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1. Framework
2. Data mining on track geometry parameters
3. Assessment and forecast of track condition
4. Optimization of M&R operations planning
5. Development of a DSS for M&R operations planning
6. Future development of the DSS
In the recent past, during a period of large investment in infrastructure, REFER has adopted strategies seeking the full modernization of the existing main lines with:

- Improved safety conditions;
- Reduction of operating costs;
- Increasing infrastructure capacity;
- Adaptation of infrastructure to the European policies of interoperability.

Nevertheless with the recent difficulties in public finances, leading to a increasable constraint of budget allocation to the public managers of infrastructure, REFER was forced to change the paradigm for the renovation / rehabilitation of infrastructure with reduced costs, while maintaining the safety and availability of infrastructure at acceptable levels.
This goal is being achieved through the use of REFER’s knowledge and experience enhanced by association with Portuguese universities and research institutes developing new strategies of inspection and maintenance, optimizing costs while maintaining appropriate levels of security, producing adequate decisions support tools.

The main subjects for development are as follows:

Tools and processes that demonstrate the perception of the real needs and solutions for renovation / rehabilitation of railway infrastructure;

The performance of the infrastructure LCC at its maximum efficiency will depend on cost effectiveness of maintenance and diagnostic systems and also in the implementation of appropriate maintenance.
Why develop a DSS for rail track M&R planning?

1. Support complex decisions
2. Amount of available information is prohibitive for the intuition
3. Precision and optimality have a considerable importance

Main advantages of using a DSS?

1. Compare investments solutions regarding the M&R planning
2. More effective use of public spending commitments
FRAMEWORK

Conceptual structure

Integrated Infrastructure Management System

- Data collection & analysis
  - condition assessment
  - GIS, remote sensing
  - inventories evaluation

- Forecast
  - deterioration forecasting
  - demand forecasting
  - impacts assessment

- Decision analysis
  - cost benefit methods
  - multi-criteria analysis
  - optimization techniques
  - risk management
  - planning, programming, budgeting systems

- Management information & reporting
  - performance reports
  - service & accomplishments
  - budgets

Infrastructure performance

Funds, policy priorities & budgeting

Management decisions & actions
Development of a DSS for planning rail track M&R operations in the Portuguese railway network.

FRAMEWORK

**Phase 1 – Prediction model**

**TRACK GEOMETRY**
- Track geometry inspection
- Rail profile inspection
- Track profile inspection

**COMPONENTS**
- Catenary inspections
- Corrugation inspection
- Etc.

**INSPECTIONS RECORDS**

**ACCUMULATED TONNAGE**

**DEGRADATION ASSESSMENT**

**MAINTENANCE AND RENEWAL OPERATIONS ESTIMATION**

**DECISION SUPPORT TOOL**

**Phase 2 (under development)**

EM-120

- Track geometry inspection
- Rail profile inspection
- Track profile inspection
- Catenary inspections
- Corrugation inspection
- Etc.
DATA MINING ON TRACK GEOMETRY PARAMETERS
TRACK GEOMETRY DEGRADATION

DEGRADATION MODELS

Isolated defects VA

SD VA and HA defects

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FIGURA 1 – Exemplo da evolução do desvio padrão dos defeitos longitudinais para troços de via de 200 metros aparentemente idênticos com o mesmo histórico de tráfego. (alguns troços renovados de velocidade máxima permitida de 220 km/h da via ascendente entre o Pk 278,2 e Pk 282,8).

§ 2.22 As rectas de regressão linear simples estimadas na figura ilustram a variabilidade dos parâmetros de degradação, bem visível pelos diferentes declive das rectas (diferentes valores para a taxa de degradação c0).

Main factors:
- Substructure characteristics
- Track characteristics;
- Loads;
- Maintenance history
- Etc.;
TRACK GEOMETRY DEGRADATION

DEGRADATION MODELS – Probabilistic assessment

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The impact of track singularities
Clusters (degradation rate VL) - Renewed segments
- e.g.: Segments with culverts with higher degradation rates
Tamping frequency

Historical data of tamping operations

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TRACK GEOMETRY DEGRADATION

RAIL DEFECTS

Modeling the evolution of rail defects (ex. Transv. cracks)

PK 90-100

RAIL WEAR

Modeling the evolution of the vertical wear

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ASSESSMENT & FORECAST OF TRACK CONDITION
TRACK GEOMETRY DEGRADATION

Comparison with RiskLognorm(230.98,197.34,RiskShift(2.769...)

Maintenace

Minimum
Mean
Std Dev
Variance

Minimum
Mean
Std Dev

0,045
0,040
0,035
0,030
0,025
0,020
0,015
0,010
0,005
0,000
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000

Forecats of M&R operations

Qi (mm)

Renewed

Not renewed

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# Ballast life cycle estimation

<table>
<thead>
<tr>
<th>Criteria</th>
<th>MGT VA</th>
<th>YEAR VA</th>
<th>MGT HA</th>
<th>YEAR HA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria 1</td>
<td>312.2</td>
<td>22.3</td>
<td>229.7</td>
<td>16.4</td>
</tr>
<tr>
<td>Criteria 4</td>
<td>264.1</td>
<td>18.9</td>
<td>176.9</td>
<td>12.6</td>
</tr>
<tr>
<td>Criteria 5</td>
<td>286.1</td>
<td>20.4</td>
<td>207.8</td>
<td>14.8</td>
</tr>
</tbody>
</table>
Train delays

Historical data of train operations

<table>
<thead>
<tr>
<th>Cause</th>
<th>Number of events</th>
<th>Total delay (min.)</th>
<th>Average delay per event (min.)</th>
<th>Standard deviation (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track failures</td>
<td>77498</td>
<td>598804</td>
<td>8</td>
<td>10.21</td>
</tr>
<tr>
<td>Formation/maneuvres</td>
<td>46392</td>
<td>439722</td>
<td>9</td>
<td>43.0</td>
</tr>
<tr>
<td>Passenger boarding movements</td>
<td>41407</td>
<td>313981</td>
<td>8</td>
<td>3.9</td>
</tr>
<tr>
<td>Lost time in the trajectory</td>
<td>29673</td>
<td>248778</td>
<td>8</td>
<td>9.3</td>
</tr>
<tr>
<td>Rolling stock failure</td>
<td>9351</td>
<td>74429</td>
<td>8</td>
<td>25.8</td>
</tr>
</tbody>
</table>
OPTIMIZATION OF M&R OPERATIONS
PLANNING
Optimization model for track renewal planning
MILP model – Life Cycle Cost Approach

Objective Function: Minimize the rail track LCC

\[
\text{min } LCC = \sum_{w \in W} \sum_{t \in T} \sum_{n \in N} C_w^r Y_{wtn} + \sum_{k \in K} \sum_{t \in T} \sum_{n \in N} C_k^m X_{ktn} - \sum_{w \in W} \sum_{t \in T} C_w^r P_{wt} - \sum_{k \in K} \sum_{n \in N} R_{kn}
\]

- Renewal costs
- Maintenance costs
- Economy of scale benefits
- Residual value
Optimization model for track renewal planning
MILP model – Life Cycle Cost Approach

Main contributions:

1. Consideration of the rail track components degradation process to estimate the renewal scheduling;

2. The optimization approach uses an LCC assessment to estimate the investment during the life cycle of the track components;

3. Identification in time and space of renewal activities (rail track segments that should be renewed);

4. Possibility of performing an opportunistic renewal of different components in the same segment and in adjacent segments.
Optimization model for track renewal planning

Multi-objective algorithm – Consideration of track availability

Track unavailability - Maintenance & renewal works

\[ \min U = \sum_{w \in W} \sum_{t \in T} \sum_{n \in N} U_{wtn} + \sum_{k \in K} \sum_{t \in T} \sum_{n \in N} U_{ktn} \]

Main contributions:

1. Quantification of track unavailability during the life-cycle of track components;

2. Rail track LCC estimation for a given availability index (guarantee performance indexes);

3. Measure budget restriction effects on LCC-unavailability trade-off;

Min. LCC (M&R)
CURRENT STAGE OF THE DSS TOOL
PROJECTION OF M&R WORKS

OUTPUTS

Track geometry characterization for the Portuguese railway network according to different quality standards (standard deviation of vertical and horizontal alignment defects)

Goodness of fit tests with probability distributions of degradations rates for 200m segments

Maintenance needs, timeline estimation of tamping operations for 200m track segments and heavy renewal estimations
AUTOMATIC REPORTS

Track geometry

REPORT INFORMATION:
- Resume;
- Current track condition;
- Track quality thresholds;
- Current deg. rates;
- Estimation of tamping

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Rail condition

REPORT INFORMATION:
- Resume;
- Geographic distribution;
- Rail type;
- Defect type;
- Evolution during time periods
(…)

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Development of a DSS for planning rail track M&R operations in the Portuguese railway network
FUTURE DEVELOPMENTS OF THE DSS
1. Development of a robust RAM assessment of the rail track
   • Consider track unavailability costs in the M&R decision making;
   • Achieve a more reliable infrastructure by integrating the forecast of isolated and SD of VA and HA defects;

2. Integrate new modules such as:
   • Rail corrugation prediction (assessment of inspection data from rail corrugation);
   • Other railway systems (catenary, signalling, etc.);

3. Complement the track degradation data mining procedure with GeoRadar data (identification of critical zones);

4. Continue the development of the DSS:
   • Database system to centralize data of track asset;
   • Interface to ensure new assessments of the track condition;
THANK YOU FOR YOUR ATTENTION!

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