Energy Efficient Timetabling

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Applications to verify and improve the robustness of timetables

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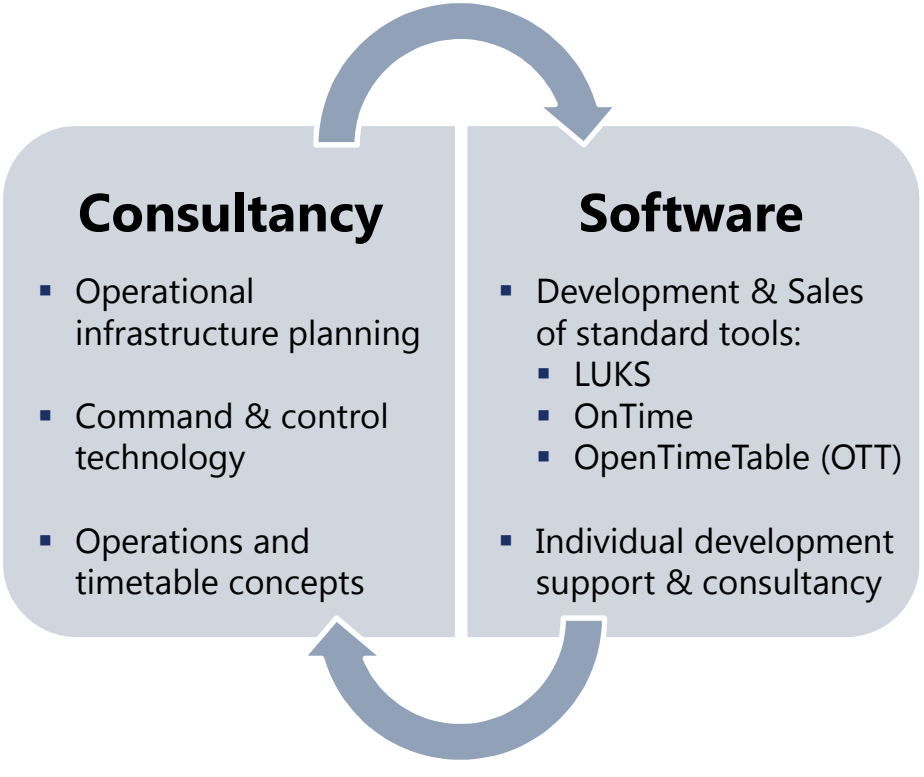
Agenda

1. Introduction
   Who we are and what we do
2. Basics of LUKS®
   Different approaches merged into one tool
3. LUKS-K module
   Conflict detection and timetabling
4. LUKS-S module
   Stochastic simulation of operation
5. OptDis module
   Mathematical optimization of timetables

VIA Consulting & Development GmbH
Key figures

One-stop consulting and software

- Founded in August 2008
- Spin-off from RWTH Aachen University in private ownership
- 28 employees, thereof 15 full-time and 19 with university degree:
  - Civil & traffic engineers
  - Developers
- Customers in eleven countries:
  - Infrastructure Managers
  - Authorities
  - Institutions & Universities
- ~2,35 Mill. Euro turnover (in 2017)
- DIN EN ISO 9001:2008 certified



General characteristics of LUKS®

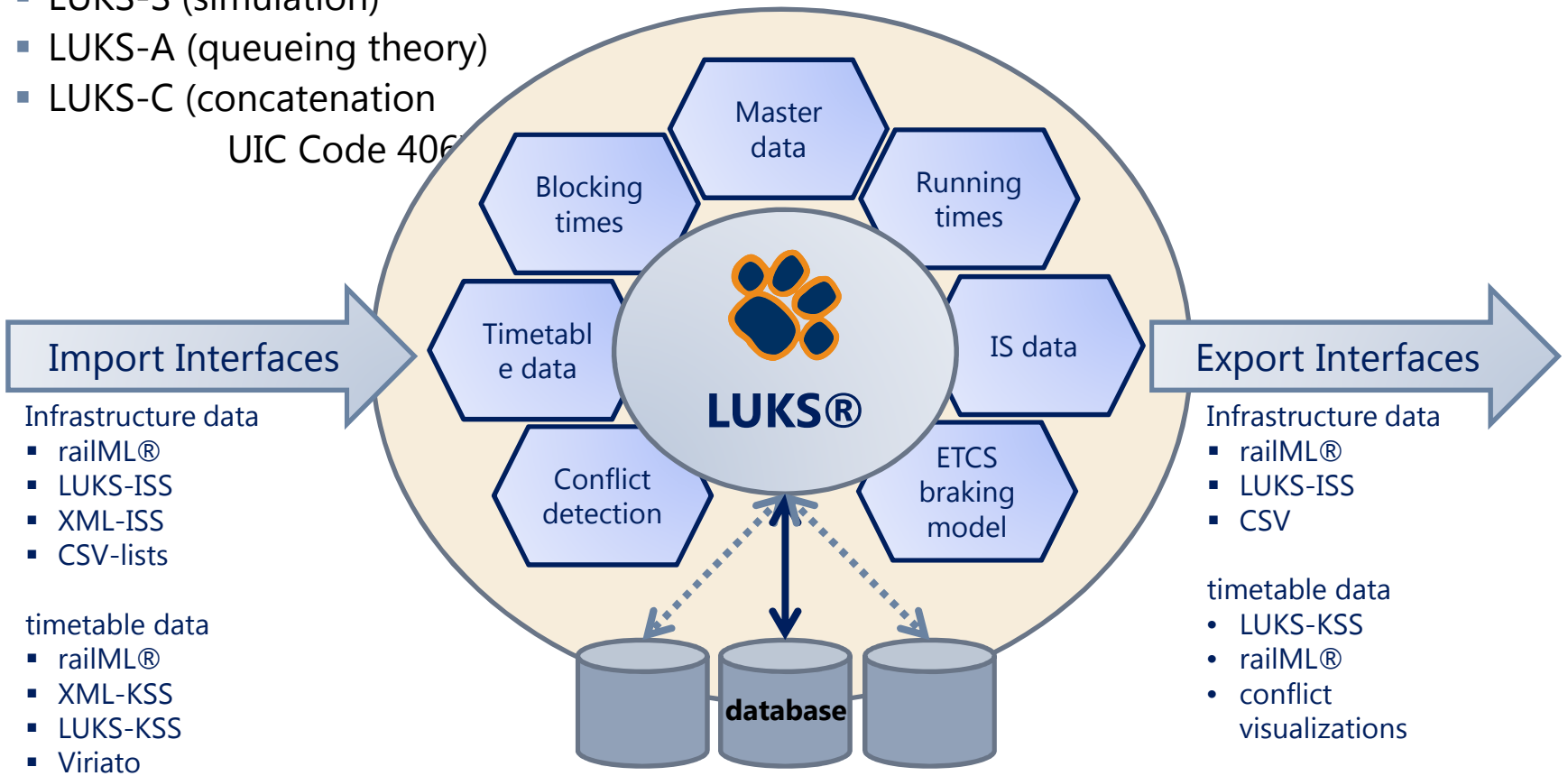
Functional modules

- LUKS-K (construction)
- LUKS-S (simulation)
- LUKS-A (queueing theory)
- LUKS-C (concatenation

UIC Code 406

Common data structures for all modules

→ sustainable data management



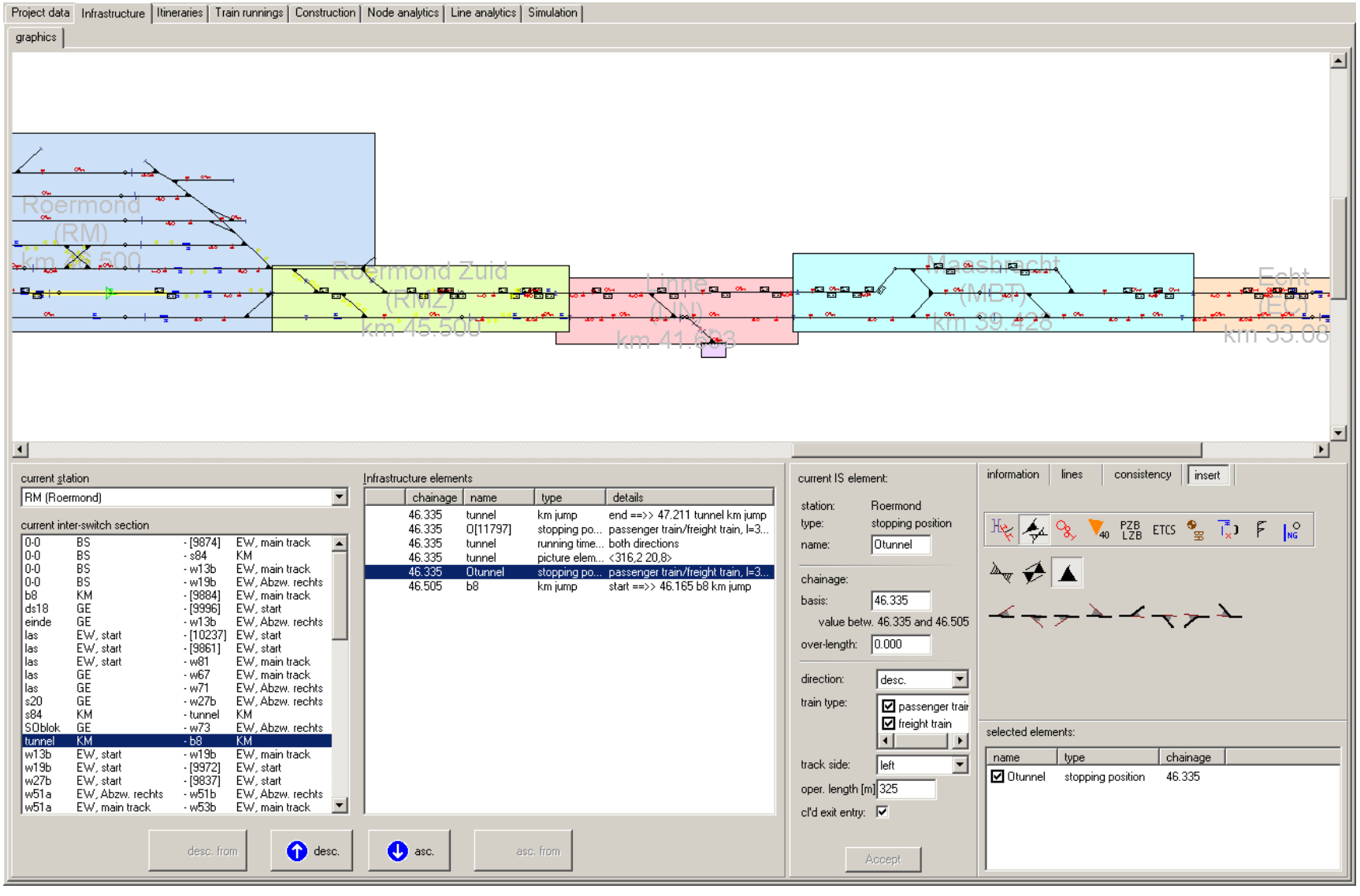
Infrastructure data
- railML®
- LUKS-ISS
- XML-ISS
- CSV-lists

timetable data
- railML®
- XML-KSS
- LUKS-KSS
- Viriato

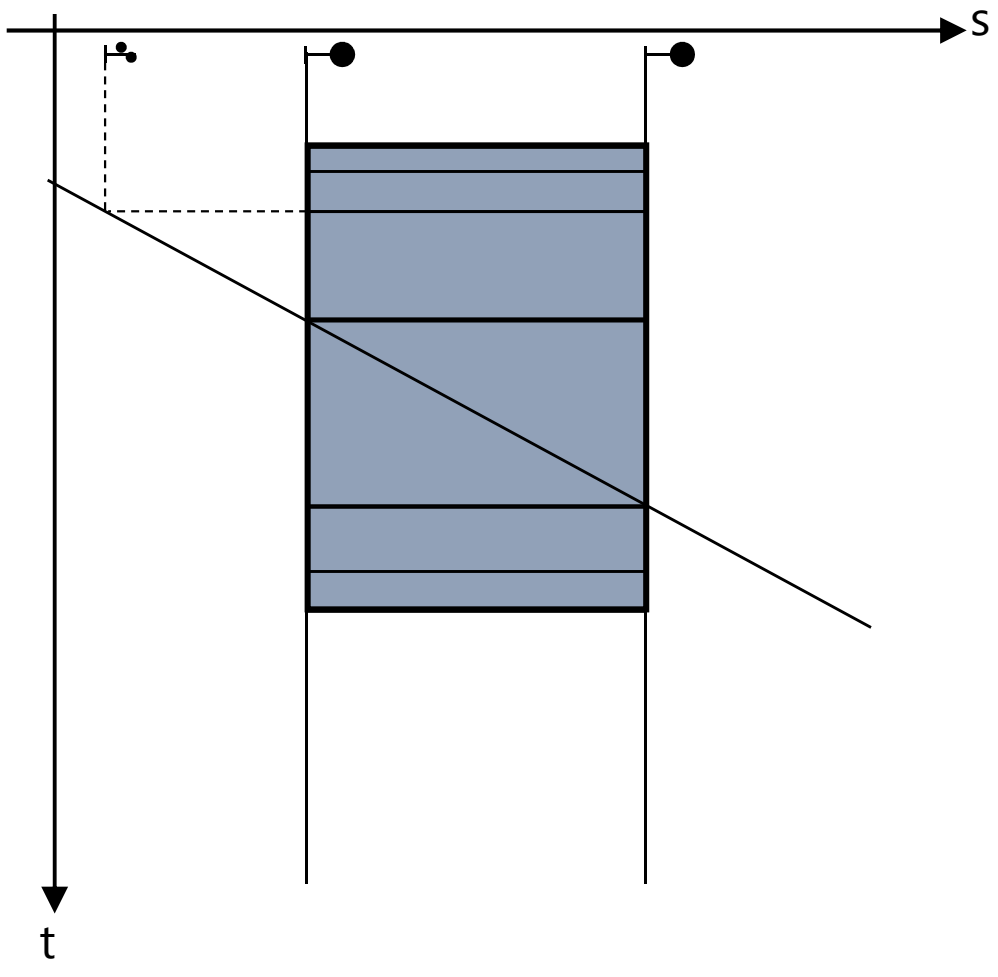
Infrastructure data
- railML®
- LUKS-ISS
- CSV

timetable data
- LUKS-KSS
- railML®
- conflict visualizations

Infrastructure is modelled as a microscopic graph



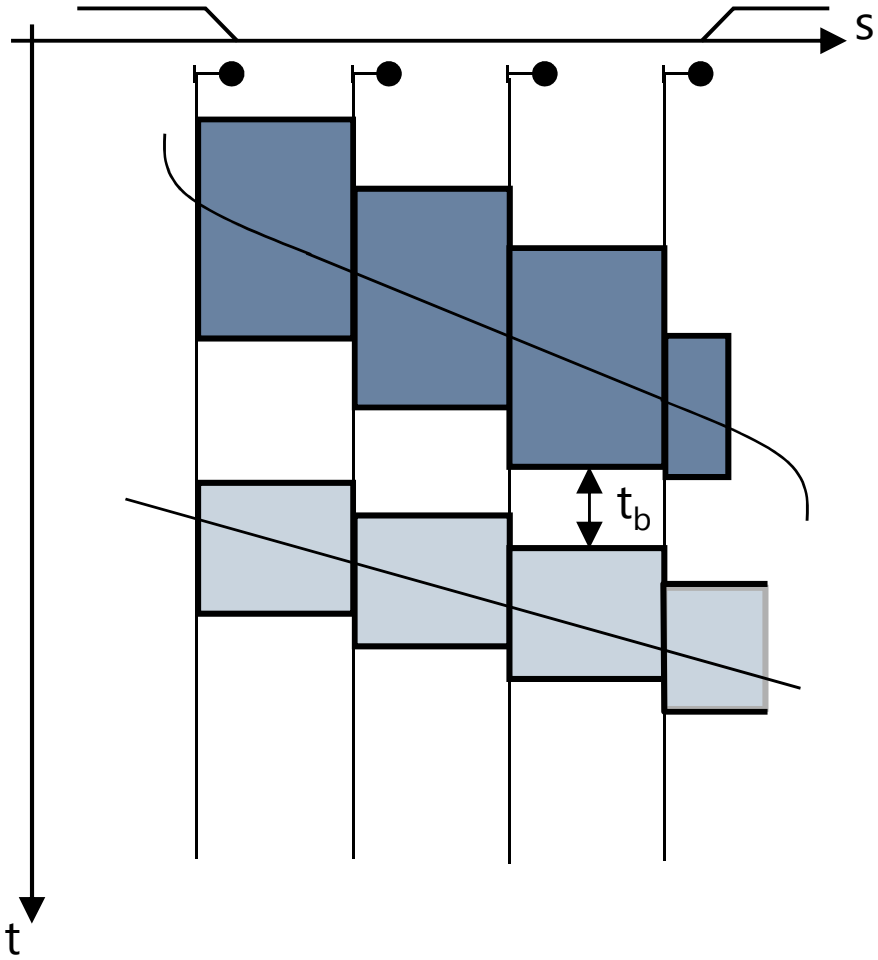
Basis of conflict detection: the blocking time model



Physical occupation
+ clearing time
+ approach time
+ switching times
+ response time

= blocking time

Each train move is represented by its blocking-time series



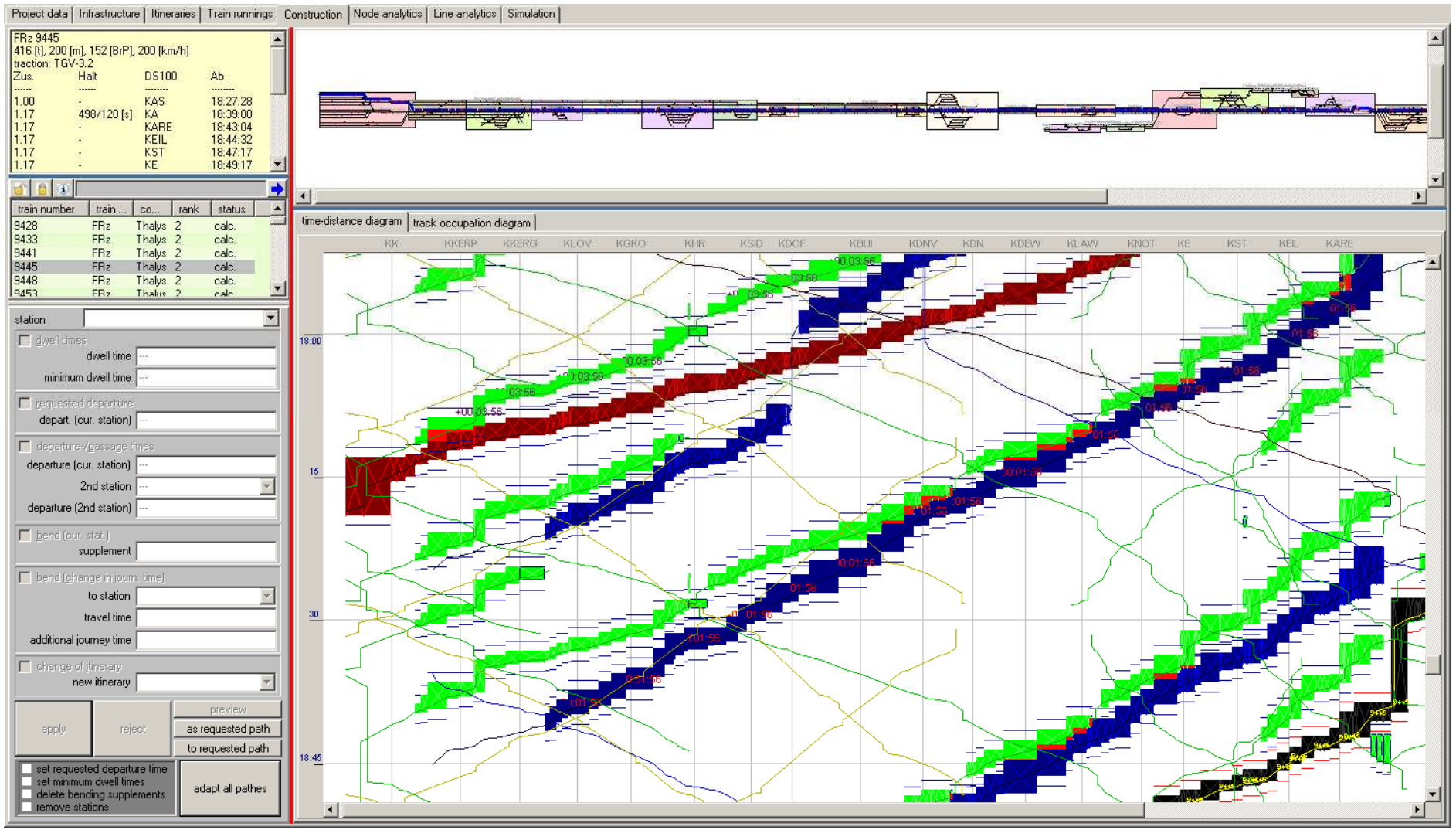
Application of blocking time series

- Exact representation of capacity occupation
- Guarantee of conflict-free timetabling
- Easy determination of actually available buffer times

Realistic model of capacity occupation

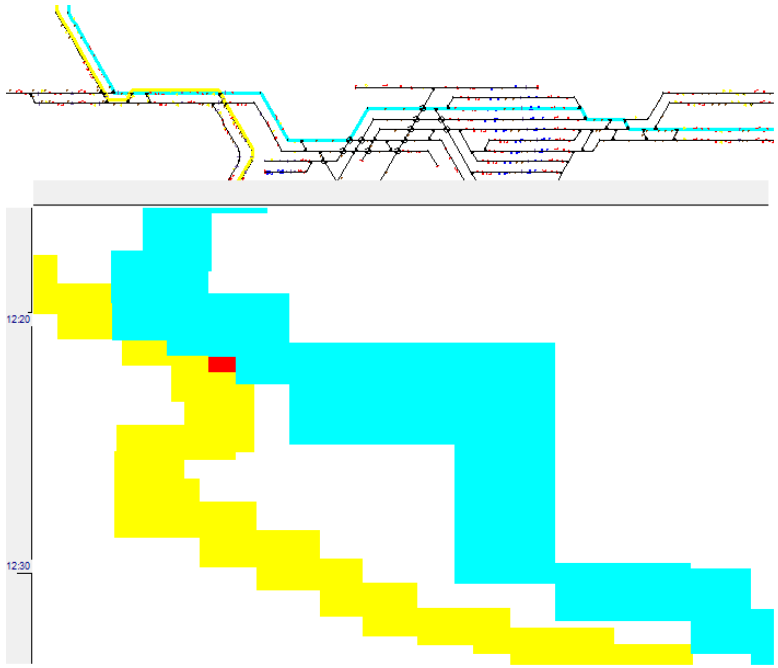
- Occupation from an operational POV
- Takes into account all operational aspects
- Easy detection of bottlenecks

LUKS-K: Visual conflict detection and timetable construction



Conflict detection batch mode is available

- Loading of microscopic infrastructure
- Import of daily timetable data
- Microscopic running and blocking time calculation
- Detection and classification of all conflicts
- Visualization and export

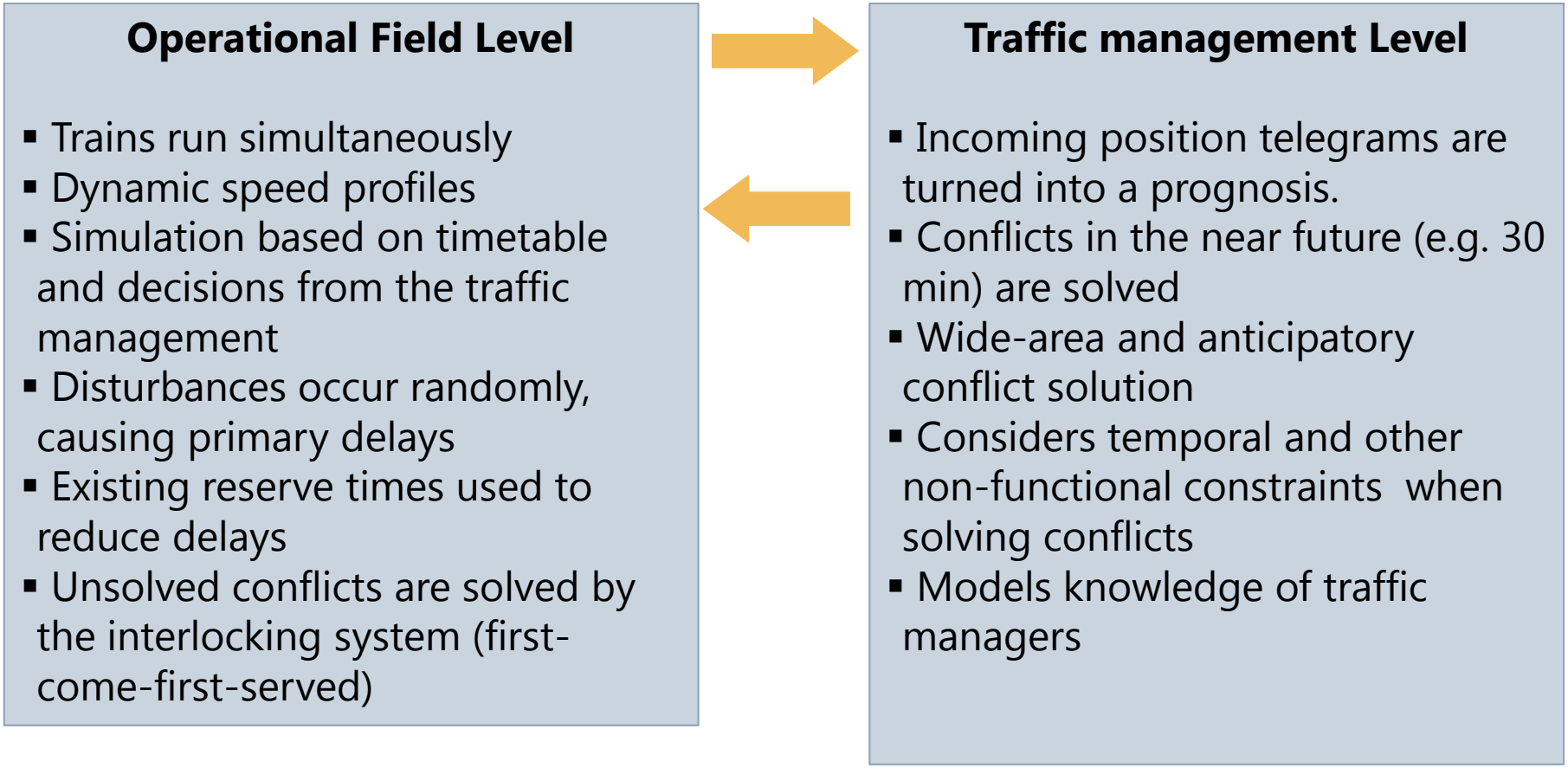


Stochastic simulation of railway operations

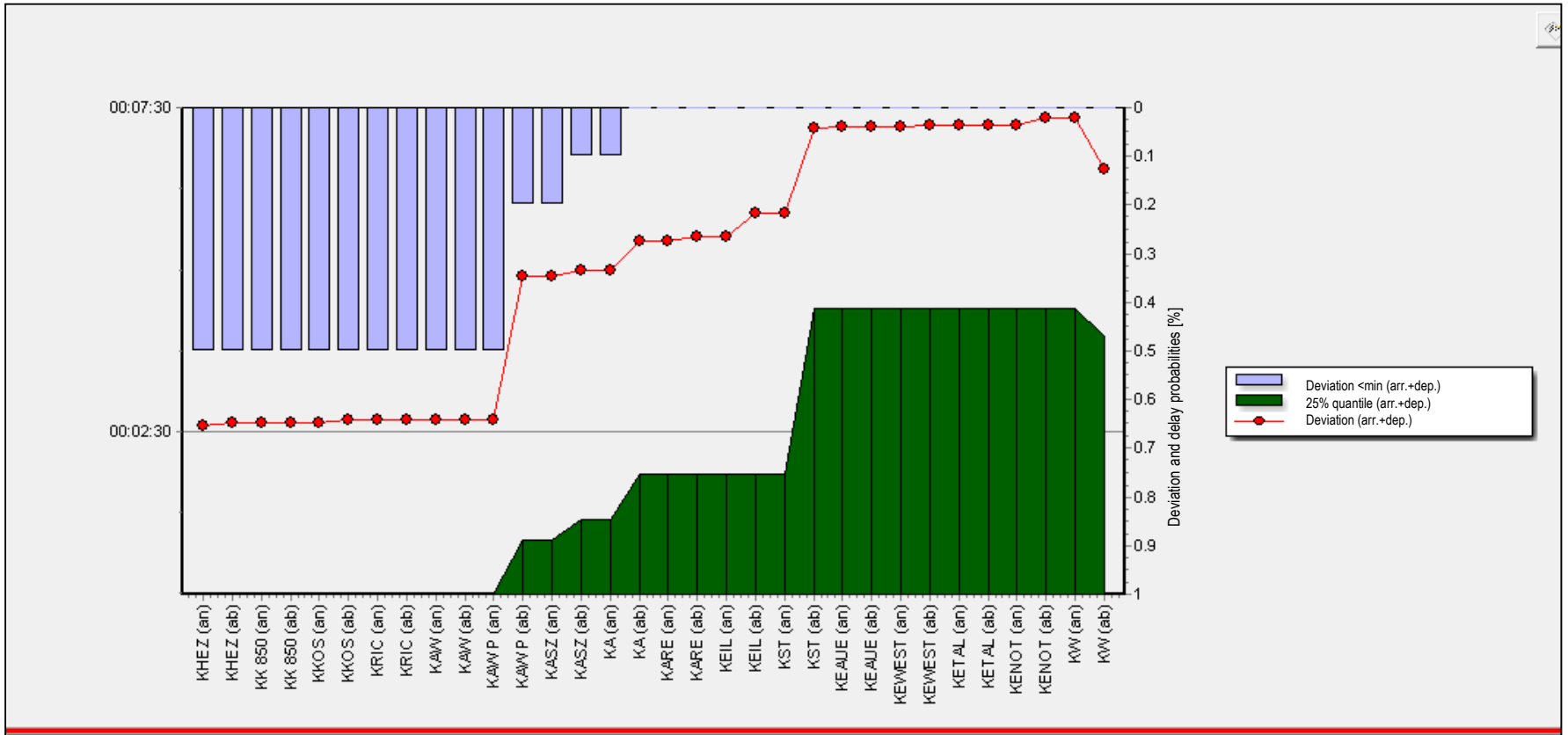
Operational simulation models the interaction between a centralized traffic management, the trains and the interlocking system

- The conflict-free timetable is disrupted by randomly generated primary delays.
- Delays can occur before a train enters the simulation area or while it is running through the area.
- Each train has its own assumed probability distribution for delays.
- Ensuing conflicts are detected and solved by the traffic management.
- Different primary delays are generated for each simulation run. This model different traffic situations or days.

LUKS simulation is an interaction between two levels

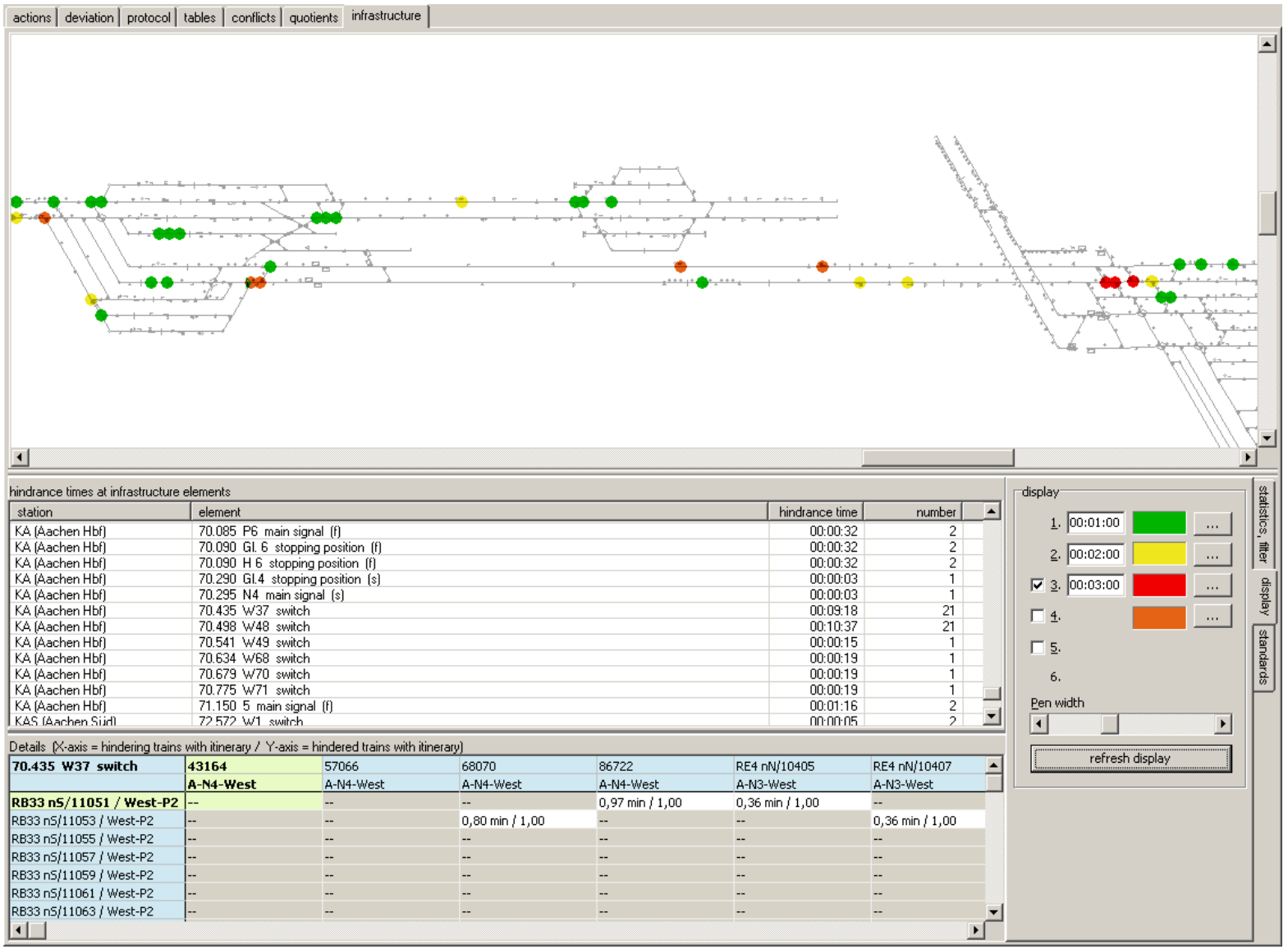


Delay evolution and quotients can be analyzed and evaluated in detail



BtrSt	Abweichung (Ankunft) [min:sec]	< 0:59 (Ankunft) [%]	25% Quantil (Ankunft) [min:sec]	Abweichung (Abfahrt) [min:sec]	< 0:59 (Abfahrt) [%]	25% Quantil (Abfahrt) [min:sec]
KHEZ	00:02:36	50	00:00:00	00:02:39	50	00:00:00
KK 850	00:02:39	50	00:00:00	00:02:39	50	00:00:00
KKOS	00:02:39	50	00:00:00	00:02:42	50	00:00:00
KRIC	00:02:42	50	00:00:00	00:02:42	50	00:00:00
KAW	00:02:42	50	00:00:00	00:02:42	50	00:00:00
KAW P	00:02:42	50	00:00:00	00:04:54	20	00:00:49
KASZ	00:04:54	20	00:00:49	00:05:00	10	00:01:09
KA	00:05:00	10	00:01:09	00:05:27	0	00:01:51
KARE	00:05:27	0	00:01:51	00:05:30	0	00:01:51
KEIL	00:05:30	0	00:01:51	00:05:53	0	00:01:51

Bottlenecks are also represented in graphical form



OptDis – Automatic timetable optimization

Key features

- Global optimization of all trains inside the considered area
- Application of state-of-the-art optimization techniques (MIP)
- Complete integration of leading solvers (Gurobi and CPLEX)
- Highly configurable objective function

OptDis automatically optimizes a roughly planned timetable

- Solves all occupation conflicts (intersection of blocking times)
- Supports all common timetabling approaches
- Respects turnarounds and regular intervals
- Minimization of deviation from roughly planned trajectories
- Maximization of robustness (buffer times and running time reserves)

LUKS: Application to verify the robustness of timetables

LUKS offers several approaches based on a common database

- Microscopic infrastructure graph and train data
- Advanced blocking time calculation

Conflict detection based on blocking times

- Essentially deterministic timetable simulation
- Visualization of all occupation conflicts and buffer times (interactive and batch)

Stochastic simulation of operations

- Models the interaction between a traffic management, trains and interlocking system
- Determines the robustness in case of disturbances
- Train- and infrastructure based

Automatic timetable optimization

- Automatically optimizes a roughly planned timetable
- Maximizes the timetable robustness (buffer times and running time reserves)