Energy-efficient Train Timetabling

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- Timetabling
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Introduction

Connecting Europe Express

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- Measures for railway undertakings with low investment cost + high energy savings + CO_2 reduction:
  - Energy-efficient train driving
  - Energy-efficient train timetabling

Energy-efficient train driving (1/2)
Energy-efficient train driving, what it is not…
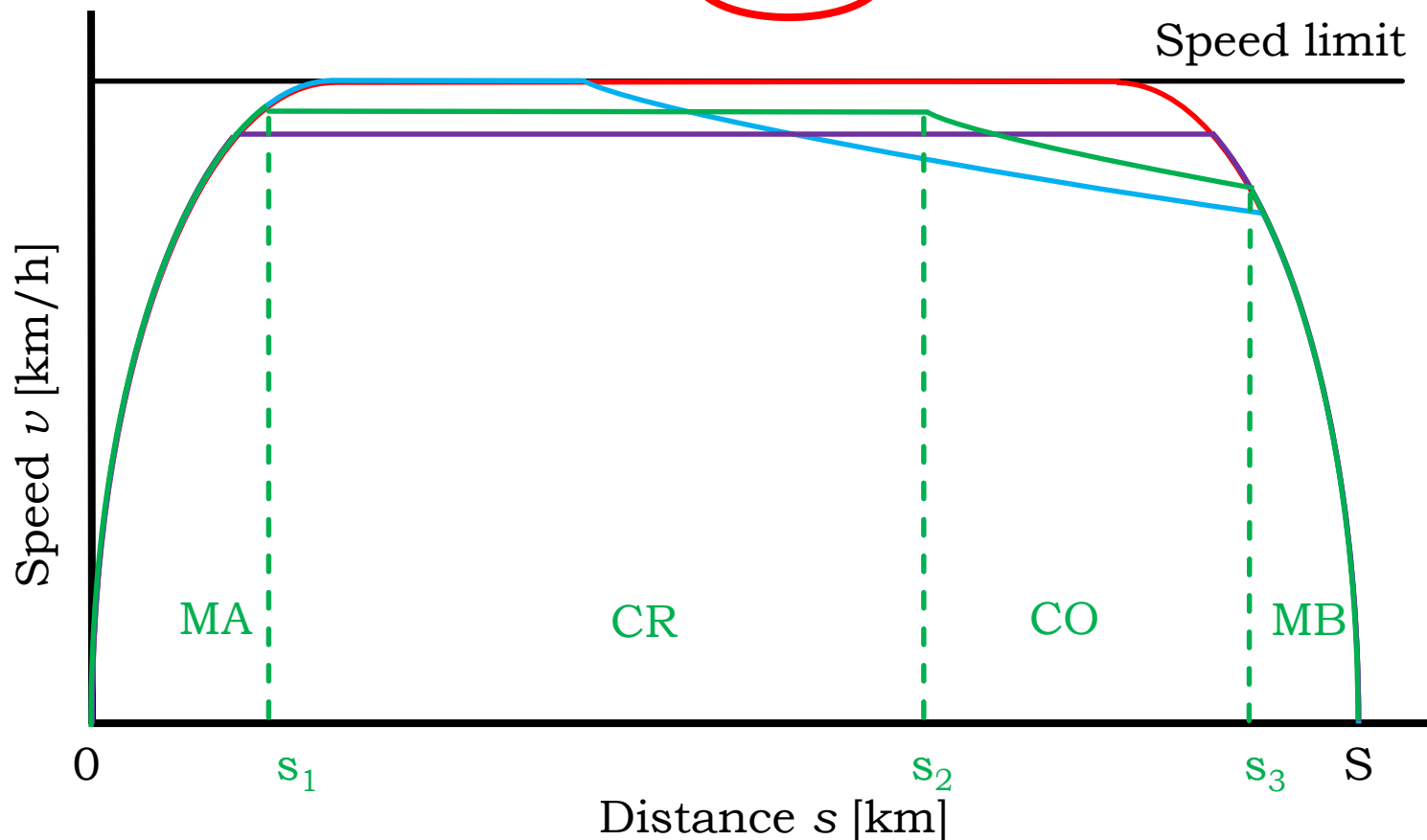
Energy-efficient train driving (2/2)
What is the energy-optimal driving strategy?

EETC: minimize total traction energy consumption given total running time

MTTC: minimum time train control   RMS: reduced maximum speed
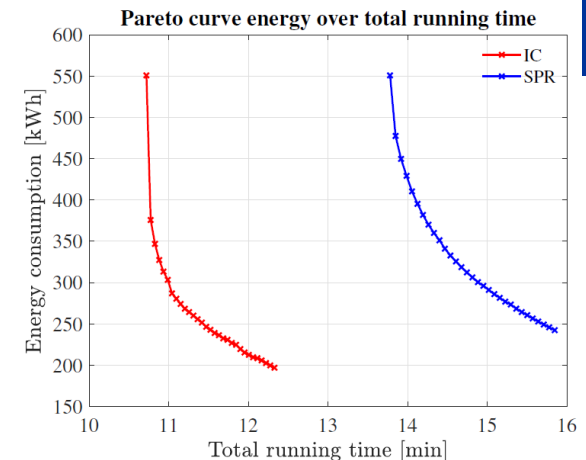
MC: maximal coasting   EETC: energy-efficient train control

Timetabling (1/2)
Energy-efficient train timetabling

- Running time supplements: extra running time above technical minimum running time to cope with running time variations & small delays that can be used if train is on-time for energy-efficient train driving

- Energy-efficient train timetabling (EETT): incorporate energy-efficient train driving in timetable design:
  - Synchronizing accelerating & regenerative braking trains
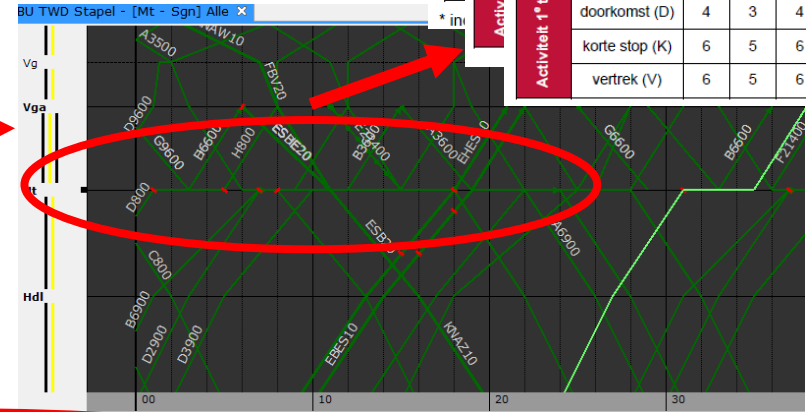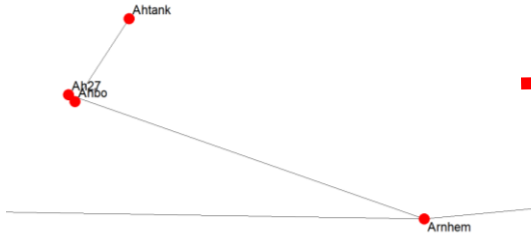 - Optimal amount + distribution of running time supplements

Pareto curve energy over total running time

Timetabling (2/2)
Macro vs. micro

Infra modelling

Conflict detection

Macro

Micro

Research gap

- Scientific research:
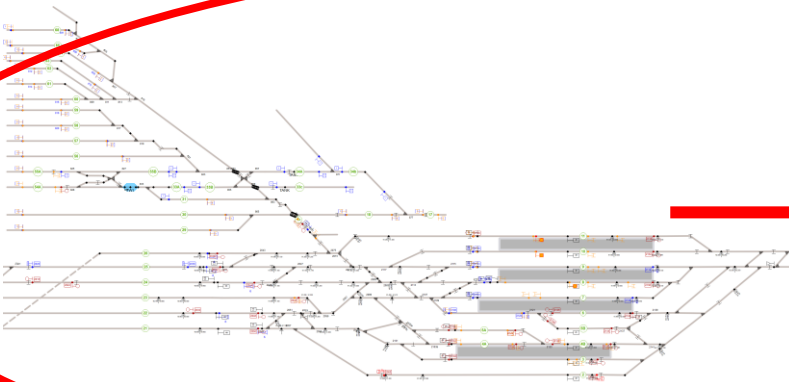 - Microscopic timetable optimization is limited considered
  - Energy-efficient train driving is limited considered in timetable optimization
- Practice:
  - Timetable optimization is not considered
  - Energy-efficient train driving is not considered during timetable design

Aim

- Incorporate energy-efficient train driving in timetable design in order to improve potential for energy-efficiency of railways
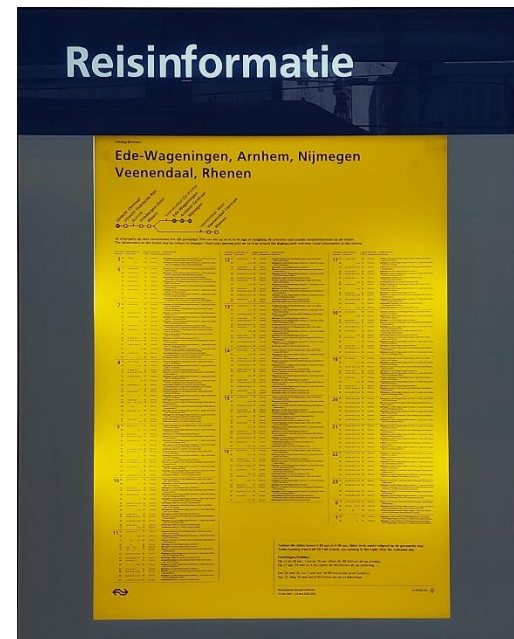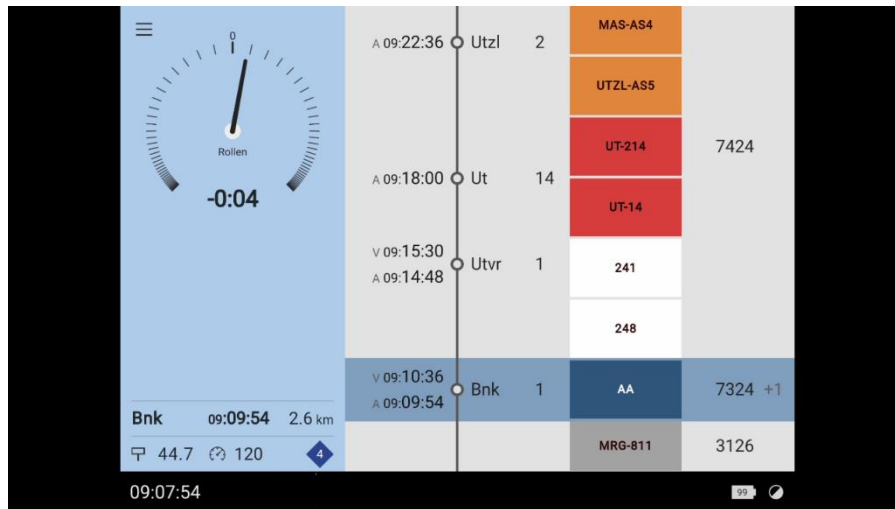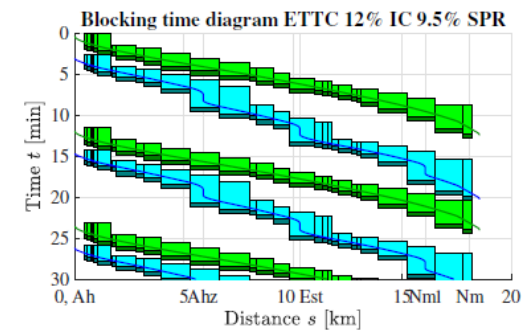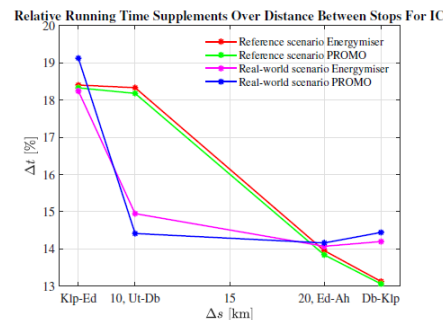
Contributions of this thesis (1/3)
Scientific

- EETC (energy-efficient train control):
  - Thorough literature review
  - EETC with nonlinear regenerative braking and mechanical braking
  - Comparing different driving strategies
- EETT (energy-efficient train timetabling):
  - Thorough literature review
  - The optimal distribution of the running time supplements in the timetable for a single train over multiple stops
  - Multiple-objective timetable optimization problem considering total running time, infrastructure occupation, robustness and energy consumption at micro level on a corridor

Contributions of this thesis (2/3)
PROMO prototype

Speed and gradient over distance for IC

- Different driving strategies
- Different braking strategies
- Trajectory optimization algorithm to solve EETC problem
- Distribution of the running time supplements
- Blocking time computation at micro level
- Search algorithm to determine optimal solution for multiple-objective optimization problem

Speed over distance for IC

Relative Running Time Supplements Over Distance Between Stops For IC

Blocking time diagram ETTC 12% IC 9.5% SPR
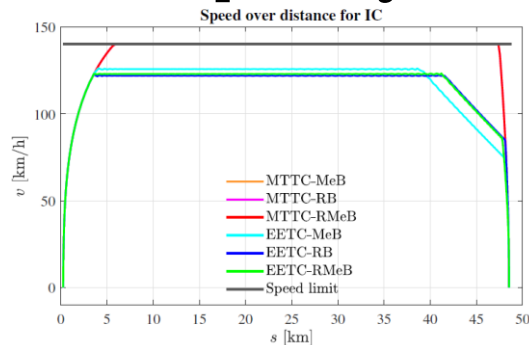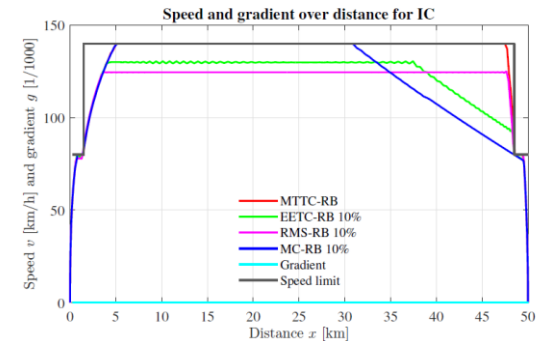
Contributions of this thesis (3/3)
Societal

- Energy-efficient train driving contributes to sustainability
- Comparison between different practical driving strategies on multiple key performance indicators
- Balanced timetable design by considering multiple objectives
- Incorporating energy-efficient train driving in timetable design leads to realistic speed profiles for train drivers

Conclusions

- Energy-efficient train driving is incorporated in timetabling by formulating & developing algorithms for multiple-objective optimization problem

- EETC in timetable optimization balances other objectives, and contributes to energy efficiency & sustainability

Thank you for your attention!

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