TRACK CIRCUIT RELIABILITY ASSESSMENT FOR PREVENTING RAILWAY ACCIDENTS

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SUMMARY

The safe operation of a railway signaling system depends on accurate and up-to-date information on the position and movements of trains provided by train detection devices. Track circuits are the most popular systems used over the world to provide information on position and movements of trains and ensure safety of circulations.

In close cooperation with experts and practitioners of the French national railways company SNCF, we have designed a reliability model of track circuits taking into account local conditions: environment, vehicles, track, traffic, track circuit technology and use. Combined with an assessment of potential consequences of failure, this model supports managers' strategies to reduce the risks and optimize resources allocation.

This model is also used to predict potential locations of track circuits that may generate malfunctions, using a measure of similarity with track circuits' locations where malfunctions occurred. Using the database of past malfunctions, the similarity measure uses the model's parameters to set up and update a classification of malfunction types. Each type is compared with the database of track circuits to identify those that are similar enough to raise attention and check if appropriate prevention measures are already in place or need to be added.

The model is combined with a support tool that guides the local staff to choose the prevention and protection measures fitted to every track circuit. This allows managers to optimize the resources to ensure safety by identifying which measures are needed for every situation.

The model was designed and implemented in a French region where track circuits malfunctions have a higher probability to occur due to climatic conditions in autumn that pollute the wheel-rail contact. It will be applied this autumn in two more regions and extended to other types of risks in the near future.

INTRODUCTION

Railway safety is based on three main contributors: technology, organization and human resources. Technology contributes to safety by design and maintenance of trains, signaling systems and infrastructure. Organization contributes by setting up management patterns, regulations, procedures and information management that address nominal and abnormal/incidental situations. Human resources contribute by their skills, vigilance, reactivity and respect of regulations and procedures.

Signaling systems play an important role in railway safety because they ensure the interface between infrastructure, trains, drivers and switchmen. One of the basic functions of signaling systems is to locate trains on tracks, in order to organize the traffic while preventing collisions. Signaling systems are designed and maintained to reach a very high level of reliability, which contributes to a very low number of malfunctions and failures, but any single failure may have great consequences.

Among signaling systems, track circuits are one of the most popular systems to locate trains on tracks. The basic principle is to establish an electrical circuit between rails that is short-circuited by the train, which in turn triggers a relay signaling the presence of a train on this section. This signal is used to command different types of devices, as stop signals for other trains or level crossings barriers.

Reliability of track circuits depends on the electrical contact between train wheels and rails. Some factors contribute to the contact quality: heavy trains, intense traffic, while other factors degrade it: rail and wheel pollution, low traffic, light trains.

Track circuit malfunctions combine several causes that vary in space and time. On one hand, managing risk of failure needs to account for local/temporal context to identify which track circuits are potentially less reliable. On the other hand, the potential severity of a failure also depends on the local context. By combining these two dimensions it is possible to assess the priority level of track circuits and allocate appropriate resources for risk reduction measures.

ASSESSING TRACK CIRCUIT RELIABILITY

Identification of relevant parameters

A number of studies have been made in several countries to identify which factors contribute to the reliability of track circuits. In addition to this existing knowledge, we used a questionnaire sent to SNCF managers and operational staff to collect their opinions about which parameters contribute to improve or degrade the wheel-rail contact.

Three main groups of parameters have been identified: environment, traffic and detection ability. We present in table 1 the 14 parameters that contribute the most in wheel-rail electrical contact. Each parameter is evaluated on a 4-level scale:

- 1: highly improves contact reliability;
- 2: slightly improves contact reliability;
- 3: slightly reduces contact reliability;
- 4: highly reduces contact reliability.

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

Table 1: main parameters driving the reliability of track circuits

Track circuit reliability model

We used the data found in historical records of track circuit malfunctions to identify what role these different parameters played in the occurrence of malfunctions.

From this analysis and the interviews of SNCF experts and field staff, we designed a reliability model of track circuits that uses local values (1 to 4) of the 14 parameters at the scale of the track circuit. This model identifies 3 contributing factors: environment, traffic and track circuit sensitivity.

Analysis of past malfunctions shows that the different sources of pollution don't combine and only the greatest one has an influence. Analysis also shows that 2 independent parameters also influence reliability: climate and profile degradation. We make the hypothesis that the "environment" factor is a combination of the worst pollution source with the worst aggravating factor. The "environment" factor is assessed by combining the maximum value of the different sources of pollution with the maximum value of the two aggravating factors.

Analysis of past cases shows that the "traffic" factor is a weighted combination of the related parameters, as each parameter contributes to the reliability of the track circuit, the daily tonnage being the most influential.

The last factor addresses the sensitivity of the track circuit. This factor depends on the sensitivity of the track circuit type and the ability of the trains to shunt correctly the circuit. We assess this factor by keeping the maximum (worst case) of these two parameters.

Finally, we combine these three factors to assess the reliability level, from 1 (very high) to 4 (very low). Figure 1 presents the reliability model.

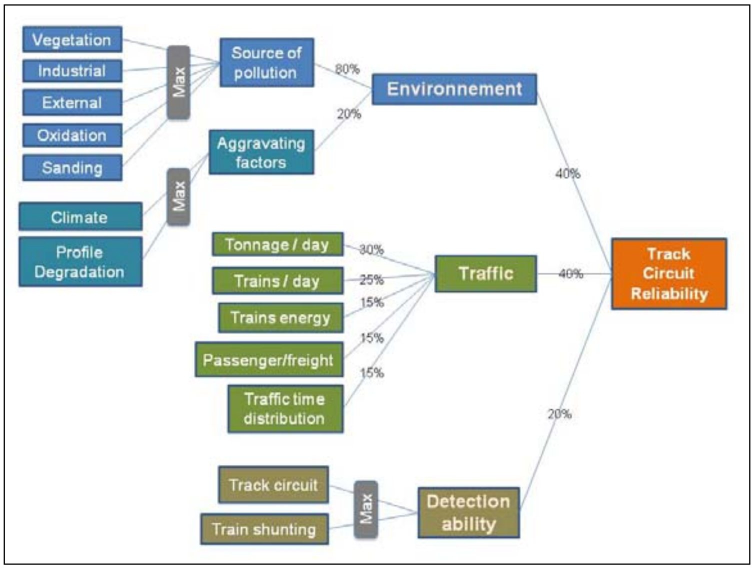

Figure 1: track circuit reliability model

ASSESSMENT OF FAILURE SEVERITY

Track circuits are used to provide information on trains' location/presence but also to trigger safety devices, as stop lights or level crossings barriers. In order to assess the potential severity (range 1 to 4) of a track circuit malfunction, we first list the different types of accident that may occur. We used reports of past accidents to assess the average severity of each type of accident, all causes combined:

- Face to face collision, severity 4;
- Catch up collision, severity 2;
- Switch double route, severity 3;
- Sideways collision, severity 3;
- Collision with vehicle, severity 4;
- Collision with pedestrian, severity 3.

Then we list the different exploitation configurations in which track circuits are used and we associate to each configuration the related types of accidents. The maximum potential severity of an accident occurring in a given configuration corresponds to the accident type with the highest severity that may happen in the configuration the track circuit is part of.

In order to assess the potential severity of an accident caused by a malfunction of a given track circuit, we propose to take into account two factors addressing the local context:

- Aggravating/reducing factors: density of traffic, trains speed, dangerous goods transportation, infrastructure (tunnel, bridge), visibility;
- Values at stake: number of potential victims (neighbours, passengers and staff), financial impacts, damage to the environment.

Depending on the local context, these factors may increase or decrease the average potential severity; for instance, if traffic consists in high speed passenger trains or if the track circuit triggers a level crossing controlling a high traffic road, the severity will be higher than the average.

Figure 2 presents the severity model.

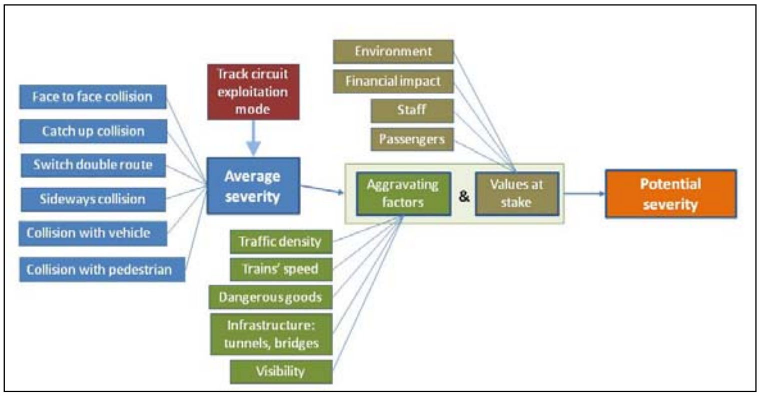

Figure 2: assessment of accident potential severity model

PRIORITY ASSESSMENT AND DECISION SUPPORT

Railway company managers need to know the relative level of risk associated to track circuits in order to allocate resources to put efficient risk reduction measures where they are needed.

We use a classical risk model, combining the possibility of track circuit failure and the potential consequences of this failure. The possibility of failure can be assessed using the reliability scale presented above: the higher the reliability, the lower the possibility of failure. The risk matrix uses a 4-level priority range:

- 1: no priority: actual situation is ok;
- 2: low priority: only surveillance of potential deviations is needed;
- 3: medium priority: prevention or protection measures are needed;
- 4: high priority: prevention or protection measures are urgently needed.

Figure 3 presents the risk model combining track circuit reliability and potential severity:

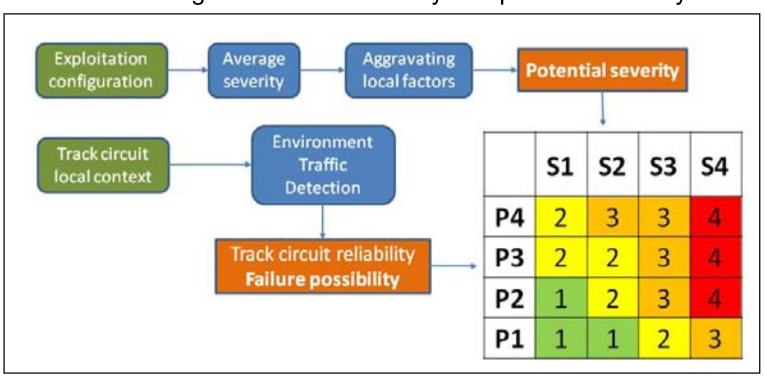

Figure 3: risk model

Choice of appropriate measures to reduce risk

When priority level is medium or high, railway company managers must identify which measures can reduce the possibility (prevent failures) or reduce the potential severity (protect values at stake) and allocate resources to set in place these measures (technical or organizational ones).

The choice of risk reduction measures depends on the local context and on the cost/benefit ratio of measures. SNCF experts have identified a set of measures that proved to be efficient and associated each measure to the context in which it can be applied. Every risk reduction measure is characterized by its efficiency (based on audits and analysis of incidents and accidents) and its cost, which helps local managers to choose the most appropriate measures needed to reduce risks.

CONCLUSION

Track circuit failure is one of the many causes of railway accidents. Railway company managers need to assess the risks and reduce those risks when and where it is needed. We argue that an efficient risk management need to take into account the local context that influences the reliability of track circuits but also the potential consequences of malfunctions and failures.

The model we developed with SNCF experts and local operational staff aims at clarifying what makes a track circuit more or less risky and supporting risk management decisions by identifying what risk reduction measures are the most appropriate to any local situation.

In the next months, this model will be applied in several regions in France to check its validity and make adjustments where needed.

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