Improving passenger robustness by taking passenger numbers and recurring delays explicitly into account on the tactical level

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Objective

Improving passenger robustness

- Short travel times
- Reliability

Minimizing total weighted real travel time of all passengers in case of frequently occurring small delays
Framework

We focus on the tactical level: timetable – routing plan – platform assignment

busy railway station areas

small daily delays
Approach

**Optimization algorithm**

strives to maximize
the sum of the minimal buffer times
between all trains in a fixed time window

↓

indirectly improves passenger robustness
of an existing timetable

**Simulation**

directly evaluates passenger robustness
Optimization algorithm
Optimization algorithm

Routing module exact: based on a NPP

\[
\begin{align*}
\min & \quad \sum_{(t,r) \in T \times R_t, (t',r') \in T \times R_{t'}} \frac{1}{B(t,r),(t',r')} x(t,r) x(t',r') \\
\sum_{r \in R_t} x(t,r) &= 1 & \forall t \in T \\
x(t,r) + \sum_{r' \in R_t} x(t',r') &\leq 1 & \forall (t,r) \in T \times R_t, t' \in T \setminus \{t\} \\
x(t,r) &\in \{0,1\} & \forall (t,r) \in T \times R_t
\end{align*}
\]
## Optimization algorithm

<table>
<thead>
<tr>
<th>Module</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routing module</td>
<td>exact: based on a NPP</td>
</tr>
<tr>
<td>Timetabling module</td>
<td>local search heuristic (tabu search): shift – combined shift - swap</td>
</tr>
<tr>
<td>Platforming module</td>
<td>local search heuristic (tabu search): platform change</td>
</tr>
</tbody>
</table>

Interaction between modules
Some buffer times are more important than others

Passenger numbers

1000 passengers
5 passengers

Recurring delays

- 1 min
2 min
3 min
Weighted buffer times

Passenger numbers (absolute)

number of passengers that are on the second train or will board on the second train after the place of the shortest buffer time

\[
\min \sum_{(t,r)\in T\times R_t; (t',r')\in T\times R_{t'}} \frac{N}{B(t,r),(t',r')} x(t,r)x(t',r')
\]
Weighted buffer times

Recurring delays (relative)
the ratio of
the planned and expected buffer time

\[
\min \sum_{(t,r) \in T \times R_t; (t',r') \in T' \times R_{t'}} \frac{B_{(t,r),(t',r')}}{B_{(t,r),(t',r')}}^\text{expected} \frac{1}{B_{(t,r),(t',r')}} x_{(t,r)} x_{(t',r')}
\]
Case study
## Results

<table>
<thead>
<tr>
<th>Timetable</th>
<th>Ref</th>
<th>No weights</th>
<th>P</th>
<th>D</th>
<th>P · D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger robustness</td>
<td>$4.15 \cdot 10^6$</td>
<td>$3.84 \cdot 10^6$</td>
<td>$3.77 \cdot 10^6$</td>
<td>$3.72 \cdot 10^6$</td>
<td>$3.68 \cdot 10^6$</td>
</tr>
<tr>
<td>% improvement</td>
<td>7.47%</td>
<td>9.16%</td>
<td>10.36%</td>
<td></td>
<td>11.33%</td>
</tr>
<tr>
<td>Total knock-on delay per hour for all trains</td>
<td>211.53</td>
<td>145.31</td>
<td>142.17</td>
<td>136.38</td>
<td>138.40</td>
</tr>
<tr>
<td>% improvement</td>
<td>31.30%</td>
<td>32.79%</td>
<td>35.53%</td>
<td></td>
<td>34.57%</td>
</tr>
<tr>
<td>Percentage extra delayed trains</td>
<td>47.71%</td>
<td>37.36%</td>
<td>38.53%</td>
<td>36.98%</td>
<td>37.66%</td>
</tr>
</tbody>
</table>
Conclusion

We further improve passenger robustness up to 11% by taking passenger numbers and recurring delays explicitly into account on the tactical level.

Future research

More delay scenarios (dwell delays)
Taking transferring passengers into account
Constructing a timetable and routing plan from scratch