International Railway Safety Council 2017
October. HONG KONG

Hong Kong
22-27 October, 2017

27th International Railway Safety Council 2017

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

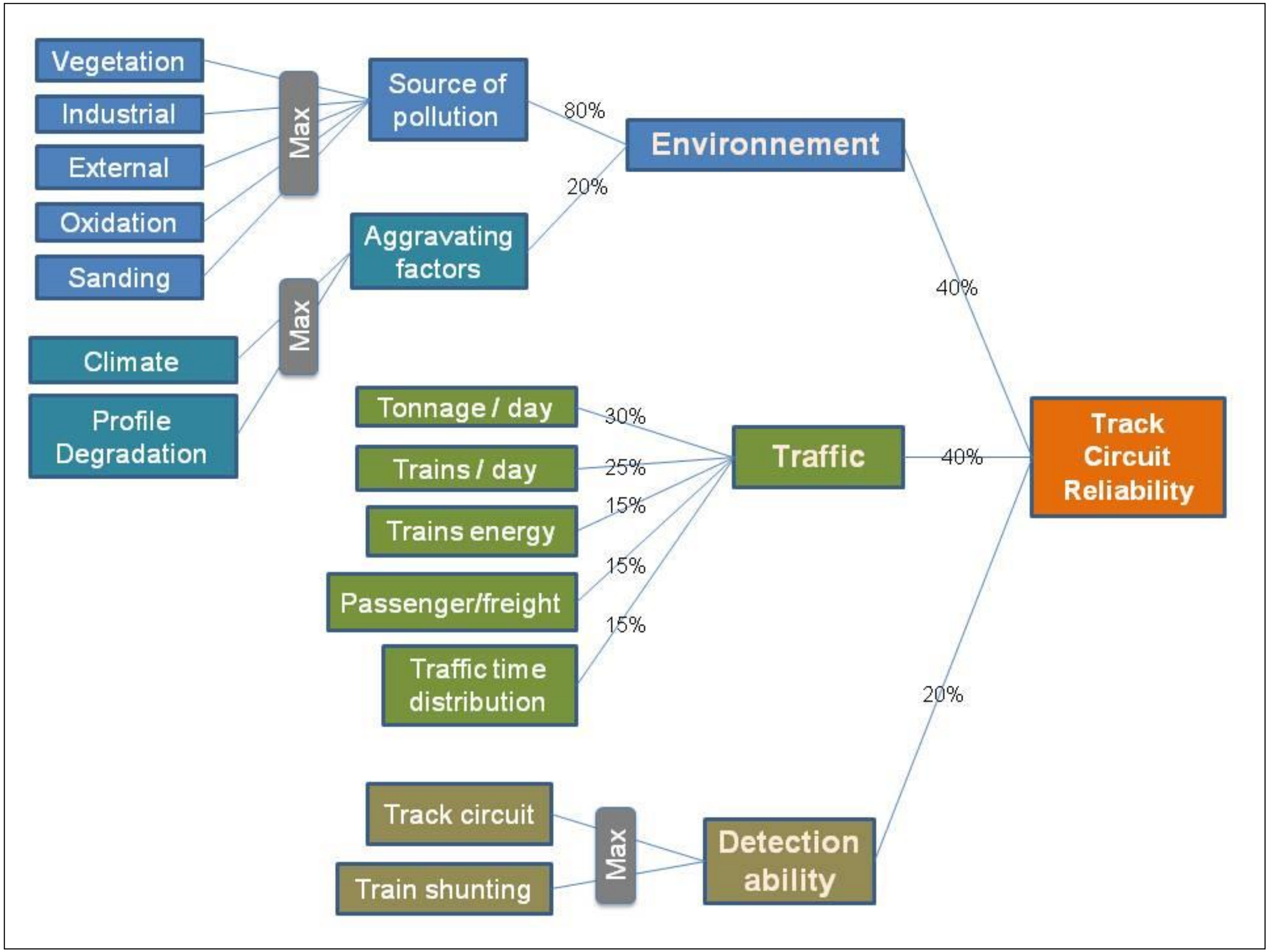
Causes of Track Circuit malfunctions

- 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

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%

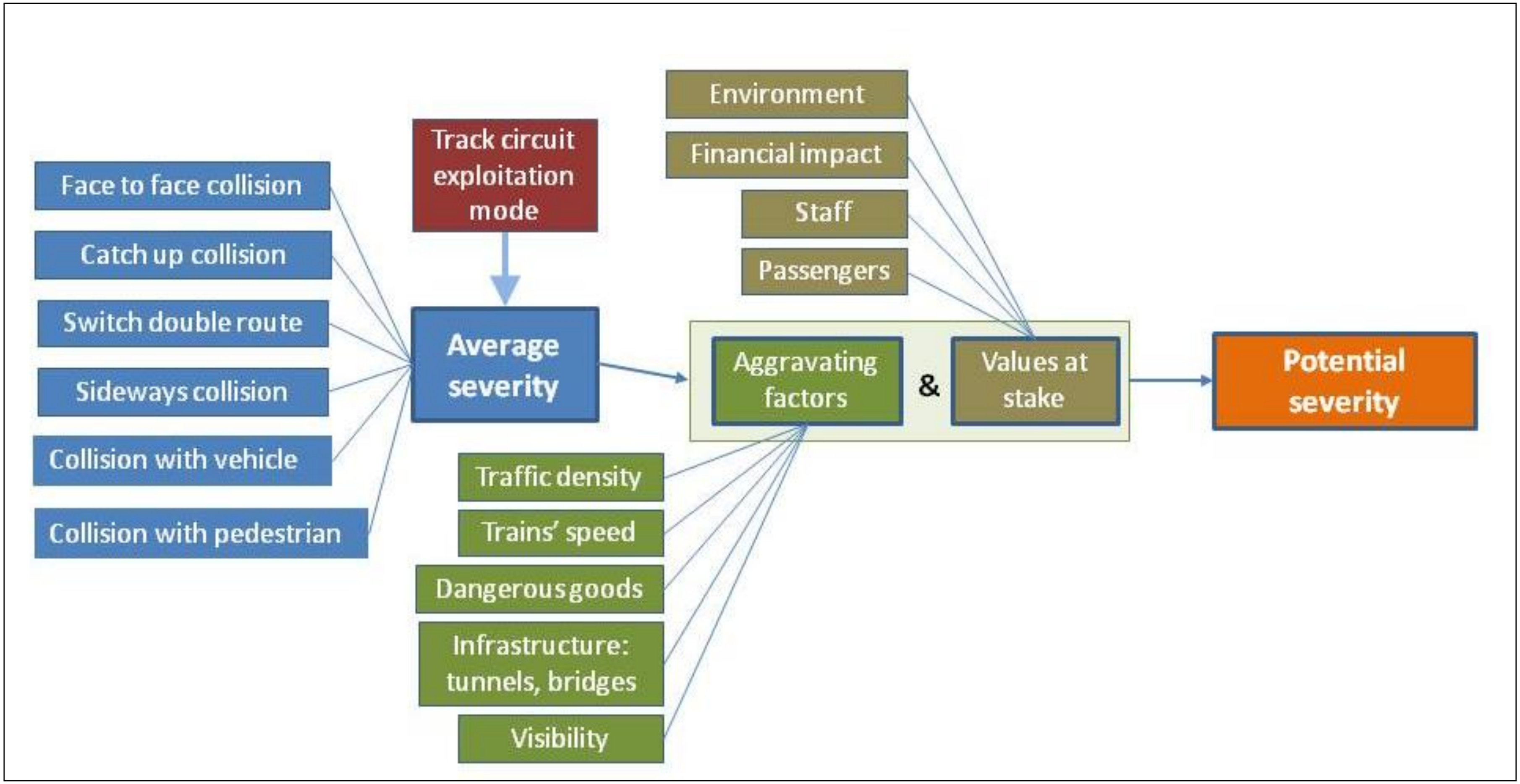
TC Reliability model



Potential severity of TC failure

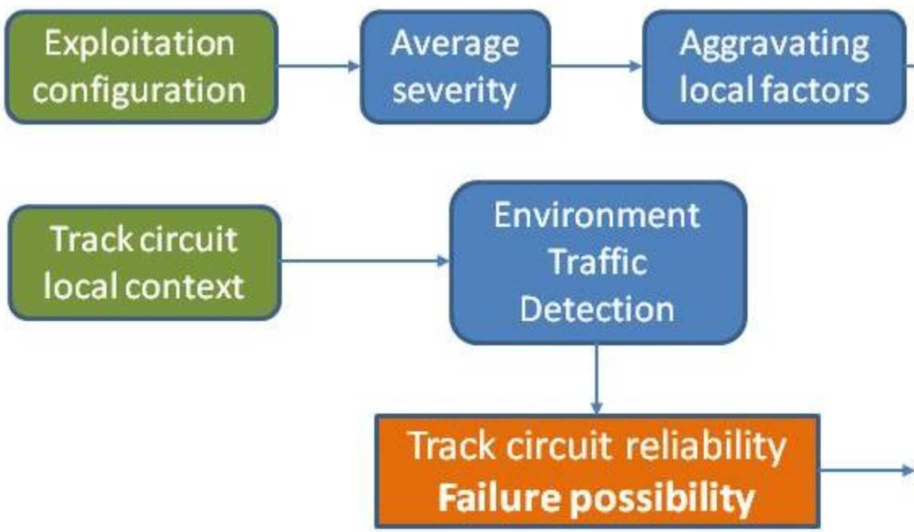
- Track Circuits are used in different configurations
  - Each configuration corresponds to one or several accident scenarios
- Each accident scenario has an average severity
  - Assessed from analysis of past accidents
- Local context influences the potential severity of accidents
  - Aggravating/reducing 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



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)**



	S1	S2	S3	S4
P4	2	3	3	4
P3	2	2	3	4
P2	1	2	3	4
P1	1	1	2	3

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 prespectives

- 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 is 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