C4R

Capacity for Rail

Simulation and models to support planning and management of railway traffic for improving capacity

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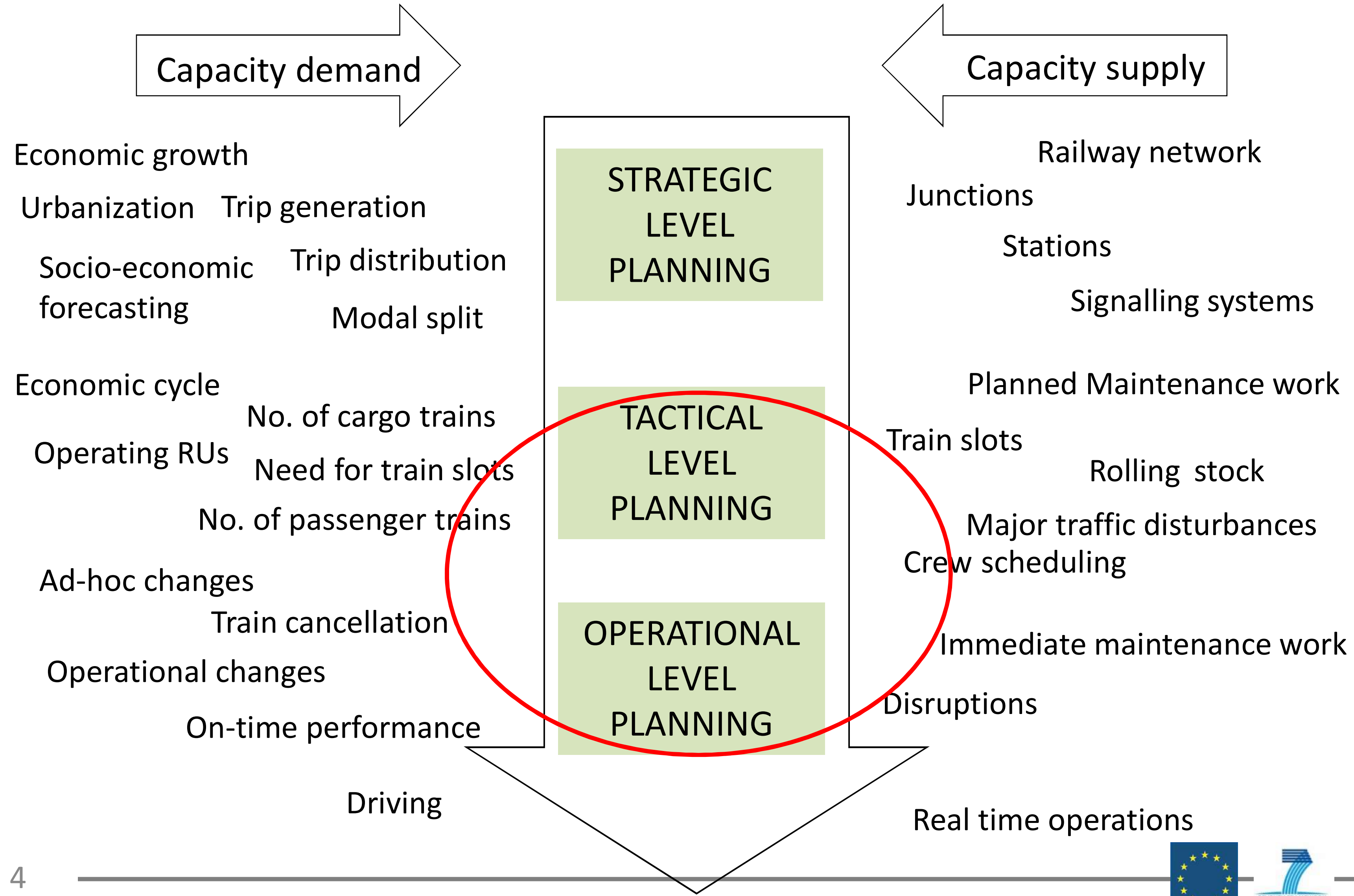
SEVENTH FRAMEWORK PROGRAMME

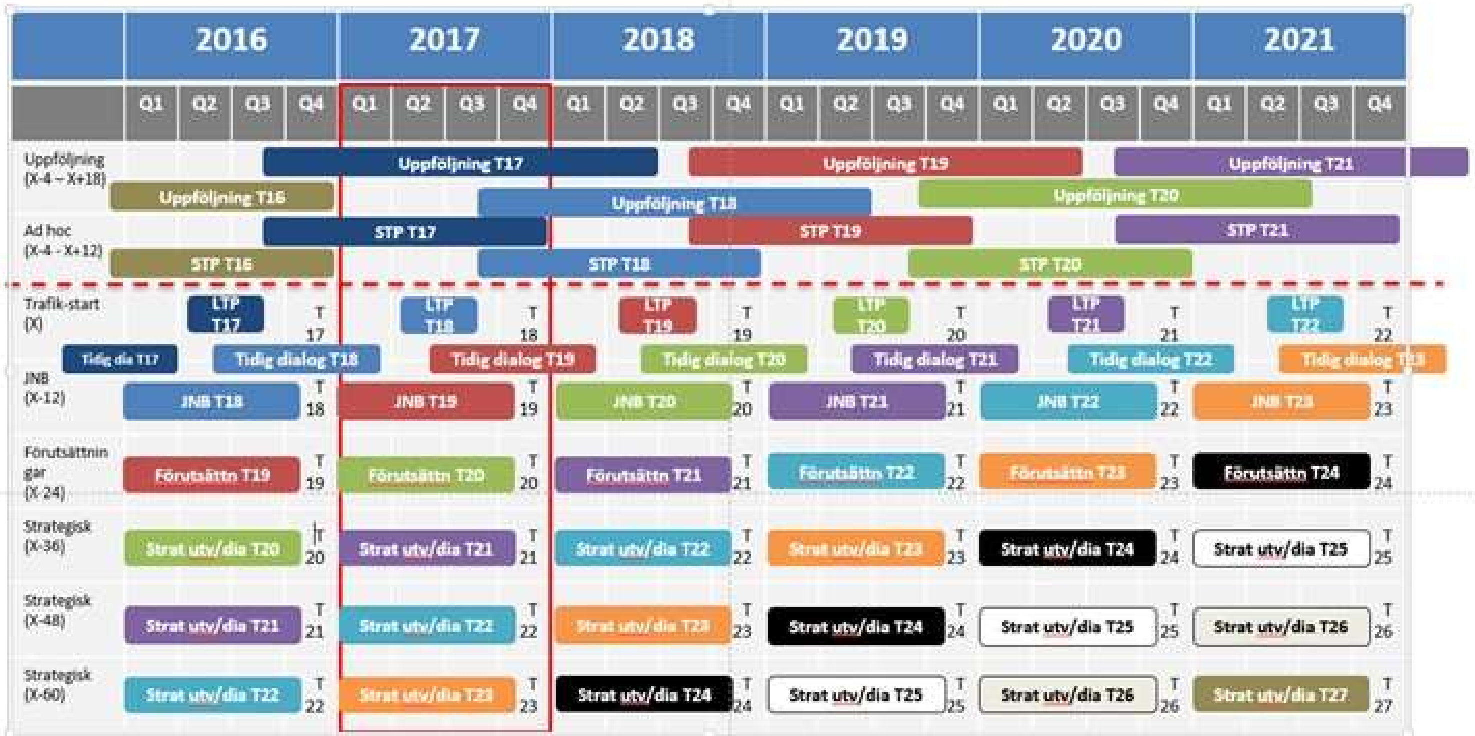
- Main challenges of traffic planning and management in today's railways (Scope)
- An integrated tool for railway traffic planning and management: the CAIN/LiU framework
- A real case study: The Malmö-Hallsberg corridor in Sweden
- Outcomes, recommendations, and conclusions on use of modelling tools for automated traffic planning and management.

Main challenges of traffic planning and management in today's railways (Scope)

Modelling railway capacity

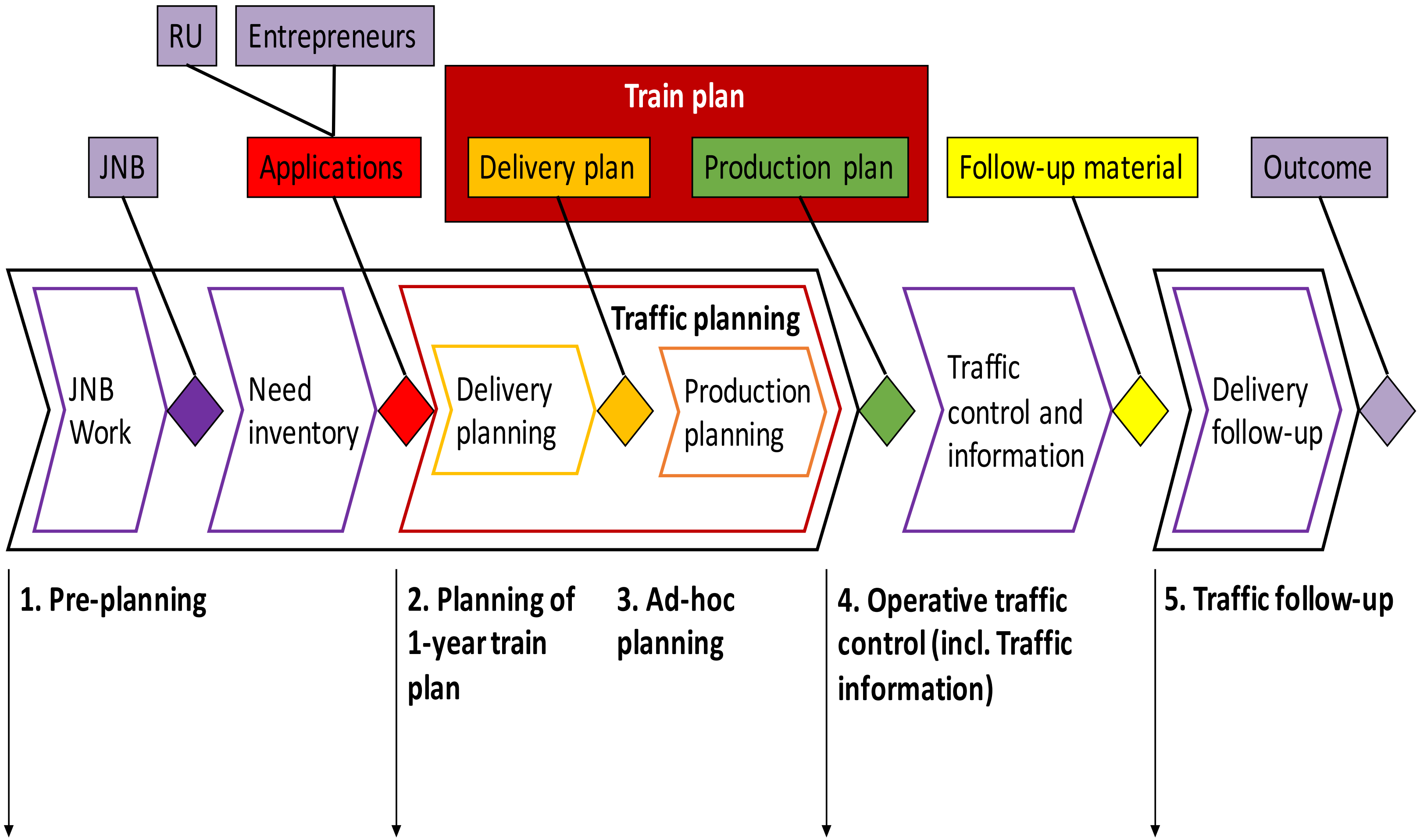


Capacity planning follow up – 5 years ahead



STP = Short term planning
LTP = Long term planning
JNB = Järnvägsnätsbeskrivning
Strat utv/dia = Strategisk utveckling och dialog

Capacity planning follow up – 1,5 years ahead



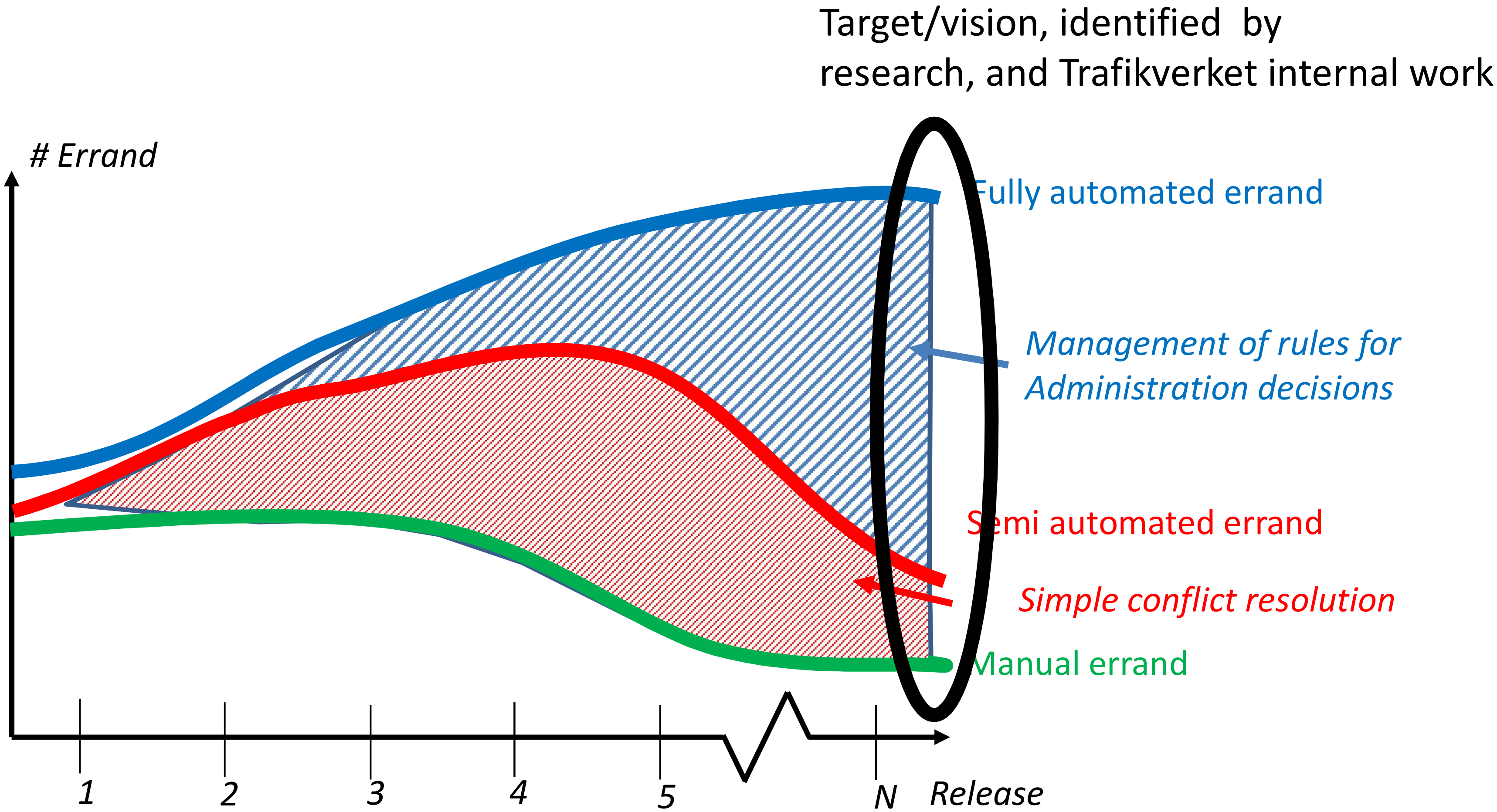
Increased automation of tactical planning and operational process

- Ongoing trend tactical timetable planning process and operational traffic process is merging

- The limit between planning and operational traffic is 3 days to 8 hours before traffic starts

- A third process is to carry out maintenance and monotoring (status of infrastructure and vehicles)

Development of automation in timetable planning process Trafikverket



WP 3.2 Simulations and models

- Main focus research GAP tactical planning and operational traffic (digitalisation)
- Purpose:

Improve methods in tactical (timetable) planning and operational traffic => better capacity and improved punctuality/robustness

- Main partners
  - Infrastructure manager Trafikverket
  - System supplier Oltis – Traffic management systems
  - Research institute Linköping U - optimisation

Project work

First part

- state-of-art, models and processes, research Gap, scenarios, set up a framework

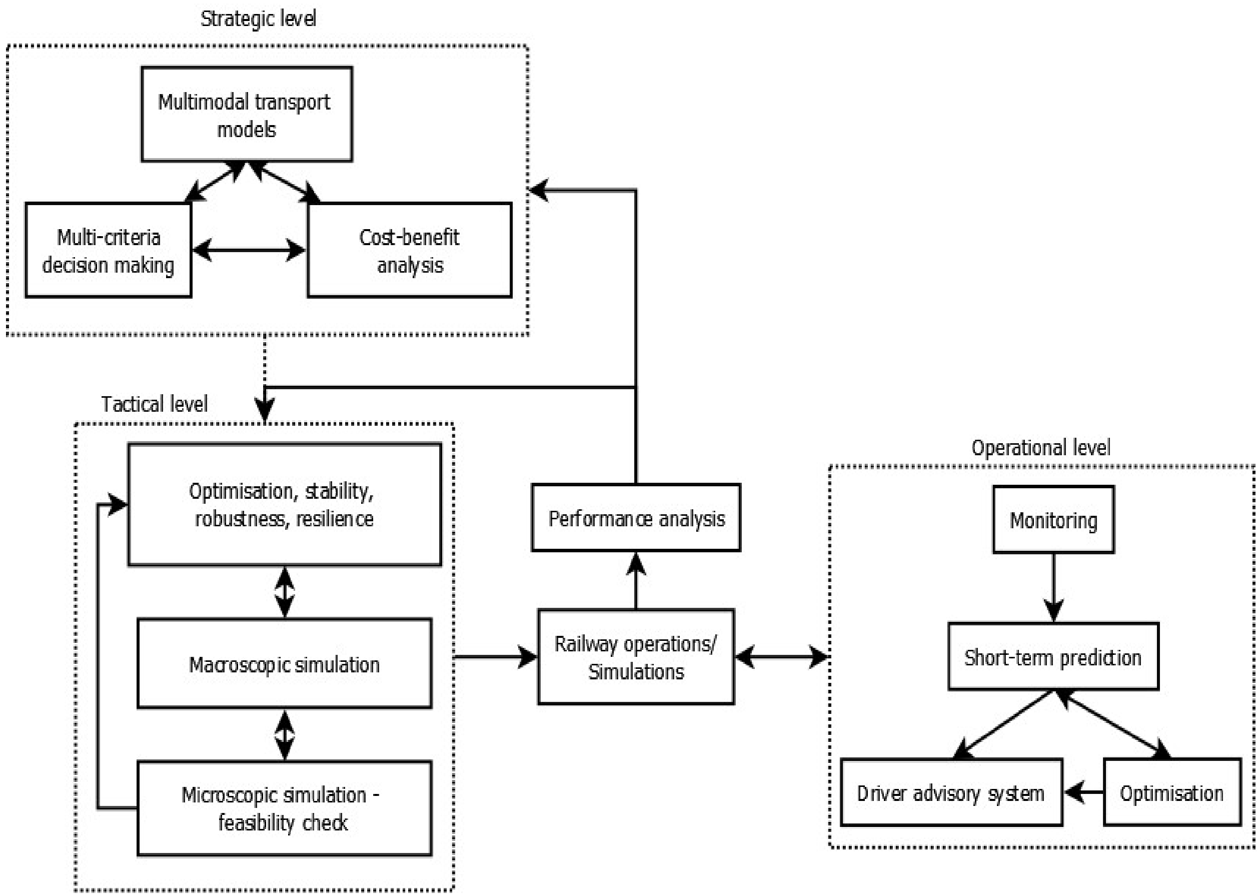
Second part

- Enhancing frameworks for modelling and simulation
- LiU model optimisation
- Oltis IT system
- Demonstrator CAIN – Hallsberg - Malmö

Third part demonstration/results – conclusions

- Strategic capacityplanning
- Demonstration Cain – LiU
- Simulation of robustness critical points

Capacity4Rail – framework modelling and simulation

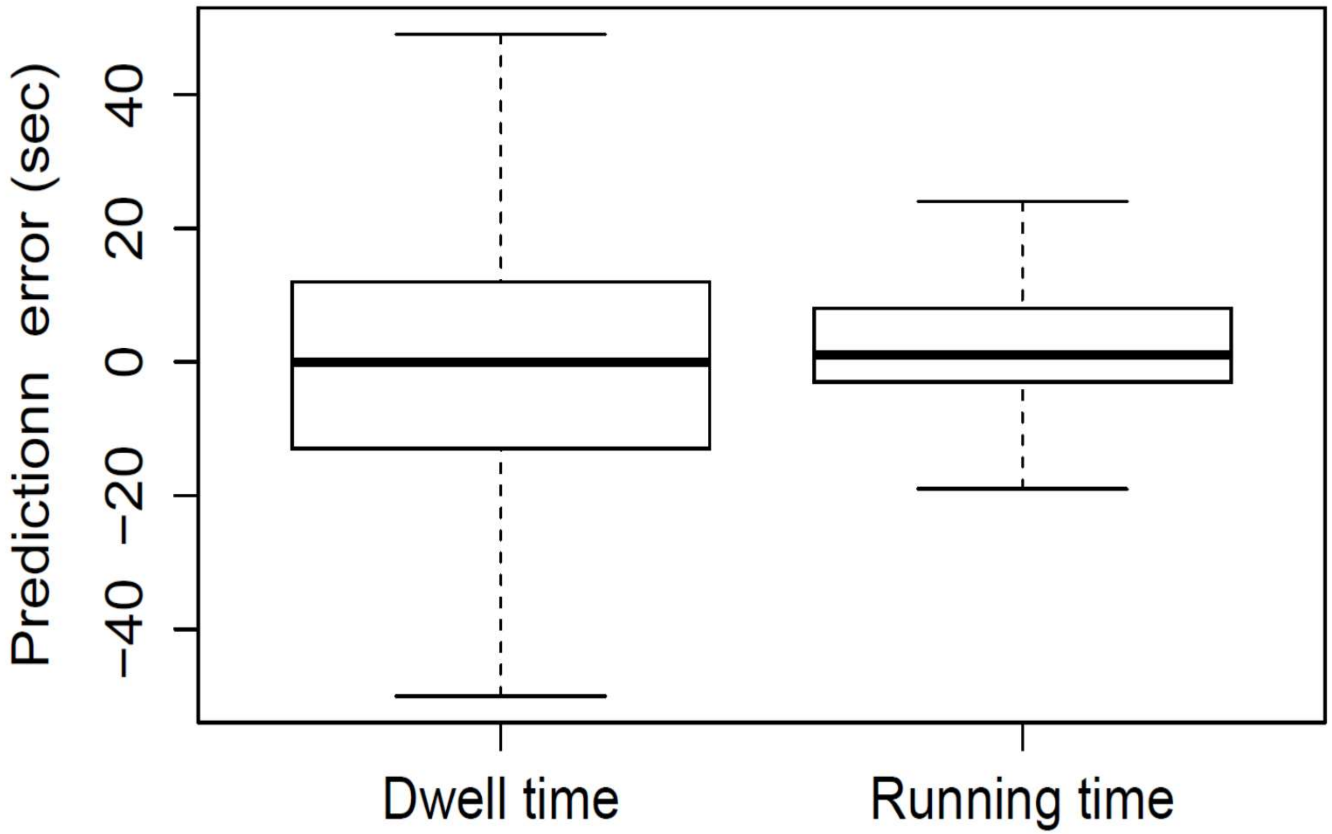


An integrated tool for railway traffic planning and management: the CAIN/LiU framework

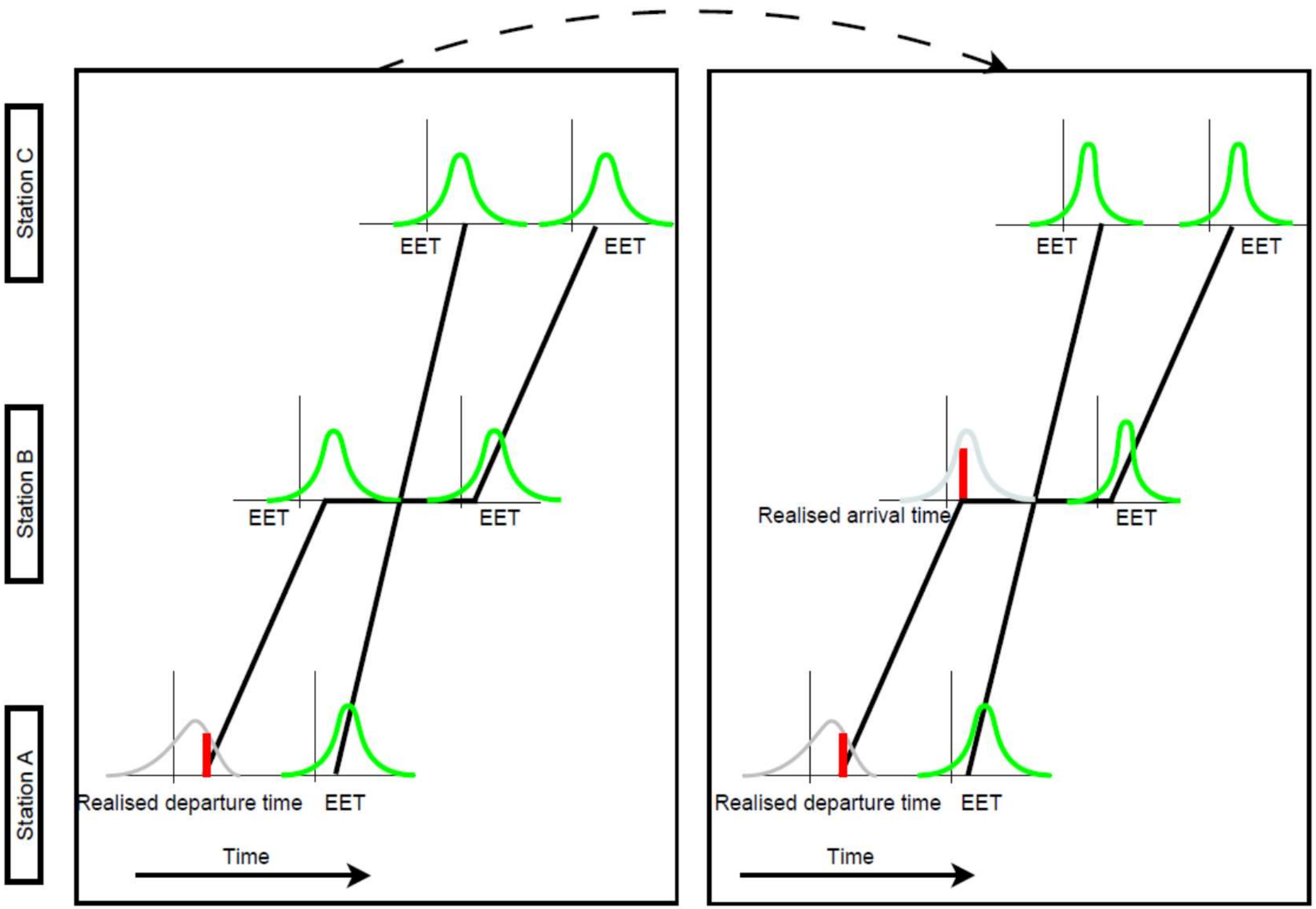
LiU model at a glance

- Stochastic railway traffic model
- Data-driven model of traffic based on Bayesian networks (BN)
- Data driven model of traffic control actions based on Naïve Bayes classifier (NBC)
- Online use – uses real time information for dynamics of uncertainty and predicts traffic over long horizons
- Offline use – timetable simulation resulting in analysis of stability, robustness and resilience

Input to the model: Statistical information

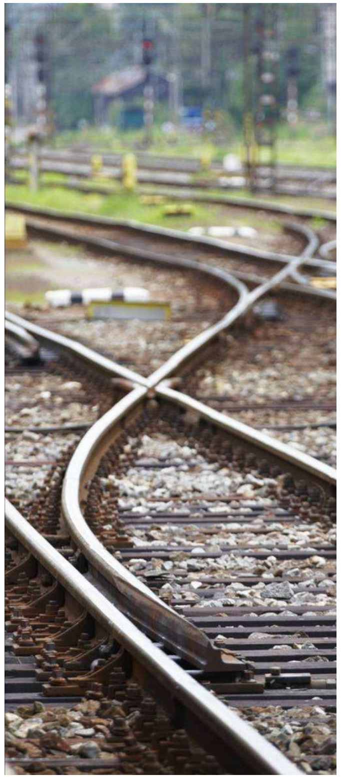


Improved traffic control prediction of uncertainties



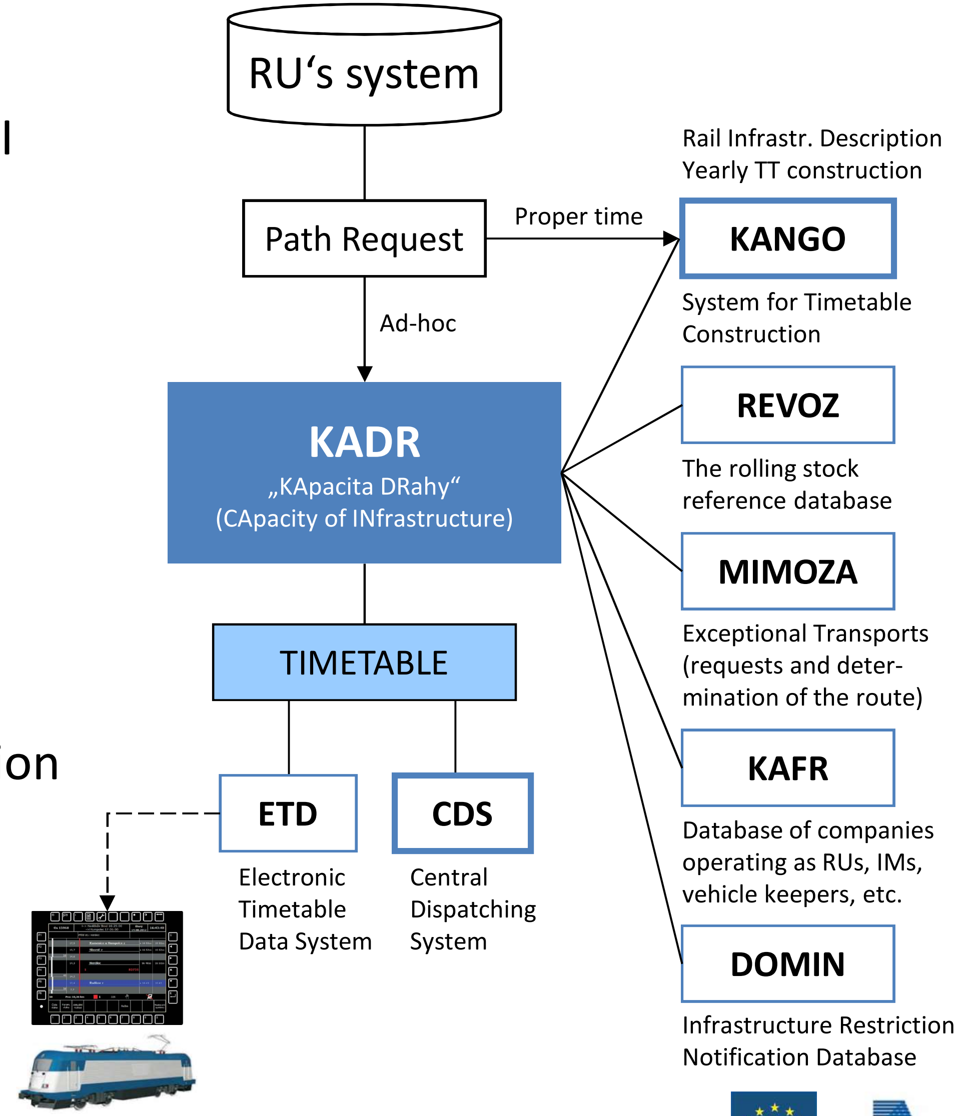
The CAIN - LiU:

Demonstrator



Scheme of Oltis KADR and systems

- Request for path and capacity
- Support of communication in TSI TAF/TAP (ver. 5.3)
  - Path Request
  - Path Details
  - Path Cancelled
  - Receipt Confirmation
  - Error
  - Update Link
  - Path Section Notification
- Common Interface communication
- Timetable optimization
- Changes in timetables

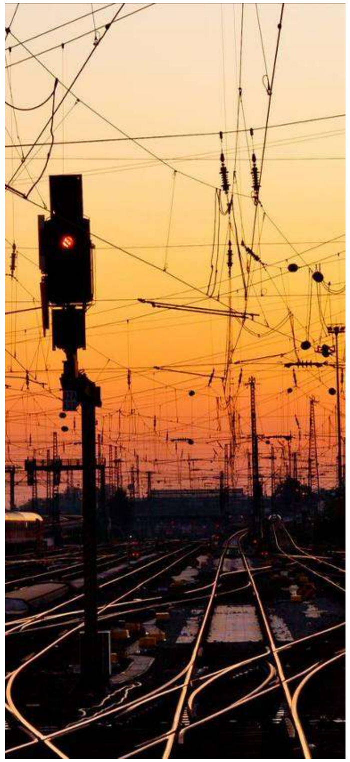


oltis group

*CAIN – **CA**pacity of the **IN**frastructure*

CAIN – Demonstrator

- IT tool developed by OLTIS Group
- Based on KADR (CZ & SK infra-managers)
- Real time software for:
    - input of ad-hoc train paths into the real timetable
    - optimisation of the timetable
    - simulation of different scenarios
- CAIN interacts with the model from Linköping University



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*CAIN – **CA**pacity of the **IN**frastructure*

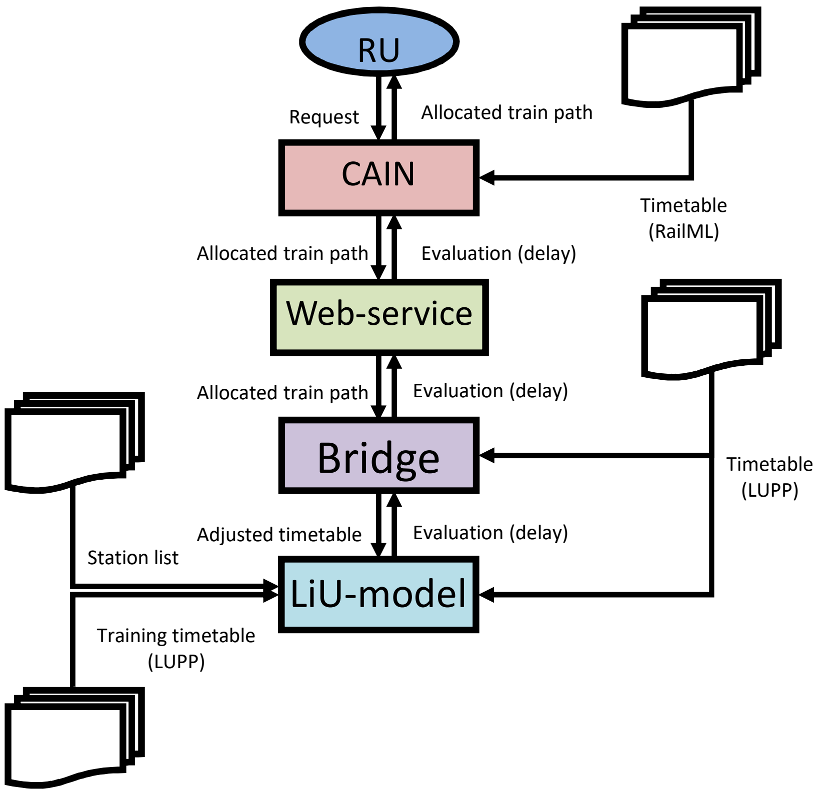
Capacity for Rail

CAIN – part I

- **Import** static data of Sweden:
  - **Railway infrastructure**
  - **Timetable**
  - **Vehicles**
- **Corridor Malmö – Hallsberg**
- Data in RailSys/railML format
- **Process** the data
- **Create** a virtual network
- **Display** the railway network

The LiU model – Interaction with CAIN

1. A request for an new train path sends to CAIN. (blue)
2. CAIN creates an allocated train path. (red)
3. An application (Bridge) fetches the allocated train path from CAIN via an Web-service. (green)
4. The bridge inserts the allocated train path into an adjusted timetable. (purple)
5. The LiU-model evaluates the adjusted timetable. (teal)
6. The Bridge sends the evaluation back to CAIN via the web-service



CAIN / LiU model:
Life demonstration

Marek Neustadt, OLTIS Group
Zuzana Fikejzl Velčovská, OLTIS Group

Results presentation – Summary 1

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CAIN – **Real time software** for:

- Input of ad-hoc train paths into the real timetable
- Optimisation of the timetable
- Simulation of different scenarios

The CAIN development has given us **new knowledge** about how to **implement** the IT system specified **from particular IM** (in 2 countries) **into different IM** in a European country (corridor Malmö – Hallsberg):

- Railway infrastructure / Timetable / Vehicles
- Process the data / Create a virtual network / Display the network

The data transfer has learned us about **specific parameters** of timetables used at **different IM**.

Data in RailSys/railML format:

- The CAIN demonstrator has learned us how to **transfer data** from **TAF/TSI** to Railsys and interact between **different data exchange standards**

Results presentation – Summary 2

CAIN – LiU

- New train path
- Predicting timetable robustness and punctuality in the network due to changes in the timetable
- Calculation of traffic impact

The CAIN – LiU model and interaction have given us new knowledge about **interaction** between **IM timetable system** and **optimisation** (data analysis) **model**.

Good example of knowledge and development about:

- Processes
- Information
- Communication

Automation of timetable planning to meet demand from customers.

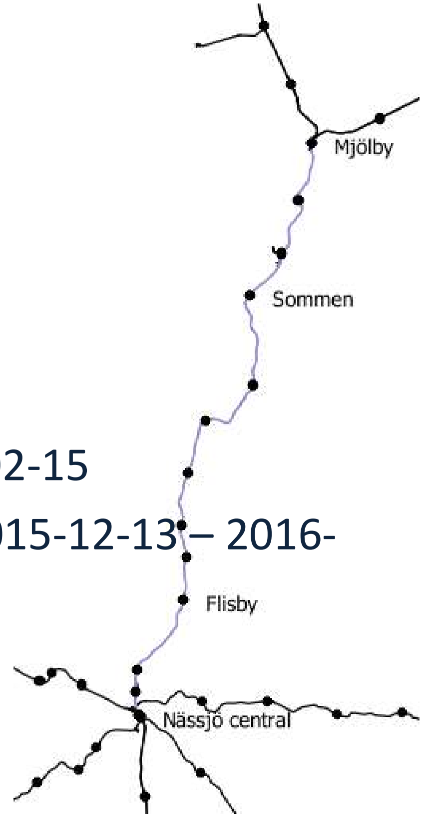
Numerical results - Specifications

Train path specification

- Type of train: Freight train
- Maximum speed: 90 Km/h
- Desired route: Mjölby – Nässjö
- Desired arrival time: 10:00

Simulation parameters

- Calibration dates for Bayesian network: 2016-02-11 – 2016-02-15
- Calibration dates for random deviation of departure time: 2015-12-13 – 2016-03-12
- Number of simulations: 200



Numerical results - Cases

Case 0 – Unchanged timetable

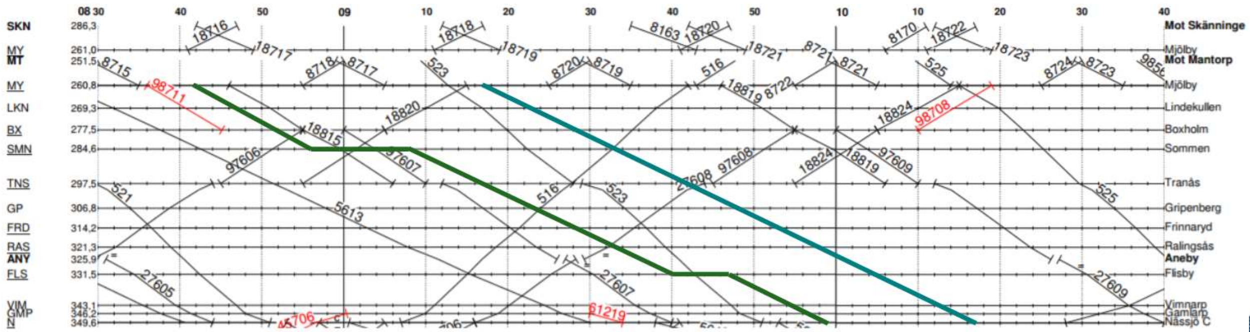
- Used as a benchmark for the different cases

Case 1 – Ad hoc train **(green)**

- Departing from Mjölby at 08:40
- Waits at Sommen and Flisby for passing passenger trains
- Arrives at Nässjö at 09:59

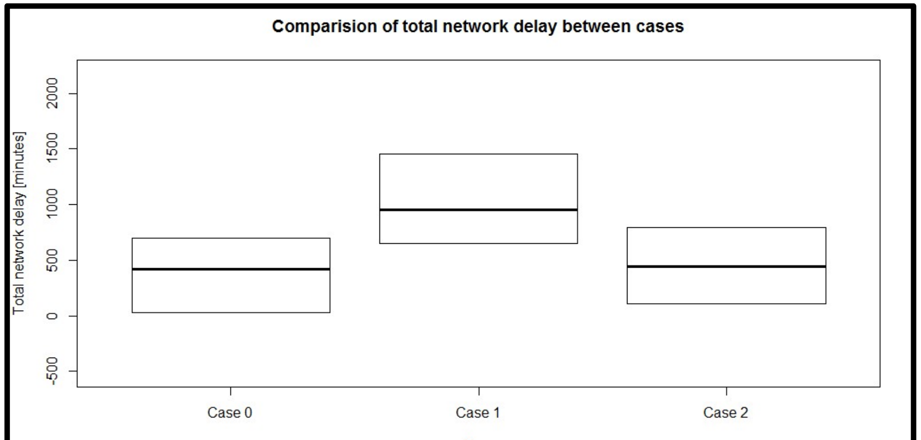
Case 2 – Ad hoc train alternative slot **(teal)**

- Departing from Mjölby at 09:17
- Arrives at Nässjö 10:17



Numerical results - Comparison

- Using the desired train path in case 1 more than double the estimated delay in the railroad network.
- Using the alternative train path in case 2 increases the estimated delay in the railroad network with 5 %.
- The best choice from a robust time schedule point of view is case 2.



Case	Arithmetic mean	Median	Difference to case 0
0	357.23	421.87	-
1	993.21	949.6	+ 125.09 %
2	429.7	444.14	+ 5.28 %

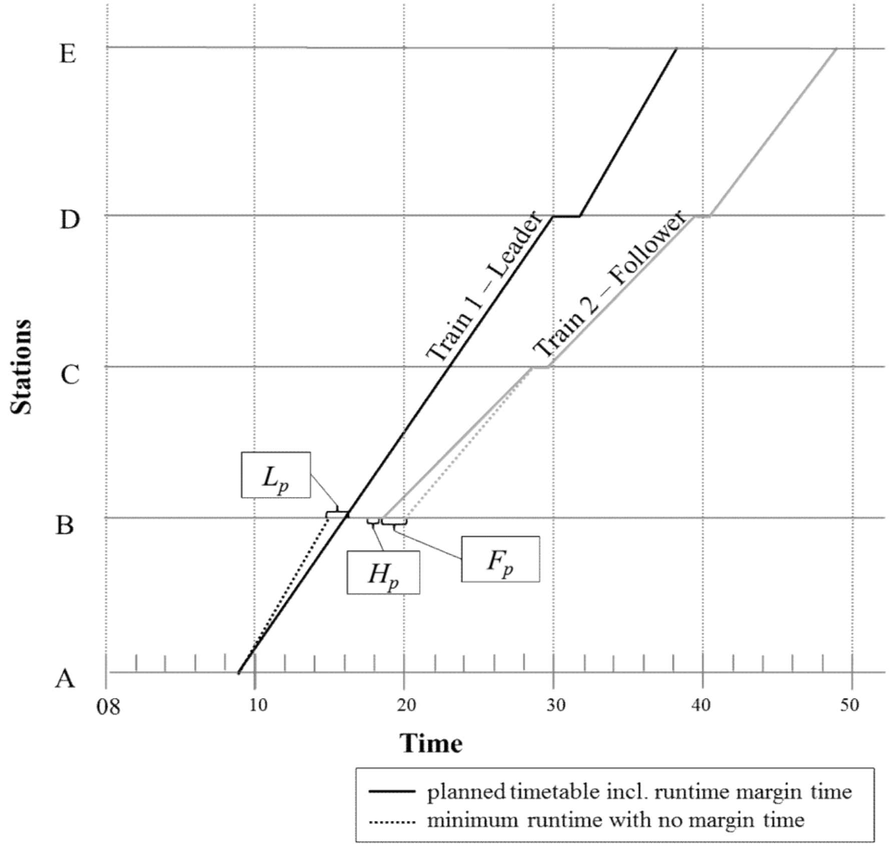
The Concept of “Critical Points” – algorithm to improve punctuality

Robustness in Critical Points (RCP)

Available marginal time in a critical point can be computed as

$$RCP_p = L_p + F_p + H_p$$

Adjusts the timetable to ensure that $RCP_p \geq 360$ holds for all points p.



Test case

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Swedish Southern Mainline

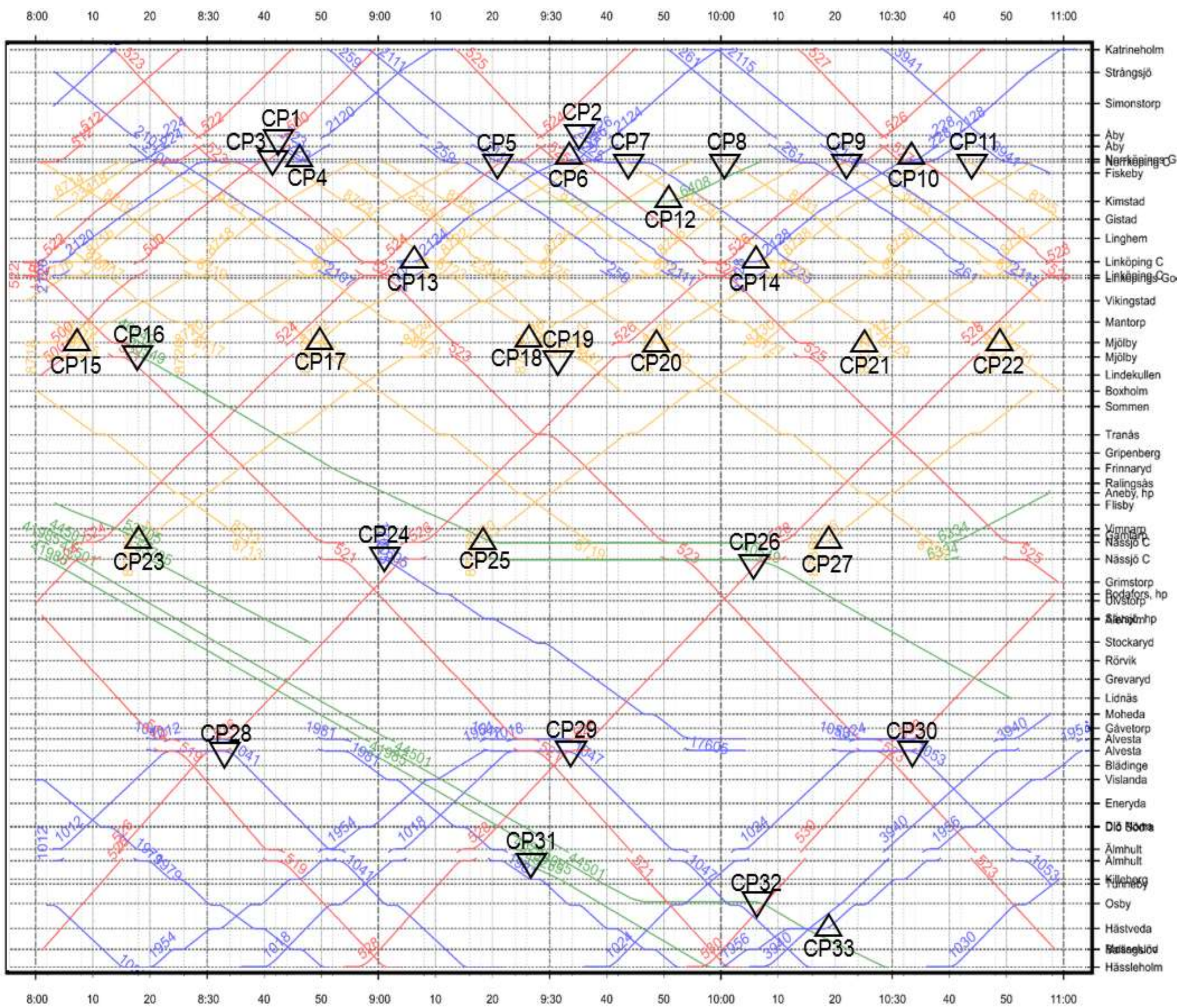
(Södra stambanan)

Katrineholm–Hässleholm

– 8.00–11:00, T14

33 Critical P's

– RCP values ranging from 18 to 1238 seconds.



Primary delays

Disturbances are added in the form of

1. initial disturbances at departure station
2. dwell-time disturbances
3. driving disturbances.

Experiment 1:

Initial disturbances identical to the previously performed macroscopic evaluation.

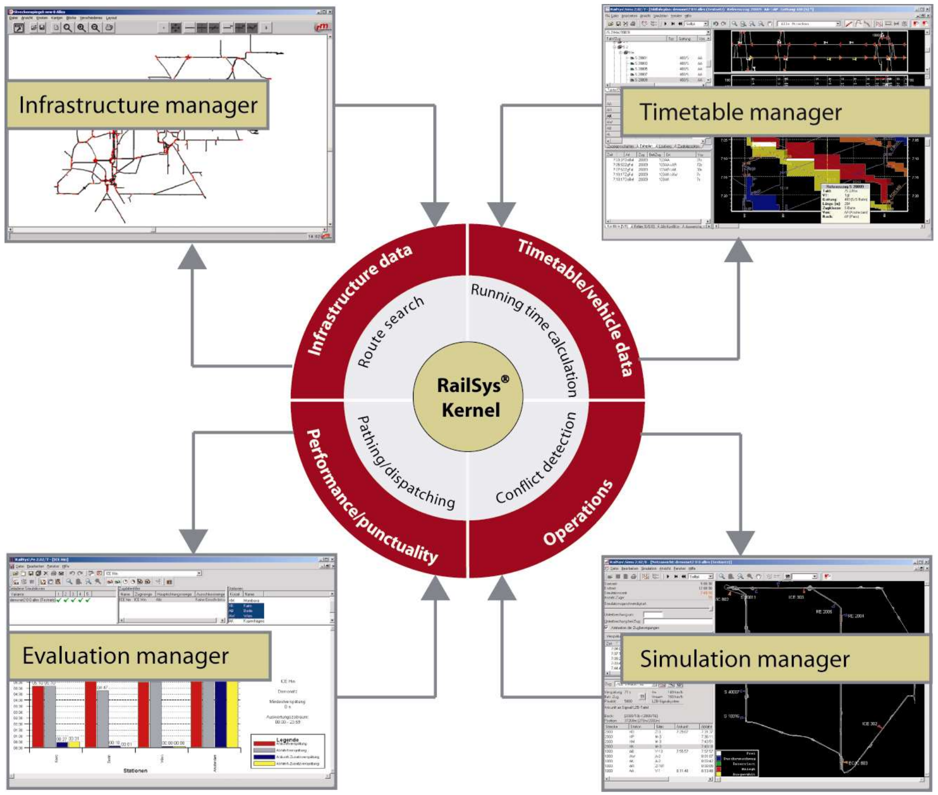
Experiment 2:

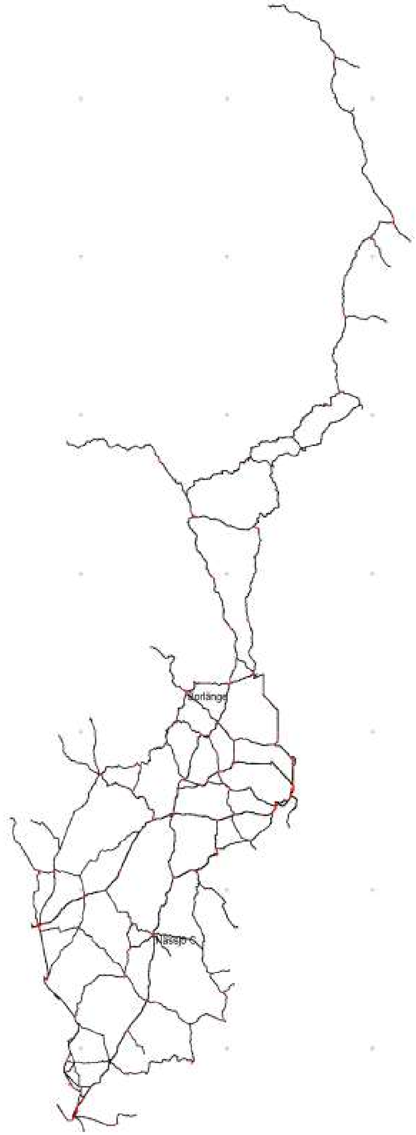
– Initial disturbances according to Trafikverket statistics (Lupp T14)

– Dwell-time and driving disturbances according to values provided by KTH.

➢ Requires extensive calibration to represent reality correctly.

Trafficsimulation – Railsys





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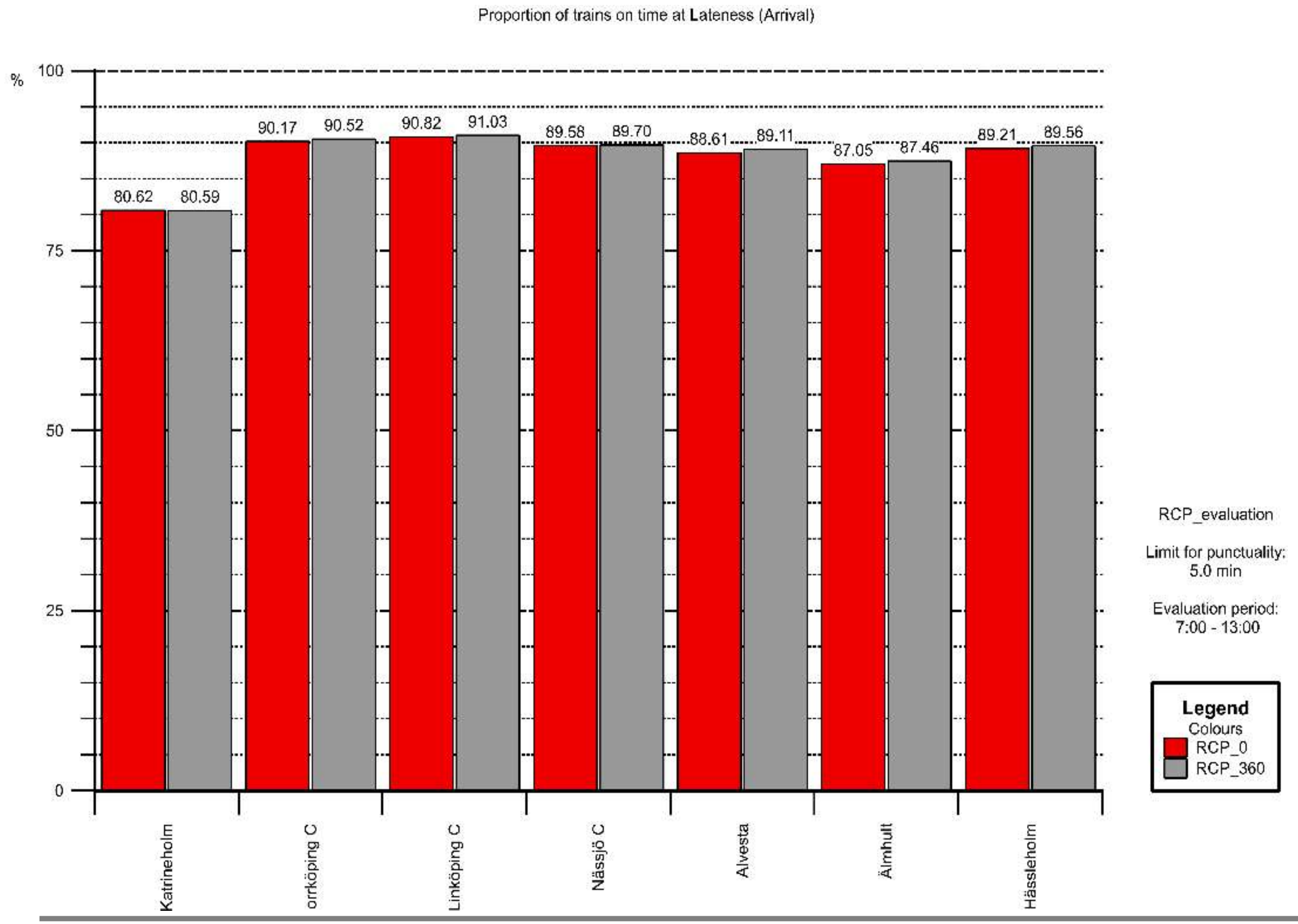
Comparison to previous results

Robustness measure	Macroscopic		Microscopic	
	Initial	Optimized	Initial	Optimized
Total delay – terminal destination	16.0	14.4	23.7	18.8
Number of on-time trains (+5) – terminal destination	98.9	98.9	98.0	98.4
Total delay– at all scheduled stops	115.2	98.7	105.8	92.8
Number of on-time trains (+5) – all scheduled stops	88.0	88.9	88.4	89.5

SEVENTH FRAMEWORK PROGRAMME

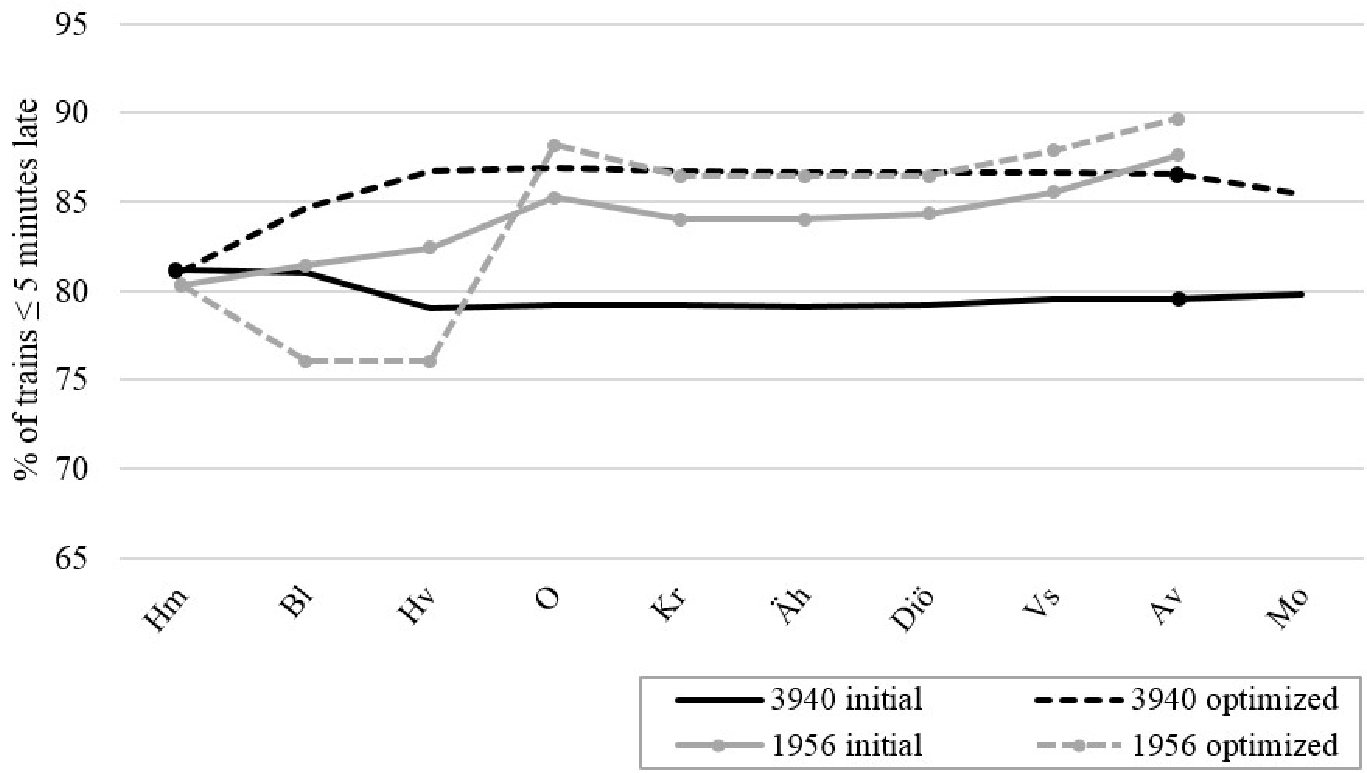
Results – Experiment 2

Path punctuality (Kanalpunktlighet), on-time +5, southbound trains (Too aggregated values…)



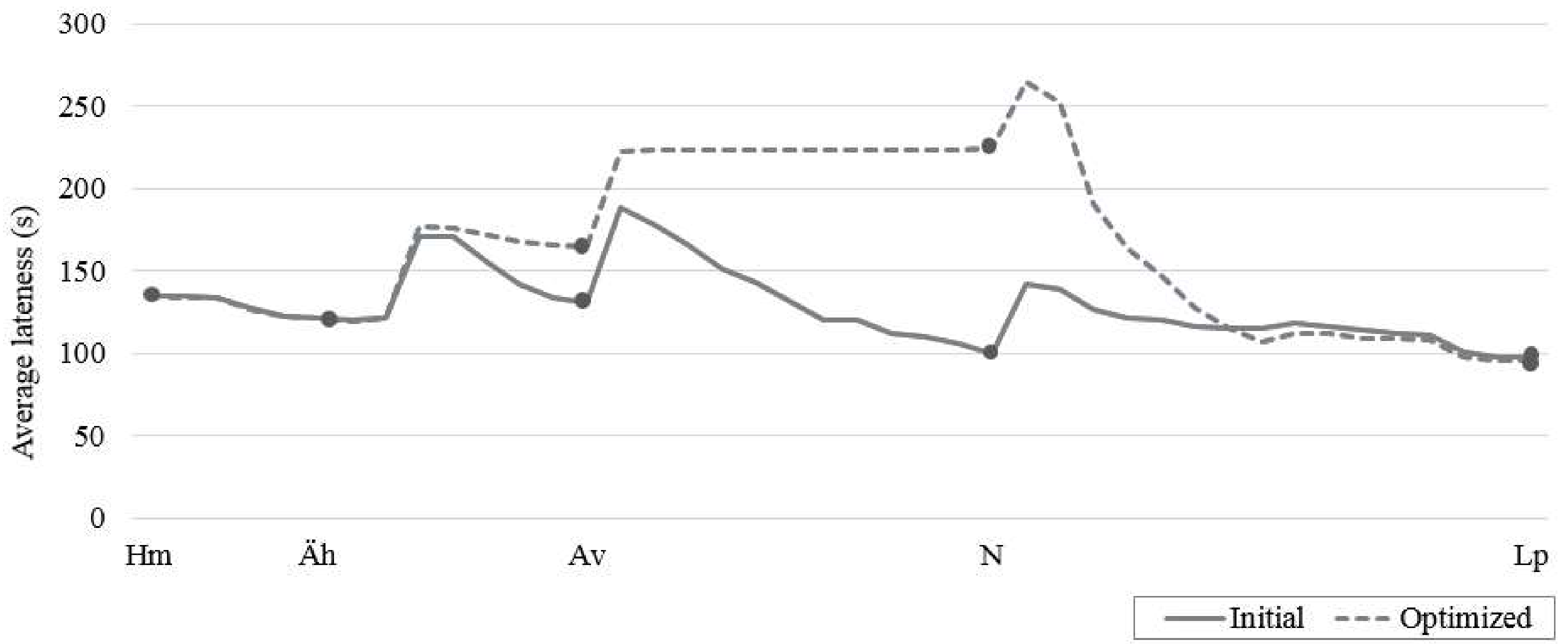
Results – Experiment 2

Punctuality for two trains involved in a critical point (overtaking Hv)



Results – Experiment 2

Punctuality for a train involved in a critical point just before Lp:



Conclusions

- Increased RCP values give a more robust timetable, also in a more detailed simulation environment with more realistic dispatching.

- However, the type of primary delays affect the results, and it is important to define the degree of freedom for re-scheduling of marginal time
  - Also the level-of-detail in the optimization model should be increased to avoid very unrealistic changes.

Outcomes, recommendations, and conclusions on use of modelling tools for automated traffic planning and management.

Main results

1. To define a framework strategic – tactical planning – operational traffic with micro-simulation, macro-simulation, data analysis and optimisation. By combining these methods especially tactical planning and operational traffic can be improved. By better planning methods there Is possibility to run more trains and/or to raise punctuality.

2. The LiU model have given us knowledge about a data analytic model to predict punctuality, when parameters in the timetable are changed.

3. The CAIN – LiU model interaction have given us new knowledge about interaction between IM timetable system and optimisation/data analysis model to predict timetable robustness and punctuality in the network due to changes in the timetable.

Main results

4. The development of CAIN demonstrator and connection to LiU model have learned us how to transfer data from Railsys and Lupp database to LiU model and CAIN demonstrator.

5. Optimisation of the concept Critical points have learned us more knowledge about the algorithm and the possibillity to implement decision support algorithm to increase punctuality in a double track line with an existing timetable. To quantify RCP algorithm results by traffic simulation in Railsys. The results show that it is necessary to use several KPIs to effectively evaluate the effects of an RCP increase.

6. To define a method with analysis of exante measures and then by simulation compare the outcome in traffic simulation with Railsys.

Scientific publications

Capacity for Rail

Scientific publications arisen from the work in C4R, WP3.2:

- Jovanović, P., Kecman, P., Bojovića, N. and D. Mandića (2017) “Optimal allocation of buffer times to increase train schedule robustness”, *European Journal of Operations Research* 256, pp. 44-54.
- Kecman, P., Corman, F. and L. Meng (2015) “Train delay evolution as a stochastic process”, in: *6th International Seminar on Railway Operations Modelling and Analysis RailTokyo 2015*, Tokyo, Japan, March 23–26, 2015.
- Kecman, P., Corman, F., Peterson, A. and M. Joborn (2015) “Stochastic prediction of train delays in real-time using Bayesian networks”, in: *CASPT 15: Conference on Advanced Systems for Public Transport*, Rotterdam, The Netherlands, July 19–23, 2015.
- Solinen, E., Nicholson, G. and A. Peterson (2017) “A microscopic evaluation of robustness in critical points”, accepted for publication in: *7th International Seminar on Railway Operations Modelling and Analysis RailLille 2017*, Lille, France, April 4–7, 2017.

Deliverables and leaflets

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D 32.1 Evaluation measures and selected scenarios, 2014-12-18

D32.2 Capacity impacts of innovations, 2017-03-31

Leaflet WP3.2 simulations and models, Innotrans 2017-09-20

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