Evaluation of long-term maintenance of switches & crossings with respect to life-cycle costs and socio-economic impact

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OUTLINE

1. Background
2. Focus & Aim
3. Methodology
4. Preliminary analysis
5. Conclusions
1. BACKGROUND

- **Maintenance of switches and crossings (S&Cs)** is a (necessary) requirement for good quality freight and passenger train services.

- An **efficient** maintenance of S&Cs **minimizes the (socio-economic) costs** over the life cycle of the asset, i.e., LCCs.

- LCCs are affected by:
  - Train **traffic** (type of traffic, traffic volume, etc.)
  - Design of the **infrastructure** (type of switch, components, etc.)
  - **Maintenance** strategy
    - **What** measures (e.g., grinding, track direction) have been performed?
    - **When/How often** were the measures performed?
2. FOCUS & AIM

- The project focuses on **standard turnout S&Cs** and aims to analyze dependencies between:
  - **Maintenance** strategies (with a focus on **rail grinding** and **track alignment**)  
  - Expected **socio-economic effects** over the life cycle

- The goal is to:
  - Calculate LCCs of different **maintenance strategies** (preventive/corrective)
  - Find **more efficient** maintenance strategies for S&Cs
2. METHODOLOGY

a) Overview
b) Mechanical simulation
c) LCC modeling
d) Maintenance strategies
e) Preventive & corrective measures
a) OVERVIEW

• The methodology is based on two main components:

  • **Component 1**: Simulation of the damage evolution in S&C for different maintenance strategies to investigate the relationship between maintenance status and damage development at S&C

  • **Component 2**: LCC modeling to calculate the socio-economic costs of a particular maintenance strategy over the S&C life cycle
b) MECHANICAL SIMULATION

- The dynamic vehicle-S&C interaction and resulting mechanical damage over time in S&C is investigated by means of simulation.

- The goal is to investigate the relationship between:
  - the maintenance measures, i.e., track tamping & rail grinding
  &
  - the development of mechanical damage, i.e., in the form of track irregularity (misalignment) and contact geometry degradation.
b) **MECHANICAL SIMULATION**

- Simulation of accumulated S&C damage using iterative Whole System Model scheme
- The simulations will be performed for different maintenance interventions to compare long-term performance

**Dynamic vehicle-track interaction**

- Simulation output
- Updated damage state
- Damage modelling
  - Running surface
  - Ballast settlement
  - Sleeper & crossing bending loads (fatigue risk)
c) LCC MODELING

- LCCs cover different **phases** and **costs/benefits**, e.g.,
  - Maintenance, replacement and operations, etc.
  - Costs (labor, traffic loss, etc.) or benefits (increased traffic reliability, etc.)
- A model of the total **LCCs** (noted $TSEC$) is

\[ TSEC = CML + LTP - GTP \]

<table>
<thead>
<tr>
<th>Phase of the life cycle</th>
<th>Socio-economic costs (-) and benefits (+)</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance (or replacement)</td>
<td>(-) Costs of material and labour</td>
<td>$CML$</td>
</tr>
<tr>
<td></td>
<td>(-) Loss in potential traffic production</td>
<td>$LTP$</td>
</tr>
<tr>
<td>Operations</td>
<td>(+) Gain in future traffic production (quality)</td>
<td>$GTP$</td>
</tr>
</tbody>
</table>
d) MAINTENANCE STRATEGIES

- The impact of maintenance and operations on LCCs are closely dependent on the adopted maintenance strategy.

- Different strategies (preventive/corrective) have different characteristics (requirements & consequences).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Preventive (proactive)</th>
<th>Corrective (reactive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>Requires more knowledge about the assets (e.g., frequent inspections)</td>
<td>No knowledge is required</td>
</tr>
<tr>
<td>Traffic</td>
<td>Pre-planned and less expensive losses of traffic (e.g., maintenance windows)</td>
<td>Unplanned and more expensive losses of traffic (e.g., delay, accidents)</td>
</tr>
<tr>
<td>Work</td>
<td>Shorter and less expensive maintenance work (labour and material)</td>
<td>Longer and more expensive maintenance work (unplanned, time pressure, etc.)</td>
</tr>
</tbody>
</table>
e) PREVENTIVE & CORRECTIVE

• To model (among others) the relation between
  • (Performed) **preventive** measures
  • (Need for) **corrective** maintenance

• A regression analysis is performed
  • **Corrective** represent, e.g., #failures
  • **Preventive** represent, e.g., #preventive maintenance measures.

• **X** holds selected important variables related to
  • Traffic (volume, type of traffic, axle load, etc.)
  • Infrastructure (type/model of S&Cs, etc.).
3. PRELIMINARY ANALYSIS

a) Databases
b) Data (& KOMBI)
c) Key S&C
d) Life cycle
e) Case study
a) DATABASES

- The relevant databases are managed by Trafikverket
- Data are available for different assets, here only related to S&C are selected

<table>
<thead>
<tr>
<th>Database</th>
<th>Content</th>
<th>Time (interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIS</td>
<td>Infrastructure</td>
<td>In 2021, also in 2014</td>
</tr>
<tr>
<td>Bessy</td>
<td>Inspections</td>
<td>Between 2014 and 2021</td>
</tr>
<tr>
<td>Ofelia</td>
<td>Failures/delays</td>
<td>Between 2014 and 2021, also from 2003</td>
</tr>
<tr>
<td>Lupp</td>
<td>Train traffic</td>
<td>During 2017</td>
</tr>
</tbody>
</table>
### a) DATA (& KOMBI)

<table>
<thead>
<tr>
<th><strong>Data(bases)</strong></th>
<th><strong>Main content (columns)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure 2021 (BIS)</td>
<td></td>
</tr>
<tr>
<td><strong>Replacement date</strong></td>
<td><strong>Object number</strong></td>
</tr>
<tr>
<td><strong>S&amp;Cs number and model</strong></td>
<td><strong>Location, track</strong></td>
</tr>
<tr>
<td><strong>Maximum allowed speed</strong></td>
<td></td>
</tr>
<tr>
<td>Inspections 2014-2021 (Bessy)</td>
<td></td>
</tr>
<tr>
<td><strong>Date</strong></td>
<td><strong>S&amp;Cs number and model</strong></td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td><strong>Inspection type</strong></td>
</tr>
<tr>
<td><strong>S&amp;Cs Component</strong></td>
<td><strong>Recommended action</strong></td>
</tr>
<tr>
<td>Failures 2014-2021 (Ofelia)</td>
<td></td>
</tr>
<tr>
<td><strong>Date</strong></td>
<td><strong>Object number</strong></td>
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<td><strong>S&amp;Cs number and model</strong></td>
<td><strong>S&amp;Cs Component</strong></td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td><strong>Disturbed trains</strong></td>
</tr>
<tr>
<td><strong>Delay</strong></td>
<td><strong>Recommended action</strong></td>
</tr>
<tr>
<td>Train traffic 2017 (Lupp)</td>
<td></td>
</tr>
<tr>
<td><strong>Departures &amp; arrivals</strong></td>
<td><strong>Traffic type</strong></td>
</tr>
<tr>
<td><strong>Train vehicles</strong></td>
<td><strong>Train load &amp; km</strong></td>
</tr>
</tbody>
</table>

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### Diagrams

- **BIS @2021**
  - Inläggningsdatum (>2014)
  - Objnr
  - Valnr
  - Plats (Bandel-km)

- **Inspections - Bessy (2014-2021)**
  - Datum
  - Typ (korrektiv/preventiv/underhåll/special/?)
  - Valnr
  - Objnr
  - Plats (Bandel-km)

- **Failures 2014-2021 (Ofelia)**
  - Datum
  - Objnr
  - S&Cs number and model
  - S&Cs Component
  - Location
  - Disturbed trains
  - Delay
  - Recommended action

- **Train traffic 2017 (Lupp)**
  - Departures & arrivals
  - Traffic type
  - Train vehicles
  - Train load & km

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### Notes

- Link using **Objnr**
- Link using **Valnr**
- Link using **Plats** (Bandel-km)
b) **KEY S&C**

- Focus on model **60E-R760-1:15**
- **Spatiotemporal** distribution of S&Cs
- Focus on S&Cs **replaced in 2014**
- Failures and **delays** statistics
- **#observations** (inspections, maintenance measures)
- Train traffic

➔ **Vxlnr 133 in Kimstad**
c) LIFE CYCLE (OF THE SELECTED KEY S&C)

Timeline (2014-2021) of the life cycle of the selected S&C

<table>
<thead>
<tr>
<th>Alignment</th>
<th>Failure</th>
<th>Alignment</th>
<th>Failure</th>
<th>Inspection</th>
<th>Inspection</th>
<th>Failure</th>
<th>Alignment</th>
<th>Grinding</th>
</tr>
</thead>
</table>

Alignment
4. CONCLUSIONS

a) Highlights

b) Next steps
a) HIGHLIGHTS

• A **methodology** combining different approaches (simulation, regression & LCA) for the evaluation of long-term maintenance of S&Cs

• Consideration of **socio-economic impacts** in the LCCs

• Linking different data sources into a **combined database** for use in similar LCC studies

• Identifying **key S&Cs** with regards to different characteristics (model, #obs, traffic, etc.)

• **Timeline** of selected S&Cs for LCA
b) NEXT STEPS

- Mechanical simulations
  - Degradation of S&Cs
- Regression analysis
  - Effect of preventive measures on corrective maintenance
- LCC model combining the simulation results and regression output
  - Evaluation of the LCCs including the socio-economic impacts
  - Comparison of different maintenance strategies for S&Cs
Thank you for your attention!
Question?

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