Track circuit reliability assessment for preventing railway accidents

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Track circuits role in railway safety

- Railway safety is based on 3 main components:
  - Technology, Organization and Human Resources
- Technology: trains, infrastructure and signaling systems
  - Safety is ensured by design, surveillance and maintenance
- Track circuits: a common and essential component
  - Used to determine the location of trains and ensure safe traffic
  - Used to trigger safety devices: stop signals, level crossings
- Track circuits reliability depends on the contact wheel-rail
  - Some factors contribute to pollute the contact
    - Leaves in autumn, chemical compounds, sand, oxidation
  - Other factors contribute to clean the contact
    - Heavy rolling stock, electrical current, frequency of trains
- Traffic evolution in the recent years raises concerns
  - Less freight traffic and lighter passenger trains decrease TC reliability
Causes of Track Circuit malfunctions

- Several sources were used to identify the main parameters that influence Track Circuits reliability:
  - Sources of knowledge to understand malfunctions’ causes:
    - Studies’ results from SNCF and different countries (NL, GB, BE)
    - Analysis reports of past accidents in which TC malfunctions were cited
  - Sources of data to identify TC malfunctions’ occurrences (time & location)
    - Records of TC automatic Surveillance systems
    - Data log of computerized switching systems
- TC reliability is a balance between polluting and cleaning
  - Several sources of pollution create an isolating layer
    - Vegetation leaves, chemical compounds, sand, oxides
    - The climatic conditions and the rail profile degradation make pollution worse
  - Traffic characteristics influence rail cleaning
    - Tonnage, frequency, electric traction, time distribution
- TC reliability also depends on the TC type and train type
  - Some TCs use less sensitive technology or cover long distances
  - Some trains don’t shunt reliably (disk brakes, narrow wheel contact)
# Main parameters driving TC reliability

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1 (++)</th>
<th>2 (+)</th>
<th>3 (-)</th>
<th>4 (--)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollution due to vegetation (leaves on rails, mainly in autumn)</td>
<td>None</td>
<td>Low</td>
<td>High</td>
<td>Very high</td>
</tr>
<tr>
<td>Industrial of agricultural pollution on rails</td>
<td>None</td>
<td>Low</td>
<td>High</td>
<td>Very high</td>
</tr>
<tr>
<td>Pollution imported from outside the track circuit</td>
<td>None</td>
<td>Low</td>
<td>High</td>
<td>Very high</td>
</tr>
<tr>
<td>Sanding of rails by trains</td>
<td>Never</td>
<td>Seldom</td>
<td>Often</td>
<td>Very often</td>
</tr>
<tr>
<td>Rail oxidation</td>
<td>Very low</td>
<td>Low</td>
<td>High</td>
<td>Very high</td>
</tr>
<tr>
<td>Rail profile degradation</td>
<td>Very low</td>
<td>Low</td>
<td>High</td>
<td>Very high</td>
</tr>
<tr>
<td>Climatic conditions reducing contact quality (wind, humidity, fog, …)</td>
<td>No</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Daily tonnage passing on the track (Tons)</td>
<td>&gt;15000</td>
<td>&gt;3000</td>
<td>&gt;1000</td>
<td>&lt;=1000</td>
</tr>
<tr>
<td>Number of trains per day</td>
<td>&gt;20</td>
<td>&gt;12</td>
<td>&gt;6</td>
<td>&lt;=6</td>
</tr>
<tr>
<td>Type of trains’ source of energy</td>
<td>All electric</td>
<td>Mostly electric</td>
<td>Mostly thermic</td>
<td>All thermic</td>
</tr>
<tr>
<td>Type of trains: light (passengers) vs. heavy (freight)</td>
<td>All freight</td>
<td>Mostly freight</td>
<td>Mostly passengers</td>
<td>All passengers</td>
</tr>
<tr>
<td>Timely distribution of traffic (along the day, along the week)</td>
<td>Non-stop</td>
<td>Mainly continuous</td>
<td>Some interruptions</td>
<td>Often disrupted</td>
</tr>
<tr>
<td>Existing failure/malfunction cases for this track circuit type</td>
<td>None</td>
<td>Very few</td>
<td>Some</td>
<td>Many</td>
</tr>
<tr>
<td>Proportion of trains known as “weakly shunting”</td>
<td>&lt;20%</td>
<td>&lt;50%</td>
<td>&lt;80%</td>
<td>&gt;80%</td>
</tr>
</tbody>
</table>
TC Reliability model

- Vegetation
- Industrial
- External
- Oxidation
- Sanding
- Climate
- Profile Degradation

- Source of pollution
- Aggravating factors

- Tonnage / day
- Trains / day
- Trains energy
- Passenger/freight
- Traffic time distribution

- Track circuit
- Train shunting

- Environnement

- Traffic

- Detection ability

- Track Circuit Reliability
Potential severity of TC failure

- Track Circuits are used in different configurations
  - Each configuration corresponds to one or several accident scenarios
- Each accident scenario has an average severity
  - Assessed from analysis of past accidents
- Local context influences the potential severity of accidents
  - Aggravating/reducing factors (speed, traffic, dangerous goods, ...)
  - Values at stake (number of passengers, financial impacts, ...)
- Potential severity is evaluated by:
  - Identifying the type of TC’s exploitation mode
  - Identifying the accident scenario with the highest severity
  - Evaluating the effect of local context
TC failure potential severity model

- Face to face collision
- Catch up collision
- Switch double route
- Sideways collision
- Collision with vehicle
- Collision with pedestrian

Track circuit exploitation mode

Average severity

Aggravating factors
- Traffic density
- Trains’ speed
- Dangerous goods
- Infrastructure: tunnels, bridges
- Visibility

&

Values at stake
- Environment
- Financial impact
- Staff
- Passengers

Potential severity

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Risk assessment model

- Risk assessment supports decisions for resource allocation
  - Risk is represented by the combination of possibility and severity levels
  - The Risk Matrix associates a priority level to every combination
    - From 1 (situation OK) to 4 (urgent need of risk reduction measures)
TC malfunction risk reduction

• Preventive measures can improve reliability
  – Remove vegetation along the tracks to prevent leaves falling on rails
  – Organize circulation of heavy trains after traffic interruptions
  – Increase time constant of TC receivers
  – Wash rails frequently using high pressure water jets
  – Install cleaning brushes on wheels
  – Equip weakly shunting trains with TC assisters
  – Replace low sensitivity TCs by more recent technologies
  – Add complementary devices (shunting pedals for level crossings)
  – Replace TC systems by other more reliable technologies

• Few protective measures can reduce severity
  – Manage less reliable circulations using a more controlled way
  – Replace level crossings by tunnels or bridges
Assess risk reduction measures efficiency

• Every risk reduction measure is described by:
  – The context in which it can be applied
  – The parameter(s) on which it has a reduction effect
  – A Confidence index assessed from the analysis of historical data
    • This confidence index determines the amount of reduction
  – Resources needed to set up the measure (initial, periodic)

• Risk reduction is determined
  – Reduction is applied to all parameters influenced by measures
  – Reliability and severity models are applied with reduced values
  – Reduced risk level is put in the risk matrix to assess priority level

• It is important to keep in mind initial risk level
  – To explain the role of measures and ensure their presence
  – To be prepared to the failure of risk reduction measures
Conclusion and perspectives

• The reliability of train detection using track circuits can be assessed using a small number of parameters

• Potential severity of the consequences of TC failure depends on how it is used and the context in which it is placed

• TC’s risk of failure combines Reliability and potential severity and depends on local context

• The models presented here allow SNCF managers to choose the most appropriate risk reduction measures by:
  – Using a national-level evaluation of risk-reduction barriers
  – Using a common method to assess reliability, severity and risk
  – Choosing the reduction measures fitted to every TC’s local context