PATH ALLOCATION RE-ENGINEERING OF TIMETABLE NETWORK FOR EUROPEAN RAILWAYS (PARTNER)

Project Report (D1.1)

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State-of-the Art and User Needs in Capacity Management and Access Charging

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Contents

1 Introduction

The project PARTNER aims to develop an Internet based software demonstrator that provides a common platform for international path allocation for European Infrastructure Managers of railway networks (IMs). The work of project PARTNER will become the basis for a software tool that flexibly supports the international timetabling process and uses new service applications to reduce the necessary time of the process by up to two to five days.

The European Commission has endeavoured to liberalize the European railway market for many years. In its 5th framework (Competitive and Sustainable Growth), the European Commission supports the project PARTNER to contribute to the re-engineering of the international timetabling process for the free access of Railway Undertakings (RUs) to the rail infrastructure. The project was started in October 2003. The duration is 24 months and the budget of the project is 1.9 million €.

Workpackage 1 (State-of-the-Art and User Needs) captures details of the present process in place and current state-of-the-art ideas as well as reviews the results of previous EU-RDT in the interest area. In addition, the requirements of the PATHFINDER project of Forum Train Europe are taken into consideration.

The state-of-the-art of current Access Charging is analysed (chapter 2). Moreover, the state-of the-art of Capacity Management is assessed by evaluation of other EU-RDT results and the latest literature, which specifically concerns the Capacity Management methods (chapter 3). A structured survey of European Infrastructure Managers and Railway Undertakings was completed in order to determine user needs and requirements (chapter 4). The lessons learned from the first workpackage are intended to convince the prospective users that the project will meet their interest and to get the necessary support from them (chapter 5).

The detailed results of the survey with European Infrastructure Managers and Railway Undertakings are summarised in appendix A. Appendices B and C contain the structured questionnaires for the IMs and RUs.

2 State-of-the-Art in Access Charging

2.1 Introduction

Rail infrastructure charging is a strategic issue for strengthening the European railway business. The rail industry has been subjected through a new regulatory framework to a range of economic and structural reforms in order to create competition. The first main milestone is the European Union (EU) Council Directive 91/440/EC, the application of which has involved the separation between Infrastructure Managers and Railway Undertakings. This directive marginally deals with charging methods. Further, the EU Council Directive 95/18/EC only deals with licenses for the use of infrastructure, while the EU Council Directive 2001/12/EC amends Directive 91/440/EC, but not the articles dealing with charging. It is EU Council Directive 2001/14/EC where the principles regarding the charging methods addressed in EU Council Directive 91/440/EC are elaborated upon. This directive states which features charging methods should obey, leaving considerable freedom for implementing these features.

The main objective of this report is to scrutinize the current tariff systems of the EU member states (plus Switzerland) in relation to the requirements for rail infrastructure charging in Directive 2001/14/EC. Our main sources of information for this are the Network Statements provided by IMs and the research by Peter (2003). National Network Statements, which can be found via *www.railneteurope.com*, prescribe conditions for access to rail infrastructure, rules for the application for access to infrastructure and prices. The paper by Peter gives an overview of current charging methods in Europe and analyses four charging systems with respect to EU Directive 2001/14/EC. Additionally, the final report of EuROPE-TRIP (European Railway Optimisation Planning Environment – Transportation Railways Integrated Planning) has been used. The idea behind TRIP was to build a reference framework designed to assist the IMs in resource and planning issues, focusing on business strategy, access to infrastructure ruling and market behaviour, methods for defining the cost of using infrastructure and assessing the capacity of railway lines.

The structure of this chapter is as follows. In Section 2.2 we present basic economic issues, including cost components of the rail infrastructure, and principles for setting prices. The requirements for the charging of track use, laid down in Directive 2001/14/EC, are summarised in Section 2.3. Section 2.4 is devoted to current tariffs for rail infrastructure access in EU member states and Switzerland; the tariffs are analysed on the basis of Sections 2.2 and 2.3. An existing software tool implementing the current charging methods to provide price information on requested paths along European corridors, called EICIS (European Infrastructure Charging Information System), is described in Section 2.5. We conclude in Section 2.6.

2.2 Economics of rail infrastructure charging

Rail infrastructure charging is an issue under the "hat" of monopoly regulation. Railways are an example of a natural monopoly (exhibiting increasing returns to scale, as is typical for many activities where a network is involved: electricity, gas, phone lines), and they have been a legal monopoly for a long time.

The railway industry has some specific features. It is a "multi-product" industry, with product indivisibilities and public service obligations. Also, externalities are important, which is especially relevant when comparing with competing modes of transportation. The cost structure of the railway business is one of its crucial economic characteristics, which deserves special attention here.

Railway costs are often classified into four broad cost categories:

- Train operating costs, which in general vary with train mileage; they include the costs of providing transport services (fuel, crew, maintenance and the depreciation of rolling stock).
- Track and signalling costs, which usually vary with the length of the route and the number of trains for which rail paths are required; they include the operation, maintenance and depreciation costs of the infrastructure.
- Terminal and station costs, which depend on the traffic volume; they vary considerably with the type of traffic.
- Administrative costs, which tend to vary with the size of the firm.

This overview excludes externalities; they are dealt with later on.

Pricing considerations are crucial in order to recover the real costs of the rail infrastructure. In all EU member states, governments influence the prices of the rail infrastructure slots in the form of (direct or indirect) price regulation. Usually governments seek to maximize the “public interest" when designing their transport policies, where the "public interest" embraces objectives like economic efficiency, profitability, environmental sustainability, income distribution, and relationship with macroeconomic policy. Economic efficiency criteria play a central role in rail infrastructure access charging.

Economic efficiency involves making best use of scarce resources efficiently, i.e., to produce those goods and services most valued by consumers, and requires:

- Productive efficiency: firms deliver the highest possible output from given inputs, and so produce at the lowest unit cost;

- Allocative efficiency: resources are allocated to the production of the goods and services most valued by society.

Allocative efficiency in a given market involves the comparison of the cost of producing an extra unit – marginal cost – with the benefit gained from its consumption – marginal benefit. A price is allocative efficient if it maximises social welfare. However, the necessary conditions for a "first-best" solution are not usually found in the real world as a result of some of the reasons listed below:

- Indivisibilities of supply, in the form of short-term fixed capacity constraints;
- Indivisibilities of demand, in the form of peak load problems;
- Elements of monopoly, instead of perfect competition;
- Externalities, in the form of congestion and pollution.

In addition, there commonly is a lack of complete information about future prices and subsidies. In consequence, it is very unlikely that the market, without regulation, will set transport prices equal to marginal social cost and social welfare will not be maximised. This corresponds to a "second-best" solution.

From economic theory the basic *pricing principles* are:

a) Marginal cost pricing:
   - Short run marginal cost pricing;
   - Long run marginal cost pricing;
   - Social marginal cost pricing (i.e., taking into account relevant externalities);

b) Ramsey pricing;
c) Fully distributed costs pricing
d) Average cost pricing.

a) *Marginal costs* are specific variable costs related to the provision of a service or use of infrastructure. Marginal cost (MC) is the extra cost that is incurred by increasing output by one unit.

   For rail infrastructure charging, *short-run marginal costs* (SRMC) are the additional operating maintenance costs associated to a marginal increase in output without any increase in physical capacity. The determination of short run marginal costs requires detailed cost studies to evaluate operating costs that can be traced to a particular train movement, wear and tear costs for maintenance and renewal of the infrastructure, costs for energy consumption and additional timetable planning and management and administrative costs.

   When SRMC pricing also takes externalities into account, such as ecological costs, impact on congestion, noise level and accident costs on other parties, they are referred to as *short run marginal social costs*. It is important to note that if prices only reflect short run marginal (social) costs, then the fixed costs are not recovered.

   Long-run marginal costs also include the capital costs of increasing capacity to accommodate an increase in output.

b) Ramsey pricing aims to maximise social welfare under the constraint of deficit coverage. It considers the fact that rail infrastructure is a multiple product natural monopoly and tries to find mark-ups for these products to cover the deficit that results from SRMC pricing. This involves varying charges reciprocal according to the elasticity of demand of each user or group of users. Ramsey prices are a “second-best” solution as they deviate from unconstrained welfare maximisation.

c) Fully distributed costs (FDC) take the SRMC into account and cover the deficit by allocating the remaining costs according to selected parameters such as train-km, revenues or the SRMC themselves.

d) Average (short-run) costs are obtained by dividing the total costs of delivering all services, given current capacity, by the number of services delivered. In the long run approach capacity is not fixed. Average cost (AC) can be split into average fixed cost and average variable cost. Average cost pricing is a pricing method which sets the price of a product by adding a percentage profit mark-up to the average cost or unit cost. This method is equivalent in most respects to fully distributed cost pricing (as below); indeed the terms are often used interchangeably. The AC pricing principle argues for setting prices equal to the average cost of production and distribution, so that prices cover both marginal costs and fixed overhead cost incurred through past investments. This involves the (sometimes arbitrary) apportionment of fixed (overhead) costs to individual units of output, though it does seek to recover all the costs that would have been avoided by not producing the product.

Well-known *pricing methods* are linear pricing and two-part tariffs. A *linear tariff* consists of various components, where each term is obtained by multiplying a basic cost parameter (such as tonne-km [tkm] or type of train) by corresponding coefficients. Such a tariff is commonly used to cover marginal costs; public spending is required to finance the infrastructure. A *two-part tariff* consists of a fixed charge (connected to fixed costs) plus a variable part; both components are marginal, but often based on different characteristics. A two-part tariff is an example of a non-linear pricing method, of which many forms exist, though usually based on marginal costs.

Cost allocation is a complex matter and regulators usually adopt marginal cost pricing principles and attempt to make a clear distinction between costs that are avoidable and those that are not. Since avoidable costs are uniquely allocable to specific traffic or users they represent a lower bound for requested prices. Charging less than avoidable costs would obviously lead to operating at an economic loss.

2.3 Basic requirements in Directive 2001/14/EC

In Articles 7, 8 and 9 of Directive 2001/14/EC, the following basic requirements on principles of charging and discounts are presented in detail:

a) Charges for the minimum access package and track access will be set at the cost directly incurred as a result of operating the train service.

b) Costs that reflect scarcity of capacity of identifiable segments of the infrastructure during periods of congestion are allowed.

c) Charges to cover environmental costs are allowed under restrictions related to similar charges applied by competing modes of transport.

d) Mark-ups to recover the total costs can be applied on the basis of efficient, transparent and non-discriminatory principles only if the market segment can bear it.

e) Higher charges can be set on the basis of a long-term approach to cover costs of specific investment projects if they increase efficiency and/or cost-effectiveness.

f) To prevent discrimination, marginal charges for equivalent uses of the infrastructure have to be comparable and comparable services in the same market segment are subject to the same charges.

g) Discounts are limited to the actual savings of the administrative costs. Also time-limited discounts are allowed to encourage the use of underutilised lines under the condition to be available for all users.

In addition the directive provides for setting up “long-term” contracts, subject to certain conditions.

2.4 Current charging systems in the European Union

Our sources for studying current charging systems are the official national Network Statements developed by the IMs as required by Directive 2001/14/EC, and the paper by Peter (2003) on the current tariff systems from 14 European countries.

The table on the next page provides a brief introductory overview on current charging systems. The columns in the table correspond to EU countries (excluding Greece and the Irish Republic) and Switzerland, and the rows correspond to parameters used in the current charging systems. The symbols “+” and “-“ in the table indicate for each country whether the respective parameter is used or not in the tariff system.

Below the Table 2.1, we present in some detail the structure of each of the 14 tariff systems.

	Au	Bel	Den	Fin	Fr	Ger	It	Lux	Net	Por	Sp	Swe	Swi	UK
Fixed Amount	-	-	-	-	+	-	+	+	-	-	+	-	-	+
Train-km	+	+	+	-	+	+	+	+	+	+	+	+	+	+
Gross tonne-km	+	+	-	+	-	-	-	-	-	-	-	+	+	+
Line types	+	+	-	-	+	+	+	-	-	-	-	-	-	-
Train type	+	+	-	-	-	-	+	+	-	-	-	-	-	+
Tonne of freight	-	-	-	+	+	-	-	-	-	-	-	-	-	-
Traffic density/scarcity	+	-	-	-	-	-	-	-	-	-	-	-	-	+
Gross train load	-	+	-	-	-	+	-	+	-	-	+	-	-	+
Axle load	-	-	-	-	-	+	-	-	-	+	-	-	-	+
Congestion time of train	+	+	-	-	+	-	+	+	-	-	-	-	-	+
Out of gauge load	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Commercial value	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Environment	-	-	-	-	-	-	-	-	-	-	-	+	-	-

Table 2.1: Overview of the structure of 14 tariff systems

Austria (Au)

In Austria the tariff system has the following components:

- A circulation fee per train-km, which is dependent on the line category; six types of lines are distinguished.
- A wear and tear component per gross tkm, which takes only maintenance into account; it is set using a marginal cost study.
- A scarcity-based charge per train-km such that higher prices apply during two daily peak periods on two busy lines (going into Vienna).
- For single-load freight transport a discount per train-km is applied.
- Shunting fee (personnel)
- A fee for access to Passenger Stations (platforms and passenger information) for 3 train types and 5 line categories
- A parking fee per vehicle and day
- A fee adjustment for track-friendlyness of locomotives (optional for 2005)

Belgium (Bel)

In Belgium the rail tariff has one component for the use of tracks and another one for the use of stations. The charge per train-km for the use of tracks is based on:

- The operational segregation of the network into four sections;
- The consideration of six different types of lines from the technical equipment point of view, where the maximum operating speed is important; maintenance and investment costs are considered;
- The gross train load;

- Differentiation of treatment based on train type via a coefficient which does not charge empty runs and takes into account the train speed and the priority given to a train;
- A capacity surcharge via a coefficient reflecting the specific demand for a requested line: there is a weekday and season based variation, and higher prices apply during two daily peak periods;
- The impact of the train run on the environment;
- The duration of the train journey in relation to the standard speed of the line.

Denmark (Den)

In Denmark the tariff consists mainly of the following elements:

- A circulation fee per train-km, which distinguishes between passenger trains and freight trains, and takes into account the type of lines. Only two types of lines are considered: main lines (Öresund-coast - Copenhagen H / Padborg border) and other lines. This distance-related fee is higher for passenger trains than for freight trains.
- Bridge fees for the Danish stretch of the Öresund and for the Great Belt. The first fee distinguishes between passenger trains and freight trains, being higher for freight trains. The fee for the Great Bell is the same for each passenger train; there is a fixed fee per freight wagon under the condition that the fee for a freight train should not exceed a certain fixed amount. These bridge fees facilitate the financing of a new infrastructure.
- Additionally, only freight trains are charged with an annual access fee per km of used lines. For internal freight transport an environmentally motivated subsidy per tkm is granted.

Finland (Fin)

In Finland the tariff system is also based on SRMC. There is no variation between different parts of the network and the cost function allows no differentiation on the basis of the technical characteristics of vehicles.

The basic component of the tariff is a circulation fee per gross tkm, which is based on maintenance and renewal costs. The circulation fee for passenger and freight trains is similar (slightly more expensive for freight trains). The use of stations is included in this fee. Additionally, there is a charge per gross tkm for environmental and accident costs, which distinguishes between passenger trains, diesel freight trains and electric freight trains. A supplementary charge for freight trains is levied per tonne of freight.

France (Fr)

In France the tariff consists of three elements:

- A fixed access fee per track-km (and month);
- A reservation fee per path-km;
- A circulation fee per train-km.

Both the access fee and the reservation fee depend on the category of the section of the network. There are four categories of lines which are divided into twelve subcategories by taking into account the demand for slots within each category. There are different fixed access and reservation fees for each of the twelve subcategories. Furthermore, the access fee on some network sections depends on the number of paths reserved per month in the respective category, via a modulation factor. The fixed access fee increases (per unit) with the number of train-runs on a specific section; this variation according to the volume of demand could imply a demand-based decrease of the operators' willingness to pay. A decrease of the access fee is granted for operators signing a long-term contract. Slow freight trains running long distances pay only a bit of the access fee. The reservation fee depends additionally on the time of the train run (normal time, peak hours and week time). The circulation fee is charged for the usage of the infrastructure; it depends on the type of transport (passenger trains and freight trains).

Germany (Ger)

In Germany the current charging system sets the price of a slot in three steps. In step 1, a base price is set, based on line categories. There are nine line categories reflecting the functional role in the network and the technical quality of the line whose most important indicator is the maximum speed. The base price is charged per train-km and varies significantly within the group of long distance lines. In general, the tariff increases with the (allowed) maximum speed. For feeder lines the base price does not differ much. A surcharge is charged on lines with a high demand in order to spread traffic (a mark-up for scarcity).

In step 2, the base price is multiplied by a coefficient based on path product categories. This step distinguishes between passenger transport and freight transport. The path product categories reflect the priority of a path for route scheduling and delay management, and the average speed on the path. Different coefficients apply for express paths, standard paths and feeder paths for freight transport, and for express paths, regular-interval paths and economy paths for passenger transport.

In step 3, multiplicative and/or additive surcharges are imposed. Multiplicative surcharges correspond to the following parameters: steam traction, out-of-gauge-load and regional factors (only for regional passenger transport). Additive surcharges per train-km have to be paid in case of tilting trains and/or when the gross weight or axle load of the train exceed a certain amount.

The tariff system in Germany is characterised by supply-side and demand-side price differentiation. If the price system and priorities in the timetabling process do not solve the rivalry for a certain path, then the IM tries to mediate between the involved RUs. The ultimate solution is a bidding process, which differentiates on the basis of the RUs' willingness to pay.

Italy (It)

In Italy the tariff essentially consists of three elements:

- An access fee for line sections, which is different between main and regional lines, and depends on the quality (e.g. technological category) of the section.
- Variable or usage costs. For main lines it depends on train speed, weight, congestion, time- band, and distance travelled; for regional lines it depends only on trip distance.
- An access fee for nodes, with a fixed base price plus per unit time of stay.

Luxemburg (Lux)

In Luxemburg the tariff consists of three elements:

- An access fee which depends on the path type; this fee is paid per timetable period.
- Usage costs which depend on the length of the path (in km), the train gross weight and the train type.
- A congestion-related fee paid for paths using those sections of the network that face congestion. This fee depends on the length (in km) of the congestion section and the time-band; a "rigidity" coefficient reflects the tightness of a particular path in the timetable.

The Netherlands (Net)

In The Netherlands the structure of the tariff is extremely simple since charges are levied per train-kilometer. There are three different charges: passenger trains (basic charge), freight trains (reduced charge) and deadhead runs (no charge).

The tariff is designed to cover the marginal costs, consisting of daily and major maintenance, traffic management and use of stations. There is a planned annual increase in charges such that marginal costs will be totally covered in 2005 for passenger trains and in 2007 for freight trains and charges for passenger trains and freight trains will be equal in 2007.

In case two RUs want the same path and this rivalry cannot be resolved by setting the path price and the priorities deployed during the capacity allocation process, then an auctioning process is used to decide to whom the path is allocated.

Portugal (Por)

In Portugal there are two IMs: Rede Ferroviara National EP (REFER) and its competitor Fertagus. The charging system of REFER is based on total costs which are estimated annually as a function of track kilometres, under the assumption of the highest efficiency in usage and maintenance. These virtual costs are distributed among the train operators taking into account parameters like train kilometres, speed, axle load and the composition of rolling stock.

The charging system of Fertagus is defined in its concession, taking into account passenger-kilometres, which have to be estimated by the RUs. The government finances renewals, upgrading and building new infrastructure.

Spain (Sp)

In Spain the tariff consists of the following main elements:

- An access fee, which entitles train operators to the use of the whole network.
- A reservation fee per train-km ordered.
- A fee based on the commercial value of the train, based on the capacity of the train (measured in passenger seats for passenger trains and in tkm for freight trains). This element of the tariff is related to the operators' willingness to pay.

Sweden (Swe)

In Sweden the charging system is based on SRMC pricing. The marginal cost is derived from the total cost function, which allows no differentiation on the basis of vehicle characteristics, despite their significant influence on the wear and tear costs. There is no variation between different parts of the network.

The main body of the tariff is a circulation fee per gross tkm, which is based on maintenance costs of tracks, more specifically the wear and tear components. It distinguishes between passenger and freight trains. In the passenger train circulation fee a mark-up for the financing of the Öresund-Bridge is included. Other components of the Swedish charging tariff are:

- A charge per train-km for accidents. It distinguishes between passenger and freight trains and is based on average costs
- A charge for information on platforms and at stations, to be paid for per gross tkm.
- A diesel charge per litre (accounting for the emission of nitrogen oxides), levied only for trains with diesel traction. It distinguishes between old (passenger and freight) vehicles and newer vehicles.

Switzerland (Swi)

In Switzerland there are two IMs: Schweizerische Bundesbahnen AG (SBB) and Bern-Loetschberg-Simplonbahn AG (BLS). The infrastructure tariff for the use of tracks consists mainly of two parts. First, all trains have to pay a maintenance fee per gross tkm and an operation fee per train-km. The operation fee is the same for all trains. The maintenance fee differs for passenger trains and freight trains, since freight trains are subsidised.

In addition to this minimum charge, a contribution margin is levied, which distinguishes between freight trains and passenger trains. Further, there is a different treatment for franchised passenger transport and non-franchised passenger transport. For franchised passenger transport a fixed percentage of its revenue is paid as defined by the regulatory body for each franchise. Non-franchised passenger transport pays a fixed amount per train-km. The contribution margin for freight transport depends on the specific infrastructure. On the SBB infrastructure a marginal contribution per net tkm is levied, while on the BLS infrastructure a marginal contribution per gross tkm is charged. Slow freight trains pay an extra fee.

The federal government pays the contribution margin for freight trains running on both networks.

United Kingdom (UK)

In the United Kingdom operators are fully charged for the avoidable costs they cause and have to pay a part of common costs. The avoidable costs consist of usage costs (track usage, traction current, peak hour charges) and directly attributed fixed costs (the long-run avoidable costs generated by an operator). The common costs include costs for joint use of specific sections of the network, costs attributed to specific geographic regions and other network costs.

One can structure the obtained (average) tariff in a variable costs part and a fixed costs part. Variable charges in the tariff regard maintenance and renewal costs of different asset elements (tracks, structures, etc) which are distributed over all vehicles using the respective assets by taking into account the damages caused by different vehicles.

Congestion costs are specified by network section and time-band being reflecting in the tariff system.

A negotiation procedure is used to allocate costs exceeding the avoidable costs. The charges for freight carriers are subsidised by the Strategic Rail Authority (only the variable charges remain to be paid).

2.5 Comparison of existing systems, Directive 2001/14/EC and the economic theory

The remainder of this chapter deals with an overview of the current tariff systems. We compare them with the requirements of Directive 2001/14/EC as presented in Section 2.3 and with the economic theory on pricing as set out in Section 2.2.

Linear tariffs apply in Sweden, Finland, The Netherlands, Austria, Belgium, Denmark, Portugal, Switzerland and Germany. Tariff systems in Sweden and Finland are mainly based on SRMC pricing. Differences in price components between Sweden and Finland are caused not only by the inclusion of renewal costs in Sweden, but also by different input prices, standards and geographical conditions, and the different definition of track maintenance in the two countries. It is considered that the tariff system in The Netherlands is based on

SRMC pricing, too. More insight into the marginal cost study in The Netherlands could clarify the independence from the parameter gross tkm, which is strongly related to the SRMC pricing. The current tariff in Denmark does not take into account gross tkm and the way in which the bridge fees are charged in Denmark shows that the Danish tariff is not SRMC oriented. The tariff system in Portugal is entirely based on FDC pricing. In Germany there is a FDC pricing approach in the tariff setting, where a part of the fixed costs is distributed among the users of a line. The surcharge for highly utilised lines can be interpreted as a Ramsey-pricing element of regional price differentiation. The path-product coefficients as well as the regional factors can also be seen as an application of Ramsey pricing. Paths for regional passenger transport can be more expensive than paths for long-distance transport. This might be a sign of FDC pricing or Ramsey pricing. The highest marginal cost (per gross tonne) in Europe occurs in Finland and Austria.

Components of infrastructure access tariffs appearing as a surcharge for scarcity and congestion apply in Austria, Belgium, Switzerland and Germany, in line with Directive 2001/14/EC. The most sophisticated is the capacity surcharge in Belgium. The capacity surcharge in Austria is more differentiated than in Germany. In Switzerland on the BLS network, the time difference with a defined standard path is charged.

The current tariffs in Italy, Spain, Luxemburg, the United Kingdom and France are non-linear tariffs. Such tariff systems may have negative welfare effects on the end consumer markets and seem not to accomplish the requirements of Directive 2001/14/EC. The access fee in Italy has to be paid per section, independent of the class of track or line category. The price is set according to origin and destination and is not neutral to the choice of route by the RU. The willingness to pay of RUs depends heavily on the specific origin and destination and this is in line with Ramsey pricing. The tariff in United Kingdom includes a congestion charge, which is based on historical data. In France the usage prices are the same for each section of the network and do not depend on the train gross weight, as SRMC pricing would suggest.

2.6 EICIS (European Infrastructure Charging Information System)

EICIS is a protected software system, available at *www.eicis.com*, which can provide actual path and price information. Requests are addressed using a user-friendly interface. Basic input data are the type of train (passenger train, freight train or other train), the type of path (see the description of the German tariff system), train characteristics, information about origin station, destination station (and via station if any desired) and the selection criterion (shortest path or lowest cost). EICIS handles each customer request in real time. The system is only used to compute reference prices and no active timetable data are provided. The total price for cross-border transportation and the price to be charged for each country are provided. However it is questionable whether this calculation of these prices is completely based on the current tariffs, as described in Section 2.4. Zoom-in facilities are available such that information about price can be provided at request at different levels of detail (even charging cost per kilometre).

By using EICIS, a customer considering transport by rail can get quick information on the price of international rail services along European corridors. EICIS illustrates the fact that there are significant differences in the level of charging price among IMs from different European countries.

2.7 Concluding remarks

The study of existing charging methods in this report shows that tariff systems in use now exhibit considerable variance; harmonization in view of Directive 2001/14/EC is still required. This directive calls for marginal cost pricing and allows for mark-ups; social marginal cost pricing of infrastructure is recommended as the most efficient policy to follow. To implement social marginal cost pricing requires estimating the impact on other network users of an additional train at existing allocated slots. Network congestion costs should be estimated using a model simulating the interaction of demand and supply on the rail network. The idea is to reflect in the charging price all the social costs imposed by the RU on the rest of society by the use of a particular slot. Specific slots are allocated to particular RUs. The main effect of excess demand is not congestion but the inability of particular RUs to obtain the slots they want. The element of social marginal cost to which this gives rise is the "scarcity value" of the slot, i.e., its opportunity cost. There is no general way of calculating this "scarcity value" from information about the characteristics of the route and the volume of traffic. Estimation of the "scarcity value" of specific slots on rail infrastructure requires a way of revealing the value placed on the slots by alternative possible users, both in terms of commercial rail operators and in terms of government bodies wishing to provide social services. The potential users' willingness to pay for alternative slots could play a more important role in the future approach of rail infrastructure charging if suitable revelation mechanisms can be found. The Final report "Calculating Transport Congestion and Scarcity Costs" (1999) and the paper by Nilsson (2002) could be inspire the development of a new efficient charging method where the RUs' willingness to pay and the congestion level are both taken into account.

The basic idea for developing a new charging method, i.e., to accomplish the task of workpackage (WP) 4 (Charging methods) of the PARTNER project, is to find a sort of standardisation of the structure and pricing parameters of the rail tariffs based on the knowledge obtained by scrutinising the tariff systems of the EU member states and Switzerland. Such standardisation will be expressed by a more harmonized table of charging parameters. The need for standardisation of the national charging methods is also underlined in the paper by Schwalbach (1998). This requires identifying essential parameters for joint use within a linear tariff. How many parameters to adopt depend on a trade-off between the accuracy with which the infrastructure costs are reflected in the prices and the cost and complexity of the chosen pricing instruments.

It is expected that the questionnaires for IMs and RUs elaborated within WP 1 will play an important role. The questionnaires are essential for identifying users' needs with respect to path allocation pricing and for improving the knowledge about the state-of-the-art of the current national charging methods. The information obtained via the questionnaires and interviews, as expected in chapter 4, is expected to be a valuable input for developing an international charging system with different offers able to answer requests for international train paths, in particular via One Stop Shops. The new international charging method which has to be the output of workpackage 4 will be a basic ingredient of a demonstrator for a software tool implementing slot allocation and charging.

3 Capacity planning

We survey the methods for determining the capacity of rail lines, with particular reference to European corridors. Definition of line capacity is a classical problem of railway systems, generally aimed at determining how many trains can operate on a given line per unit of time, and to construct a good timetable for the same line or a more complex rail system (e.g. more lines which interconnect at stations or major junctions and nodes), possibly the entire network. The capacity of lines is what the Infrastructure Manager has to sell as its final product. Therefore the definition of standards and robust methods for its evaluation are very important.

The overall process can be subdivided in the following phases:

- Demand and marketing plans;
- Line planning;
- Commercial Train scheduling;
- Technical Train scheduling.

The first three phases pertain to Railway Undertakings, whereas the last phase to the IM. *Demand analysis* has to estimate the origin-destination (OD) traffic flow (passenger or freight), congruent with other marketing policies. The *line planning* problem consists in choosing a set of 'operating lines' within the railway network and their frequency in order to accommodate the traffic demand and optimize some given objectives. The trains in the commercial train scheduling travel along these logical lines. *Commercial train scheduling* can be considered the first phase of timetable construction, which determines the number of trains that must serve a route or physical line in the railway network, within a fixed period or planning horizon. This activity takes into account frequencies and other specific requirements (e.g. regular periodic schedules, desired departure times, passenger connection intervals, etc.). This eventually produces train requests to the IM, who is responsible for the *technical train scheduling.* This must accommodate more RUs schedules and can be further subdivided into specific phases, according to organization, operational agreements, procedures and tools. The output of the last phase is the final timetable that defines for each train the departure time from its first station, the arrival time at its last station, and the arrival and departure times for the intermediate stations.

3.1 Technical Train Scheduling

We will focus our attention on technical train scheduling assuming that the commercial phase preceding it has already been performed. The main constraint to be taken into account in this case is the headway (or minimum 'clear distance') between a train and the next one along the track, in order to guarantee safety and regularity margin. Minimum safety distance is imposed by the signaling system and other operating procedures. This represents however only a minimum requirement for spacing trains (i.e., braking distance plus some safety margins). In addition, a regularity margin is usually needed for absorbing irregularities and to guarantee that the train flow is as smooth as possible. These margins represent a design factor that can be very critical for assuring good timetable standards.

Typically, in the train scheduling phase, separate timetabling problems are solved for distinct lines within the overall network. Each problem is associated with either a single or a double-track line and has to deal with trains having different speeds, according to their type or class (e.g. intercity, regional, metropolitan, freight, etc.). For single track lines, trains running in opposite directions have to cross at appropriate stations. For single and double track lines trains running in the same direction, but having different speeds, must overtake at appropriate stations. Sometimes the timetabling problems considered in the literature are also concerned with the determination of the vehicle size (number of cars or train seats) necessary to accomplish the proposed services. However, this is not the case if the commercial and technical train scheduling phases are separated, and therefore behind the scope of the present survey.

We stress that line capacity or timetable planning assumptions (e.g., regularity margins) can only be validated a posteriori from the operational results, these may introduce corrections or modify standards.

3.1.1 Main characteristics

The main characteristics of technical train scheduling are related to:

- New or existing lines
- Block system
- Single/double tracks
- Train mix
- Definition of lines, routes and time windows
- Quality of service
- Full or residual capacity evaluation
- Network effects
- Regular timetables.

3.1.2 New or existing lines

The solution approach is generally different in case new (i.e., to be designed) or current (i.e., available) lines are considered. In the second case, that is by far more frequently encountered, several constraints are already set and the traffic to be accommodated often becomes a more constrained, marginal capacity problem.

3.1.3 Block system

Besides track quality and maximum speeds, which can vary along the line (gradients, curves) and are permitted for various types of trains, the actual block system is the dominant factor. We distinguish between two types of systems: fixed and moving block signaling.

In a fixed block signaling system the line is divided into block sections of predetermined length, and the position of each train is known only by which block section(s) it occupies. The separation between trains is maintained by imposing that each block section is occupied by at most one train at a time. Block section lengths and train speeds and length are therefore important parameters in this case. Actually, 'buffer' empty block sections are also needed between consecutive trains, in order to guarantee braking distance and smooth train flow. Block section lengths generally vary according to line sections; in particular the so-called short sections, aided by the ATC (Automatic Train Control) are designed to increase line capacity, particularly in high density areas (e.g. metropolitan junctions and nodes), where speeds are also lower.

In a moving block signalling system - which is a modern technology - the position of each train is known continuously, and movement authorizations are displayed in the driving cab, thus permitting better regulation of the relative distances. This requires an efficient communication system between line signals, cabs and control centres. In addition, speeds that can be achieved by trains can be limited in practical situations by different factors other than track geometry and signalling, such as catenary or power traction constraints, if the overall performance of the infrastructure is not properly balanced and enhanced. At the moment this type of block is not yet often found in European railways; and it is being implemented on new high-speed lines (i.e. so called ETCS Level 3 – European Train Control System).

3.1.4 Single/double tracks

Whether the line is single or double track is a general characteristic that obviously has a major impact on capacity. Moreover, the length of line sections between stations (where crossing and/or overtaking are allowed) are important to achieve the desired capacity level, as the ability of the line to manage different speed flows increases quickly as the average line section length decreases. In this context, the concept of 'bottleneck' (or more constraining line section, e.g., the longest one along the line) is traditionally introduced as the bounding factor to the overall capacity. In general one notices that the traffic flow can potentially increase and be better managed as the line sections between the stations become shorter, and more siding tracks are available at the station in order to allow crossing and by-passing operations.

3.1.5 Train mix

The capacity of the railway line is very much dependent on traffic mix and traffic pattern that in turn are also linked to the so-called 'quality of service'. The ideal case is when all trains are the same or have the same speed ('omotachic' circulation). As the mixture of different trains ('eterotachic' circulation) grows, more interferences are generated, which require overtakes - this has an overall impact on line capacity as it reduces the train flow. Besides maximum speed, other rolling stock characteristics such as acceleration and deceleration are important.

3.1.6 Definition of line, route and reference interval

In assessing the line capacity, the railway line itself must be defined, namely the list of stations along the line and the characteristics of these stations that have to be taken into account. The latter can vary according to the method and stage of analysis. In addition to 'simple' lines, alternate routes can be also considered, when motivated by traffic volumes and market needs for moving a certain volume of traffic elsewhere. In the long run, the line capacity should develop into a 'network' capacity problem as soon as other parallel routes are available to provide the same kind of services. This can be particularly the case of freight transport on some main European corridors. In this case the total capacity can be estimated by summing up the contribution of independent lines and finding alternate route sections in order to overcome bottleneck problems detected on the main line.

Finally, one should define the interval or unit of time taken as reference for computing the desired line capacity figure (i.e., trains per unit of time). Traditionally this is set either to one hour or to the whole working day (reduced by maintenance or so-called possession periods). However, in the case of European corridors, this interval can span various days as one has to deal with different traffic situations in different countries.

3.1.7 Quality of service

This concerns the quality of the service which is provided by the IM's timetable planners to the RUs commercial departments. In its evaluation, one has first to take into account the quality of the 'deviation' of the train paths with respect to their 'ideal' versions in the commercial scheduling, i.e., the changes that are required in order to have a feasible timetable. (The lower commercial speed, due to path flexing, can be regarded as 'planned loss of quality'). Second, as train operations are not perfect, some 'buffer' times must be taken into account in order to design a robust timetable, considering that random disturbances and minor to major failures occur in the real management of trains, reducing the theoretical capacity. This stochastic effect is often difficult to take into account in the line capacity evaluation. The quality of service can usefully be assessed only on a posteriori basis (i.e. measuring the overall performance of the schedules) and can be dependent upon the buffers or regularity margins accounted for in the commercial and technical train scheduling.

3.1.8 Full or residual capacity evaluation

There are two main scenarios under which line capacity should be evaluated, namely the case in which no train has been scheduled yet (blank diagram) and the case in which there is an existing timetable and one wants to add new paths (reserved diagram). The question has no definite answer, as it can depend on specific situations, e.g. network zones and time windows with reserved capacity. In the short term view, residual capacity evaluation is of more practical use than the re-design of a complete timetable. Moreover, in the European Corridors perspective, this approach can determine the spare capacity that is available and can be commercially exploited. On the other hand, there can be situations where a new infrastructure design and use can be studied and a new timetable can be proposed, either for some time windows within the day or in the long term perspective. Therefore in general both scenarios are worth considering.

3.1.9 Network effects

Railway line capacity heavily depends on 'network effects', that is a single line can not be considered as a fully independent part of the whole network, due to crossing and overlapping lines that can be true bottlenecks. This is usually the case near large stations and railway nodes. The network effect means that a long distance infrastructure is never independent of the rest of the network (high-speed lines generally converge on classical lines when they approach big cities, freight routes are never totally independent from passenger routes, etc.) A consequence is that one cannot define the capacity of a line without considering what happens on the interfering lines.

3.1.10 Regular timetables

A specific target of the line planning and train scheduling problems is the construction of periodic timetables, which means train services of the same class departing at fixed intervals (also called 'regular' or 'clockfaced' timetables). This requirement has increasingly gained public acceptance in many high density rail passenger systems, like the European market (for both local and intercity traffic). Therefore, it often represents a strong commercial constraint for technical train scheduling. Timetable regularity is also a common assumption to estimate line capacity.

3.2 Solution Methods

Line capacity evaluation can be approached at different levels, within a top-down or hierarchical framework, as illustrated in the Projects EuROPE-TRIP and LIBERAIL:

1) Analytical methods
2) Optimization methods
3) Simulation methods.

Analytical methods are aimed at determining the 'nominal capacity' of a rail line, given some (possibly restrictive) design assumptions. This represents a preliminary high level planning approach, which can also be used for comparison purposes. The output of this phase is not a detailed timetable but only some estimate or reference figure of its general characteristics about the utilization of the line, such as number of trains per unit time period or mix traffic shares among different train classes.

Optimization methods are generally heuristic algorithms possibly based on mathematical programming tools, with the purpose of finding an 'optimal' timetable starting from some 'desired' input (e.g. trains to be serviced with a given departure and arrival times).

Simulation is intended to provide a model as close as possible to reality in order to validate a given timetable, verifying feasibility, robustness and other service characteristics, taking into account random events and possibly embedding optimization methods for local traffic resolutions.

The three levels represent a general methodological framework for capacity planning. Typical target tolerances of the methods, respectively in terms of trains that can be scheduled can be typically 10-15% for analytical methods, 1-3% for optimization methods, and 0-1% for simulation methods. In terms of the nominal running time for the paths on output, the error can be typically 5 minutes or less for optimization methods and less than 1 minute or seconds range for simulation models.

Optimization and simulation methods can provide an outstanding support to the planner activity, although they happen not to be used very much in practice. Indeed, timetable planners traditionally rely on their own experience - to our knowledge the best progress achieved so far has been the introduction of CAD (Computer Aided Design) tools that provide interactive modes to design timetable diagrams on high resolution graphic interfaces. Simulation tools have been mainly adopted by the offices in charge of infrastructure planning and development more than by timetable departments. These tools can provide the planner with more intelligent functions supporting conflict detection and block distance verification. As far as we know, optimization methods have still to be experimented in real life operations. Nevertheless a lot of progress on the application of mathematical programming to train timetabling has been made in recent years, and some outstanding developments towards their practical application are underway. These could eventually change the current ways of making railway timetables.

An 'integrated' methodology, which embeds analytical, optimization and simulation approaches, could become a common tool for all the stakeholders in the railway organizations, i.e. strategy planners and infrastructure designers, capacity managers, and train planners. In particular the 'capacity manager' is a new figure introduced in the European railways following their reorganization and separation between infrastructure and transport operators (Directive EU 91/440 and following “packages”).

In addition, one may devise a system which can consider at the same time the various structural parts and links which come to play as network effects, by integrating lines with junctions or railway nodes and stations. In particular, limited station capacity leads to the so-called platforming problem.

As an exemplary implementation of the methodologies discussed so far it is appropriate to mention ROMAN, which is in use at several European Railways. ROMAN is currently based on CAD and simulation methodologies without supporting optimization. The analytical examination of timetable planning is supported by the mentioned characteristics such as infrastructure topology, block sections and running time calculation in the planning process as well as reports providing capacity relevant data for a desired route. The computer aided design tool can support the conflict detection but not yet automatic resolution. In practice, often capacity data is obtained for mature timetables rather than for early conceptual studies as discussed above, but it is also possible to use the tool for studies early in the planning process, because at this stage the definition for timetable planning can be coarser than for simulation. The timetable data then can be passed to the simulation module (and vice versa) where finer analysis and the stability of the timetable can be assessed. It is possible to put exceptions such as track closures, speed reductions or disturbances (either random or defined) into the system and simulate their effects on the timetable. The results are presented in graphical and tabular outputs and this can help to study the so-called robustness of the designed timetable. Disturbances and other contingency events can be particularly derived from historical analysis of recorded trends and service performances on the specified line. These can be due either to the Infrastructure Manager or the Transport Operators (e.g. infrastructure or rolling stocks reliability rates, breakdowns and resolution times).

3.3 Literature survey

The framework illustrated in the previous section is not new, as already pointed out by Assad (1981), who suggests that hybrid optimization/simulation methods are very promising. More precisely, the results of an analytical method could be the input to an optimization tool that should in turn drive a simulation tool. Furthermore, an optimization or simulation tool should work in the feasible region and close to the solution provided by the upper level, and the latter (i.e. analytical or optimization tool) should be eventually calibrated by the lower level outcome. This hierarchical methodology can be quite obvious, but to our knowledge has not been explicitly mentioned before.

Short surveys on the literature concerning analytical, optimization, and simulation methods are given in the following.

3.3.1 Analytical Methods

One of the most recent references about analytical methods is Malaspina and Reitani (1995), that discusses how to compute the capacity of a railway line and compare it with previous ones. The fairly rough approximation at this level is testified by the wide range of results given by different methods for the same case study. For example, given an instance of a 100 km line of the Italian network, the paper shows that results about line capacity (train number) vary within wide ranges. We can recall that the UIC method UIC Leaflet 405-1 (1983) has been officially dropped some years ago and is not recognized any more as standard leaflet, superseded by more general recommendations (UIC Leaflet 405 OR, 1996), and finally by a new proposed method.

The results of the analytic formulations may be very dependent on the input (i.e. traffic mix); however we are not aware of any reported work in literature to validate the analytical results with a simulation tool. Morimura (1972) introduces a pseudo-diagram flow-chart which is however described in detail only in the original work (in Japanese). Frank (1966) studies the single-track case providing some theorems for a periodic transport plan with priority of trains in one direction. Petersen (1974) presents a single-track analytical model assuming that the departure times are uniformly distributed over the time period of interest and that three distinct train speeds are possible. Canciani (1991) proposes a method based on two-speed train types, that offers good insight into the problem of diagramming 'high' and 'low' speed trains, with simplifying assumptions about the line (stations regularly spaced over the line). Among the analytical methods one should also recall the attempts to estimate the delays of a given traffic flow by a stochastic approach, as reported in Chen and Harker (1990) and Hallowell and Harker (1996). These authors, motivated by the North American experience, notice that their models work better for low-medium traffic lines.

Among the more mathematically oriented approaches in railway timetable design we also cite the method based on the so-called “max-plus” algebra, undertaken by Goverde and Al. (1998, 2002) in The Netherlands, which particularly aim at synchronized and periodic schedules on networks.

Turning back to more pragmatic approaches, as above noticed the UIC has more recently introduced a so-called “compaction” method, which aims to find residual capacity (UIC Leaflet 405-1, 2003). For a given timetable, this essentially requires for compacting or making parallel shift of the train paths in order to find available free capacity. This geometric exercise on the time-distance diagram should not however allow to modify each path and its position relative to others (e.g. connecting services or over-passes at given stations). This approach could be better described as quasi-optimization method.

Another simple approach aimed to assess the spare capacity on a given timetabled line, i.e. having train schedules which must remain fixed, is to try to fill the diagram with some standard paths (e.g. passenger or freight trains) until saturation; the additional paths may or may not have delayed running times or stops to be better accommodated. This can also be done through simple analytic algorithm, if no other tools are used, and replicates the basic behaviour of the traditional planner.

3.3.2 Optimization methods

Optimization methods are designed to provide more strategic methods for solving the rail capacity problem, with no or given constraints (e.g. fixed or predetermined schedules) on the line under study. Moreover they take more advantage from more advanced algorithms and progress in operations research methods.

Many references consider mixed integer linear programming formulations in which the arrival and departure times are represented by continuous variables and there are logical (binary) variables expressing the order of the train departures from each station.

References before the 80s can be found in the bibliography by Assad (1980). Among these, Szpigel (1972) is the first to propose a branch and bound algorithm for train scheduling on a single-track line, given their departure times. He considers a variant of the models mentioned above in which the order of the train departures from a station is not represented by binary variables but by disjunctive constraints. The problem is then solved by branch-and-bound for small size instances by computing bounds through the relaxation of these disjunctive constraints.

Only in the 90s the problem seems to have attracted the attention of operations researchers. In particular, Jovanovic and Harker (1991) solve a version of the models above, calling for a feasible schedule rather than for the optimization of a suitable objective function, by branch-and-bound techniques. Cai and Goh (1994) illustrate a constructive greedy heuristic driven by one of these models. Carey and Lockwood (1995) describe an algorithm for double-track lines, namely a heuristic that considers the trains one at a time (in appropriate order), and for each train solves a mixed integer linear program analogous to those mentioned above in order to schedule the train optimally, keeping the path of the previously scheduled trains partially fixed. More precisely, the relative order of the train departures for these trains is kept fixed, whereas their arrival and departure times may be changed. Carey (1994a, 1994b) extends the model to a more general network, with choice of lines and station platforms, applying it to a small network, as well as to handle trains on a single-track two-way line, showing somewhat surprisingly that it is generally easier to solve for the instances considered. Higgins, Kozan and Ferreira (1996, 1997) define local search, tabu search, genetic and hybrid heuristics, finding a feasible solution by using a model in the family above. Oliveira and Smith (2000) model the problem as a special case of the Job-Shop Scheduling Problem, considering trains as jobs to be scheduled on tracks regarded as resources, and present a hybrid algorithm devised under the Constraint Programming paradigm, showing how to adapt this framework in some special real-life applications.

A network optimization formulation in presented in Mees (1991), with a mix of double and single tracks. Kraay, Harker and Chen (1991) introduce the 'pacing' problem by finding the meet-pass plan and allowing the train velocity profile to be determined by the algorithm.

Brannlund, Lindberg, Nou and Nilsson (1998) focus on a profit maximizing timetable, considering a deregulated market where each transport operator specifies its preferred timetable, the associated value, and a loss function if that deviates from the most preferred one. They discretize the time into 1-minute time slots and subdivide the track line into blocks. Operational constraints impose that two trains cannot be in the same block in the same time slot. This model is not suited for large size instances as those arising for the main European corridors. According to our knowledge this is an on-going research at CTS centre in Sweden.

Different models based on graph theoretic representation of the problem are presented by Caprara, Fischetti and Toth (2000). In this work, times are discretized and expressed in minutes and Lagrangian relaxation is used to derive bounds on the optimal solution value as well as to drive a simple heuristic procedure. The approach was proved to produce good relaxations and heuristic solutions also for large-size instances and long distance rail corridors.

Schrijver and Steenbeek (1994), Lindner and Zimmermann (2000), and Peeters and Kroon (2001) consider the case in which the timetable is identical with a period of one hour (rather than one day, as is the case of the problem considered in the other references), and address the general case of a railway network instead of a single (main) line. The problem is solved through a mixed integer linear programming formulation in which the times are again represented by continuous variables and integer variables are used to impose that the differences between pairs of time variables belong to a certain interval modulo one hour. Further references on this version of the problem can be found in Peeters (2003).

Timetable scheduling which also considers the economic impact, i.e. the determination of the values of train paths assigned to several operators willing to use the same infrastructure, is studied by Harker and Hong (1994), who introduce a computable equilibrium model of an internal market for track resources following a game theoretic approach.

Practical contributions to rail scheduling by optimization methods have been recently reported, as research works, by the Swiss and Dutch railways. A complete system network and various planning levels - i.e. lines and stations - are addressed here. In particular in the Dutch project a hierarchical approach is followed: at the upper level in the hierarchy a tentative timetable is produced, taking into account the specific platforming problems of the trains at the railway stations at an aggregate level. At the lower level it is checked whether the above is feasible with respect to the safety rules and the connection requirements at the stations. To carry out this consistency check, detailed schedules for trains at the railway yards, i.e. assignment to platforms, have to be generated. The final objective of the project is to develop a decision support system, called DONS, which is made of two layers: at the upper level preliminary timetables are generated by a sub-system called CADANS, based on the algorithms presented in Schrijver and Steenbeek (1994) and Peeters and Kroon (2001), and at the lower level works a refining sub-system called STATIONS, based on the platforming methods illustrated in Zwaneveld, Kroon, Romelin and Salomon (1996).

In the framework of the EuROPE-TRIS project (4th EU Framework), a new algorithm for determining line capacity and making a good feasible timetable has been developed, i.e. TCM (Traffic Capacity Management); this is based on the algorithm developed in Caprara, Fischetti and Toth (2002). In addition, within the works motivated by the LIBERAIL and EuROPE-TRIP research, another algorithm called FLOU has been implemented, conceived to find residual line capacity. This also represents an optimization-based evolution of the traditional FS analytic method. It is based on minimum cost-maximum-flow algorithm borrowed from graph theory, it is not as complex as most of the above mentioned methods, but it may be a fair compromise to find preliminary solutions within limited computing time.

It should be noted that while the optimization algorithms can provide their solutions in terms e.g. of feasible maximum capacity, this could still remain a nominal performance of the line, eventually subject to some tailoring for more regular and exploitable traffic flows.

3.3.3 Simulation methods

For train scheduling, simulation has often been used in combination with other methods, originating what could be defined 'hybrid models'. Since the 80's Petersen and Taylor (1982) are quoted for their seminal work using combined techniques, such as dynamic programming and branch-and-bound in a simulation context. Welch and Gussow (1986) use simulation and heuristics to evaluate the relative effect of the many factors that influence line capacity. A composite simulation and optimization method also appears in the work of Jovanovic and Harker (1991) mentioned in the previous section. A model called 'Strategic Capacity Analysis for Network' (SCAN) has been developed by Kaas (1991), who has defined factors, at different level of detail, which together determine the capacity of a network. Among others, Ercoli, Giordani and Lucertini (1995) report on research within the framework of Progetto Finalizzato Trasporti 2, sponsored by the Italian CNR (National Research Council), aimed at providing a basis for the design of a PC-based railway simulator.

Besides purely academic products, various simulation environments have been produced and are commercially available in the rail industry. To give a complete and world-wide marketing analysis is out of the scope of this survey. In the table below we summarize the main European systems which represent the current state of commercially available simulators that can support the rail companies in their timetable production or - as it is more often the case - in the infrastructure planning tasks. The general performances of these simulators are comparable, and their main technical differences concern: interface design, user interaction and flexibility, track infrastructure and other data management, integration with company information systems. These tools normally generate timetables by time-stepping simulation using the train motion differential equations. Alternatively, they can be used to validate a given timetable, provided e.g. by optimization methods, in which case running interferences and delays on the preliminary timetable hypothesis can be detected and analyzed. Specific constraints which are set by the planner (e.g. speed slowdowns, station platform choice, etc.) can be part of the input; in addition the software logic generally provides local optimization or decision rulings (e.g. train priority based delay minimization, itinerary selection, etc.). Infrastructure description can be done at a high level of detail, and results are usually given with very high precision. In spite of this, according to our knowledge, railway simulation is not yet widely accepted as a standard tool in timetable departments. The situation should be however changing in the next years, following the decreasing cost of the systems and of computing resources, the integration with infrastructure data management systems, the fine tuning of some user-oriented functions and the increasing pressures on timetable planners from the deregulated railway market.

3.3.4 Summary of the main implemented methods

In Table 3.1 we summarize the names and main characteristics of the most quoted methods that have been or are currently implemented in practice.

Method	*Reference Name*	***Incre-mental***	***Flexible***	***Capa-city***	***Satu-ration***	***General***	***Simple***	***Country***
Analytical	**UIC Formula**	No	**yes**	**yes**	no	**yes**	no	
	CFF	No	**yes**	no	**yes**	**yes**	**yes**	Switzerland
	SIMON	No	**yes**	**yes**	no	**yes**	**yes**	Sweden
	FS	**yes**	**yes**	**yes**	no	no	**yes**	Italy
	NS	No	no	**yes**	no	no	**yes**	Netherlands
	DB	No	no	**yes**	no	no	**yes**	Germany
	Schwanhausser	No	no	**yes**	no	no	no	Germany
	DGCFF	No	**yes**	**yes**	no	no	**yes**	Switzerland
	ROMAN, Other traditional CAD systems	possible	possible	possible	no	**yes**	no	Various
	Reitani-Malaspina	No	**yes**	**yes**	no	yes	**yes**	Italy
Optimization	**UIC**	No	possible	no	**yes**	**yes**	**yes**	
	CAPRES	**yes**	possible	no	no	**yes**	no	Switzerland
	DONS	possible	possible	no	no	**yes**	no	Netherlands
	SCAN	No	possible	no	no	**yes**	yes	Denmark
	FLOU-TRIP	yes	possible	yes	yes	**yes**	yes	Italy
	TCM-TRIS	yes	yes	yes	yes	**yes**	no	Italy
Simulation	**CHAO**	possible	possible	no	**yes**	**yes**	no	France
	FASTA	possible	possible	no	no	no	no	Switzerland
	RAILSIM	possible	possible	no	no	**yes**	no	USA
	ROMAN-S	possible	**Yes**	possible	possible	**yes**	no	Malaysia, Sweden
	SERGOB	possible	possible	no	no	**yes**	no	France
	SIMON	possible	possible	possible	no	**yes**	no	Sweden
	SLS family	possible	yes	yes	no	**yes**	no	Germany
	SYSIFE	possible	possible	no	no	**yes**	no	France
	UX-SIMU	possible	possible	possible	no	**yes**	no	Germany
	SITRAF	possible	possible	no	no	**yes**	no	Italy
	VISION	possible	possible	no	no	**yes**	no	UK

Table 3.1: Analytical, optimization and simulation methods currently implemented in practice.

The first characteristic ("Incremental") corresponds to methods that, starting from a given train schedule, are able to indicate the number of trains that can be added to this schedule.

The second characteristic ("Flexible") indicates whether the method considered can be applied by changing the values of some parameters such as the minimum spacing between consecutive trains.

The third characteristic ("Capacity") indicates if the method is capable to compute the capacity of the line.

The fourth characteristic ("Saturation") indicates if the method is capable to obtain the saturation ratio of the line directly.

The fifth characteristic ("General") indicates if the method can be applied in all practical cases or if certain restrictions must be imposed in order to use it.

The last characteristic ("Simple") indicates if the implementation and use of the method require considerable investments in terms of time and/or budget.

In addition to the above mentioned, new methods are to be considered which concern the train capacity planning, taking into account the moving block characteristics of the new railway lines. Among these we find Hill and Bond (1995), Zou, Oghanna and Hoffmann (1999) and the results from the COMBINE2 project within the 5^{th} EU RDT Framework. The paper by Holgate. is standing out as a nice introduction to the rail line capacity evolution from the multi-aspect fixed block signaling to the moving block system.

3.4 Conclusions

The analysis of the above table shows that many possibilities and exploitable areas exist in setting up more complete and integrated tools to support the rail line (network) capacity determination and allocation. On the other hand the Computer Aided Design tools currently used in timetable planning do not take full benefit from the exploitable technology of more advanced (i.e. optimization) methods, or better integration with more fine tuning tools (i.e. simulation).

Generally speaking, the analytical methods often entail hypotheses that, being very broad and oversimplified, can be used only to have an indication of the line capacity. Another major limit is that they only apply to line sections. Their major use seems to be an indication of which line sections are most loaded and have to be studied in more detail with the help of other methods.

Optimization methods have to consider a simplified scenario, but have the advantage to provide on output a timetable that can be validated through simulation. This may be an entirely new timetable or a timetable obtained from an existing one by the addition of new path requests. The increased pressure towards the fast and effective design of train paths given the commercial request will increase the relevance of these methods.

Simulators are the most precise and sophisticated tools; they often require a greater budget (to purchase the software, collect data and computerise them, etc.). But in general they are not very intelligent and strategic. In this view the best ones can provide only local optimization and cannot for instance shift departure times in order to reduce subsequent path flexing.

In this perspective we can imagine a re-engineered timetable process which can be based on a three level planning system (analytical level, optimization level, and simulation level), can be company process integrated (i.e. among various departmental functions) and can also be able to redesign a national timetable book in much shorter time and more productive way than currently done.

4 Evaluation of the survey of European IMs and RUs

4.1 Introduction

From February, 11th 2004 to March 12th 2004, project PARTNER completed a survey of European Infrastructure Managers of railway networks and of Railway Undertakings. The objective was to describe the current situation about route planning on international corridors within a timetable period. The overview of domestic software tools and practical workflows of international timetabling has been also an important input to the project work.

4.2 Procedures

The project consortium prepared two questionnaires that were respectively orientated to the target groups of IMs and RUs. Some Operators of combined Road-Rail transport, Forwarders and other Transport Operators, who play an active role in rail freight transport, were also asked to fill in the questionnaire for Railway Undertakings.

The questions were tailor-made to the interviewed groups of undertakings with the help of the inputs of Rete Ferroviaria Italiana (of the project internal user group) and the Austrian railways OeBB (as a member of the project external user group of PARTNER). We recall that DB Netz and OeBB are the members of the project external user group and have expressed their interests to the project.

The German Aerospace Centre DLR completed the interviews as an independent research centre. The questionnaires and the detailed results are attached in appendices A, B and C.

The questionnaires were distributed by e-mail to contact persons and undertakings or, if this was not possible, by air mail to their address. We obtained the necessary information of the contact persons and addresses of undertakings from the Internet. The web sites of Rail Net Europe, Forum Train Europe, UIRR and Rail Freight Association were particularly useful sources of contact information. Additional information was obtained from the home pages of the several undertakings. All participants of PARTNER supported the selection of suitable interview partners by their own information.

The IMs were very easy to find with the help of the information on the web sites of Rail Net Europe and Forum Train Europe. We also had to select such companies which are major operators in international rail transport. As indicated above we obtained the information on these companies from the UIRR, Rail Freight Association and other sources.

For each interview contact information was recorded so that we would be able to get back in touch with respondents if additional information is required.

It might be possible for experts to draw conclusions from several answers to the respondents. On the other side we have evaluated and present anonymous results. So it is not possible to draw conclusions from all results to individual answers of IMs or RUs.

The interviewed persons had two possibilities to fill in the questionnaire. On one side they could use the traditional way and print the questionnaire to fill in by hand and send back by mail. Alternatively, they could use our on-line questionnaire, which was available via Internet (www.rail-partner.org). We provided explanations about PARTNER and the objectives of the survey in an accompanying letter and at our web site. Furthermore, we offered support in case of any questions by telephone.

After two weeks, we made telephone calls and sent e-mail to remind the contact persons and organizations about our questionnaire. Details about the countries of origin and the responses are given within the following table.

Country	**Infrastructure Managers**		**Railway Undertakings**	
	Interviewed	response from	interviewed	response from
Austria	2	2	5	3
Belgium	1		4	1
Bosnia	2	1	2	1
Bulgaria	1		1	
Croatia	1	1	1	
Czech	1	1	1	1
Denmark	2	1	3	1
Estonia	1		1	
Finland	1		1	
France	1		3	
Germany	1	1	20	3
Great Britain	2	1	4	
Greece	1		1	
Hungary	1		1	
Italy	1	1	8	2
Latvia	1	1	1	
Lithuania	1		1	
Luxembourg	1	1	1	
Netherlands	1	1	5	
Norway	1		2	
Poland	1		6	
Portugal	1		1	1
Romania	1	1	1	
Slovenia	1		1	
Slovakia	1		1	
Spain	1		6	1
Sweden	1	1	3	
Switzerland	2		9	2
Yugoslavia	1		2	
Total	34	14	96	16

Table 4.1: Countries of origin of Infrastructure Managers and Railway Undertakings which were contacted to fill in the questionnaire and the feedback. Overall we obtained response from 14 IMs and 16 RUs.

4.3 Results of the survey

4.3.1 General remarks

We had a response rate of 41% for the Infrastructure Managers and 17% for the Railway Undertakings as well as, Operators of combined Road-Rail transport, forwarders and other Transport Operators. We were pleased with the response rate of IMs but were a bit disappointed that less than 20 % of RUs responded. One cause could possibly be that the former governmental RUs have still established relations to their IMs. Otherwise, the new RUs have other, more significant problems in operating of international trains and the timetable process and the path allocation is not yet in their main focus.

All fourteen IMs that have provided responses have transmitted their contact in case of any requests. Thus, we will have the opportunity to make special requests concerning the domestic planning tools and the requirements on the interfaces. Additionally, eight IMs are poised to support the project and provide data for a test application.

Eight Railway Undertakings, five Operators of combined transport Road-Rail, one Transport Operator and two other Operators from ten European countries took part and have provided responses to our questionnaire. Most of these RUs (13) offer rail freight transport and six are active in passenger transport.

Nine of the fourteen IMs have informed us that the guideline of EU 2001/14/EC is already transferred into national law.

The following section concludes the results of the survey under the perspective of project PARTNER. More details about the feedback of RUs and IMs can be seen at the appendix A.

4.3.2 Current situation about train path

In this part we wanted to know more about the current situation of the timetabling process. It should help us to compare the situation of the European Infrastructure Managers.

It is evident that the number of international train paths studies is periodical and depends on the dimension of the network (Figure 4.1).

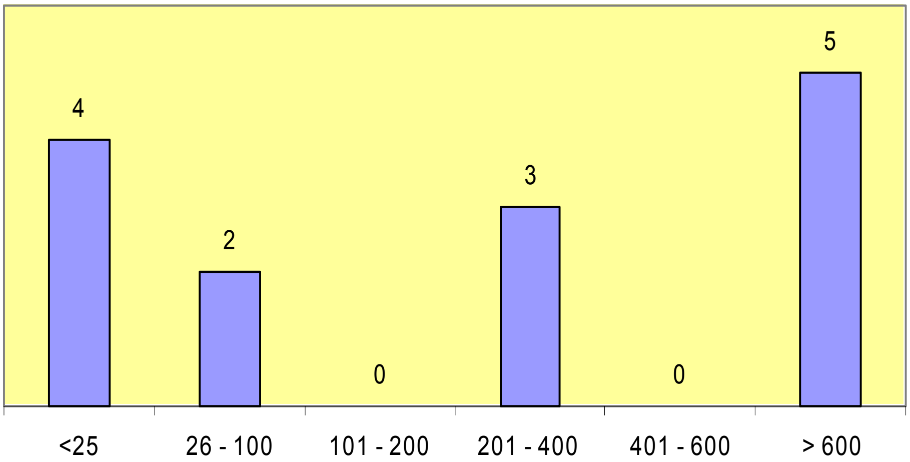

Figure 4.1: Number of international train paths/studies IMs have to produce per year

Overall all IMs require improved processes and most of them also wish to use better CAD tools.

4.3.3 Existing supporting process systems

This section of the survey is aimed at the current process of timetable design and path allocation between two or more independent IMs with regard to international route planning and the tools used to support this process.

All participating IMs already use computer-based timetable planning tools. Twelve of the fourteen IMs expressed that they are familiar with PATHFINDER for international timetabling and eight of them already use PATHFINDER.

At present, IMs contact other IMs and vice versa with regard to cross-border timetable design mainly by phone, by e-mail, by facsimile or at joint meetings. Twelve IMs believe that a computer-based workflow will improve the process and eleven IMs would be prepared to share other timetable information.

The conclusion of these answers is that there exists scope for a higher degree of cooperation for more data exchange in the international timetable process. It is therefore to be concluded that there is an interest for using new software tool or systems like the one addressed by PARTNER.

4.3.4 Business Process

This part of the questionnaire was aimed at characterizing the activities falling under the allocation of rail capacity and charging on international routes from the point of our view of business process management. This will be one basis of the following steps of the project

PARTNER. We will contact several IMs to ask for special details about the interfaces to the domestic planning tools or to discuss workflows.

4.3.5 Train path charging on international corridors

One of the aims of the project PARTNER is to develop a charging method that is based upon some generalized formula. In order to understand the current charging methods and to get a clearer picture of what a 'fair' charging method should look like, we wanted to learn more about the current situation.

Regarding responses, we found that the opinions of IMs and RUs in general are similar. The majority of the respondents think that a charging system should vary according to the type and the weight of the trains.

However RUs and IMs have a slightly different opinion about the following items. The majority of IMs think that the charging fees should vary according to the time of the day and to the expected congestion of the route. But 40% of RUs disagree with this opinion (Figure 4.2, Figure 4.3).

Infrastructure Manager	9 YES	3 NO	1 don't know
Railway Undertaking	8 YES	6 NO	2 don't know

Figure 4.2: Responses to the question whether a fair charging system on international corridors should vary according to the time of the day

Infrastructure Manager	11 YES	1 NO	2 don't know
Railway Undertaking	9 YES	6 NO	1 don't know

Figure 4.3: Responses to the question whether a fair charging system on international corridors should vary according to the expected congestion on the route

Moreover, very different opinions between IMs and RUs exist concerning the following questions. While the majority of RUs do not believe that the charging system on international corridors should distinguish between national and international trains, the majority of IMs think that this would be a realistic scenario (Figure 4.4).

Infrastructure Manager	8 YES	2 NO	4 don't know
Railway Undertaking	3 YES	11 NO	2 don't know

Figure 4.4: Responses to the question whether a fair charging system on international corridors should distinguish between national and international trains on the same line section

On the other hand, the majority of IMs refuse to impose penalties on slower trains that impose lower speeds on faster trains on the same line section. 56% of RUs think that this rule would be desirable (Figure 4.5).

Infrastructure Manager	2 YES	11 NO	1 don't know
Railway Undertaking	9 YES	4 NO	3 don't know

Figure 4.5: Responses to the question whether a fair charging system on international corridors should impose penalties on slower trains that impose lower speeds on faster trains on the same line section

From the above sample, we may believe that the railway market has not yet achieved full convergence about the IMs and RUs views about the path charging on international corridors.

4.3.6 Capacity methods

This section concerns the methods that are currently adopted by IMs in order to design timetables and allocate capacity to the train path requests of RUs. The established view of the RUs is compared with the responses of IMs.

There is a wide difference between the IMs and RUs concerning the estimate of the necessary average time to respond to a request on short notice for a new international train path (Figure 4.6):

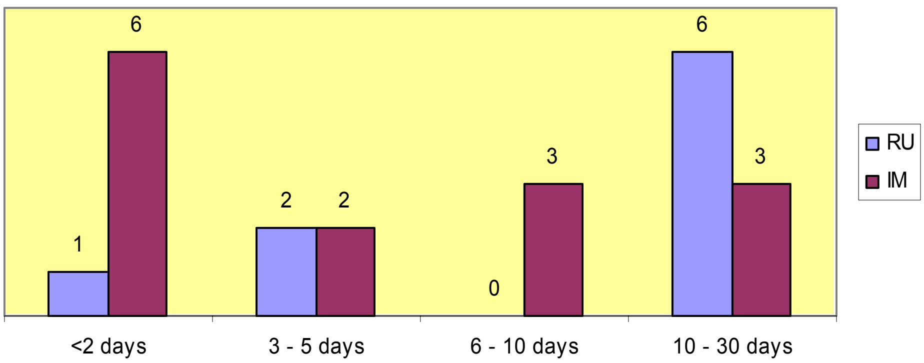

Figure 4.6: Comparison of the IMs and RUs estimation of the necessary time to respond to a short notice for a new international train path

That difference can be partly explained by the fact that several IMs have remarked that they often miss additional data from RUs to start the domestic timetable process. They could not get these data by the neighbor IM and so they have to ask the domestic RU (which hauls the train) or to give back the request to the neighbor IM to add the necessary data.

The majority of the involved RUs and IMs think that it is necessary to manage faster planning or re-planning (adaptation) of timetables (Figure 4.7). RUs appear to be more eager to get this.

Infrastructure Manager	8 YES	5 NO
Railway Undertaking	10 YES	6 NO

Figure 4.7: Responses to the question whether a fast planning or re-planning (adaption) of timetables (i.e. within 1 day) is required

In connection with this opinion, the respondents who answered 'YES' require that current performance should be improved such that re-planning is carried out within 24 hours (Figure 4.8).

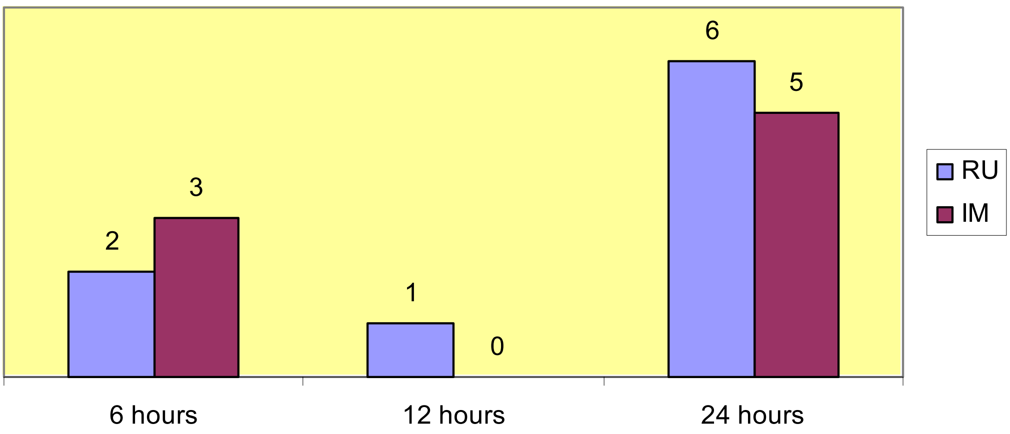

Figure 4.8: Responses to the question whether the current performance should be improved such that re-planning is carried out within the demanded period

An important and critical success factor requested by IMs to freight transports RUs, is more time flexibility in designing and providing path allocation on international corridors.

Thirteen of the fourteen IMs offer paths that are constructed ad hoc in response to demand from their costumers. Nine IMs publish their dummy or pre-constructed paths (e.g. in a public catalogue). Eight IMs have dummy or pre-constructed paths that are not available as public catalogue.

On the demand side, ten of the RUs request tailor-made paths while four RUs are content with adapted paths.

Twelve of the fourteen IMs believe that passenger and freight trains should have basically the same priority rules in capacity allocation. Only two IMs think this is not desirable and bring forward the argument that the national law determines the rules with a general preference given to public service trains.

Nine of fourteen IMs are satisfied with their available software tools. Hence, the development of further software tools should be aimed at solutions with interfaces to the domestic timetable planning systems. On the other side, only three IMs are already using decision support systems (optimisation algorithms) for timetable design and path allocation.

RUs would readily accept some regularity tolerance for the arrival of international freight trains. The comparison between the answers of IMs and RUs shows that the IMs do not sufficiently consider this acceptance of RUs in the timetable planning process (Figure 4.9).

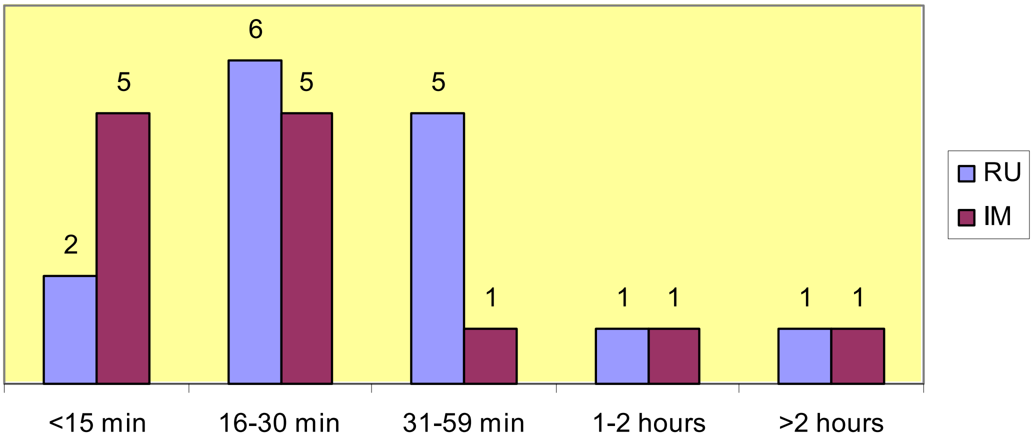

Figure 4.9: Responses to the question whether a regularity tolerance would be accepted for the arrival of international freight trains.

The IMs recognize more requirements beyond the current UIC guidelines (451-1) in international standardization in specific subjects (Figure 4.10).

rules for running time calculation	9 YES	3 NO
Standard catalogue paths	9 YES	2 NO
Locomotive traction power margins	8 YES	3 NO
haulage availability	7 YES	4 NO

Figure 4.10: Responses to the question whether the definition of more international standards are required (in the given areas).

4.3.7 Additional information about the respondents

The following figure shows the number of IMs representing different rail network extensions (Figure 4.11).

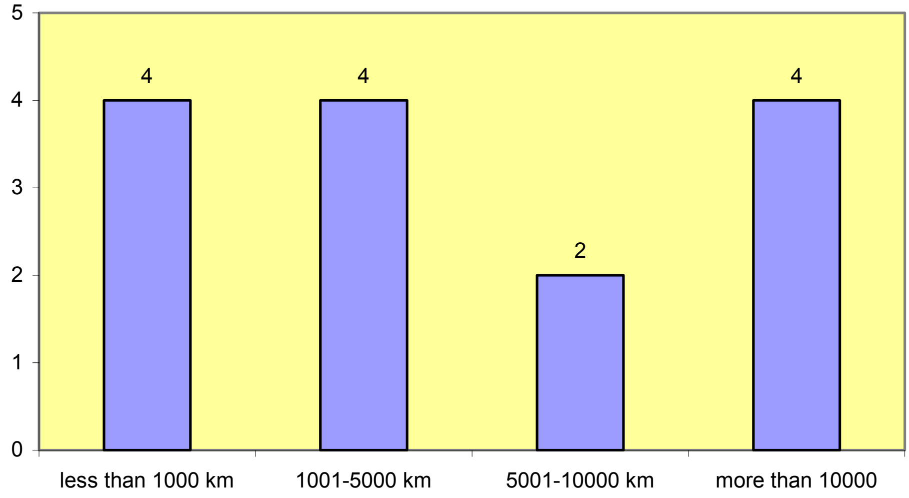

Figure 4.11: The number of IMs managing different rail networks by size

A well-balanced change of interest is also noticed within the group of RUs. The criteria are the number of international trains crossing one or more European borders that are managed by these RUs and their transport figures (Figure 4.12, Figure 4.13).

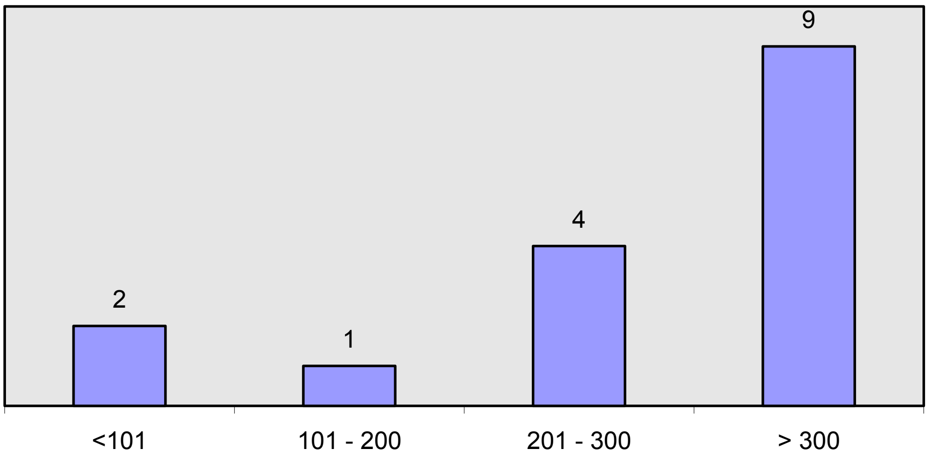

Figure 4.12: Numbers of international trains per annum managed by RUs who have given responses

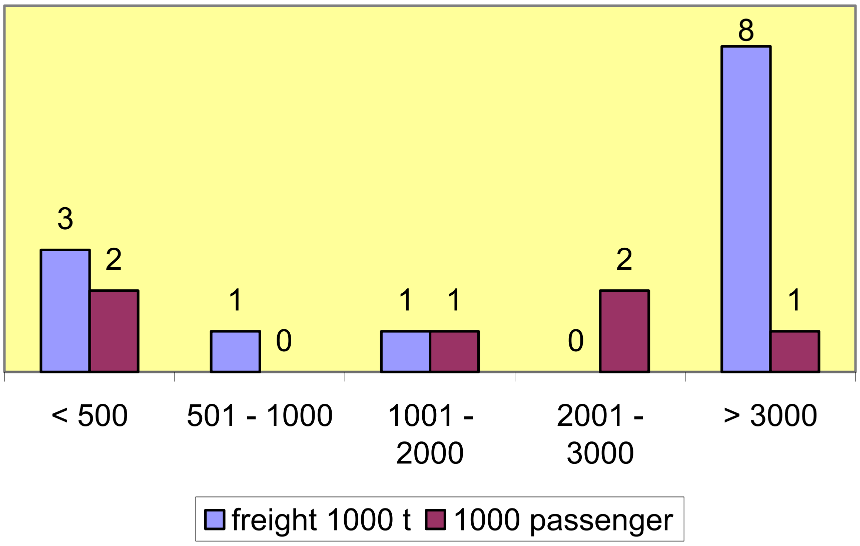

Figure 4.13: Number of RUs managing the respective transport figures per year

4.3.8 Concluding remark

The results of the survey underline the needs of IMs and RUs in the timetable planning process. The respondents confirm the objectives of project PARTNER and can help to adjust the following steps of the project.

Additional detailed information about the current situation and the problems that should be solved were given. It is thus possible to better describe the user needs and requirements. In addition, the project participants can keep in touch with several respondents to get more information about the domestic software tools and processes. Finally, we are optimistic that the survey will make a significant contribution to the other workpackages of the project and to the overall better understanding of the market.

5 The PARTNER Vision: Conclusions and future steps

5.1 Introduction

The re-reorganization of the European rail transport industry and the related open access-to-infrastructure have introduced unprecedented requirements for implementing the new market policies, their respective business models and operational tools. Major focus is on the *timetable construction process*, which is required to be more flexible and responsive to final transportation demand, particularly freight transport.

The so-called first and second-package of EU directives for the rail sector have particularly remarked the importance of timetable scheduling to support modern rail operations. Briefly we recall that:

- contingent scheduling ability is required to schedule trains for short-notice demand (i.e. 2-to-5 days);
- sufficient infrastructure capacity is to be retained for unexpected or extraordinary traffic.

Efficient timetable planning thus becomes essential to accomodate these market needs, specifically on international “corridors”, where more Infrastructure Managers need to coordinate, various working methods are to be amalgamated, and usually different tools must communicate through common language and open architecture. Procedures and technical systems for supporting the Europe-wide timetable design process are not alien to overcome their original design differences and finally reach the necessary integration.

This project is based on the recognition of this general need and the requirements to obtain an overall faster and seamless timetable planning for international trains. This vision has been generally confirmed by the user analysis and questionnaire responses, summarized in Chapter 4 of this report. In particular this survey has outlined that:

- open access and more planning needs can be adversely constrained by traditional methods and available human resources;
- use of different computer tools is a potential barrier to achieving cooperative working.
- computer and telematic penetration still remains very low in sustaining activites which are based on different and remote sites;
- paperwork and time-consuming meetings and trips still represent the general means to reach agreement on international paths.

On the other hand there appears to be an increasing recognition that more Information Technology (IT) can provide better means to facilitate the process and improve the current state-of-the-art.

At the same time when this project was proposed, the re-organization of the so-called Timetable Conferences (i.e. FTE, *Forum Train Europe*) was also taking place, and a new project referred to as PATHFINDER , was in parallel launched by FTE. In addition this has been recently taken over by the newly formed RNE (Rail Net Europe) asociation among Infrastructure Managers, as symptom of continuing evolution and finding the better way to exploit the railway market.

PATHFINDER, which is being put into production at the time of writing, has usually been described as a “communication platform” to support the work of the former Conferences. Its main rationale provides for setting up a train “dossier”, where new path requests from Railways Undertakings are collected, and the interested IMs are required to assemble the required paths, each for his domestic section; the dossier is then built up through the corresponding exchange of files, according to standard (XML) format, and a final path can be released.

All the design and decision-making activities of the timetable planning remain however in the background and the main use of the system is for process coordination and data collection. Moreover the interface and integration between PATHFINDER and the domestic Timetable Design System (TDS) remain in the responsibility of each Infrastructure Manager.

The PARTNER project understands that additional user needs are emerging and more integration requirements are to be fulfilled in the area:

1) *between* PATHFINDER and the different IM’s computer aided tools (Timetable Design System), through which the detailed path construction is carried out, and
2) among various domestic Timetable Design Systems, during the same design phase or construction of the international paths.

Furthermore one can understand that more *design support* is required, in addition to data communication and file exchange facility.

To address these requirements, we propose a three-layer architecture through which can be carried out the integration of PATHFINDER, PARTNER and the domestic Timetable Design System (TDS). The availablity of a PARTNER module can therefore “fill the gap” and improve the overall performance of both the international access-to-infrastructure (PATHFINDER focus) and the operational scheduling process (which is more PARTNER focused) on international corridors.

The other major difference between the two projects is that PATHFINDER should be regarded as a tool to support the RU-to-IM relationship, while PARTNER exclusively addresses the IM-to-IM activity.

Finally PARTNER will provide an experimental platform where more analytical and optimization algorithms for capacity utilization can be tested, while PATHFINDER represents the more official and “legal” system of path catalogue.

These concepts can be summarized in the Table 5.1 below, outlining the major points where the projects PATHFINDER and PARTNER are different or complementary.

PATHFINDER	PARTNER
Communication tool for international pathes	Design support for border-time negotiations More closely integrated with TDS
RU/OSS – to- IM dialogue	IM - to - IM (exclusively) cooperative planning support Activity typical to *IM* organization and logistic chain
Catalogue – Public information of pathes	Study, preliminary forecasts and prospective analysis; other IM internal purposes
More “train-aimed”	More “capacity- driven”
Only process oriented	Including analytical and optimization tools
Legal, institutional platform	Experimental platform
High level interface and “C2B” coordination	Mintermediate, lower level “B2B” coordination. More technical data standardization.

Table 5.1: PATHFINDER and PARTNER characteristics

5.2 Architecture Concept

The PARTNER projects rationale can be sketched in the following Figure 5.1, where the general PARTNER architecture and links with other systems and components are represented.

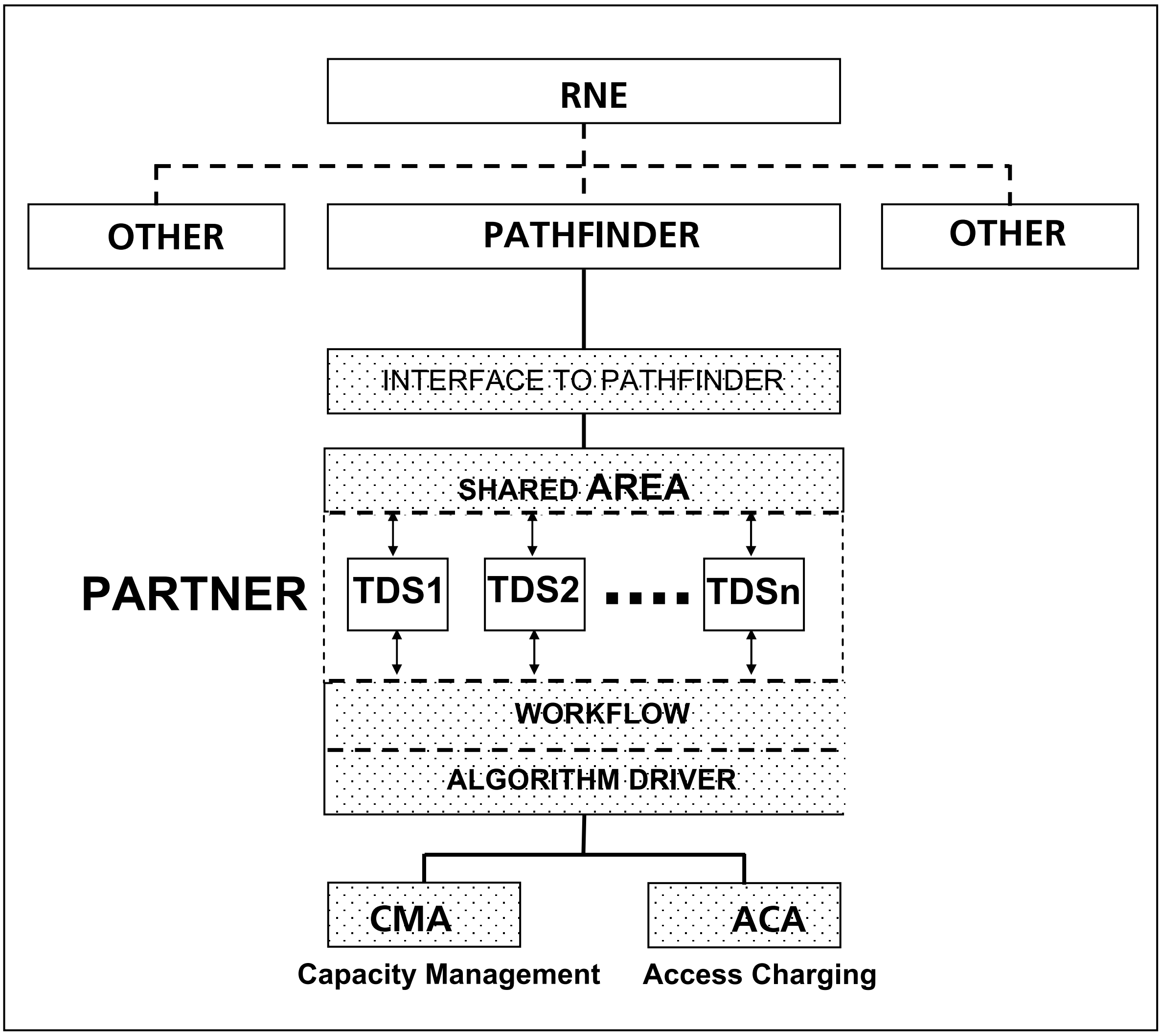

Figure 5.1: The PARTNER project architecture

The project fits in the business requirements more generally declared under the RNE – Rail Net Europe umbrella, that is the organization jointly set up by the European Infrastructure Managers to faster the access-to-infrastruture and develop the rail operations on international corridors.

To support this mission, specific business models have to be put at work, and corresponding information technology systems or tools are to be provided. Among these the Pathfinder project can fit the need for commercial access-to-infrastructure i.e. between RUs and IMs – essentially for planning, making available a path catalogue and assigning the paths.

The PARTNER project fits in the more internal, operational activities, where the various IMs have to coordinate their efforts in more detailed scheduling process, analyse infrastructure capacity and bottlenecks, and have their domestic Timetable Design Systems more closely working together, in order to prepare and finalize the paths to be upstream offered.

In this view the architecture concept is based on a layered models. It consists of the following three main layers, from top to bottom:

- The Interface to Pathfinder
- The “Core” stratum
- The Algorithm modules.

More specifically the intermediate core layer consits of further functional layers, which are made of:

- A shared working area
- A workflow engine
- An algorithm driver.

Finally the algorithm modules are made of two basic modules, respectively implementing:

- The capacity management algorithm (CMA)
- The access charging algorithm (ACA).

In between the shared or common data area and the workflow application we can virtually put the various timetable design systems of the “domestic” IM which can exchange their working data between them at relevant and agreed steps of the planning process.

We therefore observe how PARTNER is complementary to Pathfinder, and the latter can benefit and be more successful by the former. The performance of the overall timetable process on international rail corridors can obviously increase if all the process activities are implemented, and the various functions and modules are integrated within a synergic architecture.

5.3 PARTNER Use Cases

The following part of this project will design the use cases which will provide the basis of development of the project functionalities. A use case in the present context is a characteristic function to be provided by the system, through the main user interactions and expected product, including the basic sequence of operations.

Several uses cases have been so far identified and they will be expanded in subsequent work. However, for the purpose of the present report, we summarize below the major use cases which have been already defined and can be expanded in subsequent phases of the project, e.g.:

1) A new international path is cooperatively studied by two bordering IMs.
This use case outlines the exercise when one IM triggers a new path study and this is carried out through its end, in cooperation with a bordering IM. The case can be extended where more than two IMs are involved.

2) The system is used in response to a request (dossier) activated in PATHFINDER.
This use case is very similar to number 1. However the trigger event is not "internal", i.e. provided by one IM, but under the intended case the request is initiated through an "external" entity (e.g. PATHFINDER, where a new study dossier is opened following a request explicitly made by one Railway Undertaking).
This is intended mainly for using the workflow and shared area facilities of the same use case as above.

In implementing these use cases we will also aim to produce an access charging algorithm appropriate for using on international rail corridors, based on the various methods introduced in Chapter 2, and we will integrate the results of previous EU-RDT projects, as far as regards the new state-of-the-art algorithms developed for capacity management, as already described in previous Chapter 3.

The general goal is to demonstrate how the new use cases developed in PARTNER can provide the basis for new methods to undertake the capacity planning work on international corridors through more efficient, timely and co-operative solutions.

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Figures

Tables

Appendices

Glossary

Access Charging (ACA)	Algorithm for international access charging on international routes
Capacity Management (CMA)	Algorithm for optimization of timetable construction
CAD	Computer Aided Design (software system)
DB Netz	DB Netz AG: Infrastructure Manager of Germany (Deutsche Bahn AG)
EICIS	European Infrastructure Charge Information System
EU-RDT	Research, Development and Testing Programme (Framework) sponsored by European Union
FTE	Forum Train Europe. The organisation for coordinating international timetable planning over Europe (now transferred to RNE)
Infrastructure Manager (IM)	Infrastructure Manager of European Railway Networks Plural: IMs
LIBERAIL	Project "Liberalised and Interoperable Railways" in the 4th Framework of EU
OeBB	Austrian Railways
PATHFINDER	Project of Forum Train Europe (FTE) to re-organise timetable conferences (now transferred to RNE)
Rail Net Europe (RNE)	Rail Net Europe. The Organisation set up among European Infrastructure Managers in order to develop rail transport on international corridors.
Railway Undertaking (RU)	Any private or public undertaking whose main business is to provide rail transport services for freight and/or passengers with a requirement that the undertaking should ensure traction. This includes in this study also Operators offering combined transport Road-Rail, forwarders with special offers of rail freight transport and other Transport Operators; Plural: RUs
RFI	Rete Ferroviaria Italiana S.p.A. - Infrastructure Manager of Italy.
ROMAN	Route Management System. A CAD system (TDS) developed by Siemens PSE.
Timetable Design System (TDS)	Generic CAD Domestic System to support the domestic timetable planning

UIC	Union Internationale des Chemins de Fer, International Union of Railways
UIRR	Union Internationale des sociétés de transport combiné Rail-Route / International Union of combined Road-Rail transport
XML(eXtensible Markup Language)	A very flexible format used as standard to exchange information between software applications. Originally designed to meet the challenges of large-scale electronic publishing, XML is also playing an increasingly important role in the exchange of a wide variety of data on the Web and elsewhere.