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Innovations in Timetable planning and Traffic control

ON-TIME Timetable Planning
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Optimal Networks for Train Integration Management across Europe
Collaborative Project
7th Framework Programme

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ON-TIME Timetable Planning

• Introduction
• Review literature and practice
• Timetable performance indicators
• Timetabling approach
• Demonstration
• Final remarks
WP3

• Development of robust and resilient timetables

Innovation 2

• The development of improved methods for timetable construction that are robust to statistical variations and resilient to perturbations in operations
Literature

- Macroscopic timetable optimisation models
  - Good input required for good output
- Microscopic timetable models
  - Running time and infrastructure capacity computations
  - Blocking time theory
- Evaluation of timetables
  - Macroscopic models for stability or robustness
  - Microscopic generic railway simulation models

Practice

- Either macroscopic models using normative input
- Or microscopic blocking time models per corridor
- Evaluation after design without well-defined feedback
Performance indicators

Timetable trade-off between performance measures

- Short travel times
- Seamless connections

- Realizable
- Conflict-free
- Stable: acceptable capacity occupation in corridors and stations
- Robust
- Resilient
- Residual capacity for freight paths
- Energy efficient
Performance indicators

Stations, signals

Time
Performance indicators

Time

Distance
Timetabling approach

- Modular three-level approach
  - Microscopic models at local level
  - Macroscopic models at network level
  - Fine-tuning models at corridor level
- Efficient consistent micro-macro network transformations
- Standardized RailML I/O data format (with extensions)
- Integrated performance-based timetabling approach
  - Microscopic running time computations, conflict detection and UIC capacity consumption
  - Macroscopic network timetable optimization including stochastic robustness evaluation using Monte Carlo simulation
  - Energy-efficient speed profiles
  - Stochastic optimization of arrival and departure times within corridors regarding dwell time distributions
Timetabling approach

MACROSCOPIC

Robustness Evaluation

Minimum Running Time Computation

Macro Timetable Optimization

Macro Timetable

MICROSCOPIC

RailML Data
- Infrastructure
- Rolling Stock
- Interlocking
- Signalling / AP
- Routes

RailML Converter

Other Timetable Parameters
- Turn-around times
- Minimum dwell times

Microscopic Data

Minimum Headway Computation

Operational Running Time Computation

Conflict Detection

Yes

Feasible Timetable

Capacity Evaluation

No

FINE TUNING

Conflict Detection

Yes

Feasible & Stable Timetable

Energy Efficient Trajectory Computation

Energy-efficient Timetable

RailML Writer

RailML Timetable

Bandwidth Estimation

Corridor Timetable Optimization

Macro Timetable

Min RT

Open RT

Min RT

FP7 - ON-TIME Collaborative Project

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Microscopic module

Objectives

- Realizable train paths
- Conflict-free timetable
- Stable operations

Approach

- Running and blocking times based on feasible speed profiles including running time supplements
- Conflict detection using blocking times (rejection criteria)
- Infrastructure occupation/stability (UIC rejection criteria)
- Accuracy 1 s
- Computation micro/macro transformations and bandwidths
Macroscopic module

Objectives

- Optimal network timetable
  - Minimization of running, dwell, transfer times, and settling time of delays
  - Scheduling all train path requests

Approach

- MILP model with weighted sum of cost terms
- Heuristic algorithm generates multiple (1000) solutions
- Robustness analysis (for selected solutions): mean setting time of 1000 Monte Carlo delay propagation simulations
- Selection of optimal timetable (incl. robustness cost)
- Timetable precision 5 s
**Objectives**

- Minimizing energy consumption at maximum robustness

**Approach**

- Energy-efficient speed profiles using optimal control theory
- Computation of bandwidths of local trains between ICs
- Timetable optimisation of local trains within the corridor regarding stochastic dwell times and minimizing expected energy consumption and expected delays
- Stochastic dynamic programming model
- Timetable precision 30 s
Demonstration

**Dutch case study**

- Infrastructure and line plan 2012
- Two intersecting corridors
  - Utrecht-Eindhoven and
  - Tilburg-Nijmegen
- Hourly timetable pattern with
  - 2 x 8 ICs per hr
  - 2 x 10 local trains per hr
  - Two freight paths per hr (Ut-Ehv)
  - Many transfers in ‘s Hertogenbosch
    (and elsewhere)
**Model sizes**

- **Microscopic network**
  - 1500 nodes
- **Block section level**
  - 1000 nodes
- **Macroscopic network**
  - 16 nodes
Demonstration

Time distance diagram for corridor Ut-Ehv
Demonstration

Blocking time diagram for the route of train line 3500

Distance [stations]

Time [min]
Final remarks

- Modular implementation of three-level timetabling approach
- Input from standardized RailML files (Infrastructure, Rolling Stock, Interlocking, Timetable)
- Output in standardized RailML Timetable file with scheduled train paths and speed profiles at section level
- Multilayer timetable with multispeed freight path catalogue
- Classification of Timetabling Design Levels
  - TDL 0: Low quality
  - TDL 1: Stable
  - TDL 2: Conflict-free (and stable)
  - TDL 3: Robust (and conflict-free and stable)
  - TDL 4: Resilient (proof that a robust conflict-free timetables exists and can be derived dynamically fast w.r.t. freight and delays)