Examination of operation quality for high-frequent railway operation

Alex Landex, al@transport.dtu.dk
Anders H. Kaas, Anders.H.Kaas@atkinsglobal.com
Agenda

• Traditional assessment of punctuality

• Operation quality for high-frequent railway operation
  – Service frequency
  – Travel time
  – Combined approach
  – Passenger delay model

• Overview

• Conclusions
Traditional statement of punctuality

• When is a train delayed?
  - Danish S-train 2½ minutes
  - The Netherlands 3 minutes (departure)
  - Germany 5 minutes (line end station)
  - Danish Regional and Intercity trains 6 minutes
  - Danish freight trains 10 minutes
  - Great Britain 5 and 10 minutes respectively
  - AmTrack dependent on the length of the train route (not length of passengers’ route)

• When are the trains registered?
  - Arrival at station
  - Departure from station
  - Arrival at line end station

• Goal for punctuality
  - Denmark 90%
    • S-train 95%
  - The Netherlands 90%
  - AmTrack – Long distance 70%
  - AmTrack – Short distance 85%
  - AmTrack – Corridor trains 90%
  - AmTrack – Premium trains 94%
  - AmTrack – Contract based commuter trains 95%
Punctuality

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10-02-2009
Traditional assessment of punctuality

Advantages
- Low complexity
- Only planned and realized timetables are required

Disadvantages
- Not well-suited for high-frequent operation
- Travel time not taken into account
Service frequency

- Planned number of trains
- Simulated number of trains in case of disturbances

<table>
<thead>
<tr>
<th>Time interval</th>
<th>Planned</th>
<th>Simulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-8</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>8-9</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>9-10</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>10-11</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>11-12</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>12-13</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>13-14</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>14-15</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>15-16</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Difference</td>
<td>15</td>
<td>10</td>
</tr>
</tbody>
</table>
Long time intervals can hide fluctuations

- Planned number of trains
- Realized number of trains

10 minutes delay of the train planned to depart 9:00
Too short intervals

![Bar chart showing the planned and realized number of trains per time interval. The chart indicates that there are too short intervals between trains, with a higher realized number of trains compared to the planned number for most time intervals.]

- Planned number of trains
- Realized number of trains
## Service frequency

### Advantages
- Low complexity
- Reliability taken into account
- Requires the realized timetable only

### Disadvantages
- Works for high frequent operation only
- Travel time not taken into account
- The examined railway line only can be taken into account – not the entire network
- The time intervals are crucial
Travel time
Time supplements vs. no supplements

![Graph showing the comparison between timetable with supplements and without supplements.](image)

- **Accumulated Probability** vs. **Running time**
- **Minimum running time** and **Scheduled running time for train with supplements**
- **Timetable without supplements** (solid line)
- **Timetable with supplements** (dashed line)

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10-02-2009
Travel time delays

Station A

δrt_{A,B}=30s

Δrt_{A,B}=-30s

Station B

δrt_{B,C}=30s

σrt_{B,C}=55s

Δrt_{B,C}=55s

Δrt_{A,C}=25s

Station C

δrt_{C,D}=30s

Δrt_{C,D}=-30s

Δrt_{A,D}=25s

Δrt_{A,D}=-5s

Station D

σrt: delay

δrt: time supplement

Δrt: time difference from published timetable
Travel time

Advantages
- Low complexity
- Requires the realized timetable only
- Travel time is taken into account

Disadvantages
- Works best for high frequent operation
- Frequency not taken into account
- The examined railway line only can be taken into account - not the entire network
Combined approach

The service frequency and travel time approaches can be combined
- Combined approach

**Advantages**
- Low complexity
- Reliability taken into account
- Travel time is taken into account
- Requires the realized timetable only

**Disadvantages**
- Works best for high frequent operation
- The examined railway line only can be taken into account – not the entire network
- The time intervals are crucial
Passenger delay models

- **0\(^\text{th}\) generation**
  - Train delay multiplied with the amount of passengers

- **1\(^\text{st}\) generation**
  - Route choice model
  - Full knowledge

- **1½ generation**
  - Route choice model
  - Full knowledge is achieved when the passengers arrive at the station

- **2\(^\text{nd}\) generation**
  - Passengers know the delay distributions and take this into account when considering their route according to 1st generation models

- **3\(^\text{rd}\) generation**
  - Passengers plan their route according to the planned timetable
  - Passengers reconsider their route at that point in time and space where a certain threshold of delay is achieved
  - When passengers reconsider their route full knowledge is assumed
<table>
<thead>
<tr>
<th>Considerations of passenger delays</th>
<th>Train delays (0\textsuperscript{th} generation)</th>
<th>Cross-section delays (0\textsuperscript{th} generation)</th>
<th>Counting train delays (0\textsuperscript{th} generation)</th>
<th>Optimal route choice model (1\textsuperscript{st} generation)</th>
<th>1\textsuperscript{½} generation mode</th>
<th>Passenger delay model (2\textsuperscript{nd} generation)</th>
<th>Passenger delay model (3\textsuperscript{rd} generation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complexity of the method</td>
<td>Very simple</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Needs of information on passenger demand</td>
<td>No</td>
<td>Average alighting passengers</td>
<td>Counted passengers</td>
<td>OD matrix</td>
<td>OD matrix</td>
<td>OD matrix</td>
<td>OD matrix</td>
</tr>
<tr>
<td>Passengers may predict delays in the future (full information is assumed)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Partly</td>
<td>Can be incorporated</td>
</tr>
<tr>
<td>Passengers may arrive before time if a better connection emerges</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Very low</td>
<td>Quite low</td>
<td>Fairly low</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Bias</td>
<td>Mostly underestimates delays</td>
<td>Will quite often underestimate delays</td>
<td>Will fairly often underestimate delays</td>
<td>Large underestimation of delays</td>
<td>Underestimates delays</td>
<td>No systematic bias</td>
<td>No systematic bias</td>
</tr>
</tbody>
</table>
3rd generation passenger delay models

Calculation of optimal route and the time usage by use of a route choice model on the planned timetable

Storage of the passengers “planned” routes

Calculation of time usage by route choice model on realised timetable. The passengers follow – as far as possible – their “planned” route

Difference in time

Passenger delay
Coupling of the passenger delay model with railway operation simulation tools

Evaluation

Passenger delay model

Simulation

Infrastructure

Train regularity [%]

Passenger regularity [%]

Arrivals before time [%]

Timetable

Examining operation quality for high-frequent railway operation
Simulated passenger delays

- Cross section delays
- Train delays
- 1st generation model
- 3rd generation model

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Passenger delay approach

**Advantages**
- Takes the passengers’ experience into account
  - 3rd generation models are at present the most advanced models in daily use
- Can be used for evaluation of both high and low frequent operation
- Can include both a single railway line or the entire network
  - Includes transfers
- Additional information about inconveniences for passengers
  - e.g. unscheduled transfers

**Disadvantages**
- Data intensive
  - Planned timetable
  - Realized timetable
  - Origin-Destination matrix divided into time intervals
- High degree of complexity
- Requires calibration of the model
### Overview

<table>
<thead>
<tr>
<th>Service frequency</th>
<th>Travel time</th>
<th>Combined approach</th>
<th>Passenger delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Reliability</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>In vehicle time</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Total travel time</td>
<td>No</td>
<td>No</td>
<td>Rough estimate</td>
</tr>
<tr>
<td>Capacity restrictions</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Complexity</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Required data</td>
<td>Realized timetable</td>
<td>Realized timetable</td>
<td>Realized timetable</td>
</tr>
<tr>
<td>Include transfers</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Entire network</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Low frequency</td>
<td>Partly</td>
<td>Partly</td>
<td>Partly</td>
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<tr>
<td>Changed route choice</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Load factor of trains</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Future operation</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Precision</td>
<td>Low</td>
<td>Low</td>
<td>Below medium</td>
</tr>
</tbody>
</table>
Conclusions

• “Traditional” assessments of punctuality is not the best method for high-frequent railway operation

• Simple approaches to assess operation quality for high-frequent operation
  – Service frequency
  – Running time
  – Travel time

• Operation quality does not necessarily reflect passengers’ experience

• 3rd generation passenger delay models reflects passengers’ experience the best
  – Can be used for all frequencies
  – Can examine the entire network as well as a particular railway line
  – Can be combined with railway operation simulation software to guesstimate future delays
  – Data intensive
Thank you for your attention

Alex Landex
Technical University of Denmark
Department of Transport
al@transport.dtu.dk