The application of OpenTrack in education and research at Delft University of Technology

Dr. Rob M.P. Goverde

Delft University of Technology
Faculty of Civil Engineering and Geosciences
Transport & Planning Department
r.m.p.goverde@tudelft.nl
Outline

The application of OpenTrack in education and research at Delft University of Technology

- Introduction
- MSc Course “Railway traffic management”
- MSc thesis projects
  - Capacity analysis
    - Single-run simulation
  - Dynamic traffic management
    - Multiple-run simulation
- Conclusions
Education

MSc Course Railway traffic management

• Theory
  • Railway timetables (design and analysis)
  • Railway traffic control (route setting, dispatching, rescheduling)
  • Safety and signalling systems, blocking time theory

• Practicum: OpenTrack exercises
  • Increase understanding of the theory of timetabling, capacity analysis and railway operations using simulation exercises
  • Given: infrastructure, engines & trains, itinaries, train line data
Education: given data

- Infrastructure The Hague – Gouda – Utrecht: 3 OpenTrack windows
- Train line data (direction The Hague – Utrecht only)
  - Three types, regular interval 30 min

<table>
<thead>
<tr>
<th>Train</th>
<th>Type</th>
<th>Units</th>
<th>Stops</th>
<th>Start</th>
<th>Dwell times</th>
</tr>
</thead>
<tbody>
<tr>
<td>1723</td>
<td>IC</td>
<td>2xICM3</td>
<td>Gvc-Vb-Ut</td>
<td>7:08</td>
<td>60</td>
</tr>
<tr>
<td>2025</td>
<td>IR</td>
<td>IRM4</td>
<td>Gvc-Ztm-Gd-Wd-Ut</td>
<td>7:16</td>
<td>60 (Wd 30)</td>
</tr>
<tr>
<td>9827</td>
<td>R</td>
<td>SGM3</td>
<td>Gvc-Vb-Ztm-Ztmo-Gd-Gdg</td>
<td>7:27</td>
<td>20</td>
</tr>
</tbody>
</table>
Education: OpenTrack exercises

- Exercise 1: Scheduling trains
  - Minimal running times, supplements, performance parameter
- Exercise 2: Simulating train runs, comparing schedule variants
  - Effect of track speed and stop pattern changes on running times
- Exercise 3: Capacity analysis
  - Minimum headway and capacity consumption (timetable compression)
- Exercise 4: Simulation of timetable disruptions
  - Signal failure (30 min), rolling stock breakdown (running at 40 km/h)
**MSc projects**

- **P.W. Vorage: Capacity analysis (2006)**
  - Rotterdam/The Hague – Gouda – Utrecht
  - Platform allocation Gouda

- **M. van Dijk: Dynamic railway traffic management (2006)**
  - Utrecht – ’s Hertogenbosch
  - Dynamic overtaking, control strategy (FCFS, FOFS), planning strategy

![Diagram of railway network and statistics]
Capacity analysis

- MSc project P. Vorage (2006)
- In cooperation with ProRail (Traffic Control)
- Rotterdam/The Hague – Gouda – Utrecht
- Timetable 2005 and concept 2007
Capacity analysis

- Minimal running times (100% performance) vs schedule (2005)
- Some unrealizable scheduled running times
- Varying running time supplements up to 25% (5:50, IC)
Capacity analysis

• Blocking time diagram
• Short headways, small buffer times, timetable not conflict-free
• ProRail issued congestion statement Rotterdam – Utrecht

- Tight headway IC-R (2 min) in Rotterdam
  - R accelerates quicker -> conflict in Rtn

- Slow speed of freight train (61 km/h) due to R train
  - Freight homogenized with stop pattern of R trains between Rotterdam – Gouda

- Conflict freight train with R train after stop Gdg
  - Scheduled headway 3 min in Gdg too short
  - Time loss due to acceleration after stop underestimated

- Too short headway (2 min) IC-R in Woerden
  - Hinder to R trains
  - Later departure R train possible
Capacity analysis

- Blocking time diagram (2007), on-time performance 85%
- Buffer time unevenly distributed
- Further homogenized traffic: IC’s have excessive supplements
Capacity analysis

Comparison basic hour pattern 2005/2007

- Rotterdam-Gouda: equal train intensity but capacity decreased
  - Homogenization of traffic
- The Hague-Gouda: increased train intensity and capacity consumption
  - Changed traffic mix (2 IC, 2 IR, 2 R) to (4 IC, 4 R)
  - Increased running time differences due to removed stop from IC train (Voorburg) and added stop to R train (Ypenburg)
- Gouda-Utrecht: increased train intensity and capacity consumption

<table>
<thead>
<tr>
<th>Line</th>
<th>2005</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tr/h</td>
<td>Buffer (min)</td>
</tr>
<tr>
<td>Rtd-Gd</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Gvc-Gd</td>
<td>6</td>
<td>28</td>
</tr>
<tr>
<td>Gd-Ut</td>
<td>12</td>
<td>16</td>
</tr>
</tbody>
</table>
Platform capacity consumption Gouda

- Timetable 2005
- Platform track occupation (upper) and blocking time (lower)
- Capacity consumption up to 60%
  - Platform track 8: 60% (6 trains), track 10: 20% (2 trains)
Platform capacity consumption Gouda

- Timetable 2007 (concept)
- Blocking time conflicts at platform tracks
- Uneven capacity consumption on tracks 8 (12 trains) and 10 (4 trains)
Platform capacity consumption Gouda

- Timetable 2007 (improved)
- Proposed adjusted allocation of platform 8 and 10
  - Platform 8: all 8 trains to Rotterdam
  - Platform 10: all 8 trains to The Hague
Platform capacity consumption Gouda

- Proposed adjusted routing and crossings Gouda Goverwelle (Gdg) and Gouda (Gd)

- Actual adjusted platform allocation (2007):
  - Platform 8: 10 trains (6 to Rotterdam, 4 to The Hague)
  - Platform 10: 6 trains (2 to Rotterdam, 4 to The Hague)
Dynamic railway traffic management

- MSc project M. van Dijk (2006)
- In cooperation with ProRail (Railway Development)
- Utrecht – ’s Hertogenbosch
- Timetable 2004 and future heavy traffic corridor model (6 IC + 6 R)

- Comparison of combinations of strategies
  - Infrastructure: number of overtaking locations
  - Planning: conventional versus recovery time savings
  - Control: order at overtaking locations (FCFS, FOFS)

- Multiple simulation required
  - Validation of initial delay and running time distributions
Validation

Reference situation
- Timetable 2004

Realization data (from train describer records)
- Departure delays input station (Utrecht)
- Running times Utrecht – s’ Hertogenbosch (including stops)
- Arrival delays output station ‘s Hertogenbosch (sum of the above)

Validation procedure
- Fit departure delay distribution input station (initial delays)
- Tune unhindered running times w.r.t. realization data
- Tune running of all trains
Validation

Tuning parameters (per train category)

- Initial delay
  - Delay probability
  - Mean delay (exponential distribution)
  - Maximum delay

- Running time
  - Delayed performance parameter (technical minimum running time)
  - On-time performance parameter (mean running time)
  - Scheduled arrival, departure and through times (delay measurements)

- Dwell time
  - Delay probability
  - Mean delay (exponential distribution) (per stop)
  - Maximum delay
Validation regional trains

Running time (R 19600)

- Delayed performance parameter
  - Technical minimum running time
- On-time performance parameter
  - Mean running time
- Dwell times
  - Minimum dwell time
  - Delay probability
  - Mean delay (exponential distribution)

Initial delay

- Straight-forward parameter estimates
  - Good fits between model and realizations

January 24, 2008

IT08.Rail OpenTrack Userworkshop
Validation IC trains

Running time (IC 8/900)
- Delayed performance parameter
  - Technical minimum running time
- On-time performance parameter
  - Mean running time
- No intermediate dwell times!
- Scheduled through times
  - Move between delayed/on-time running
- Difficult to smooth the two modes corresponding to delayed/on-time running

New feature (not yet in study)
- Performance distributions to model stochastic driver behaviour

January 24, 2008

IT08.Rail OpenTrack Userworkshop
Validation (all trains)

- Reference timetable 2004
- Varying values
- Delayed performance parameter 97%
- Mean dwell delay 20 s (for min dwell time 40 s)

<table>
<thead>
<tr>
<th>Train line</th>
<th>Intercity 3500</th>
<th>Intercity 8/900</th>
<th>Regional 6000</th>
<th>Regional 16000</th>
<th>Regional 19600</th>
<th>Regional 7101</th>
<th>Regional 7102</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-time perf. (%)</td>
<td>87</td>
<td>83</td>
<td>88</td>
<td>80</td>
<td>83</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Delayed perf. (%)</td>
<td>97</td>
<td>97</td>
<td>97</td>
<td>97</td>
<td>97</td>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td>Mean initial delay (s)</td>
<td>80</td>
<td>95</td>
<td>94</td>
<td>49</td>
<td>71</td>
<td>19</td>
<td>164</td>
</tr>
<tr>
<td>Max initial delay (s)</td>
<td>1600</td>
<td>1800</td>
<td>1500</td>
<td>1200</td>
<td>900</td>
<td>1500</td>
<td>1300</td>
</tr>
<tr>
<td>Prob. initial delay (%)</td>
<td>60</td>
<td>60</td>
<td>65.5</td>
<td>46</td>
<td>49</td>
<td>31</td>
<td>97</td>
</tr>
<tr>
<td>Min dwell time (s)</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>Mean dwell delay (s)</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>0</td>
<td>20</td>
</tr>
</tbody>
</table>
Comparing strategies

Traffic
- Timetable 2004 (4 IC + 4 R)
- Heavy traffic corridor (6 IC + 6 R)

Planning
- Conventional feasible timetable
- Saving recovery times (regional trains depart as early as possible)

Control (order at overtaking locations)
- First Come First Served (FCFS)
- First Out First Served (FOFS)
  - The train that will first reach the next overtaking location goes first

Infrastructure
- Number of overtaking locations
  - Houten, Geldermalsen, Zaltbommel at about ¼, ½ and ¾ distance
  - In reference timetable 2004 Geldermalsen is overtaking station
Comparing strategies (results)

Performance criteria

- Running times
- Capacity consumption
- Number of route conflicts (restricted signals, safety)

Timetable 2004

- Saving of recovery times + FOFS
- Overtaking in Geldermalsen sufficient

Heavy traffic (6 IC + 6 R)

- Saving of recovery times + FCFS + 2 overtaking locations (Ht, Gdm)
Conclusions

• New MSc project (start 1 February 2008)
  • Validation of OpenTrack
  • In cooperation with Movares railway consultancy

• Future intentions
  • Together with ProRail and Dutch railway consultancies
  • Automatic import from Dutch infrastructure database
  • Validated railway simulation tool