Optimal Tamping for Railway Tracks
- Reducing Railway Maintenance Expenditures by the Use of Integer Programming

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Agenda

• Introduction
  – Preventive condition-based maintenance
  – Current challenges

• A Danish railway corridor

• The previous study and our approach

• Results and Conclusions
Introduction

• Railway maintenance is critical
  - Safety, train punctuality and overall capacity utilization

• Track maintenance covers five main operations
  - Track quality measuring;
  - **Tamping**
    - Rail grinding
    - Replacement of rails, sleepers and fastenings
    - Ballast cleaning, profiling and stabilization
Introduction

• Tamping is the most important track quality control but
  – Costly (30 – 100 k Euro per km per year)
  – A complex and critical task
    • Track alignment
    • Climatic conditions
    • Rolling stock conditions
    • Budgets and priorities
    • Resources availability etc.
Introduction

• The challenges
  – Track degradation
  – Alignment etc.


P. Veit (2007)
Case Study: Odense–Fredericia (Od-Fa)

- Key figures
  - Double track
  - 57.2 km (9 stations)
  - Main line (max: 180 km/h)
  - Passengers & Freights
  - UIC60 rails
  - 5 types of sleepers
  - 2 types of sub-structures
Initial Track Quality and Alignment
Track Degradation & Recovery after Tamping

Degradation: Linear

Recovery: $w_i^t = 0.63\sigma_i - 0.26$
The pre-Model

- Minimize the number of tamping
  - Not always cheap!
Why minimum N <> minimum Cost

Running

Ramping up

Ramping down

Tamping

Tamping Machine
Our Model

- Minimize the tamping costs (time)

\[
\text{min} \sum_{i \in I, t \in T} c \cdot x_i^t + \sum_{t \in T} f \cdot z_t + \sum_{i \in I, t \in T} s \cdot y_i^t
\]

- Tamping cost
- Ramping up/down cost
- Running cost
## Result

<table>
<thead>
<tr>
<th>Model</th>
<th>N</th>
<th>T</th>
<th>Total Number of Tamping</th>
<th>Total Costs in minutes</th>
<th>Computing Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimizing Tamping Cost</td>
<td>220</td>
<td>12</td>
<td>55</td>
<td>1,545</td>
<td>26m</td>
</tr>
<tr>
<td>Optimizing Tamping Amount</td>
<td>220</td>
<td>12</td>
<td>52</td>
<td>3,116</td>
<td>04m</td>
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</tbody>
</table>
Discussions

- Continuous tamping is better than tamping-driving-tamping by integrating the meddle section.
  - Cheaper with one more tamping
Discussion

- Tactical planning is better than looping yearly planning

<table>
<thead>
<tr>
<th>Scenario</th>
<th>N</th>
<th>T</th>
<th>Number of Tamping</th>
<th>Total Costs</th>
<th>Computing Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Looping yearly planning</td>
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<td>4+4+4</td>
<td>56</td>
<td>1,637</td>
<td>1m</td>
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<tr>
<td>Tactical planning</td>
<td>220</td>
<td>12</td>
<td>55</td>
<td>1,545</td>
<td>26m</td>
</tr>
</tbody>
</table>
Conclusion

• This paper presented a mathematical model for
  – Scheduling the predictive railway tamping, based on
  – Condition-based preventive tamping process

• Minimizing the tamping cost gives better result
  than minimizing the number of tamping

• Predictive tamping planning is more optimal
  scheduling than looping yearly planning.
Thank You