Asset Degradation and Intervention Strategies

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WP 2 - Objectives

- To identify and model important degradation phenomena and processes for selected railway assets for the purposes of LCC and LCA analysis
- To develop performance time profiles for selected asset types
- To quantify the influence of intervention strategies on degradation time profiles
- To validate the developed degradation and performance models through case studies
WP2 – Participants

- **COWI**: Design & management of transport infrastructure systems
- **MAV**: End user expertise on railway assets
- **SKM**: Design & management of transport infrastructure systems
- **Network Rail**: End user expertise on railway assets
- **SETRA**: Deterioration and intervention strategies; life cycle analysis
- **Surrey**: Degradation modelling; Risk and reliability analysis
- **TU Graz**: Track deterioration and whole life costing
- **TWI**: NDT, monitoring and sensor systems; structural integrity
- **UIC**: Experience from railway projects; link to project management
12 questions for each asset:
Q1. Describe experienced degradation mechanism(s)
Q2. What is the primary aggressor for this degradation?
Q3. How is this degradation monitored or inspected?
Q4. How fast does an imminent failure develop over time?
Q5. What are the current trigger points (thresholds) for intervention? (e.g. visual condition worse than X, crack size larger than Y)
Q6. Are interventions related to a condition or a safety assessment?
Q7. Rate degradation in terms of costs (O&M and renewal) (1-10, 1 being the most costly)
Q8. Is there a lack of knowledge with respect to this degradation mechanism? (1-10, 1 being the degradation mechanism least understood)

Q9. What documents are used to assess this degradation mechanism? (guidelines, codes, internal documents)

Q10. Do you have accessible inspection or monitoring data for this mechanism?

Q11. What key parameter(s) is/are recorded through monitoring or inspection?

Q12. Is monitoring continuous or periodic? (please state the relevant time intervals/parameters).
Task T2.1: Selection of asset types and specification of degradation scenarios & performance states

- Selection of specific assets and degradation scenarios
- Definition of relevant performance/limit states

**D2.1 Degradation & performance specification for selected assets**

**Selected Assets:**
- Cuttings
- Metallic bridges
- Tunnels with concrete and masonry linings
- Plain line and switches and crossings
- Retaining walls
Cuttings – Main degradation mechanisms

**Soil cuttings**
- Presence of water
- Weathering (e.g. swelling of clay)
- Long term creep
- Excavations
- Failure of supporting structures and services
- Erosion (scour)
- Mining subsidence
- Landslides
- Vegetation

**Rock cuttings**
- Weathering
- Presence of discontinuities
- Constructions method
- Climatic influence (freeze/thaw)
- Vegetation
- Failure of slope support system
Track - Main degradation mechanisms

**Ballast:**
- Cracking of ballast stones
- Abrasion
- Fouling
- Contamination
- Appearance of mud spots

**Rails:**
- Wear (side-wear)
- Rolling Contact Fatigue (RCF)
- Fatigue
- Corrugation

**Rail pads:**
- Wear

**Fasteners:**
- Breaking/loosening of clamping

**Sleepers:**
- Missing frictional connection
- Rotting
- Delayed Ettringite Formation
- Corrosion (duo-block)
Task T2.2: Degradation profiles and specification of input parameter ranges
- Review existing data/methods for selected assets
- Identify modelling approaches and develop degradation time profiles

Task T2.3: Effect of intervention strategies on degradation profiles
- Determine changes in deterioration/damage rates due to maintenance / repair

D2.2 Degradation models & intervention strategies

Developed deterioration models for:
- Plain track
- Soil Cuttings
- Metallic bridges
- Tunnels with concrete linings

Lack of data / models for:
- Retaining walls
- Rock cuttings

http://www.mainline-project.eu
Deterioration modelling: Physical Models

- Specification
- Application
- Exposure
- Protective system
  - Structural element
  - Structural system

Coating deterioration

Corrosion
Example: Loss of coating

\[
\frac{A_{pr}(t)}{A_{pr0}} = 1 - \left( \frac{0.6t^2}{T_L^2} - \frac{0.1t}{T_L} \right)
\]
Example: Thickness loss due to corrosion

Values from ISO 9223 / ISO 9224

**Coefficient A** (Table 2 in ISO 9223):
- C1 – A = 0.0013mm / year
- C3 – A = 0.05mm / year
- C5 – A = 0.2mm / year

**Coefficient B**: 0.575 (mean + 2 std. dev.)

\[ C(t) = A t^B \]
Deterioration modelling: Empirical Models

Condition assessment based on:
- Slope geology and geometry (base values)
- Degradation observations and their inter-relationships (assessment values)
- 17 fields of input data are required from site examination
- Extensive field records available
**Example: Condition of cohesive soil cuttings**

<table>
<thead>
<tr>
<th>Slope Angle (°)</th>
<th>SAF Factor</th>
<th>SHF Factor</th>
<th>ALF Factor</th>
<th>Adjacent Land</th>
<th>Slope and water course</th>
<th>Slope and unstable land</th>
<th>SIW + UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;15</td>
<td>0</td>
<td>&lt;3</td>
<td>-1(2)</td>
<td>+ve</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15-25</td>
<td>1</td>
<td>3-10</td>
<td>0</td>
<td>flat</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>25-35</td>
<td>2</td>
<td>&gt;10</td>
<td>1</td>
<td>+ve</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>&gt;35</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Slope Assessment Value (SAV)**

\[
SAV = [MA OR VA]^{(1)} + [SWA OR DA]^{(2)} + CAA + BA^{(3)} + PRA
\]

- **(1)** If VA = -1, then reduce MA by 1. Highest of MA or VA to be taken. Take highest of SWA or DA.
- **(2)** Burrowing scores should also be looked at in isolation as this necessitates very specific intervention. Either adopt value, or if remediation directly addresses a specific element, reduce that to 0 (see PRA tab).

**Cutting stability value (At time of assessment) SV (0)**

\[
SV (0) = S_{AV} \times (1.0 + C_{BV}/10)
\]
## Modelling of intervention strategies

### Condition Assessment Parameters (SKM Proposed algorithm for cohesive cuttings)

<table>
<thead>
<tr>
<th>Input name</th>
<th>Soil Type</th>
<th>Slope Angle Factor</th>
<th>Slope Height Factor</th>
<th>Adjacenet Land Factor</th>
<th>Movement</th>
<th>Vegetation</th>
<th>Surface Water</th>
<th>Drainage</th>
<th>Burrowing</th>
<th>Construction Activity</th>
<th>Previous Remediation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input code</td>
<td>ST</td>
<td>SAF</td>
<td>SHF</td>
<td>ALF</td>
<td>MA</td>
<td>VA</td>
<td>SWA</td>
<td>DA</td>
<td>BA</td>
<td>CA</td>
<td>PR</td>
</tr>
<tr>
<td>Regular Earthworks Examinations</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ground Investigation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Monitor to manage risk</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Clean out drains</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>X</td>
<td>X</td>
<td>0</td>
<td>0</td>
<td>X</td>
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<tr>
<td>Vegetation management</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>X</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td>Gas and exclude vermin</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>X</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td>Reactive isolated slope repair</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>0</td>
<td>X</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td>Rehabilitate drainage</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>0</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td>Full slope regrade</td>
<td>0</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td>Excavate and replace</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>0</td>
<td>X</td>
<td>X</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td>Soil reinforcement</td>
<td>X</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td>Install new drainage</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>0</td>
<td>X</td>
</tr>
</tbody>
</table>

**Key**
- **X**: Condition uplift effect to be applied to input parameter (numerical values to be determined following further development of the model)
- **0**: No anticipated effect on assessment parameter
WP2 – Completed Tasks

Task T2.4: Performance Time Profiles

- Establish degradation to performance relationships and time profiles
  - Condition profiles
  - Capacity profiles
- Case studies and sensitivity analysis

D2.3 Performance profiles for LCC/LCA

Developed performance–time profiles for:
- Plain track
- Soil Cuttings
- Metallic bridges
- Tunnels with concrete linings
Element-based approach suitable for LCC/LCA

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Example: Metallic bridges

A short-span metallic bridge in an urban area: atmospheric environment with medium pollution ($\text{SO}_2$: 5 – 30 $\mu$g/m$^3$, some effect of chlorides)

A medium-span truss bridge in a rural environment: low atmospheric pollution
### Systems for complete recoating (NR/GN/CIV/002)

<table>
<thead>
<tr>
<th>Environment as defined in BS EN ISO 12944-2</th>
<th>Recoating systems (to accord with surface condition)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recommended</td>
</tr>
<tr>
<td>C2 (external)</td>
<td>M20, M24</td>
</tr>
<tr>
<td>C3</td>
<td>M20, M24</td>
</tr>
<tr>
<td>C4</td>
<td>M20, M21</td>
</tr>
<tr>
<td>C5</td>
<td>M20, M21</td>
</tr>
</tbody>
</table>

### Table 1 — Categories of corrosivity of the atmosphere

<table>
<thead>
<tr>
<th>Category</th>
<th>Corrosivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Very low</td>
</tr>
<tr>
<td>C2</td>
<td>Low</td>
</tr>
<tr>
<td>C3</td>
<td>Medium</td>
</tr>
<tr>
<td>C4</td>
<td>High</td>
</tr>
<tr>
<td>C5</td>
<td>Very high</td>
</tr>
<tr>
<td>CX</td>
<td>Extreme</td>
</tr>
</tbody>
</table>

BS EN ISO 9223:2012. Corrosion of metals and alloys – Corrosivity of atmospheres
Example 1: Short-span metallic bridge

Main elements:
- 2 no. External Girders
- 1 no. Centre Girder
- 4 no. Stringers

- 2 no. End Cross Girders
- 3 no. Internal Cross Girders
Example 1: Short-span metallic bridge

- Capacity checks:
  - Bending resistance
  - Shear resistance
  - Axial resistance
  - Local buckling

- Key ratio for LCAT use:
  \[ \frac{P(t)}{P(t=0)} \]

- For example: Section modulus
  \[ \frac{Z(t)}{Z(t=0)} \]
Example 1: Short-span metallic bridge

Element type: Outer main girder

Classification of exposure conditions: Urban (C3)

Coating characteristics: M24, $T_L = 10$ years

Steel grade: $f_y = 300$ N/mm$^2$

Cross-sectional area = $0.02624$ m$^2$
Surface area = $4.62$ m$^2$/m run

Diagram showing the normalised moment capacity (%)

- Blue line: with coating
- Red line: w/o coating

Time (years) on the x-axis: 0 to 100
Normalised moment capacity (%) on the y-axis: 110 to 50
WP2 – Ongoing Tasks

Task T2.5: Validation through case studies
- Compare results from degradation and performance profiles with field data
- Establish confidence for degradation model predictions

**D2.4 Field-validated profiles**

Validation depends on model provenance and data availability:
- Field observations (Danish bridges and tunnels)
- Additional sources (Austrian, Norwegian, Swiss and Croatian track data)
- Sensitivity analyses (UK cuttings)
Progress towards objectives

- Good progress on deterioration and performance modelling
  - Both physical and empirical models
  - Wide range of input conditions
  - Profiles suitable for LCA/LCC analysis
- Covered both condition and capacity based criteria for:
  - Soil cuttings
  - Track
  - Metallic bridges
  - Concrete lined tunnels
- Wide range of profiles developed for LCAT modelling
  - Representative condition-based profiles
  - Some capacity-based profiles (more case specific)
  - Selection of intervention strategies
- Currently finalising model validation