Optimum Allocation and Utilisation of track possession time: A case study of tamping

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Introduction to project

Capacity assessment of Swedish transport administration network

Maintenance improvement Framework
Introduction to article

• Railway transport is expected to be competitive and sustainable transportation.
• Competitiveness requires increase in quantity (capacity) and quality of service.
• Sustainability ensures tomorrow’s competitiveness is not limited by present performance.
Research Question

• Decision support for allocation and utilisation of track possession time (efficiency).

• Strategy to support quality (effectiveness) and sustain quality of track.

Track strategy = Investment strategy + Maintenance strategy

Existing infrastructure
Railway Track Behavior

• Patience? During a period of inadequate maintenance, it is a relatively long time before the track shows signs of stress.

• Anger? The track reacts badly & irreversibly to a prolonged maintenance deficiency and could result into undesired consequence.

• Should we understand it then we can manage it - Track geometry geometry parameters map this behavior.

Conventional or derived parameter
Railway track behavior

- Track geometry quality EN 13848 1-6

![Diagram with models and techniques]

- Track quality estimation/prediction
  - Trend
    - Grey Model
    - Linear Model
    - Exponential Model
  - Randomness
    - Markov Model
    - Fourier Transform
    - Artificial intelligence
    - Smoothening technique
Track geometry prediction

- Good track quality deteriorates slowly while poor one does rapidly

\[ \frac{\Delta \sigma}{\sigma} = b \]
\[ \frac{d\sigma}{dt} = b\sigma \]

*solving the differential equation*

\[ \sigma = \sigma_0 e^{bt} \]
Existing tamping strategies

- Assumed degradation rates of the track geometry,
- Known critical/problem spots
- Track geometry data showing where problems are emerging
- Availability of the tampers itself
- Correction of isolated defects (c-failures)
- Line tamping when TQI becomes very low
- Advantage of short term saving but long term cost
Proposed strategy

• Line tamping using multiple sleeper tamper
• Spot tamping
• Both are based on longitudinal defect

Track possession time ➔ Systematic + Spot tamping

• Fix the root cause of isolated defects and not tamping
Case Study

- Northern section of iron ore line
- Length considered is ca 134km
- Divided into 200m segment
- Renewal period 2006-2009
- Special treatment for S&C, critical areas (stations) with recurrent c- failures or irregular measmt
Track geometry measurement data

20 inspections from April 2007- Aug 2012
b with distance

Segment from Kiruna to riksgränsen

Distribution plot of $b$ on 111

Weibull

- Shape: 1.632
- Scale: 0.0008567
- N: 597

Distribution of $b$
Modelling process

**INPUT**

- \( V = \) tamping speed
- \( u = \) travel speed
- \( t_p = \) prepratn time
- \( n = \) nos of segments
- \( \sigma = \)
- \( b = \) degradtn rate
- \( C_p, C_f, \eta_p, \eta_c, \sigma_p, \sigma_c \)
- \( N_{hp} = 1,2,3,......10 \)
- \( N = \) years, 730 days

**MODELLING PROCESS**

- Tamping strategy
  1. Direct
  2. Distributed

**OUTPUT**

- \( N_{sp}, N_{sc}, T.C_p, T.T_p, T.C_c, T.T_c \)
- \( TC, TT \)
Modelling Process
Strategy 1: Direct

Search for Worse area

Each segment is characterised by $\sigma$, $b$, description of the quality and its evolution over time.
Modelling Process
Strategy 2: Selective

Search for Worse segment
Optimization Framework

Flow chart
Model Formulation

Constraints & Limits

Growth of defects

\[ \sigma(s,t) = \sigma_0 e^{b_s t} \]

When to tamp

\[ \overline{\sigma}(nm,t) = \frac{1}{nm} \sum_{s}^{s+nm} \sigma(s,t) \geq \sigma_p \quad (s = 1, \ldots, N - nm) \]

Otherwise when

\[ \sigma(s,t) \geq \sigma_c \]

Limit for a shift

\[ \frac{s_o d}{v} + \frac{\Delta s_p d}{u} + \frac{(s_o + \Delta s_p)d}{v} \leq 6 \quad (d = 200m) \]

Recovery or improvement

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Table B.4 — Longitudinal level – AL – Standard deviation

<table>
<thead>
<tr>
<th>Speed (in km/h)</th>
<th>Standard deviation (in mm)</th>
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</thead>
<tbody>
<tr>
<td>v \leq 80</td>
<td>d1</td>
</tr>
<tr>
<td>80 &lt; v \leq 120</td>
<td>2.3 to 3</td>
</tr>
<tr>
<td>120 &lt; v \leq 160</td>
<td>1.8 to 2.7</td>
</tr>
<tr>
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<td>1.4 to 2.4</td>
</tr>
<tr>
<td>230 &lt; v \leq 300</td>
<td>1.0 to 1.5</td>
</tr>
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Model Formulation

Number of segments

\[ N_{p(c)} = \sum_{1}^{s} \sum_{1}^{730} f \left[ \sigma(s,t) - \sigma_{\text{threshold}} \right] \]

\[ f(x) = \begin{cases} 
1 \left( x \geq 0 \right) \\
0 \left( x < 0 \right) 
\end{cases} \]

Objective Functions

Total cost

\[ \text{Total cost} = \sum_{1}^{s} \sum_{1}^{730} \left( c_p \ast f_p + c_c \ast f_c \right) \]

\[ f_p(s,t) = \begin{cases} 
1, & \sigma(s,t) \geq \sigma_p \\
0, & \text{else} 
\end{cases} \]

\[ f_c(s,t) = \begin{cases} 
1, & \sigma(s,t) \geq \sigma_c \\
0, & \text{else} 
\end{cases} \]

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Optimization

i. The problem is a mixed binary non linear programming

ii. The optimization is done using FORTRAN.

iii. The expected output include
Result

• Estimation of tamping need (nos of segment that will require tamping over a period of time)

• Optimum number of systematic tamping for a given period of time

• Number of spot tamping for a given period of time under a specified specified preventive

• Expected track possession time for different scenario of the parameter combination
Conclusion

- Estimation of maintenance need is facilitated with this approach.
- The booking of tamping machine is enhanced and planning of tamping action.
- Desired geometrical quality of track can be supported and sustained in an effective way.
- Implementing this approach with a proactive way of treating isolated failure will contribute to long term cost saving and reduced track possession time.
Future work

• Introduction of multiple machine parks

• Empirical study of recovery or improvement.

• Accommodation of critical spots into the model

• Consideration of bandwidth of exponential growth.

• Validation of model and improvement.
THANKS