Stochastic micro-simulation as a timetable robustness estimation tool

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Introduction

- Growing importance of precision in planning process
- Trade off capacity-punctuality
- Wide range of real-world collected data
- Micro-simulation can consider most stochastic phenomena

Ex-ante timetable robustness evaluation
  - Point out critical points and suggest dispatching rules
  - Evaluation of headway times
Outline

- Approach
- Timetable robustness measures
- New reliability indicator
- Model calibration
- Case study: Torino
Approach

- Real Traffic Analysis
- Model Calibration
- Dense timetable (Fiche UIC 406)
  - real train mix
  - running times with no supplements
- Variable buffer times and supplements are inserted
- Multiple stochastic simulations
- Simulation output analysis
New reliability indicator

Frequency of Delay Index ($F$)
New reliability indicator

<table>
<thead>
<tr>
<th>Train Family</th>
<th>Station</th>
<th>Arr/Dep</th>
<th>10</th>
<th>30</th>
<th>50</th>
<th>70</th>
<th>90</th>
<th>P</th>
<th>F</th>
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Micro-simulation as timetable robustness estimation method

Data flow

Planned timetable

Real traffic data (timetable points)

Train event recorder archives

Planned
- Timetable
- Calendar
- Rolling stock

Macro
- Corridor analysis
- Distributions: departure, arrival, running time, stop time

Micro
- Train analysis
- Acceleration, real speed, breaking curves, stop time

Train motion equation parameters, breaking curves

railML

Stochastic distributions

Stochastic simulations

OPEN TRACK
# "Micro" Analyzer

<table>
<thead>
<tr>
<th>Acceleration</th>
<th>Acceleration Percentage</th>
<th>Distributions</th>
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<tbody>
<tr>
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<td>Gradients</td>
<td>Running Time Calculator</td>
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<td>Tractive Effort/Speed Curve</td>
<td>On Time / Delay</td>
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<td>Gradients</td>
<td>On Time / Delay</td>
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<td>Planned BWP</td>
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<th>Stop Time</th>
<th>Distributions</th>
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<td>On Time / Delay</td>
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Acceleration Analysis

![Graph showing acceleration analysis with different curves representing various speeds and distances.](image)
Case Study: Torino Node

- 180 km line, different interlocking systems
- Various train mix
- Frequent perturbations due to node saturation or delayed trains from Milan
Torino Node: Results

![Graph showing Mean Delay at the last station vs Mean Initial Delay (all trains)](image)

- **February 2008**
- **December 2007**

Legend:
- R 4000s
- IC 600s
- R 2000s
- R 20000s

Micro-simulation as timetable robustness estimation method
Dense Timetable

Micro-simulation as timetable robustness estimation method
Compensation of stochastic phenomena

- Buffer times
- Supplements
  - distributed
  - concentrated
- stop time
Buffer times and running time supplements

Arrival % with less than 3' delay as a function of buffer times and supplements

![Graph showing the relationship between buffer times and running time supplements and the percentage of arrivals with less than 3' delay. The graph includes data points for different buffer times (0, 30, 60, 90, 120) and running time supplements.](image-url)
Buffer time and initial delay

Delay propagation as a function of initial delay and buffer times

Initial Delay
- 30
- 60
- 90
- 120
- 180

Mean Arrival delay (s)

Buffer time (s)
Conclusions and outlook

- Very precise traffic representation
- Combination of “micro” and “macro” data
- Relationship between various parameters
- Search for a capacity - stability equilibrium

- Various block and ATP Systems
- Fit of resulting curves to obtain rules
- Other case studies
thank you for your attention!

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