A personal history of railway operations research

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Outline

A personal history of railway operations research

- Event data mining
  - Past
  - Present
- Timetable stability
  - Past
  - Present
- Future
  - Closed-loop traffic management
Introduction

Train delays

- Initial delay
  - Late start or entry

- Primary delay
  - Disturbance

- Secondary delay
  - Path conflict

> Supplement

> Buffer time
Event data mining – Past

TNV-logfiles (1997)

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>08:00:00</td>
<td>TNV_DLM VTNR</td>
<td>103: Elementmelding aangaande DT$815BT toestand: BZ_ONBEZET.</td>
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</table>
Event data mining – Past

TNV-Prepare (1999)

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<tr>
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<th>Drg</th>
<th>Drg</th>
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<th>71T</th>
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<th>78</th>
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Mini-Symposium on Railway Operations Research
Event data mining – Past

Accuracy of online and registered arrival delays

Arrival IC2500 in Breda

Aantal treinen

-3 -2 -1 0 1 2 3 4 5

Aankomst volgens sectiebezetting - aankomst volgens NVGB (min)
Event data mining – Present

Train path realizations (TNV/TROTS)
Intermezzo – Blocking times

- Blocking time
- Block occupancy
- Sight and reaction time
- Approach time
- Running time
- Clearing time
- Release time
- Train length
- Conflicting predecessor
- Sight distance
- Distance
- Time
- Delay
Event data mining – Present

Occupation and blocking time realizations/conflicts

Scheduled stops

Blocking time

Track section occupancy (occupation and release time)
Timetable stability – Past

Timetable (time-distance diagram)
Timetable stability – Past

Events and precedence relations

Distance

Time
Timetable stability – Past

Events and precedence relations incl. min headway
Timetable stability – Past

Timed event graph = max-plus model

Arc weights are minimum process times

Event times are maximum of precedence relations and timetable
Timetable stability – Past

Delay propagation of 10 min delay IC2200 Dt-Rtd

Period
- 4
Timetable stability – Past

Critical circuits: minimum cycle time of timetable

- Minimum cycle time = maximum cycle mean (of critical circuit)

\[ \lambda = \max_C \frac{\text{Total minimum process time on cycle } C}{\text{Scheduled periods on cycle } C} \]

- Example 2007 timetable DONS data \( \lambda = 60:23 > 60 \), so unstable
- Realization data median \( \lambda = 59:26 \), 10th pct \( \lambda = 56:59 \) (5% slack)
Timetable stability – Present

Switching max-plus model
Timetable stability – Present

Switching max-plus model

Characteristics
- Change of event orders,
- Cancelled connections,
- Varying arc weights

Usage
- More flexibility,
- Apply control decisions

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Timetable stability – Present

Stochastic max-plus model
**Timetable stability – Present**

**Stochastic max-plus model**

Characteristics
Stochastic arc weights, Stochastic event times

Analysis
Delay propagation, Expected cycle time, Stationary delays
Future – Closed-loop traffic control

Predictive max-plus model from event data

- Passenger information
- Traffic control
- Actual timetable and route setting
- Railway operations
- Train descriptor
- Event time predictions
- Predictive traffic model
- Historical traffic database

Traditional feedback

Intelligent feedback
Future – Closed-loop traffic control

Conflict detection and resolution

Customer satisfaction

Model-predictive optimization

Delay prediction

Conflict detection

Real-time decision support

Communication actual timetable

Reordering, retiming, rerouting, Speed advise

IM, TOCs

Timetable, crews, rolling stock

IM, TOCs, Drivers

Customers

Train positions, resources

Railway operations

Model-predictive optimization

Train positions, resources

Real-time decision support

Communication actual timetable

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Train positions, resources

Railway operations
Conclusions

Key principles

• Planning
  - Aim at (real-time) conflict-free train paths
  - Use blocking times with precision in seconds
    - Conflict detection and feasibility proof
  - (Stochastic) stability analysis of integrated network timetables

• Support tools for efficient railway traffic management
  - Use live data streams as much as possible
  - Provide effective monitoring information on past and current situation
  - Support decision-making with intelligent model calculations
    - Conflict detection, delay prediction, train path feasibility
    - Dynamic railway traffic management
  - Automate routine tasks
    - Route setting from time-distance diagram
  - Communicate actual timetable to all parties involved