a revision of those schemes usually will take an even longer time. In the case of the trans-European networks a revision of the masterplans is planned to take place every five years. Obviously the flexibility in the decision making process is very low. But Portugal will need some fast decisions in the future if it does not want to fall behind further.

The influence of the European supply industry lead to the push of a new transport technology, the high-speed rail. It seems as if this transport concepts has reached its limits of profitability in the European core region already. But still this is the main project in Portugal's and the European Community's infrastructure plan and it seems that Portugal mainly relies on the forthcoming of the high-speed rail network, which due to the many impediments is developing very slowly. It is clear to many observers, that the introduction of such a technology will be close to impossible in a peripheral region such as Portugal due to scarce financial resources. The time factor in this respect is a decisive one, already the realisation of large scale infrastructure projects takes a decade or more.

It can be shown that in a system consisting of three regions A, B and C improvement of infrastructure between A and B leads to a decrease in transportation costs between A and B in both directions. The effect on region C (the region not directly involved) is unambiguously negative, for the regions directly involved the effect is not clear, however. The loss on the home market has to be traded off against an increased penetration of the market of the other region. One thing is clear, namely that the sum of effects for A and B together will be positive as a consequence of the improvement of infrastructure. The conclusion was that although it is not obvious which of the regions directly involved in the improvement of transport infrastructure will be the winner, the regions not involved will certainly be losers (Rietveld and Nijkamp, 1992).

Portugal is very much in danger to be one of these loser regions if it continues with its current transport policy, that seems to be guided by a passive strategy. A multi-modal network structure could be a flexible approach with a good long term perspective offering a number of alternative solutions to future development scenarios. Action is needed very soon to transform one of Portugal's major drawbacks into a functioning service for its economy.

Opting for the pendular train technology as a low cost alternative to the classic high-speed rail systems like the TGV, would allow Portuguese Rail to up-grade its lines to similar performance, but avoiding the pitfalls of financial constraints. Taking into account all kind of aspects of intermodality, such as efficient interfaces with airports and urban transport systems in the planning stage already can safeguard an infrastructure network meeting the requirements of the demanding user. This network approach is very well documented by research studies and experience from practical implementation. Also the engineering know-how has been available for a long time now. The problem factor in this case can be found on the decision making level, where indecisive behaviour and lack of co-ordination are dominating.

Current practice shows that the biggest airport, Lisbon, expands without connecting either to the urban underground system nor providing a direct rail link to the national network. Of the three alternative locations studied for a new airport two do not offer the possibility to connect with the railway system and no other initiatives in the field can be observed to improve the situation. Therefore a concerted action of all parties involved into transportation in Portugal is urgently needed to work on the integration of the country's modal networks to generated a maximum benefit for its users and Portugal's economy. Unfortunately up to date the decision makers, for what ever reason, seem to be rather reluctant to get such an action started. The consequence for Portugal is to remain on the waiting list for being connected with the economic core regions.

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