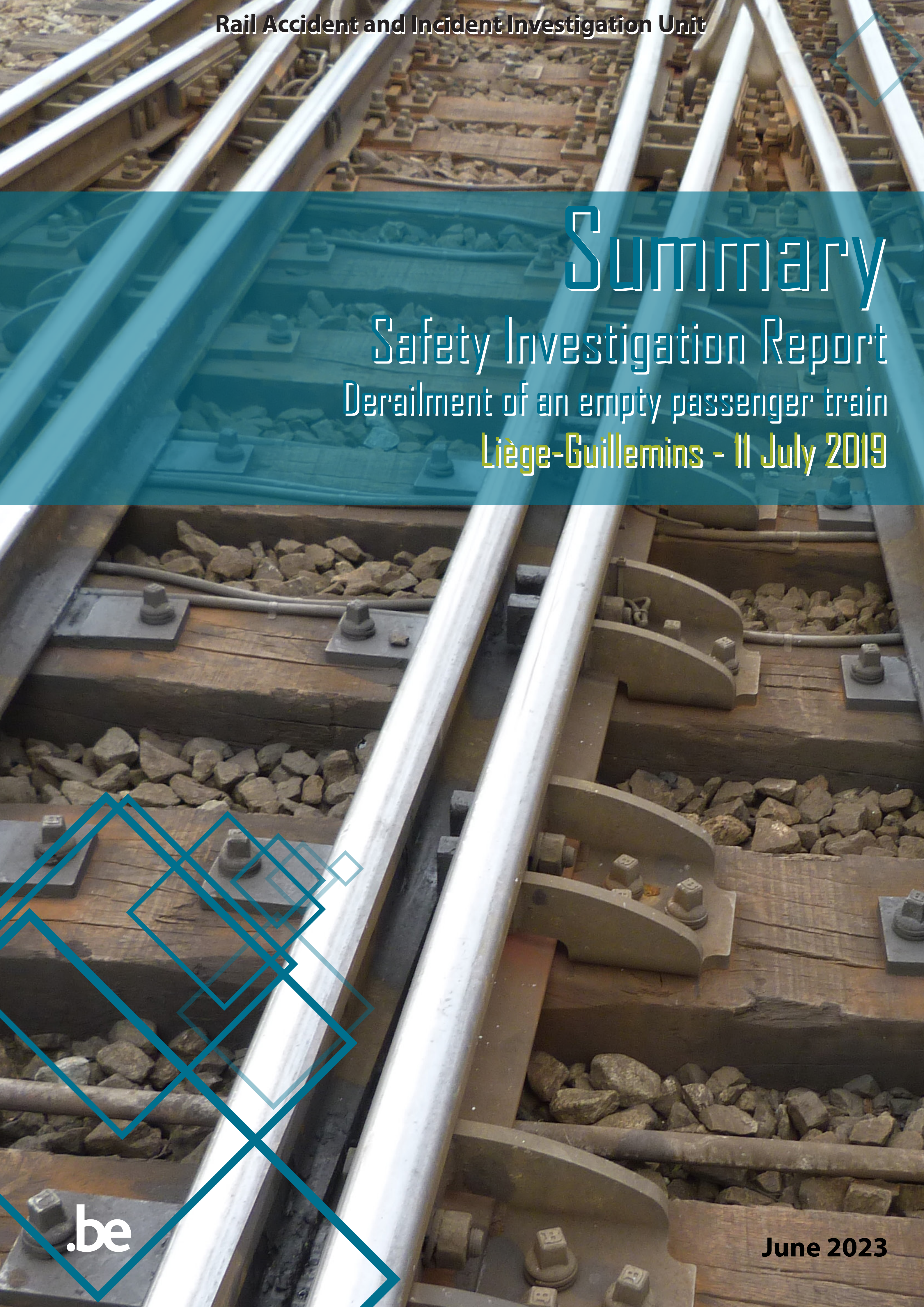
Rail Accident and Incident Investigation Unit



Summary

Safety Investigation Report

Derailment of an empty passenger train

Liège-Guillemins - 11 July 2019

.be

June 2023

REPORT VERSION TABLE

Version number	Subject of revision	Date
1.0	First version	22/06/2023

Any use of this report with a different aim than of accident prevention - for example in order to attribute liability - individual or collective blame in particular - would be a complete distortion of the aims of this report, the methods used to assemble it, the selection of facts collected, the nature of questions posed and the ideas organising it, to which the notion of liability is unknown. The conclusions which could be deduced from this would therefore be abusive in the literal sense of the term.
In case of contradiction between certain words and terms, it is necessary to refer to the French version.

SUMMARY

On Thursday 11 July 2019, a passenger train of railway undertaking SNCB/NMBS is stopped at Waremme station due to a technical problem (high voltage tripping on the electric locomotives of the train) and passenger disembarkation is organised.
After unsuccessfully trying to repair his train, the driver declares it to be broken down.

A type 18 locomotive is sent as emergency locomotive to pull the broken-down train to Liège-Guillemins station. After coupling the locomotive 18 to the head of the broken-down train and after a successful type A brake test, the train pulled by the locomotive 18 leaves Waremme station.

At around 09:48 a.m., as the train arrives at Liège-Guillemins station, the first coaches of the train derail on switches at the entrance to the station grid. The brake system pipe ruptures, bringing the train to stop.
There are no casualties and little material damage.
The Investigation Unit (IU) did not consider investigating this derailment, which does not meet the definition of a serious or significant accident.

However, during a meeting where the first elements gathered by SNCB/NMBS and Infrabel were presented, the IU realised:

- that the analysis of this low-speed derailment at the entrance to Liège-Guillemins station was more complex than it appeared,
- that there was no consensus between the two parties.

Following the qualification of the accident, the measurements taken on the premises were few and concerned:

- the condition of the track,
- the rolling stock,
- the recording tapes of the train.

In addition, when the IU investigators arrived at the accident site, some elements related to the rolling stock (coupling hook, pneumatic hoses) had been modified without being recorded or photographed, contrary to what is specified in article 8 of the Royal Decree of 16 January 2007 laying down certain rules relating to investigations into rail accidents and incidents.

The IU analysed these various data: they proved to be within standards and tolerances, and the analysis of the various factors separately could not explain the derailment.

Following a public contract, the IU then appointed Mastéris, a company providing external expertise, to conduct an analysis of the factors and forces to which the train was subjected when it entered Liège-Guillemins station, and to run a computer simulation of the dynamics of the train, in order to highlight the combination of factors that may have contributed to the derailment.

In a first deliverable, Mastéris established:

- a scenario covering all the contributing factors;
- the calculation of the forces generated.

Not all the data required for the Mastéris study, and in particular for the simulation with the railway dynamics software, were available. Therefore, at the request of the IU, Mastéris varied various parameters during its analyses and simulations on the basis of the elements made available to them.

Notwithstanding the seriousness of the consequences of an accident, in the case of a mainline passenger train derailment, the parties involved should collect all the relevant data concerning the infrastructure, the rolling stock and the actions of the operators that will make it possible to determine the factors having contributed to the accident. Gathering all the data at the accident site could have made the simulation closer to the real situation.

The results of these simulations are included in the second Mastéris deliverable.
The deliverables of Mastéris are appended to the investigation report and give full details of the explanations and calculations; the main approaches are summarised below.

TRACK ALIGNMENT FOR THE TRAIN ROUTE

The derailment takes place at the entrance to Liège-Guillemins station: the route of the train on the day of the derailment is not frequently used; it crosses the entrance grid to Liège-Guillemins station and is winding. The existence of a winding alignment results in a geometric offcentring between 2 coupled vehicles, which leads to a reduction in the contact surface of two buffers. This can lead to a risk of derailment.

This alignment has been checked for compliance with the Infrastructure TSI rules and the European standard EN13803: the route has no non-compliant winding alignment.
At first sight, the cause of the derailment is not the theoretical alignment.

TYPE OF BRAKING AND FORCES GENERATED

The train passed through the switch zone at the entrance to Liège-Guillemins station at a speed of around 30 km/h: this low speed complies with the regulations. However, as the train passed through these switches, the driver only used the rheostatic brake (or dynamic brake) of the locomotive to slow down the train. This is an electric braking in which, schematically, the direction of the current in the locomotive motor is reversed, inducing a resistive torque in the driving shaft.

In this braking mode, only the traction unit brakes. This can lead to longitudinal compressive forces in the set of wagons behind the locomotive.

An internal SNCB/NMBS rule specifies:

The use of dynamic braking on locomotives involves certain dangers associated with small radius curves and switches in diverging position, where longitudinal compressive forces can lead to an over-riding of buffers, or even derailment.
The use of dynamic braking alone is prohibited in these zones when the maximum permitted speed is 40 km/h or less.

The switch zone at the entrance to Liège-Guillemins station is a high gradient area with curves and reverse curves.

At European level, paragraph 4.2.4.4.4 of Regulation 1302/2014 of 18 November 2014 concerning a technical specification for interoperability relating to the 'rolling stock — locomotives and passenger rolling stock' subsystem of the rail system in the European Union states that:

If a unit is equipped with a dynamic brake system:
1) It shall be possible to prevent the use of regenerative braking on electric units so that there is no return of energy to the overhead contact line when driving on a line which does not allow that.
2) […]
3) Where on locomotives the dynamic brake is used independently from other brake systems, it shall be possible to limit the maximum value and rate of variation of the dynamic brake effort to predefined values.
Note: this limitation relates to the forces transmitted to the track when locomotive(s) is (are) integrated in a train. It may be applied at operating level by setting the values necessary for compatibility with a particular line (e.g. line with high gradient and low curve radius).

With regard to the regulations of the Infrastructure Manager Infrabel, the RSEIF/VVESI 4.2 specifies the value of the maximum dynamic braking force when the maximum dynamic braking force and the maximum gradient for increasing or decreasing the dynamic braking force of a locomotive are not managed automatically.

	Effort maximum du frein dynamique	Effort maximum du frein dynamique utilisé conjointement avec un autre frein
Une locomotive assure l'effort de traction	150 kN	105 kN
Plusieurs locomotives accouplées assurent l'effort de traction	75 kN	105 kN

The on-board recording system of the locomotive does not record the intensity of this braking. Based on the speed recordings and the profile of the tracks used by the train, the braking intensity was calculated by Mastéris. Determining this value is important not only for calculating the longitudinal compression forces in the set of wagons, but also for computer simulation (the subject of the second part of the analysis conducted by Mastéris).

The value determined by Mastéris (150kN) corresponds to the maximum value authorised by Infrabel in their regulations when the locomotive provides the tractive effort and the dynamic brake is used alone.

Given the braking scenario identified and the geometry of the track area where the derailment occurred, Mastéris conducted a longitudinal dynamic analysis and calculated the compressive forces generated.

Longitudinal compressive forces

Usually and historically, this speciality concerns freight trains, which are more prone to risk because of their length and tonnage, as well as their heterogeneity and, in particular, the presence of empty wagons, which contribute to these risks. Longitudinal compressive forces are generated in freight trains in various driving configurations (pneumatic braking, reverse running, dynamic braking, etc.) and can in some cases exceed the permissible LCF of the wagons making up the train.

A risk of derailment is deemed to exist when, for a given vehicle, the longitudinal compressive force exceeds the permissible value for the vehicle. However, derailment occurs in case of unfavourable characteristics when the maximum longitudinal compressive force is reached (curve and reverse curve of small radius, loading of the wagon, condition of the surface of the buffer plates, etc.). The risks of derailment due to longitudinal compressive forces are not studied on passenger trains for various reasons, including the short length of the convoys, which leads to low longitudinal compressive forces, and the mass of the coaches, which leads to high permissible longitudinal compressive forces. The Mastéris study is therefore one of the first in the 'Passenger' field to tackle this subject.

Mastéris extrapolated the reference values for freight wagons to the rolling stock involved in the derailment: these values come from studies and standards of the International Union of Railways.

This analysis shows that the calculated longitudinal compressive forces (130kN or 200kN in high value) remain well below the empirical permissible value (504kN) considered in this study.

The digital simulation of the dynamic behaviour of the derailed vehicle in the derailment zone, carried out afterwards by Mastéris, aims to examine the lifting of the wheels from the rail, that could cause the derailment in the switch zone where the train passed through.

Two criteria are used to study the risk of derailment:

- the lifting (dz) of the outer wheel at the curve of the leading axle of the first coach of the train;
- the contact force ratio Y/Q (where Y represents the transverse force and Q the vertical force) of this same wheel.

To provide an order of magnitude for these two criteria, "limit" values have been taken from the European standard EN14363:2016+A1:2018:

- For approval tests on the ability to negotiate track distortions without derailing, the limit value for wheel lift (dz) is 5 mm. However, it should be noted that this corresponds to conditions well defined by the standard (curve radius of 150 m, distortion of 7 mm/m).
- For approval tests on the dynamic behaviour of the train, the contact force ratio (Y/Q) for the front wheel must remain below 0.8.

An initial case is simulated and will serve as a reference and comparison for subsequent simulations that vary various parameters: the aim is to highlight the parameters that increase the risk of derailment.

The second Mastéris deliverable in appendix sets out in detail the various simulations carried out: below is a summary of the factors having an impact on the risk of derailment.

ADHESION AND COEFFICIENT OF FRICTION OF WHEEL-RAIL CONTACT

Wheel-rail adhesion is the basis of traction and braking. Traction and braking power is transmitted by the wheels to the rail. As a result, the adhesion coefficient has an impact on acceleration and braking.

The adhesion coefficient varies with the temperature of the rail and with the presence of substances on the rail such as rain, ambient humidity, oils, greases, etc.
The various parameters used to establish the adhesion coefficient were not recorded by either the Railway Undertaking or the Infrastructure Manager.

The Mastéris study therefore varied the coefficient of friction during simulations, making it possible to assess the real value, which is unknown. The results show that the coefficient of friction of the wheel-rail contact has an impact on the risk of derailment: a dry rail increases the risk of derailment.

With a perfect track (no defects, no wear, etc.) and a nominal train (no deformation, balanced masses, etc.), the derailment zone is sensitive, but the derailment criteria are always below the limit values, whatever the condition of the surface of the wheel-rail contact.

TRACK ALIGNMENT

Although the winding alignment complies with the rules of the International Union of Railways, the computer simulation enabled us to check the behaviour of the train in the derailment zone. This zone is characterised by a sequence of a left-hand curve and a right-hand curve with an alignment of 8.1m.
Given this sequence, the maximum contact force ratio (Y/Q) is located at the entrance to the curve, corresponding to the derailment zone.

The simulation carried out with a new rail profile and a minimum braking force (15kN) shows that the contact force ratio (Y/Q) is sensitive to the alignment characteristics of the derailment zone, without however exceeding the limit value (0.8).

APPLICATION OF A BRAKING FORCE

In the first part of their study, Mastéris calculated the maximum value of the dynamic braking force of the locomotive, as this value is not recorded on board the rolling stock.
The result of this calculation was a value of 150kN.
During the simulations carried out in the second phase of the Mastéris study, two cases were compared, with new rail profiles and new wheel profiles:

- application of a braking force of 15kN
- application of a braking force of 150kN

Under new profile conditions for both rails and wheels, applying a braking force of 150kN increases the Y/Q contact force ratio by 12% (compared with applying a braking force of 15kN), from 0.67 to 0.75. The ratio remains below 0.8, but the 150kN braking force clearly has a significant impact on the contact force ratio.

RAIL PROFILE

Rails are subject to vertical wear (infrequent) and lateral wear (much more frequent). Wear is a function of traffic, i.e. the tonnage, the number and the speed of trains.
Lateral wear is most noticeable on the outer rail.

The simulation results show that, irrespective of the braking force, the impact of a worn rail profile on the risk of derailment is significant.

TRACK GAUGE WITH BRAKING FORCE

The track gauge is the distance separating the inner flank of the two rails of a railway track.
The standard gauge is 1435 mm, which corresponds to the standard gauge of the International Union of Railways.

Gauge measurements were not available for the entire section concerned by the derailment: gauge values were determined by Mastéris from profile drawings supplied and reproduced using computer-aided design software.

At the entrance to the derailment zone, the gauge values vary between 1452 and 1461mm (the nominal value for this zone is 1448mm).
Three values were considered for the simulation: 1452, 1455 and 1458mm.

With a braking force of 150kN, the increase in track gauge (from 1448 to 1458mm) leads to an increase in the contact force ratio (Y/Q) by 18%, from 0.75 to 0.89. The limit value for this ratio (0.8) is therefore exceeded.
This increase is due in particular to the decrease in vertical force by around 16% (additional offloading of the front wheel).
The impact of track gauge on the contact force ratio (Y/Q) is negligible when braking force is not applied.

An increased track gauge has a significant impact on the risk of derailment when combined with a braking force of 150kN.

BOGIE AND/OR TRACK DISTORTION

It is well known that a distortion related to a track displacement and/or bogie deformation increases the risk of derailment:

- The highest distortion value recorded by the Infrastructure Manager is 2.15mm/m at 13.54m from the switch tip;
- In the absence of real data available to specify the value of the distortion of the bogie, the simulation carried out by Mastéris adds a 20 mm wedge to the primary suspension of the first left-hand outer wheel, in order to model these distortion defects as part of a parametric study.
- This corresponds to a total distortion (track + bogie) of 7.8 mm/m.

The simulation, with a braking value of 150kN (i.e. the maximum value calculated), allows comparison of the behaviour between a distortion with a worn rail profile and a distortion with a new rail profile.

The results clearly show that a distortion defect, coupled with a 150kN braking force, increases the risk of derailment:

- **with a new rail and no other track defects (straightening, levelling), the values for the two criteria (wheel lift and contact force ratio) are still below the limit values;**
- **combining the same distortion defect with a worn rail could result in a derailment (wheel lift exceeds the limit value (5 mm)).**

CONCLUSION

An initial simulation with nominal parameters (new rail, perfect track with no defects, train characteristics at nominal) showed that the derailment zone is a sensitive zone with regard to two derailment criteria:

- wheel lift (dz)
- the wheel-rail contact force ratio (Y/Q).

The parametric studies carried out led to a number of conclusions, including the following:

- The entrance to zone 14AE, identified as the derailment zone, is indeed the most critical zone on the route, even with faultless track, a nominal train and a low rheostatic braking force by the leading locomotive.
- A dry rail increases the risk of derailment.
- The rail profile has an impact on the risk of derailment, whether or not it is combined with a braking force.
- Increasing the track gauge has a significant impact on the risk of derailment when combined with a high rheostatic braking force by the leading locomotive.
- Distortion defects related to bogie and/or track deformation, combined with rail wear and a high rheostatic braking force by the leading locomotive, can cause the train to derail in the zone under study.

The study conducted by Mastéris shows that the derailment zone is particularly sensitive compared with the previous switch zone and that, due to the combination of various influencing factors (dynamic braking force, track gauge greater than the nominal value, distortion defect, worn rail profile, coefficient of friction), derailment criteria are likely to be met or exceeded.

Rail Accident and Incident Investigation Unit
http://www.raiiu.be