WP3: Real time network management and simulation of increasing speed for freight trains

Deliverable 3.1 State-of-the-art and specification of innovations, demonstrations and simulations

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Executive summary

The document contains Deliverable 3.1, “State-of-the-art and specification of innovations, demonstrations and simulations”, in FR8HUB WP3, “Real time network management and simulation of increasing speed for freight trains”. WP3 will deliver a demonstrator showcasing the effects of 1) improved traffic management through better interaction between line and yard, and 2) increased freight speed and its effects on overall increased capacity, punctuality and reduced travel time for both passenger and freight trains.

Section 1 introduces the work package and its objectives. In Section 2, the WP3 scope is described and the relation with IP5 ARCC project and WP4 intelligent videogate is given, in particular concerning the data correlations between these. Furthermore, the ARCC project will be finished during the autumn of 2018, and gives valuable input about yard management and yard – line interaction to WP3. In WP4, an intelligent video gate will be developed to gather information about trains, wagons and loading units passing through the gate.

Section 3 gives specifications of the innovations in real time network management which are part of WP3. The main innovations are in 1) tactical data driven timetable planning, 2) operative traffic control adjustment for a single train, and 3) tactical planning, analysis and models of yard and network interaction. In Section 4, the objectives, analysis of input data and future work regarding a Multimodal Data-Exchange Platform is described. In Section 5, the demonstrations which are part of WP3 are described. The demonstrator will be applied to the line between Malmö and Hallsberg and is based on data from RailSys. The other contents of the chapter are architecture; functionality and first mock-up; interfaces and data format.

Section 6 is about faster freight trains. The categories are fast freight rail 120 – 160 km/h, very fast freight rail 161 – 200 km/h and High-speed freight rail > 200 km/h. For each category, concepts, in operations and discontinued train sets have been described. Section 7 contains an analysis of railway lines in Germany for evaluation of faster freight traffic. The main lines to further study are Karlsruhe – Basel and Hamburg – Hannover. Finally, conclusions are given in Section 8, together with references in Section 9.

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Abbreviations

AWP	Annual Work Plan
CA	Consortium Agreement
CCA	Cross Cutting Activities
CT	Cooperation tool
DB	Deutsche Bahn, German Federal Railway
DUSS	Deutsche Umschlaggesellschaft Straße Schiene
EC	European Commission
ED	Executive Director
ETCS	European Train Control System
ETR	Elettro Treno Rapido
GA	Grant Agreement
ICE	InterCityExpress
IP	Innovation Programme
IPR	Intellectual Property Rights
LDHV	low density, high value
LZB	Linienzugbeeinflussung
MAAP	Multi-Annual Action Plan
NGT CARGO	Next Generation Train Cargo
S2R JU	Shift2Rail Joint Undertaking
SC	Steering Committee
SMP	Strategic Master Plan
TD	Technical Demonstrator
TGV	Train à grande vitesse
TMT	Technical Management Team
WP	Work Package
WPL	Work Package Leader

AWP	Annual Work Plan
CA	Consortium Agreement
CCA	Cross Cutting Activities
CT	Cooperation tool
DB	Deutsche Bahn, German Federal Railway
DUSS	Deutsche Umschlaggesellschaft Straße Schiene

1 Introduction

1.1 Objectives

Network Management will develop methods for improved interaction between network management and yard management and evaluate the effect on line capacity. The work package will deliver a demonstrator showcasing the effects of;

1. Improved traffic management through better interaction between line and yard

2. Increased freight speed and its effects on overall increased capacity, punctuality and reduced travel time for both passenger and freight trains.

To evaluate and validate the effects, two important lines on the Scandinavian-Mediterranean Corridor in the TENT network (Malmö-Hallsberg and Hamburg-Hannover) in Sweden and Germany will be used as case studies.

The project is in line with the targets of MAAP TD 5.2 and within the scope of digitalization of future freight traffic. The project will be in parallel to current shift2Rail IP5 TD2 project started in 2016 ARCC project. Synergies between TD 5.2, IP2 (TD2.9) and IP4 (TD4.1) will be used. In this sense, Work Area 4.2, relation with Integrated Mobility Management (I2M), in Cross-Cutting Activities, will specify and implement the substructures needed for automated message exchanges between Freight operations and Traffic management systems via the Integration Layer, in order to achieve Shift2Rail objectives.

The activity is expected to provide a simulation of real-time network management based on the developed data-exchange platform in a test environment. (TRL 5)

The activity will develop a prototype consisting of a graphical user interface to simulation and analytical models, operating on data from the platform. The prototype will be used to demonstrate the analysis of freight capacity in yards/terminals and in the lines, for the two important lines on the Scandinavian-Mediterranean Corridor in the TEN-T network stated above.

The following are the main overall objectives of WP3:

- Scanning of innovations and actions to increase overall speed of freight trains by improved train performance with economic evaluation, processes and automation. Investigations related to both improvements in planning and operational processes and in the effects of improved railway technology from a system perspective.

- Simulation of faster freight trains for important and mixed traffic bottleneck railway lines in Sweden and Germany with the aim to harmonize speed and increase capacity and punctuality.

- Definition of a Data-Exchange Platform to improve the management and process for freight trains including data exchange, traffic information and traffic simulations between infrastructure managers and freight transport stakeholders

- To develop improved methods in connecting yards/terminals and network. The main goal will be to create a high level model about freight capacity in yards/terminals – network.

Thus WP3 will develop methods for improved interaction between network management and yard management including:

- Development of a data exchange platform for intermodal hubs for connecting rail freight stakeholders, facilitating operation of mixed traffic (passengers and freight)

- Specification of integration layers for real-time yard management and real-time network management applications. Evaluation of the effect that a technological upgrade of one hub, will affect other hubs and nodes in the network

- Simulation of operational scenarios on freight corridors to increase the average speed improving train dynamics with the aim to optimize time-tabling systems.

Moreover, FR8HUB will contribute to increasing punctuality by at least 10 % through:

- The network management system, enabling improved tactic and operational planning and through this a better allocation of allowance time. (WP3)

- By simulation, prove the positive punctuality effects from increased average and absolute speed for freight trains by better train dynamics, leading to larger absolute allowances, and improved network and yard operational planning (WP3)

To summarize WP3 will answer to the work stream of FR8HUB by research in following areas:

1. A method of improved management and process for freight trains in interaction including data exchange, traffic information and traffic simulations.

2. Design and development of a prototype data sharing service, where data from the performed simulations will be made available. Design and specification of input data format, following TAF TAP TSI, from real-time yard management and real-time network management applications.

3. Innovations in increase of overall speed of freight trains by improved infrastructure and train performance with economic evaluation, processes and automation. Both improvements in planning and operational processes and in the effects of improved railway technology from a system perspective will be investigated.

Figure 1.1 illustrates the tasks covered in the WP3. The first three tasks are a part of this report, Deliverable 3.1.

TDs	TASKS		TRL	2016				2017				2018				2019				2020				Input from other TD
Tasks	Name	Deliverable		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
3.1	Scanning of innovations and best practice M1 – M9 Trv, CFW, Indra (Trv lead)	D3.1	2							■	■		● ◇											IP5 ARCC and WP4 Intelligent videogate
3.2	To define scenarios for simulations and network management M7 – M12 TRV, CFW (Trv lead)		2									■	■											
3.3	Design of demonstrator functionality and high-level methods for network management M7-M12 TRV (Trv lead)											■	■											
3.4	High level System architecture and videogate information M7 – M18 Indra, Trv, CFW (Indra lead)		2									■	■	■	■	■	■ ◇							IP5 ARCC and WP4 Intelligent videogate
3.5	Traffic simulation of defined scenarios M13 – M36 Trv, CFW (CFW lead)		3											■	■	■	■	■	■	■	■ ●			
3.6	Demonstrate new methods for FR8Hub networkmanagement concept M13 – M24 Indra, CFW, Trv (Trv lead)	D3.1	3											■	■	■	■ ●							IP5 ARCC and WP4 Intelligent videogate
3.7	Evaluation of the defined scenarios M27 – M36 Trv, CFW (CFW lead)	D3.3	4																■	■	■			
			-																					

◇ milestone — D3.1 – State-of-art and specification of innovations in Fr8Hub and defined scenarios (TRV, Report: M12) TRV

● Deliverable — D3.2 – Demonstration of FR8HUB Network management concept. TRV, M24) TRV

■ planned activities — D3.3 – Results of traffic simulation of defined scenarios and evaluation (TRV, Report: M34) CFW

Milestones

MS WP3.1 – Specification of innovations and demonstrator

MS WP3.2 – Overall high-level architecture of Data-Exchange Platform and connection to terminal intelligent videogate (Report: M18) Indra

Figure 1.1. Structure of the tasks covered in WP3.

Task 3.1: Scanning of innovations and best practice in interaction between Network management and yard management (Leader: TRV, contributors, DLR, INDRA, Start: M1, End M12)

• Ensure a state-of-art and best practice in interaction between Network management and yard management. In this sense it will be specified benefit and need for real-time yard management and real-time network management applications.
• Specify the innovations in WP3 and how they will be evaluated and demonstrated.
• In correlation with WP4, establish the format of input data (identities of in- and outbound trains, wagons and LUs) from the Intelligent Video Gate.
• In correlation with ARCC project, describe Network management and yard management visions for FR8HUB WP3.

Outputs of ARCC project, relation with Time Table Planning (TD5.2.1) and Real-time Yard Management (TD5.2.2) will be used as inputs for the definition of the interfaces of the Data-Exchange Platform in Task 3.4.

Task 3.2: To define scenarios for simulations and demonstrations (Leader: TRV, contributors: DLR, Start: M7, End M12)

There are two areas for simulation and demonstration in FR8HUB; higher speed freight trains (raising speed, train performance, improved infrastructure) and automation and improved processes between network and yards and terminals. The work content in this task will be to:

• Analyse actions to increase average and absolute speed for freight trains. What actions are relevant and what is the impact? To select most promising actions to be further studied. For selected actions describe how they can be evaluated and simulated.

• Create an overview and select relevant bottle neck lines which is of importance for freight traffic in the Scandinavian-Mediterranean Corridor in the TEN-T network (Malmö – Hallsberg and Hamburg – Hannover).

• Define a base scenario of selected bottleneck lines according to current state.

Timetables will be validated using a commercial micro simulation tool in RailSys. This tool is used for timetable analysis today at Trafikverket.

Task 3.3: Design of demonstrator functionality and high-level methods for network management (Leader: TRV, Start M7, End M12)

The task will define demonstrator functionality and methods for interaction between network management and yard management.

The remaining tasks, T3.4-3.7, will be carried out in the coming deliverables and are briefly described below:

Task 3.4: High level System architecture and video gate information
(Leader: INDRA, contributors: TRV, DLR, Start M7, End M18)
This task focuses on the definition of the high level architecture of the Data-Exchange Platform and information from video gates in terminals. • Define the general architecture of Multimodal Freight Data-Exchange Platform for data exchange between freight transports stakeholders, in order to ensure the full integration of freight transport stakeholders in global railway operations. • Define Use Cases and Operational tests to validate the defined architecture in relevant environment (Task 3.5).

Task 3.5: Traffic simulation of defined scenarios
(Leader: DLR, contributors: TRV, Start M13, End M36)
Simulations will be made according to the defined methods.

Task 3.6: Develop demonstrator for FR8HUB network management concept
(Leader: TRV, contributors: INDRA, DLR, Start M13, End M24)
A network management simulation prototype will be developed, based on the design developed in previous tasks. The prototype will be used to demonstrate the network management concept of FR8HUB, based on the high-level system architecture from Task 3.4 and the high level methods of freight capacity and interaction between yards/terminals and railway network from Task 3.3.
The demonstration will be performed in a simulated environment on selected bottleneck lines and yards/terminals along the TEN-T corridors in Sweden and in Germany, and will be validated using micro-simulation based on Task 3.5.

Task 3.7: Evaluation of the defined scenarios for higher speed freight trains
(Leader: DLR, contributors: TRV, Start M27, End M36)
Economical evaluation of studied scenarios regarding cost and benefit from the perspective of train operating and Infrastructure Manager. Other benefits may be commented.

2 Real time network management scope

The scope for real time network management is to develop the interaction between yards and terminals and the railway network. Yards and terminals for freight traffic are handled by a Yard manager or a terminal manager. In this chapter the connection is described with:

- Relation between WP3 and other projects in IP5 especially ARCC project which gives valuable input.
- WP4 intelligent video gate which gives input to scenarios and demonstration in WP3.

2.1 Input from other EU projects

ARCC WP2 focus is on Yard management but also handle network partly. WP2 started October 2016 and ends September 2018.

In D2.1 following yards and terminals were studied:

- Yards: Hallsberg, Mannheim, München
- Terminals: Årsta, München Riem

D2.1 was finalised in September 2017.

In D2.2 further studies about planning process in short term and ad-hoc planning to daily timetable and processes in operational traffic in Sweden. Main roles are infrastructure manager (network manager), Marshalling Yard manager and Freight operator.

Shortcomings and difficulties in the processes for yard management and yard – network management. Improvement potential has been discussed.

D2.2 was finalised in February 2018.

In D2.3 – Modelling Requirements and Interface Specification to Yard Simulation System is further studied. New concepts for handling single wagon load traffic is considered – e.g. Freight booking, Incremental planning and improved short-term and ad-hoc planning. Basics for real-time decision processes for yard and yard-line operations are described. Objectives for support decision processes for yard and for line - yard is also described. Modelling requirements for a real-time decision support system for yard and yard-line operations is the overall result.

D2.3 will be finalised in August 2018.

D2.4 is the final step. The task is to describe scenarios for a Real-time Yard management system.

D2.4 will be finalised in November 2018.

In ARCC WP3 research and innovation activities identifies areas with a need for improved timetable planning methods. A starting point is the needs at the freight nodes, but the problem also involves all other traffic sharing the same infrastructure-related resources. ARCC WP3 will result in one deliverable (D3.1), entitled “Final pre-study for an improved methodology for timetable planning including state-of-the-art and future work plan”. Deliverable D3.1 will be finalised in August 2018.

In 2018-05-29 it was a one day seminary in Stockholm organised and hosted by ARCC project. The main purpose was to communicate and discuss current research in ARCC WP2 about interface to traffic management and WP3 research plan pre-study improved timetable planning. Shift2Rail projects ARCC, FR8Hub and Optiyard were participating. Extensive documentation of the seminar will be included in ARCC WP D3.1.

2.2 Input from Intelligent video gate WP 4

Within the Fr8hub project there are eight work packages (WP's) which are outlined by the Grant Agreement (GA) of the project. The closeness of the relation between the work packages is varying, where an especially close cooperation is outlined for this work package, WP3 Network management, and WP4, Intelligent Video gate (IVG). The following objectives of WP3 are related to WP4:

- To follow and monitor the results and performance effects of WP4 Intelligent Video gate on freight traffic.
- In correlation with WP4, establish the format of input data (identities of in- and outbound trains, wagons and LUs) from the Intelligent Video Gate.
- To describe how a multimodal exchange platform could connect and exchange data between the video gate and infrastructure manager, railway undertakings and other stakeholders

The first deliverable of WP4 is Deliverable 4.1 which is bound to be finalized in June 2018 (M9) and consists of two main tasks:

1. Description of functional and technical requirements – a compilation of the prerequisites for IVG technology. (Leader: Duss)
2. Selection of components – a market study ensuring appropriate components are selected. (Leader: Ansaldo)

Four project partners are involved in both WP3 and WP4; Trafikverket, DB (Duss in WP4), Indra and KTH. Other partners in WP4 include Ansaldo, EUROC/ÖBB, TfK, SICS RISE and LearningWell. The latter three as well as KTH are linked in third-parties from Sweden contracted by Trafikverket.

Two more tasks are to be covered in the second and final deliverable of WP4:

- T4.2 Technical proof of concept – a technical test and progress report to validate the functionality of IVG. (Leader: INDRA) (M18)
- T4.3 Rollout & Implementation plan - Overall structure for introducing IVG technology to the market. (Leader: Trafikverket) (M24)

Figure 2.1 illustrates the main tasks covered in the WP4. The first two tasks have been merged into one deliverable, Deliverable 4.1, and the latter two tasks, have been merged into deliverable D4.2.

				2017		2018				2019				2020		
	Description	Leader	Deliv.	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
WP4	Intelligen video gate	DB														
T4.1	Description of functional and technical requirements	DB	D4.1													
T4.2	Selection of components	ASTS	D4.2				D									
T4.3	Technical proof of concept	INDRA	D4.3													
T4.4	Rollout & Implementation plan for pilot site(s)	TRV	D4.4									D				

Figure 2.1. Structure of the tasks covered in WP4, Intelligent Video Gate.

As stated above the task 3.1 in this deliverable consists of establishing the format of input data (identities of in- and outbound trains, wagons and LUs) that can be derived from WP4 the Intelligent Video Gate. Following data correlations between the two work-packages have been identified thus far:

- identities of in- and outbound trains, wagons and LU
- central connection to databases (train data, wagon data, LU data)
- communication of data deviations between pre-notified data and IVG real-time data
- automatic check of incoming wagons and load units is expected to yield time savings, thus reducing the terminal throughput time with approximately 30 minutes per train.
- automatic checks and increased safety for outbound trains
- improved operations at nodes is not achieved only through automatic checks and deviation handling, but also through optimizing the transhipment process and the interface towards road transportation as well as other benefits that improved and digitalized information exchange can imply.
- more reliable ETA and ETD of trains and initiation of terminal services in case of deviations.

The main functions of the technologies considered in WP4 are the following:

- Identification: Video cameras and RFID-systems - including readers and tags.
- Detection and Classification: Cameras and Laser scanners.

Figure 2.2 illustrates the intermodal supply chain considered in WP4 of which the rail based transport chain part is directly related to the network management perspective adopted in WP3 and Network management. The figure also highlights suitable positions for video gates. The main position considered is marked as “X” in the figure and positioned in-between the rail entrance/exit of the intermodal terminal and the shunting operator. These gates would imply enabling improvement of information exchange between Terminal-to-terminal/rail undertakings and network managers. For the terminal operator the gates would imply improvement in operational efficiency mainly due to:

1. Faster arrival process (Deviation handling, automated arrival e.g. check/damage claims/handling of dangerous goods)
2. Improved and faster operational handling as wagon and ILU sequence (and any deviations) are known in advance, enabling optimized transshipment plans and interface towards road hauliers. The latter in particular when combined with road video gates, marked as “Z” in the figure.
3. Faster departure process (Automated departure check, improved safety, handling of dangerous goods)

These factors can lead to significant reduction of service times at terminals (to be analyzed further) and thus reduces disturbance sensitivity of the transport chain as well as the probability of the terminal constituting a capacity bottleneck in the chain.

Detection points – in this context defined as gates with only partial functionality of the intelligent video gates that can use RFID readers for detection purposes. Cameras and scanners can be excluded from these points if classification or other functionalities are not required. The positioning of the detection points is marked as “O” in Figure 2.2 and is between the shunting operator and the main rail network. The points can also be added to any other yard managers’ facilities along the train’s route thus contributing to traceability and higher efficiency as any reconfigure of the train along the route is known in advance by the terminal operator who could then re-plan their processes.

Wagons are equipped with RFID tags and Infrastructure managers have RFID readers that can position wagons: wagon unit ID, when it passes and what direction. In Sweden there are about 350 RFID communication points June 2018. This data can be used to increase quality, capacity and efficiency in the railway system. High speed detection, well over 200 Km/h is possible although it will not be reached in the context of IVG-application in intermodal terminals but high speed requirements could be relevant for the detection points.

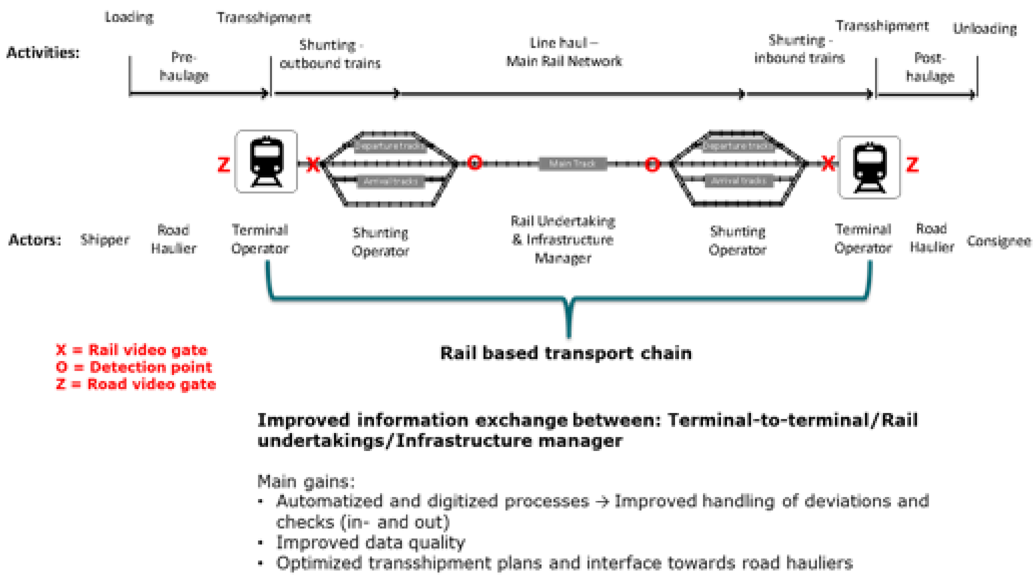


Figure 2.2. Potential effects on the intermodal rail based transport chain integrated with IVG.

2.3 Summary Connection FR8Hub WP3 – WP4 and related works

The intelligent video gate is gathering data that can be used for more efficient terminal processes. These data are of interests for:

- Infrastructure manager
- Yard manager and terminal manager
- Railway undertakings
- Transport customers

There is a current development with more digitalised data. Wagons are equipped with RFID tags and Infrastructure managers have RFID readers that can position wagons: wagon unit ID, when it passes and what direction. In Sweden there are about 350 RFID communication points June 2018. These data can be used to increase quality, capacity and efficiency in the railway system.

Intelligent video gate is gathering information about the train, wagons and loading units.

Technical systems are video cameras, laser scanners and RFID-systems - including readers and tags.

Data correlations between the two work-packages WP3 real time network management and WP4 Intelligent video gate have been identified.

The Intelligent video gate gives faster terminal process: arrival, operational handling wagons and loading units and departure process.

The initial plan is to consider IVGs located at the entry and exit points of a rail yard. Inputs to the demonstrator are:

- A train arrives/departs **early**
- A train arrives/departs **late**
- A train arrives/departs with **dangerous goods**

ARCC project gives valuable input about state-of-art and real-time decision processes for yard and yard-line operations in Sweden and Germany. It also describes requirements for demonstrators and deficiencies in current processes. There is potential to increase punctuality and efficiency by better planning methods and planning support.

3 Specification of innovations in real time network management

Freight train operators generally ask for more changes close to operation than passenger train operators. Today there is a challenge to accommodate these without interfering with existing (passenger) traffic. The main innovations in WP3 are related to decision support for strategic, tactical and operational capacity planning to support these requests. In particular, new concepts and algorithms for re-planning and adjustments of train timetables will be implemented.

The involved actors are Infrastructure manager, Yard or terminal manager and Railway undertakings. The perspective is mainly from the infrastructure managers that are responsible for network management capacity and timetable. There is an interaction between Infrastructure manager, yard manager/terminal manager and railway undertakings both in planning process and in operational traffic.

There is a current digitalization improving processes by better decision support and information exchange. Processes that today are done sequential and slow can in future be done automated and in parallel.

Today there are shortcomings in planning and operational processes. These have been documented in ARCC deliverable 2.2 and 3.1.

3.1 Best practice timetable planning and operational traffic control

Network management in WP3 is the management of train activities on the line, and the impact on train operations that yard operations may have. The range of planning processes in railway operations today includes mainly timetable, infrastructure, vehicle scheduling, construction sites and crew management. There are also different planning horizons in which these processes can be considered. The most general classification corresponds to the underlying railway operations management processes for **strategic** planning, **tactical** planning as well as **operational** traffic control and train driving. The planning processes within the scope of network management and the project are short-term (daily timetable up to 1 year) and planning within the operational process, i.e. the ad-hoc planning process. In Sweden, Trafikverket's planning department hands over the daily timetable to operational process at 3 p.m. the day before operation. The operational process, where the real-time traffic plan is updated, is also in scope.

Short-term planning includes minor capacity constraints (e.g. minor construction sites) as well as adjustments to vehicle and crew management. Daily adjustments are made for crew and vehicles management and operational traffic consider dispatching and handling disturbances. From a freight perspective, changes are also made due to variations in demand, which both affect train size (length and weight) and the need for additional trains.

The project scope aims at improving the planning activities in the railway system, mainly from the perspective of the infrastructure manager, by means of precise railway simulation and optimisation. In particular, methods for microsimulation and optimization for re-planning of timetables to increase overall freight speed and manage disturbances during the tactical and operational phases are considered. We will assume an annual timetable is given, but need to be updated to accommodate for later changes.

Today, simulations are mainly made in the pre-planning phase of the annual timetable, for example when evaluating infrastructure investments. It is also commonly used to evaluate the annual timetable, and when planning for major maintenance activities and disturbances. In the annual timetable, simulations are made to get the timetable conflict free and study its robustness. The process for timetable planning and operation is harmonized in Europe by Rail Net Europe, European legislation, Network statements and European corridors for freight traffic.

Figure 3.1 illustrates the process for timetable planning for the Swedish Traffic Administration – Trafikverket, and how the work in FR8HUB WP3 will be subdivided. The planning is divided into an annual timetable and ad hoc adjustments of the timetable. The ad hoc timetable process is the interface between tactical and operational processes. There is a need for better connecting timetable planning and operational methods due to an ongoing trend of the tactical timetable planning process and operational processes merging. In tactical planning simulation and optimization methods improve the planning and interaction between the Infrastructure manager (IM) Yard Managers (YM), Maintenance Entrepeneurs and Railway Undertakings (RU) throughout the process. JNB (Järnvägsnätsbeskrivningen) is the Swedish network statement, providing the pre-requisites for planning.

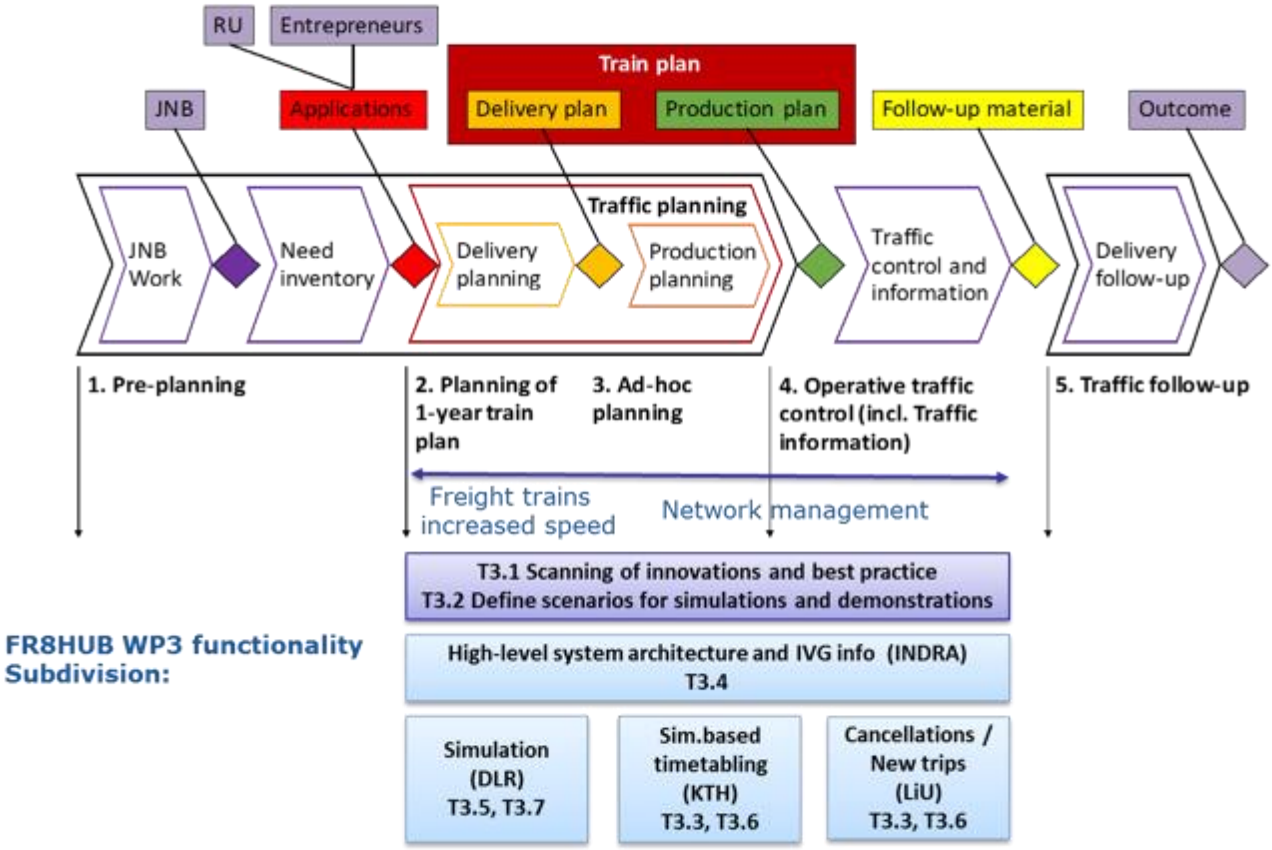
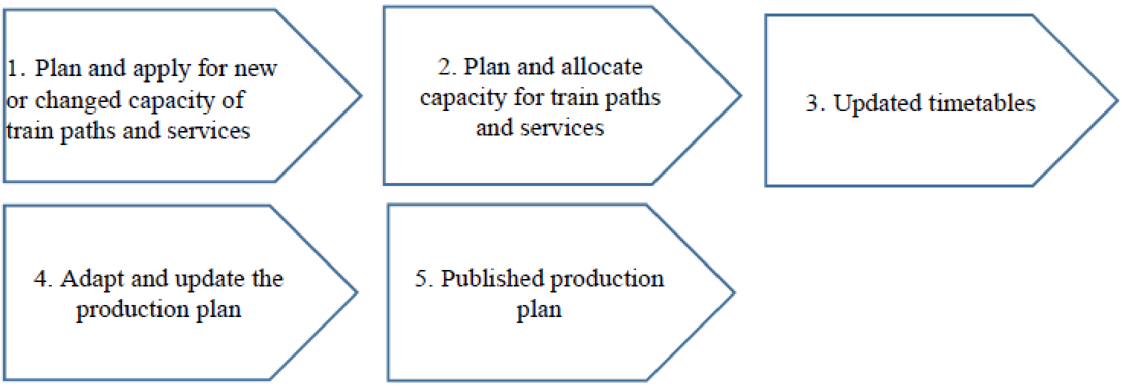


Figure 3.1. Process for timetable planning and connection to tasks in FR8HUB WP3.

3.2 Short term planning in Sweden (Trafikverket)

The capacity allocation processes produces a one-year Timetable. This timetable for 2018 is published in September 2017 and traffic according to the new timetable commences at early December. During the year it is possible for a railway undertaking (freight- or passenger railway undertakings) to apply for a train path in the adhoc-process.

The adhoc-process for the existing timetable normally starts in October and is a sequential process



1. Planning and application of services and capacity for train paths is made by railway undertakings and entrepreneurs using the e-service on the Swedish Transport Administration's website.
2. Planning and management of conflicts. Agreed train paths signed for in the same way as in the annual allocation process.
3. When allocating capacity for train paths and services, the current timetable is updated. Only agreement points are covered at this stage when allocating capacity for train paths.
4. The production plan is adapted and updated to take into account new and changed conditions. This means that apart from agreement points, other production data can be changed up until the time of publication.
5. Publication of the production plan. The published production plan includes route plans and other services. Publication takes place at a specified time before the next operational period.

Figure 3.2. Adhoc process from Trafikverket network statement 2018.

The process of allocating capacity at main shunting yards and terminals differs, as the capacity at a yard and terminal can be owned and managed by a railway undertaking. In Sweden this is the case in Hallsberg, Malmö and Gothenburg and some other places. Other railway undertakings that want to use the shunting yards facilities still applies for capacity in the ad-hoc-process, but confirmation from the yard management company has to be received before the train can enter the yard.

3.3 Specification of innovations network management

The innovations in network management are related to innovations in data-driven future operative and strategic decision support systems. The core new data flow as imagined in Fr8Hub WP3 is the automated reporting of cars and train movements from ongoing digitalization efforts, such as the Intelligent Video Gate developed in Fr8Hub WP4. As the projects run in parallel, we will work with synthetic data in WP3, with the goal of seamless information integration once the project has finished and IVGs are deployed. Other information sources will also be possible to integrate with the algorithmic innovations in WP3.

As an initial plan we will work with an information model where data from a set of IVGs comes as a time-stamped series of train and load carrier IDs. We will consider IVGs located at the entry and exit points of a rail yard. The following data in particular will be considered as input to the demonstrator:

- A train arrives/departs **early**
- A train arrives/departs **late**
- A train arrives/departs with **dangerous goods**

In addition, the following user input scenarios will be considered:

- **Cancellation requests** for trains
- **New slot requests** for trains

From these basic building blocks, realistic scenarios where dynamic replanning is performed can be constructed as sequences of cancellations and slot requests. For example, temporal and spatial replanning of a slot will be considered as a cancellation followed by a new slot request. Spatial re-planning includes both the use of alternative tracks, at double track lines, but also rerouting in other geography.

For the approach to be realistic, it is important to realize that, due to rolling stock and train crew being shared among several slots, some sequences of requests will be much more likely to occur than other series. Staff schedules and vehicle circulation certainly also bound the flexibility when re-planning.

The replanning will be considered in two different perspectives, described below.

3.4 First outline of innovation scenarios and algorithms

Scenarios will be described about how innovative methods and algorithms can be used in planning and operational process.

3.4.1 Tactical data driven timetable planning

In **Tactical planning,** multiple changes to the timetable will be considered simultaneously, with a basis in quality parameters such as punctuality and empirical delay distributions. The algorithms will be based on previous work in this area, in particular extensions to work by Högdahl et al. (2017). **KTH** is the main responsible partner for this functionality and it has a connection to RailSys simulator.

3.4.1.1 Concept and research area

Högdahl et al. (2017) have proposed a two-step approach for tactical timetable planning, where a delay prediction function is first calibrated and then included in a timetable optimization model to adjust a given timetable such that it minimizes the weighted sum of scheduled travel time and expected delay time. The model will serve as a basis for continued development in WP3. The basic approach in FR8HUB can be described as follows.

1. Core timetabling model is the hybrid micro-macro model developed by Högdahl et al. (2017) but extended with parametric hub/yard delay models, based on the activity model in Bohlin et al. (2015).
2. Parametric yard delay models are calibrated using historical train data
3. Simulated IVG indication of increased hub processing time leads to increase in predicted yard delay (with simulated tailing-off)
4. Replanning of train timetable is done based on new approach

The current delay prediction function is based on experimental data (which could be collected either from simulation or real operations) and the approach could therefore be considered to be a data-driven timetabling approach.

In-scope research topics related to this area include:

- Further development of the methodology of data-driven timetable planning.
- Adapt the approach to the scope of FR8HUB.
- Explore other delay prediction functions.
- Theoretically justify data-driven timetabling approaches.

3.4.2 Operative traffic control adjustment for a single train

In **operative traffic control**, the timetable will be considered fixed and smaller adjustments should be made. In particular, single train adjustments will be considered, and the relay on and extend the algorithm framework developed for finding a new train path (Ljunggren et al., 2018). In this framework a timetable is given, and sought for is a new train path between two yards/terminals, that fulfil some side constraints on departure time, travel time and arrival time, as well as other logical and technical constraints for train traffic. Unlike other proposed methods for re-scheduling, the approach by Ljunggren et al. can easily be extended to search for train paths in alternative geographies, which is important when, for example, when there are main disturbances and stretch closures, it is also beneficial for finding good train paths through complex station areas.

The work will include considering various goals for the insertion, such as robustness and travel time, but also various constraints for departure and arrival, at end or intermediate stations, due to, for example, staff schedules. The concept and usability of this algorithm will be further analysed in next research step of this project.

Linköping University is the main responsible partner for this functionality.

3.4.3 Tactical planning analysis and models Yard and network

For yards and network there are needs to better understand how interaction can be improved. In Sweden today, only few freight trains follow their scheduled train path. A majority of the trains are running ahead of schedule, some trains are punctual arrival and departure. There are also freight trains that are delayed, see Figure 3.3 below. There is a need to better plan and control freight traffic in the Swedish network, and timetable planning needs to be more flexible to account for the freight traffic needs.

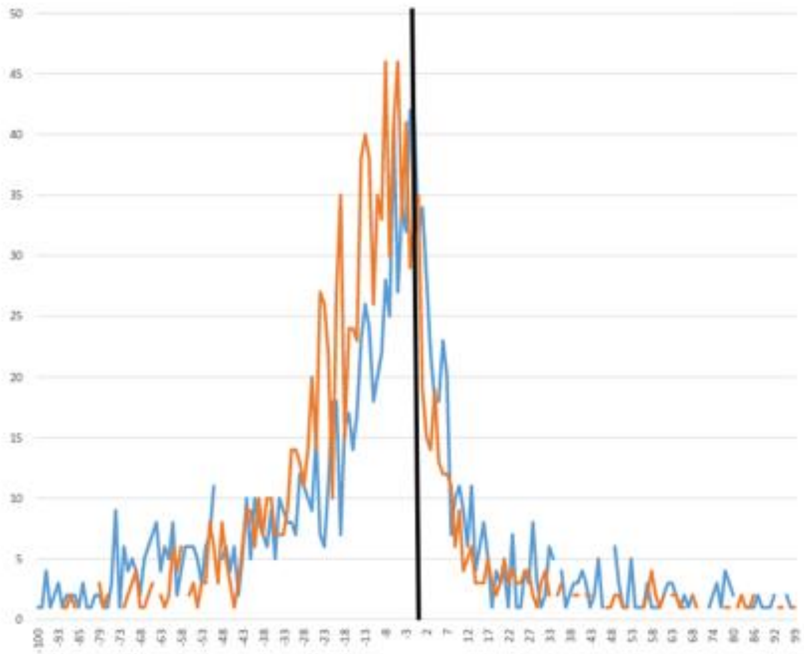


Figure 3.3. Time deviations for arriving trains (orange) and departing trains (blue) at Hallsberg marshalling yard during March 2017. Solid black line is "planned departure time", negative time means "earlier than planned" and positive "later than planned". Data provided by Trafikverket.

Freight traffic has a big impact on system punctuality. In Sweden punctuality work is measured by disturbance hours and effect areas. The effect areas with highest number of disturbance hours are departure delays (avgångstid/noder). This is shown for the years 2013 – 2017.

Table 3.1: Disturbance hours 2013 – 2017, for different effect areas. Source: Trafikverket.

Area of effect	2013	2014	2015	2016	2017
Departure delays/nodes	23 300	21 100	21 700	21 300	17 400
Infrastructure	15 600	20 100	15 100	15 400	12 000
Vehicles	13 000	12 500	11 400	13 500	11 900
From abroad	7 600	8 700	9 300	7 800	9 700
Track maintenance	5 200	4 800	3 800	4 800	4 500
Unauthorized personnel in track area	2 700	3 900	5 200	5 800	5 300
Traffic- and resource planning	5 200	5 900	6 500	4 400	4 000
Operative traffic	3 500	3 800	3 600	4 200	5 800

For departure delays the following 14 yards and stations have highest number. Malmö, Hagalund and Hallsberg are the top 3 in the list.

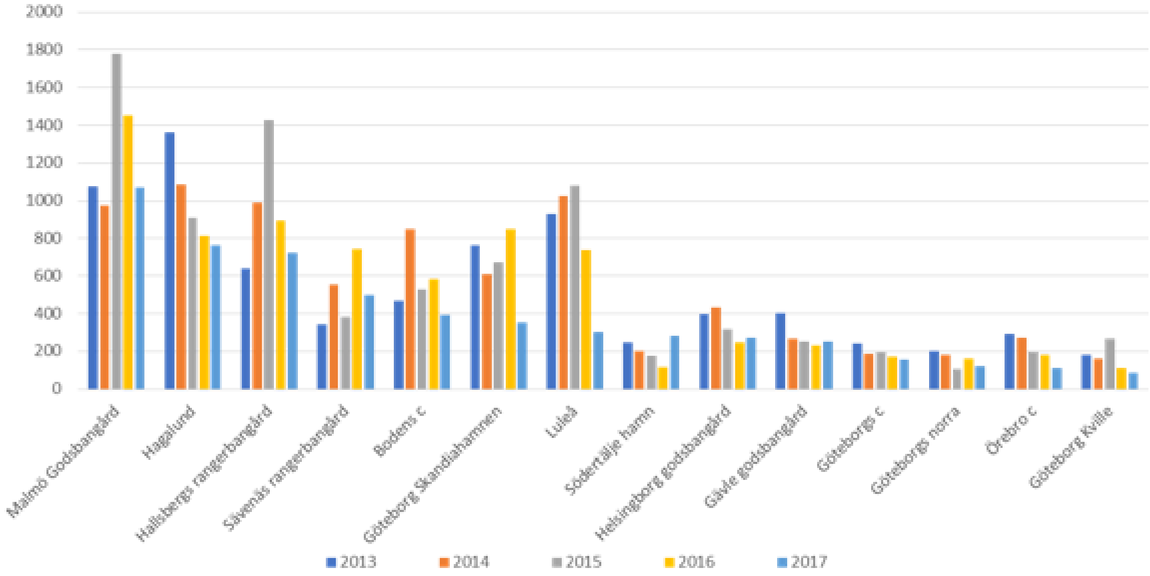


Figure 3.4. Disturbance hours due to departure delays 14 yards/stations (all trains).

Models how to increase system punctuality by improved planning and operative traffic control will be further studied.

3.4.3.1 Yard delay model

Yards in the model can be either shunting yards or intermodal terminals. Some examples of hump yards in Sweden are shown below.

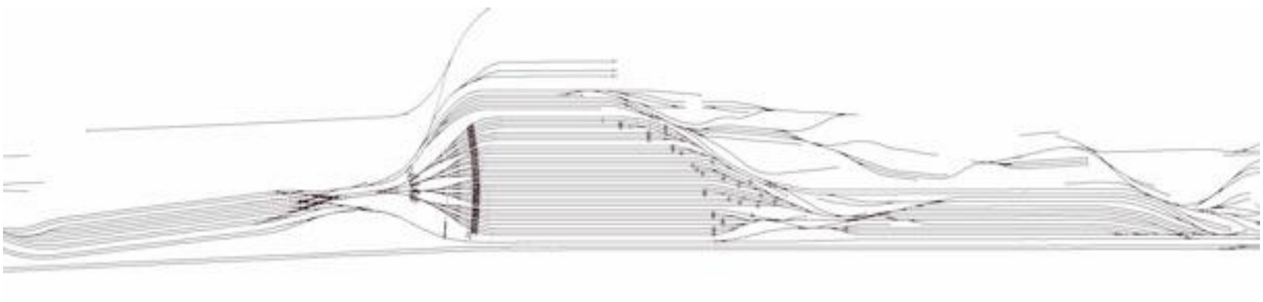


Figure 3.5. The Hallsberg (Hrbg) combined shunting yard and intermodal terminal in Sweden (not in scale for visibility).

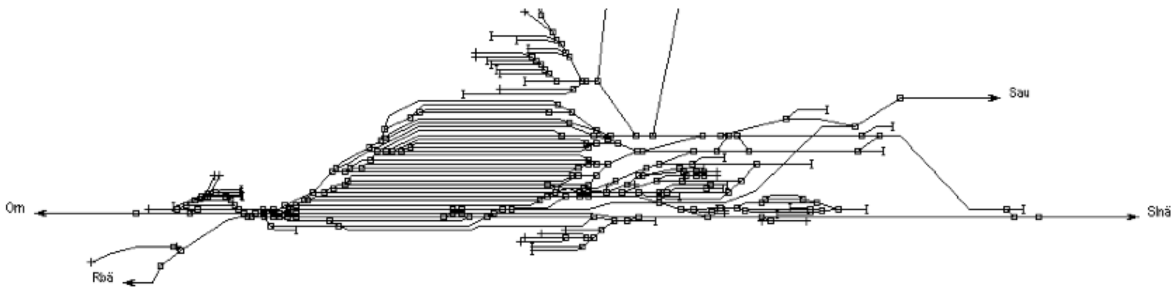


Figure 3.6. The Borlänge yard in Sweden.

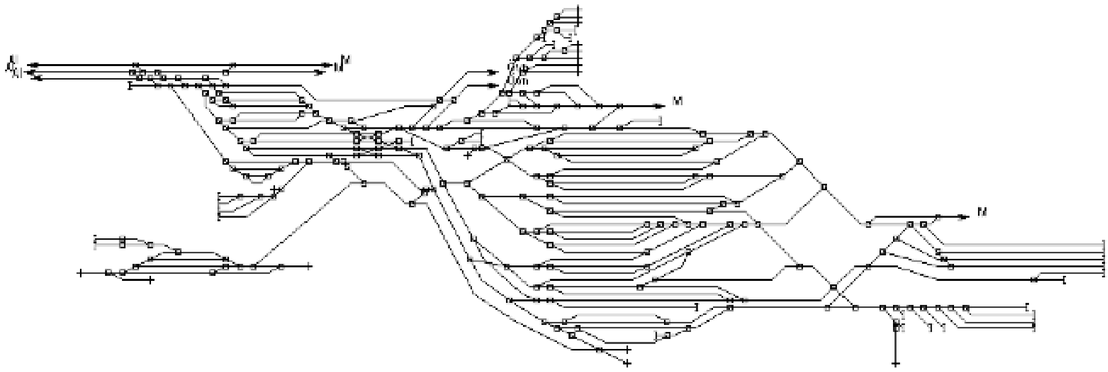


Figure 3.7. The Malmö yard in Sweden

Yards are treated in the same way, no matter their type. We assume that we want to model the delay of an outbound freight train. A shunting yard and the activities therein (see Figure 3.8) is used for the base model.

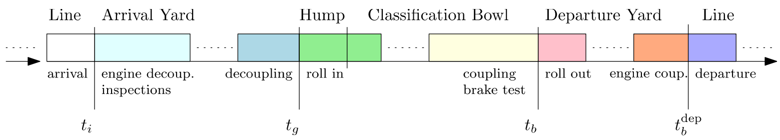


Figure 3.8. Typical activities at a shunting yard.

For any yard, there is typically a "minimum" processing time between t_i and t_b^{dep} (for Hrbg it's around 2-3 hours). The actual departure time of a train *b* depends on:

- The actual arrival time of the line locomotive + driver and all wagons / ILUs
- Yard congestion i.e. amount of freight and fan-in / fan-out
- Any replanning actions (switch loco, switch driver, reassign wagons / ILUs
- However, critical data is owned by railway undertaking or yard manager and not easily accessible

The following assumptions are made:

- Line locos are assigned in timetabled first-in first-out order and some wagons/ILUs "follow" the locomotive
- Possible interaction between any arriving train and all departing trains in a different direction within 24 hours of arrival
- Possible congestion delay dependent on the number of trains present at the yard 2-3 hours before departure.
- No yard re-planning actions

The yard delay model for a departing train b with delay t_b^{Δ} is:

$$t_b^{\Delta} = \alpha(t_a^{\Delta} - T_1) + \sum_i \beta_i\left(t_i^{\Delta} - T_2\right) + \gamma \#_i\{t_b^{\text{tt}} - T_3 \leq t_i^{\text{arr}} \leq t_b^{\text{tt}}\} + \delta,$$

where t_a^{Δ} is the arrival delay of the engine, t_i^{Δ} is the arrival delay of cargo *i*, t_b^{tt} is the timetabled departure of train *b* and t_i^{arr} is the arrival time of train *i*. α, β_i, γ and δ are correlation coefficients and T_1, T_2 and T_3 are buffer times. This model will be used as a starting point for further research in the project, and to adapt the timetable planning model, to estimate parameters, and to perform experiments.

4 Multimodal Freight Data-Exchange Platform

Within the objectives of the WP3 it is included the definition of a data exchange platform for inter-modal hub required for connecting freight transport stakeholders. This Multimodal Data-Exchange Platform as the aim to connect freight operation with other rail systems in order to support new methods for improved operation between network management and yard management. Multimodal Freight Data-Exchange Platform will allow the integration of required flows of information between all the actors and stakeholders involved in the freight railway operations in order to ensure the full integration of freight transport stakeholders in global railway operations.

With the definition of the Multimodal Data-Exchange Platform It is intended to improve the integration of the freight operations in the management of the traffic of mainlines through the integration of the involved actors into a common platform for exchanging information between them during the complete cycle of operation. This integration will allow the creation of specific and more accurate services for the freights that at moment are not completely supported by the Traffic Management Systems.

The integration of the freight stakeholders for supporting the freight operations in the global operation through a common platform is aligned with the principles of the Shif2Rail IP2 projects, which are working on the definition, and development of a common communication backbone of the rail operation system. This backbone is named as Integration Layer and it provides the substructures needed for allowing the integration and the exchanged of information between the different involved actors.

The final goal is to improve the efficiency of the freight operations and the mitigation of the effects of the difficult situations detected. For achieving this purpose, the definition of the integration platform and the identification of the data structures to be exchanged between the actors in the different current and desired operational scenarios will be performed. The basis for this definition will be the current freight operation and the identified difficulties.

The definition of this platform will be achieved through the following activities to be carried out and whose results will be available on the Deliverable FR8HUB D3.2:

- Study of open and standard connection solutions.
- Analysis of input information.
- General Architecture of Multimodal Freight Data-Exchange Platform.

4.1 Study of open and standard connection solutions

As previous step to the definition of the multimodal data exchange platform, the intention of this activity is to analyses the existing standards supporting the railway operations.

Several initiatives are currently ongoing around the EU with the objective to standardize the interfaces and communication among different actors involved in the railway operations for different purposes. Although the goal of the definition of the Data-Exchange Platform is not to define and to close the specific formats of the information to be exchange, the study of the most relevant initiatives in this field is required in order to get an overview of the interfaces and situations addressed in these initiatives.

Through this analysis, the actors, operational cases and exchanged information defined in each initiative will be identified.

Together with the analysis of the input information, and the definition of the operational cases for freight operation, will support the identification of the information to be exchanged between the freight operation actors and the other global railways actors.

4.2 Analysis of input information

On one side, the definition of the Multimodal Data-Exchange Platform will be based on the outputs of the ARCC project. The main objective here is to understand the shortcomings of the current freight operation in order to provide within the Multimodal Data-Exchange Platform the flows of information required to improve the global railway operation.

For approaching the knowledge of the freight traffic current situation, their difficulties and shortcomings the deliverables provided by the ARCC project will be analysed as previous step to the platform definition. Additionally, a common workshop with the different partners of ARCC project will be carried out. In this sense, the objective here is to reach a better alignment on the approach of the platform definition with the aim to define later on the flows of information required to the mitigation and resolution if possible of the difficulties previously detected.

On the other hand, as new methods for improved interaction between network management and yard management, the results of the WP4 Intelligent Video Gate will be analysed as input for the definition of the Multimodal Data-Exchange Platform. For this purpose it will be analysed and considered the available information data that could be provided by the Intelligent Video Gate. The results and performance effects of the WP4 Intelligent Video Gate on the freight traffic will be monitored and follow with the aim to describe how the Multimodal Data-Exchange platform will allow exchange data between the IVG and the remaining actors participating into the freight operation (Infrastructure manager, Railway undertakings and other stakeholders). The impact of having available this information will be analysed in order to improve some of the operational cases and difficulties detected when possible.

The definition of the Multimodal Data-Exchange Platform within the WP3 is in line with the targets of MAAP TD 5.2 and within the scope of digitalization of future freight traffic. Synergies between TD 5.2 and IP2 (TD2.9) will be used. In this sense, Work Area 4.2, relation with Integrated Mobility Management (I2M), in Cross-Cutting Activities, will specify and implement the substructures needed for automated message exchanges between Freight operations and Traffic management systems via the Integration Layer, in order to achieve Shift2Rail objectives.

4.3 General Architecture of Multimodal Freight Data-Exchange Platform

Using the knowledge provided by the input information as well of the existing open standards, the intention here is to define the required flows of information between the actors involved on freight operation. To analyse and define who is able to provide the required information and when is required to be provided the information looking for mitigate the current status of freight operation.

In this sense the main actors involved on freight operations as well as the IVG will be taken into account.

For the freight operations, the principal actors to be integrated in this platform will be those with active role in the management of the freight traffic and services:

- Infrastructure Manager (IM): Owner of the infrastructure (lines, stations, depots, sidings, yards, terminals). It is responsible for capacity allocation and dispatching on lines.

- Yard Manager (YM): It is responsible for yard operation and planning (in collaboration with the IM). It is included in this role also the manager of terminals and sidings.
- Freight Operating Company (FOC): It provides transportation services. It is responsible for rolling stock and drivers. It applies for railway capacity.
- Transport customer and carrier service: It buy railway transportation services to the FOC.

Based on the previous analysis performed in ARCC project regarding the yard management and its integration with the network management, the current operational scenarios can be extracted, as well as some difficulties and shortcomings to be improved in the future.

The definition of the architecture for integrating the exchanges of information between the freight operation actors involves the following activities:

- System concept connecting yards/terminals with network: Description of the integration layer concept for connecting all the actors involved in the railway operations, not only but also the freight related actors.
- Definition of Operational Cases: Description of operational cases involving Infrastructure Managers, Yard Managers, Freight Operations Companies, Transport Customers and other actors if required for covering the freight operation regarding its interface with the traffic management. The cases will intend to cover the expected operation and to improve the difficulties detected.
- General Architecture: Description of the architecture of the Multimodal Freight Data Exchange Platform.
- Definition of Data Structures: Identification of the exchanges of information between involved actors for supporting the operational cases.

5 Demonstrator and demonstrations

5.1 Demonstrator scenarios

The FR8HUB demonstrator will initially be applied to the line between Malmö and Hallsberg. The network is shown in the image below.

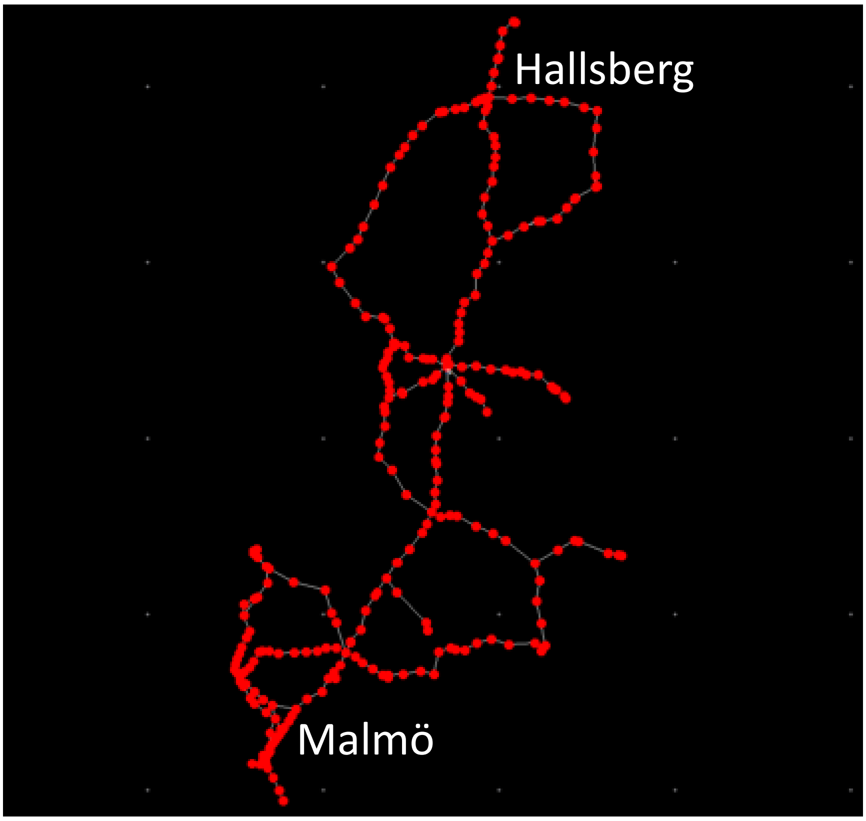


Figure 5.1. Macroscopic view of the network between Hallsberg and Malmö.

The infrastructure models include stations as nodes and each track between all stations on the line, including the main direction. As pre-processing, connecting lines and stations will be excluded so that only traffic on the actual line is considered (i.e., timetabling for trains on connecting tracks will not be considered, apart from the part of the trips which actually traverse the main line in question, which will be included).

Replanning of timetables will be initiated for the following events:

- A train arrives or departs earlier/later than expected
- A new train path is requested
- A train is cancelled
- Data from the IVG indicates that the predicted throughput time at a yard or terminal is higher or lower than expected.
- Data from the IVG indicates that the train composition deviates from plan in terms of, e.g., load profile, axle load or dangerous goods, requiring rescheduling via alternative geography.

For the demonstrator, an overall simulation of the capacity planning, where pre-determined or random events of the type above happen at pre-specified or random time points, will be used.

5.2 Architecture

The demonstrator is composed by several integrated systems, working together in order to improve train scheduling for defined scenarios. The demonstrator is providing optimization of an initial scheduling according to the requirements defined in a scenario in order to improve the network management. This demonstrator also has the aim to show the use of standardized information among the involved systems in demonstrator, as a first approach to the future use of an integration platform for network management, instead traditional and isolated systems.

Along this chapter, the following aspects of the WP3 demonstrator will be described:

- Involved systems in demonstrator.
- Responsibility of each involved system.
- Information workflow.

The systems involved into WP3 demonstrator will be the following:

- Timetable Planning Tools provided by KTH and LIU.
- Timetable Viewer provided by Indra.
- RailSys, a product of RMCon available on TRV.

On the following diagram are shown involved systems into the demonstrator and a preliminary idea of the information involved and the demonstrator workflow.

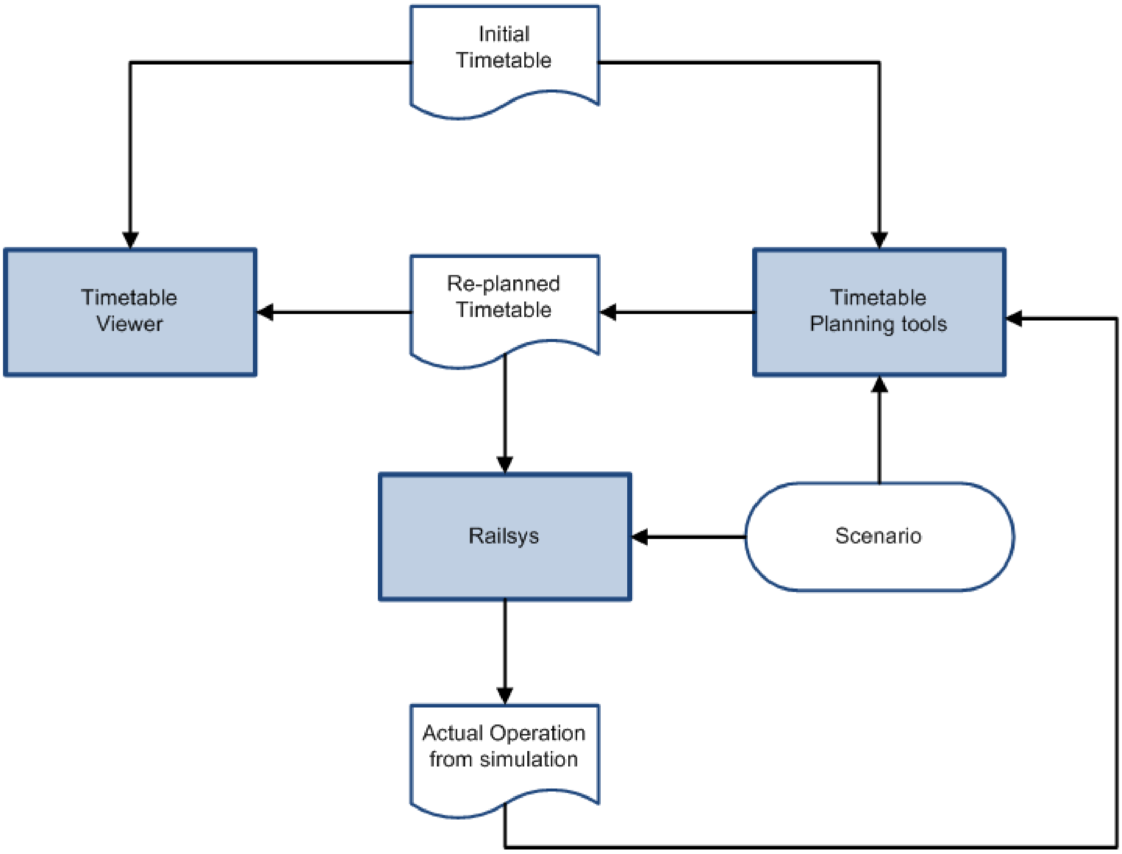


Figure 5.2. Demonstrator Architecture

The main purposes of involved systems are the following:

- **Timetable Planning Tools** are in charge of timetable optimization as frame of traffic management innovations. Within this tool adjustments over the Initial Timetable provided are applied. As mentioned before, this tool provides both, adjustments related the tactical planning as well as dynamic re-planning related to the operative traffic control. In this sense:
    - A re-planning module developed by KTH will be able to reschedule multiple trains with a short-term planning horizon.
    - A re-planning module developed by LiU will be able to reschedule single trains in close to real-time planning horizon.
- **Timetable Viewer** is a graphical user interface in charge to monitor and display the planning information updated. This application is in charge to automatically display the Current Timetable when adjustments on the Initial Timetable are applied by the Timetable Planning Tools. Timetable Viewer allow to display the Initial Timetable face the Current Timetable in order to visualize the effects of the optimization carried out by algorithms of Timetable Planning Tools.
- **RailSys** Is used manually for simulation of initial re-planned timetables in order to obtain quality parameters related to the optimizations achieved by the algorithms of the Timetable Planning Tools.

As it is shown in the previous diagram, the involved systems into demonstrator will use the following information:

- **Initial Timetable**: Original timetable information coming from a production plan, before any timetable optimization. Contains related information to original scheduled timetables for all train involved on a defined scenario.
- **Re-planned Timetable**: Re-scheduled information coming from Timetable Planning Tools. Contains updated information related to timetables for all train involved on a defined scenario in use. According to the conditions of a defined scenario, the timetable optimization may require several Re-planned Timetables during a single demo.
- **Current Timetable**: Is the last version of the Re-planned Timetable provided by the Timetable Planning Tools until now.
- **Actual operation from simulation:** Output provided by RailSys for each Re-planned Timetable, providing quality parameters of operation for each Re-planned Timetable. The output from RailSys is a CSV-file which contains log data. For each event at least the following data is registered: Time, Train number, Position, Route of last signal (or stop board), Last signal (or stop board), Station (if at station), Track (if at station), Event, Current speed in km/h, Obstructing train, Lateness[s].
- **Scenario**: As described on the previous subchapter the scenario defines a specific traffic situation that tries to be optimized in planning time.

Giving the components of the demo, the involved systems and the defined information, the workflow of the demonstrator will be defined according to the following steps:

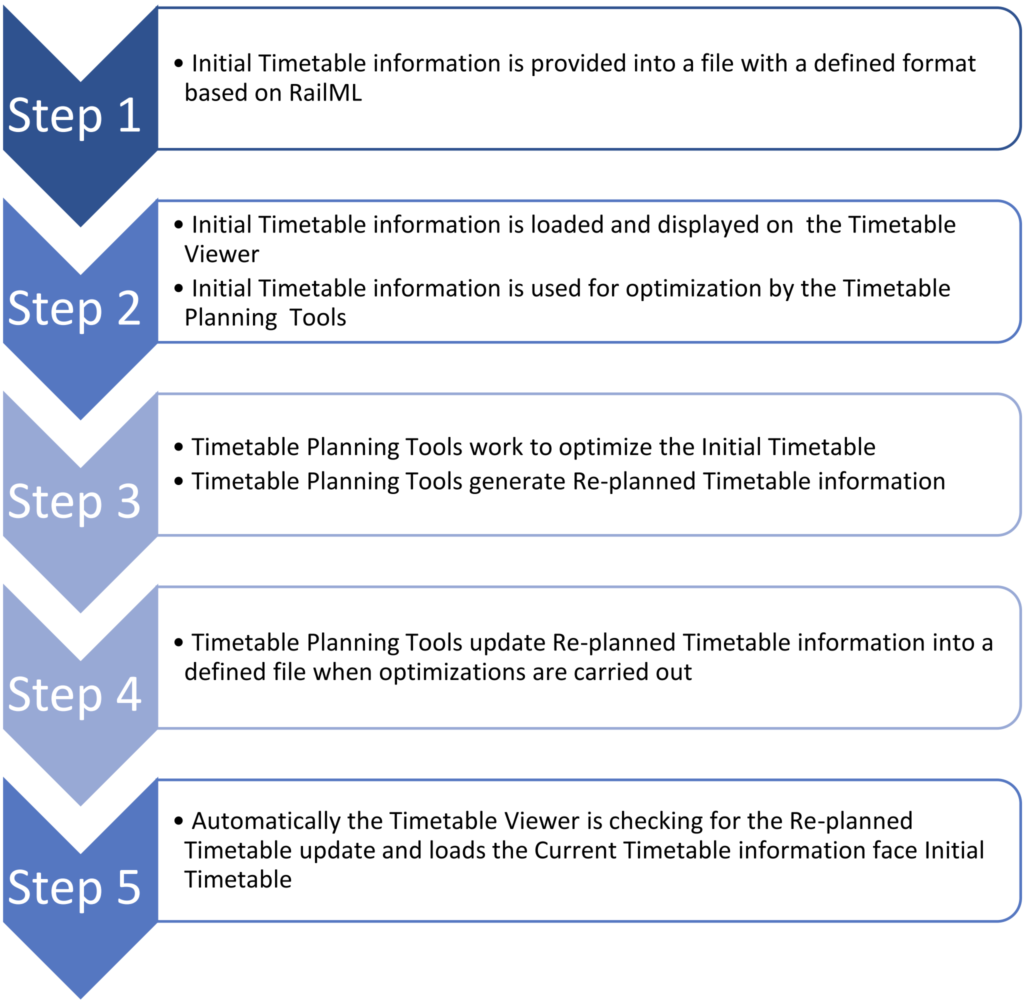


Figure 5.3. Information Workflow of demonstrator

Giving the nature of each scenario several re-planning actions may be required within a demo, thus according with the above figure, steps 1 and 2 represent the initial state of the demo and the steps from 3 to 5 are taking place each time that a new re-planning action is carried out.

That is to say, for the demonstration of each scenario:

- The Initial Timetable is used for optimization by algorithms of the Timetable re-planning tools. These algorithms are able to provide an optimized version of the planning and generate an updated Re-planned Timetable. Then algorithms will be used to optimize continuously the Re-planned Timetable according the current criteria.
- The Initial Timetable is loaded manually on the Timetable Viewer, then automatically each time that the Re-planned Timetable file is updated the GUI will read the content of the file and display the file information, that is to say the current Re-planned Timetable. This information is displayed face the Initial Timetable with different trace/draw, in order to display into a space-time diagram both type of information and visualize improvements carried out by algorithms during the demonstration.

5.3 Functionality and First Mock-up

5.3.1 Timetable Planning Tools

The timetable planning tools are developed separately by KTH and LiU and are used to reschedule the Initial Timetable in order to adapt to changes in operations.

The timetable planning tools will differ in scope, where the tool by KTH will be used for short-term tactical re-planning of multiple freight trains and the tool by LiU will be used for close to real-time re-planning of single trains.

As input data the timetable planning tools require an initial timetable, including the infrastructure model, and a scenario definition file. This is then used together with optimization to find the best timetable (called the Re-planned Timetable) based on the given scenario. The Re-planned Timetable is written to a separate file in the same format as the Initial Timetable.

5.3.2 Timetable Viewer

The Timetable Viewer allows the user to visualize at same time the Initial Timetable and the Re-planned Timetable for a scenario. After loading the Initial Timetable for a scenario, the Timetable Viewer displays graphically the content of this timetable, as well as, monitors the Re-planned Timetable generated by the optimization modules in order to display the content of the last generated Re-planned Timetable. The last generated Re-planned Timetable is considered as the Current Timetable; because of it is the timetable with the best performance according to the innovative timetable modules.

Through the concurrent visualization of the initial and the Re-planned Timetable, the user is able to analyse graphically the differences between both of them and to check the improvements provided by the innovative Timetable Planning Tools.

The Timetable Viewer provides the following main functionalities:

- Manual loading the Initial Timetable.
- Initial Timetable content display.
- Automatic monitoring of Re-planned Timetable corresponding to the previously Initial Timetable loaded.
- Current (last Re-planned) Timetable display.
- Simultaneous display of Initial Timetable and Current Timetable.

The Timetable Viewer provides data visualisation of the loaded information provided through the Initial Timetable and the Re-planned Timetables. Any calculation is performed by the Timetable Planning Tools. In this sense, only the graphical comparison between the initial and the Current Timetables is provided to the user. This comparison allows the user to have the global situation of the scheduled period and to detect the modifications introduced by the innovative planning modules.

Additionally, the graphical functionalities of the Timetable Viewer allow the user to visualise other details of each scheduled service.

The graphical interface of the Timetable Viewer is able to display the following main elements:

- Details of the scenario:
  - Line affected by the timetable.

  - o Title of the Scenario.
  - o Description of the Scenario.

- Train-Graph: Graphical representation of the timetables. The Train-Graph displays the timetable and route for all the trains defined in the Initial Timetable and in the Current Timetable in a distance-time representation in which the time is shown in the x-axis, and the distance in the y-axis. Both travel directions are displayed overlaid.

  Therefore, the travel times between nodes and the time during the train is located within a Node are graphically displayed. The colour or trace is different for the Initial Timetable and the Current Timetable in order to display simultaneously both timetables in the same Train-Graph.

  The Train-Graph is able to provide different levels of information according to the selection of the user. Information about the following elements can be displayed optionally:
  - o Location of the Nodes.
  - o Distance between Nodes.
  - o Identifiers of Trains.
  - o Times of Arrivals and Departures to each Node.

  In order to improve the usability of the viewer, the Train-Graph provides scrolling options and different levels of zoom for the time and the distance axis, which can be adjusted by the user at any time.

  Additionally, the Train-Graph displays graphically the tracks within the Nodes where the trains stops or passes in case the Node include more than one track.

- Log of events: It displays the timestamp when the Initial Timetable is loaded and when the Re-planned Timetables are detected and displayed.
  It is able to display another relevant event defined into the loaded files.

Figure 5.4. Timetable Viewer with Initial Timetable loaded includes a first mock-up of the Timetable Viewer when an Initial Timetable has been loaded, but Re-planned Timetable information has not been already generated. The available options for the user will be the following ones:

- Load Initial Timetable: A file explorer window is displayed in order to allow the user to select an Initial Timetable file.

  In case the information of a timetable is previously displayed, then this information is removed, and the monitoring of the previous Timetable is stopped when the user selects an Initial Timetable file in the file explorer window.

  The information of the Initial Timetable is displayed and the monitoring of the Re-planned Timetables for this timetable is launched.

- Graphical options in the Train-Graph:
  - o Increase and decrease the general level of Zoom.
  - o Increase and decrease the zoom at time-axis level.
  - o Increase and decrease the zoom at distance-axis level.
  - o Scrolling.

- Display and hide additional information: Node locations, distance between Nodes, Train identifiers and departure and arrival times.
- Fold and unfold track information in Nodes.

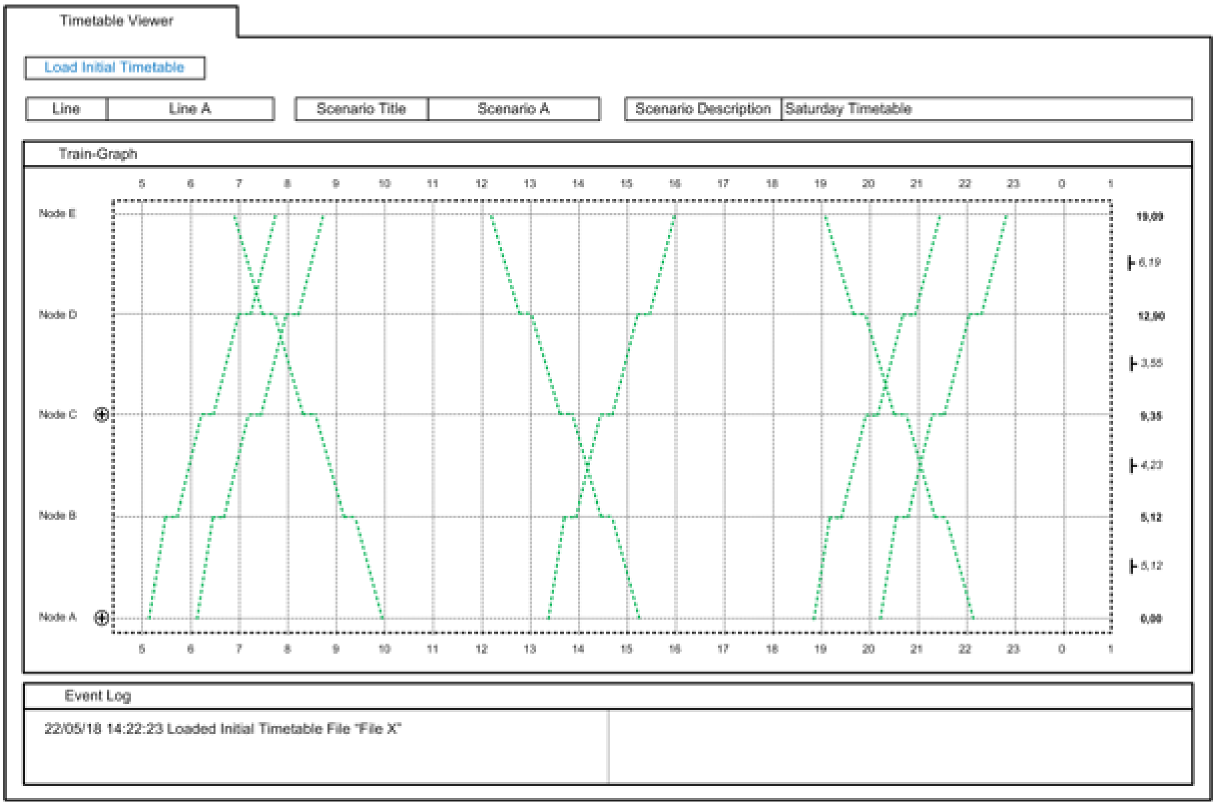


Figure 5.4. Timetable Viewer with Initial Timetable loaded

When Re-planned Timetable information for the loaded Initial Timetable is detected both representations are displayed at same time in the same Train-Graph, as it is illustrated in Figure 5.4. The Event Log displays the registered main events that have occurred regarding the timetable.

The Timetable Viewer performs the monitoring of the Re-planned Timetable information automatically, without any interaction required by the user.

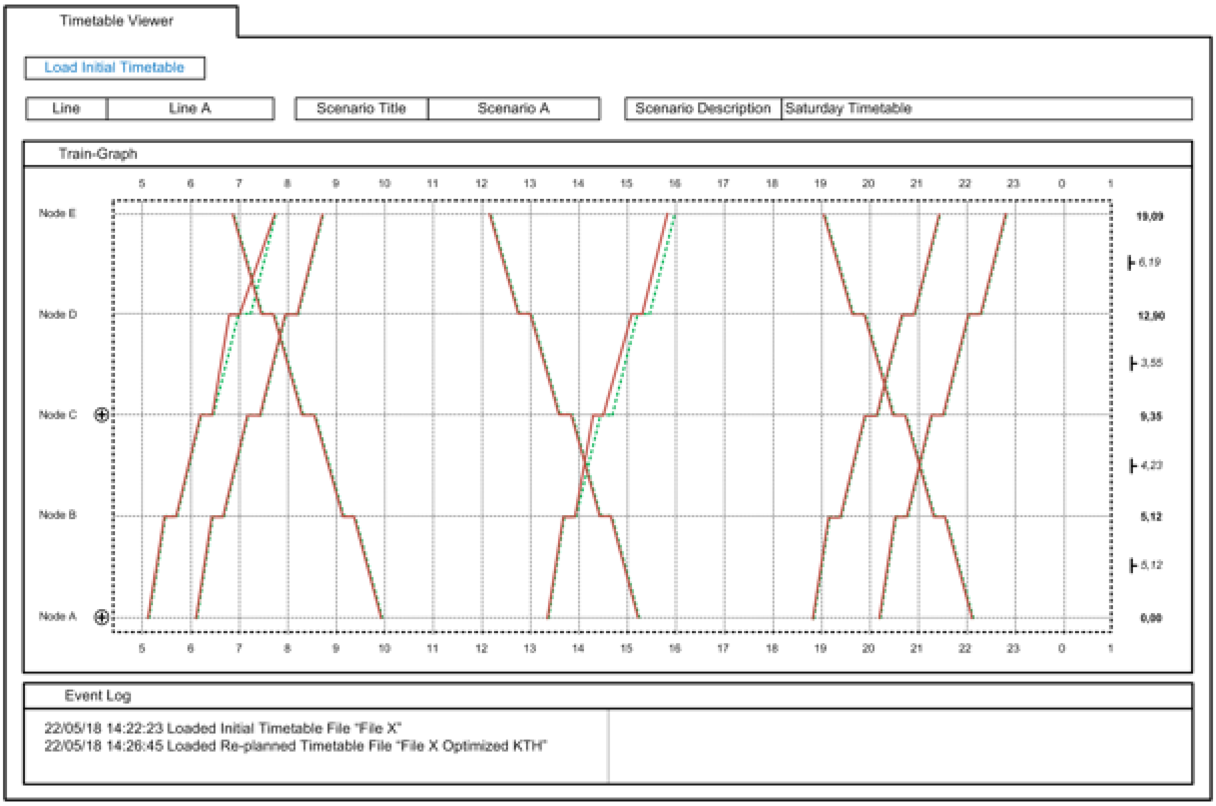


Figure 5.5. Timetable Viewer with Initial and Current Timetable displayed

5.3.3 RailSys

RailSys is a commercial software developed by Rail Management Consultants GmbH used to plan, model, simulate, and evaluate railway traffic. It is the standard simulation tool used by the Swedish Transport Administration and is planned to be used as follows in the demonstrator:

- As a data source of the infrastructure, rolling stock, and the initial timetable.
- As a data source in the Timetable Planning tool developed by KTH.
- As a validation tool to assess quality performance indicators such as punctuality etc., of the Initial and the Re-planned Timetables.

RailSys is formed by several modules. Within the scope of the demonstrator:

- Timetable and the Simulation Manager will be used for simulation purposes.
- Evaluation Manager may be used for evaluation of the simulations if required.

RailSys will be used both by DLR to simulate and evaluate high-speed freight concepts, and by KTH to generate timetabling and quality data as well as to validate timetabling approaches.

5.4 Interfaces and data format

The inputs provided to the Timetable Viewer are the following ones:

- Initial Timetable.
- Re-planned Timetable.

The input files is generated according to RailML version 2.2 with some project specific additions to simplify the conversion back to RailSys format, which is required when simulating the timetables.

The information that can be included in the files covers the following areas:

- Infrastructure data: It includes all main line tracks and all stations (as Nodes), as well as the identifier, location, and tracks of each Node.
- Timetable information. Detailed timetable for arriving and leaving the nodes for each scheduled train.
- Rolling Stock information: It includes train identifiers and types.

Additionally, in order to provide additional information in the Timetable Viewer, specific formats to be included in the files could be defined for specific purposes.

6 Faster freight trains scope

6.1 General classification

In this chapter the operational characteristics of fast and high speed rail freight transport are described. In general, there are different categories for freight trains regarding transport speed: First, there is the conventional rail freight transport, which is the most important category in the present time. The maximum freight train speed is in a range from 80 to 120 km/h. The next category is called fast freight rail transport and has a speed range of more than 120 km/h, but less than or equal to 160 km/h. The third group (very fast freight rail) covers the speed range with more than 160 km/h and up to 200 km/h. The category with top speeds above 200 km/h is called high speed rail freight transport. In this project the main focus is on the fast freight rail category. Nonetheless, it is important to compare this category with the growing group of high-speed freight rail concepts. Therefore, both categories are presented in the following sub chapters. The two categories are divided into subgroups according to the following scheme: the first group represents current freight rail systems, which have started in the past and are still in operation. The second group deals with discontinued systems. This group contains systems, which had been in an active status, but are no longer in operation. In conclusion, in the third group systems in concept stage are presented. In this group the systems have a different planning status. They have not been active yet.

Table 6.1. Categories of freight rail regarding speed

Number	Transport category	Top speed range (km/h)
1	Conventional freight rail	< 120
2	Fast freight rail	120 - 160
3	Very fast freight rail	161 - 200
4	High-speed freight rail	> 200

Table 6.2. Fast and very fast freight rail systems, sorted by year

Fast freight rail system	Country of operation	Category	Vmax in km/h	Status	Period / year
Expressgut InterCity	Germany	Very fast freight rail	200	discontinued	1980-1997
InterCargoExpress	Germany	Fast freight rail	160	discontinued	1991-1995
The Royal Mail Train	United Kingdom	Fast freight rail	161	in operation	1996-now
Danish postal train	Denmark	Fast freight rail	140	discontinued	1997-?
Sernam (trains blocs express)	France	Very fast freight rail	200	discontinued	1997-2011
OverNight Express Amsterdam – Milan	Netherlands, Germany, Switzerland, Italy	Fast freight rail	140-160	discontinued	2000-2001
Parcel InterCity	Germany	Fast freight rail	140-160	in operation	2000-now
Swedish postal train	Sweden	Fast freight rail	160	in operation	2000-now

XPressNet	Germany	Fast freight rail	140	concept	(2007)
SPECTRUM	Europe	Fast freight rail	140	concept	(2012)
China CRH parcel train	China	Fast freight rail	160	in operation	2016-now

The following trains carry both passengers and freight and therefore have a high priority in the operational handling:

- OverNight Express Amsterdam – Milan

Bibliography:
[Denis2004]
[Verkehrsrundschau2011]
[NederlandseSpoorwegen2011]
[RailwayGazetteInternational2011]

Table 6.3. High-speed freight rail systems, sorted by year

Fast freight rail system	Country of operation	Category	Vmax in km/h	Status	Period / year
ic: kurier / time:matters	Germany, Netherlands, France, Switzerland, Austria	High-speed freight rail	200-320	in operation	1982-now
TGV postal	France	High-speed freight rail	270	discontinued	1984-2015
ICE-G	Germany	High-speed freight rail	280	concept	(1987)
HGV-G	Germany	High-speed freight rail	> 250	concept	(1993)
Fracht-Express	Europe	High-speed freight rail	> 250	concept	(1999)
EuroCarex	Europe	High-speed freight rail	300	concept	(2006)
Velaro Cargo	Europe	High-speed freight rail	320	concept	(2008)
TGV Fret	Europe	High-speed freight rail	320	concept	(2008)
Highspeed Cargo Train	Europe	High-speed freight rail	> 250	concept	(2011)
NGT Cargo	Europe	High-speed freight rail	400	concept	(2016)
China CRH Cargo	China	High-speed freight rail	250	concept	(2017)
High Speed Rail Eurasia	Eurasia	High-speed freight rail	350	concept	(2017)

China CRH Fuxing Cargo	China	High-speed freight rail	350	in operation	2017-now
Mercitalia Fast	Italy	High-speed freight rail	300	in operation from October 2018	From 2018

The following trains carry both passengers and freight and therefore have a high priority in the operational handling:

- ic: kurier / time:matters
- China CRH Fuxing Cargo
- NGT Cargo (when coupled with NGT passenger train)

Bibliography:
[time:matters2018]
[Eurailpress2004]

6.2 Fast freight rail up to 160 km/h

In most cases fast rail systems with a speed range between 120 and 160 km/h use the conventional existing infrastructure. In this speed range it is possible to use locomotive covered freight trains. Unlike the high speed rail freight it is not necessary to develop new rolling stock. The wagons are specially adapted for the slightly higher speed. One important adjustment concerns the braking system. In most cases the wagons are upgraded with electro-pneumatic brake systems. Because of this it is possible to reach a maximum speed of 140 km/h without other technical improvements. So, the freight train can meet the allowed braking distance within the pre-signal distance. If the speed is increased up to 160 km/h, it is necessary to use a continually automatic train protection. Therefore the locomotive’s point-shaped train control is upgraded to a cab signaling system (e. g. German Linienzugbeeinflussung LZB, European Train Control System ETCS).

6.2.1 Current systems

6.2.1.1 Parcel InterCity

The Parcel InterCity is the successor of the Expressgut InterCity, which is described in the following subchapters. This freight rail system is operated overnight to connect mail and parcel centres throughout Germany.

The systems started in the year 2000 with the main axis Hamburg/Bremen/Hanover to Stuttgart/ Nuremberg/Munich using the high-speed lines Hanover – Wurzburg and Mannheim – Stuttgart.

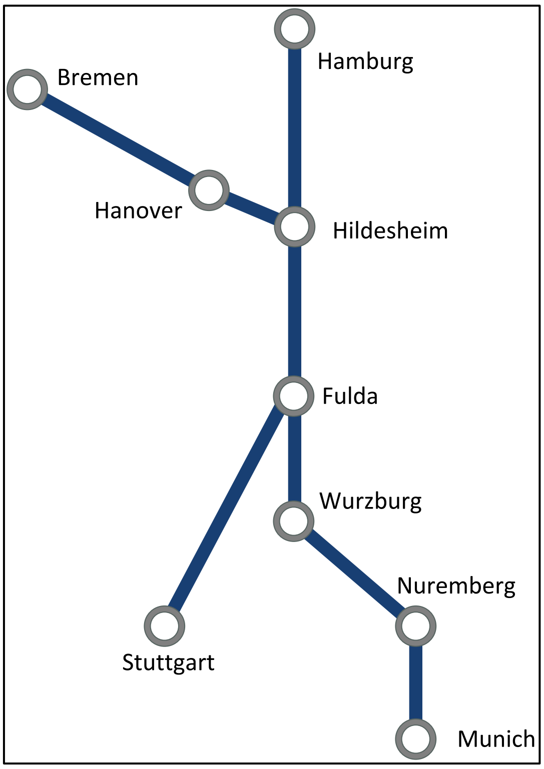


Figure 6.1. Parcel InterCity network in Germany, 2001

The trains run according to a fixed timetable, departing between 7 and 9 pm and arriving between 3 and 5 am in the morning. To reach a maximum speed of 160 km/h, the train consists of a 101 series locomotive with high-speed container wagons, which are equipped with disc brakes. The train run between Hamburg and Munich takes nearly eight hours with an average transport speed of 104 km/h. The night run causes many problems with conventional freight trains, which run only at speeds between 80 and 120 km/h.

The Parcel InterCity trains had a very high priority in overnight operations to get quickly through the network and to ensure the on time arrival in the early morning. First timetable drafts showed travel time extensions up to 45 min for conventional freight trains. A high effort in timetable optimisation makes it possible that the travel time extensions for slower freight trains do not affect the overall transport quality for the customers. But nonetheless in 2010 the loss of capacity was too high. So, the operators decided to reduce the maximum speed to 140 km/h in order to mitigate the capacity situation. Consequently, the track capacity usage of the faster Parcel InterCity trains could be decreased. Some other reasons for speed reduction were high energy consumption and expensive wagon maintenance for the Parcel InterCity trains. The system is still in operation until today.

Figure 6.2. Parcel InterCity passes through a station in Germany; source: Wikimedia Commons, author: KlausMiniwolf, Creative Commons Attribution-Share Alike 4.0 International

Bibliography:
[Dorn2001]
[Troche2005]
[ParcelInterCity2016]

6.2.1.2 Swedish postal train

In Sweden there are dedicated mail trains for the Swedish post office, which run mainly at night. The trains are operated by the Swedish railway undertaking Green Cargo. The Swedish post is shipping mainly letter products but also pallets and parcels on a smaller scale. The system consists of three lines by using the Western and Southern main line and the East Coast line in Sweden:

- Stockholm – Malmö (Southern line)
- Stockholm – Gothenburg (Western line)
- Stockholm – Sundsvall (East Coast line)

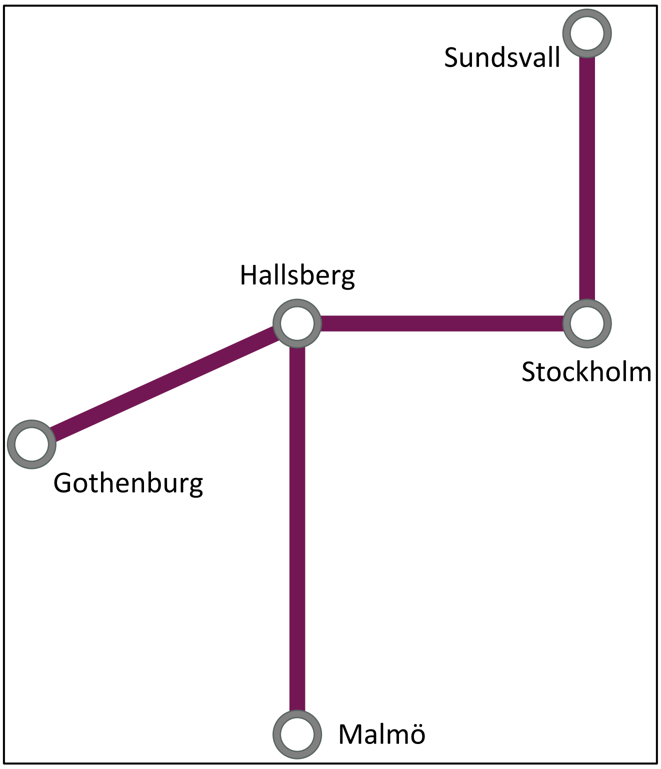


Figure 6.3. Swedish postal train network, current status

In 2000 Green Cargo has ordered new rolling stock, due to higher demands in transport quality by the Swedish post office. Therefore, proven freight wagons were reengineered in order to realise a higher speed and offer the possibility to ship swap bodies. Accordingly, the new wagons can reach a top speed of 160 km/h. Each train is loco-hauled and composed of intermodal wagons for swap bodies and covered wagons.

Figure 6.4. Swedish postal train covered wagon; source: Wikimedia Commons, author: Bilden tagen av Fredrik Tellerup, Creative Commons Attribution-Share Alike 2.5 Generic

The swap bodies have side doors for easy unloading and loading in the terminals. Moreover, the transport speed is increased by using an efficient operation strategy. For example, at midway stops the trains diverge from the mainline into a terminal and the load and unload process only takes five to ten minutes. In addition, the Swedish postal trains have a higher priority in the allocation of capacity in the yearly timetable planning. Due to this, the trains can use express train paths and have a priority as high as an express passenger train. This means, that conventional freight trains have to stop to let the postal train pass. The system is still in operation until today.

Bibliography:
[Lundström2018]
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[SwedishPostTrain2007]

6.2.1.3 The Royal Mail train

In 1996 the mail train system in Great Britain was restructured fundamentally. Royal Mail and the responsible railway undertaking Rail Express System created a new concept for rail mail on the British network. One the one hand it was set up a new network and timetable for mail trains. On the other hand the mail transport on passenger trains was stopped.

The loading and unloading of freight mail trains was getting faster by introducing a new fleet of specialized electric multiple units (trainsets) and creating new terminals and hubs for mail freight (e.g. main hub in London-Wembley). Besides the four-car multiple unit trainsets there are still conventional loco-hauled mail freight trains. The new electric multiple units (British Rail Class 325) reach a top speed of 100 mph (161 km/h). Therefore, these trains are the fastest cargo trains in Great Britain.

For the most amount of transport the West and the East Coast mainline of the British network are used. With regard to the different connections, the main axes of the system are the London – Warrington – Glasgow line and the London – Newcastle line.

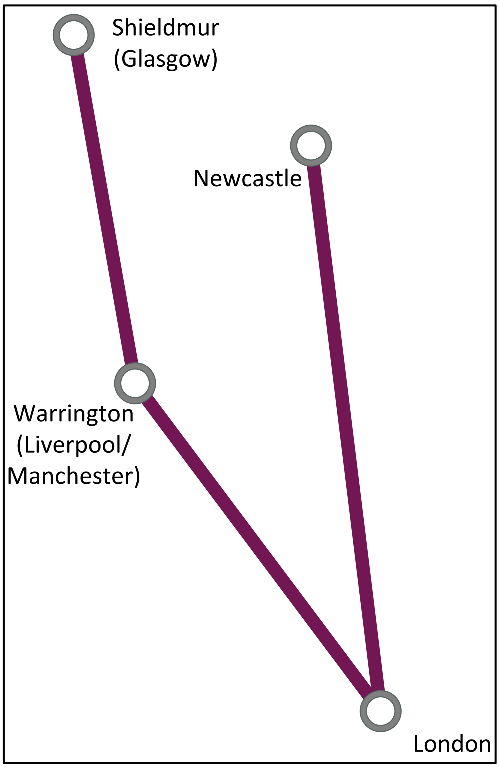

Figure 6.5. Royal Mail Train network in Great Britain

In each station there is a special Royal Mail terminal, where the trains diverge from the mainline into a terminal. Inside the terminals there are platforms parallel to the main tracks, which allow an easy loading and unloading.

The Royal Mail trains with the British Rail Class 325 are operated in ten daily train services. Since 1996 the operator of the trainsets changed several times, today DB Cargo UK is the railway undertaking for this fast freight train service throughout the country. Royal Mail has high demands in transport quality of the Royal Mail Train. A punctuality of 95 % is assumed by Royal Mail. If the train is running late with 10 minutes or more, this will be considered as a delay. Consequently, the Royal Mail trains must be given a high priority in the operating procedure to get through the network quickly. The system is still in operation today, using 15 trainsets in total.

Figure 6.6. British Rail Class 325, used for the Royal Mail Train; source: Wikimedia Commons, author: Hugh Llewelyn, Creative Commons Attribution-Share Alike 2.0 Generic

Bibliography:
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[Werner2017]
[BritishRailClass2009]

6.2.2 Discontinued systems

6.2.2.1 InterCargoExpress

The InterCargoExpress was an overnight transport service with a maximum speed of 160 km/h. The train service was started in 1991 by German Federal Railway to offer a fast freight train service comparable to the new Intercity Express network for passengers. Therefore, the new cargo trains used the high-speed dedicated lines between Hanover and Wurzburg, Mannheim and Stuttgart. The InterCargoExpress was intended for general cargo and parcel services as well as for combined transport (CT). The train consisted of 20 four-axle container wagons and was hauled by a type 120 locomotive. Some two-axle sliding wall wagons were used to transport single consignments and part cargo.

Between 1990 and 1995 two train parts arrived from Hamburg and Bremen and were coupled together. To the south of Hanover the coupled train continued its journey to Stuttgart. Another train connected Hamburg and Munich directly with intermediate stops in Hanover, Wurzburg and Nuremberg.

The InterCargoExpress ran during the night with a maximum speed of 160 km/h mostly on high-speed lines (on conventional lines the speed was reduced to 140 km/h, because LZB was not available). After the introduction of the new high-speed network in Germany (e. g. the line Hanover – Würzburg), more and more conventional freight trains used these lines, mainly overnight like the InterCargoExpress. Therefore the negative influence of the 160 km/h InterCargoExpress became apparent. The higher speed of the InterCargoExpress led to less capacity of the whole line. Because of this, German Federal Railway decided to reduce the freight train speed at night to a level of 120 km/h on these lines. Due to the harmonized speed of the trains, the track capacity increased, but the time advantages of the higher top speed decreased. In 1995 the InterCargoExpress was ceased for economic reasons. Nowadays the container wagons of the InterCargoExpress are used in conventional rail freight traffic and the Parcel InterCity.

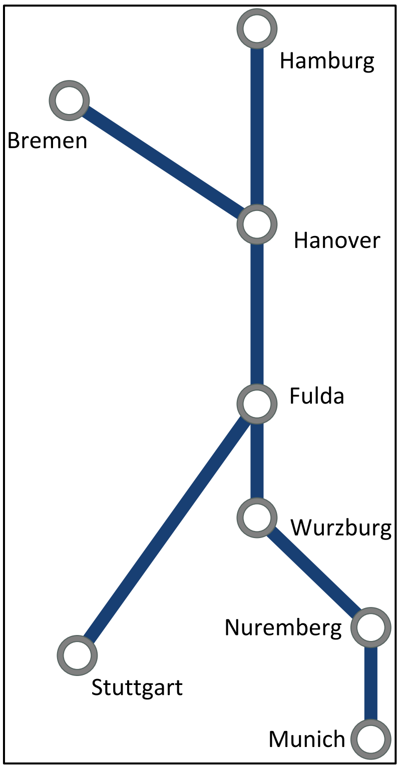

Figure 6.7. Network of InterCargoExpress in Germany

Bibliography:
[Flämig2017]
[Troche2005]

6.2.3 Systems in concept stage

6.2.3.1 XPressNet

The "XPressNet" was a concept for a high-quality network for the transport of time-critical consignments on rail. The network was planned by actors from the transport industry like DHL, DB Schenker, Hellmann, kombiverkehr and DUSS. Moreover, DB Netz was involved in the development, which made it possible to transfer the concept into the timetable design of 2010. This made it possible to examine the concept in the light of the existing timetable.

The XPressNet trains ran on the conventional network and had to be integrated into the existing timetable and operations. The previously planned transport speed of 160 km/h was reduced to 140 km/h, in order to integrate the train paths into the timetable easier.
High speed lines were only used in in the sections Hanover – Wurzburg and Ingolstadt – Munich. For transshipment existing combined transport terminals were selected.

The project showed that the speed of 140 km/h was sufficient to be able to offer the required transport services in overnight operation. Due to the lower speed, trains could be integrated conflict-free into the timetable structure. Moreover, it was possible to use cheaper wagon material and to transport a wider range of loading units. So, the XPressNet system was more interesting from an economic point of view. However, the integration of the train paths into the timetable was very difficult, especially in the section Hamburg – Hanover, even though the speed of the XPressNet trains was reduced to 140 km/h. Problems occurred in particular with train paths of conventional freight trains with a speed lower than 120 km/h.

Taking everything into account, the XPressNet concept underlined, that a freight train speed of 140 km/h is the technical and economic optimum in terms of travel time. The travel time is short enough for a competitive transport service.

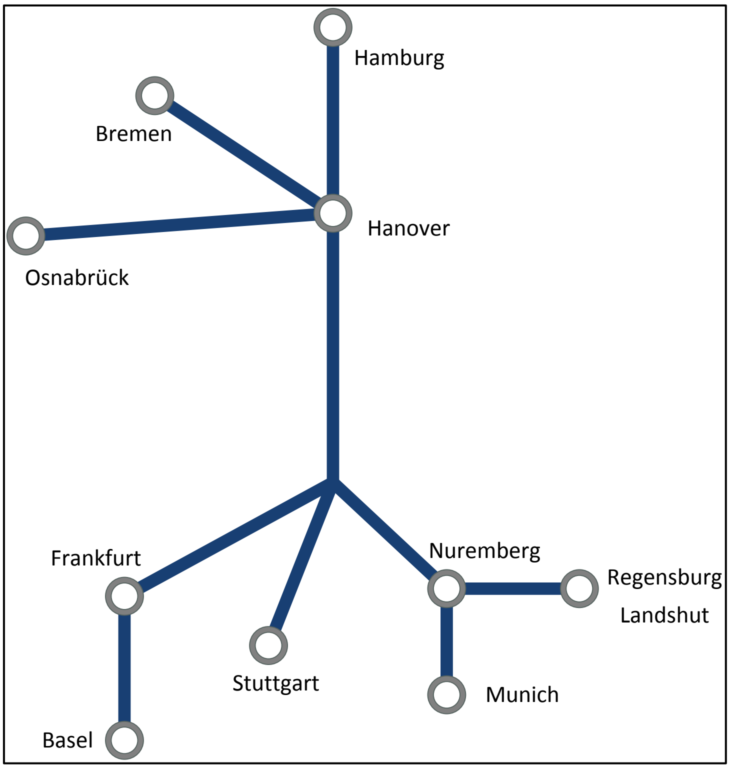

Figure 6.8. Planned network for XPressNet in Germany

Bibliography:
[Büchner2011]

6.2.3.2 SPECTRUM

SPECTRUM was a project of the European Union to explore market opportunities for low density, high value (LDHV) goods by using innovative rail concepts. The main focus of the project was the analysis of carryings between terminals for intermodal transport on routes currently dominated by road freight. These point-to-point connections had a high potential of light and high-quality goods (Low Density High Value - LDHV) over longer distances. Within the scope of the investigation several interesting relations for LDHV in Europe were analyzed.

- Daillens – Chur (Switzerland)
- Hallsberg – Copenhagen (Sweden, Denmark)
- Turin – Lyon (Italy, France)
- Halkali – Kapikule (Turkey)

In the concept the freight trains ran with 140 km/h maximum speed, which was sufficient in most cases. A speed of 120 km/h would be too low for the freight train to integrate easily into passenger operation. An interesting aspect was the decision to give the SPECTRUM freight trains the same priority as passenger trains to get through the network quickly.

The carried goods were swap bodies and ISO-containers. The trains consisted of a conventional locomotive combined with further developed container wagons. The authors underlined, that the driving power and acceleration of a conventional locomotive might not be sufficient for operation of faster freight trains in order to reach a performance level compared to passenger trains. The usage of two locomotives would lead to a commercially unattractive concept. So, it would be important to find a locomotive, which could haul the SPECTRUM train in single traction, to reach a competitive position in the freight market.

Bibliography:
[Panteia2012]
[Schoemaker2012]
[SPECTRUM2012]

6.3 Very fast freight rail up to 200 km/h

Very fast freight rail systems can be classified by a speed range between 160 and 200 km/h. In most cases the trains use conventional existing infrastructure or upgraded lines. In this mid-level speed range it is possible to use locomotive covered freight trains. In contrast to fast freight rail trains, the adjustments of the freight wagons are more complex (e. g. bogies, braking system). When the speed is increased to over 160 km/h, it is mandatory in most countries to use continuous train control. Due to this the locomotive’s train control is upgraded to a cab signaling system like LZB, TVM or ETCS. Beside the conventional network very fast freight trains often use upgraded lines with a maximum speed up to 200 km/h.

6.3.1 Discontinued systems

6.3.1.1 Expressgut InterCity

The Expressgut InterCity was a fast rail mail system in Germany. It was in service between 1982 and 1997. The main idea was to create a fast rail mail network throughout Germany. The Bundespost (German federal post office) wanted to replenish their night airmail network, which was in service since 1961. Furthermore, the Bundespost was interested to increase the overnight transport speed of rail mail compared to the common rail mail trains.

The key point in this development was the start of the German InterCity network in 1979 by the Bundesbahn (German Federal Railway). From 1979, the Bundespost converted several of its rail mail wagons for a top speed of 200 km/h (650 cars in total). So, it was possible to replenish some passenger InterCity trains with rail mail wagons. Most passenger InterCity trains had been pulled by the 103 series express locomotive with a top speed of 200 km/h. At night time the 103 series locomotives were not in service. Therefore, the Bundespost had the idea to use these locomotives for its new fast rail mail network for overnight services to set up own rail mail trains. The Bundespost called these trains “Expressgut InterCity”.

The network for the 1982 timetable covered largely the same relations of the passenger InterCity trains running every hour during the day. First and foremost the new network was in service in order to transport letters throughout Germany. The letters were sorted during the transport by

Bundespost employees. With this network the Bundespost could offer a system for the overnight letter delivery. The network was in operation until the middle of the nineties. Although the system worked well, several reasons led to cessation of operations.

On the one hand there have been the following problems in railway operations. The speed difference between the Expressgut InterCity trains and the conventional freight trains was very high. In addition to this, the Expressgut InterCity trains had long stops at many stations in between compared to freight trains (up to four minutes). Furthermore, the Expressgut InterCity trains had a very high priority. This was important, because the Bundesbahn wanted to avoid that the Expressgut InterCity trains interfere with the starting passenger InterCity service in the morning. The conventional freight trains ran with speeds between 80 and 120 km/h at night. Accordingly, the Expressgut InterCity trains consumed a huge amount of line capacity.

One the other hand the Bundespost changed its business policy and created new Frachtpostzentren (cargo mail centers). These cargo mail centers were designed for truck transport. Because of this, the meaning of the Expressgut InterCity network diminished. The last Expressgut InterCity train ran in mid-1997. So, the transport of letters by rail was cancelled in 1997. The focus of the Expressgut InterCity changed to parcel transport. The Parcel InterCity system could be called as the the successor of this system and is still in service today.

Bibliography:
[Scharf1983]
[Stern2013]

6.4 High-speed freight rail with more than 200 km/h

Beside the freight trains with speeds up to 200 km/h there is a growing importance of high-speed freight rail. Although some systems and approaches were discontinued or not pursued further, an increasing number of concepts for innovative high-speed freight rail systems are developed recently. The speed range for these types of trains varies from 200 up to 350 km/h and more. In this category in most cases the train types used in high-speed passenger traffic are adapted to rail freight traffic. Therefore, the composition of the high-speed multiple units is retained. However, the wagons for passenger transport are modified for carrying goods. For example, many wagons are equipped with roll-up doors and roll floors. Due to this wagon design, the most common cargo types for high-speed cargo trainsets are goods in air freight containers and rolling containers. During most of the trip the high-speed freight trains use dedicated high-speed lines with maximum speeds more than 200 km/h.

6.4.1 Current systems

6.4.1.1 Fast freight trains in China

In China there are several fast freight trains which are already in operation or are developed currently. The developments are driven forward by the national Chinese railway company CRH (China Railway High-speed). On the one hand, there are fast freight trains with a maximum speed varying from 120 to 160 km/h, which are used for fast parcel transport. The 160 km/h-trains are in operation since 2016 and thus reach the maximum speed in conventional freight traffic in China.
On the other hand, a concept for a high-speed freight train service is under development. The Chinese train manufacturer CRRC is developing a 250 km/h electric multiple unit for the delivery of fresh products or higher-value cargo such as e-commerce goods. The train will be able to travel on all high-speed lines of the Chinese rail network.

Figure 6.9. CRH CR400AF Fuxing Hao, electric multiple unit, used for the CRH fast delivery service; source: Wikimedia Commons, author: N509FZ, Creative Commons Attribution-Share Alike 4.0 International license

Finally, the third concept is already in operation. In September 2017 the Fuxing Hao passenger trains connect Beijing with Shanghai in 4 hours and 30 minutes for the first time. The maximum speed was increased from 300 up to 350 km/h. The increase has saved half an hour of driving time. However, the railway operator China Railway High-Speed (CRH) does not only want to transport passengers, but also light, urgent goods in these trains. For this purpose, the trains are equipped with special compartments that can accommodate several parcels. As space is currently limited, the transport service is only suitable for e. g. business mail, urgent personal items or important medicines. The customers have to accept restrictions, similar to hand luggage in air traffic. If the customer sends a parcel from Beijing, it takes ten hours until delivery in Shanghai. This makes parcel transport two hours faster than air freight. Therefore, the ten hour delivery time makes the new parcel service the fastest delivery service in China.
Bibliography:
[Yan2017]
[Pandaily2017]
[Waters2016]
[Ziyan2017]
[CR400AF2017]

6.4.1.2 Mercitalia Fast

The Italian Railways (Ferrovie dello Stato FS) announced a new concept for a high-speed freight train system in April 2018. The system will be operated by Mercitalia, the subsidiary company of FS for freight transport and logistics services in Italy and Europe.
With the new Mercitalia Fast service FS wants to use the Italian high-speed network also for fast freight rail. The aim is to be able to offer the customer a fast and reliable dispatch of goods. The new service is intended for the transport of time-sensitive products such as parcels or express mail. FS will use existing electric multiple units of the ETR500 series for the Mercitalia Fast. The wagons will be specially equipped for the transport of roll containers. Each trainset will consist of 12 wagons and the total loading volume will be as large as two 747 cargo aircrafts.

Figure 6.10.. FS ETR 500, electric multiple unit, will be used for the Mercitalia Fast service; source: Wikimedia Commons, author: Creatività & Broad Casting FS Italiane, Creative Commons CC0 1.0 Universal Public Domain Dedication

Operation will start in October 2018 with the connection from Naples (Caserta terminal) to Bologna (Interporto terminal). The delivery time will be 3 hours 20 minutes at an average speed of 180 km/h. In the future, FS intends to expand its fast cargo service to other terminals in Italy (cp. to figure: Italian high-speed network). Cities that are directly connected to the Italian high-speed network are particularly suitable for this (e. g. Turin, Novara, Milan, Brescia, Verona, Padua, Rome, Bari).

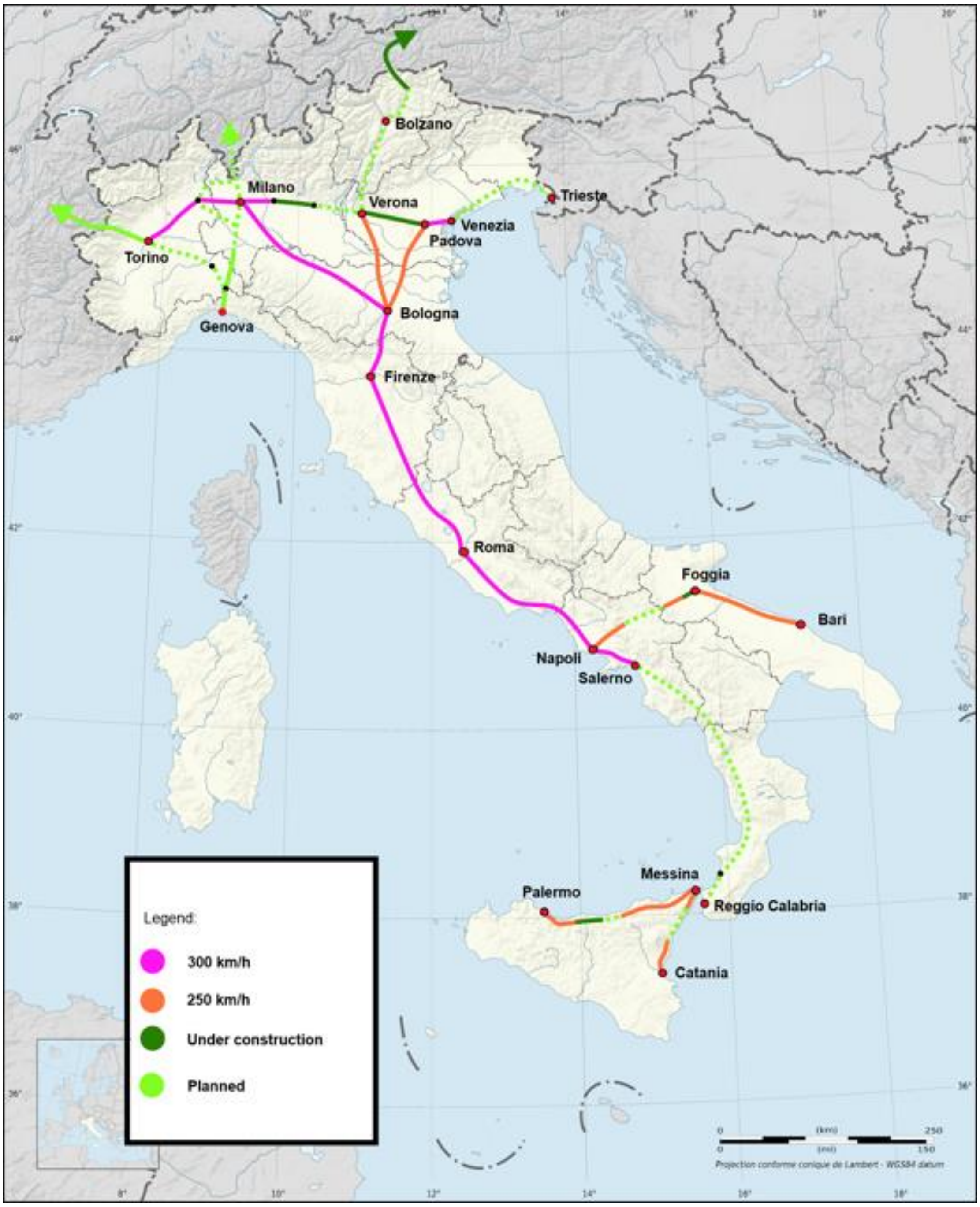

Figure 6.11. Italian high-speed network; source: Wikimedia Commons, author: Sinigagl, Creative Commons Attribution-Share Alike 3.0 Unported

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[RailwayGazetteInternational2018]
[FSETR2010]
[Sinigagl2006]

6.4.2 Discontinued systems

6.4.2.1 TGV postal

The Train à grande vitesse postal (TGV postal) was a joint project of the French railway company SNCF and the French Post Office (La Poste). It has been used since 1984 to transport intranational mail quickly and reliably by land. For this purpose TGV passenger trains were adapted for freight traffic. Instead of wagon doors at both ends, a single door was installed in the middle of the wagons for loading and unloading of roll containers. Moreover, the interior passenger equipment (e.g. seats) and the wagon windows could be omitted. This made it possible to increase the payload. A trainset consisted of eight wagons with two locomotives at both ends.

Figure 6.12. SNCF TGV postal, electric multiple unit; source: Wikimedia Commons, author: Florian Pépellin, Creative Commons Attribution-Share Alike 3.0 Unported

Figure 6.13. SNCF TGV postal wagon interior; source: Wikimedia Commons, author: Saturne, Creative Commons Attribution-Share Alike 2.0 Generic

The introduction of the TGV postal had several reasons. Due to the start of the passenger TGV network since 1981 many conventional passenger trains were omitted. So, the passenger TGV

replaced slower trains, which were also used for carrying mail. Furthermore, SNCF and the French Post Office planned to replace air mail by creating a new, fast rail freight network.
The TGV postal mainly ran at night at a maximum speed of 270 km/h on the TGV high-speed line between Paris and Lyon/Marseille and have been the fastest freight trains in the world. The timetable has been adapted to the post's logistics concept. Each of the three sets commuted once a day between Paris and the freight distribution centers near Lyon and Marseille.
In June 2007, La Poste and SNCF announced the extension of high-speed freight services to the entire TGV network. But since 2014, La Poste has been discussing the termination of the TGV postal service. Since most TGV postal mail was sent overnight, there were problems with the maintenance window of the French high-speed lines, which are only maintained at night. For example, this causes delays or track closures for the TGV postal. Moreover, the transport of urgent letters to be delivered the next day is no longer profitable due to the massive decline in letter mail. Since 2007, the volume of urgent shipments decreased by 50 %. The use of the trains would only be profitable at full capacity. In 2015 the TGV postal service has been discontinued mainly for economic reasons.

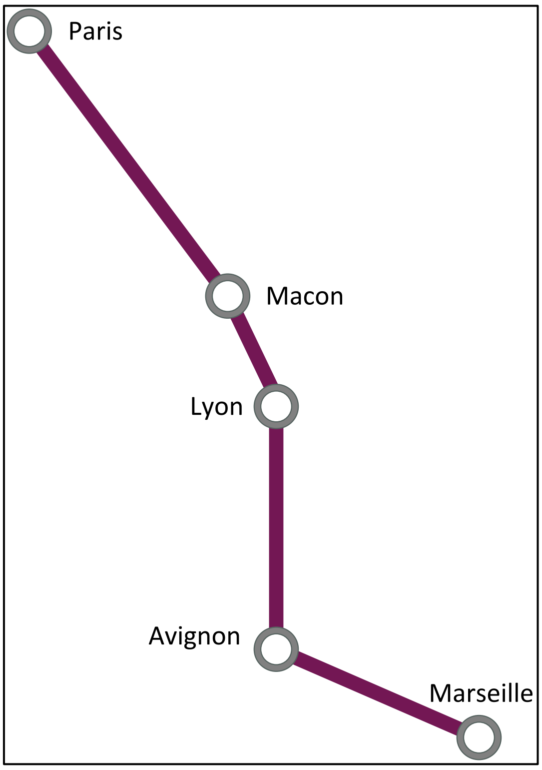

Figure 6.14. SNCF TGV postal network, 2015

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[Siegmann2017]
[Gaidzik1987]
[Klingsieck2014]
[SNCFTGVpostale2009]
[SNCFTGVpostale2011]

6.4.3 Systems in concept stage

6.4.3.1 ICE-G

The ICE-G (InterCityExpress-Güter) is a concept for a high-speed freight train in Germany. The concept is based on the ICE network, which is in operation in Germany since 1991. To put it simply, the passenger ICE 1 train is used as a high-speed freight train with certain improvements for cargo transport. The concept was developed between 1987 and 1993. In the 1970s and 1980s the market share for urgent goods was increasing, but the bulk of the growth was covered by road freight transport. Due to this Deutsche Bahn (German Federal Railway) and the authors of this concept wanted to develop a concept so that the railways, especially the new ICE network, would also be involved in express goods traffic. Interesting cargo load for the ICE-G were e. g. medicines, chemical products, IT systems, machines, machine parts or metal goods. Furthermore, there was a market potential to transport books, newspapers or magazines. In addition, the cargo portfolio of the ICE-G was added by consignments from night air mail, air freight traffic and passenger baggage. Transport and transshipment takes place exclusively by means of roll containers. The rolling containers are handled manually on ramps or lifting platforms. The transshipments is carried out at conventional passenger platforms in the railway stations. Taking everything into account, the preliminary investigations showed a sufficient market potential, the business case was positive. The ICE-G should have used the dedicated high-speed lines of the new ICE network, which had started in 1991. The intended relations were Hamburg – Hanover – Nuremberg – Munich and Hamburg – Hanover – Frankfurt – Stuttgart – Munich. The aim was to link 17 economic centres in Germany.

Figure 6.15. DB ICE 1 BR 401, intended for the operation of the ICE-G; source: Wikimedia Commons, author: S. Terfloth, Creative Commons Namensnennung – Weitergabe unter gleichen Bedingungen 2.0 Deutschland

The operation of the ICE-G would have been overnight, connecting the cities Hamburg and Munich and the intermediate stations. The trains would have run according to timetable, departing at 8 pm in the evening and arriving at 4 am in the morning. The journeys would have end either at passenger stations, freight traffic centres, freight centres of the Federal Post or at combined transport stations. Nonetheless, the night-time operation of the ICE-G on the German high-speed lines would have worsened the operating quality, because it would have had a negative impact on the other railway traffic. The train ride at night would have caused many problems with conventional freight trains, which run only at speeds between 80 and 120 km/h. The ICE-G trains would have had a very high

priority in overnight operations to make sure the on time arrival in the early morning. Therefore, a decrease of operational quality was expected for the conventional freight trains.
The results of the study regarding the decreasing operating quality led to the fact that the concept was not introduced.

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[IVE1990]
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[ICE2007]

6.4.3.2 HGV-G

The concept HGV-G (Hochgeschwindigkeitsverkehr für Güter, high speed rail for freight) focuses on large-volume vehicles for rail freight transport with speeds greater than 250 km/h. The authors of this concept consider goods transports from 200 km transport distance as interesting. The concept was developed in 1993 by Institut für Schienenfahrzeuge (RWTH Aachen, Germany).
The high-speed freight rail system should be nationwide, customer-oriented, well organized and reliable. The range of services should meet two minimum requirements: first, an on time service, which ensures term guarantees until 9 am the following day and second, to provide detailed information about the posted shipment.
The network combines two north-south and two east-west relations throughout Germany by using high-speed lines. The HGV-G system also offers options for transfer services and train coupling and sharing.
The most important characteristics of goods for fast freight transport are high-value, urgent or perishable. Moreover, goods are interesting, which are integrated into just-in-time production processes. The trains will be loaded with rolling containers.

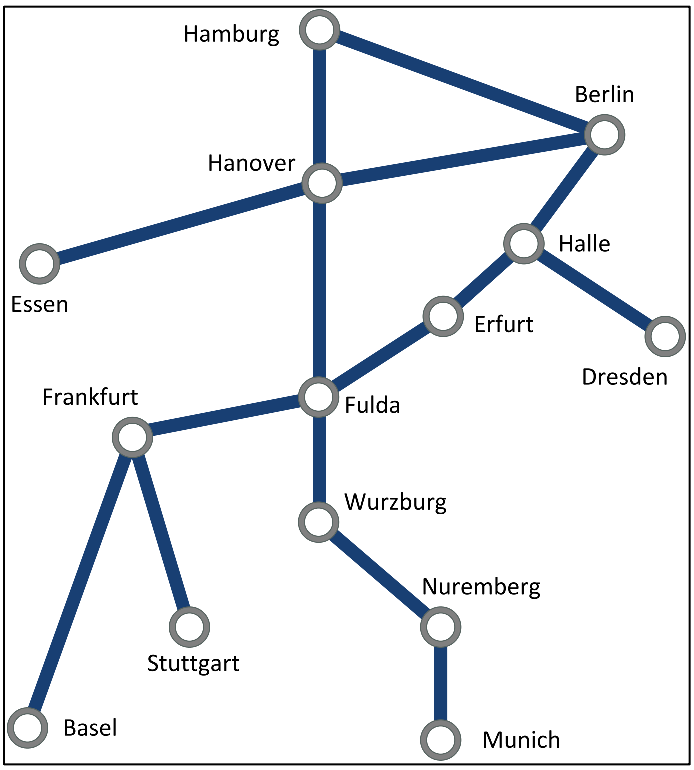

Figure 6.16. network proposal for HGV-G in Germany

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6.4.3.3 Fracht-Express Paris – Frankfurt

The Fracht-Express (freight express) is a concept for a high-speed freight train between France and Germany, which connects Paris with Frankfurt. The concept can be seen as a continuation of the ICE-G.

Deutsche Bahn (Germany Federal Railway) and SNCF (French Federal Railway) have investigated whether a common high-speed rail freight system between both countries would be possible by using dedicated high-speed lines. The trains run between Frankfurt and Paris, with intermediate stops in Cologne and Brussels. A main focus of this concept is the linking of air and rail freight. Therefore, the trains will stop at Frankfurt, Cologne and Paris Charles de Gaulle Airport. The connection between Frankfurt and Paris is the first step and is considered as a base scenario. Network expansions towards London, Amsterdam and Zurich are planned. The vehicles would be based on the proven ICE or TGV. The wagons are designed, so that they can be loaded with air cargo containers. Due to this, the wagons must be equipped with a roller floor. The concept was published in 1999, but further developments are not yet known.

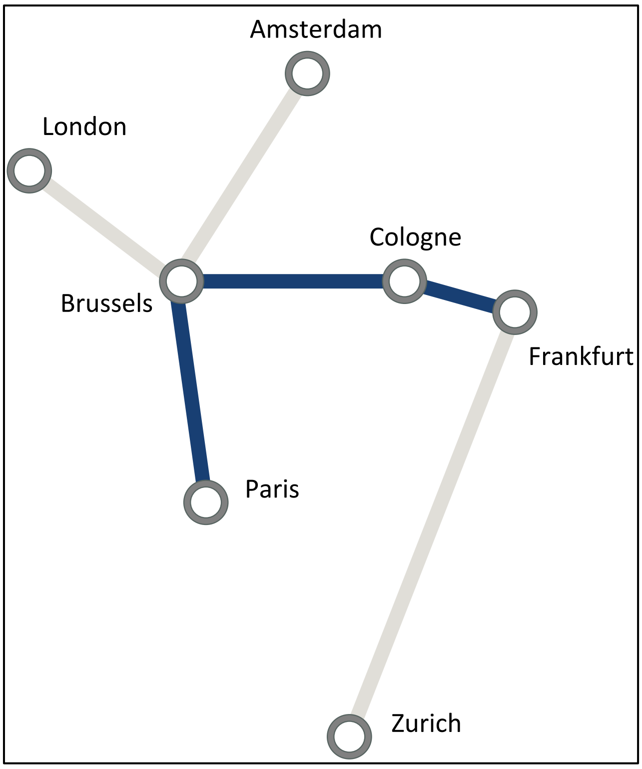

Figure 6.17. network of Fracht-Express, with proposed lines for future extensions (grey)

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6.4.3.4 Highspeed Cargo Train

The Highspeed Cargo Train (HSCT) concept was created by the French consulting company Sigma Conseil from 2011 on. The company recommends to establish a high-speed freight train network between Paris – Frankfurt, Paris – Cologne, Lyon –Cologne and Lyon – Liège. The focus should be on the use of existing high-speed passenger lines. The logistics system corresponds to that of air transport.
Unlike the CAREX project, the HSCT project is not limited to connecting airports, but will cover major routes throughout Europe. Building on the existing high-speed rail networks, the entire European market is to be served.
An important point is that terminals represent a multimodal interface between air, road and rail transport. To reach this goal, more than 15 terminals have to be built along the planned corridors, which are oriented along the most important commercial transport axes and high-speed train projects. In order to optimize the combination with other transport modes, the positioning of terminals near freight airports is suggested.
The targeted freight structure is similar to that of air freight transport. The Highspeed Cargo Train is supposed to carry goods, whose transport is subject to high demands in terms of safety and care and which are to reach their destination on time.
Regarding operations it is recommended to operate the train in a short headway to be able to offer a fast and reliable transport. Otherwise, it would not be possible to exploit the time advantages of the system.

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6.4.3.5 EuroCarex

The EuroCarex (Euro Cargo Rail Express) concept is based on the idea to use the existing high-speed network in Europe for high-speed freight rail. One of the main concerns of the project is the close interaction between air and rail freight. The systems focuses on an overnight traffic between European airports. The system will show the possibility to transport air freight at night with a speed up to 300 km/h. Therefore, new terminals (called Carex railports) have to be built, which are close to high-speed lines, airports and motorways. The concept is developed since 2006 as an successor of the TGV Postal. Initiators of the project are the project partners of TGV Postal, SNCF and other railway companies. The EuroCarex system aims at the goods of air freight replacement traffic and air freight traffic.
Within the EuroCarex system the following stops were planned to be served:

1st phase : start was planned for 2015
- France: Lyon Saint-Exupéry airport, Paris-Roissy Charles de Gaulle airport
- Belgium: Liège airport
- England: London (near to the high-speed line High Speed One)
- The Netherlands: Amsterdam Schiphol airport
- Germany : Cologne airport, Frankfurt airport (via Cologne)

2nd phase : start was planned for 2018
- France: Bordeaux, Marseille, Strasbourg
- Germany: Frankfurt airport (via Strasbourg)

3rd phase : start was planned for 2020
- Italy: Bologna, Milan, Turin
- Spain: Barcelona, Madrid

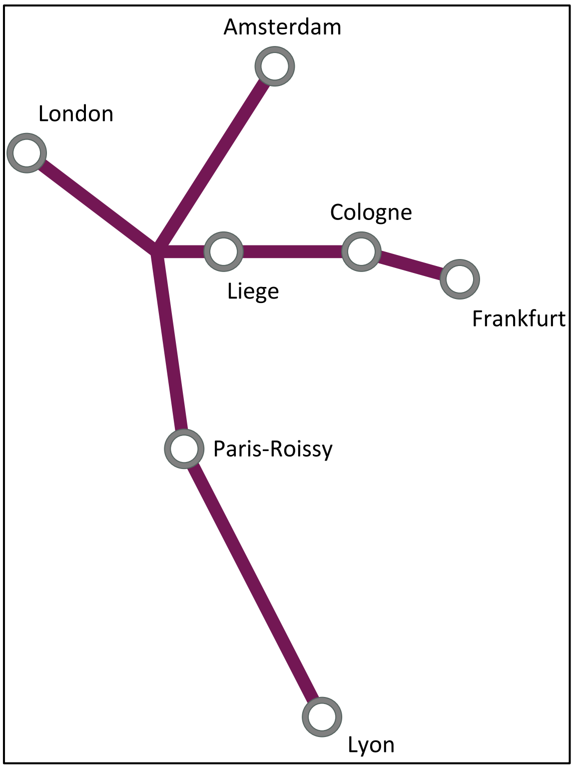

Figure 6.18. EuroCarex high-speed network, first phase, start was planned for 2015

The rolling stock will be derived from passenger high-speed trains like the Alstom TGV Duplex or the Siemens Velaro. The French SNCF has carried out a study to upgrade the TGV for freight transport. The result was a new type of cargo trainset (TGV Fret) based on the previous TGV Duplex, which was manufactured by Alstom. At the invitation and request of the EuroCarex consortium, Siemens has drawn up a vehicle concept for a high-speed cargo train. The train (called Velaro Cargo) is derived from the Siemens Velaro family, which has so far only appeared on the market as a passenger train (e. g. Germany, Spain, United Kingdom, Russia, Turkey, China).

Figure 6.19.. DB ICE 3 BR 407 Siemens Velaro D, part of the Siemens Velaro model family, design basis for the Velaro Cargo; source: Wikimedia Commons, author: Wiki05, Creative-Commons-Lizenz „CC0 1.0 Verzicht auf das Copyright"

Figure 6.20. SNCF TGV Duplex, design basis for the TGV Fret; source: Wikimedia Commons, author: Florian Pépellin, Creative Commons Attribution-Share Alike 4.0 International

With regard to operational issues it is emphasized, that on French and Belgian high-speed lines may occur some problems for the EuroCarex trains. The realization of night traffic on French and Belgian high-speed lines is more difficult than in other countries, as the high speed routes are closed for maintenance work at night. This can have a negative effect on the operating concept of the EuroCarex, e. g. due to diversions, line closures and delays.

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[RailwayGazetteInternational2012]
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[Velaro2012]
[Duplex2018]

6.4.3.6 High Speed Rail Eurasia

The High Speed Rail Eurasia network is a concept of the Russian Railways (JSC RZhD) with the aim of linking the high-speed rail networks of Europe and China. The concept envisages a gradual introduction of the missing high-speed lines in Eurasia. The concept can be seen as an addition to the New Silk Road project, which will connect Europe and the Middle East with Eurasia and China. One of the main objectives is to create a fast rail link from Moscow to Beijing. A first step is the construction of the high-speed line between Moscow and Kazan. In the medium and long term, route extensions in the direction of Europe and China are planned. The concept aims to compete with air traffic between China and Europe. Consequently, the system focuses on the transport of urgent, high-quality goods.

The maximum speed of the high-speed trains will be 350 km/h. The trainsets with 12 wagons each will carry both passengers and freight. The wagons are designed, so that they can be loaded with specialized cargo containers similar to air transport. The trains will be equipped with a system, which can automatically adapt the track gauge to be able to ride on the different networks in Europa, China and Eurasia. According to the Russian Railways the construction of the Moscow-Kazan high-speed line will start in 2018.

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6.4.3.7 NGT Cargo

The German Aerospace Center (DLR) has developed an innovative concept called Next Generation Train Cargo (NGT CARGO) train. The aim of the concept is to significantly increase the attractiveness and thus the share of rail in European freight transport. As the transport of small, urgent consignments in particular will increase sharply in the future, the concept focuses on fast and reliable freight transport. It is characterized by a high degree of automation, intelligent handling and higher speeds.

Figure 6.21. Next Generation Train Cargo (NGT CARGO), multiple unit with power car, source: DLR

Block trains currently dominate freight traffic in Europe. These trains are not shunted, because they form a complete unit. Block trains transport a large, uniform volume of freight from one railway node to another with a large number of wagons. Up to now, single wagonload transport has been a very complex process with rigid operating procedures. The assembly and separation of wagons, their collection and delivery are very resource- and time-consuming. A multitude of manual coupling processes leads to long downtimes of the individual wagons. Consequently, the average system speed in single wagonload transport is only 18 km/h.

Figure 6.22. NGT CARGO last mile terminal, source: DLR

To make single wagonload transport fit for the future, the intelligent freight wagons in the NGT CARGO concept have their own drive system based on electric motors. They also have an integrated battery that stores the energy recovered during braking. This means that the individual wagons can maneuver independently and shunting personnel is no longer required. It is possible to dispense with shunting locomotives or an overhead line. In addition, the individual wagons can automatically and autonomously drive the last few kilometers to the respective customer (cp. to locomotives with last-mile module). For this purpose, each individual wagon is equipped with the appropriate sensors. The wagons can also be driven directly into ports, transshipment stations or specialized logistics terminals, where they are also loaded or unloaded automatically. With regard to the handling process, the wagons are designed, so that they can be loaded with air cargo containers. Due to this, they will be equipped with a roller floor. The NGT CARGO will be able to cope with all power and train protection systems in the planned area of operation.

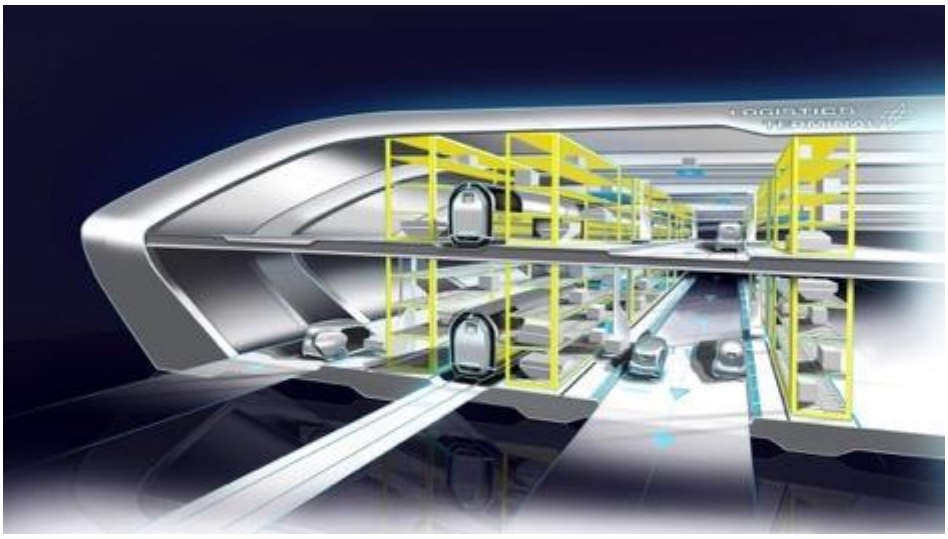

Figure 6.23. NGT CARGO intermodal logistics terminal, source: DLR

For high-speed operation, the NGT CARGO single wagons form a unit and are integrated into a complete electrical multiple unit (trainset) with one or two power cars at the ends. The power cars provide the additional traction required for high-speed operation. The NGT CARGO can reach a speed of up to 400 km/h, if a suitable infrastructure is available. Where no high-speed lines are available, the NGT CARGO will use existing infrastructure with lower maximum speeds.

The high speed of the NGT CARGO makes it possible to adapt to passenger traffic on high-speed and upgraded lines. Capacity reserves on most high-speed passenger traffic lines generally allow a conflict-free train path design. Challenges for train path allocation exist on mixed traffic lines with fast long-distance passenger traffic and slow commuter trains. Mixed traffic during the day with the much slower conventional freight trains causes minor problems, as the NGT CARGO overtakes them like a fast passenger train. In return, this means longer waiting times and obstructions for conventional freight trains.

An interesting application for the NGT CARGO would be the use in intercontinental freight traffic between Europe and Asia. This would be an alternative to transport by ship. Moreover, the competitive position in comparison to air transport would also be worth a closer look.
Several electrical multiple units can be virtually assembled during the journey (so-called dynamic winging). They form a train but are not connected to a material coupling. A combination with the high-speed passenger train NGT HST (high-speed train) is also possible. In this way, passenger and freight traffic are bundled in order to make optimum use of existing line capacities.

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7 Simulations increasing speed of freight trains

7.1 Objective of the study and method of line selection

The scope of this chapter is to find a railway line in Germany, which is adequate for the evaluation of faster freight trains. The aim of increasing the speed of freight trains is the reduction of bottlenecks - not the increase of transport speed.

In Germany some lines see fast passenger traffic with ICE trains on it and also a high number of freight trains. Due to effort reasons not the whole German mainline network could be simulated. A choice has to be done. To find out an adequate line, some factors are important for the decision:

- Line has to be a bottleneck line or needs to have a train load close to the maximum capacity
- Line category should be a mixed traffic line
- The freight train load has to be high
- The share of freight trains compared to passenger trains should be close to 50%
- There should be a big speed difference between the fastest passenger trains and the freight trains
- The line should be part of the TEN-T network, which marks the line as international important

For simplifying the choice, a utility-value-analysis is set up. That's why all the selection factors need a weight. The most important factors are the following three:

- Bottleneck: Without being a bottleneck, there is no benefit for the line capacity, but an effort due to the more expensive fast freight trains.
- High number of freight trains: this is essential to have the opportunity to introduce innovations on the trains and only bottleneck lines with participation of freight trains are chosen
- Big speed difference between passenger and freight trains: The higher the speed difference is the higher is the effect on capacity harmonizing the train speeds.

The share of freight trains is weighted heavier for the day time because in the night time, the travel time requirements of passenger trains are less strict. Often regional trains and even long-distance trains have extended running times to fulfil gaps that occur due to the reduction of frequencies. In doing so more stops are served and waiting times for connections are longer. Thus, passenger trains can be rescheduled easier because of freight trains than during daytime.

So, the following weighting factors are used:

High number of freight trains	30%
Bottleneck	25%
Line category (mixed)	5%
Freight/Passenger-Mix daytime	10%
Freight/Passenger-Mix night	5%
Speed difference Freight/Passenger	25%

7.2 Factor Freight Train Utilization

One source for the utilization of German railway lines with freight trains is a study commissioned by the Federal Environment Agency (UBA) which presents solutions for a doubled volume of rail freight.

This study shows on which lines a doubled rail freight volume under the current conditions could not be tackled. The base case for this investigation is the number of freight trains for 2007.

The map with such a prospective bottleneck is shown in Figure 7.1. The heaviest loaded lines are chosen and marked with numbers.

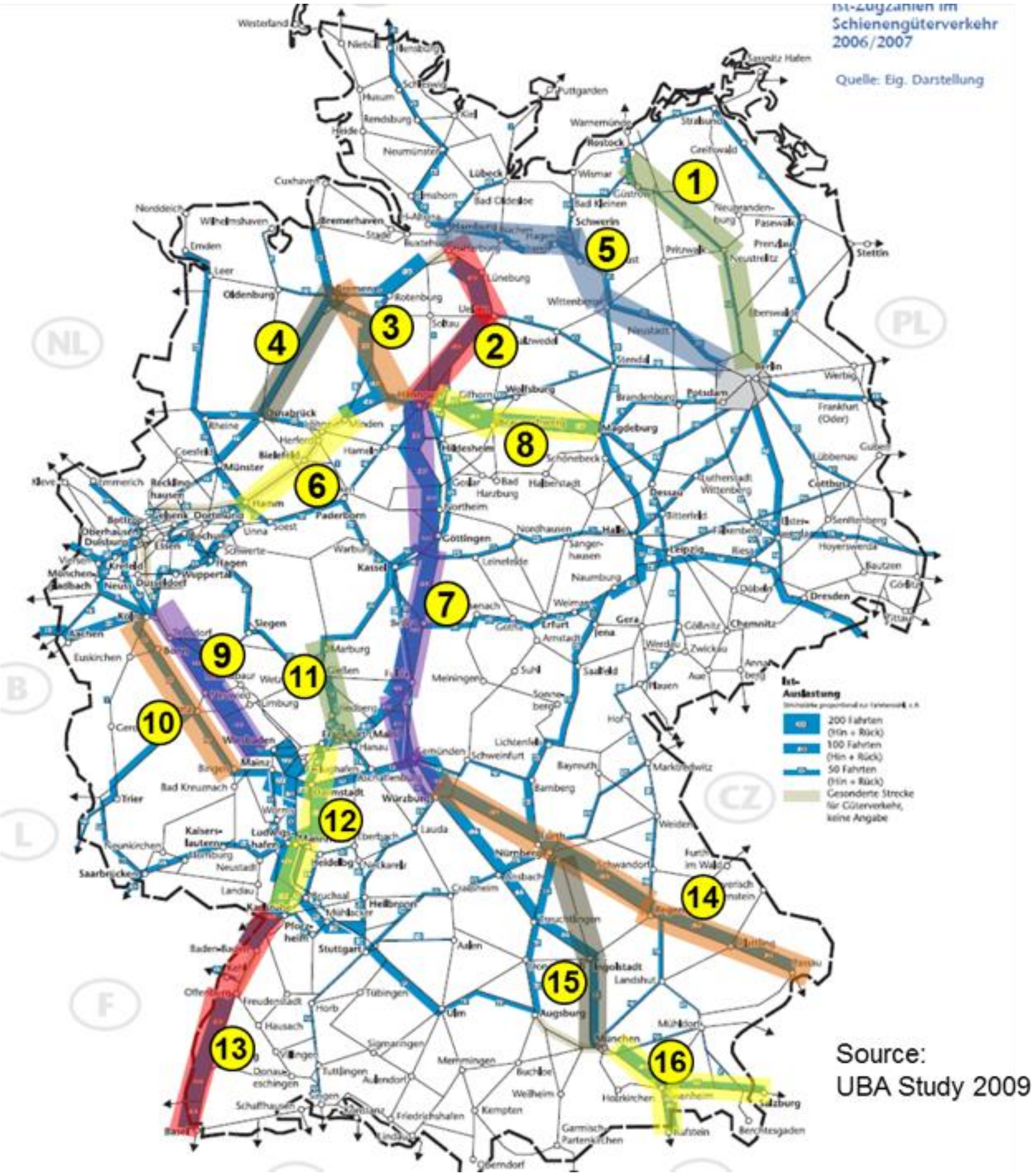

Figure 7.1. Daily Freight Train Numbers of the timetable year 2007 (Source: UBA 2009)

Table 7.1 shows the lines with the highest freight train numbers.

Table 7.1. Lines with highest freight train numbers

ID	Line	Number of daily freight trains
2	Hamburg - Hannover	185
3	Bremen - Hannover	155
7	Hannover – Würzburg (Old Line)	210
9	East Rhine Railway (Köln - Wiesbaden)	235
12	Frankfurt - Karlsruhe	260
13	Karlsruhe - Basel	210
14	Würzburg - Passau	155

7.3 Factor Bottleneck

To find bottleneck lines, a map from the Federal Transport Route Plan (BVWP) is used, where the rail lines are put into three categories:

- Line with capacity reserve (blue)
- Fully loaded line (black),
- Overloaded line (red).

A line utilization of 100% is not the maximum. It is a calculated value, in which the line is used at an economical optimal value, which still allows to buffer delays. The load can increase to over 100% still having a conflict-free timetable, but smaller delays can't be solved and influence many other following trains.

The utilization does not only depend on the number of trains, but also to the mix, the speed differences and the number and position of operational points like passing loops.

Figure 7.2 shows the map with the assignment of all German railway lines to a load category. Table 7.2 shows the longest overloaded lines with the total number of daily trains.

Table 7.2. Overloaded lines with the total number of daily trains

ID	Overloaded Line	Total Number of Trains per Day
2	Hamburg - Hannover	320
3	Bremen - Hannover	308
9	East Rhine Railway	334
12	Frankfurt - Karlsruhe	322
13	Karlsruhe - Basel	350
14	Würzburg - Passau	247
15	Ingolstadt – München	280
16	München - Rosenheim	330

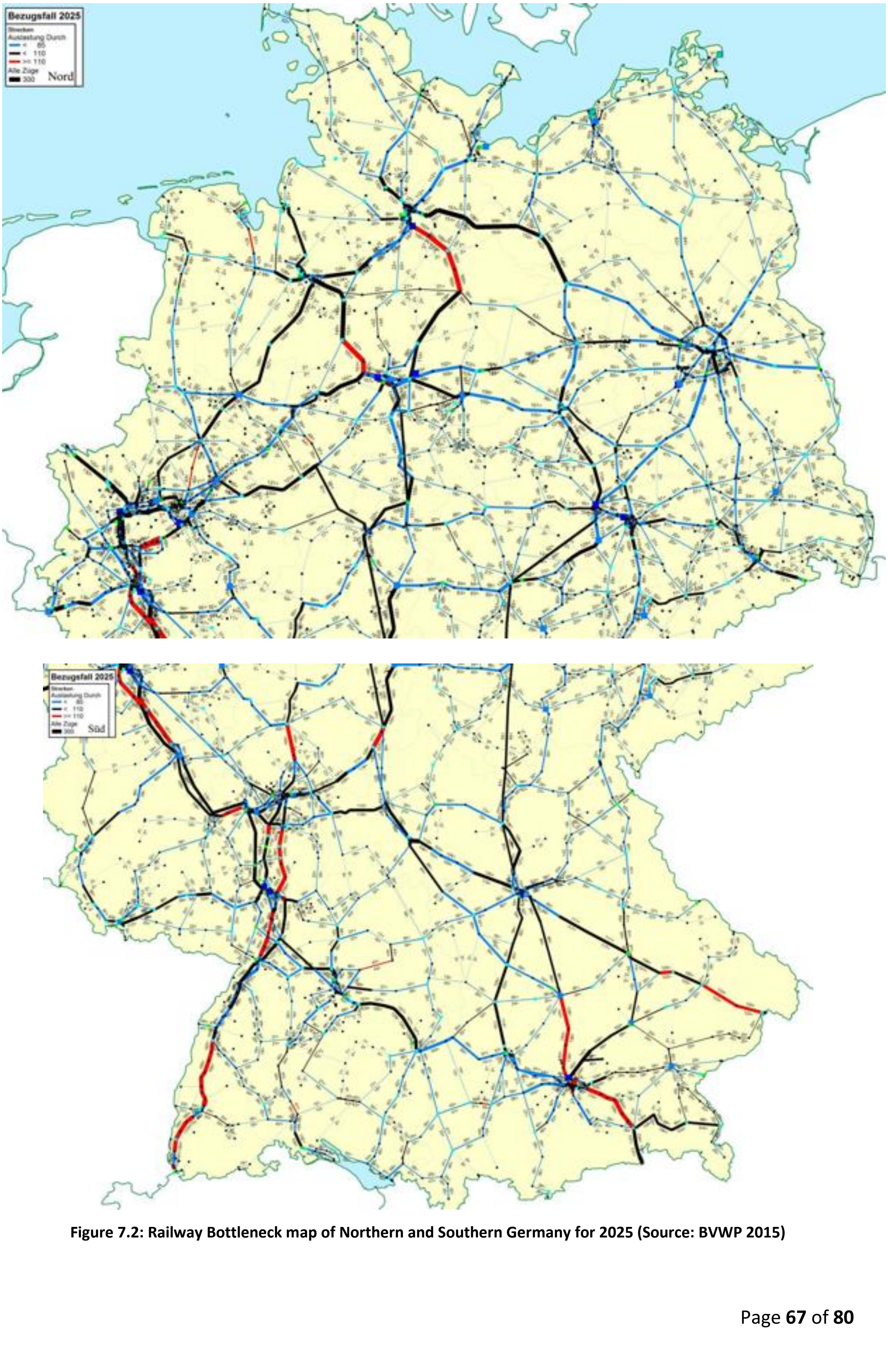

Figure 7.2: Railway Bottleneck map of Northern and Southern Germany for 2025 (Source: BVWP 2015)

7.4 Factor Speed Difference

Beside the bottleneck and heavy freight load characteristic, also the speed difference between the fastest passenger and freight trains is a criterion for selecting a line. The German high-speed lines are all used (or at least planned) for mixed traffic, but due to restrictions of encountering freight and high-speed trains in tunnels they are used by high-speed trains during daytime and freight trains in the night. Thus, the speed difference doesn't matter for this type of line, which is drawn in orange and violet on the maps (Figure 7.3 and Figure 7.4).

The only high-speed line which can be used by freight trains all day long is the line between Berlin and Hamburg (Number 5). The other interesting lines are upgraded lines for 200 km/h (No. 2, 4, 12, 14). The 10 km long Katzenberg-Tunnel (No. 13) consists of two separated tubes. This is the section with the biggest speed difference, but the affected line section is only slightly longer than the tunnel. Section No. 13 has four tracks with separated lines between local and high-speed passenger traffic. Freight trains are difficult to integrate from the perspective of timetable on both lines.

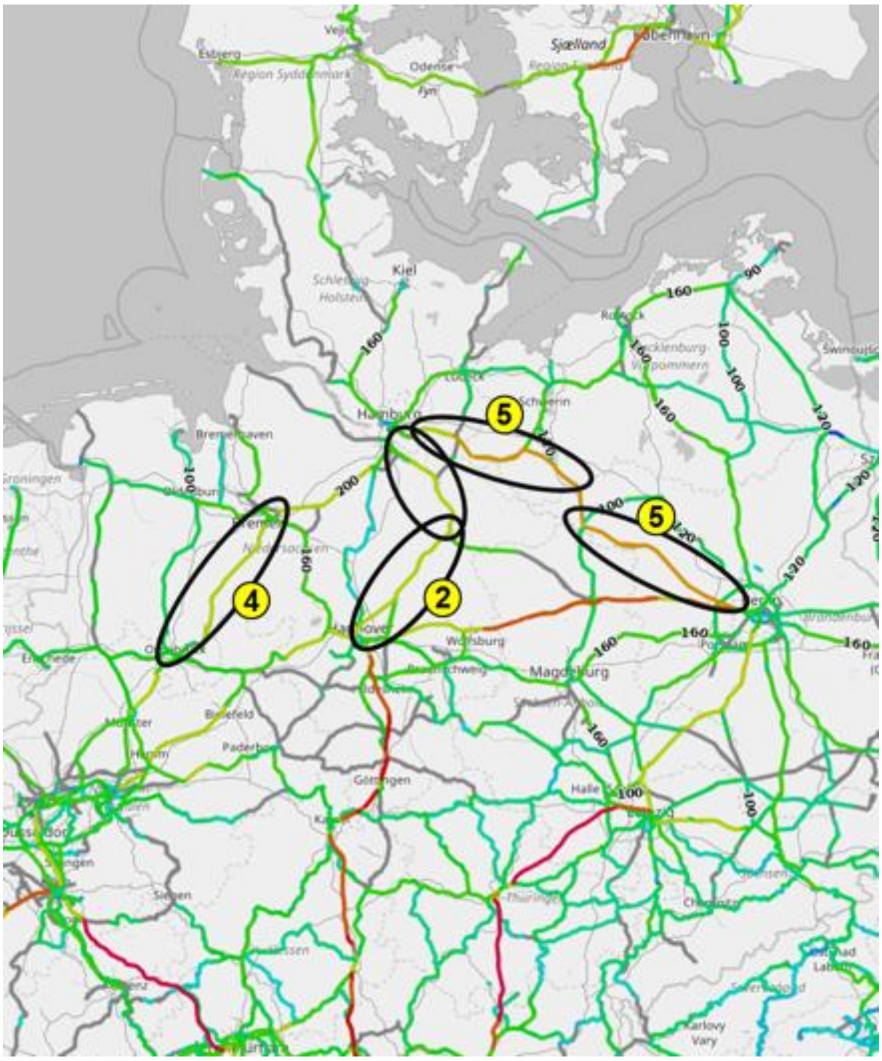

Figure 7.3: Railway line speed limits for Northern Germany (Source: OpenRailwayMap / OpenStreetMap Contributors)

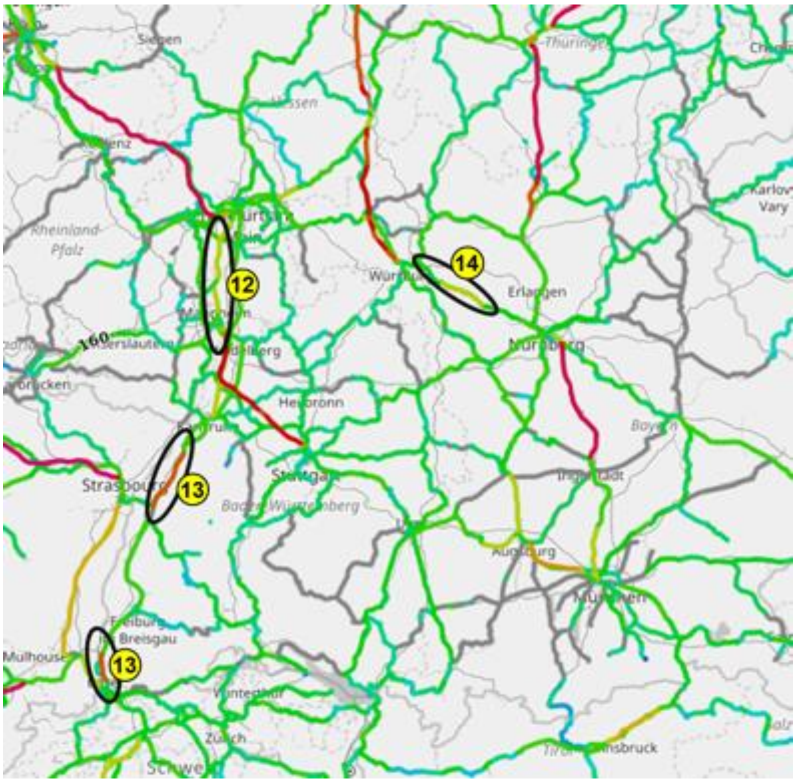

Figure 7.4. Railway line speed limits for Southern Germany (Source: OpenRailwayMap / OpenStreetMap Contributors)

7.5 Factor Train Mix

As already mentioned in chapter 7.4 the interest is to find railway lines with an intensive mix of train types all the day. One data source with separated information about the number of different train types for day and night is the noise mapping of the Federal Railway Bureau (EBA Noise). These maps have to be diverted between day (6-18h) and night (18-6h) due to different noise thresholds. Since the data has to be derived from a website by clicking on a specific place on the line, it is not possible to get a complete picture about the mix on all lines. That’s why only the line section which have been identified for the previous factors are investigated deeper. A share of 50% is defined as the preferable value with descending relevance up and down.

Table 7.3 shows the freight train share for relevant lines.

Table 7.3. Freight train share on relevant railway lines (calculated based on EBA Noise Maps)

ID	Line	Cross Section	Daytime share of freight trains	Nighttime share of freight trains
2	Hamburg – Hannover	Bienenbüttel	41%	66%
3	Bremen – Hannover	Dörverden	51%	73%
4	Bremen – Osnabrück	Barnstorf	33%	52%
8	Hannover – Magdeburg	Peine	52%	70%
9	Eastern Rhine Line	Neuwied	50%	71%
12	Frankfurt – Karlsruhe	Heppenheim	42%	67%
13	Karlsruhe – Basel	Lahr	45%	62%
14	Würzburg – Passau	Neumarkt/Opf	35%	52%

7.6 Selection of a line for simulation

After collecting all required data for the selection, the utility-value-analysis is done as described in chapter 7.1.

The points for all line sections and all categories are shown in Table 7.4 and

Table 7.5. Every cell is filled with values ranging from 0 to 10, with 10 representing the maximum.

- **Bottleneck** consists of three values (0 = free capacities, 5 = full load, 10 = overload).
- The **line category** gives 10 points for M230, 9 for M160, 7 for M120, 5 for P230 and P160 and 3 points for P300 and G120. The M stands for mixed-traffic line, P for passenger and G for goods. The number is the speed class.
- The **number of freight trains** gives 10 points to the maximum value of 300 freight trains a day and is used linear.
- The **freight train share** gives 10 points for 50% freight trains and changes linear in both directions to 0 for 0% and 100%.
- In the **speed difference** category 10 points are given for a passenger train speed of 250 km/h. The value decreases linear to 0 reaching 80 km/h.
- The weighted average is calculated for every line section.
- Finally, a length-weighted value is calculated for the whole line.

Table 7.4. Utility-Value-Analysis for the Southern German lines

	Criteria	Section Length	Representative Cross Section for noise map (EBA)	Bottleneck	Line category	Number of freight trains	Freight train share at day	Freight train share at night	Speed difference	Section Evaluation (0-10)	Line evaluation (0-10)
		km		25%	5%	30%	10%	5%	25%	100%	
	Northern Germany										
1	Rostock-Berlin	184	Nassenheide	0	9	1	2	4	4	2,0	2,0
2	Hamburg-Hannover	73	Bienenbüttel	10	10	6	8	7	7	7,8	6,9
		96	Unterlüß	5	10	5	7	7	7	6,2	
3	Bremen-Hannover	36	Achim	5	9	4	6	8	5	5,0	5,8
		31	Dörverden	5	9	5	10	5	5	5,7	
		34	Neustadt/Rübenberge	10	9	5	7	7	5	6,7	
4	Bremen-Osnabrück	122	Barnstorf	5	5	3	7	10	7	5,2	5,2
5	Berlin-Hamburg	91	Bad Wilsnack	0	5	2	3	7	9	3,6	4,6
		44	Karstädt	5	5	2	5	10	9	5,2	
		94	Boizenburg	5	5	3	5	9	9	5,4	
6	Hamm-Minden-Hannover	112	Oelde	0	5	3	5	9	7	3,9	4,9
		43	Stadthagen	5	5	5	6	10	7	5,8	
		21	Seelze	10	5	10	6	9	7	8,5	
7	Hannover-Göttingen-Kassel-Fulda-W	100	Alfeld	0	3	7	8	4	5	4,2	4,1
		81	Bad Sooden-Allendorf	0	5	5	8	4	5	4,0	
		56	Bad Hersfeld	5	5	7	10	5	5	6,0	
		74	Jossa	0	3	5	3	1	2	2,7	
8	Hannover-Braunschweig-Magdeburg	45	Peine	5	5	6	10	6	4	5,4	4,6
		83	Eilsleben	0	9	5	9	6	5	4,2	

Table 7.5. Utility-Value-Analysis for the Northern German lines

	Criteria	Section Length	Representative Cross Section for noise map (EBA)	Bottleneck	Line category	Number of freight trains	Freight train share at day	Freight train share at night	Speed difference	Section Evaluation (0-10)	Line evaluation (0-10)
		km		25%	5%	30%	10%	5%	25%	100%	
	Southern Germany								0		
9	Right Rhine route Köln-Wiesbaden	59	Neuwied	10	3	8	10	6	2	6,7	5,5
		87	St. Goarshausen	5	3	7	7	4	2	4,7	
10	Left Rhine route Köln-Mainz	59	Remagen	5	5	3	4	9	2	3,8	3,7
		60	Boppard	5	5	2	4	10	2	3,6	
11	Frankfurt/Hanau-Marburg	31	Bad Vilbel	5	9	2	1	4	4	3,4	4,3
		31	Butzbach	10	9	3	4	8	4	5,4	
		30	Lollar	5	9	2	2	7	5	4,0	
12	Frankfurt-Mannheim-Karlsruhe	51	Heppenheim	10	9	6	8	7	5	7,0	5,6
		56	Bürstadt	5	5	3	4	7	7	4,9	
		70	Worms	5	3	3	1	7	5	3,8	
		60	Schwetzingen	10	3	9	5	2	5	7,0	
13	Karlsruhe-Basel	23	Durmersheim	5	9	7	4	7	5	5,7	6,7
		23	Muggensturm	0	9	7	7	8	5	4,8	
		41	Baden-Baden	5	3	7	8	8	10	7,2	
		71	Lahr	10	9	6	9	8	5	7,2	
		34	Müllheim	10	9	7	8	8	5	7,4	
		21	Katzenbergtunnel	0	3	7	7	5	10	5,6	
14	Würzburg-Nürnberg-Passau	94	Markt Bibart	5	5	4	5	10	7	5,5	6,0
		100	Neumarkt/Opf	5	9	5	7	10	5	5,6	
		138	Straubing	10	9	4	7	10	5	6,5	
15	Nürnberg-Ingolstadt-München	87	Allersberg	5	3	0	0	0	10	3,9	4,8
		51	Petershausen	10	10	3	4	7	7	6,4	
16	München-Rosenheim-Österreich	37	Grafing	10	9	4	6	9	5	6,4	4,7
		81	Prien	5	9	2	3	8	3	3,9	
		30	Kiefersfelden	5	9	3	6	10	4	4,7	

The line 1 (Rostock – Berlin) was only a test to see, whether the analysis is working well. It is a line with only a few freight trains, so it gets only 2 points.

Winner line for Northern Germany is the number 2 (Hamburg – Hannover). This results primarily from the speed difference and the high number of freight trains. In second place is the line 3 (Bremen – Hannover), another port hinterland railway line. The line number 7 (Hannover – Würzburg) is the following section of the hinterland connection, but it gets only 4.1 points. This results in the low speed difference and the free capacity. The parallel high-speed line allows the separation of fast and slow traffic and thus the line is not interesting for this study.

The line 13 (Karlsruhe – Basel) takes first place for Southern Germany. This results primarily from the high number of freight trains and the bottleneck character. The speed difference is only a problem for some shorter sections of this line. In second place is the line 14 (Würzburg – Passau) which gets points for a bigger speed difference over longer sections. The line 9 (East Rhine Railway) takes the third place, but it is not interesting for this study due to a very low speed difference.

The line Hamburg – Hannover is already modelled and can be used with less effort. As the main line for investigating faster freight trains we chose the line **Karlsruhe – Basel** in the current state.

7.7 Collection of line, track and timetable data

The first step of modelling the new line in RailSys is the creation of the infrastructure. For this purpose, we use different sources apparent in Table 7.6**.**

Table 7.6: Data sources for modelling the infrastructure

Source	Data
Wikipedia article about the line	Station sequence with kilometrication of the cross sections
OpenStreetMap	Track layout Speed limits
DB Infrastructure Register	Line properties Track layout
Video captures of cab rides or photos	Position of the cross section Signal positions

The rolling stock data is primarily derived from previous project, in which high-speed trains, various regional trains and different freight train types are defined with all necessary data, e.g. mass, length, tractive force, train resistance, braking force.

The sources shown in Table 7.7 are used to create the base scenario timetable.

Table 7.7: Data sources for creating the base scenario timetable

Source	Data
DB Passenger Timetable (Course Book)	Long-distance and regional passenger train times
UBA Study	Number of Freight Trains
Different sources	Share of freight train types

7.8 Further process

In addition to the modelling of the line the simulation scenarios have to be defined. Every scenario has varying values for the share of faster freight trains, the maximum speed and the acceleration and braking capability.

8 Conclusions and future work T 3.4 – 3.7

This work package – Real time network management and simulation of increasing speed for freight trains - will deliver a demonstrator showcasing the effects of:

1. Improved traffic management through better interaction between network and yard/terminal

2. Increased freight speed and its effects on overall increased capacity, punctuality and reduced travel time for both passenger and freight trains.

The main contents of this deliverable are:

- The scope for real time network management and how WP3 connects to:
    - other projects in IP5 especially ARCC project (2016 09 – 2018 11) and
    - WP4 intelligent video gate which gives input to scenarios and demonstration in WP3.

- First outline of three innovation scenarios:
    1. Tactical data driven timetable planning,
    2. Operative traffic control adjustment for single trains, and
    3. Tactical planning analyse and models yard and network
- A brief description of a multimodal freight data-exchange platform
- A FR8Hub demonstrator applied Malmö-Hallsberg in Sweden, a description of functionality and first mock-up
- Fast freight rail system characteristics and description of fast freight rail systems and the status of the system (concept, in operation or discontinued).
- Analysis of railway lines in Germany for evaluation of faster freight traffic. The main line to investigate is Karlsruhe – Basel, also the line Hamburg – Hannover is expected to be used.

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