A Rolling Horizon Based Framework for Rolling Stock Rescheduling

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Presentation Outline

1. Outline
2. Problem description
3. Rolling stock rescheduling
4. Computational results
5. Conclusions

Introduction

Reasons for unexpected disruptions

- Infrastructure malfunctions
  - Rails, switches, catenary, bridges
- Computer problems in control centers
- Rolling stock breakdowns
- Accidents with other traffic
- Weather conditions
- Crew no shows
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Numbers from 2007 for the Netherlands

Disruptions	#
Small	933
Medium	1011
Large	834

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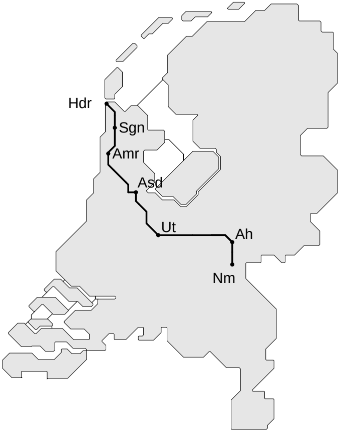
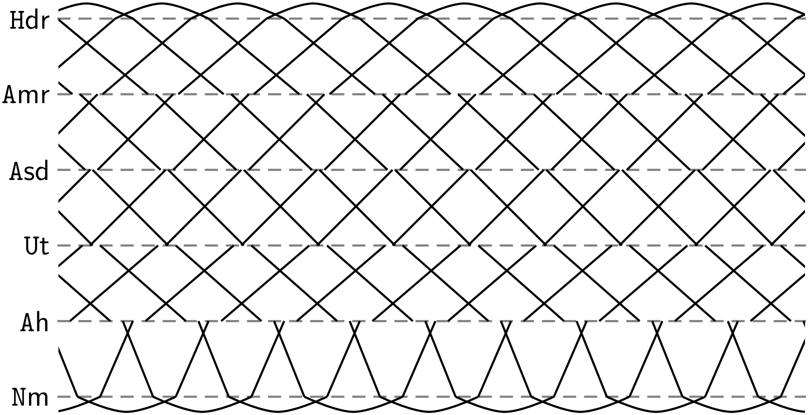
Our research focuses on the rolling stock.

Example



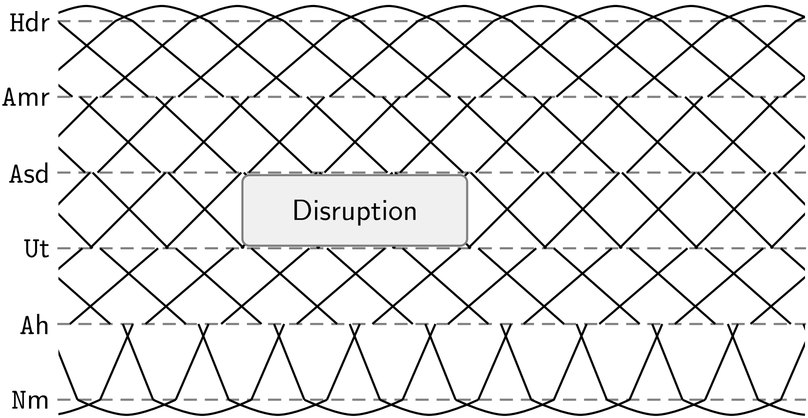
Example

Time-space diagram for a line.



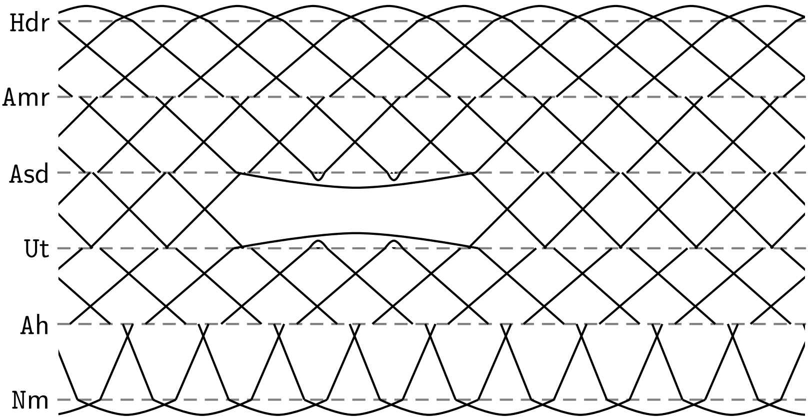
Example

Disruption



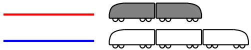
Example

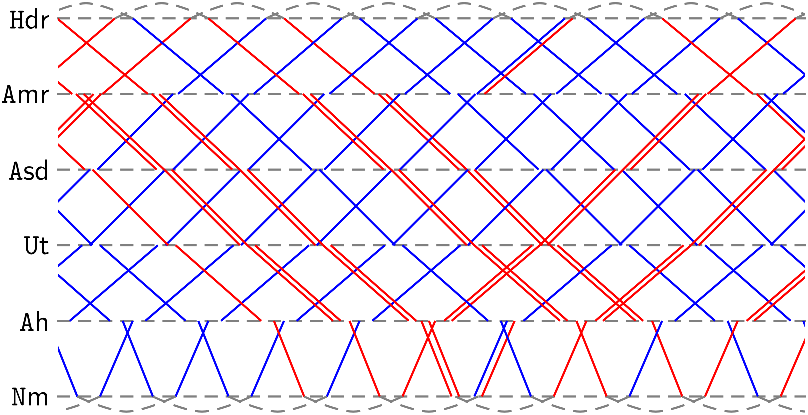
Updating the timetable



Example

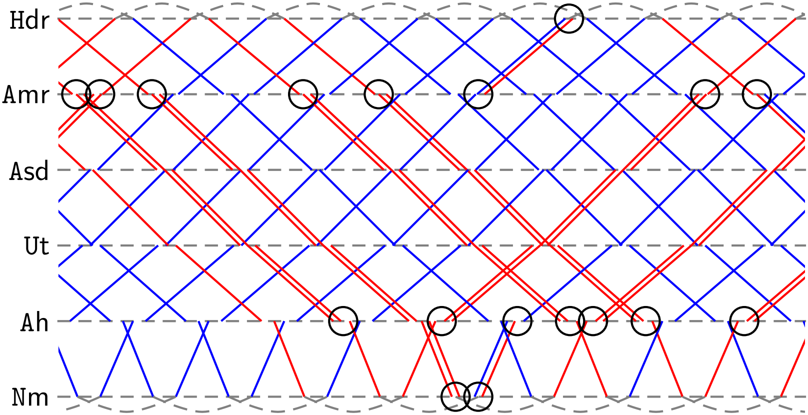
Rolling stock assignment





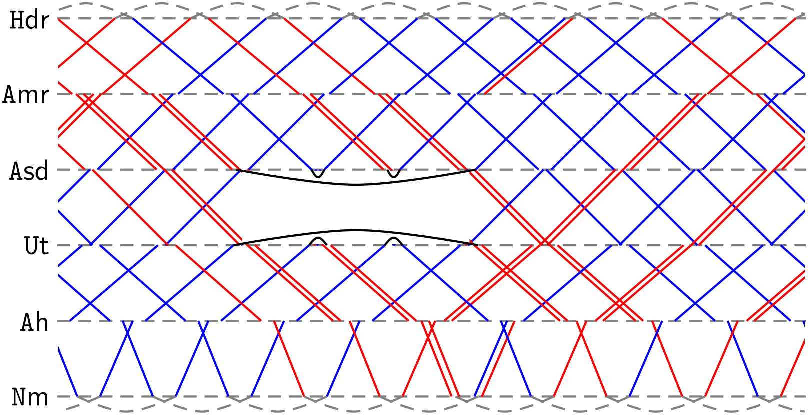
Example

Train length is adjusted at certain stations



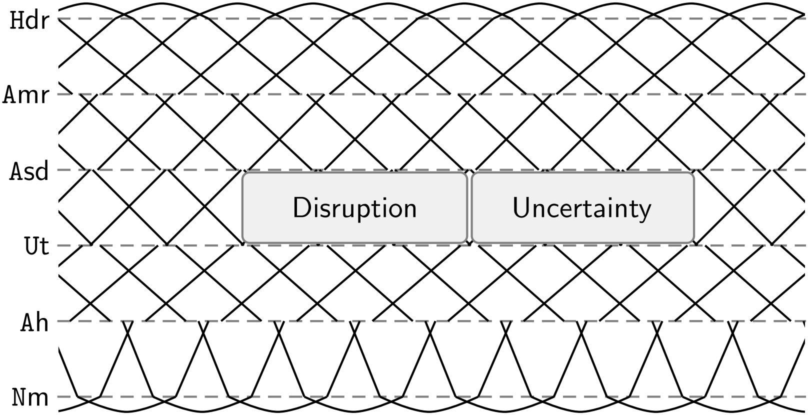
Example

Original rolling stock assignment is not feasible during disruption



Example

Uncertainty related to the disruption



The Online Rolling Stock Rescheduling Problem (Online RSRP)

Input:

- Original timetable $\mathcal{T}_0$.
- Original rolling stock circulation $\mathcal{C}_0$.
- Finite list of changes to the timetable,

$$\langle t_1, \mathcal{T}_1 \rangle, \ldots, \langle t_n, \mathcal{T}_n \rangle .$$

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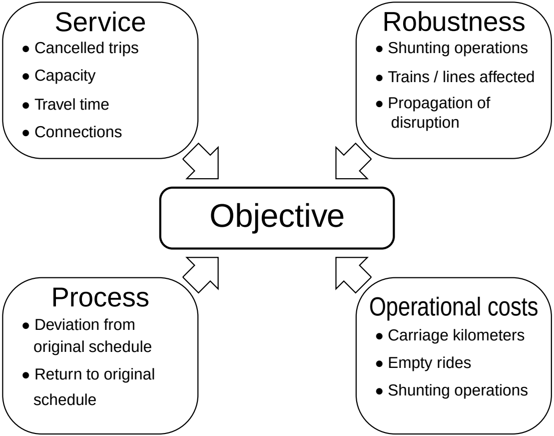
Objective:

- Minimize the deviation of $\mathcal{C}_n$ from $\mathcal{C}_0$.

Objectives

Perspectives of the overall managerial objective:



A model for RSRP at NS

Based on the MIP model by Fioole et al. (2006):

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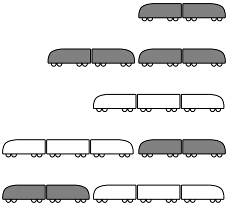
- For a trip r:

"0" $X_{r,0}$



X_{r,c_1}

X_{r,c_2}

X_{r,c_3}

X_{r,c_4}

X_{r,c_5}

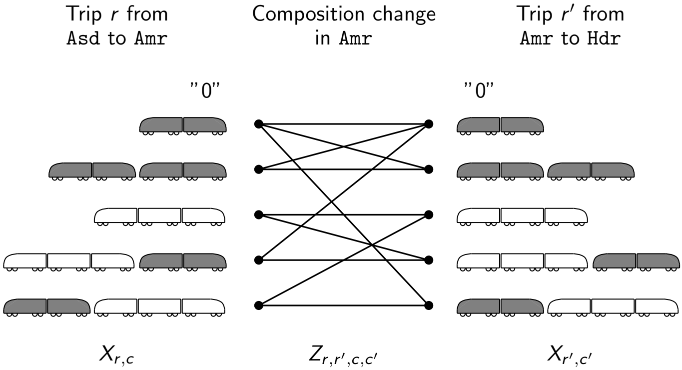
$\in \{0,1\}$

Subject to

$$\sum_{c} X_{r,c} = 1$$

A model for RSRP at NS

Composition changes between trips



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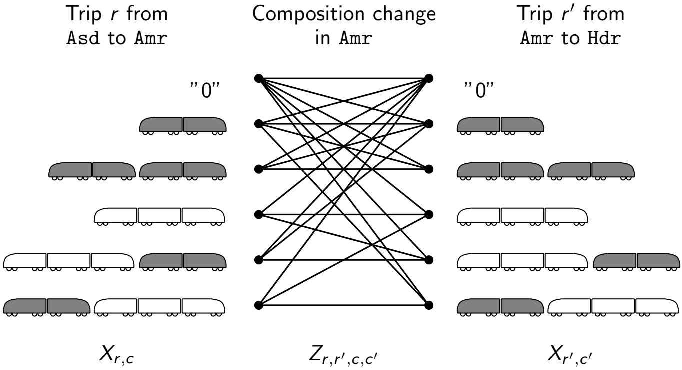

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Objective:

$$\min \sum_r w_r X_{r,0} + \sum_{r,r'} \sum_{c,c'} \gamma_{r,r',c,c'} Z_{r,r',c,c'} + \sum_s \sum_m \beta_m D_{s,m}$$

Cancellations

Off balances

Changed shunting operations

Problem decomposition

Observations:

- Computation time is a bottleneck.
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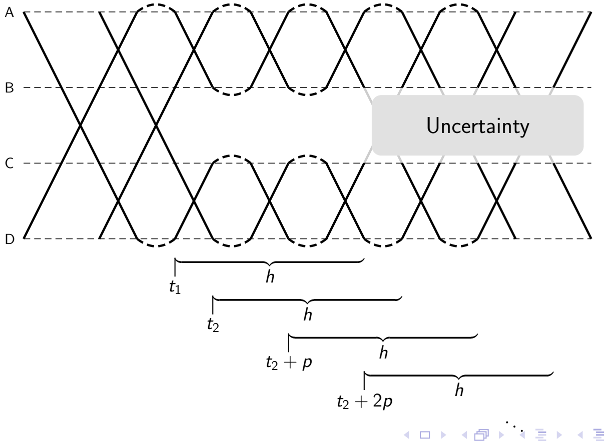
Rolling horizon approach:

- Only look h timesteps ahead.
- Revise whenever new information becomes available.
- If no new information is revealed, revise after p timesteps.

Rolling horizon approach



Accounting for off balances

- Off balances are counted at the end of the day.
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Heuristic approach:

- Observation: The original circulation has no off balances.
- Use the intermediate balances of the original circulation as a guideline.

Accounting for off balances

- Arguably the accuracy of this approach increases over time.
- When rescheduling at time t, multiply the cost of off balances by a factor $\rho(t)$:

$$\sum_{s} \sum_{m} \rho(t) \beta_m D_{s,m}$$

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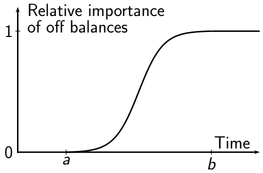

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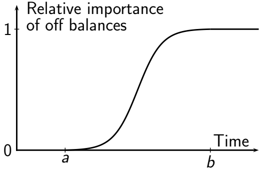
  - $\rho(t)$ depends on the time t at which the horizon ends.
  - Parameter a: When intermediate balances are taken into account.
  - Parameter b: Off balances are taken into account with full cost.



Computational tests

Test instances:

- Several disruptions in rolling stock circulations at NS are used.
- Each instance contains several timetable updates.

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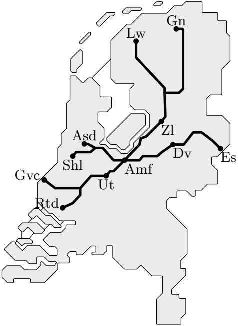
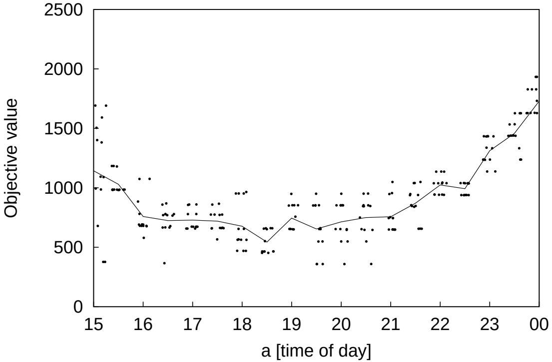
- Each instance contains several timetable updates.

- The presented results come from a number of instances involving the Noord-Oost lines.



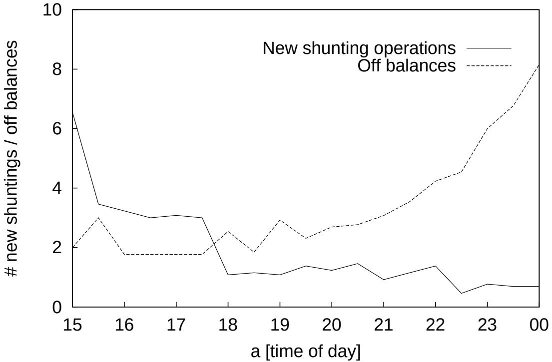
Parameters for the intermediate balances

Objective vs. when intermediate balances are taken into account.



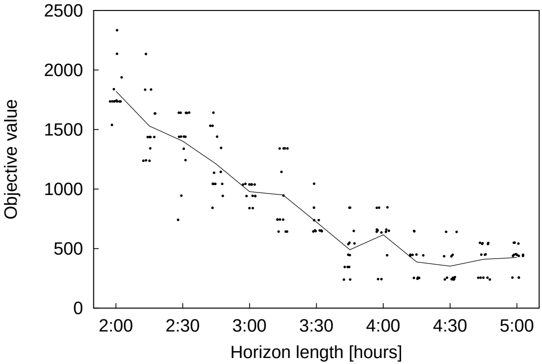
Parameters for the intermediate balances

Off balances/shunting operations vs. when intermediate balances are taken into account.



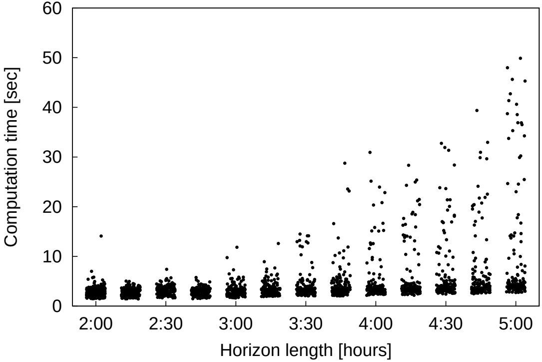
Parameters for the horizon

Objective vs. horizon length.



Computation time

Computation time vs. horizon length.



Conclusions

- Disruptions in the rolling stock schedules are modeled by the Online RSRP.
- A rolling horizon approach is used to reduce problem size.
- A model for generic rolling stock scheduling is adapted to the real time case at NS.
- Off balances are dealt with heuristically by comparing with the original circulation.
- The approach yields good results on instances from practice.
- Computation time depends on horizon length.