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Study into best practice measures capacity enhancement for railways

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Executive Summary

An international survey was undertaken for the Dutch ministry of transport as part of the capacity enhancement program 'Landelijke markt- en capaciteitsanalyse spoor (LMCA)', The purpose of this survey was to provide an overview of international best practice solutions for improving the utilisation of railway networks, where these solutions were suitable for the specific situation in the Netherlands.

The results of this survey provide the building blocks from which different types of solutions can be formulated. It gives insight into how these solutions can be introduced to resolve bottlenecks in the Dutch rail network and enhance the network capacity. Capacity enhancement is defined for this project as the increase in number of planned train paths available.

A hypothesis driven approach was used. In this approach, 19 measures were initially identified that could impact on the capacity of the railway network. The study was then able to focus on international implementation of these 19 measures and identify additional measures that were taken by the participating countries.

The international survey included corridors and complete networks in 11 countries. These were selected to provide a reflection of the challenges being faced in the Netherlands. The lessons learned and best practices from the survey were then mapped against the actual situation in the Netherlands (taking into account including the measures already in use and current innovation programs). This mapping yielded a ranking of the measures. 4 out of the 19 measures were identified as having promising potential for capacity enhancement. These are:

- Method for timetable design
- Dynamic traffic management
- Capacity improving measures in the infrastructure
- Understanding of pinch point analyses

Method for timetable design
This measure is subdivided into three aspects, margins, base for timetable design and planning with conflict.

Margins
Margins can be broken down into three aspects. The first is the capacity that is used in planning as percentage of the theoretical available capacity. This aspect is very dependent on multiple factors, making a like for like comparison between countries difficult.

The second and third aspects are margins on travel time and margins on headway.

In the Netherlands the margins on travel time are equally distributed over the entire length of the route. It could be beneficial to apply the margins to specific locations where they are needed. In those locations where there is a confluence of lines it could be beneficial to remove all margins, both on travel time and headways, in order to maximise the capacity at this bottleneck.
Current timetable design practice sees planning being done in seconds but the operation is managed in minutes. The use of decimal minutes would prevent unintended extra margins due to rounding of figures.

Basis for timetable design
The hourly pattern as used in the Netherlands is seen as state-of-the-art for timetable design. Other type of design methods do not provide benefits from a capacity point of view. The use of the hourly pattern strictly over all hours of the day does mean that the margins are larger in off-peak hours when trains are shorter. These extra margins could potentially be used in combination with ‘margin allocation’ and ‘planning with conflict’ for additional train paths.

Planning with conflict
Planning with conflict and transferring conflict solving to the operational phase is a strong measure to prevent unnecessary capacity usage. It prevents measures such as placing a freight train in a loop (to be overtaken by a fast train) to be taken, a measure that is very ineffective when considering capacity.

Dynamic traffic management
Dynamic traffic management allows the timetable to be adjusted to reflect the actual situation at any point in time. It provides a capability to reposition margins and apply ‘just-in-time route setting’ in response to the actual situations that arise on the network. It provides a mechanism to resolve conflicts and increase performance through efficient resolution of those conflicts. This results in better utilisation of the available capacity. Just-in-time route setting prevents unnecessary occupancy of infrastructure. This is particularly an issue at highly utilised yards and junctions with at grade crossing movements.

Capacity improving measures in the infrastructure and understanding of pinch point analyses
These two measures are considered in conjunction. As large scale capacity improving measures in infrastructure (e.g. construction of additional railway lines) fall outside the scope of this study, the focus is on infrastructure measures based on pinch point analysis.
A pinch point is a location in the network that imposes a capacity restriction. it is important to conduct a thorough analysis of the pinch point in order to solve the real issue. The optimal solution needs to use a toolkit that includes assessing a wider range of stakeholders in the industry.
Whilst the pinch point analysis is not a capacity enhancement factor in itself, it plays a central role is solving capacity constraints and ensures a focused allocation of funds.

These measures individually yield time saving anywhere between 6 seconds or 2 minutes. In order to be able to take advantage of these potential savings, one must ‘make use of the second’. This means that planning and operation should work with identical time increments, being decimal minutes.

The remaining 15 measures were scored with categories of ‘++’, ‘+’ and ‘o’. Measures ranked ‘++’ do not represent a single optimal solution but can be used to supplement the most promising measures. Measures ranked ‘+’ offer smaller potential benefits but may be used selectively as part of an overall strategy to enhance capacity. Measures ranked ‘0’ did not provide any contribution to capacity enhancement within the Dutch context.

The definitive ranking is shown in the table below.

Group	#	Measure	
Planning	A	Method for time table design	+++
Operation	H	(Dynamic) traffic management	+++
Infrastructure	K	Capacity improving measures in infrastructure	+++
Planning	P	Understanding of pinch point analysis undertaken	+++
Planning	D	Alternative routing	++
Planning	E	Sub-optimisation to create capacity	++
Planning	L	Platform utilisation analysis	++
Infrastructure	Q	Signalling headways	++
Staff	R	Education of personnel	++
Planning	C	Management at junctions for through trains	+
System relationships	G	Performance regimes	+
System relationships	I	Legislation	+
Operation	O	Regulation and route prioritisation	+
Staff	S	Availability of fault clearing service rolling stock	+
Planning	B	Travel time improvement for passengers and freight	o
System relationships	F	Differentiate access charges	o
Rolling stock	J	Rolling Stock requirements	o
Infrastructure	M	Availability measures in Infrastructure	o
Rolling stock	N	ATO (Automatic Train Operation)	o

The relation between the four most promising measures and the other measures was examined to determine which sets of solutions could be applied together as a package of measure to enhance capacity. This is presented on the menu list. The menu list is categorised on the basis of the type of capacity constraint:

- general applicable solutions
- a confluence of lines over a limited length of line
- busy yards and at grade crossings

The menu list is shown on the next page.

The international survey indicated that the Netherlands is making good use of the available capacity. The identified measures will therefore not realise a major increase in capacity, they will however help to solve specific capacity issues. The menu list was applied to a case study in the Netherlands. The result was that a conflict in train paths was resolved and an extra train path was realised, whilst reducing the need for infrastructure measures.

Menu list for general capacity issues

Course 1	Applicability	Requisite	Strengthened by measure	Impacts with measure	Might benefit from measure
A1. margin allocation	Generally applicable	Dynamic trafffic management Make Use of the Second	-	Timetable Education of personnel Sub optimisation Through train at junctions	Alternative routing Platform utilisation study
A2. margin reduction	Generally applicable	Dynamic trafffic management Make Use of the Second	-	Timetable Education of personnel Sub optimisation	Alternative routing Platform utilisation study
A3. plan with conflict	Generally applicable	Dynamic trafffic management	-	Timetable Education of personnel Sub optimisation Through train at junctions	Alternative routing Platform utilisation study

Menu list for capacity constraint at confluence of lines

Course 2	Applicability	Requisite	Strengthened by measure	Impacts with measure	Might benefit from measure
A4. margin reposition	Confluence of lines	Dynamic trafffic management Make Use of the Second	Signalling headways	Education of personnel Through train at junctions Performance regime	Alternative routing Platform utilisation study

Menu list for capacity constraints at yards and at grade crossings

Course 3	Applicability	Requisite	Strengthened by measure	Impacts with measure	Might benefit from measure
H1. JIT route setting	Yards and at grade crossings	Make Use of the Second	-	Timetable Education of personnel Through train at junctions	Platform utilisation study

1 Introduction

The Dutch railway network has a high level of capacity utilisation, especially when compared to the rail networks of other European countries. It is expected that both passenger and freight transport will increase in the near future, requiring the Dutch rail network to deliver additional capacity. To address this requirement, the Ministry of Transport, Public Works and Water Management (further referred to as V&W) has instituted ‘Landelijke markt- en capaciteitsanalyse spoor (LMCA)’, a programme that aims to identify the location and nature of the bottlenecks on the rail network, and develop solutions to enhance capacity at these sites.

LMCA Spoor has two main objectives, and should deliver results in 2007:

- Develop options and identify capacity enhancement solutions to accommodate a major quality improvement for passengers in the ‘door-to-door mobility chain’
- Develop options and identify capacity enhancement solutions to accommodate increasing demand for rail freight transport

A number of work streams have been identified within the LMCA to provide a structured approach. This study interrelates with the work stream defined as ‘product’.

The purpose of this study is to provide an overview of international best practice solutions suitable for the specific situation in the Netherlands. It will provide the building blocks from which different types of solutions can be formulated and give insight into how these solutions can be introduced to resolve Dutch network bottlenecks.

V&W have formulated 5 questions to be addressed in this assignment. These are:

1. What is best practice for managing and resolving capacity issues in other countries which are experiencing increasing demand for rail transport?
2. What is the effect of these best practices in those countries?
3. To what extent and under what conditions can these best practices be adapted in the Dutch environment?
4. Which complementing and conflicting relations exist between the identified capacity utilising solutions?
5. How can these capacity enhancement solutions be structured in a typology of solutions that serve as a menu list in step 4 of work stream ‘product’ of LMCA Spoor.

This report is structured as follows:

- Chapter 2 describes the project approach, project definition of capacity and the starting hypothesis
- Chapter 3 describes the international best practice and lessons learned, with detailed information being provided in appendix 5
- Chapter 4 describes the best practices in the Netherlands and international best practices as well as the definitive ranking of measures
- Chapter 5 elaborates on the most promising measures
- Chapter 6 elaborates on the other measures
- Chapter 7 describes the impact, interrelation and prerequisites of the various measures
- The definitive menu list is presented in Chapter 8

2 Boundaries

2.1 Approach

For this study, a hypothesis driven approach is used. In this approach, a set of hypothesis regarding what would constitute a set of viable solutions for capacity enhancement in the Netherlands is identified.
The activities throughout the assignment are then focused on the verification of those hypothesis; the hypothesis will developed throughout the project.

The project was structured such that stakeholders are involved in the project at vital moments. This was realised by defining work packages and workshops with stakeholders. The following work packages were defined:

0. **Establishing starting hypothesis**: identification of an applicable list of measures and an initial ranking;
1. **Alignment with stakeholders**: discuss and refine the starting hypothesis with Dutch stakeholders, define project boundaries and definitions;
2. **Desk top research**: research work done in the Netherlands and prepare international interviews;
3. **International interviews**; develop international best practices and lessons learned, refine hypothesis into a draft list of measures;
4. **Development in depth**: discuss the draft list of measures with the stakeholders, define a definitive list of measures;
5. **Characterisation**: refinement of the identified list of measures, in conjunction to the LMCA project, to the definitive list of measures;
6. **Final report**: capture the findings in a definitive report.

2.2 Project definition of capacity

Whilst capacity enhancement has many aspects, a clear understanding of the project definition of capacity enhancement is necessary in order to be able to translate the international best practices into the Dutch situation. In the table below aspects of capacity enhancements are identified with their importance being identified jointly with stakeholders during the first workshop. A summary of the workshop is included as appendix 3.

Table 1: project definition of capacity enhancement

Aspects of capacity enhancement	Importance
Increase the number of train paths	+++++
Increase number of seats	-
Increase number of services	+++++
Reduce journey times	++
Provide more frequent 'Metro style' services	+++++
Improve performance	++
Limited/no investment	++++
Improved access to network at specific times – weekends	++
Safety culture changes to improve access	+
Maintenance/engineering requirements	-

In summary: for this project capacity enhancement is defined as the increase of number of train paths that can be offered with limited investment. The latter means that full scale track doubling or complete resignalling of the network is outside the scope of this project.

2.3 Starting hypothesis

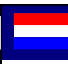
At the start of the project, 19 measures were identified that affect capacity. These measures are shown in Table 2, together with a grouping, a identification number, an short explanation of the content of the measure and their initial ranking.

The grouping of the measures is done on the basis of divisions within the rail industry. Identified groups are:

- infrastructure
- rolling stock
- staff
- planning
- operation
- system relationships

This grouping is used throughout the document, for example to map international lessons learned.
The identification number is used throughout the document. A full explanation on the measures, itemised by the identification number is shown in appendix 2.
At the start of the project, an initial ranking was made. This ranking of the measures constitutes the starting hypothesis.

Table 2: overview of identified measures, their grouping and initial ranking

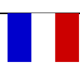
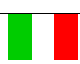
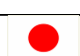
Group	#	Measure		Explanation
Infrastructure	K	Capacity improving measures in infrastructure	+	Infrastructural measures ranging from full sclae track doubling to small works based on pinch point analysis
	M	Availability measures in Infrastructure	++	Decrease down time infra / engineering hours
	Q	Signalling headways	++	Distance between signals, type of signalling (aspect as fixed or moving block) etc
Rolling stock	J	Rolling Stock requirements	++	Max speed of freight train, acceleration of regional trains, aspects related to dwell time, etc
	N	ATO (Automatic Train Operation)	o	Aspect of the automatic train control that allows the computer to drive the train
Staff	S	Availability of fault clearing service rolling stock	+++	To solve small problems in stations
	R	Education of personnel	++	Instruction and education to improve awareness
Planning	A	Method for time table design	+++	Design basis (e.g. hourly pattern), margins etc.
	B	Travel time improvement for passengers and freight	++	Harmonisation of speeds
	C	Management at junctions for through trains	++	green waves' for freight trains
	D	Alternative routing	+++	Use of route alternatives
	E	Sub-optimisation to create capacity	++	Adapt speed of faster trains, overtaking in station, etc
	L	Platform utilisation analysis	++	Dwell times, platform occupancy time, etc
	P	Understanding of pinch point analysis undertaken	++	Find the root cause of a bottleneck
Operation	H	(Dynamic) traffic management	++	Tool for regulation and restructuring of train paths in the operational phase
	O	Regulation and route prioritisation	+	Priority for specific types of trains, in planning and operation phase
System relationships	F	Differentiate access charges	++	From a capacity point of view: differentiate for time of day to relieve peak hours
	G	Performance regimes	++	Structured approach to understand the cause of delays
	I	Legislation	++	Limited operating hours of lines due to noise, investment for mitigation measures track or train side

3 International survey

3.1 Countries included

A careful selection for the international survey was made. We selected a number of countries to be considered as a whole as these have railway systems that are somewhat similar to the Netherlands. In addition to these countries we selected a number of corridors / small size networks that have (had) capacity issues. The list in completed with countries that have specific experience with one of the measures. A full overview of the countries included in the international survey is given in Table 3.

Table 3: countries included in the survey including focus

Country	Specific corridor or aspect	Reason why included in the benchmark
	n/a	Switzerland Operates the rail network with the highest train density in Europe and has introduced scheduled passenger services with transfers at every larger station at fixed time a day. With the introduction of "Bahn 2000 Phase 1" a frequency of 30 minutes for long-distance and several regional services was introduced at major lines. In addition transit traffic for freight trains on the Gotthard and Lötschberg routs has grown significantly causing bottlenecks.
	n/a	In Germany a multiple of corridors are of interest as e.g. Frankfurt-Mannheim. Here are parallel routes between these cities and these are all used by a mix of freight, long distance passenger and regional trains.
	n/a	Belgium is a country that has many similarities to the Netherlands with respect to topography and the mixture between passenger and freight trains. The main routes with the combination of (high-speed) intercity services, regional- and freight trains are of interest with respect to capacity utilisation.
	West Coast Main Line Greater London ares	The London area is known for its busy train services that are a combination of freight, metro, regional and long distance trains. Furthermore capacity utilisation at West Coast Main Line, which is just totally upgraded, is a major issue.
	NorthEast Corridor	Heavily used infrastructure with over 11.000 passenger trains and 210 freight trains a week and a mixture of regional and high-speed service
	Victoria Country Greater Sydney area	The V/Line services are challenged by the integration of freight and passenger transport over the same rails. Whilst the traffic density of the V Line network is not comparable to that in the Netherlands, there are specific similarities in the capacity utilisation issues that must be addressed. The Sydney network has great similarities with the Dutch National network. It has similar topology and faces the challenges of a diverse passenger fleet and sharing routes with freight trains.
	Warszawa-Poznan-(Berlin)	This route is a heavily used route with a combination of Eurocity, regional and freight trains and is modernised as part of the Pan-European corridor II
	Differentiation usage cost	In France, usage costs are determined on the basis of the type of line, its free capacity and the time of operations. This is a used to regulate actual routing and stimulate off-peak travel by financial means.
	Performance regime freight	The performance regime is used since 1 January 2005 and allows a clear allocation of reasons for delay. Such information helps with identifying bottlenecks in the network. The program reduced the delays and is therefore interesting with respect to actual line capacity and reliability of services (=quality).
	Capacity management on Brenner route	In order to further develop international freight traffic on the international München – Verona corridor, A corridor management system (CMS) is developed. The CMS is the basis for a capacity increase.
	Short, fast freight trains	JR Freight has developed a 16-car train set that is composed of two powered cars at each end and 12 intermediate trailing flat wagons. With a maximum speed of 130 km/h and bi-directional running such trains could be more easily mixed with passenger trains.

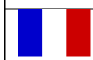
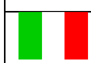
3.2 Lessons learned

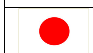
For the countries and focus corridors introduced in Table 3, a desk research was performed and focused interviews with representatives of the railways were carried out. For the interview a standardised questionnaire was used as a guidance. This questionnaire is shown in appendix 9. The full results of the desk research and the interviews are provided in appendix 5. The results are summarised in lessons learned as shown in Table 4. Please note that the lessons learned are shown by the groups as introduced in Table 2. The lessons learned summarise the views of these countries on the respective measures in the groups.

Table 4: international survey, lessons learned

	Infrastructure	Rolling stock	Staff	Planning	Operation	System relationships
	• Adaptation of signalling headways to improve capacity at lines with maintenance activities with longer duration; • ETCS level 2 improves capacity at lines with large differences between various trains and at yards	• Changing type of rolling stock is considered when timetable constraints are identified	• Educating staff for new measures is relatively easy • When introducing operational measures take impact on motivation into account	• Planning is made with 6 sec time units; • Reduction of the punctuality norm is necessary to take advantage of small time savings • Train delays due to speed restrictions for long construction activities are included in the timetable • Grouping of train paths with same characteristics maximises capacity • Small planning conflicts are transferred to operation phase	• Optimisation of the departure procedure reduces the time that a set train path is not used • Real time re-scheduling; • Constraining train drivers to their train path is necessary to prevent interaction of succeeding trains	• Access charges not used to influence capacity
	• Large infrastructure projects required to meet the need for additional services		• Staff need to be trained and the emphasis put on service operation and timekeeping	• Additional trains are added to the train plan on a short term basis not included in the permanent timetable plan	• Regulation and timekeeping important if additional services are to be operated on the Network	

	Infrastructure	Rolling stock	Staff	Planning	Operation	System relationships
	• Capacity improvement is not an issue in the discussion to implement ERTMS				• Rerouting is frequently used during operation • During long period of construction work for HST, a triple track section is used to be able to shift crossing movements of trains and thus avoid conflict • Traffic optimisation model used in conjunction with former item	• Differentiation of access charges have no impact on passenger services and only very limited on freight •
	• Targeted investment to remove infrastructure pinch points instead of wholesale new lines and infrastructure • Focus on best use of station capacity	• Longer trains are being used to deliver more train capacity before infrastructure changes		• Stopping patterns of trains are altered in order to avoid potential conflicts		• Formal process introduced to meet forecast growth – Route Utilisation Study • Each improvement must have a business case and value for money
	• Targeted investment to remove infrastructure pinch points instead of wholesale new lines and infrastructure					• Each improvement must have a business case and value for money
	• Use of loops to generate additional capacity on the main line • Use of bi- directional signalling to improve overall performance	• Investment in rolling stock to decrease sectional running times		• Use of pinch point analysis		• Framework agreements are used for capacity allocation

	Infrastructure	Rolling stock	Staff	Planning	Operation	System relationships
	• Modernisation works include capacity improving measures: o increase of line speed o reduced signal spacing o reduced switch angles			• Margins on travel time are applied on the basis of infra quality / age		• Height of access charge based on line quality and type of train • Access charge is not used to regulate capacity • Ccancellation of train path is charged with 25% of the total price
						• differentiation of access charges have no impact on passenger services • access charges consist of five aspects • reservation fees need to be paid • cancellation fee for train paths is considered
				• Catalogue freight paths increase capacity and quality of train path • Catalogue paths for long distance travel is considered		• Performance regime does improve performance as it gives information on the cause of delays and thereby the means to resolve issues • Access charge is not the main cost driver for operators when considering time of travel • Allocation of penalties does not lead to major issues between parties

	Infrastructure	Rolling stock	Staff	Planning	Operation	System relationships
		• Interoperability of locomotives is key issue to relieve congestion at border stations		• Definition of catalogue train paths helps to maximise available capacity • To guarantee the free-market system train path ownership needs to be reconsidered • Required flexibility can be provided by e-services for train path allocation	• A corridor quality management system, supported by training of personnel, aids performance and reliability	• Take a holistic approach to solve corridor issues • Involve all major stakeholders in solving the issue
		• Fast freight trains are not used to operate in between passenger services • environmental awareness driver for modal shift from road to rail				

Gray shaded areas were not considered as part of the benchmarking, refer Table 3

4 Best practices and applicability in the Netherlands

4.1 Characteristics of the Netherlands

The Netherlands have one of the busiest railway networks in the world. Every day approximately 5,400 passenger and 300 freight trains use the network that comprises some 6.500 track kilometres.

The Dutch timetable is based on an hourly pattern that effectively is a 30 minute pattern.

With the rapid growth of passenger and freight transport, optimisation of capacity usage is a permanent issue. Some of the measures for capacity enhancement as defined for this project in section 2.3 are common practice. In addition to these commonly used measures, new measures are being tried such as:

- Smart overtaking: overtake a regional train in a station without increasing the dwell time for the regional train;
- RouteLint: a tool to provide the train driver with up-to-date info on trains in front and behind him aimed to improve punctuality and reduce energy consumption.

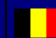
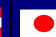
More detailed information on the Netherlands in included in appendix 4.

4.2 Overview best practices

Table 5 gives an overall overview of best practices. This table gives the following information:

- column 1 – 3: list of measures as introduced in section 2.3
- column 4: *initial ranking*, this column shows the initial ranking as per starting hypothesis
- column 5: *ranking after WS1*,with the discussion with stakeholders in workshop the initial ranking was refined
- column 6: *in use in NL*, this column show what measures are currently in use in the Netherlands
- column 7: *innovations in NL*, measures that are being tried, the measures marked with X1 are part of a single innovation
- column 8: *identified areas for improvement NL*, in an earlier study commissioned by the ministry, areas for improvements were identified
- column 9 – 19: these are international best practices established on the basis of the lessons learned
- column 20: *final ranking*, this is the final ranking as applicable to the situation in the Netherlands; the final ranking represents an expert opinion and is based on the best practices and lessons learned, combined with the situation in the Netherlands and measures already taken, as summarised in column 6 – 8; (Example: use of regional trains with improved acceleration characteristics is seen as a best practice for measure J, it is scored ‘o’ as this is already implemented in the Netherlands so no extra benefits can be gained.)

Table 5: overview table of best practices in the Netherlands and international best practices combined with provisional and definitive ranking of measures

Group	#	Measure	Initial ranking	Ranking after ws 1	In use in NL	Innovations in NL	identified areas for improvement NL												Final ranking
Infrastructure	K	Capacity improving measures in infrastructure	o	+	X	X1		X	X	X	X	X	X	X			X		+++
	M	Availability measures in Infrastructure	+++	++	X														o
	Q	Signalling headways	++	++		X1				X									++
Rolling stock	J	Rolling Stock requirements	o	++	X						X		X					X	o
	N	ATO (Automatic Train Operation)	o	o															o
Staff	S	Availability of fault clearing service rolling stock	++	+++															+
	R	Education of personnel	+++	++				X	X										++
Planning	A	Method for time table design	+++	+++	X		X	X			X			X		X	X		+++
	B	Travel time improvement for passengers and freight	+	++	X														o
	C	Management at junctions for through trains	++	++	X												X		+
	D	Alternative routing	+	+++	X														++
	E	Sub-optimisation to create capacity	++	++	X					X									++
	L	Platform utilisation analysis	+++	++							X								++
	P	Understanding of pinch point analysis undertaken	+++	++	X						X		X				X		+++
Operation	H	(Dynamic) traffic management	+++	++	X	X		X		X									+++
	O	Regulation and route prioritisation	+++	+	X														+
System relationships	F	Differentiate access charges	o	++															o
	G	Performance regimes	+++	++							X					X			+
	I	Legislation	+	++			X												+

4.3 Discussion on changes in ranking

A number of measures see a relatively big change between the initial, workshop 1 and final ranking. The major reason for these changes lay in the clear definition of capacity for this project, see section 2.2, that was defined after completion of workshop 1. The table below elaborates on the reason for the changes for these measures.

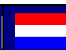
Table 6: elaboration on reasons for a changed ranking

Group	#	Measure	Initial ranking	Ranking after ws 1	Final ranking	Elaboration on changes in ranking
Infrastructure	K	Capacity improving measures in infrastructure	o	+	+++	At the time of the initial ranking the definition of this measure included large scale infra measures; after defining the project definition of capacity, large scale measures were excluded, and the score applies to small scale infra measures based on pinch point analysis
	M	Availability measures in Infrastructure	+++	++	o	With the more precise project definition for capacity we found that although this is an important aspect for the overal system performance it will not create additional capacity in planned capacity
Rolling stock	J	Rolling Stock requirements	o	++	o	Such measures have a large impact on capacity but it was found that a lot of aspects are already implemented in NL
Staff	S	Availability of fault clearing service rolling stock	++	+++	+	Although an important aspect for overall performance, there is no direct link with timetable margins and therefore no increase in planned capacity can be expected
	D	Alternative routing	+	+++	++	The possibilities in NL for rerouting are greater then aknowledged at the time of the initial ranking; all alternative routes however still use busy corridors
Operation	O	Regulation and route prioritisation	+++	+	+	This is potentially a strong measure but can not be used as a result of the non-discriminatory principle for allocating train paths.
System relationships	F	Differentiate access charges	o	++	o	A strong measure for regulating actual utilisation of capacity but it has no impact on planned capacity; the differences in ranking are due to the clear project definition of capacity
	G	Performance regimes	+++	++	+	Initially ranked as a strong measure as these help to find the root cause for problems; when considering the project definition of capacity it does not provide extra capacity in itself but is a strong support for pinch point analysis, see the table with interrelation between measures

4.4 Definitive ranking of measures

Column 20 of Table 5 shows the final ranking as applicable to the situation in the Netherlands. The final ranking represents an expert opinion and is based on the best practices and lessons learned, combined with the situation in the Netherlands and measures already taken. The definitive ranking, sorted by ranking, is shown in Table 7.

Table 7: definitive ranking of measures

Group	#	Measure	
Planning	A	Method for time table design	+++
Operation	H	(Dynamic) traffic management	+++
Infrastructure	K	Capacity improving measures in infrastructure	+++
Planning	P	Understanding of pinch point analysis undertaken	+++
Planning	D	Alternative routing	++
Planning	E	Sub-optimisation to create capacity	++
Planning	L	Platform utilisation analysis	++
Infrastructure	Q	Signalling headways	++
Staff	R	Education of personnel	++
Planning	C	Management at junctions for through trains	+
System relationships	G	Performance regimes	+
System relationships	I	Legislation	+
Operation	O	Regulation and route prioritisation	+
Staff	S	Availability of fault clearing service rolling stock	+
Planning	B	Travel time improvement for passengers and freight	o
System relationships	F	Differentiate access charges	o
Rolling stock	J	Rolling Stock requirements	o
Infrastructure	M	Availability measures in Infrastructure	o
Rolling stock	N	ATO (Automatic Train Operation)	o

5 Elaboration on most promising measures

5.1 Introduction

A review of best practices for capacity enhancement in the survey countries indicate that 4 out of the 19 identified measures which are promising for capacity enhancement, see also Table 7. These are:

- Method for timetable design
- Dynamic traffic management
- Capacity improving measures in the infrastructure
- Understanding of pinch point analyses

These measures are elaborated on in the following sections. Sub measures are identified if appropriate and conclusions are captured in blue boxes.

The latter two measures are considered in conjunction, as large scale capacity improving measures in infrastructure fall outside the scope of this study, hence the focus is on infrastructure measures based on pinch point analysis.

5.2 Method for timetable design

Timetable design has a fundamental impact on capacity. The best practice review indicates that with regard to capacity enhancement, the most important elements of timetable design are:

- applied margins
- base for the timetable design
- planning with conflict

5.2.1 Margins

Margins on travel time and headway in the timetable are used in conjunction with a maximum used percentage of theoretical available capacity, to build in recovery time from potential disruptions in the operational phase, i.e. stability.

Maximum planned capacity use
In order to create a stable operating service, the available capacity on the railway network cannot be utilised at 100% throughout the day, as this eliminates the ability of the timetable to absorb disruptions. UIC recommends 76% as a maximum based on long term experience from its members.

The benchmarking indicates that there are great differences in the maximum capacity that is used. In the Netherlands up to 80% is used, Switzerland is progressing towards 85%. In a number of countries it is common practice to have higher percentages during peak hours, in the UK up to 110% is used and in Italy around major cities up to 100%. Germany claims to use 140% on certain lines. Disruptions in traffic can in these cases can be recovered from during off-peak hours.

It should be emphasised that the level of utilisation is dependent, amongst others, on the signalling system and train speed. For example, using caution signals can raise the level of capacity utilisation by reducing the headway between trains. The capacity utilisation value itself does not capture the number of trains as illustrated with a simple example in the figure below, showing two railway lines that are both ‘full’.

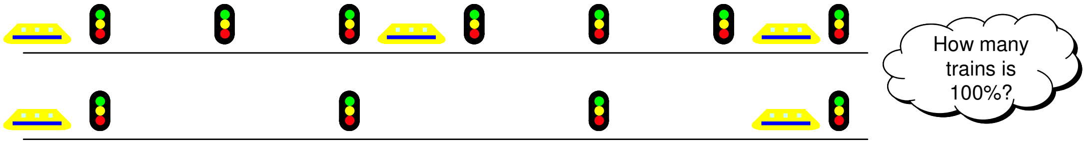


Figure 1: visualised discrepancy between network capacity usage and number of trains

Other aspects that effect the level of utilisation are whether empty trains are scheduled and the size of margins.

The percentage of used capacity is dependant on multiple factors, making a like for like comparison difficult. The level of utilisation does not provide information on the theoretical capacity available – the number of train paths provided.

Other margins
Various margins are used by railway administrations to allow the service to recover from disruptions and prevent conflicts between services. Whilst rail administrations have adopted different approaches to define the margins, the basic principles are the same. Applied margins can be summarised in two groups:

- margins on the travel time
- margins in the headway

Within the timetable planning process, these margins can be applied in a number of different ways each having a different impact on capacity. This is illustrated in the figure below showing time distance diagrams for three basic cases.

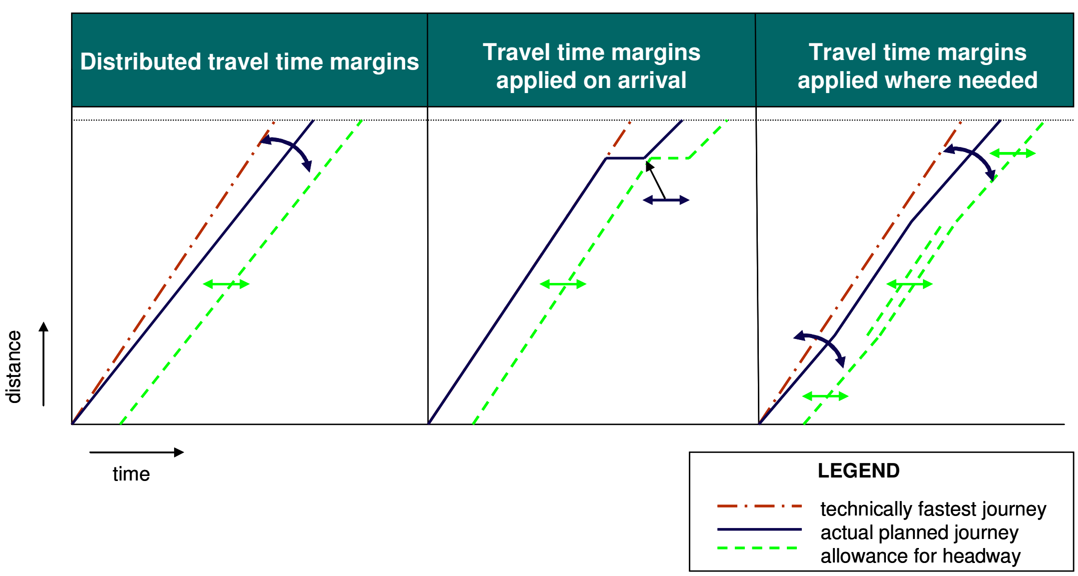


Figure 2: possibilities of margin application

The left part of the figure illustrates where the margin on the travel time is equally distributed over the entire length of the journey, with the margin on headways as a fixed value on every section. This approach is used on most European railway systems.

The middle part of the figure demonstrates a case where the margins are applied just before arrival at the destination. This type has the implication that if platform tracks are occupied, trains will come to a stop in front of the station with the likeliness of arriving late due to the lower speeds in the final section. Also here, the headway margins are fixed values over the entire line. This type is in use in Great Britain.

The right part of the figure above shows a case where the margins are applied at the location where they are needed. This case illustrates where two lines run together and all margins have been removed either before or after this section. The total margins on the entire journey are the same as for the other two cases, but the removal of margins in the middle section allows for an increase of capacity in that section. This type has been successfully applied at a number of pinch point locations throughout Europe in order to increase the throughput of trains, although mostly on a trial basis.

The margins on headways are generally 15-40%. Due to rounding of the calculated figures to whole minutes, extra time is added to the margin. Planning with seconds or decimal minutes and using the same unit in the operational phase would prevent this extra unintended time to be used.

Develop towards application of travel time margins to locations where these are needed. Focus use of equally distributed margin on travel time at those lines without specific pinch points.

Reposition margins before and after pinch points in order to maximise the available capacity.

Use decimal minutes for planning and operation to prevent unintended extra margins to take up capacity as a result of rounding up.

Margins are the link between the performance and capacity of a railway, and performance related measures tend impact on capacity, refer to section 7.1 for further details.

5.2.2 Base for timetable design

Many approaches for timetable design exist and the hourly pattern is regarded as state of the art. An hourly pattern requires relatively large traffic volumes and is only used in the Netherlands and Switzerland. Germany and Belgium use a cadenced time table with additional services during peak hours. In countries with lower traffic volumes, long distance and inter regional services are provided based on arising demand with less

An alternative to the hourly planning is the clock faced timetable with departures at times like .00, .15, .30, .45. This is easy for passengers to remember, although there is often a difference in the published timetable and the planning in order to solve constraints in the planning. A clock face timetable imposes severe restrictions on the planning flexibility predictability for the passenger, examples are Poland, Italy and France. The planning is more difficult as 24 hours a day need to be planned, compared to 1 hour in an hourly pattern timetable. Italy are developing its timetable design towards long distance catalogue paths.

Although hourly patterns are regarded as state of the art as the basis for timetable design they impact capacity and planning flexibility. In terms of capacity, the schedule is based on the longest train. A long train is slower due to the fact that it is longer in an area where lower speeds apply (at yards) and for countries with 1500 V DC overhead lines, the maximum traction is limited resulting in slower acceleration rates for electric multiple units.

Timetabling methods other than the hourly pattern do not provide more capacity. The hourly pattern timetable however has potentially higher margins during the off-peak that could be used in combination with ‘margin allocation’ and planning with conflict. Flexibility with respect to train intervals within the hour makes optimal use of capacity possible (e.g. intervals between 4 identical services at 13 – 17 – 13 – 17 minutes rather then all intervals being 15 minutes).

5.2.3 Planning with conflict

Transferring conflict solving to the operations has benefits in terms of resolving small service irregularities. Incoming international freight is particularly sensitive to delays (on certain routes) and hence solving all conflicts in the timetable is not an optimal approach.

The allowable severity of the conflict should be based on the types of trains involved (freight or passenger), and a 1 or 2 minute conflict could be deemed acceptable for passenger trains.

The allowable severity of the conflict is a function of the definition of punctuality. Punctuality is generally defined as arriving at the destination within a fixed number of minutes of the scheduled arrival time. Different punctuality norms are used throughout Europe as illustrated by a comparison of norms used for passenger trains:

- 2 minutes Switzerland
- 3 minutes The Netherlands
- 5 minutes Belgium, Germany, Italy regional services
- 15 minutes Italy, long distance services

Planning with conflict and transferring conflict solving to the operational phase is a strong measure to prevent unnecessary capacity usage.

5.2.4 Timetable measures in summary

In summary, the measure of timetable design can be broken down into 4 aspects:

- Margin allocation
- Margin reposition[1]
- Margin reduction
- Plan with conflict

[1] *Margin reposition is a differentiation of margin allocation and is identified as an individual aspect as this can be used to solve different challenges.*

5.3 Dynamic traffic management

Dynamic traffic management is a tool that can support in the following situations:

- handle conflicts during operation
- just-in-time route setting
- increase of overall performance

Dynamic traffic management is operational in a number of European countries but currently limited to specific line sections or on trial basis. Network level deployment of dynamic traffic management could allow significant benefits to be achieved, as elaborated in the table below.

Table 8: aspects of dynamic traffic management

	Conflicts	Just-in-time route setting	Overall performance
explanation	• provides insight into the impact of operational choices, which is the key to solve operational issues with a minimum of lost time and capacity • it allows removal or significant reduction of margins at a confluence of two lines	• informs all stakeholders of actual time to prevent routes to be set and not used for multiple deciminutes as is the case with the normal train departure procedure	• allows adjusting the train speed in order to avoid a red signal improves the throughput • allows anticipation of train delay impact on other trains and connecting services
requisite	• short calculation times for solutions • real time info on actual (revised) train schedule for stakeholders	• training and trust of personnel	• train driver sticks to its schedule • short calculation times for solutions • real time info on actual (revised) train schedule for stakeholders

Dynamic traffic management is a requisite to reduce margins, reposition margins and supports increasing performance.

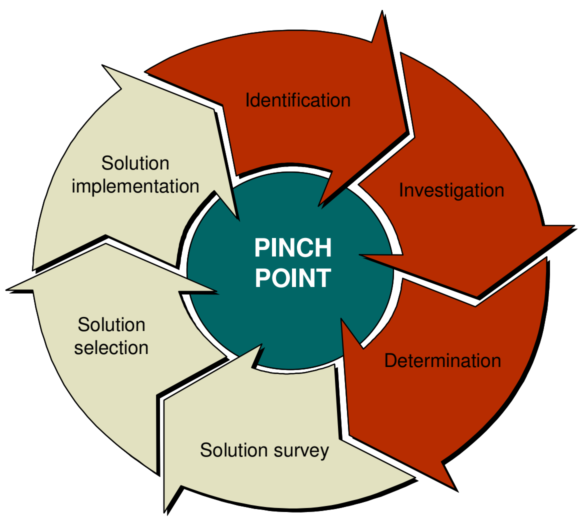
Just-in-time route setting prevents unnecessary occupancy of infrastructure, which is particularly an issue at highly utilised yards and junctions with at grade crossing movements.

5.4 Capacity improving measures on infrastructure based on pinch point analysis

Focused analysis of pinch points results in cost effective and feasible measures that may or may not involve infrastructure measure. Understanding pinch points can be broken down into 6 steps:

- Identification
- Investigation
- Determination
- Solution survey
- Solution selection
- Solution implementation

In the UK a solution toolkit is defined giving a full overview of possible measures, see Figure 3. Such a toolkit should be made specific for application in the Netherlands.



PINCHPOINT SOLUTION TOOLKIT

- Timetable solutions
  - Mix of services
  - Passenger train stopping patterns
  - Quantity of trains on particular route sections
  - Routeing of longer-distance services
- Length of trains
- Rolling stock solutions
  - Deployment of rolling stock type
  - Internal design of passenger rolling stock
- Demand management arrangements
- Engineering access arrangements
- Station depot and freight terminal locations
- Infrastructure solutions
  - Track
  - Signalling
  - Stations

Figure 3: process structure to understand pinch points

It must be emphasised that pinch point analysis in itself is not a capacity enhancement factor, but it does play a central role is solving any capacity constraint.

Conduct a thorough analysis of the pinch point and chose the optimal solution using a toolkit which includes assessing a wider range of stakeholders in the industry.

6 Elaboration on other measures

6.1 Measures ranked '++'

Measures ranked '++' do not represent the optimal solution, however they can supplement the '+++' ranked measures.

6.1.1 Alternative routing

The network in NL does provide a number of opportunities for alternative routing, though this is only an option for freight trains. As alternative routes are generally longer, using these routes affects journey time (including the rolling stock turnaround time) and personnel deployment, as well as increasing energy consumption. Therefore it is important that the decision to use alternative routes is made with consensus between planner and operator. Alternative routing can also be built into the timetable planning as an option should disruption occur.

6.1.2 Sub-optimisation to create capacity

Speed harmonisation is a strong measure for capacity enhancement but results in increasing journey times for long distance traffic. In most European countries this is seen as unacceptable as long distance passenger traffic has absolute priority, and hence this measure is not applied. In terms of capacity enhancement, this is a potentially strong measure, however application of speed harmonisation needs to be viewed in the context of prioritisation of long distance services which, in reality, will limit its viability.

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Sub-optimisation has been applied to freight services, which in practice means that these trains are placed in a loop. Unless the loop is of sufficient length to allow the train to enter and exit the loop at maximum speed (very long loops) such measures use up significant capacity due to the relatively slow deceleration and acceleration of freight trains. Delaying a long distance train for 1 or 2 minutes in the schedule in such a case is preferable in terms of capacity.

6.1.3 Platform utilisation analysis

Train stations can be capacity bottlenecks especially at termini stations where trains have relatively long dwell times. Where there are capacity issues at stations, utilisation analysis of platform capacity helps to identify appropriate measures. Platform utilisation analysis is essentially a specific application of pinch point analysis.

6.1.4 Signalling headways

On many sections of rail networks, signalling headways are a key constraint on the number of available train paths, see Figure 1 in section 5.2.1. Often average figures for signalling headways are used with specific information only available at the most highly utilised locations. With the increase of services and planning of catalogue paths, the use of average headways potentially results in an understatement of the available capacity. Analysis of actual signalling headways per route and their use in timetable planning is advisable. Improvement of headways should be carried out as part of pinch point solving.

Full scale introduction of ETCS level 2 from a capacity point of view is interesting for yards and lines with mixed traffic, i.e. great differences in train characteristics. As this requires a major investment in the total transportation system, this falls outside the scope of this project, refer to section 2.2.

6.1.5 Education of personnel

Education of personnel is a key driver for an on-time operation, the quality of staff underpins the success of all rail operations. Further training staff to proactively and efficiently work to resolve problems can generate significant capacity enhancement. An important aspect is giving responsibility to staff, and encouraging ownership of the issue.

6.2 Measures ranked '+'

Measures ranked '+' offer smaller potential benefits but may be used selectively as part of an overall strategy to enhance capacity.

6.2.1 Management at junctions of through trains

Unplanned stopping of freight trains uses up significant capacity and can severely increase journey times. Timetable design is generally focused on passenger traffic on certain corridors and travelling between major hubs. The design should be extended to include planning for freight services travelling through the hubs. Also in terms of operations delaying a freight train on one corridor by even two minutes could result in the train missing its slot on the adjacent corridor. A dynamic traffic management system would help by determining the impact of a decision to delay a freight train on its entire journey.

6.2.2 Performance regimes

Performance regimes are powerful tools to determine the root cause of conflicts, potentially improve performance, and identify operational trends. Often the regime is also used as a means of allocating delays, and unproductive time is spent on blaming other parties, limiting the effectiveness of this measure. However the results are varied, the experience with the performance regime in Italy is very positive whilst in the UK the system tends to have more problems with the penalty allocation.

6.2.3 Legislation

Noise legislation affects network capacity by limiting opportunities for rerouting freight during night hours due to noise thresholds. Although it is commonly recognised that diminishing noise at the source is more effective, legislation prevents the government to subsidise modifications to trains but allows erection of noise screens. Trials with innovative breaking systems show promising results, so a review considering the amendment of legislation to subsidise noise-reduction investment on trains would provide capacity benefits.
An other aspect of legislation is capacity allocation in case the demand is higher than the available capacity. EU guideline 2001/14 considers that capacity allocation should be in line with a maximisation of capacity usage. This could e.g. mean that faster trains are slowed to provide more train paths.

6.2.4 Rolling stock requirements

Acceleration rates for rolling stock are especially interesting for regional services. A greater number of doors and an adapted interior design will facilitate faster loading/unloading of passengers reducing dwell times. Increased acceleration, combined with shorter dwell times, results in a higher average train speed. It can therefore be considered as an alternative method for speed harmonisation. Although a strong measure, the score is low as such trains are already used in the Netherlands with the Sprinter trains, with new Sprinter trains in delivery.

6.2.5 Regulation and route prioritisation

Regulation in the timetable design is in conflict with the non-discriminatory principle. In operations route prioritisation can help reduce the recovery time from disruptions. Understanding the impact of prioritisation decisions can be provided by a traffic management system.

6.2.6 Availability of fault clearing service for trains

An aspect that is of interest in operations is ensuring that trains with small defects are quickly repaired. Comprehensive analysis of rolling stock defects would identify the most frequent failure modes. Availability of fault clearing services at those locations where they are most common (e.g. combining and splitting of EMU's in stations) increases performance of the system.

6.3 Measures ranked with 'o'

The remaining ranked 'o' measures will not contribute to capacity enhancement.

6.3.1 Travel time improvement for passenger and freight

Improved acceleration of regional trains is considered under rolling stock requirements. Faster intercity services increase capacity constraints as the speed difference between faster and slower trains increases. Freight operators are focusing on increasing tonnage rather than increasing speed. The fast freight train in Japan is used to make the round trip during nights as part of the total parcel delivery chain and is not used to operate in between passenger services.

6.3.2 Differentiation access charges

Differentiation of access charges has been implemented or considered in a number of countries but is not seen as a measure to increase the available number of train paths. Passenger services are defined by demand and these are highest during peak hours. For freight services, the differences in charges are relatively low and other factors are more important cost drivers such as personnel costs. Furthermore, international freight train journeys are long and peak hours will be travelled more than one country.
The many aspects that are part of differentiation of access charges, e.g. reservation and cancellation fees, can however play a role in the actual utilisation of planned train paths and structuring the demand for train paths.

6.3.3 Availability measures in infrastructure

Availability measures in the infrastructure reduce the down time. When considering the hourly pattern as a basis to design the timetable, such measures do not provide extra capacity. However, for the overall performance of the transportation system, this is an important aspect.

6.3.4 Automatic Train Operation

Automatic train operation is the means to realise a very predictable train operation. Different levels of ATO exists with different involvement of train personnel. The use of ATO is especially suited for metro networks with a confined network size and confined rolling stock fleet.
The open and interoperable network make ATO poor value for money and unfeasible when considering open access. ATO is not being considered by any rail administration. The proposed measures, with optimised departure procedures, re-time rescheduling, operation on deci minutes and train drivers sticking to their paths effectively cover aspects of ATO but with the driver fully responsible for driving the vehicle.

7 Aspects of application of the measures

7.1 Relation between performance and capacity

The discussed measures have an impact on either performance or directly on capacity. Improving performance has an indirect relation to capacity via margins. This relation is explained in the following.

With a defined stability level, a key issue for enhancing the useful capacity of the network is improving the performance. Performance and margins are the levers to realise a stable operating service, see the left side of Figure 4. At the same time margins and the number of train paths are the levers for network usage.

Improvement of performance would allow the margins to be reduced, which would create the possibility for extra train paths. It must be emphasised that performance improvement is an aspect that takes some time to implement and take the full benefit from. Taking measures to improve performance will therefore not directly result in an increase of train paths that can be scheduled, it will take a year or two before the impact in capacity can be capitalised.

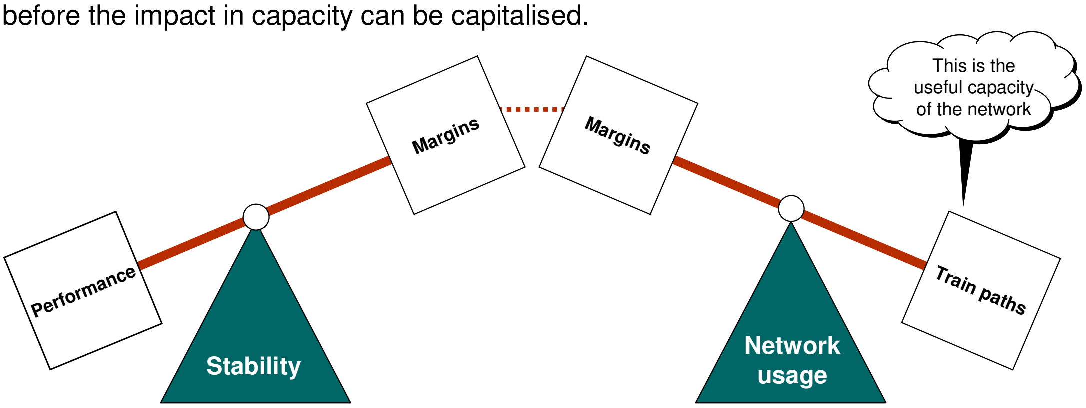


Figure 4: relation between performance and capacity

7.2 Impact of promising measures

As discussed in previous sections, the utilisation of the Dutch network is high, and many (aspects of) measures are already in use to maximise the number of train paths in the timetable. The promising measures as discussed in section 5 do therefore not represent a major break though but still they potentially can have a significant impact on capacity. Table 9 on page 31 gives a summary of the most promising measures, their potential impact and prerequisites.

The measures can support solving constraints in the planning, making an impossible train path possible or reduce the need for large scale infrastructure measures. An example of application of a suite of measures is discussed in section 7.5

Table 9: summary table of promising measures with yield and prerequisites

	TIMETABLE	TIMETABLE	TIMETABLE	TIMETABLE	DYNAMIC TRAFFIC MANAGEMENT	PINCH POINT
	Margin allocation	**Margin reposition**	**Margin reduction**	**Plan with conflict**	**JIT route setting**	**Analysis**
Description	Apply margins where needed instead of e.g. uniform distribution of travel time margins and fixed margins on headways	Remove all margins from a line section with limited length that has a capacity issue. Reposition the margins outside this line section	Reduce the applied margins	Leave small conflicts in the planning to be resolved in the operational phase	Optimise the departure procedure in stations to prevent not-used routes; evaluate route setting procedure in other situations	A correct understanding of the actual cause of the pinch point is essential in solving it
Yield	App 1 to 10 deciminutes per train path	App 10 to 20 deciminutes per train path	App 3 to 8 deciminutes per train path	Up to app 60 deciminutes per conflict	App up to 10 deciminutes per route set	Dependant on situation
Prerequisite	MUS	MUS Dynamic traffic management	MUS Dynamic traffic management	MUS Dynamic traffic management	MUS	Sufficient data on the problem

MUS: Make Use of the Second: adopt planning and operational time unit in deci minutes, refer section 7.3

7.3 Make use of the second

As shown in Table 9, the identified measures yield time savings anywhere between 6 seconds and 2 minutes. In order to take advantage of savings in the seconds, planning and operations should work with the same time increments, as visualised in Figure 5. For example: a saving of 40 seconds in a system with punctuality norm of 5 minutes is meaningless: trains will float anywhere between the schedule and + 5 minutes and still be on time. The same 40 seconds with a punctuality norm of 1 min is significant.

In order to take advantage of the promising measures one must 'make use of the second'.

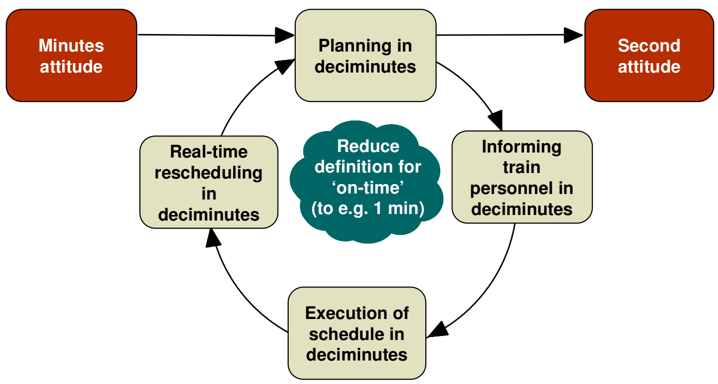


Figure 5: towards a second attitude

Awareness of the importance of the second is a cultural issue. Personnel will need to get used to work on the basis of seconds rather then minutes. In addition, personnel should not have to rely on personal watches to know what time it is. It is of importance to provide the right incentives for the personnel to make such a culture change.

One can only be on time if one knows what time it is.

7.4 Interrelation between the various measures

As discussed in section 6, the measures that are ranked '++'or '+', support the most promising measures. In order to solve capacity constraints on a specific location or corridor, a suite of measure can be chosen. Table 10 gives insight in the interrelation between the various measures. Four types of interaction are distinguished:

- '++' the measure on the horizontal axis strengthens the most promising measure
- '+' the measure on the horizontal axis has a relation with the most promising measure in that column , that means it could be beneficial
- '-' there is not a direct relation
- 'G' a general relation, meaning that the measure on the horizontal axis can also be used as a stand alone measure

Table 10: summary table of interaction between promising measures and other measures

Legend
G general relation
++ strengthens
+ related
- not-related

		TIMETABLE	TIMETABLE	TIMETABLE	TIMETABLE	DYNAMIC TRAFFIC MANAGEMENT	PINCH POINT
		Margin allocation	Margin reposition	Margin reduction	Plan with conflict	JIT route setting	Analysis
++ ranked measures	D; Alternative routing	G	G	G	G	-	+
	E; Sub optimisation	+	-	+	+	-	+
	L; Platform utilisation analysis	G	G	G	G	+	+
	Q; Signalling headways	-	++	-	-	-	+
	R; Education of personnel	+	+	+	+	+	-
+ ranked measures	C; Through train at junctions	+	+	-	+	+	+
	G; Performance regimes	+	+	+	+	-	++
	I; Legislation	-	-	-	-	-	+
	J; Rolling stock requirements	+	-	-	-	-	+
	O; Regulation and route prioritisation	-	-	-	-	-	-
	S; Availability of fault clearing service	-	-	-	-	-	-

This interrelation table will be reflected in the definitive menu in section 8 that specifically identifies supportive measures and pre-requisites of the most promising measures.

7.5 Case study

A simplified case, based on a real problem, indicates how the measures can be applied to create capacity. In this case, the pinch point is a conflict between a regional train and an intercity service. The dwell time of the regional train is not sufficient to let the intercity service overtake, and increasing dwell times will create further problems down the line.

Figure 6 shows the problem and identifies the type of measures that can be taken to solve the constraint.

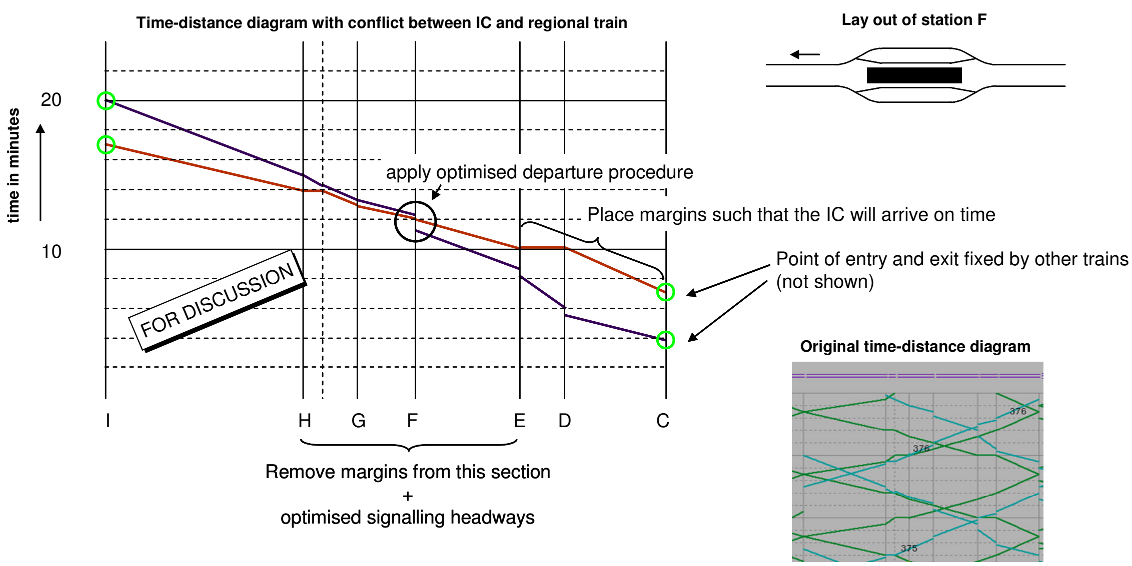


Figure 6: case study, problem definition

Line section E – H is the main bottleneck with the station in F. The station layout is such that the intercity service can pass at maximum speed. Application of the optimised departure procedure makes that the regional train can depart sooner after the intercity is passed. With the removal of margins in section E – H and an optimisation of the signalling headways, the intercity is running closer to the regional train making that he passes the regional train in station F earlier in time. A repositioning of the margins make sure that the intercity arrives in time at point E.

Figure 7 shows the changed time distance diagram for this case. The applied measures are summarised in the table within the figure.

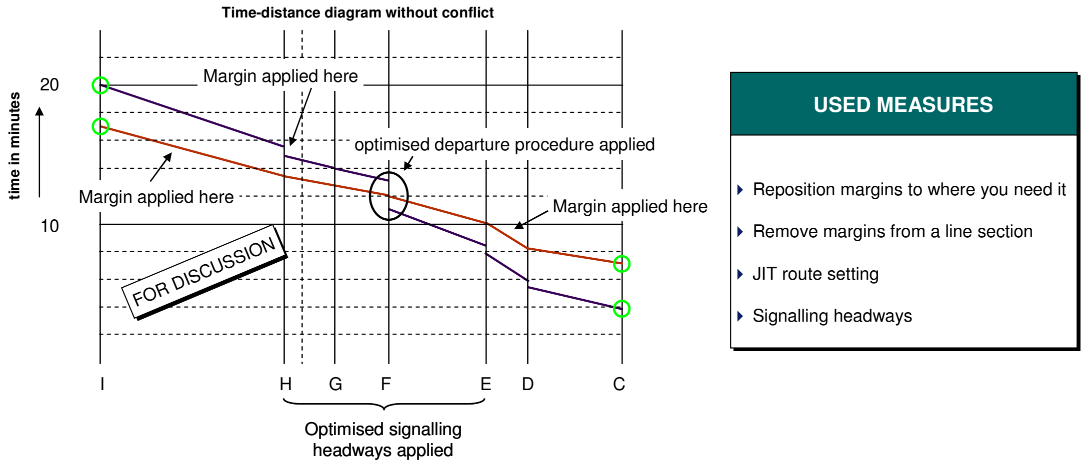


Figure 7: case study, how applied suite of measures solve the problem

With the applied suite of measures, the conflict of this simplified case is solved. In this case the suite of measures make it possible that both intercity and regional train can be operated, without the need of extra infrastructure, thereby underlining the potential of the measures.

8 Menu list

For practical use of the measures, these are presented as a menu list. The menu list has three main courses, based on constraints that come up with drafting the timetable. The main courses are:

- general applicable solutions
- a confluence of lines over a limited length of line
- busy yards and at grade crossings

In addition to these courses, the basis of solving capacity constraints is understanding the real problem. Understanding the pinch points is the requisite for finding the most (cost-)effective solution. In analogy to the menu with its three main courses, this is identified as 'coperto', Italian for cutlery.

8.1 Coperto

Pinch point analysis is not a capacity enhancing measure in itself, but it does play an important role in solving any constraint and should be the starting point for solving any capacity constraint. A performance regime is a strong tool to collect the necessary data to understand the issue at hand.

8.2 Course 1: general applicable solutions

Table 11: menu list for general capacity issues

Course 1	Applicability	Requisite	Strengthened by measure	Impacts with measure	Might benefit from measure
A1. margin allocation	Generally applicable	Dynamic trafffic management Make Use of the Second	-	Timetable Education of personnel Sub optimisation Through train at junctions	Alternative routing Platform utilisation study
A2. margin reduction	Generally applicable	Dynamic trafffic management Make Use of the Second	-	Timetable Education of personnel Sub optimisation	Alternative routing Platform utilisation study
A3. plan with conflict	Generally applicable	Dynamic trafffic management	-	Timetable Education of personnel Sub optimisation Through train at junctions	Alternative routing Platform utilisation study

8.3 Course 2: a confluence of lines over a limited length of line

Table 12: menu list for capacity constraint at confluence of lines

Course 2	Applicability	Requisite	Strengthened by measure	Impacts with measure	Might benefit from measure
A4. margin reposition	Confluence of lines	Dynamic trafffic management Make Use of the Second	Signalling headways	Education of personnel Through train at junctions Performance regime	Alternative routing Platform utilisation study

8.4 Course 3: busy yards and at grade crossings

Table 13: menu list for capacity constraints at yards and at grade crossings

Course 3	Applicability	Requisite	Strengthened by measure	Impacts with measure	Might benefit from measure
H1. JIT route setting	Yards and at grade crossings	Make Use of the Second	-	Timetable Education of personnel Through train at junctions	Platform utilisation study

8.5 Example of use of menu list

As an example how to apply the menu list, the corridor Alkmaar (Amr) – Amsterdam (Asd) – Utrecht (Ut) – Eindhoven (Ehv) is analysed. y and do not represent the actual situation.

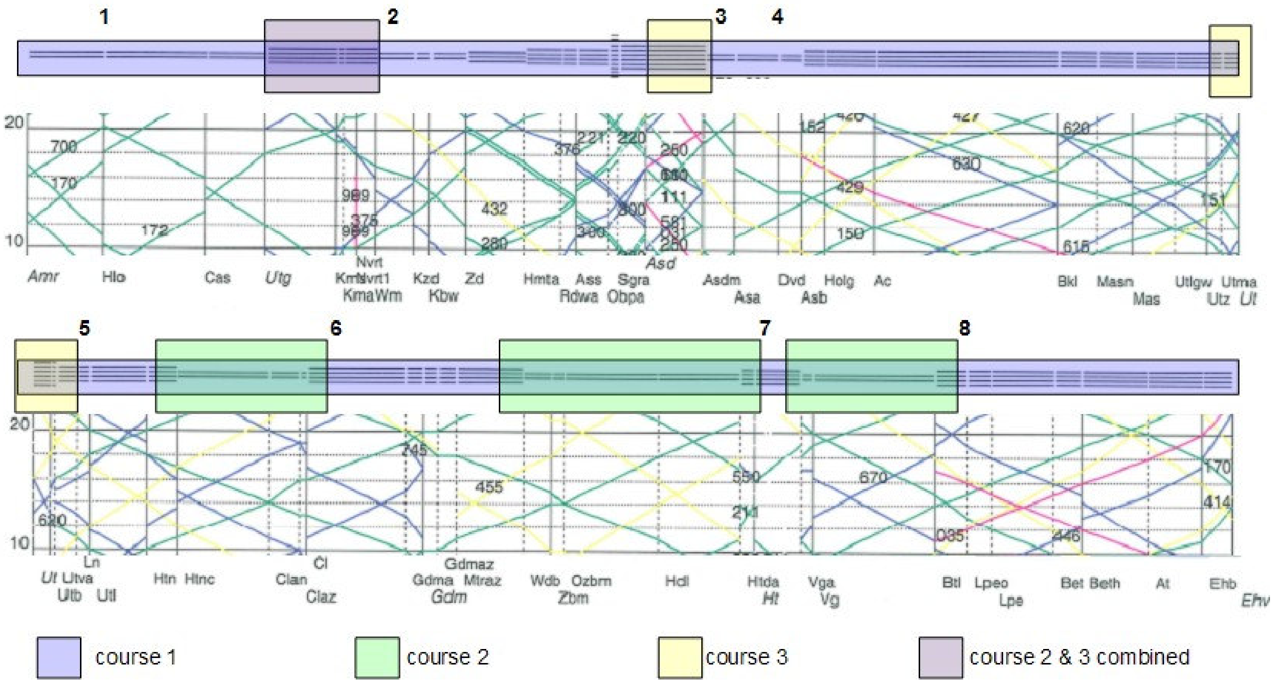


Figure 9: example of use of menu list on Alkmaar - Amsterdam - Utrecht - Eindhoven corridor

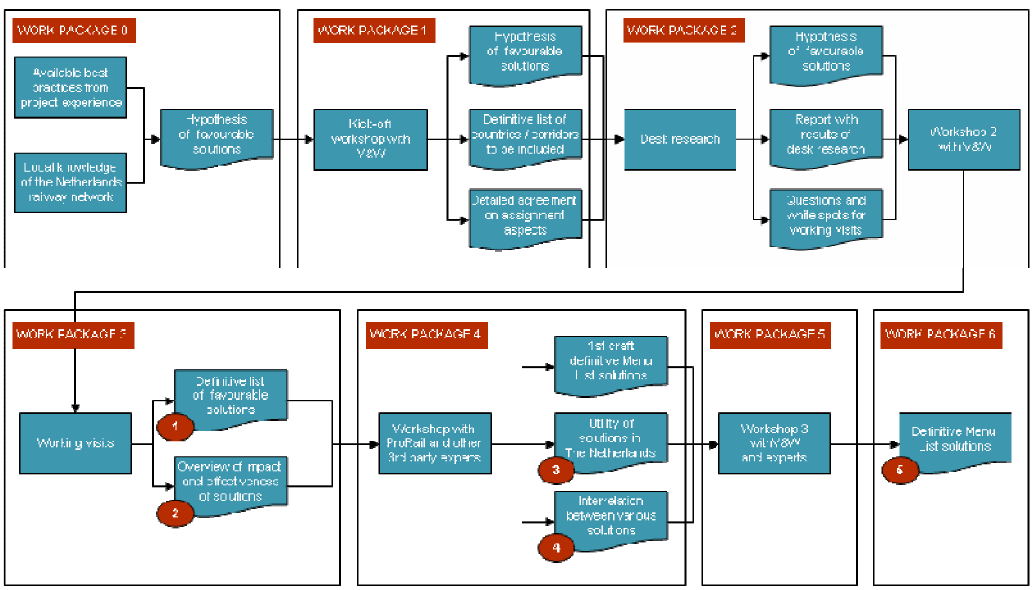
Explanation of numbers in figure	
1	Course 1 can be applied over the entire line
2	A combination of course 2 and 3 can prevent quadrupling the tracks in this area, this is the section as used in the case study
3	Amsterdam is a typical example of a busy yard
4	This is not a confluence of lines and no additional measures are needed
5	Utrecht is a typical example of a busy yard
6 7 8	Integral quadrupling of the tracks between Utrecht and Eindhoven is costly due to the major river crossings in line section. Use of course 2 will make it possible to minimise the required length of quadrupling

Appendix 1: Assignment approach

For this study, a hypothesis driven approach is used. In this approach, a set of hypotheses regarding what would constitute a set of viable solutions for bottlenecks in the Netherlands is identified.
The activities throughout the assignment are then focused on the verification of those hypothesis (or the creation of an alternate hypothesis should one of the original hypothesis be demonstrated to be incorrect). As the study progresses the document “hypothesis of favourable solutions” is further developed. The questions that need to be answered are thereby identified early in the process and this ensures that research and interviews can be focused and highly receptive.

The advantage of this approach is that the study will remain sharply focused thus allowing a greater focus on understanding aspects that can really work, rather than wasting time on searching for aspects that will not work at all.

We have structured our approach by defining work packages as is detailed in the following diagram. The numbers 1 to 5 in this diagram refer to the deliverables as associated with the main questions from V&W as discussed in chapter 1.



Work package 0: establish hypothesis
With a hypothesis driven approach, the start of the project sees the definition of the hypothesis. In this case these are the defined measures.

Work package 1: kick-off and alignment
This work package is used to achieve a common view with V&W on the assignment, discuss the countries to be included in the benchmark and discuss the hypothesis.

Work package 2: desk top research
During this phase, available documents and completed research in the Netherlands will be reviewed and preparations for the international benchmarks will be done.

Work package 3: international visits

During this phase the international visits will be done resulting in a best practice overview. The list of solutions and its ranking will be made final.

Work package 4: development in depth
Assessment of issues facing implementation of the measures in the definitive list of favourable solutions, taking into account major characteristics of the various corridors. In this assessment it will be made clear what interrelation exists between the individual measures. Effectively a filter for the Netherlands will be defined to filter the international best practices to useful solutions in the Netherlands.

Work package 5: characterisation
With a final workshop to define the characterisation of the identified solutions to enable them to be easily identified and applied in the Netherlands, the final deliverable will be drafted.

Work package 6: final report
The result of the total assignment will be combined in the final report, containing the definitive 'Menukaart'.

Appendix 2: Elaboration on identified measures

A. Method for time table design
Timetables can be clock face (e.g. BUP) or otherwise. Whilst the clock face timetable provides an easy interface for the customers it introduces capacity constraints. The definition of smart timetables allows for fixed train paths whereby an envelope of rolling stock characteristics is used for defining such a path. Tighter envelopes that better match the particular train characteristics can impact the available capacity. Other aspects include times in stations and turning ties as well as the use of buffer times. These are mostly optimised to the performance of the train operator (% on time running) but not to the line capacity.

B. Travel time improvement for passengers and freight
The harmonization of train speeds and the so called green wave are two mechanisms that can be used to improve travel times. Homogeneity of speeds works best at routes with little peak demand in order to allow a constant flow of freight trains and regional trains in between. Similar issues need to be addressed with mixes of rolling Stock.

C. Management at junctions for through trains
A characteristic of a network is that train paths must cross. This simple fact results in a potential infrastructure utilization constraint when the passing of trains is not well coordinated. This may occur at junctions along the route or at stations e.g. passenger trains which have to cross several tracks to get to their final track within a passenger station cut into the capacity for other incoming or departing trains as well as for passing trains through the station. critical junctions can define the capacity of the entire line

D. Alternative routing
This usually only applies to freight trains where a longer route can be a better alternative, if freight trains will have priority on those routes. In Belgium such a scheme was successfully implemented for freight traffic southbound to Luxembourg and Switzerland. For passenger trains this is generally not an option as passenger flows can not be diverted and most of the regional traffic is funded by regional governments and through this the routing is fixed.

E. Sub-optimisation to create capacity
There are many sub-optimisations implemented for operational execution of railway systems. Given the complexity of the networks and the diversity of the parameters that are being utilised, tradeoffs are a necessary part. The degree to which a trade-off can be made between the service, punctuality, reliability and utilisation will need to reflect the weighting attached to the driving issues.

Another example of sub-optimisation is where travel times of regional trains may slightly go up due the float principle behind freight trains. This can make sense when the overall capacity of this route goes up or additional capacity at a congested mainline can be created through putting freight trains on alternate routes.

F. Differentiate access charges
Several concepts have been published, but practically this will only work for freight trains where there is some flexibility regarding time of the day, transit time and routing provided the operator can save access charges

G. Performance regimes
Established in some European countries, but there value being disputed. Especially with international freight trains the cause of delay may be the foreign infrastructure manager or train operator and the penalty will hit the national train operator. Also from the point of the infrastructure manager performance regimes do not free up capacity, but only increase charges

H. (Dynamic) traffic management
The use of computer based traffic control systems provide a dynamic capability for the regulation and restructuring of train paths. The most common forms available today allow operation by timetable, with many examples of additional functionality to assist in regulation conflict resolution. A key factor in the ATP strategy of most railways is the degree to which additional benefits can be achieved through interfacing train control systems with dynamic timetable management systems.

I. Legislation
The railway does not operate in a vacuum. This fact is reflected in the legislative environment in which it must run. Restrictions on noise emissions and more importantly these days, carbon emissions are two examples where legislation has an impact on the utilisation of the infrastructure. Consideration can also be given the application of the same legislation on alternate formed of transport which would then have a impact on the rail corridor (for example pricing of road freight).

J. Rolling Stock requirements
Here the focus shall be on traction and rolling stock upgrades for freight trains to allow higher speeds and through this better homogeneity with passenger trains as well as reduction of noise levels that impact on allowable speed and operating hours. Furthermore the acceleration characteristics of regional trains are of particular interest.

K. Capacity improving measures in infrastructure
Infrastructure improvements are generally the first item that is considered in the search for additional capacity. It is generally reviewed in terms of additional track, however consideration needs to be given to incremental adjustments or additions that can gain significant benefits without significant cost or time impacts.

The focus should be on critical bottlenecks which mostly occur at junctions rather than en route. Bottlenecks can be missing loops, too low allowable diverging speed on switches, equal grade line crossings.

L. Platform utilisation analysis
In a similar manner to the issue of management at Junctions, station occupancy and dwell times play a key role in defining overall network capacity. The ability to turn trains at intermediate stops or beyond the confines of the station area can often provide enhancements to the overall route in eliminating bottle necks.

M. Availability measures in Infrastructure
Optimisation of asset effectiveness can also be impacted by reducing the downtime of the network or lines for maintenance and renewal (i.e. increasing the availability of the railway for operations). This has been a particular issue on the UK network, where the use of blockades (no trains for a period of days) has been increasing in recent years.

N. ATO (Automatic Train Operation)
Automatic train operation assists in reducing the impact of human factors on infrastructure utilisation loss. Critical pinch points can be managed more efficiently in the event that the driving characteristics of the trains are more predictable. Whist this is extensively utilised in metro systems, main line applications are burdened by the cost to equip the network and the diversity of the fleet.

O. Regulation and route prioritisation
Utilisation of the infrastructure is directly impacted by the prioritisation of the traffic that runs over it. Whilst this is recognised as a national study, looking at the Dutch network, consideration needs also to be given to international services. Consider the combination of prioritisation of international services with institutionalised delays across the border. The impact of the delay in Belgium will be imported to the Netherlands with corresponding reduction in the utilisation.

P. Understanding of pinch point analysis undertaken – contributory factors
In the evaluation of the problem areas, it is necessary to look at the issue of causation. The occurrence of a problem on a part of the network is readily seen as it generally manifests itself in terms of real operational disturbances. The cause for that problem is often not as apparent. Unless there is a clear understanding of the contributing factors, the incorrect conclusion may be drawn from the analysis. Consider the issue of a restrictive junction. One view may dictate that significant structural work is required to provide a flyover whereas an alternate solution could be found in timetabling.

Q. Signalling headways
A primary aspect of infrastructure improvement is adjustment in signalling. This can also be taken on board with the introduction of driver display, positive distance enforcement and Automatic Protection. In essence passing the need for overlaps from infrastructure to train.

Differentiation in tonnage and speed will necessitate signalled layouts to be adapted (usually) to the worst case situation. The use of the worst case characteristics will effectively dampen the response of the entire corridor. Use of fragmented blocks and advanced signalling systems can assist in mitigation of this capacity loss.

R. Education of personnel
Railway personnel have a big impact on the realisation of the time schedule. Aspects include time of arrival at the train they operate, actual departing time by the second, waiting for connections. Extra instructions and education increase the awareness of personnel.

S. Availability of fault clearing service rolling stock
The capacity of the infrastructure will be severely affected through faults. These may be in the rolling stock or in the infrastructure. Apart from robust engineering to design in redundancies, and the contribution of maintenance regimes to prevent faults, consideration is required on what regimes are in place to react to the occurrence of faults.
For example, at stations where trains are combined or split or where the travelling direction is changed, the chance of defects that instigate small train delays are higher. An effective fault clearing service, together with timely arrival of train personnel helps to minimise the impact. In a similar manner, location and response of teams for trackside elements will be critical in evaluation the robustness of the network, contributing to the overall capacity.

Appendix 3: Alignment (work package 1)

Introduction

As initiation of the assignment, a kick-off workshop took place in Den Haag on 20th April with participants from the Ministry, ProRail, NS and freight sector. The objectives of the workshop were to

- Definition of capacity enhancement
- Review the starting hypothesis:
  - discuss measures to reach common understanding
  - identify if measures are used or considered previously in the Netherlands and if so what were the relevant aspects
- Consider the application of a specific measure which could be achieved in a number of different ways. It is important to reflect on the nuances surrounding a measure, rather than the measure itself as this could yield the greatest benefits for its application (or not) in the Netherlands.
- Rank the measures as to their applicability to the Netherlands
- Discuss the Railway Administrations to be consulted during the working visits

Aspects discussed in Workshop 1

This section gives an overview of discussed aspects during the 20 April workshop in Den Haag.

Timetable
The timetable is the start point of the process for the use of the available capacity and defines how efficiently the available pathways are utilised. Although a recast of the Dutch timetable has recently been undertaken it was decided that this measure should be taken forward to understand what options other Rail administrations had considered to deliver improved capacity.

Measures discussed included:

- Adding time to some services to allow others to operate unhindered
- Use of pathing time
- Set down and pick up timings
- Non advertising of stops
- Set departure time/clock face departures
- Stopping patterns
- Rolling stock diagrams
- Mix of speed
- Diagramming – staff and rolling stock
- Station dwell times and turn a round times at terminals

Adding time is a measure that is used in the Netherland ('uitbuigen'). The use of set down and pick up timings and non advertising stops was discussed in more detail as such issues are not used in the Netherlands to date.

Platform Utilisation

The efficient use of platform space is key to ensure that the train plan is delivered and that the line capacity is maximised. The objective of the station dwell time is to balance the need for passengers to join and leave services and to minimise the track occupation and thus improve pathway utilisation.

Measures discussed included:

- Dwell times
- Control movement –speed boarding
- Position of passengers relative to doors/coaches on platform
- Luggage, bikes, pushchairs
- Signage – route to the train
- Layovers in stations – train preparation
- Cross platform change
- Adherence to train plan for platforms

The aspect of station dwell times was discussed in length, although it was not regarded as a topic were much could be gained.

Regulation and Route Prioritisation

The ability to path the maximum number of trains across the infrastructure depends upon the regulation of the services once the train plan has been defined. The management of services in the Netherlands follows the normal International rules in that International/Cross border services have first priority followed by Long distance, limited stop, stopping and freight.

Regulation also covers recovery from incidents in order to maintain the best possible train service taking cognisance of late running and failures

Measures discussed included:

- Real time control – CCF decision support tool
- Recovery from perturbation
- Timetable break
- Cancellations
- Knowledge of train revenue necessary – does this or should this affect the decision making process when recovering from any incident or management of late running services

Infrastructure
The operation of the train service depends upon the availability of the infrastructure and the Rules that are applied by the Infrastructure Provider as to what proportion of the theoretical capacity will be allowed for traffic and what is held back for recovery from perturbations or margins to preserve performance. The infrastructure provider also needs to maintain and improve the rail infrastructure thus requires possessions which affect and constrain the access to the network.

Measured discussed included:

- Rules of the Route
- Junction margins
- Platform re-occupation
- Pathing time
- Engineering allowances
- Capacity utilisation
- Infrastructure provider having a track access contract to allow for Engineering possessions as the train operator does for the timetable
- Patrolling and inspection regime constraints

Some two years ago a test was done between Utrecht and Amersfoort with a limitation of service around noon for inspection and small maintenance purposes. Especially NS is not happy with such arrangements as it impacts their service offerings too much.

Freight Routing
To maximise the capacity of the infrastructure all passenger trains would run at the same speed and have the same calling patterns thus trains could be flighted at even spacing. However in practice trains run at differing speeds and have totally different stopping patterns which affects the capacity of a route. Freight services accelerate and brake significantly slower than passenger services thus adding more constraints on the line capacity. In some countries dedicated freight routes have been introduced and in others special freight routing is considered to separate the passenger services and maximise capacity

Measures discussed included

- Freight trains tend to be less time sensitive- avoid ‘peak’ passenger times
- Route via less busy lines
- Avoid crossing main lines on flat junctions
- Use of loops
- Dedicated routes - Belgium
- Faster/shorter services
- Limit STP paths- maximise permanent timetabling/use of regular pathways
- ‘Keep running’ – more time lost starting and stopping

Routing is an aspect that was discussed in more detail. Especially when the Betuwe route will be opened, different relations become possible. It is seen that the BRG (association of freight operators) proactively thinks with possible routing.

Speed Harmonisation
An alternative to train separation is to minimise the speed differential between services in order to maximise the capacity available to operate services.

Measures discussed included:

- Services operate at differing speeds
  - Long distance passenger
  - Local express
  - Local stopping
  - Freight
- Either
  - timetable by consensus
  - separate slow and fast services
  - Use of loops
  - Bi directional signalling
  - Twin tracks

Staff Management
The operation of the train service is highly dependent on the performance of the staff both on-train and on the station. The staff can directly affect the time keeping and performance of the train plan whether by a change in rostering practices or flexibility whilst working.

Measures discussed included:

- On-train staff
  - Full crew working
  - Major terminals work in and out
- Platform staff
- Diagramming & rostering
- Training of staff
- Recovery plans
- On time running everyone's responsibility

It was discussed that staff issues are always sensitive in the Netherlands, especially after 'het rondje rond de kerk', an attempt to roster personnel to fixed routes.

Performance Regimes
A Performance regime provides an incentive to both the infrastructure provider and train operators to seek to minimise lateness and cancellation of train services. It also enables train operators to be appropriately compensated for the effects on their revenue resulting from poor performance by the Infrastructure Provider. Performance Regimes can be between the Infrastructure Provider and train Operator or between train operators. The Performance Regime may not directly affect capacity but by improving punctuality and performance it may lead to more of the infrastructure capacity being allocated by the infrastructure owner.

Measures discussed included

- Assists in maximising achieved capacity
- Allows judgement of revenue against performance risk
- Seeks to identify delay causation and rectify negative trends
- Risk and reward for performance
- Forces attention to detail
- Can hide true delay causation if too much performance allowance – SWT
- Leads to too much caution (recovery time)
- Cheaper to pay than rectify issues
- Measures end to end not intermediate timings

This aspect is not regarded as an issue that really impacts the capacity.

Understanding Pinch Points
Within every rail administration people are aware of the main constraints of the infrastructure which cause pinch points on the operation of the train plan. Under this measure the user must look beyond what is the actual pinch point to understand any contributory factors which may lead to the infrastructure bottleneck. This allows a holistic view of a pinch point which may lead to a different solution to that first considered.
Measures discussed included:

- Is the pinch point the issue
- What contributing factors lead to pinch point
- Understand the dynamics of services and minor changes that can eliminate pinch point
- Root cause analysis

This aspect was discussed in further detail based on the Welwyn viaduct in the UK. The main issue is that pinch points need careful consideration on what the real problem is.

Rolling Stock Fault Clearing
This measure again affects performance more than directly being associated with capacity improvement. As with other rail administrations the Netherlands have issues associated with delays to services caused by Rolling Stock failures although significant investment has been introduced into rolling stock in recent years. By

increasing training for drivers and improved response times for fitters the faults on stock can be rectified more rapidly thus the service delays are reduced.

Measures discussed included

- Design of doors affect speed of boarding alighting
- Door closure sequence
- Failure rectification
- Performance acceleration/braking
- Splitting and joining – curved platforms

As a consequence of the recent rolling stock investment issues around stock modifications not to be considered as a priority in this assessment.

Definition of capacity enhancement

In order to be able to translate the international best practices into the Dutch situation, a clear understanding of capacity enhancement is necessary. In the table below aspects of capacity enhancements are identified with their importance being identified.

Aspects of capacity enhancement	Importance
Increase the number of train paths	+++++
Increase number of seats	-
Increase number of services	+++++
Reduce journey times	++
Provide more frequent 'Metro style' services	+++++
Improve performance	++
Limited/no investment	++++
Improved access to network at specific times – weekends	++
Safety culture changes to improve access	+
Maintenance/engineering requirements	-

Discussions of measures

The measures were presented at the workshop and discussed fully as to their advantages and disadvantages and their relative merits against the remit. Recommendations were made for each of the options, either to 'park' them or take them forward for further development.

Ranking of Measures

Each measure was ranked by the applicability to Netherlands Railways based upon the discussion of the workshop.

#	Measure		Remarks
A	Method for time table design	+++	Effectuated with time table change 2007
B	Travel time improvement for passengers and freight	+	Especially possible for freight
C	Management at junctions for through trains	++	Green waves for freight trains
D	Alternative routing	+	will be effective after completion of Betuwe route
E	Sub-optimisation to create capacity	++	Adapt intercity timetable to fit with freight
F	Differentiate access charges	o	Especially for freight
G	Performance regimes	+++	Relative new aspect of which the merits are not clear
H	(Dynamic) traffic management	+++	Already tried at stations
I	Legislation	+	Especially noise will be an issue
J	Rolling Stock requirements	o	Max speed of freight trains and reliability of rolling stock
K	Capacity improving measures in infrastructure	o	The ojective should be to refrain from those as much as possible
L	Platform utilisation analysis	+++	Platform capacity is an issue, consider together with aspect H
M	Availability measures in Infrastructure	+++	With a change in infra usage, such measures could relieve pinch points
N	ATO (Automatic Train Operation)	o	Probably not achievable form a cost perspective
O	Regulation and route prioritisation	+++	Difficult from a viewpoint of equal oportunities for freight and passenger
P	Understanding of pinch point analysis undertaken	+++	Much effort done in study Benutten en Bouwen
Q	Signalling headways	++	Introduction of ERTMS
R	Education of personnel	+++	Staff has a big impact on the actual time schedule
S	Availability of fault clearing service rolling stock	++	Rolling stock defects is a relatively big issue

Appendix 4: desk research and interviews the Netherlands

Introduction

The Netherlands have one of the busiest railway networks in the world. Every day approximately 5,400 passenger and 300 freight trains use the network.
ProRail is the infrastructure manager in the Netherlands. Passenger services on the main network are provided by NS with other passenger operators being restricted to regional lines.

The timetable is designed by ProRail and based on requests for capacity / train paths from train operators. As public transport is an element in the total mobility of the country, regional authorities are involved in the planning of the timetable as well.
A board meeting ('directeurenoverleg') of the co-operation of NS, Railion, Rail freight sector and ProRail, called 'Samensporen', will deal with trade-offs that have to be made in the last phase of the timetable design.

Timetable basics

In the Netherlands, the timetable is built since the 1970's according to a standard hourly pattern ('basisuurpatroon', BUP). The BUP is seen as a very effective method to provide passengers with a very predictable train service and attract the most passengers. A timetable according to a BUP effectively means that a single scheduled train path is available 24 times a day.

In the BUP, the rolling stock characteristics are included such as acceleration and deceleration characteristics and train speed. For passenger transport the types of trains are predictable with intercity and all-station trains having distinct and predefined train series. For freight trains the variability is larger. For this reason two standard train types are defined that are used to build the BUP, corresponding to heavy freight trains and less heavy freight trains.

After a period of over 30 years, the timetable is completely rewritten per 2007 to accommodate the traffic growth, new stations and new infrastructure such as the high-speed line and Betuwe freight route and a number connecting curves. The timetable is still based on a basic hourly pattern.
The new time table 2007 is based on the timetable 2009: the year that all new infrastructure and the majority of the new stations are fully in service.

Innovation program

ProRail has an innovation program in place with multiple initiavtives being studied. Two of those are specifically interesting in the view of this project. These are elaborated in the following.

Smart overtaking

The possibility to take over slower trains and/or freight trains is also seen as an option to increase capacity for fast trains and for train paths for through trains. To obtain this, additional infrastructure is needed, together with a flexible planning. Disadvantages are the increase in travel time for passengers on the slower train, and the higher personnel and material costs.

RouteLint
To improve punctuality, energy consumption and passenger comfort, ProRail has developed a tool, RouteLint. This consists of a display that provides the train driver with up-to-date information about the trains that run in front and behind the train.

Results of a pilot project showed that train drivers achieved better punctuality, drove more smoothly and reduced energy consumption.
RouteLint also provides delay information and as such can be used for real time rescheduling.

Aspects related to rolling stock

Actualisation braking tables
The braking tables that are used in developing the time table are said to be very conservative. The tables date from the 1960's and do not take new rolling stock characteristics into account. ProRail will be updating the braking tables to take advantage of the improved braking characteristics of the rolling stock.

Aspects related to planning

Aspect	Value
Planning priority	1. long distance, regional, suburban and freight
Type of timetable	Hourly pattern
Margins	5%
Signalling headway	Technical minimum (on busiest routes) 2,1 minutes; a margin of 30% is added and then rounded to whole minutes; for specific situation / locations 2 minutes is used
Time unit for planning	seconds but rounded to minutes
Empty trains scheduled	no; critical empty train movements (high-speed trains from the yard to Amsterdam main station) are planned
Punctuality norm	3 minutes

ProRail have defined a set of so-called usage buttons ('benuttingsknoppen'), which are used to design a time table that is fulfilling the requirements. The main goal is to avoid or delay the construction of new infrastructure, and if new infra is needed, to limit the size.

Harmonisation of speed ('Homogeniseren')
This measure has several sub items:

- Reduce speed of fast trains. This will lead to a longer turnaround time, and thus to higher personnel and material costs. The travel time will increase.
- Increase speed of slow trains. This will lead to a shorter turnaround time, and thus to lower personnel and material costs. The travel time will

decrease. It will require the procurement of new trains and will increase the demand of traction power.

- Increase travel time by alternating stops. This will lead to a shorter turnaround time, and thus to lower personnel and material costs. The travel time will decrease. The time table will be more complicated, with less travel options for passengers
- Increase speed for freight by increasing traction capacity. This requires new and/or more locomotives and will increase wear of the track. The higher speed also increases maintenance costs.
- Increase speed for freight by reduction of payload. This decreases the capacity, requires more train paths (more personnel and maintenance), leads to higher access charges and leave less capacity for maintenance.

ProRail also investigated the use of the HSL – by running freight trains on the line, or by running passenger trains and thus creating capacity on the other line. However, use of the HSL is different from using other lines - it imposes some new constraints caused by the contract structure (concession between the State and HSA currently does not allow for this). Additionally, the infrastructure may not be suitable for other trains and require (costly) adaptations.

Rerouting: freight
By rerouting freight trains from busy lines capacity is increased, off course reducing capacity on other lines. This trade off can be optimised, but a longer travel distance will lead to higher personnel and material costs.

Prioritising
ProRail considers the option of prioritising types of trains during the day, by running more passenger trains during peak hours and more freight trains in between (Intercity/stop train/freight 6/6/0 during peak, 6/3/3 off-peak and 3/3/6 in evenings). This increases capacity for passengers in peak hours, and allows for maintenance during off-peak hours.

An extreme example of prioritising is rejection of freight on specific line sections. This provides additional train paths for passengers, but requires rerouting to other lines, or shifting to another mode of transport (road, water, air).

Utilisation of train paths
Combination of trains is seen to be a measure to create capacity. The longer trains that are needed to accommodate all passengers are more vulnerable to delays – impacting reliability. Longer trains may require additional infrastructure as well.

Creating capacity
Although the time table is designed for a equally division of trains over the day, exceptions to this principle could in some situations lead to more train paths. It also leads to an unequal spread of passengers over the different trains.

Aspects related to operations

ProRail experiments with dynamic traffic management at specific locations. The best example is at the tunnel at Schiphol Airport, where conflicting routes coincide with a limited platform capacity at the station. By using a first-come-first-serve switch (and dynamic passenger information), a better use of the platforms is achieved.

Identified aspects for improvement in the Netherlands

Inherent obstacles

Due to the very nature of the railway sector organisation with various parties having their own responsibilities, inherent obstacles for the performance and capacity of the railway system are created. The most significant aspects that have an impact on the capacity are:

- **Personnel input in timetable design**; use of experience from train personnel could be used to identify / eliminate pinch points, although this is mainly a performance issue it could have an effect on the planned capacity.
- **Minimum service level for stations**; in exploitation concession minimum requirements for trains per hour at stations are defined. Some of the stations have too little passengers to justify the number of trains every hour. A reduction of stops has a positive effect on the available capacity.
- **Basic hourly pattern**; a differentiation of service between peak and off-peak gives more flexibility for planning, this issue strongly relates with a clock faced timetable.
- **Timetabling margins**; in order to allow recovery of the system in case of disturbances, rigid margins are built in the timetable design, these margins however take up capacity and might be used is a different way.
- **Noise reduction freight trains**; a reduction of noise levels for freight trains would provide the possibility of longer operating hours; cost allocation of such measures makes realisation difficult as 'value' and 'money' are not all within one party.

Overview of identified time table issues

Whilst drafting the timetable, many issues may arise that are conflicts. Most of those issues can be solved, either by rescheduling or using so-called usage buttons, see further in this appendix. Some time table issues remain, and these impact on performance. These issues are listed in the table below.

	Location	Description
1	Roosendaal I	Timetable optimisation
2	Roosendaal II	Timetable optimisation
3	Tilburg West/Tilburg GE	Timetable optimisation
4	Meteren	Timetable optimisation
5	Utrecht Centraal	Timetable optimisation
6	Apeldoorn	Timetable optimisation
7	Rotterdam CS	Timetable optimisation
8	Zutphen	Timetable optimisation
9	Zwolle	Timetable optimisation
10	Deventer	Timetable optimisation
11	Amsterdam Centraal	Timetable optimisation
12	Hemtunnel aansluiting	Timetable optimisation
13	Zwolle – Olst	Timetable optimisation
14	Anna Paulowna	Timetable optimisation
15	Utrecht – Blauwkapel*	Timetable optimisation

Source: OBBI: (Optimalisering Benutting Bestaande Infra)

Overview of identified pinch points

ProRail have defined several pinch points that are related to the capacity of the infrastructure. These pinch points are said to form a risk for the robustness or the punctuality of the time table.

The following table gives an overview of the pinch points. It should be noted that none of these are conflicts between different train operators.

	Location	Description
16	perronspoorcapaciteit Zwolle	Platform utilisation Almelo Deventer
17	Geldermalsen	- (*)
18	Flevolijn	Overtake location Almere Poort
19	Amersfoort westzijde	Free crossing
20	Vechtbrug Weesp	Opening bridge
21	Amsterdam Muiderpoort – Watergraafsmeer	- (*)
22	Amsterdam Centraal – Bijlmer	Signalling
23	perronspoorcapaciteit Amsterdam Centraal	- (*)
24	Amsterdam Transformatorweg	Free crossing
25	Schipholtunnel	Dynamic Traffic management and measures tunnel safety
26	Den Haag HS noordzijde	- (*)
27	Schiedam – Rijswijk	- (*)
28	Rotterdam – Gouda	- (*)
29	Rotterdam – Lage Zwaluwe	- (*)
30	Kijfhoek	- (*)
31	Breda	Platform lay-out
32	Tilburg oostzijde	- (*)
33	’s-Hertogenbosch	Crossings on N and S side
34	Eindhoven zuidzijde	- (*)

(*) – currently an operational solution is chosen

Source: NWA: Netwerkanalyse Spoor

Sources

- Eindrapport Ontwerp 2007; Kernteam ontwerp 2007; 27 March 2006.
- Plannings- en capaciteits normen ontwerp 2007; 26 April 2004
- Memo aangaande aanpassing planningsnormen ontwerp 2007; 20 July 2005
- Benutten en Bouwen 2003 – 2015, rapportage eerste fase; February 2002
- Benutten en Bouwen 2003 – 2015, rapportage tweede fase; May 2002
- Benutten en Bouwen 2003 – 2015, rapportage derde fase; April 2003
- Benutten en Bouwen 2003 – 2015, derde fase; Heilige Huisjes; 8 April 2003
- Benutten en Bouwen 2003 – 2015, lange termijn visie 2020; 22 April 2003
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- Start document LMCA, werkstroom Product; 14 March 2007
- Innovaties voor Herstelplan Spoor 2e fase; ProRail presentation 14 May 2007
- Netwerkanalyse spoor; versie 2, januari 2007
- Overbelastverklaring OBBI (Optimalisering Benutting Bestaande Infra); 18 september 2006
- Spoor in cijfers 2007; March 2007

Appendix 5: International desk research and interviews

Switzerland

Introduction

Switzerland is a country with many railways, many of which are narrow gauge railways in mountainous areas. The main normal gauge network is owned by two companies:

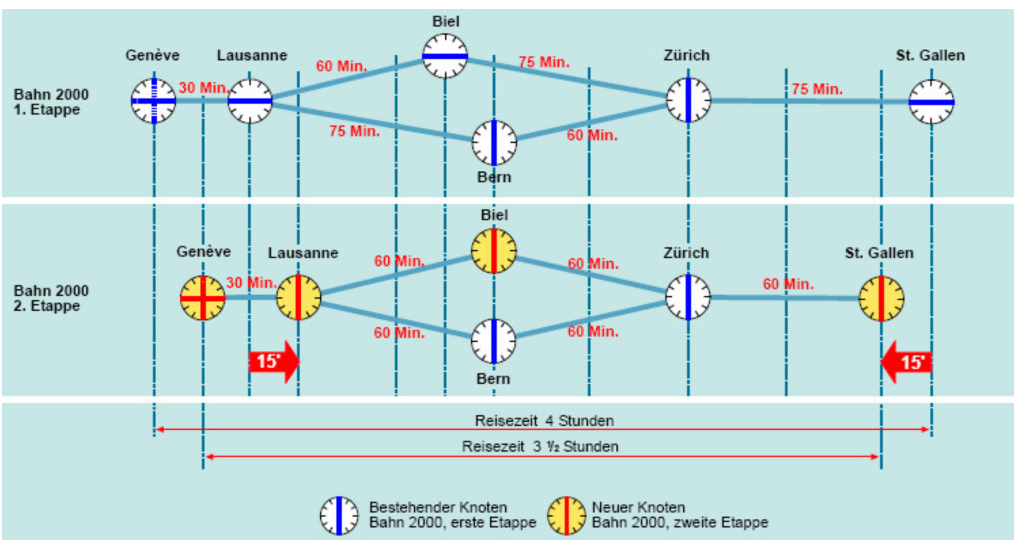
- SBB
- BLS

The networks, operations and ticketing of both companies are fully integrated, providing a seamless service for its passengers.

The many narrow gauge lines are not considered in this benchmark as their environment is too specific and would not provide a good comparison within this benchmark.

Timetable basics

The main traffic streams for passengers are in the east-west axis from St. Gallen to Genève whilst the main freight routes run north-south from Basel over the Lötschberg or Gotthard routes. The Swiss timetable is based on a nodal structure since the timetable change in 2005. The basic principle is that all trains enter and leave the station around the same time, e.g. on the hour, providing a maximum of interchanges. In order to realise this, infrastructure measures where taken to normalise the travel times between the main cities as shown in the figure below. Further optimisation is planned as shown in the same figure, bottom.



Innovation program

SBB is developing a program to increase the usage of capacity by a 3-step approach:

1. optimise train departure procedure
2. let train driver stick to their exact schedule
3. re-plan train paths in real time

sub 1

The departure process is a sequence of events, involving traffic controller, train guard, train driver and passenger. As it is not clear who has overall responsibility for timely departure, the average train leaves the station with 25 sec delay with a dispersion of 60 sec. It means that the same amount of time is lost in capacity: the route is set but not used. In a pilot at Luzern station, the departure process is done in parallel, informing the train crew on the actual (re-scheduled as the case may be) departure time, accurate to the tenth of minute. The train guard will start the departure procedure some 20 seconds before actual departure, with the route being set 5 sec before actual departure. To realise co-operation of passengers, train advertisers are turned blank as soon as the departure procedure starts.

sub 2
When the train driver sticks to its scheduled path, interference with other train on the same line and on crossing is prevented, reducing the number of unnecessary stops (and related delay and increased energy consumption). Test were done near Luzern and a bigger pilot is being prepared between Zürich and Chur. The train driver is informed by traffic control about the time he needs to be at a certain location. A requirement is that the train knows where it is. This is realised by calculation of distance travelled on the basis of axle revolutions with a calibration at every signal.

Sub 3
Re planning of train paths in real time is a requisite to take real benefit from aspects 1 and 2. In order to provide a useful tool, the calculation time should be in the order of 30 sec. To be able to realise this, critical areas within the network are defined, so-called nuclear areas. These areas can be a station , a line section, a junction, etc, and can be relatively large. Within these nuclear areas all possibilities for train movements can be defined, an 'internal rhythm'. These are the basis for the quick algorithms. The tool is under development.

Aspects related to infrastructure

A number of extensive infrastructure enhancement programs are being undertaken and in planning phase.

- Alp transit tunnels, the Lötschberg and Gotthard base tunnels
- Connection to the European high-speed network
- ZEB program, solving pinch points throughout the country

Within the ZEB program a number of measures are taken to improve capacity and reduce travel times, these include:

- partial track doubling
- disentanglement of traffic streams by construction of fly-overs
- optimisation of signalling headways

Introduction of ETCS level 2 is completed for the new Olten-Bern line, the Lötschberg tunnel and is planned for the Gotthard and Ceneri tunnels. The rest of the network will be fitted with ETCS level 1 within a framework of 15 years.

Aspects related to rolling stock

Dwell times and acceleration rates are specific for types of rolling stock. These characteristics are used in the timetable, meaning that not every type of train can do all sorts of services. Changing type of rolling stock is considered when timetable constraints are identified.

An aspect of concern is the amount of traction on mountainous lines where often heavy freight trains ride with too low traction, therefore not being able to stick to their path.

Aspects related to staffing

For the optimised departure procedure, additional instruction of personnel is necessary.

Aspects related to planning

The timetable is made by SBB for the complete network. Planners from BLS are involved in the process.

Aspect	Value
Planning priority	1. long distance within takt system (franchise traffic) 2. regional, suburban and freight and additional long distance
Type of timetable	Hourly pattern
Margins	Minimum 5%, average 7%; actual % defined per section based on performance history and planned maintenance
Signalling headway	Technical minimum (on busiest routes) 105 sec, margin of 15 sec added totalling minimum headway to 120 sec
Time unit for planning	tenth of minutes (units of 6 sec)
Empty trains scheduled	yes
Punctuality norm	2 minutes

The speed of passenger trains is determined on the travel distance in combination with the nodal structure. The trains run as fast as they need, not as fast as they can. Travel time improvements are an important aspect in relation to the nodal structure only.

Sub-optimisation to create capacity is not an issue as speed and travel times are based on the nodal structure. The planning of the long distance trains is not revisited to better fit lower priority trains.

Platform utilisation at the main stations is an important issue within the nodal structure. As many main station are (used as) terminus stations, the dwell time is relatively long to allow the train driver to change position.

Pinch points analysis are undertaken resulting in the ZEB program. Not all sources confirm a full understanding of the pinch points is reached, questioning the proposed pinch point solutions.

The network lay-out is such that alternative route possibilities are limited. With the new Lötschberg tunnel in service, an alternative is provided between (Basel -) Thun and Brig (- Milano), although the old route has a longer journey time and additional constraint with regard to traction.

Aspects related to operation

Small conflicts in the planning are transferred to operations to resolve.

A dynamic traffic management system is under development to allow real time rescheduling of trains.

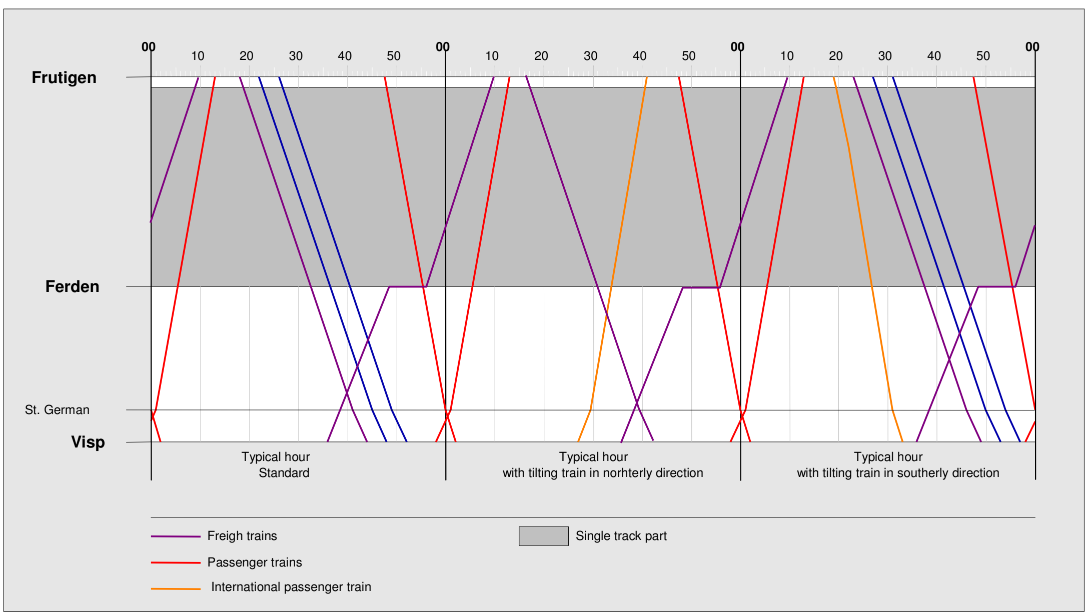
In the operational phase the emphasise lays on preventing that an ‘ill’ (delayed) train affects other services. A delayed passenger train has no priority over a timely freight service.

Aspects related to system relationships

Usage cost is not used as a means to regulate traffic. It is being considered to increase charges for freight trains to relieve peak travel and also to award more quite trains. As access charges are low however, it is thought that such measures will have very limited impact.

Other issues

- In case of speed restrictions for engineering works for a longer period of time, a reduction of the block length is applied to increase capacity.
- In order to be able to take advantage of small time gains, the punctuality norm needs to in line: “If you want more trains to run on time, you need to reduce the punctuality norm”.
- The new Lötschberg tunnel is for only 13 of the 34 km constructed as double track. Combined with the differences in speed between the slowest freight trains, 100kph and the international tilting trains with 250 kph, there is a severe constraints on the number of scheduled train paths. The figure below shows three variants of a standard plan hour.



In order to maximise the capacity during operation, it is important that trains occupy the single track part as quick as possible, hence that they pass the switch at Ferden towards the single track at maximum speed. For this reason, a

traffic control system is developed that informs the train driver on the speed profile in order to reach the maximum speed at Ferden.
- At single track section up to 4 trains an hour are scheduled. Conflicts are planned in the stations, minimising need for overtaking tracks.

Summarised lessons learned

- Planning is made with 6 sec time units;
- Optimisation of the departure procedure reduces the time that a set train path is not used
- Real time re-scheduling;
- Constraining train drivers to their train path is necessary to prevent interaction of succeeding trains
- Reduction of the punctuality norm is necessary to take advantage of small time savings
- Grouping of train paths with same characteristics maximises capacity;
- Train delays due to speed restrictions at sections with longer term construction or maintenance activities are included in the timetable;
- Adaptation of signalling headways to improve capacity at lines with maintenance activities with longer duration;
- ETCS level 2 improves capacity at lines with large differences between various trains and at yards;
- When introducing operational measures take impact on motivation into account;
- Access charges not used to influence capacity;
- Changing type of rolling stock is considered when timetable constraints are identified.

Summarised best practices

- Planning with 6 sec units;
- Optimised departure procedure;
- Real time re-scheduling;
- Constraining train drivers to their train path;
- Reduce punctuality norm
- Take measures in infra based on pinch point analysis

Sources

- ZEB; M. Friedli, B. Weibel, presentation Zürich 7 April 2006
- Zukünftige Entwicklungen der Bahninfrastruktur ZEB, Litra, 7 June 2007
- The challenge to fulfil customer expectations; F. Laube, Conference on Railway capacity, ImechE, London, 12-13 June 2007
- Railway capacity – speed & traffic optimisation in the novel train traffic control centre of the Lötschberg base tunnel in Switzerland; E. Ackermann, M. Montigel, Conference on Railway capacity, ImechE, London, 12-13 June 2007
- Interview with SBB, J. Haller and M. Schürch, 25 June 2007
- Interview with SBB, F. Laube and O. Stalder, 26 June 2007
- Interview with BLS, M. Wenger, 17 July 2007

Germany

Introduction

Germany is a country with a dense railway network. The network is operating under great pressure with the increase of freight traffic since unification. There is a large number of international trains which operate through Germeny as well as the need to serve the internal destinations and major conurbations.

Although there has been significant investment in high-speed trains and modern infrastructure there are still a number of pinch points on the network which need to be solved.

In planning terms DB has various major upgrades still to deliver in the coming years.

In terms of making best use of capacity the emphasis is on providing new routes and additional track through large infrastructure projects.

Timetable basics

Timetable is undertaken to the second and drivers are expected to drive to the second to allow the timetable to operate as planned, although is practice this is not realised.

With the number of freight trains which operate on a day to day basis there is a need to plan on very short term basis and often trains are flighted down particular corridors at less than the signalled headway to maximise the throughput. This leads to trains operating at less than line speed but it increases the capacity

Aspects related to infrastructure

The strategy for DB is to provide additional capacity through major projects

Aspects related to rolling stock

This is a mixed railway with high speed and freight traffic. Investment in the high speed network allows separation and thus new stock can operate at their designed potential.

Aspects related to planning

The timetable is made by DB for the complete network.

Aspect	Value
Planning priority	1. long distance (national and international) 2. regional, suburban and freight
Type of timetable	Hourly pattern combined with peak increase; during peak hours (7:30-9:00 and 16:00-18:30) the number of trains is significantly higher.
Margins	Margins on the travel time consist of 9%
Signalling headway	The technical minimum headway on the main lines is approximately 4 minutes

Time unit for planning	Second
Empty trains scheduled	yes

Aspects related to operation
There is an issue with lack of attention to operational performance and focus is required on staff training and the importance of right time dispatch.

Aspects related to system relationships – usage cost
No differential charging used for capacity issues

Summarised lessons learned
- DB are investing in major infrastructure projects to deliver capacity
- Staff training to improve performance

Summarised best practices
- As the remit of the benchmarking did not cover major investment there is little to take forward from the interview with DB

Sources
- Interview with DB, K. Junker, 28 June 2007.

Belgium

Introduction

Belgium is a country with a dense railway network. The network is mainly developed around Brussels, through which most trains serve almost all Belgian cities. The most important lines are the international lines that run north-south from Antwerp via Brussels to Paris and from Liège via Brussels also to Paris. The national lines all terminate near the Belgian border. As these are quite often rural areas, traffic density is generally low at the end of these lines.

Infrabel is the sole infrastructure manager in Belgium, and railway operations are predominantly carried out by NMBS/SNCB.

According to Infrabel and due to the quality dialogue with its customers, capacity limits have not been reached yet, even in the busy area of Brussels. Infrabel has relatively few pinch points and works are planned to cope with the expected bottlenecks. Due to the network characteristics, many options for rerouting/alternative routing exist.

Total number of trains per day:

- 3600 passenger trains
- 1200 empty passenger trains
- 850 freight trains
- 50 occasional freight trains
- 450 empty freight trains

Total: 6150 trains per day

Timetable basics

Infrabel does not use a strict hourly timetable design. During peak hours (7:30-9:00 and 16:00-18:30) the number of passenger trains is significantly higher.

A prioritisation is used. In designing the timetable, the long distance trains are scheduled first, these are the High Speed Trains (PBKA, Eurostar, TGV France), because they are not numerous and even if they do not have the first legal priority. They are followed by IC-IR trains, local trains and freight trains.

Infrabel uses a worst case scenario, where the timetable is designed using the train with highest loads, worst traction and standard brake curve (wet rails).

Margins on the travel time consist of 5% on top of the dimensioning travel time plus an additional 1 minute per 35 km.

The technical minimum headway on the main lines is approximately 2 minutes, rounded to 3 minutes in the timetable.
In the Brussels North-South Junction the headway is effectively reduced to 1,5 minutes by using shorter block lengths (250 instead of 370m) and a maximum speed of 50 km/h. This system is in use since the 50-60's. The tunnel has 3 tubes with 2 tracks each. Per tube 16 trains can run in each direction. 50% of all passenger trains in Belgium run through this tunnel – all domestic trains stop at Brussels Central. As all tracks have platforms, no dynamic traffic management in allocating the trains.

An interesting aspect of the timetable is that empty trains are also scheduled. On average 1 in 3 trains is empty, caused by the characteristics of the network, where many lines end in rural areas with no maintenance/cleaning yards.

In the near future a more structured freight system is expected with shuttle services.

Aspects related to infrastructure

The Belgian network has relatively few pinch points and Infrabel has the possibility to reroute trains over a railway section nearby, to bypass a certain point in case of disruption. This is frequently used and avoids a spread of delays when a certain point on the network is blocked due to a defective train or an infrastructure failure.

During the heavy works for the HST, Infrabel used a junction with 3 tracks, which softened the classical junction problems (crossing of tracks). An announcement model was also established from some kilometres further down the line to predict the problems and optimise the traffic.

Infrabel uses 'Crocodile' as train protection system. Infrabel stated that there is pressure from society to implement ETCS for safety reasons - one serious accident (9 killed) happened in 2002. The Belgian court could hold the management of Infrabel personally liable for a new accident of this kind, if nothing is done. It should be noted that capacity improvement is not used as reason to implement ETCS.

In the Brussels North-South Junction the signalling system is designed with a shorter block length. Combined with a lower speed (that is also harmonized as all trains stop in Brussels) the capacity is high. This system was designed in the 1950's.

Infrabel is able to run on average 3 trains per hour on single track operation. For many lines located on more than 60 km from Brussels and for regional lines, this allows for maintenance activities during the daytime.

Aspects related to rolling stock

For timetable purposes, Infrabel uses the train with highest loads, worst traction and standard brake curve (wet rails) for the calculation of the basic journey time to be integrated in the timetable.

Aspects related to planning

The timetable is made by Infrabel for the complete network.

Aspect	Value
Planning priority	3. long distance (national and international) 4. regional, suburban and freight
Type of timetable	Hourly pattern combined with peak increase; during peak hours (7:30-9:00 and 16:00-18:30) the number of trains is significantly higher.
Margins	Margins on the travel time consist of 5% on top of the dimensioning travel time plus an additional 1 minute per 35 km.
Signalling headway	The technical minimum headway on the main lines is approximately 2 minutes, rounded to 3 minutes in the timetable.

Time unit for planning	minutes
Empty trains scheduled	yes
Punctuality norm	5 minutes

Aspects related to operation

If the planning is not respected this can lead to conflicts and "operations" has to resolve these.

Aspects related to system relationships – usage cost

Usage cost is used as means to regulate traffic. Charges are differentiated by time and location via a complicated formula, endorsed by the Belgian government. Infrabel cannot change this formula, but can adjust the value of the parameters. As access charges for freight trains are relatively low in the total cost of the production chain, it has shown that measures on tariffs have very limited impact.

On passenger trains there is no impact – passenger services have to be provided. In peak hours utilisation (passenger) approaches 100%.

For freight, the charges have increased 24-30% in the past year. Still the number of trains grows, mostly due to a modal shift (road to rail).

Summarised lessons learned

- rerouting is frequently used during operation
- differentiation of access charges have no impact on passenger services and only very limited on freight
- capacity improvement is not an issue in the discussion to implement ERTMS
- during long period of construction work for HST, a triple track section is used to be able to shift crossing movements of trains and thus avoid conflict
- traffic optimisation model used in conjunction with former item

Summarised best practices

- maximise capacity and bottleneck by adopting identical stopping pattern, reducing line speed and reducing signalling block length
- application of third track to prevent crossing movements
- use of dynamic traffic management to avoid conflict

Sources

- Interview with Infrabel, G. Vernieuwe, 28 June 2007

United Kingdom

Introduction

The UK has a fully privatised railway with separate passenger and freight train operators. The infrastructure is owned and maintained by Network Rail who are also responsible for the development of the network under the Route Utilisation Strategy. Network Rail is regulated by the Office of the Rail regulator where train operators can refer issues for adjudication. The passenger train operators are contracted to run services by the Department of Transport via a franchise bidding process with either subsidy paid or premium received by the DfT depending on the type of franchise.

Capacity is defined either as number of train paths per unit of time or number of seats/passenger accommodation provided

Timetable basics

Four train types are distinguished:
- Long distance, max speed 125 mph
- Outer commuting trains, max speed 100 mph
- Inner commuting trains, max speed 70 mph
- freight trains, max speed 90 mph but in practice this is 60/70 mph

Mix of services on line of route little segregation of traffic all use either the fast or slow lines. There is a mix of four, two and single line infrastructure depending on the location on the Network

Aspects related to infrastructure

All major modernisation projects need to fit within the business planning process and answer the value for money criteria. For developing the services a process of Route Utilisation Strategies has been adopted

- Seeks to set out a strategy to balance the future supply of and demand for rail services
- Uses the Regional Planning Assessment which is undertaken by the DfT as the base demand
- Makes forecast traffic by route

The RUS then seeks to identify the gap between what the system can do to what resources are required

- What a system can do now (supply)
  - Infrastructure
  - Train services
- What it needs to do (demand)
  - Passenger
  - Freight
  - Performance

In practice there are three types of gap, as a do nothing would indicate that supply mat6ches demand over the asse3ssment period which is highly unlikely and thus discounted

- Supply and demand mismatched now

- Supply and demand predicted to be mismatched in the future

- Funders' 'key outputs' that are in scope and consistent with funds that are or are likely to be available

Types of gap are

- Performance
  - Where the performance outputs of the railway system fall short of requirements
- Journey times
  - Where location to location journey times (passenger or freight) do not meet current or future needs
- Capacity
  - Where the size, number and mix of services (passenger and/or freight) does not meet current or future needs

Once the gap has been assessed and identified, Network Rail use a 'toolkit' of measures to close the gap and provide the supply required

Timetable solutions
    - Mix of services
    - Passenger train stopping patterns
    - Quantity of trains on particular route sections
    - Routeing of longer-distance services
- Length of trains
- Rolling stock solutions
    - Deployment of rolling stock type
    - Internal design of passenger rolling stock
- Demand management arrangements
- Engineering access arrangements
- Station depot and freight terminal locations
- Infrastructure solutions
    - Track
    - Signalling
    - Stations

When considering the solution to provide for forecast growth the toolkit is followed to minimise spend on infrastructure which is considered as a last resort and then only as a targeted measure.

Initial the design of the timetable is considered to see where margins and allowances can be altered to provide additional pathways. As part of this process NR will use simulation models to test new timetables and Rules of the Route to ensure that performance remains robust. This also allows for the identification of pinch points on a route which may eventually lead to target investment in track, signalling or stations.

The simplest way of providing additional capacity is by operating longer trains but in turn this may require additional infrastructure in longer platforms, alteration in depots and signalling alterations if braking characteristics are changed.

The RUS program seeks to satisfy the aspirations of the many stakeholders involved in the development of the timetable specification including Local Councils who may wish to invest in the local railway to deliver a rail service to reduce congestion elsewhere in the transport system.

Aspects related to planning

The timetable is built on demand from the operator. The operators develop their own timetables normally based upon the service currently operating with modifications as required. Timetables are submitted to Network Rail who consider the requests made for pathways and adjudicate using agreed flexing limits to develop a final route timetable which is circulated to all operators. Operators can then agree or if they have grounds for complaint to the Rail Regulator they can enact this process. Timetables are normally changed in December with minor alterations being made in May

Aspect	Value
Planning priority	1. long distance 2. regional, suburban and freight
Type of timetable	Based on demand
Margins	These depend upon each route and type of trains. Network Rail are responsible for set the Rules of the Route in conjunction with the operators
Time unit for planning	Half minute
Empty trains scheduled	Yes but after all other trains are planned

Train operators do simulate their timetables in order to check on the effect any change will have on performance. Pinch points on the network are thus highlighted and fed back to Network Rail for their consideration during the RUS program.

Aspects related to operation

There is a split between fast and slow lines in order to maintain the speed of trains. Stopping patterns are altered in order to avoid potential conflicts

Aspects related to system relationships

Operators pay access charges to the infra manager. The cost is determined on the basis of number of trains operated

Summarised lessons learned

- Targeted investment to remove infrastructure pinch points instead of wholesale new lines and infrastructure
- Each improvement must have a business case and value for money
- Formal process introduced to meet forecast growth – Route Utilisation Study
- Focus on best use of station capacity
- Longer trains are being used to deliver more train capacity before infrastructure changes
- Stopping patterns of trains are altered in order to avoid potential conflicts

Summarised best practices

- Targeted investment
- Route Utilisation Strategies

Sources

- Interview with Network Rail, P Norfield, 20 June 2007
- Interview with TfL, Peter Field 20 June 2007
- Interview with DfT, Stuart Baker 5 June 2007
- Interview with SWT Ian Gee 19 June 2007
- Presentation on Route Utilisation Strategies, Network Rail

United States

Introduction

Amtrak serves as both the infrastructure manager and the lead operator (intercity passenger rail) on the NEC Other operators on the NEC include commuter rail (New Jersey Transit, etc.) and freight rail companies.

Management challenges: multiple stakeholder interests (operators, but also political issues around Amtrak's mission (business vs. public service))

Trade off between capacity and On-Time-Performance: estimated that Amtrak is at about 90% capacity, and achieving 90-95% OTP

Capacity is defined either as number of train paths per unit of time or number of seats/passenger accommodation provided

Timetable basics

Ideal throughput would be 30 trains/hour at 2 minute headways
Actually get 24-25 trains/hour (>= 3 minute headways)

Aspects related to infrastructure

Technical challenges: multiple equipment types, local and express, aging infrastructure, etc.

Constrained by equipment with worst profile (dictates Maximum Allowable Speed and signal settings – some stops have as many as 9 aspects to provide more flexibility)

- Pinch Points:
    - 1225 trains per day at New York Penn Station
    - Yard limitations
    -
- 2-minute goal for dwell time in stations, but longer in stations like Philadelphia

Aspects related to planning

Timetables developed collaboratively every 6 months

- Train Performance Calculator (TPC) to determine acceleration and braking profiles of all equipment
- Simulation run using Rail Traffic Controller (RTC) - begin with ideal objectives for all operators
- Run variations to 'optimize' timetable - adjust objectives to reach acceptable timetable
- Slots assigned

Timetable includes tolerance (5-7 minute pad on a 2.75 hour trip time)

Capacity objective balanced against operational objectives (on-time performance, etc.)

Aspect	Value
Planning priority	1. long distance 2. regional, suburban and freight
Type of timetable	Based on demand
Margins	These depend upon each route and type of trains.
Time unit for planning	Half minute
Empty trains scheduled	Yes but after all other trains are planned

Aspects related to operation

Must be able to adjust to:

- Weather impacts
- Equipment failures
- Operators missing their slots

Event management:

- Requires coordination between operations and engineering
- Dispatching becomes critical – real-time adjustment of timetable performed primarily manually around location of disturbance (depends on dispatcher's knowledge of switches, signals, etc.)
- Goal is to minimize overall delay vs particular trains/operators

Penn Station Central Control was shared – operated by Amtrak half of year and commuter representative other half of year, to demonstrate that no preference being given

Aspects related to system relationships

Amtrak serves as both the infrastructure manager and the lead operator (intercity passenger rail) on the NEC

Summarised lessons learned

- Targeted investment to remove infrastructure pinch points instead of wholesale new lines and infrastructure
- Each improvement must have a business case and value for money

Summarised best practices

- Targeted investment

Sources

- Interview with Amtrak , John Bennett, Roy Johanson, 15 June 2007

Australia

Introduction

Victoria's rail network is the backbone of the local transport system and in the last 20 years patronage has grown by 43%. To meet this rising demand requires investment not only in large infrastructure projects but also in identifying measures to improve local capacity issues.

Timetable basics

Prefered measure is passengers per hour - note that this ignores freight operators and reflects RailCorp's principal role as a commuter operator. Trains per hour, but planning to move to passengers per hour as the measure.

RailCorp operates a form of clock face timetable but there are exceptions and adjustments to the detail. Two years ago the timetable was slowed to provide more recovery time since increasing dwell time at major stations (slow loading double-deck trains) was a factor in poor on-time running.

RailCorp operates five train types - (1) stopping all stations suburban, (2) limited stop suburban - typically run express over inner part of journey (3) Outer Suburban - limited stop or express to the edge of suburban territory (4) Intercity - EMU and DMU services to other cities in the greater Sydney area (e.g. Newcastle, Blue Mountains) run express from Sydney Terminal to the edge of suburban territory, thence limited stop or stopping (5) Countrylink - DMU or 'XPT' diesel trains (= UK HST) express through InterCity territory.

In the peak some services are planned to operate below their normal characteristics, to balance the maximum number of people with minimum number of trains. Off peak meets minimum headway criteria (most suburban lines minimum is half hourly, intercity hourly)

Aspects related to infrastructure

Main lines are up to six tracks. In the case of Redfern to Strathfield (inner west) two lines are express ('Main line'), two limited stop ('Suburban')and two stopping (Local). All RailCorp main lines are at least double track. Not much single track - major projects are under way to duplicate single track sections on Richmond and Cronulla Lines and to quadruple East Hills line to Revesby - details on the TIDC Web site. Some lines are a mix of two, three and four tracks. Strathfield to Hornsby is a significant example - from the Strathfield end it has 3 > 2 > 3 > 4 > 3 (one out of use due to major works) >2 tracks. See NLA 122, which details West Ryde to Hornsby, attached. This section carries 4 suburban limited stop services, 5 intercity/outer suburban, and 3 short worked suburban stoppers, plus one CountryLink service in the peak direction morning peak hour. Each type of train transits the section at a different average speed.

Refuge loops are used, for example near Thornleigh shown on NLA 122. Freight trains are held on loops or off the passenger network until they have a clear path. In the Strathfield-Hornsby example, down freight trains are held at 'tonnage signals' back from steep grades until they have a clear run up the grade. There is one at Epping ahead of the 'Beecroft Bank' (about 4 km of 1:40 rising grade against down trains), which results in freight trains being held on the four track section south of Epping for extended periods.

Aspects related to rolling stock

New suburban EMUs have better power to weight ratio, faster acting doors and more open vestibules to improve operation and SRTs

Aspects related to planning

The timetable is made by RailCorp for the complete network.

Aspect	Value
Planning priority	1. long distance 2. regional, suburban and freight
Type of timetable	Hourly pattern combined with peak increase; during peak hours (7:30-9:00 and 16:00-18:30) the number of trains is significantly higher.
Margins	Margins on the travel time consist of 5%
Signalling headway	The technical minimum headway on the main lines is approximately 2 minutes, although to operate freight this is reduced
Time unit for planning	minute
Empty trains scheduled	yes

Aspects related to operation

Access agreement for freight and third party operators includes pathing commitments and priorities. By law passenger has priority in NSW. There is a freight curfew during the commuter peaks.

RailCorp (greater Sydney area) control centres are separate from ARTC (country & interstate) control centres. Main control (Rail Management Centre- RMC) is in Sydney Central Station; however other major centres exist at Sydenham and Strathfield - these are major signal boxes. The Sydney area is still directly controlled by local signal boxes - train controllers at RMC provide oversight and communicate with the boxes by telephone

Recovery procedures are documented for some situations; however it is mostly down to the experience of the train controllers. Senior train controller at RMC has executive power to deal with perturbations, which are mostly sorted by the duty controllers. Major incidents once called by the senior train controller are handed over to an on-site commander.

Bi-directional lines are used principally where three track sections occur or at certain junctions. At North Strathfield there are four tracks described as down relief - down main - up main - up relief. Here a freight-only line joins the down relief, which is bi-directionally signalled to Rhodes, about 3.5km. This allows up freight trains to cross to the down relief at several locations between Rhodes and North Strathfield, to suit passenger movements. The up relief is rarely used.

Aspects related to system relationships – usage cost

Grandfather rights, allocation on demand. See http://www.railcorp.info/commercial/network_access

Summarised lessons learned

- Investment in rolling stock to decrease sectional running times
- Use of loops to generate additional capacity on the main line
- Use of bi- directional signalling to improve overall performance
- Use of pinch point analysis
- Grandfather rights are used for capacity allocation

Summarised best practices

- A mix of investment in infrastructure and timetable design to generate additional capacity

Sources

- Interview with RailCorp

Poland

Introduction

Poland has an extensive rail network with some 21.000 km of normal gauge track and small sections of narrow and broad gauge.
PKP is the main operator of the country and is also responsible for maintenance and renewal, as well as timetable design. The PKP Group is a Polish conglomerate founded in 2001 from the former single national rail operator, Polskie Koleje Państwowe. The purpose of this change was to conform to European Union directives of dividing transport service from rail system management and founding separate companies able to sell their service outside the rail business.

After the fall of the Berlin wall, traffic volumes have steadily decreased for a period of 10 years but are now growing again.

Capacity is defined as number of train paths per unit of time.

Timetable basics

Three train types are distinguished:
- express trains, max speed 160 km/h
- regional trains, max speed 100 km/h
- freight trains, max speed 100 km/h but in practice this is 80 km/h

The traffic mix on the Warszawa – Poznan (- Berlin) route is 40% express trains, 40% regional and 20% freight trains.

Aspects related to infrastructure

Major modernisation programs are undertaken to increase capacity, decrease travel times and increase permissible axle loads. The E20 route, an international route from Berlin via Poznan to Warszawa (and further east) is such a corridor where the modernisation includes track renewal, signalling and increase of diverging speed of switches.

Aspects related to planning

The timetable is built on demand from the operator. Traffic volumes are not high enough to facilitate an hourly pattern. The express trains are planned with the highest priority. Freight trains have low priority, especially during peak hours.

Aspect	Value
Planning priority	1. long distance 2. regional, suburban and freight
Type of timetable	Based on demand
Margins	Margins on the travel time are based on the line quality (age): • 5 min margin per 100 km for tracks older then 10 years • 3 min margin per 100 km for tracks younger then 10 years
Time unit for planning	Minutes
Empty trains scheduled	yes

With the express trains having highest priority, sub optimisations are not used.

There is no general understanding of pinch points as infrastructure renewals are based on modernisation programs of complete sections.

Aspects related to operation

The relatively large speed differences between express and other trains cause capacity problems. Slower traffic is directed to overtaking tracks in case of conflicts such that the express train experiences no impact.

Aspects related to system relationships

Operators pay access charges to the infra manager. The cost is determined on the basis of:

- line quality
- type of train: passenger or freight, with further categorisations for freight

In case a train path is not used, the operator is still eligible for 25% of the cost. Access charge is not used as a measure to regulate capacity.

Summarised lessons learned

- modernisation works include capacity improving measures as increase of line speed, reduced signal spacing and reduced switch angles
- height of access charge based on line quality and type of train
- access charge is not used to regulate capacity
- margins on travel time are applied on the basis of infra quality / age
- cancellation of train path is charged with 25% of the total price

Summarised best practices

- applying margins based on line quality / age

Sources

- Interview with PKP, J. Michniokowski, K. Lisowski, 19 June 2007
- Case Study Report Corridor II, code ten, 10 March 1999
- www.evd.nl

France

Introduction

The French railway network is large (31.000 km) with a combination of high speed (TGV) and regional lines. The network is highly centralised, most of the network is focused on Paris, where all TGVs terminate. Around the larger cities (mainly Paris, Lyon, Marseille) regional lines run.

Réseau Ferré de France is a Public Establishment of an Industrial and Commercial nature, or "EPIC", that was created in 1997. The company owns and manages the French rail network, and is responsible for upgrading, developing, and enhancing the network. RFF is owner of the national rail network and in charge of ensuring the finance, development and consistency of and obtaining full value from the network.

As project leader for investment in the rail network, RFF articulates its requirements, then orders and finances the structures built by contractors: development projects (modifications to the existing network, new lines) and modernisation (major refurbishment of equipment). RFF is responsible for the control of costs and timescales and of the quality of construction work.

RFF third role is as Infrastructure manager to determine principles and objectives applicable to operations and traffic management, and to the operation and maintenance of the network. The company is responsible for the attribution of train paths to train operators.

SNCF is by far the biggest operator 95+%, and is also delegated infrastructure maintainer. In this role, SNCF pays infrastructure usage charges to RFF.

The SNCF, appointed by RFF, is in charge of :

1. the management of regulation and safety systems
2. the operational management of rail traffic
3. the efficient operation of the network and its technical installations (surveillance, maintenance, routine and emergency repairs).

RFF measures capacity as the number of trains, not train paths. According to RFF capacity limits have not been reached. RFF do not have a cadenced timetable, there is no basic hourly pattern. Timetables are fragmented throughout the country and not integrated – interfaces are seen an issue. This is considered to be an organisational problem.

Timetable basics

Timetable design is based on demand although the TGV timetable sees some hourly cadenced services.
Sidings are commonly used to allow other trains to overtake. Priority is given to the train that is not delayed.
Timetable is designed using the requested train path. A fast, efficient, train is given a fast and efficient path, and similar to slow trains.
The technical minimum headway on the main lines is 3 minutes, but often more is used. This is depending on the type of train, the route and the signalling system (there are various signalling systems). This is defined in a big book that is published annually.

Aspects related to infrastructure

RFF have no general overview of pinch points, although RFF do measure punctuality and thus have a good overview on delays. If this is clearly caused by the infrastructure, actions are taken.

Rerouting of trains on other lines is not used. If no train paths are available, an alternative time is offered. The system is very market orientated, and uses an usage cost system to allocate train paths.

Aspects related to planning

The timetable is made by RFF for the complete network.

Aspect	Value
Planning priority	1. long distance (TGV) 2. regional, suburban and freight
Type of timetable	Based on demand although the TGV timetable sees some hourly cadenced services
Signalling headway	The technical minimum headway on the main lines is 3 minutes, but often more is used. This is depending on the type of train, the route and the signalling system (there are various signalling systems).
Time unit for planning	minutes

Aspects related to system relationships – usage cost

Usage cost is used as means to regulate traffic, mainly freight. On passenger trains there is no impact – passenger services have to be provided.

Usage costs are calculated by using a complicated system that differentiates charges by time and location.

The charge consists of 4 items:

- There is an initial Access Charge to get on the network, different for train types but not for operators
- Train operators have to pay Reservation charges for train paths
- Actual Running costs
- Station stop costs (pay per stop)

Additional to these 4 items energy costs are invoiced separately.

At the moment operators pay for reservation of train paths, but they can cancel the reservation free of charge. Clearly this causes unnecessary reservations. RFF announced that soon a cancellation fee of 80 euros is introduced.

Other issues

A performance scheme is in an early stage of development.

Summarised lessons learned

- differentiation of access charges have no impact on passenger services
- access charges consist of five aspects
- reservation fees need to be paid
- cancellation fee for train paths is considered

Sources

- Interview with RFF, Michel Dupuis, 5 July 2007

Italy

Introduction

Rete Ferroviaria Italiana (RFI) is the owner of Italy's railway network, it sets train paths, provides signalling, provides maintenance and other services for the railway network. It also operates the ships that carry the trains between the Italian peninsula and Sicily. RFI is fully owned by Ferrovie dello Stato

The focus for this benchmark is the performance regime as is in use in Italy.

Timetable basics

Definition of 'on-time' depends on type of train:

- 5 min. for regional trains
- 15 min for long distance
- 30 min for freight

The maximum planned capacity lays normally around 80%; during peak hours at some locations up to 100% is planned.

Aspects related to planning

The overall timetable does not have an hourly pattern; although suburban traffic around major cities tend to run in a pattern.

RFI is moving towards providing catalogue paths for long distance passenger trains.

Aspect	Value
Planning priority	1. Freight catalogue paths 2. Long distance and regional
Type of timetable	Freight per catalogue, suburban hourly pattern and long distance and regional on demand of operator
Margins	margin on travel time on average 5 min per 100 km
Signalling headway	headways on average 6 min, at points of conflict minimised to 2 min
Time unit for planning	Minutes
Punctuality norm	5 min for regional passenger 15 min for long distance passenger 30 minutes for freight

Aspects related to operation

Priority is dependant on the time of day:

- during the night: freight
- during the peak hours: regional services
- during off-peak: long distance

Performance regime basics

The performance regime is in development since 2001, with an experimental phase during 2004 and is fully implemented since January 2005.
The performance regime is regarded as the means to increase the performance of the railway system.

In addition the performance regime provides performance information by registering causes for train delays.

The performance regime is based on train delays at start and terminal stations, is applicable to all trains in the whole network and keeps track of individual trains rather then groups of trains. Penalties are based on delays at the terminal station only. The thresholds for penalties are identical for the punctuality norms, with the exception of last minute train services (planned shorter then 4 days in advance), see table below.

Type of train	Threshold for planned services	Threshold for last minute services
Long distance passenger trains	15 min	60 min
Regional passenger trains	5 min	60 min
Freight trains	30 min	120 min

The total delay is attributed by RFI Movimento (Operations) to those parties that are responsible for the different causes concerned, excluding force majeure. In case no cause is registered, the delay minutes are attributed to the infra manager.

Since 2006, any delays abroad are disregarded.

The defined value of a minute of train delay amounts to 2 Euro. Limits to the total sum of the penalty are defined per single train and relative to the total contract sum of the operator.

Experience with the performance regime

RFI claims that the train delay minutes in Italy have decreased from some 7 millions minutes to under 3 million minutes, which is to attribute to the performance regime.

Attribution of delay responsibility does not lead to great differences op opinion between the various parties, with 18 % of the delay minutes being discussed and only 4,4 % remains an issue that is dealt with by arbitration.

The financial income for RFI of penalties amount to less then 1,5% of the total income.

On some lines the reduction of delays made application of smaller margins possible, creating one more train path per hour.

Access charge

Train operators have to pay access charges for use of the infrastructure. The access charge covers the operational cost and is based on a fixed element and a variable element, see figure below.

CHARGE = F + V* km or min

F: Fixed — V: Variable

<table>
<tr><td rowspan="2"></td><td colspan="2">Which part</td></tr>
<tr><td>FIXED ACCESS</td><td>VARIABLE</td></tr>
<tr><td rowspan="5">What RU's pay for</td><td rowspan="4">Quality of line
(number of tracks, speed and technological equipment)
(Reservation fee)</td><td>Inefficient use of capacity (speed of train)</td></tr>
<tr><td>Usure (weight)</td></tr>
<tr><td>Traffic demands (density)</td></tr>
<tr><td>Use of section (km)</td></tr>
<tr><td>F is payed for each node and each trunk line
F_{max} is payed only one time for all secondary lines</td><td>Variation is based on number of km (trunk or secondary line) and minutes (nodes)</td></tr>
</table>

As indication, the table below shows the charges for different services based on price level 2004.

Passenger long distance trains	€/km
Eurostar Milan-Rome	3.32
Eurostar on other lines	2.70
Intercity	2.58
Night Express	2.22
Regional passengers trains	**€/km**
Rome Airport Shuttle	5.74
Interegio	2.32
Regional on main lines	2.37
Regional on little used lines	1.00
Freight	**€/km**
International Freight Combined	2.02
Other freight	2.14

The access charges are not used as a means to influence capacity. For example: although the access charges are lower during the night, the main cost drivers are more expensive during the night.

No reservation charges nor cancellation fees are charged although the latter is under consideration.

Summarised lessons learned

- performance regime does improve performance as it gives information on the cause of delays and thereby the means to resolve issues
- catalogue freight paths increase capacity and quality of train path
- access charge is not the main cost driver for operators when considering time of travel
- allocation of penalties does not lead to major issues between parties
- catalogue paths for long distance travel is considered

Summarised best practices

- use of performance regime
- catalogue freight paths

Sources

- Interview with RFI, F. Marzioli, 20 July 2007
- Presentation "RFI's Performance regime", Lyon, 24 May 2006
- Presentation "Italy: charging system on the network managed by RFI", 9 July 2004
- www.rfi.it

Brenner route

Introduction

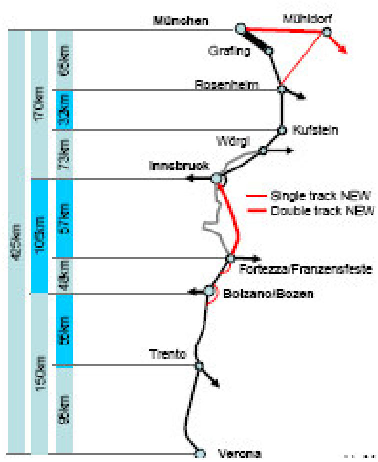
The Brenner corridor is one of the Alp transits and runs between München and Verona over a distance of 448 km, crossing three countries. The line is characterised by steep ramps with an inclination up to 26‰ and sharp curves with minimum curve radii of 260 m.
In order to increase the transport volume over this corridor, an 'action plan Brenner 2005' was identified as a co-operation between the three involved countries, Germany, Austria and Italy, involving 16 major industry stakeholders.

BRAVO project

For realisation of the goals defined in the action plan Brenner, the Bravo project was formed that is funded under the 6th Framework programme for research and technical development of the European commission, including all stakeholders of the Brenner route.

Within the Bravo project all issues that impact on the capacity and performance of the line and its services are identified and put in different work packages:

1. open corridor management system
2. train path rescheduling
3. interoperable rail traction
4. implementation of radio controlled push locomotives
5. comprehensive Brenner corridor quality management system
6. advanced train monitoring and customer information system
7. various innovations
8. transferability to other corridors



With regard to the benchmark, aspect 1, 2 and 5 are of particular interest and will be elaborated further in the following.

Corridor management system

It was found in previous studies that transport on international corridors is usually constraint by segmentations in infrastructure, legislation, interoperability, planning and operations.
In order to solve any issues and realise an enhancement of capacity, it is necessary to take a holistic approach to the problem. The corridor management system aided in identifying all relevant stakeholders and issues and addressing them in relation to each other.

Lessons learned:

- take a holistic approach to solve corridor issues
- involve all major stakeholders in solving the issue

Train path rescheduling

The three Infrastructure managers on the Brenner corridor, DB, ÖBB and RFI, have developed catalogue train paths. In the 2004-2005 timetable 30 paths a day each direction are available and they match the required quality, i.e. required length, weight of the train and duration of the trip.
Planning of catalogue freight train paths allowed to increase the available freight train paths from 60 in 2005 to 130 a day in 2007 whilst allowing passenger traffic undisturbed.

The ultimate customer of the train path is looking for services that best matches his requirements, which ultimately comes down to price. However, the EU directive 2001/14 prohibits transferral of a train path between railway undertakings, which effectively means that the ultimate customer is stuck with a railway undertaking, and if all paths are taken by large railway undertakings, the smaller once can not easily access the market, effectively obstructing the free market system . It is proposed that the ultimate customer gets ownership of the train path so he is able to change between railway undertakings.

In order to make transportation more flexible, it is proposed to make increased use of e-services for train path allocation and subsequently reducing the amount of time needed between application and actual service.

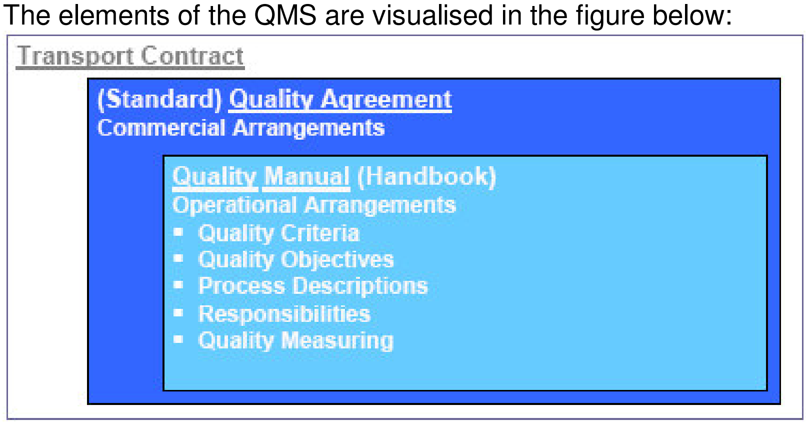
Lessons learned:

- definition of catalogue train paths helps to maximise available capacity
- to guarantee the free-market system train path ownership needs to be reconsidered
- required flexibility can be provided by e-services for train path allocation

Corridor quality management system

In order to realise a good performance or quality of service, quality objectives and indicators are defined for the complete corridor from München to Verona. The involved parties partners have documented the agreed quality objectives and all relevant processes in a unique quality manual. This quality manual contains the optimised processes of all involved companies active on the Brenner corridor whilst maintaining the existing competition.

The elements of the QMS are visualised in the figure below:



All these aspects are worked out into concrete performance indicators and the QMS is supported by training of personnel.

Lessons learned:

- a corridor quality management system, supported by training of personnel, aids performance and reliability

Summarised best practices

- a corridor quality management system to support performance
- cooperation between all (international) key stakeholders
- definition of catalogue paths for freight services with varying characteristics

Sources

- Presentation of final conference BRAVO, München, 17-18 April 2007
- Corridor management system, BRAVO RA1
- Train path availability and allocation process-summary, BRAVO RA2
- BRAVO newsletter 5, June 2006
- BRAVO newsletter 6, June 2007
- Interview with RFI, F. Marzioli, 20 July 2007

Japan

Introduction

Freight services are provided by JR Freight, formerly part of Japanese National Railways (JNR). In April 1987 JNR was privatized and split into 6 passenger rail companies, divided by region and 1 freight operator. Although it has only about fifty kilometers of track of its own, it also operates on track owned by the JR passenger railways and other companies.

M250 train

M250 is JRF's first freight train with distributed power, essentially being an EMU. The M250's is designed to provide a fast parcel service with a maximum speed of 130 km/h. The recent attention to environmental protection has seen a wish to accommodate a modal shift from truck to train. In order to be interesting for this modal shift in the parcel service, the train would have to fit in the door-to-door chain, meaning a necessary speed-up of the train.

Due to the distributed power, the axle load of the M250 is lower compared to a traditional freight train. This allows the M250 to obtain a higher maximum speed and a higher allowable speed in curves. These aspects make that the travel time is shortened dramatically, and therefore the M250 has a competitive advantage in medium transportation distance compared to road transport.

The M250 consists of 16 cars. The first two cars at each end are motor cars. Each side have Mc250 and M251. All wagons, including the four motorised cars can take on a 31 foot container.
Main system, such as traction, bogies and control equipment are developed based on the specifications of high-speed passenger trains. The 12 intermediate wagons are comparable with normal container wagons but are made suited for higher speeds by alternative bogies and disc brakes. The total train can carry 28 31 foot containers.

M250 service

The M250 train is used in a door-to-door chain parcel delivery service by Sagawa company. It runs from Tokyo freight station to Ajikawaguchi freight station (in Osaka prefecture). The train runs once a day leaving around 23:10 and arriving around 05:25. The distance is around 550 km.

Interaction with passenger traffic

The M250 is used for nightly services outside operating times for passenger trains. There is no interaction with passenger traffic. The train characteristics are not developed to fit within passenger train service but to provide a fast freight service.

M250 specification

目		SPEC					
Constitution and a car model		steel normal freight electrical train electric controlled car/ container car					
track		direct current 1,500V orbit clearance 1,067mm					
Formation (basic:16 cars) M:mortercar, T:Trailer		Mc250	M251	T260 * 6	T261 * 6	M251	Mc250
(unit)		1	1	2	2	1	1
empty car /Loading mass (t)		38.5/50.0	38.5/50.0	21.0/44.0	21.0/44.0	38.5/50.0	38.5/50.0
Main machinery		Pan Cp	Pan SIV			Pan SIV	Pan Cp
Main dimensions (mm)	Body dimensions	Length：M:20,300 T:20,500 Width：M:2800 T:2660 Height：M:3,792 (pantograph fold:4,250) T:1000					
	floor fight	1.000					
	connector hight	880					
use container		exclusive use 31feet length U54A-type one side open container, floor area 22.24m^2 inner volume 53.93m^3 gross weight11500kg					
Container dimensions(mm)	external form	length : 9410 width: 2490 height: 2641					
	Inside dimensions	length:9283 width:2396 height:2425					
	door opening	width: 2396 height: 2322					
Train performance		planned MAX speed 130km/h from Tokyo to Osaka 6 hour 10 minutes power:168kN					
EP collector device		single arm pantografh 1 mounting each M car					
connector		Mc head:ordinary wave, endposition: semiparmanent M front position : semiparmanent rear position: adoherence T: between unit:adherence inter rear unit: semiparmanent					
chassis	method	Air spring system volstules chassis					
	Dimensions	fixed axis length:2,100mm, wheel diameter M:860mm T:810mm					
drive type		middle axis pararell cardin, gear proportion 16:97/ 1: 6.06					
basic Braking means		M:unit brake T: unit brake + disk brake					
main motor		hour power 220kW (1100V-142A)					
control system		controlled VVMF inverter 3 level IGBT 1C1M (2group * 2 /per car)					
Brakes method		electric genaration pararell usage electric controll-type air brake . Spare: spring activated brake brake resistance unit ; natural cooling by wind 280 kw * 2					
electric air compressor		Mc：screw type 1600l/min per 1 mount					
Supporting power-supply unit		M:3 level PWM method inverter 85KVA * 2					
Driving security		ATS- SF type, ATS - PF type , train's radio transmission device, security radio transmission device, EB or TE device					
self check function		temperature of axis detection device					

Summarised lessons learned

- fast freight trains are not used to operate in between passenger services
- environmental awareness driver for modal shift from road to rail

Summarised best practices

- performance characteristics of freight train based on need on total logistical chain

Sources

- Questionnaire with JR freight, M. Nobuhiko, July 2007
- www.jrfreight.co.jp

Appendix 6: Background information

Freight and passenger transport characteristics

Characteristics of passenger transport needs

Passenger transport focuses on a large relatively anonymous public. This public is served by providing seats in a certain pattern based on research into the expected passenger volumes.
Passenger train operating companies rely on a so-called supply-model as there market instrument: to provide seats according to a time table.

In terms of timetabling, passenger services are planned from node to node. At the nodes passengers embark and disembark and connecting services are offered. The service offerings are optimised within a route.

Characteristics of freight transport needs

Freight transport is predominantly on specific demand, shuttle trains being the exception that resemble passenger transport. That means that the transport capacity needs to be tailored to the need of the client, which can vary during the week, season or year.

Freight transporters therefore need possibilities for freight transport, also to be able to serve new clients with, at the time of the timetable design, unknown origin, destination, sort of transport (impacting train type and thus speed) and time of day.

In contrary to passenger transport, freight transport is travelling over longer distances, effectively through the nodes that characterise the passenger network. There is little use for freight trains to stop in a node (so-called non-commercial stops) but as capacity in joining routes is mostly done irrespective of each other, stops frequently are scheduled to wait for a slot.

Appendix 7: Comparison with capacity issues in aviation industry

The problem of capacity and the best usage is not confined to the railways of the world but is one that confronts every aspect of transport and the wider business community. The need to drive efficiency and make best use of limited capacity is a challenge for all transport organisations in Highways, Aviation, and Maritime.

Perhaps one of the key issues is how transport is planned in a holistic way which provides an integrated transport system rather than competing modes. The relationship between air transportation and rail is apparent in all the countries we visited in Europe where airlines and rail networks compete for the same market especially between key European nodes.

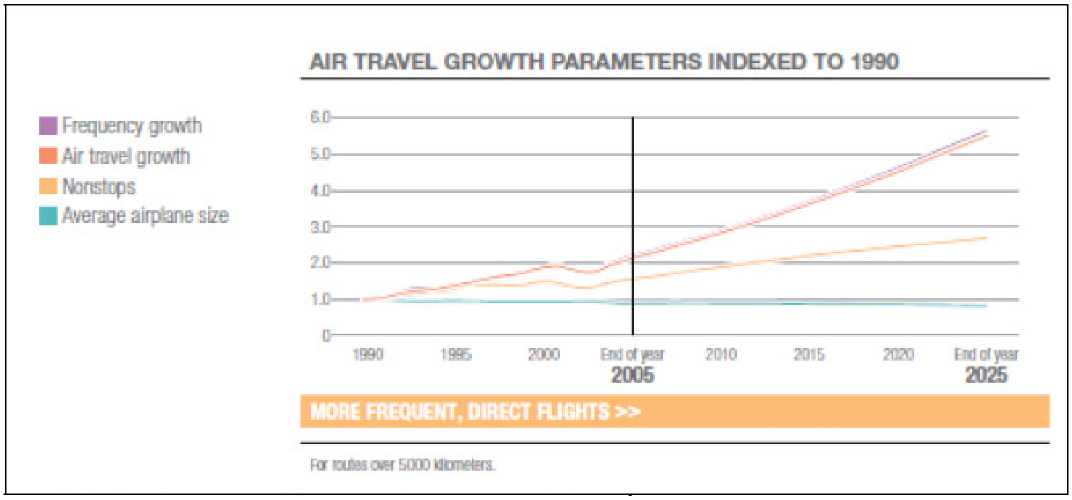
The challenge for aviation is to deliver the maximum capacity from the runways and terminals which is the equivalent of stations on the railway. In aviation although it appears that airspace is limitless many key routes to and from the main airports are at capacity similar to many tracks on the rail system.

In April 2007 a paper to the conference on 'Optimal Use of Scarce Airport Capacity' considered the efficient use of capacity from an airlines' perspective and some of the conclusions drawn were similar to those identified by our study into railway capacity. This includes increasing runway turnout speeds so that aircraft clear the runway faster, targeted investment to tackle operational pinch points on the airport and handling procedures and improved management of slots for take offs and landing with emphasis to adherence to the timetable plan.

The most significant aspect of an airports capacity is the Runway System Capacity which is defined as the hourly rate of aircraft operations which may be reasonably expected to be accommodated by the single or combination of runways. In turn this is dependant on runway occupancy times and separation standards applied to successive aircraft in the traffic mix. Other key items affecting runway capacity include:

- Availability of taxi-ways – particularly high speed exits which help to minimise runway occupancy times
- Aircraft type and performance
- Air Traffic control
- Spacing between runways and exit points
- Standard separation for avoidance of vortex disturbance
- Availability of terminal parking
- Ability to turn round aircraft
- Allocation of maintenance and handling equipment
- Availability of personnel

All these types of constraints can be correlated to similar restrictions applied to the rail infrastructure hence what if any proposals are being considered by the aviation industry to improve and maximise airport capacity.



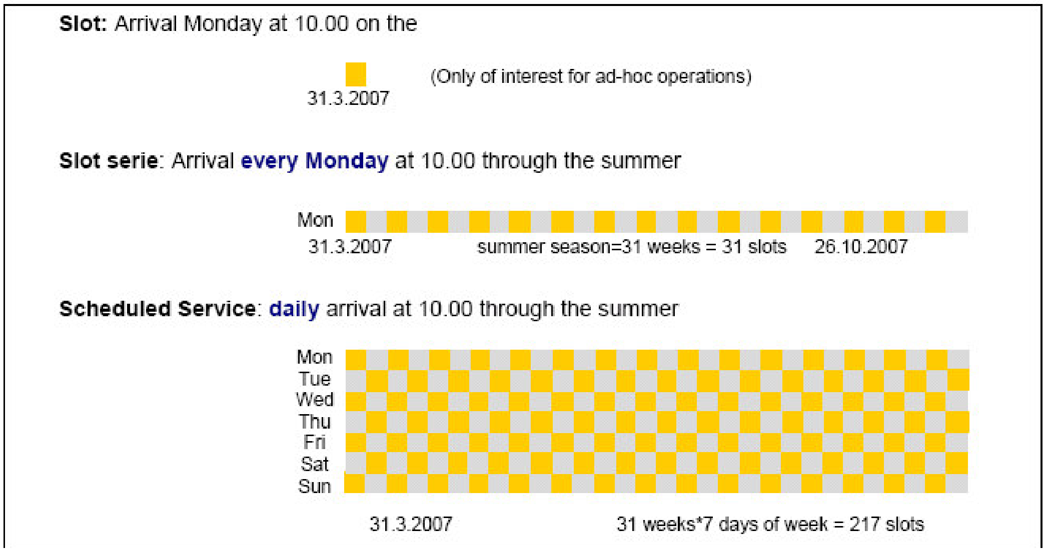
Above is the growth prediction for air travel to 2025 which seeks to breakdown the forecast utilising known parameters, such as larger plane capacities which could carry the forecast growth without the need to operate more flights. However increased aircraft capacity leads to longer turn round and handling of the aircraft which in turn affects the airport capacity.

All over Europe airport authorities are investing in new infrastructure which will be required to handle the ever increasing volumes delivered by each aircraft.

Non- stop long distance flights free up space in the 'staging airports' which are currently used for refuelling purposes however a larger fuel payload again affects the time taken for the aircraft to be maintained at final destination and the occupancy of terminal parking.

Slot Allocation

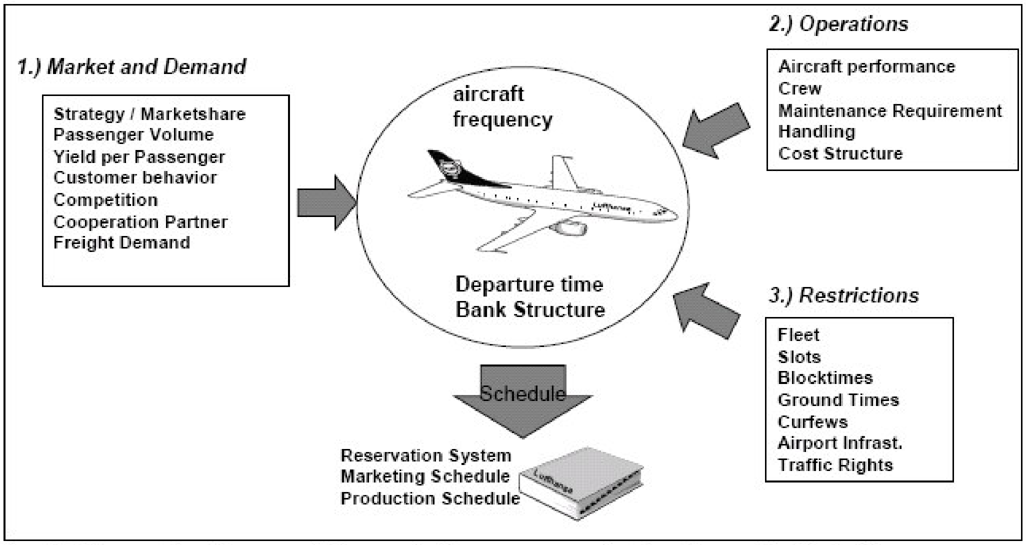
This can be allied to pathways on the rail infrastructure. In order to make best use of limited capacity, airports and Governments across Europe need to re-assess their transport needs across all modes. Should slots at airports be allocated to services which could be replaced by trains? The High Speed Rail network in central Europe has been designed to compete with the air services on both door to door journey time and quality. This in theory should release slots for longer distance or international flights. A sample slot allocation is shown below



The planning cycle for aircraft is a similar process to timetable planning with long lead times for the industry negotiations required

Slot allocation is governed by various factors such as grandfather rights, technical and economic efficiency, legal frameworks, worldwide scheduling guidelines, EU Regulations and European Regulations applicable by each member Country. All of which add constraints to an already complex structure by overlaying an additional set of planning parameters and air space rules.

The diagram below shows the relationship between internal and external factors affecting the planning and scheduling of flights.



Airports		Percentage of Slots requested	Percentage of Slots initially allocated	Slots held after Slot Return Deadline (= 100%)	Percentage of Slots used
London Gatwick	LGW	115%	104%	100%	99%
London Heathrow	LHR	113%	101%	100%	98%
Munich	MUC	120%	118%	100%	97%
Barcelona	BCN	130%	104%	100%	96%
Madrid	MAD	128%	103%	100%	96%
Milan Linate	LIN	102%	102%	100%	96%
Vienna	VIE	107%	107%	100%	96%
London Stansted	STN	108%	107%	100%	95%
Amsterdam	AMS	111%	111%	100%	95%
Milan Malpensa	MXP	106%	106%	100%	94%
Frankfurt	FRA	108%	99%	100%	93%
Paris	CDG	124%	124%	100%	92%
Düsseldorf	DUS	127%	91%	100%	90%
Average					95%

The table above shows Slot usage at Capacity Constrained European Airports in Summer 2006 this indicates a very high percentage of actual capacity used at 95% but this is achieved against a backdrop of a much higher demand by the airlines and initial allocation by the airport.

Conclusion

There are similarities between the aviation and rail industries which revolve around the allocation of slots on runways or paths on the track. The aviation industry is more regulated than rail and the imposition of both overarching and local rules limit the usage of airspace and force inefficiencies into the use of airports.

The over allocation of slots is similar to the situation on DB where the freight traffic is allocated pathways on a very short term planning timescale which can ultimately lead to a higher capacity utilisation index.

The aviation industry has however looked at targeted investment in capacity both for handling aircraft at airports and increasing the passenger payload. Both these mechanisms have been adopted by the rail industry.

From the review of Aviation technical papers the problems faced by the two industries are similar and so are the solutions but there is not one overarching idea which could be translated to the rail sector.

Appendix 8: List of interviewees

Country	Person	Position	Date	Location
	Jo Haller Michael Schuerch	Head of Path Management/Infrastructure Marketing Head of network utilisation	25 June	Bern
	Felix Laube Oskar Stakder	Head of process and methods	26 June	Bern
	Marcel Wenger		17 July	Spiez
	Klaus Junker	currently coordinator of the TERF Corridor A and formerly COO of DB Net	28 June	Frankfurt am Main
	Guy Vernieuwe	Manager startegy, nternational affairs and IT	28 June	Brussel
	Peter Field	Director London Rail Development	20 June	London
	Iain Gee	Service Planning Manager	19 June	London
	Peter Northfield	Business Manager RUS	20 June	London
	Stuart Baker	Rail Development Manager Major Projects	5 June	London
	Roy Johanson	Senior Vice President	15 June	Washington, DC
	John Bennett	Chief	15 June	Washington, DC
			21 June	Sydney
	Jerzy Michniowski Krzysztof Lisowski	Director exploitation bureau Head of platform and lines capacity analysis Department	19 June	Warszawa
	Michel Dupuis	Capacity Director	5 July	Paris
	Franco Marzioli	Commercial Director	20 July	Rome
	together with RFI		20 July	Rome
			11 June ;16 June	Tokyo

Appendix 9: Interview questionnaire

CAPACITY BEST PRACTICE QUESTIONNAIRE Ministerie van Verkeer en Waterstaat

OBJECTIVE
Our goal is to understand what measures have been employed successfully by rail administrations to improve the capacity of the infrastructure to operate additional services
METHODOLOGY
19 measures were identified which could improve capacity or performance of the network which could allow additional services to operate. These measures were refined following a workshop and ranked in importance. There are now 8 key measures, 4 important measures, 3 significant measures and 4 measures to note plus an other category The next stage is to take this questionnaire to other administrations to gauge how useful the measures have been in those countries

Contributes to		Measure		Remarks (for the Netherlands)
Capacity	K	Capacity improving measures in infrastructure	0	The objective should be to avoid as much as possible
Capacity	M	Availability measures in infrastructure	+++	Reduce downtime of the infrastructure for engineering
Capacity	Q	Signalling headways	++	Block length, signal spacing, possible ERTMS
Performance	J	Rolling stock requirements	0	Reliability of rolling stock
Performance	R	Management of staff	+++	Staff can impact time keeping/performance
Performance	S	Availability of fault clearing service - rolling stock	++	Rolling stock defects is a relatively big issue
Capacity	A	Method for timetable design	+++	Undertaken with timetable change 2007
Capacity	B	Travel time improvement for passenger & freight	+	Especially possible for freight
Capacity	C	Management at junctions for through trains	++	Green waves for freight trains
Capacity	E	Sub optimisation to create capacity	++	Adapt Intercity timetable to fit with freight
Performance	H	Dynamic traffic management	+++	Already tried at stations
Both	L	Platform utilisation analysis	+++	Is an issue consider with H
Capacity	N	Automatic train operation (ATO)	0	Probably not achievable from a cost perspective
Capacity	O	Regulation and route prioritisation	+++	Difficult from view point equal opportunities pass& Fr
Both	P	Understanding of pinch point analysis undertaken	+++	Much done Benutten en Bouwen
Both	D	Alternative routing	+	Effective after completion Benutten en Bouwen
Performance	F	Differential track access charges	0	Especially possible for freight
Performance	G	Performance regimes	+++	Relatively new aspect merits not clear
Both	I	Environmental legislation	+	Noise will be an issue
Both	-	Various		Possible other measures from interviews

No.	Measure of Success
PHASE 1: GENERAL / DEFINITION	
	Definition of improved capacity
1	Improved utilisation can be characterised in a number of ways. How would the administration define improved capacity, for example increased paths/number of seats, improved performance
2	How is capacity current measured and allocated
3	What type of track access agreement is in place - grandfather rights/differential pricing
PHASE 2: INFRASTRUCTURE	
	Increase network availability
4	How is normal engineering work planned - engineering periods
5	How are special projects/renewals planned
6	Does the Infrastructure maintainer buy access
7	What proportion of possessions overrun
8	How are overruns managed
9	What is the impact of the safety regime on possessions
10	How is patrolling undertaken - are possessions required
11	What is the split of infrastructure delays

PHASE 2: TRAIN OPERATING COMPANY	
	Management of Staff -TOC
12	Full crew working
13	Major terminals crew work same train in and out
14	What type of rostering/diagramming system used
15	Duties of platform staff for train dispatch
16	What basic training is undertaken
17	What recovery plans are in place - what consultation
18	Information provision - how is information disseminated
19	How are station delays captured
PHASE 3: TIMETABLE DESIGN / TRAFFIC MANAGEMENT	
	Timetable Design
20	What constraints exist - clock face departures
21	Mix of train speeds - stopping/express/semi fast
22	Station dwell times - especially turn a round times at terminals
23	Empty coaching stock - how are they timetabled
24	Last recast of timetable
25	What is the mechanism for timetable change - how are changes managed use of spare capacity or rewrite, flexing limits
26	What allowances are in the timetable, engineering, pathing, performance etc
27	Is the timetable developed in order to produce the best use of capacity - are some services sub optimally planned
28	What proportion of short term planning for services particularly freight
	(Dynamic) traffic management
29	How are services regulated - International Long distance commuter/local Freight
30	Where are the control centres based/ are they joint
31	What if any real time control support tool used (for example CCF)
32	What are the mechanisms to recover from perturbation - who has executive power for decision making
33	How is information disemminated to front line staff
34	How are emergency services VSTP trains handled - do they affect capacity or performance
35	What is the command and decision matrix for multi operator routes
36	Is there a performance regime in place
37	What mechanism for delay attribution and follow up to allocate to users
38	Is there an agreed recovery plan
39	Are telephone conferences/face to face meetings held to ascertain reasons for major incidents/delay
PHASE 4: INTERACTION INFRASTRUCTURE - TOC - TIMETABLE DESIGN / TRAFFIC MANAGEMENT	
	Platform Utilisation Analysis
40	Objective to minimise station dwell are the following used and are they successful
41	Control passenger movement to speed up boarding, mark position of doors, station signage clear showing route to train
42	Set down/pick up only stops
43	What proportion of starting delays are waiting signal
44	Are staff actively engaged to minimise station delay
45	What proportion of platform occupation for train preparation
	Speed harmonisation
46	To make best use of capacity
47	Timetable by concensus or rules of the plan how much interaction
48	Separate fast and slow services/proportion of two track/single line
49	Use of loops - keep freight running as use more capacity starting and stopping
50	BI directional lines use as loops or just emergency
	Understanding of pinch point analysis
51	What analysis undertaken to identify pinch points
52	Are contributory factors looked at - station location, line speeds
53	Is there a full understanding of service dynamics
54	Were timetable changes used to eliminate pinch point was this successful
55	Were infrastructure changes used to eliminate pinch point was this successful
56	What proportion of delays are attributed to the pinch point on a route

PHASE 5: NETWORK ACCES	
	Performance Regimes
57	Does a performance regime exist
58	Are there financial penalties
59	How is the PR managed
60	What percentage of theoretical capacity used for traffic
61	Does it create capacity or improve performance
62	Would improved performance lead to more theoretical capacity being released
63	What improvements have been measured by the introduction of a PR
64	Is it cheaper to pay penalty than fix problem
65	How were the base target set what analysis was undertaken
	Usage cost
75	Do train passenger and/or freight operators have to pay for access
76	Is usage costs differentiation used as means to regulate capacity
PHASE 6: VARIOUS	
	Other measures considered
66	Improve signalling headways
67	Empower users to rectify T&RS faults
68	Management of trains at junctions
69	Sub Optimisation - covered in timetables
70	Alternative routing - particularly for freight
71	Environmental issues impacting on hours of operation - noise at depots, on track (a.o. restrictions freight trains), overnight maintenance
72	New infrastructure construction
73	New rolling stock - improved performance reduced SRT
74	Automatic Train Operation
	Open items