D2.2 - Approach and specification of system integration and demonstration

Grant Agreement N°: FP7 - SCP0 – GA – 2011 - 265647

Project Acronym: **ON-TIME**

Project Title: **O**ptimal **N**etworks for **T**rain Integration **M**anagement across **E**urope

Funding scheme: Collaborative Project

Project start: 1 November 2011

Project duration: 3 Years

Work package no.: WP2

Deliverable no.: ONT-WP02-DEL-002

Status/date of document: Final, 29/01/2013 (revised 27/06/2013)

Due date of document: 31/10/2012

Actual submission date: 29/01/2013 (revised 27/06/2013)

Lead contractor for this document: Trafikverket

Project website: www.ontime-project.eu

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
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CO	Confidential, only for members of the consortium (including the Commission Services)	

Revision control / involved partners

Following table gives an overview on elaboration and processed changes of the document:

Revision	Date	Name / Company short name	Changes
1	19/09/12	Trafikverket	Draft for discussion
2	08/11/12	Trafikverket	Draft content
3	25/11/12	Trafikverket	Draft content
4	21/1/13	UoB, Trafikverket, Network Rail	Production of final draft
5	25/1/13	All, see below	Revision final draft
6	29/1/13	Trafikverket	Revision final draft
7	27/6/13	UoB	Amendments following EC review

Following project partners have been involved in the elaboration of this document:

Partner No.	Company short name	Involved experts
	TV	Magnus Wahlborg
	UoB	Clive Roberts, Lei Chen
	TUD	Thomas Albrecht
	IFSTTAR	Joaquin Rodriguez
	TUDelft	Rob Goverde
	DB	Roland Kauffman, Sebastian Fey
	UoU	Bengt Sandblad
	NR	Meena Dasigi
	RFI	Vito Achille Sante
	SNCF	Matthieu Prunac
	EUR	Dennis Huisman
	VAL	Bruno Ambrogio

Executive Summary

The key objective of D2.2 is to provide context and guidance to WP7 and WP8.

Deliverable D2.2 also provides an update on current activities in WP3 to WP 6 and considers Task 2.4: How to implement developed methods into practice (Level 2), led by TV.

In Chapters 4 and 5 the locations and demonstrations are described briefly.

The locations and demonstrations are:

1. High capacity, mixed traffic lines (represented by the East Coast Main Line in the UK);
2. Cross-border traffic (represented by the Swedish Iron Ore line);
3. Management of large complex nodes (represented by Gonesse in France);
4. Allocation of resources in significantly disturbed traffic scenarios (represented by Utrecht/Arnhem/Eindhofen in the Netherlands);
5. Incorporation of improved traffic management techniques in real-world scenarios (represented by Bologna in Italy).

In Chapter 6 the IT architecture and software platform are described.

Chapter 7 outlines the evaluation process and aspects about the integration of systems with regard to organisation and context.

Chapter 8 gives a brief overview of quantitative evaluation and its purpose in the ON-TIME project.

The next steps are:

- To proceed with research, develop methods and prototyping in WP3 – WP6;
- To develop processes and architecture in WP7;
- To perform demonstration in WP8;
- To prepare and carry out evaluation in WP2 and WP1.

Table of contents

1 INTRODUCTION

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2 DELIVERABLE M6 – PROJECT GUIDANCE

2.1 Deliverables M6 – SYNTHESIS

In Deliverables D1.1, D1.2 and D2.1 the project work was specified by recommendations in WP3 to WP6.

Work Packages 3, 4, 5, 6 and 7 cover the following areas of research:

- WP3: Development of robust and resilient timetables;
- WP4: Methods for real-time traffic management (perturbations);
- WP5: Operation management of large scale disruptions;
- WP6: Driver advisory systems, and;
- WP7: Process and information architecture.

Table 1 shows Technology Readiness Level (TRL) mapping of the state of the art technological developments related mainly to Work Packages 3 to 6 of the ON-TIME project. It should be noted that the TRL of specific technologies are different in terms of different system specifications, e.g. one mature system technology on TRL 9 may only be a component in a large system, so that the TRL falls to level 5.

Work Package	TRL	Comments
WP3	3	❖ Existing tools for railway planning and timetabling mainly act as a computer aid system without decision support and optimisation functions. ❖ Lack of unified understanding of capacity definitions. ❖ Lack of consistent and integrated processes to support the different levels of planning (and associated modeling). ❖ Lack of commonly accessible data standards /interfaces/ (tool chains). ❖ No unified criteria for timetabling assessment and evaluation. ❖ Currently, timetable construction and simulation requires significant a priori knowledge. ❖ Freight timetabling so far from time to market.
WP4	3	❖ Generally quite simple algorithms with single objective optimisation have been implemented. ❖ Issues in terms of processing power with complex approaches. ❖ Significant research has been carried out in this area but little implementation. ❖ No unified standard and interfaces in system specifications for railway traffic control.
WP5	3	❖ Generally quite simple algorithms with single objective optimisation have been implemented. ❖ Lack of consistent and integrated processes to support the different levels of operational management (and associated modeling). ❖ Lack of commonly accessible data standards /interfaces (tool chains). ❖ Little standardisation or consistency between railway operational management systems. ❖ No integration processes between railway traffic control and operational management. ❖ Lack of integration processes between railway traffic control and operational management. ❖ Lack of European standard due to different National procedures
WP6	5	❖ Lots of systems implemented with different objectives and approaches at different application levels. ❖ Little standardisation or consistency between systems. ❖ Technological components have been validated in a railway environment. ❖ No system with fully close control loop for integration of railway traffic control, operational management and DAS.

Table 1 TRL mapping of technological developments

The summarised innovations proposed in the ON-TIME project are listed in Table 2. It shows the existing TRLs of innovations, together with the step change improvement that will be brought about through research and development undertaken in the ON-TIME project.

Innovation	Current TRL	Planned TRL after ON-TIME
Innovation 1: Standardised definitions and methods	**2**	**7**
Innovation 2: Improved methods for timetable construction	**3**	**6**
Innovation 3: Algorithms to either automatically provide control, or provide decision support to controllers	**3**	**7**
Innovation 4: Methods, processes and algorithms that are able to provide decision support when events occur that require the disposition of assets and resources	**2**	**6**
Innovation 5: Interoperable approaches for the communication and presentation of information	**3**	**6**
Innovation 6: An information architecture to support the communication of standardised and contextualised train control data	**2**	**7**

Table 2 Table showing the current TRL levels and the planned step changes

2.2 Deliverables M6 – CONCLUSIONS

A set of prioritised capability requirements has been created to guide the work of WPs 3, 4, 5, 6 and 7. The requirements are shown in Table 3, related to the relevant work packages and the innovation topics involved.

IDEF0 diagrams have been developed to show in a formal way the functional flow of the timetable planning and traffic control processes. These are shown in Deliverable D2.1, Figures 4 to 31 inclusive. High level system diagrams have also been produced to show the interfaces between infrastructure managers and railway undertakings throughout the timetable and traffic control processes. These are shown in Deliverable D2.1, Figures 1 to 3 inclusive.

Table 3: A prioritised list of capability requirements related to work package and innovation topic

Table 13 Requirement Number	Requirement Priority Number	Requirements	Work Package	Innovation Topic
1.6	1	The system shall be capable of integrating its subsystems	7	5
1.2	2	The system shall be capable of objective allocation of capacity in accordance with the relevant standards	3	3,4
3.5	3	The system shall be capable of integrating all communications relating to train service disruption	4,5,6,7	5
4.10	4	The system shall be capable of real-time management of traffic	4,6	3,4

Table 13 Requirement Number	Requirement Priority Number	Requirements	Work Package	Innovation Topic
1.5	5	The system shall be capable of identifying timetable conflicts	3,4,5	2
2.10	6	The system shall be capable of creating timetables to meet specified performance levels	3	2
2.11	7	The system shall be capable of simulating timetable operation	3	2
3.1	8	The system shall be capable of optimising train recovery plans in accordance with the relevant standards	4,5,6	4
3.7	9	The system shall be capable of supporting integration of NR and RU controller actions	4,5,7	5,6
3.11	10	The system shall be capable of supporting real-time decision-making	4,5,7	3,4
4.6	11	The system shall be capable of communicating safely with drivers while they are on duty	6	5
1.4	12	The system shall be capable of verifying timetable de-	3	2

Table 13 Requirement Number	Requirement Priority Number	Requirements	Work Package	Innovation Topic
		sign		
2.13	13	The system shall be capable of rapid production of timetables and associated rolling stock and crew rosters	3,5	1,2
1.1	14	Timetable sub-systems shall be capable of transferring data between one another	7	6
1.7	15	The system shall be capable of reconfiguration in response to network changes	7	1
2.12	16	The system shall be capable of optimising use of timetable margins	3	2
3.3	17	The system shall be capable of optimising platforming of trains during perturbed operation	4,5,6	3,4
4.1	18	The system shall be capable of integrating rolling stock and train-crew rostering during service disruption	4,5,6	3,4

3 ON-TIME RESEARCH M6 – M12

3.1 WP3

In Task 3.1 a state-of-the-art assessment of timetabling is being prepared. EPFL has carried out interview sessions with infrastructure managers from the seven countries involved in the ON-TIME project. UdB has contributed a literature review on robust timetabling based on the ARRIVAL project and some recent papers provided by TU Delft. TU Dresden has contributed a part on energy efficient timetabling. The concept report will be available for review and feedback by all partners on January 31, 2013.

In Task 3.2 TU Delft and TU Dresden have started working on accurate and fast running time calculation models that will be used in all work packages to have consistent running time and speed profile computations in all of the following areas: capacity analysis, timetabling, traffic management and train advisory systems. The models are based on detailed train dynamics using traction-speed and resistance-speed functions and microscopic railway infrastructure layout descriptions, including static speed profiles and gradients. The running time computations in HERMES will have to be checked with the developed models for validity of the demonstrations.

In Task 3.3 UoU has started investigations in Sweden as a basis for producing a description of today’s systems, processes, problems and requirements concerning integration of traffic planning and operational management. Methods for ad-hoc planning of freight trainpaths should be considered.

In Task 3.4 a functional design report for timetable models is being prepared by UdB, TU Delft and TU Dresden. A draft report will be available for review and feedback by all partaners at the end of Februray, 2013.

In Task 3.5 an inventory of the timetabling models and algorithms of the participants in WP3 showed that three timetabling models and algorithms are available which have complementary scopes. It was therefore decided to combine the different approaches to develop an integrated robust timetabling model, satisfying the aim of ON-TIME. This model will be based on an extension of a macroscopic robust timetabling model from UdB, with input from microscopic blocking time models from TU Delft and stochastic/energy-efficient driving models from TU Dresden. The algorithm development in Task 3.4.2 (UdB) had been moved to Task 3.5.

In Task 3.6 the testing and system integration of the timetable tool developed in Task 3.5 will be carried out. The timetabling tool will be based on infrastructure (RailML) data from HERMES to enable a standardised input to our timetable models independent from the various data formats from the IM’s of the various countries. This data format must be agreed with WP7.

3.2 WP4

The state-of-the-art was analysed and a draft was issued.

Based on the recommendations of D2.1, a description of the functional requirements in Deliverable D4.1 was started and a draft was issued. The general structure of the optimisation problem and the decomposition of modules are described in the draft. Sequence diagrams for the interaction of modules were developed. The interaction between traffic state monitoring, track conflict resolution, connection conflict resolution and train path envelope computation was specified and serves as base for WP7 architecture development.

Basic human factor considerations were made. They are set out in a separate annex to the state-of-the-art document. The core concept of “control by awareness” shall be applied to WP4. The traffic controllers' need for information is now being analysed.

A proposal has been made for the description of the real-time traffic plan (routing and timing part for each train/ track element). This proposal has been discussed with WP7 and WP3. A first design draft has also been made for the train path envelope which will be the interface with WP6 on Driver Advisory Systems.

The applicability of the objective function developed in D1.2 was analysed. The results of the analysis showed that the objective function cannot be directly incorporated in some of the algorithms, either because the algorithm depends on a certain type of objective function or because the model behind the algorithm is simplified. Different alternatives are now being considered.

A first version of the microscopic train traffic simulator HERMES was provided for testing, which offers a first simplified Application Programming Interface (API) for testing. Requirements for input and output data are now being refined in collaboration with WP7.

The functional requirements description D4.1 will be finished early in 2013. At the same time, algorithm prototypes are integrated in the simulator environment in order to gain experiences upon which the interface definitions can be refined.

3.3 WP5

WP5 focuses on traffic changes and resource management strategies to deal with large scale disruptions. The objectives are:

- To evaluate the state-of-the-art in optimisation algorithm strategies and stakeholder processes and information flow for managing large scale disruptions;
- To specify the integration of the real-time traffic and asset management procedures, optimisation models and tools;
- To develop algorithms for resource management in the case of a large disruption;
- To design and validate effective intelligent decision support strategies and tools for the optimal human supervisory control of the recovery processes in case of a large disruption.

Task 5.1 is an evaluation of state-of-the-art in optimisation and recovery algorithms. The report, which is almost finished, considers microscopic approaches, macroscopic approaches, manual approaches and integrated approaches.

In Task 5.2 a questionnaire on best practice for managing large disruptions of traffic was sent to IMs. The results have been collected and synthesised.

For Subtask 5.3.1, which focuses on the requirements for HMI and operator strategy, an analysis of the incident log has been carried out. A set of representative incidents and a list of ten key constructs were then defined with experts from GB, France, Sweden and Italy. These sets will be used as the pool of elements in a repertory grid study with signallers and controllers. Furthermore, the application of the Critical Decision Method (CDM) is planned. CDM is a retrospective interview strategy.

Subtask 5.3.2 will define functional and technical specifications. A preliminary structure for the deliverable has been proposed to partners.

The objective of Task 5.4 is the development of algorithms for real-time asset management. A set of assumptions has been agreed and the work has been broken down into four modules: 1/ change timetable at microscopic level; 2/ change timetable at macroscopic level; 3/ change rolling stock; 4/ change crew. A project plan to develop these modules has been proposed.

Task 5.5 focuses on procedures and graphical user interfaces. Experience and tools used at the control center of the Iron Ore line have been presented to partners and will form the starting material for this task.

The objective of Task 5.6 is to perform benchmarks and validation of the strategies and optimisation algorithms. Two scenario locations have been selected. The first is a single line of the Iron Ore line in Sweden and the second is the Netherlands network Utrecht/Arnhem/Eindhoven. Work to input the data in the Hermes simulator has started. The next steps will be to perform scenarios.

3.4 WP6

WP6 focuses on generating driving advice, based on the current traffic situation “WP4” and automatically communicating this advice to the driver.

DAS state-of-the-art and relevant approaches were analysed in Task 6.1; a draft report has been issued. Different DAS technology mixes and possible driver integrations are described and evaluated.

In principle, there are three possibilities for a DAS-system (distribution of algorithmic intelligence):

- The central DAS-component connected to the TMS generates driving advice that is displayed on-board.
- The central DAS-component connected to the TMS sends target points of the timetable/traffic plan to the on-board DAS-component. The actual driving advice is thereby entirely calculated on-board.

- The central DAS-component connected to the TMS matches real-time traffic plan data to the interface format and the on-board DAS-component calculates driving advice according to the interface data and using on-board data of the vehicle.

As the next step in Task 6.2 the required DAS-system-design, including module functionalities as well as the data flow, will be described. The interface specified in this task shall be able to support each of the three above mentioned approaches, the demonstration may however be done for only one of these concepts only.

In Task 6.3 the on-board algorithms will be developed. TUD have presented current work on running time computation and train path envelope computation to the partners.

In Task 6.4 UoN have started work analysing the HMI state-of-the-art, as well as human factors relevant to DAS. Furthermore, UoN are analysing in which operational situations DAS is most useful for the driver (workload study) and are evaluating concepts with drivers (presenting different types of speed advice to the driver).

4 DEMONSTRATION LOCATIONS AND TRAFFIC

4.1 Introduction to demonstration locations

In order to demonstrate the results of the ON-TIME project a number of demonstration locations have been selected. The locations cover a number of different railway administrations across Europe, and represent specific challenges facing railway operations, namely:

- High capacity, mixed traffic lines (represented by the East Coast Main Line in the UK);
- Cross-border traffic (represented by the Swedish Iron Ore line);
- Management of large complex nodes (represented by Gonesse in France);
- Allocation of resources in significantly disturbed traffic scenarios (represented by Utrecht in the Netherlands);
- Incorporation of improved traffic management techniques in real-world scenarios (represented by Bologna in Italy).

The demonstration locations correspond directly with the challenges set by the European Commission in the project call.

In the following subchapters the relevant factors of each location are introduced. More information about the locations is given in: Annex 1a – 1 e Locations for evaluation and demonstration.

4.2 East Coast Main Line

The East Coast Main Line scenario will consider the southern section of the route. This section consists of just over 75 miles from London King's Cross station to Peterborough.

Figure 1: East Coast Main line

It comprises four tracks for most of its length, but widens to six tracks between Alexandra Palace and Finsbury Park, narrows to two tracks over the Welwyn Viaduct and through two tunnels north of Welwyn North station, and again narrows to three and then two tracks between Huntingdon and Fletton Junction. It is electrified (with 25 kV OHL) along its whole length. It intersects with a number of other routes at a number of locations, most notably with the North London Line at Copenhagen Junction and Harringay Junction, the Moorgate branch at Finsbury Park South Junction, the Hertford loop at Wood Green Junction and Langley Junction, and the Hitchin – Cambridge line at the Hitchin Cambridge Junction.

The route carries First Capital Connect (FCC) suburban services from King's Cross and Moorgate to various destinations in Hertfordshire, Bedfordshire, Cambridgeshire and Norfolk, and long distance high speed services operated by East Coast, Hull Trains and Grand Central from King's Cross to Scotland, the North East and Yorkshire. There are also some freight services.

In terms of passenger numbers, the most significant stations are King's Cross, Finsbury Park, Stevenage, Peterborough, Hitchin and Welwyn Garden City.

In each direction, during the busiest part of the day, there are currently 8 long distance high speed trains and 25 suburban trains per hour on the route. Of the suburban trains, more than half are into King's Cross.

Signalling is using track circuit blocks at present; ERTMS is due to be installed on the route in 2019.

The route model is available in RailSys and the Hermes model has been constructed and is currently being validated.

4.3 Iron ore line

The Iron Ore line and Ofoten line runs between Luleå – Narvik. The Iron Ore line (Malmbanan) runs from Luleå – Boden – Kiruna – Riksgränsen (border) and the Ofoten line (Ofotenbanan) Riksgränsen – Narvik. The Iron Ore line is 433 km long and the Ofoten line is 42 km (total length 475 km). It is a single track line. The specific area of interest to the ON-TIME project is the section from Svappavaara/Kiruna – Narvik.

A traffic control center in Boden controls Luleå – Kiruna – Riksgränsen and a traffic control center in Narvik (Norway) controls Narvik – Riksgränsen. Simulation models are already available in RailSys (Luleå – Kiruna – Narvik).

Timetable planning is carried out in Trainplan. Annual timetable planning is done by Trafikverket in co-operation with Jernbaneverket. Ad-hoc timetable planning Narvik – (Riksgränsen) is done by Jernbaneverket; Riksgränsen – Kiruna – Luleå is done by Trafikverket.

On the line there is mixed traffic with high traffic heterogeneity. The capacity conflicts are single track conflicts with meetings between trains and some passing between fast passenger trains and slow iron ore trains. The length of a crossing station is between 500 m and 750 m. The iron ore trains are 750 m.

Iron ore trains have in many aspects the highest priority. The second priority are long distance freight trains and passenger trains. The iron ore trains operate over 24 hours. There are several railway undertakings. LKAB Malmtrafik AB run 7800 ton iron ore trains Kiruna - Narvik which are 750 m and run at 60 km/h (loaded) or 70 km/h (empty). Green Cargo AB (Northland), run 3500 ton iron ore trains from Svappavaara – Kiruna – Narvik. CargoNet and Green Cargo run 100 km/h container trains, 1000 ton or 1800 ton, 520 m and/or 600 m between Oslo and Narvik. There are local passenger trains at Narvik, which run at 160 km/h and a couple of long distance passenger trains running at 160 km/h.

The infrastructure is saturated for both the 2012 and 2013 timetables. There is high demand for iron ore traffic. LKAB transported 28 billion tons in 2012 and plan to transport 40 billion tons in 2015 and 45 billion tons per annum by 2020. Northland will transport 5–7 billion tons by 2020. Trafikverket forecasts that Kiruna – Narvik will increase from 32 trains/day (6 passenger and 26 freight) in 2011 to 49 trains/day (6 passenger and 43 freight) in 2015 and 61 trains/day (6 passenger and 55 freight) by 2020.

Current innovations are Steg and Cato. The Steg decision support system is installed and used in Boden to help dispatchers from Luleå – Boden – Kiruna – Riksgränsen. Steg uses empirical data; this enables historical scenarios to be analysed. Some brief analysis has been done. The traffic control system is Ansaldo (Argus). The Cato system is installed in the iron ore trains. Cato saves empirical data about train driving. This enables historical train driving data to be analysed. Some analysis has already been done.

4.4 Gonesse

Gonesse is a 18 km node which consists of three routes merging. The routes are the high speed line in blue, the classic line in purple and the freight line in green, see Figure 1.

There is an Open Track model available for the Gonesse node.

TGV and Intercity trains are run by SNCF; freight trains are run by SNCF and other RUs, such as ECR or Colas Rail.

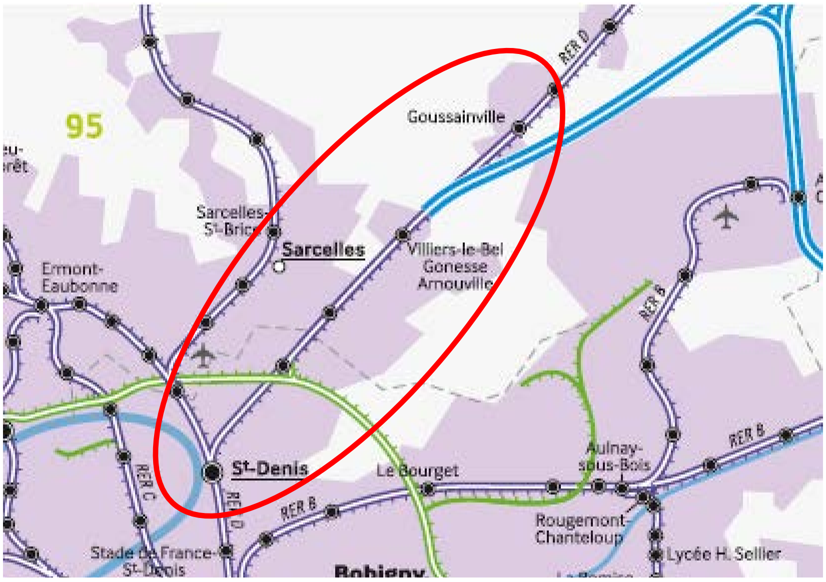

Figure 2: The Gonesse node and surrounding network

The track layout of the Gonesse node is described in Figure 2. The layout is double track and a section with three tracks.

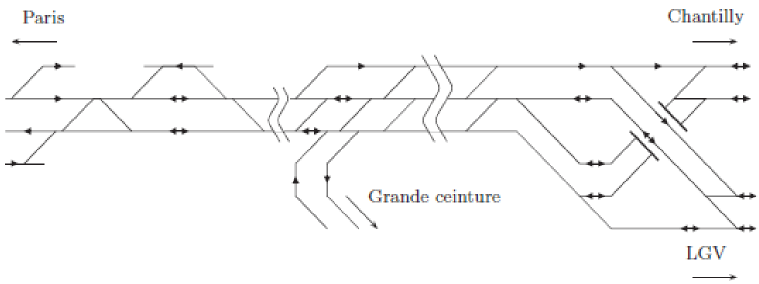

Figure 3: Track layout, Gonesse node

The traffic control centre in Paris Gare du Nord station controls the node. The annual timetable is produced by RFF and DCF Direction de la Circulation Ferroviaire.

The route has mixed traffic with TGVs, intercity trains and freight trains. Freight trains are up to 750 m and 1500 tonnes; the speed limit is 80 km/h. The intercity train speed limit is 140 km/h and the TGV train speed limit is 300 km/h.

4.5 Bologna

The Bologna node consists of routes merging together in Bologna. The length is 100 km. The routes come from Firenze, Ancona, Venezia, Verona, Milano and Pistoia.

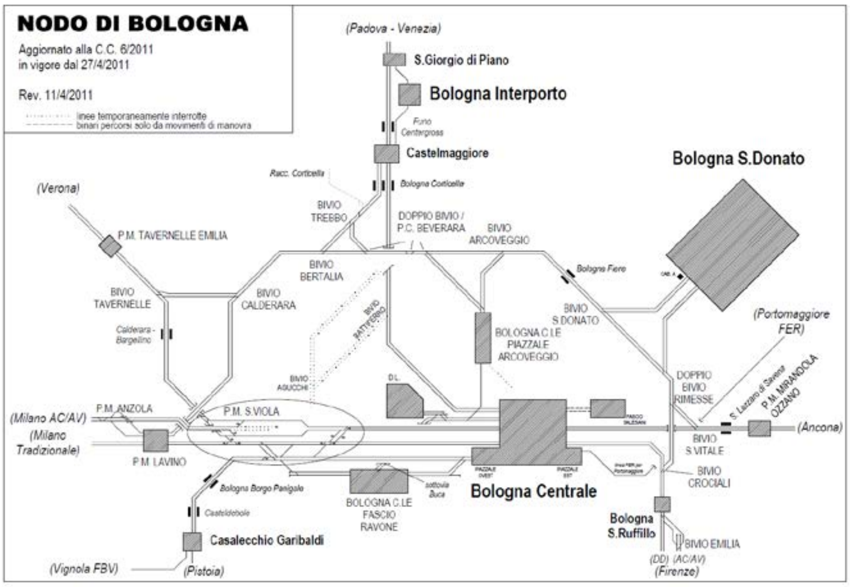

Figure 4: The Bologna node

The traffic management system stores traffic information and is an Ansaldo system. The traffic control centre in Bologna Centrale controls the node. Annual and ad hoc timetable planning is done by RFI.

The node has traffic of more than 800 trains per day. There is a mixture of high speed, long distance and regional passenger trains and freight trains. The major railway undertakers are: Trenitalia (TI) Passenger, TI Regional, Nuovo Trasporto Veloce (NTV), TI Cargo and TRENORD.

A current project is to renovate the main station (Bologna Centrale) with 2 levels to separate high speed passenger traffic from other traffic.

4.6 Utrecht / Arnhem / Eindhoven network

The Utrecht Network has mostly double track lines. A small part has 4 tracks and some branches are single-track. The routes are Utrecht-Den Bosch: 48 km, Den Bosch-Eindhoven: 32 km, Utrecht-Arnhem: 56 km, Arnhem-Nijmegen: 19 km, Nijmegen-Den Bosch: 43 km, Den Bosch-Tilburg: 22 km, Tilburg-Eindhoven: 37 km.

Figure 5: The Utrecht / Arnhem / Eindhoven network

Infrastructure data is available in RailML. Timetable, rolling stock and crew data are available for all domestic trains of NS.

Traffic control centres are located in: Utrecht, Arnhem and Eindhoven. The timetable is produced using DONNA.

Traffic consists of intercity and local passenger trains with high frequency, and some high speed trains and freight trains.

The dominant railway undertaker is Netherlands Railways. Other railway undertakers are cargo operators and NS HiSpeed/DB for the international trains to/from Germany.

There are plans to increase the passenger frequency to every 10 minutes. Candidates are the lines from Utrecht-Eindhoven and Utrecht-Arnhem.

5 DEMONSTRATION SCENARIOS

5.1 Introduction and general operation process

Research is ongoing in WP3 on timetabling, WP4 on real time operations, WP6 on driving advisory systems and WP5 on large event handling. In Figure 5 the interactions between work packages are described.

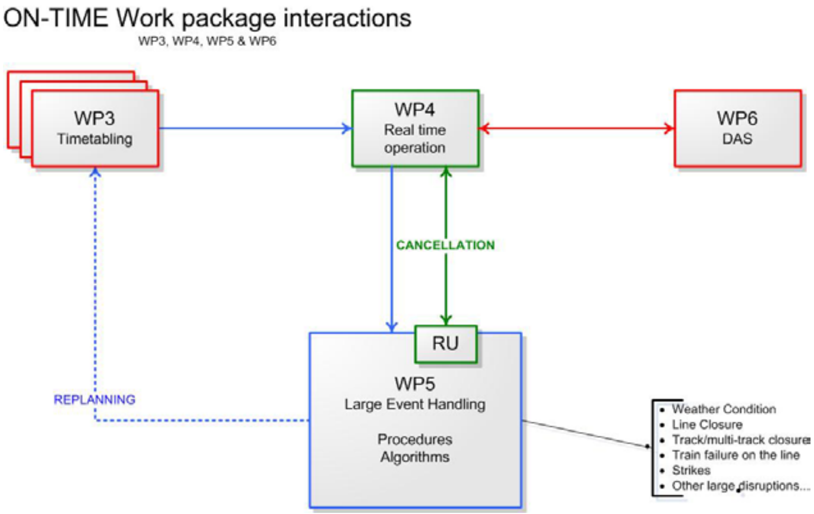

Figure 6: Work package interactions

Railway operation is multidimensional in time and involves integration in operation and planning.

WP3 is mainly concerned with procedures and algorithms for the annual timetable process and ad-hoc timetable process producing a multi-layer solution for short term requests.

WP4 covers procedures and algorithms for normal traffic operation with small disturbances. WP4 starts from the timetable today and is the master plan for the real-time timetable. For WP4, the innovation is to develop automatic decision support with human intervention and/or human interaction. In WP4 the decisions are taken by the infrastructure manager.

WP5 covers procedures and algorithms for traffic operation with big disturbances. The need for WP5 is triggered by WP4. In WP5 the problem to be solved needs decisions from both the infrastructure manager and the railway undertaker. Examples of actions are cancellation of trains, rerouting of trains and new resource plans for rolling stock and train crew.

WP6 is concerned with decision and information support to drivers. Algorithms are developed to optimise both train driving by helping drivers to stay inside the given boundaries developed in WP 4. Thus the total process of traffic control and train driving is optimized.

5.2 Models and data

To support the development of demonstration scenarios, a number of simulation models are already in place. The intention within the project is to convert the simulation models to operate with the HERMES simulation. Work has already been undertaken to convert existing RailSys models to HERMES; similarly the existing models for the Swedish Iron Ore line and Gonesse node will be converted. Work will also be carried out to incorporate the Bologna node and Utrecht area.

Existing models:

- Hermes
    - ECML, UK

- Railsys
    - ECML, UK
    - Iron Ore line, Sweden (Luleå – Kiruna – Narvik section). Empirical information is also available in the Steg and Cato systems
    - Gonesse, France

- Open track
    - Gonesse, France

- Ansaldo historic traffic movement recording
    - Bologna, Italy

- Network data in RailML
    - Utrecht, Netherlands

5.3 Demonstration scenarios and locations

Table 7 show the different demonstration locations (columns) together with the different demonstration scenarios (rows) that will be considered throughout the ON-TIME project. The infrastructure managers and operators represented in the project will support these demonstration scenarios through the supply of data and expertise to ensure that realistic and complete scenarios are developed. These demonstration scenarios will be the focus of each of the technical work packages (WP3 to WP6).

These are the types of events that can be demonstrated at the demonstrations selected for demonstration.

	East Coast Main Line, UK	Iron Ore Line, Sweden/Norway	Gonesse Small Node, France	Bologna Node, Italy	Utrecht/Arnhem/Eindhofen Network, Netherlands
Current timetable	A study of normal running and usage of the allowances and where they are.				
Progressive delay	For example, the impact of a 10 minute delay during 'crowded' peak times and non-peak times. Variation of cost function parameters can be studied - capacity for peak and energy for off peak.	Impact of decision support in capacity for peak and energy for off peak. Normal delay distribution.	Unusual speed profiles due to people working on the tracks or poor driving.	For example, the impact of a 10 minute delay during 'crowded' peak times and non-peak times.	Impact of a delayed Intercity Utrecht-Den Bosch. Should connecting trains wait or not?
Non-progressive delay	Late dispatch of one or more trains. This will be from different locations. Ie terminus or other.	Late dispatch of a high value long distance freight train with high value of arrival time Narvik (before midnight).	Impact of a 10 minutes previous delay.	Late dispatch of one or more trains. This will be from different locations.	
Crew not available	Not available but replaced or not available and resulting in a cancellation, for example, at Kings Cross, a train comes in but has no driver to take it out. It will block a platform so impacts incoming trains too.	The iron ore trainsets have very tight circulations. A delay result in disturbances for other trains and if the disturbances are too big cancellation of an iron ore train. Decision support when to cancel an iron ore train?			
Failure of train	Train blocks fast line.	A some broken wagons blocks a track at a doubletrack meeting station.	Faillure of a freight train while crossing a high speed line.	One track closed on a double line track.	

	East Coast Main Line, UK	Iron Ore Line, Sweden/Norway	Gonesse Small Node, France	Bologna Node, Italy	Utrecht/Arnhem/Eindhofen Network, Netherlands
All tracks closed	Overhead lines down. 'Contingency' plan implemetation / development. Current option is to use existing static plans and the advantage of real-time planning is of interest.	Overhead lines down or broken rail. Contingency plan is used. This means a number of installed iron ore trains. The long distance freight trains will end/start in Kiruna instead of Narvik. Bustransports for passengers Kiruna - Narvik or part of the distance Kiruna - Narvik.	Fatality case. In terms of lost minutes, fatalities have a large impact in this area (between 2,000 and 9,000 lost minutes per each case in 2012).		1. Accident with person near Rosmalen in the morning peak. Consequence no train traffic possible for 3 hours between Den Bosch and Oss w. Passengers from Den Bosch to Nijmegen w. can use the bus or travel via Utrecht and Arnhem. 2. Signalling problems near Culemborg. Consequence no train traffic possible for 2 hours between Utrecht and Geldermalsen. Passengers and/or trains from North to South w (Utrecht – Den Bosch – Eindhoven) can travel over Arnhem.

	East Coast Main Line, UK	Iron Ore Line, Sweden/Norway	Gonesse Small Node, France	Bologna Node, Italy	Utrecht/Arnhem/Eindhofen Network, Netherlands
One line of multi-track section closed	One scenario discussed for NR's Traffic Management system was what happens when one track of a 4-track section gets closed and the event progeresses with two adjacent tracks also closing to allow maintenanace. Very interesting as this brings several features together.		Fatality case. In terms of lost minutes, fatalities have a large impact in this area (between 2,000 and 9,000 lost minutes per each case in 2012).	One track of a 2 track section is closed or one section (double tracks) in the node is closed and the trains go throught other compatible tracks of the node.	
Multiple events close together or simultaneously	Normal operations and then event after event small, medium and maybe large all happenning close together - Again an example of this has been used to test TM systems.	To study multiple events in real traffic situation with Steg. To analyse the need of decision support for dispatching and for train driverguiding. To quantify the effect of better decision support.	This case could be a good way to switch from WP4 to WP5 solutions		

Table 7: Demonstration locations and scenarios

6 SYSTEM ARCHITECTURE AND SOFTWARE PLATFORM

6.1 SYSTEM INTEGRATION ARCHITECTURE

Generally, the replacement of railway traffic management and control systems for infrastructure managers involves decision making for vital systems with a life cycle of around 30 years. It could bring about huge losses if a full and effective system testing and verification process was not undertaken before system implementation, and it was found that that the new system could not handle existing and further potential railway disruption scenarios. The core elements in railway traffic management systems are the algorithms used for generating train and traffic control decisions. These algorithms are regarded to be the main challenge for system validation and verification (V&V).

Advanced algorithm development and V&V are defined as the main tasks of the ON-TIME project. These algorithms are expected to be applied for timetable optimisation, real time traffic management, operational management and energy saving driving advisory. Throughout the ON-TIME project, a systematic algorithm validation and verification platform needs to be developed with standardised open interfaces with the simulator HERMES and real traffic control systems, as shown in Figure 6, which gives a high level vision of the algorithm development and V&V in the ON-TIME project.

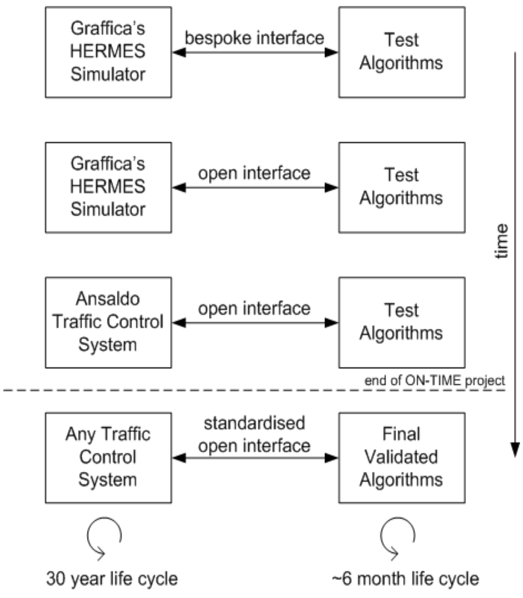

Figure 8: High level vision over time

In terms of the high level vision, the system integration mainly refers to the integration and testing of the algorithms developed in the ON-TIME project. Figure 7 shows the functional view for system integration of ON-TIME outputs. For the purpose of algorithm V&V, the HERMES simulator and real traffic management systems which replace the simulators for practical railway applications need to provide algorithms with required static and dynamic infrastructure and operational data. The algorithms are developed to generate optimised timetables, real time traffic and train control decisions, etc, and these are returned to the simulator for implementation.

The open interfaces for algorithms connecting to HERMES should realise the exchange of static data (railway infrastructure data, rolling stock configuration data, signalling deployment, nominal timetables, etc) and dynamic data (real time train position/speed data, traffic management decisions, etc).

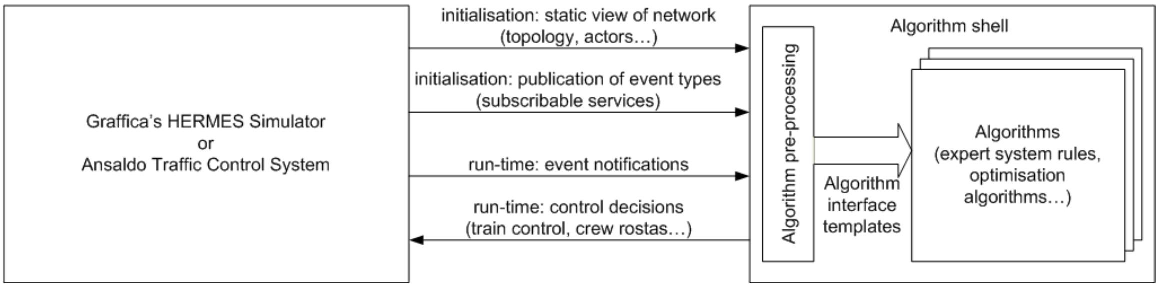

Figure 9: Functional view of system integration

The architecture of system integration is shown in Figure 8. The communication and interaction between the algorithms and the HERMES simulator is via the exchange of static data and dynamic data. Static data includes the database of railway infrastructure data, rolling stock configuration data, signalling deployment, nominal timetables, etc; these are the basic data required by railway systems. As trains are moving on railway networks, a large amount of dynamic data is also required by train and traffic management and control systems for real time decision making.

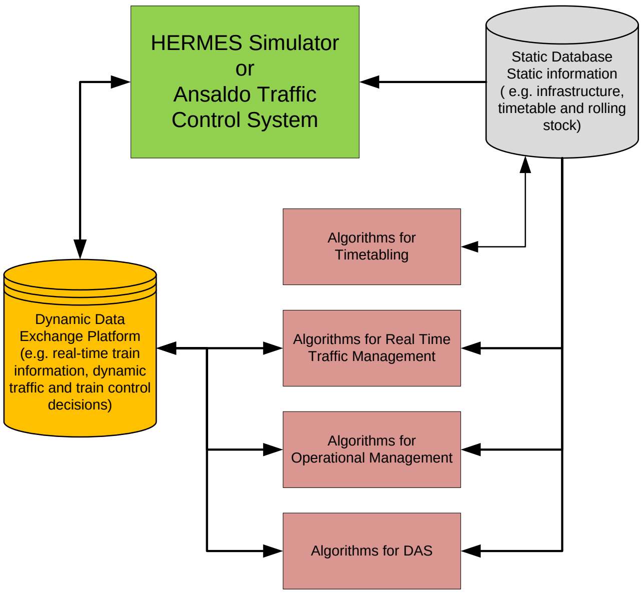

Figure 10: Architecture of system integration

6.2 PRINCIPLES

The static database can be modelled with RailML for infrastructure, rolling stocks, timetables and other common data.

The volume of static data is generally relatively big and static data are not changed frequently, therefore they need to be downloaded as a one-off, e.g. during the initialisation of the algorithm programs. If there is any change to the static data, a notice of data re-downloading needs to be broadcast to every system.

Dynamic data changes in real time; dynamic data exchange can use event-driven or periodic data communication protocols.

Dynamic data is expected to be modelled in appropriate manner that reduces information overhead. They include the real time train movement data (real time position/speed/traction), infrastructure status data (colours of signals, dynamic position of points, routes set, etc) and traffic and train control decisions. All the dynamic data have timestamps to indicate the data generation time which can be used by systems to check the time validity of the data.

Algorithms for timetabling should also be integrated into the system demonstration. Optimised timetables need to be stored in the static database and used by the simulator and algorithms.

Data communications between systems in the architecture can be achieved by using a combination of Web Services on top of HTTP/HTTPS, for on-demand data requests, and Message-Queue oriented protocols, such as AMQP, for real-time continuous flow of messages.

The developed algorithms and interfaces in the system integration architecture need to be independent from simulators and real traffic management systems. This will allow a transparent way to switch between different TMSs, simulated or not. Consistent interfaces between the algorithms and the architecture will allow the use of different implementations of the same functional modules.

Simulation scenarios need to be managed by HERMES. Short delays, long delays and other typical incidents can be simulated to test the developed algorithms. As for different levels of incidents, different algorithms will be applied to generate decisions, and the decision implementation is managed and controlled by HERMES.

Within simulation scenarios, the objective functions used in all the algorithm programs must not have any conflict with each other. Conflicting objective functions will bring conflicting decisions for train and traffic control systems.

7 IMPLEMENTATION AND INTEGRATION

This section will present some general requirements concerning implementation, deployment, usability, evaluation and integration of systems with regard to organisation and context.

7.1 From research to implemented system

Experience shows that there is a long way from research via prototypes to implemented and deployed systems that contribute to improved operations and services in an organisation in practice. We will here identify some important success factors and common pitfalls.

One fact that must not be underestimated is that important knowledge generated, as well as formal specifications, with their rationales, must be kept intact during all phases of the development and implementation. During the research phase, a lot of knowledge concerning present organisation and systems, problems, needs, expectations and requirements is usually generated. Some parts of this can be formally documented in a structured way, e.g. systems/problem analysis and process models, but much of the information that is relevant for future phases is in the form of knowledge, understanding and new competencies of involved persons in different roles. It has been shown that it is not possible to formally specify requirements in such a way that the expected system is developed and implemented.

A problem that is often encountered is that what is finally delivered to the users differs significantly from what was originally specified and from what the users actually need. One reason for this is that the knowledge needed for complete requirements is not available from the beginning but is generated during the different project phases. It is only when the final prototype is evaluated that the final requirements can be fully specified. Another reason is that important requirements, e.g. concerning details in functionality and usability, cannot be formally specified in such a way that development can be based entirely on it. The competencies, knowledge and experiences of people involved are needed in addition to formal specifications.

Important conclusions are:

- Use iterative development models. It is only when prototypes that are possible to evaluate under realistic circumstances involving skilled professionals are produced that detailed requirements can be specified.
- Keep the research and project team and common understanding intact as much and as long as possible. The researchers and the skilled professionals from the organisation develop a deep understanding for what is important; this knowledge cannot be formally described, but it is important for successful development towards the specified goals.

7.1.1 Demonstrators

A demonstrator can be seen as a prototype, with certain well specified limitations, with the purpose of illustrating and confirming the possibilities for development of a future full scale application. When a demonstrator is developed, it is important to formally specify delimitations and restrictions made in requirement specifications and in the context of evaluation.

However, a demonstrator only has relevance if it can be shown and proven to be a potential candidate for later adjustments, adaptations and finally full deployment in a specific organisation. Therefore all aspects which are important for later use in real contexts should at least be included in demonstrator projects.

A demonstrator has its strength in the possibility to evaluate and support the specifications of the final system that will be implemented and deployed in a specific organisation.

7.2 Implementation and deployment

By *implementation* we mean the technical part of the introduction of a technical system into the organisation. Methodologies and models for this are well known and applicable. In practice several problems are often encountered, e.g. problems with technical infrastructure, networks, communication with other systems, database performance, etc. It is important to specify requirements for when an installed system shall be accepted as functional by the organisation. It is not a part of the ON-TIME project to discuss this in more detail.

By *deployment* we mean the introduction of the new technical system into an organisation. The organisation which the system is implemented in will not be the same as it was before, but the organisation will always, and should, be developed into something new that can profit from the potential advantages of the new technology. “Do not pave old cow paths”: this means that the organisation, including management, work processes, roles, competences, work environment, etc, must be developed following a specification and deployment plan. It is only when the organisation is changed, utilising the new technology, that the results will be increased efficiency, quality, safety or whatever the development objectives are.

When it comes to deployment, it is important to see the organisation as a social-technical system, where the technology is one component of several. The organisation, work processes, humans in different roles, their competencies, use of the technology, usability, work environment, communication patterns, etc, must also be considered.

This is important for several reasons. One is that the use of competencies in the organisation is often an important success factor. When the potential users of the system are engaged, this also has an effect on understanding, acceptance, efficient future use, etc. It is also important because, if the different aspects of the organisation are not changed in an appropriate way, the potential benefits will not be reached. People will keep on working according to old habits and rules, but with new tools that they cannot properly apply.

There are many methods available for including competencies in the organisation in the development process, i.e. user centred development models.

The actual deployment process must be seen as a rather long process, including what is being done prior to, during and after the start of the actual technical system. It is only through adjustments after the deployment, based on evaluation and user experiences, that the usability and efficiency is reached.

7.3 Usability and user centred models

It is convenient to use the ISO-9241 definition of usability as a basis for further discussion. Here, usability is defined as:

"The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use".

This definition is extremely practical and useful. It states that usability only can be seen in a specific context of use, for specified users and for a specific purpose. It also says that it can, and must, be evaluated with respect to effectiveness (that the planned tasks can be completed), efficiency (that this can be done using minimal resources) and satisfaction (subjective experiences, work environment, etc).

It is especially necessary to understand the importance of the organisational context. A system that works in one organisation might not work at all in another. If the organisational aspects are known and considered, this obstacle can sometimes easily be overcome by appropriate adaptations, education and training. The use of available competencies within the organisation is here important. “Listen to your users” is an often used expression. This should not be interpreted as only the direct end-users, but all competencies within the local organisation, including management. When it comes to detailed specifications of what the work processes in the new organisation will look like, the competencies of the involved users must be utilised. There exist very efficient models for this.

We will use user centred models in different phases of the project. Participatory design models as well as vision seminar groups and focus groups are examples. The evaluation procedures will also partially be performed with user involvement. There is not only one specific model that will be used, but appropriate models will be chosen depending on the context. For a comprehensive overview of user centred methods and models, see e.g. “Designing Interactive Systems: A Comprehensive Guide to HCI and Interaction Design”, David Benyon, Addison-Wesley, 2010.

7.3.1 User centred systems development (UCSD)

There are a number of different approaches and models available for user involvement in development and deployment processes. They sometimes have different labels, such as participatory design (PD), user centred systems development (UCSD), or user involvement. In each development and deployment project, a suitable model should be selected.

One important experience and lesson, that is similar in all different models, is that usability is built in from the very start of a development project. It can never be added afterwards or even at a late stage. The basis for developing usable, efficient computer and information systems is generated when the goals and the initial requirements are formulated. Usability must be regarded and evaluated continuously during all phases of the development project. The deployment phase must also be user centred.

7.4 Integration

7.4.1.1 Technical

Technical integration, with regard to platforms, network, integration with other technical subsystems etc, is important. This is, however, not an issue for discussion here, since there is another work package, WP7, that will deal with such matters.

7.4.1.2 Organisational

It is important to consider the organisational and contextual integration. The system to be deployed must be adjusted and complemented to fit the local requirements, needs and expectations. A suitable model must be used for this. Professional competencies from the organisation must be actively involved. Here, iterative development models must be used.

7.5 Implementation in real railway traffic experiences and aspects

The step from simulation system to implementation in real railway traffic is a big step for an operational system. Train traffic control systems have high requirements for safety and must be fail safe (robust). Driving advisory systems must also meet the operational needs and requirements of railway undertakings.

The infrastructure managers participating in the project have current projects to implement innovations in operational systems, see Deliverable 2.1.

Implementation and use of systems for timetable planning and timetable analysis are more about processes and co-ordination between organisations. Innovations are made by infrastructure managers in co-operation with railway undertakers.

The infrastructure managers participating in the project have current projects to implement innovations in annual timetable planning and ad-hoc timetable planning, see Deliverable 2.1.

8 EVALUATION

8.1 Qualitative evaluation

When a technical system is being implemented and deployed into an existing organisation, as discussed above, the evaluation process is important. This process must be carefully specified and planned from the start of a project. Some important qualitative aspects to consider, relevant to the ON-TIME project, are:

- Evaluations must be made successively during the development project, using iterative development and user centred models.
- Evaluations must reflect realistic situations. The difference between a simplified and a real test case can be great. Evaluation based on solving real problem situations using recorded scenarios can be a functional method.
- Evaluations involving human users must be based on realistic scenarios and must allow the professional users to be prepared for the evaluation procedures. This includes understanding of the objectives, time for learning and for training. The users must have been allowed to reach a realistic skilled level.

Furthermore, it is important that the project is evaluated against the objectives as set out in the project description of work:

Objective 1: Improved management of the flow of traffic through bottlenecks to minimise track occupancy times. This will be addressed through improved timetabling techniques and real-time traffic management.

Objective 2: To reduce overall delays through improved planning techniques that provide robust and resilient timetables capable of coping with normal statistical variations in operations and minor perturbations.

Objective 3: To reduce overall delays and thus service dependability through improved traffic management techniques that can recover operations following minor perturbations as well as major disturbances.

Objective 4: To improve the traffic flow throughout the entire system by providing effective, real-time information to traffic controllers and drivers, thus enhancing system performance.

Objective 5: To provide customers of passenger and freight services with reliable and accurate information that is updated as new traffic management decisions are taken, particularly in the event of disruptions.

Objective 6: To improve and move towards the standardisation of the information provided to drivers to allow improved real-time train management on international corridors and system interoperability; whilst also increasing the energy efficiency of railway operations.

Objective 7: To better understand, manage and optimise the dependencies between train paths by considering connections, turn-around, passenger transit, shunting, etc.

in order to allocate more appropriate recovery allowances, at the locations they are needed, during timetable generation.

Objective 8: To provide a means of updating and notifying actors of changes to the timetable in a manner and to timescales that allows them to use the information effectively.

Objective 9: To increase overall transport capacity by demonstrating the benefits of integrating planning and real-time operations, as detailed in Objectives 1-8.

These objectives need to be assessed both qualitatively and quantitatively.

8.2 Quantitative evaluation

Quantitative evaluation will be carried out in line with the cost function described in D1.2. It is envisaged that each work package from WP3 to WP6 will provide solutions which are optimised in line with specific objective functions that have been developed in their corresponding work package, however, the different solutions will be evaluated (and thus comparable) using the D1.2 cost function. As part of further work in WP2 a Matlab based tool will be developed by the University of Birmingham to allow different solutions to be compared quantitatively, using HERMES simulator file outputs.

9 SUMMARY AND NEXT STEPS

This deliverable describes the current status of the ON-TIME research project of in Chapter 3.

In Chapters 4 and 5 the locations of demonstrations are described.

In Chapter 6 the IT architecture and software platform are described.

Chapter 7 outlines the evaluation process and aspects about the integration of systems with regard to organisation and context.

Chapter 8 gives a brief overview of quantitative evaluation and its purpose in the ON-TIME project.

The next steps are:

- To proceed with research, develop methods and prototyping in WP3 – WP6;
- To develop processes and architecture in WP7;
- To perform demonstration in WP8;
- To prepare and carry out evaluation in WP2 and WP1.