Investigation Body for Railway Accidents and Incidents

Safety Investigation Report

Double overrunning of signals by an international train

Antwerpen-Luchtbal - 1 November 2015

.be

November 2016

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 concepts mobilising 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 terms and expressions, only the Dutch version is authentic.

1. GENERAL INFORMATION

Nature of the incident: overrunning a signal

Type of safety investigation: incident with restricted safety investigation

Date and time of the incident: 1 november 2015 omstreeks 10u49

Place of the incident: Antwerp, close to the stopping point Antwerpen-Luchtbal, L.25

Train: SNCB/NMBS passenger train E9227, Bruxelles-Midi – Amsterdam CS, with about 250 occupants. Locomotive HLE 2806, type TRAXX, SNCB/NMBS holder. The locomotive was equipped with Memor devices (Belgian network) and ATB (Dutch network). 6 cars, NS auxiliary holder, NS auxiliary personnel

Infrastructure: between Bruxelles-Midi and Mechelen, the lines are entirely equipped with crocodiles and partially with TBL1+ and ETCS level 1. Between Mechelen and Antwerpen-Luchtbal, the L.25 was equipped with crocodiles and, where the Masterplan foresees it, with TBL1+ trackside signalling and ETCS level 1 cab signalling.

Basic facts: at the exit of the Antwerpen-Centraal tunnel, the E9227 train overran the signals G-R.12 and J-R.12, in a closed position, on the L.25. No route was defined towards the L.12: the train continued its journey on the L.4 where it came to a standstill after the intervention of surveillance staff from Block 12 Antwerpen-Berchem.

Consequences: delays and train cancellations - there were no victims or material damage.

Direct cause: the Investigation Body has retained the following hypothesis: the double overrunning of a signal caused by a state of hypovigilance due to fatigue.

Indirect causes: the overrunning of the signal was made possible by:

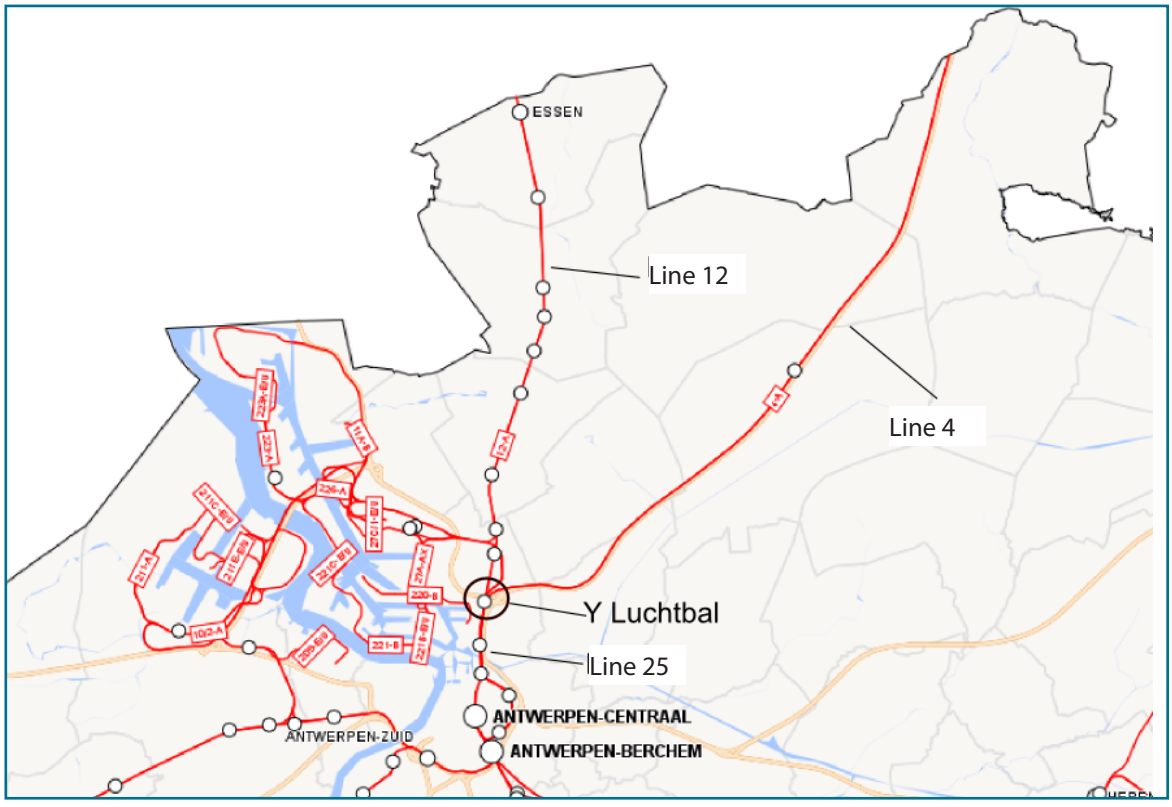
- the absence on-board the locomotive of driving assistance TBL1+ or ETCS Level 1 or 2 cab signalling.
- the fact of taking into account the idea of "driving without conflict": if the risk of meeting a signal at danger is reduced, logically the risk of SPAD is reduced. The risk of encountering a signal at danger may be reduced by ensuring the elimination of conflicts in the planning and maintenance of timetables.

Underlying cause: The absence of an LMRA or a vigilance detection system for train drivers. The implementation of a quality FRMS (Fatigue Risk Management System) increases the probability of detecting a driver's unfitness as well as the problems linked to an eventual loss of vigilance during driving.

4 recommendations concern the consumption of medication, driving without conflicts, on-board technology and the adoption of an effective FRMS.

2. SUMMARY OF THE FACTS

On Sunday 1 November 2015, after a regular stop at Antwerpen-Centraal station, the driver of train E9227 was given the green departure signal. At 10:45, the train E9227 left Antwerpen-Centraal station by the A track of L.25.
During the route, the driver passed the signal A455, which was showing a double yellow. The driver confirmed seeing the restrictive double yellow with the Memor button, belatedly but without emergency braking.
The restrictive double yellow signal A455 means that the driver of the train should adapt the speed of the train to be able to stop in time, in the present case in front of the signal at danger G-R.12. However, the driver continued accelerating up to 90 km/h and crossed the signals G-R.12 (10:48) and J-R.12 (10:49), both at danger.
In a normal situation, further on from the signal J-R.12, the train is directed from the L.25 towards the L.12 but, considering that the signalling control had not yet planned the route and the last route that it had planned led to L.4, the train continued its route from the L.25 towards the L.4.
Finally, the train came to a standstill on the L.4, around 1 km from the transition zone of the catenary voltage 3 kV to 25 kV. The train travelled 2.15 km from the first overrunning of the signal.
Following the overrunning of the signal, 250 passengers had to be evacuated and a certain number of trains were cancelled. There was not an immediate danger of collision.

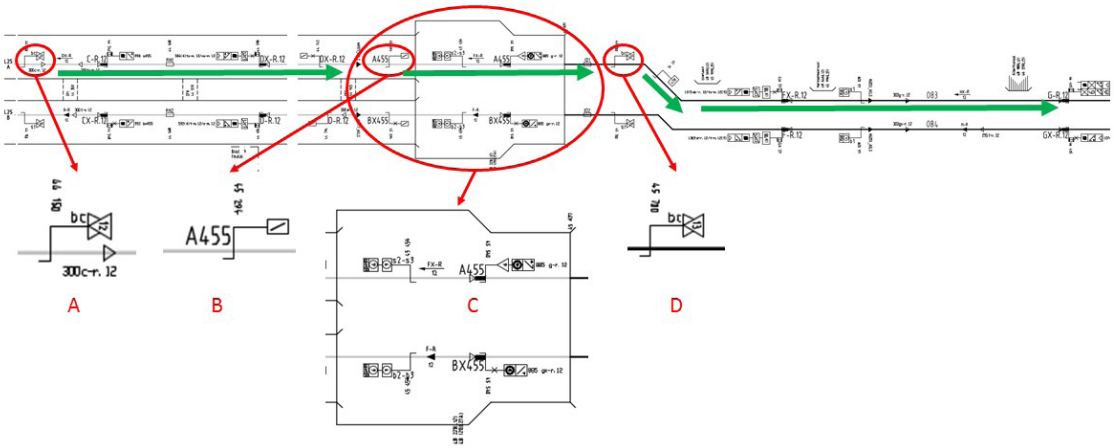


3. LOCAL CIRCUMSTANCES

At the exit of the Antwerpen-Centraal tunnel, the train travelled north. The weather was good and clear with a visibility of more than 200 m. The signals A455, JR.12 and G-R.12 as well as the signs were clearly visible.

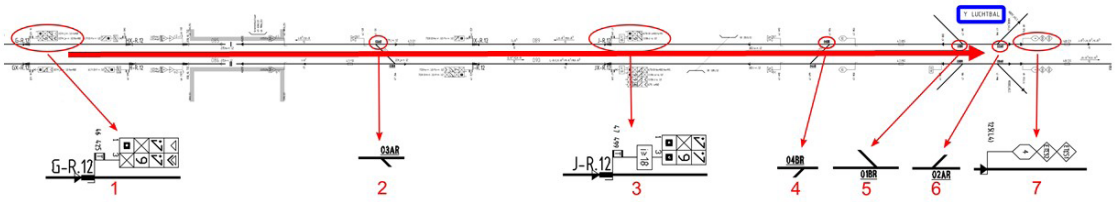
4. INFRASTRUCTURE

The signals and the points between Antwerpen-Centraal and Antwerpen-Luchtbal are served by Block 12 in Berchem, which is equipped with EBP / PLP-technology.
The signalling between Antwerpen-Centraal and Antwerpen-Luchtbal is explained using the schematic signalling plans below. The route followed and the route to be followed are shown using arrows.

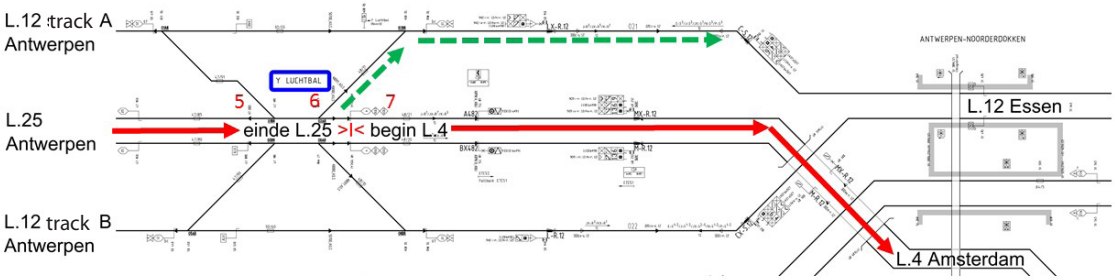


Line 25: SSD (Schematic Signalling Diagram) between Antwerpen-Centraal and the Luchtbal junction

Key
Defined route
A permanent yellow end-zone sign with green border, maximum speed 120 km/h
B repeating signal of signal A455
C automatic signal A455
D permanent yellow end-zone sign with green border, maximum speed 130 km/h



Line 25: SSD (Schematic Signalling Diagram) between Antwerpen-Centraal and the Luchtbal junction



Line 25: SSD (Schematic Signalling Diagram) - zoom on the junction Luchtbal in direction of Antwerpen Noorderdokken

Key
route not yet planned
route after overrunning of 1st signal
1 managed signal G-R.12
2 points 03AR
3 managed signal J-R.12
4 points 04BR
5 points 01BR
6 points 02AR
7 start Line 4

5. PARTIES CONCERNED

The Intercity service Brussels-Amsterdam is the fruit of a collaboration between the Dutch State, the Nederlandse Spoorwegen NV (NS or Dutch Railways) and the Belgian national railway company (SNCB/NMBS). There is a cooperation agreement between the parties stipulating that train service is assured jointly and that it must fulfil all the regulations in force to guarantee passenger transport in total safety and with a high level of quality.

Railway undertaking SNCB/NMBS

The SNCB/NMBS departments that were particularly involved in the investigation were:

- The Transport department (B-TR), responsible for operational management:
  B-TR organises the national train offer, establishes the timetable (B-TR.4) and follows the rail traffic in real time (B-TR.5 RDV).
  B-TR is responsible for the management of rolling stock, train drivers (B-TR.1 and 2), train conductors (B-TR.3), monitoring and corporate safety (B-TR.6) and operational safety (B-TR.8).
- The Technics department (B-TC), in charge of purchasing, modernisation and maintenance of rolling stock.
  The department's mission is to make sufficient safe and reliable stock available to clients which is adapted to operational and commercial needs to offer passengers a quality service.

The SNCB/NMBS acts as transporter on the Belgian territory and makes traction units available allowing the train service to be assured at a maximum speed of 160 km/h.

The IC train was pulled by a locomotive HLE 2806 of a Traxx type, belonging to the SNCB/NMBS and equipped with a driving assistance system of a Memor type for the Belgian network. There was no driving assistance equipment of type TBL1+ or ETCS Level 1 or 2 cab signalling on board the locomotive[1]. The locomotive was also equipped with an ATB (Automatisch Trein Beïnvloeding) type driving system or an automatic control system for train speed on the Dutch network.

Auxiliary enterprise Nederlandse Spoorwegen

HSA/NS[2] acts as carrier on the Dutch territory and makes available compatible cars and control cars[3], which are appropriate for the train service. NS is the owner of passenger cars. NS also makes train drivers available.

The cooperation agreement provides that the train drivers, train conductors and the rolling stock of the SNCB/NMBS and HSA/NS meet the requirements set by the legal and regulatory measures in force respectively in the Netherlands and in Belgium and by the Infrastructure Manager concerning operational safety, the driving of trains and rolling stock. The measures regarding respect for driving and rest time are a part of this.

The agreement between the SNCB/NMBS and HSA/NS outlines the tasks and responsibilities of the two parties concerning training and exams in the context of the driving of trains on the Belgian network. This agreement applies to train drivers from HSA/NS in the context of the driving of trains on the Belgian railway infrastructure.

1 *The DRSI confirms the authorisation for entry into service of TRAXX type locomotives with the configuration 7D and 7D1 and equipped with TBL1+ and ETCS L1 technology. These locomotives are put into service for the IC link between Brussels and Amsterdam. Authorisations were granted in June and September 2016.*

2 *As indicated in the agreement. Formally speaking, NS Internationaal is the railway undertaking intended here, but it is still HSA in the agreement.*

3 *The control cars known as "stuurstandrijtuigen" in the Netherlands and "voitures-pilotes" or "motorrijtuigen" in Belgium have been incorporated in the composition of trains. In any case, they cannot, at a technical/operational level, be used as driving control trailers in combination with a TRAXX type 28 motor coach. As a result, the trailer is only used for passenger transport.*

The cooperation agreement transfers to the HLT manual, but does not provide clauses involving operational safety. The cooperation agreement and the internal rules of the railway undertaking do not foresee, for example, any procedure for checking if train drivers are fit for duty prior to the start of service nor any procedure allowing the level of fatigue to be assessed during operation, and this according to medical (illness), psychological (stress, burn out) or physical (physical condition) parameters.

The Dutch train driver has the necessary authorisations to operate on the Belgian network.

Infrabel, Traffic Management & Services department

The Infrabel departments that are particularly involved in the investigation are:

- I-ICT: responsible for the networks and communication systems;
- I-TMS: in charge of the supervision, particularly in real time, of all trains;
- I-AM: responsible for the management and maintenance of the tracks and track apparatus.

The SNCB/NMBS requests the necessary capacity from Infrabel and Infrabel allocates the train paths on the Belgian network.

On the day of the accident, there were no works on the L.25 in the zone situated between Antwerpen-Centraal and Y-Luchtbal and the analysis of the EBP images and the LARA log indicates that the signalling was in good working order.

The E9227 operates between Brussels and Antwerp in accordance with the set timetable and left from Antwerpen-Centraal station at the set time. At the time of departure from Antwerpen-Centraal, the route of the train E9227 was only planned up until the signal at danger G-R.12.

The Infrastructure Manager is currently studying a safe planning system, by ensuring that conflicts are avoided in the planning and maintenance of the timetable.

The GSM-R system functioned normally and the conversations with the train driver were recorded via the Etrali system. Real time supervision by the Infrastructure Manager allows the time of signal overrunning to be recorded: at 10:49:18, the assistant station manager of Block 12 ordered the driver of the Intercity train to stop immediately.

The overrunning of signals was recorded in the EBP logbook at 10:48:17 and 10:49:00. The EBP, Lara and Etrali systems are not synchronised and record slightly different times.

6. REGULATIONS

A few rules applicable to the events:

HLT II.B.7 2 Stopping of the train

The Article 2.1 relating to stopping of the train provides that:
"*the driver immediately brings about the stopping of the train:*

- *… if his physical or psychological condition prevents driving the train safely*" …
-

An internal document NKN6000 gives the following "if you are a train driver..., warn as soon as possible and before the start of service, your local 3x8 office in Brussels that is part of the driver technical unit (CTC) that your workshop is a part of".

Neither the document nor the cooperation agreement mentions who Dutch train drivers should contact in situations like this. In principle, it is expected that they contact the Product Control service in Amsterdam.

HLT II.B.2

When it is unexpected, the driver records the whistle sounding or the flashing of the yellow lamp.
If this fact is due:

- *to the presence of a major signal out, the driver considers that the signal is an unreliable signal and applies the regulatory requirements provided;*
- *to the presence of a speed reduction indicator triangle, or a chevron-patterned sign, the driver respects the restrictions announced;*
- *to the presence of a crocodile mark sign, a signal or a sign intended for the opposite direction, the driver continues in the same direction; he prepares an E361 "Crocodile" telegram if it is a signal or a permanent sign the wrong way round*[4].
  In other cases, and if the driver is certain that it is not a major stop signal out, the driver adopts running on sight as quickly as possible. Normal running can only be recommenced:
- *from the next major stop signal and, in no case, before running a distance of 1500 m;*
- *failing having encountered a major stop signal, after running 3 km.*

The HLT manual is an integral part of internal regulations for train drivers. The train driver has had training in this. He knows these regulations and is supposed to apply them.
The railway undertakings ensure that the regulations are applied.

RGE 511 § 2.8 Order of priority of trains

The order of priority recorded in the list below, should always be applied with judgement. Excluding disruptions, decisions need to be made in real time that affect train service as little as possible overall.

It is shown in the table that the international train should have priority under the given circumstances.

4 *As indicated in the HLT: Infrabel reports that already for some time this is no longer in force.*

Preventive measures

The HLT II.B.7 booklet provides that train drivers should stop if their physical or psychological condition is in doubt.

HLT I.3 §3.1 During service

This chapter provides that, during running, the train driver "does not listen to music and only uses the multimedia devices provided by the employer (e.g. IDA device, service mobile phone). Other multimedia devices may not be found at the driver's desk.
The train driver only makes brief notes on his M510 report relating to the movement of the train; carries out no other action which could distract his attention including looking at the IDA device; observes the track as far as possible; ..."

The procedures foreseen in the internal document NKN6000 do not apply to the Dutch train drivers. The Dutch train drivers of the Dutch Railways use software unique to them. In case of problems with operation, they are supposed to make contact with the Product Control service of the NS in Amsterdam.

The investigation shows that at the start of service, there is no direct control or LMRA regarding the fitness of train drivers. The only possibility for the train driver to declare himself unfit is by telephone or electronically. The task of declaring oneself unfit for service falls entirely to train drivers who are supposed to be able to diagnose themselves reliably.

7. THE INFRASTRUCTURE

Line 25

Line 25 is a double-track line, electrified with 3 kV and with a reference speed of 160 km/h between Mechelen-Nekkerspoel and Antwerpen-Y Luchtbal. In this zone, the L.25 is equipped with Memor trackside signalling as well as - where the Masterplan provides for it - TBL1+ signalling and ETCS Level 1 cab signalling.
The train operates on the A track in the direction of the Netherlands.

Line 4

Line 4 is a double-track line, electrified with 25 kV and with a reference speed of 300 km/h between Antwerpen-Y Luchtbal and the Prorail network edge (Breda, Netherlands). The L.4 is equipped with ETCS cab signalling Level 1 and 2.

Line 12

Line 12 is a double-track line, electrified with 3 kV and characterised by a reference speed of 130 km/h between Antwerpen-Y Luchtbal and Y Sint-Mariaburg. The L.12 is equipped with the cab signalling system ETCS Level 1 and trackside signalling of TBL1+ type (eurobalises) and Memor (crocodile).
Lines 4, 12 and 25 are equipped with GSM-R and have EBP technology from Block 12 Antwerpen-Berchem.

Permanent yellow end-zone sign with green border

In the Antwerp tunnels, around 200 m from the departure signal S-M.12, there is a first permanent yellow end-zone sign with green border with the inscription 9 and, 180 m after the first sign, there is a second permanent yellow end-zone sign with green border showing 12. The signs indicate that the speed of the train may be increased in two stages to respectively 90 and 120 km/h. An acceleration can only be started from the moment that the last car of the train has passed the signal and naturally on condition that the signals do not give other instructions.

Signal A455

The signal A455 is located at the end of the tunnel, where the tunnel goes into a partially open-air shaft.

The visibility of the signal A455 is good but its position after a bend means that its aspect may be seen late.

To correct this problem, the signal is repeated before the bend (see after).

The signal A455 is an automatic signal equipped with TBL1+ technology and a crocodile. The signal may show a red, green, green-yellow horizontal or double yellow aspect and is equipped with a "9" speed sign:

- if the signal shows a green-yellow horizontal aspect, the passage in major movement is authorised and the speed of the train should be adjusted so that the speed reduction imposed by the following major stop signal can be respected. At the next signal, a speed limitation to at least 90 km/h will be in place.
- if the signal shows a double yellow aspect, the passage in major movement is allowed and the speed of the train should be adapted so that the train can stop before the next major stop signal or simplified stop signal. A train driver may encounter this aspect if another train crosses the route to be followed or is travelling in front for example.

The signal A455 was not equipped with the ETCS system at the time of the incident.

Repeating signal A455

The repeating signal A455 is located in the tunnel, 250 m before the A455 signal.
The visibility of the repeating signal is good.

A repeating signal is not equipped with the TBL1+ system or a crocodile:

- a horizontal line indicates that the passage is prohibited or passage in major movement with speed reduction;
- an oblique line indicates that passage in major movement without speed reduction is allowed.

On 1/11/2015, the LARA log recorded the following events:

- at 10:41:31, the signal A455 showed a double yellow aspect;
- at 10:41:33, the repeating signal A455 showed an oblique line.

Exit from the tunnel

The exit from the tunnel and the lighting in the tunnel were conceived to move progressively from darkness to light.

Permanent yellow end-zone sign with green border

63 m from the end of the railway tunnel, there is a permanent yellow end-zone sign with green border showing 13. The sign gives the maximum speed authorised from this area (130 km/h). The train can only increase its speed up to the value shown from the moment that the last car has passed this sign.

Seeing as the last signal encountered (signal A455) shows a restrictive aspect, the train driver CANNOT increase the speed of the train to 130 km/h, but must adapt his speed so that he can stop before the following signal, which is the signal G-R.12.

Signal G-R.12

The signal G-R.12 is located 885 m after the signal A455 and 100 m after the end of the bridge on the Albert Canal.
The visibility of the signal G-R.12 is good.

Coming from Antwerp, the track goes up to this bridge. After the bridge, the track descends in the direction of the Netherlands. The signal G-R.12 is oriented towards the south and is raised so as not to be hidden by the "crest of the bridge".

The signal G-R.12 is a managed major signal equipped with ETCS 1/TBL1+ (eurobalises) technology and a crocodile. The signal may show a red, green, green-yellow horizontal, green-yellow vertical or double yellow aspect.

On 01/11/2015, the LARA log recorded the following events:

- at 10:41:24, the signal G-R.12 showed a red aspect after passage of the movement;
- at 10:48:13, passage of the train E9227 at the signal G-R.12.

Remark concerning the TBL1+ and ETCS L1 systems:
If the signal A455 shows a restrictive aspect, the train driver should adapt the speed of the train. At 300 m before the signal G-R.12, eurobalises are placed on the tracks: if the speed of a train at these beacons is higher than 40 km/h, the TBL1+ system is activated and an automatic emergency brake is engaged. This assumes that this technology is present on the train.

TBL1+ beacons are placed at the foot of the signal G-R.12: if a train crosses these beacons while the G-R.12 signal is at danger, the train is automatically stopped via an emergency brake. This assumes that this technology is present on the train.

For trains equipped with ETCS technology, there is the same guarantee that the trains will be stopped in time.

Indicator triangle with crocodile

Operating on the A track, after the G-R.12 signal, there is an indicator triangle for a permanent limited speed zone, which is equipped with a TBL1+ beacon and a crocodile.
The train driver encountered this sign in the opposite direction: therefore he was not able to read it. The triangle announces a speed reduction of at least 50 km/h and gives the maximum permitted speed in this zone for the trains coming from the opposite direction.

Signal J-R.12

The signal J-R.12 is found at 1074 m after the signal G-R.12, on the outside of the bend. The visibility of the signal J-R.12 is good.

The signal J-R.12 is a managed major signal equipped with ETCS/TBL1+ beacons (eurobalises) and a crocodile. The signal can show a red, green, green-yellow horizontal, green-yellow vertical or double yellow aspect.

On 01/11/2015, the LARA log recorded the following events:

- at 10:43:43, the signal J-R.12 showed a red aspect after passage of the movement;
- at 10:48:57, passage of the train E9227 at the signal J-R.12.

Comment concerning the TBL1+ and ETCS 1 systems:
If the signal J-R.12 is at danger, the driver is expected to adapt the speed of the train. 279 m before the signal J-R.12, eurobalises are placed on the tracks: if the speed of a train at these beacons is over 40 km/h, the TBL1+ system is activated and an automatic emergency brake is engaged. This assumes that this technology is present on the train.

The eurobalises are placed at the foot of the signal J-R.12: if a train crosses these beacons while the signal J-R.12 is at danger, the train is automatically stopped via an emergency brake. This assumes that this technology is present on the train.

For trains equipped with ETCS technology, there is the same guarantee that the trains will be stopped in time.

Points

After the signal J-R.12, the train E9227 crosses the points 04BR (to the right), 01BR (to the left) and 02AR (to the right) without a defined route: the points were in "straight ahead" position and were not touched.

In normal operating conditions, the train should cross the points 02AR travelling towards L.12.

On 01/11/2015, the train was travelling from the L.25 to the L.4.

Marker sign Line 4 with the ETCS1 and ETCS2 marking

A marker sign gives the number of the line on which the train is embarking or the direction. Line 4 is equipped with the cab signalling system ETCS1 and ETCS2.

All the details concerning the "movement authority" are transmitted to the on-board equipment via the "eurobalises" at the moment that these are crossed (regular transmission). The data relating to the speed are transmitted by these same eurobalises (in ETCS level 1). The detection of "line clear" and the surveillance of the exit of the whole train is done via ground equipment (track circuits, axle counters, etc.). The distance between the trains is regulated by the sections.

In the zone situated between Y-Luchtbal and the ProRail network edge (Netherlands), only the L.4 is equipped with the cab signalling system ETCS. A train which is not equipped with the cab signalling system ETCS does not "listen" to the data transmitted by the eurobalises. This implies that a train which is not equipped with the cab signalling system ETCS 1 or 2 and which is engaged on L.4 can only be immobilised by the intervention of the train driver or by cutting the electricity supply. As a result, such movements are not allowed.

Stop markers A482 and A491

They show the area where the stop can be required. By analogy with trackside signalling, the stop markers are "closed" if they prevent passage when cab signalling requires a stop. Otherwise they are "open".

The stop markers can be clearly distinguished from the signals and are a clear indication that a train is engaged on a line equipped with a cab signalling system. The cab signalling system ETCS replaces the driving assistance systems TBL1+ and Memor.

To operate on the Infrabel network, the train E9227 is only equipped with the Memor system and therefore receives no impulse at stop markers. The speed of the train at the stop marker A482 is 90 km/h.

Means of communication

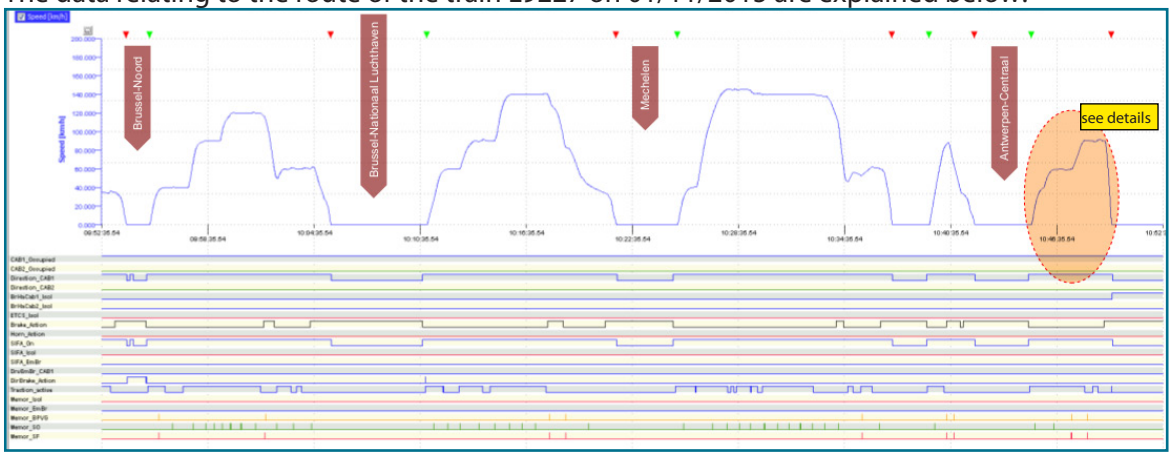
The train and the L.25 are equipped with GSM-R technology. If Block 12 Antwerpen-Berchem records the overrunning of a signal, the surveillance staff concerned immediately inform the train driver via the GSM-R network by ordering him to stop immediately.
In the SPAD file, we find the following: "No GSM-R alarm was emitted as, excluding the train responsible for the SPAD, there were no other trains involved."

In reality, the immediate sending of an emergency call after the first overrunning of a signal could have allowed the second overrunning to have been (just) avoided.

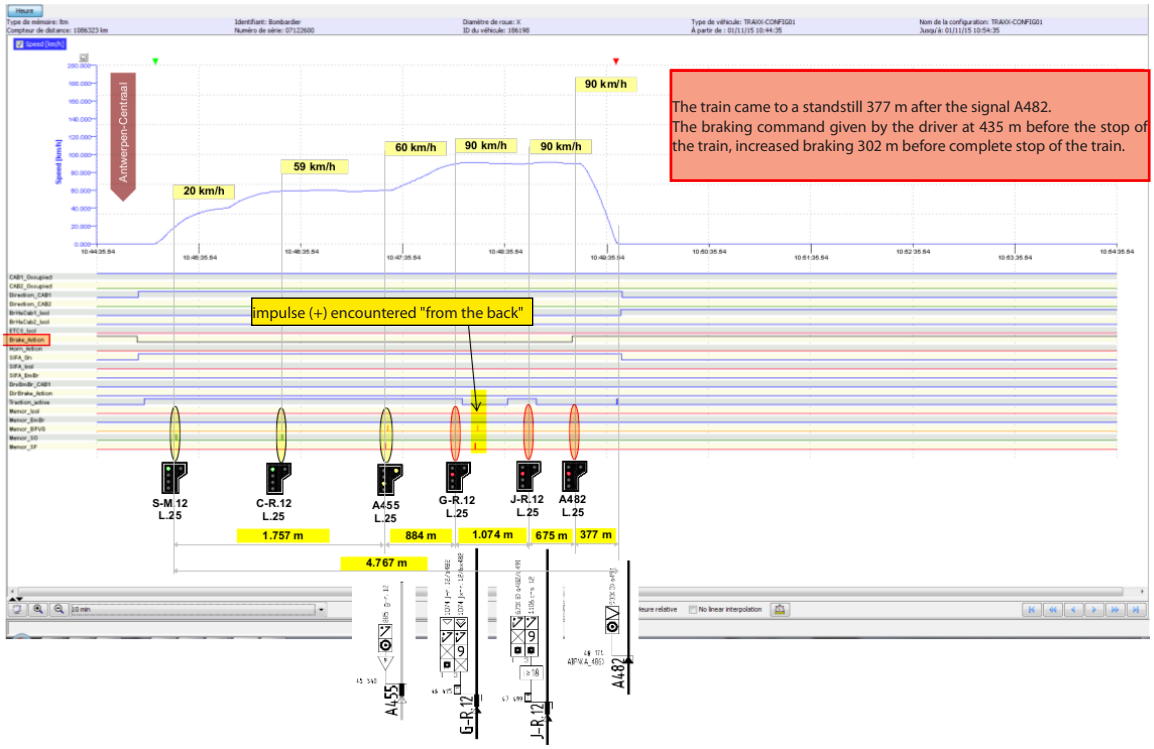
The GSM-R equipment and the GSM-R network functioned correctly.

8. ROUTE OF THE TRAIN E9227

The data relating to the route of the train E9227 on 01/11/2015 are explained below:



The first part of the route between Bruxelles-Midi and Antwerpen-Centraal was without incident. After a regular stop at Antwerpen-Centraal, the train left in direction of the border with the Netherlands. The details of the last part of the route are given below.



In the tunnel, the train driver increased the speed of the train in two stages up to 59 km/h and maintained this speed until the signal A455. The signal A455 showed a double yellow aspect. The train driver acknowledged belatedly[5] and accelerated up to 90 km/h at the moment of leaving the tunnel.

5 *See MD of 20/06/2008*

Article 4.3.3.2 Anticipated acknowledgement

Approaching a signal showing a restrictive aspect, the driver demonstrates his vigilance by pressing the acknowledgement button before passing the signal. This manoeuvre causes the light indicator recording the restrictive aspect to illuminate. The driver then has to release the acknowledgement button within 4 (+0.2; - 0.8) seconds.

Article 4.3.3.3 Delayed acknowledgement

The driver does not act on the acknowledgement button before reaching the signal showing a restrictive aspect. The driver then has to push down on the acknowledgement button within 4 (+0.2; - 0.8) seconds.

The first signal after the signal A455, the signal G-R.12, was at danger. In normal operating conditions, international trains have priority and the train driver waits for a line-clear signal. This does not mean that he does not have to wait at an unexpected signal at danger!

The train passed the signals G-R.12 and J-R.12 at danger. Between the two signals, the passage at a crocodile was acknowledged "belatedly".

The "belated" action came at an indicator triangle situated on the track A. This triangle is intended for trains travelling in counter-track direction (trains towards Antwerp). The indicator triangle is only visible to a train travelling in counter-track direction on track A:

- only a train driver travelling in counter-track direction has to adjust the speed of the train so as to comply with the indicated speed from the announced origin sign;
- as the speed limit imposed was 50 km/h in relation to the reference speed, this signal is equipped with a driving assistance system (crocodile and TBL1+ beacon): every train equipped with a driving assistance system of Memor or TBL1+ type and which travels in counter-track will receive an impulse at the moment of passing the crocodile and must confirm that he has understood the information on speed reduction by pressing the Memor button.

When a route in direction of the Netherlands is planned, a train driver cannot read the information on the reference speed sign and the train does not receive an impulse from the crocodile. As there was not yet a new route planned on 01/11/2015, the crocodile still gave an impulse as the speed limit sign was passed. The train driver did not notice this abnormal situation, he acknowledges and did not follow up on this impulse (reduce speed).

After the overrunning of the signal J-R.12 at danger, the train overran the stop marker A482.

A stop marker gives no aspect likely to be understood by a train driver and the signal can give no information to a train that is only equipped with Memor.

After passing the stop marker A482, the train was immobilised following a braking by the driver after a GSM-R call from an Infrabel employee. No emergency brake was recorded.

9. USER INTERFACE - OPERATION

Self-medication

The investigation allowed it to be determined with certainty that the passing of signals was a result of hypovigilance.

Problems of hypovigilance are very often linked to the circadian rhythm (biological) in relation to sleep health and the accumulation of fatigue.

Aside from problems of sleep health or accumulation of fatigue, other factors can also have a major influence on vigilance. Thus, the investigation allowed it to be noted that there is a risk to being unwell and self-medicating following a self-diagnosis.

The train drivers are well-aware that driving under the influence is not allowed and they are assumed to take medication that does not have (known) side effects that have repercussions on their ability to concentrate.

Information on the potential effects of medication on driving can be found in the directions for use included with the medication. In the Netherlands, it is possible to identify banned medications very simply: a yellow label (see photo) is affixed to the packaging of the medication concerned.

Source: Instituut voor Verantwoord Medicijngebruik

On 1st November 2015, the train driver took a medicine that was considered as safe by colleagues. What is more, on the instructions of the medication taken by the driver it is written:

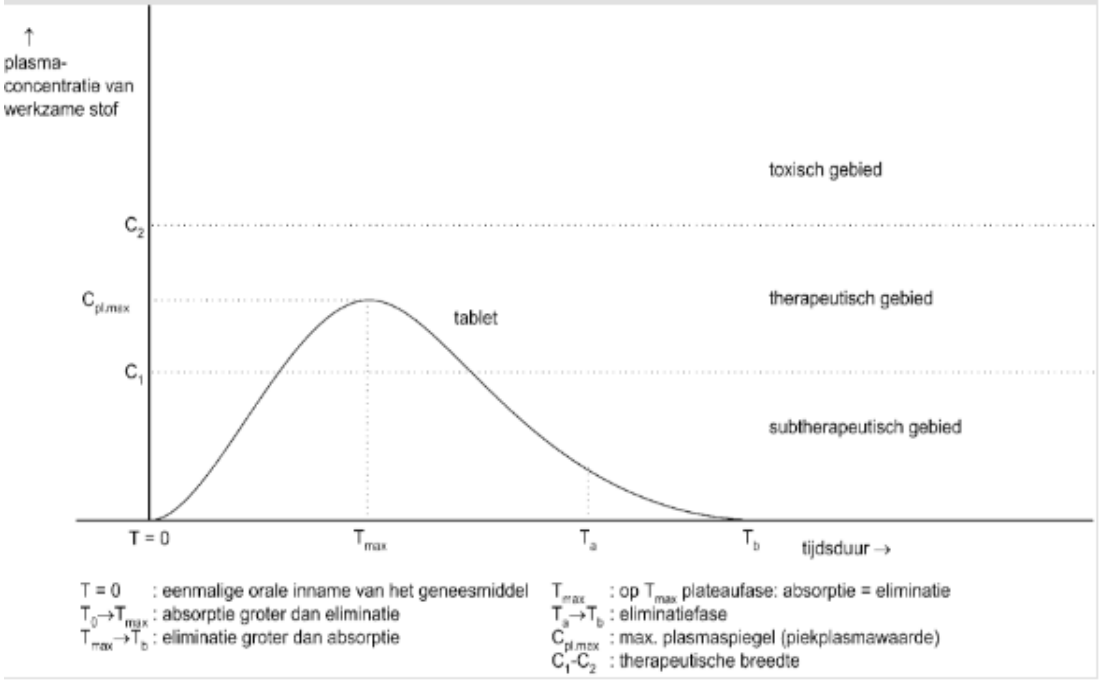
Operation of vehicles and machines
The use of the "medication" does not affect the ability to drive or operate machinery.

To get a better idea of the effects of the medication taken by the train driver, the Investigation Body contacted a pharmaceutical company marketing the medication without prescription.

According to the information obtained, the medication *"eases pain and reduces fever. Normally, the pain becomes noticeably less acute half an hour after taking the medication. The plasma peak is reached at around two hours. The duration of the analgesic effect depends on the type of pain for which the medication is taken. However, in the majority of cases, the medication acts for three to six hours: the half-life is about three hours."*

The graphic below describes generally the effect of oral administration of the '*analgesic and antipyretic*' product over time: T_{max} corresponds to the moment that the plasma peak is reached. The therapeutic zone (therapeutic window) gives the concentrations at which the medication is active.

Figuur 1 : **Het verloop van de plasmaconcentratie in de tijd na eenmalige orale toediening**



Source: Zorginstituut Nederland[6]

At first glance, there seems to be no problem for the train driver: the medication ingested is permitted! The investigation did however reveal the opposite phenomenon, namely the risk of losing the intended effect of the medication. Once the effect of the medication has passed the plasma peak, it moves towards the under-therapeutic zone where the capacity for concentration reduces progressively towards a state of reduced capacity for concentration or hypovigilance which is difficult to self-diagnose.

We notice that the train drivers and railway bodies are not sufficiently aware of the fact that ingestion of medicines can produce an incorrect impression of being fit for work and that the effect of every medication is temporary.

6 *https://www.farmacotherapeutischkompas.nl/bladeren-volgens-boek/inleidingen/inl-farmacokinetiek*

10. HOW THE EVENTS OCCURRED

Timeline

The timeline of journey recordings, calls and crossings is shown in the table below:

Event	time	EBP	ETRALI	LARA	Speed (km/u)
Departure from Bruxelles-Midi	09:45				
therapeutic zone					
sub-therapeutic zone					
Departure from Antwerpen-C	10:45				
A455 double yellow				10:47:30	60
SPAD signal G-R.12				10:48:14	90
SPAD signal J-R.12		10:49:05		10:48:57	90
GSM-R out Block 12			10:49:18		
GSM-R response driver			10:49:32		
GSM-R driver brakes			10:49:39		
A482				10:49:24	90

How the events occurred and analysis

On Sunday 1st November 2015, after a difficult night, the train driver arrived for planned duty, on the route Bruxelles-Midi – Amsterdam Centraal. The train driver felt unwell prior to starting his working day and took some medicine. The medicine does not have a negative impact on the ability to a drive a train.

When the train driver arrived for duty, the plasma peak of the medicine ingested had been reached: the train driver felt good, considered that he was fit for work and started his working day.

During the route, a certain number of elements indicate that the vigilance of the train driver reduces slowly without him reporting it.

After the planned stop at Antwerp, the train departed again. Initially, the train accelerated to 40 km/h and subsequently, from the permanent yellow end-zone sign with green border showing 9, he accelerated to around 59 km/h (speed at the moment of crossing the signal C-R.12).

At the second yellow end-zone sign with green border showing 12, he maintained this speed, and this up until signal A455 (speed of 60 km/h). The train driver complied with the speed limits and the speed of the train remained below the permitted speed.

The signal A455 was located after a bend and preceded by a repeating signal indicating the restrictive aspect of signal A455. The repeating signal A455 showed an oblique line.

By pressing the Memor button, the train driver confirmed that he had understood the restrictive aspect of signal A455. The confirmation was done late[7], i.e. (less than 4 secs) after passing the signal.

7 *HLT.II.B.2 provides that the button must be pressed in time, i.e. before passing the signal*

At 160m after of the signal A455, we find a permanent yellow end-zone sign with green border allowing the speed to be increased to 130 km/h. This information is always subordinate to the information that a signal gives, in this case the adaptation of the speed to be able to stop before the following signal.

Instead of braking, the train driver increased the speed of the train to 90 km/h from the end of zone sign. 1

At 10:48, the train passed the signal G-R.12 at danger, placed 885 m after the signal A455, at a speed of 90 km/h. 2

The train driver stated that he was distracted by an action: on exiting the tunnel, he got up to get a drink from his bag. As the sun visor was partially down, he could no longer see the signal for several seconds. He 'missed' the information given by the signal.

After the signal G-R.12, the crocodile on the "9" indicator triangle is electrified. The indicator triangle is intended for trains on counter-track (in direction of Antwerp) and could not be read by the train driver.

Passing over the crocodile, the train recorded a negative impulse. The train driver confirmed by pressing the Memor button showing that he had heard the buzzer and the Memor lamp lit up. The confirmation took place, in a quite comprehensible way, belatedly.

Under normal circumstances, a train travelling in the direction of the Netherlands never records an impulse at the indicator triangle (not readable), but as the previous route (in direction of Antwerp) had not yet been removed, the train in direction of the Netherlands nevertheless recorded an impulse. Over the course of the day, no other drivers recorded unexpected recordings and no defect was recorded: the negative impulse was not from a technical problem.

The unexpected aspect of the event explains why the train driver reacted late, but does nevertheless provoke questions:

→ in the hypothesis that the driver of the train is vigilant, he may continue the route normally on the condition that he prepares a "Crocodile" E361 telegram[8]. He reported nothing regarding the event.

→ receiving an unexpected Memor signal in this area gives the driver the chance to rectify his initial understanding, which was wrong. The train driver did not manage to use this information.

The train driver did not brake and maintained the speed of the train at 90 km/h. 3

After passing the stopping point Antwerpen-Luchtbal, the train driver can see the signal J-R.12 at danger.

→ The signal at danger gave the train driver the chance to rectify his previous understanding, which was wrong. The train driver did not manage to use this information.

At 10:49, at 1959 m after the signal A455, the train went past the signal J-R.12 at danger at a speed of 90 km/h. 4

In advance of the signal J-R.12, the train did not go towards the L.12, but straight ahead towards the L.4. From his line knowledge and training received, the train driver knew that the L.4 is only intended for trains equipped with ETCS technology, which his train did not have. The train driver did not manage to use this information. Neither did the train driver manage to identify the presence of an ETCS stop marker and to use this information. 5

8 *As indicated in the HLT: Infrabel reports that already for some time this is no longer in force*

The double overrunning of signals was noted by the surveillance staff in block 12 Antwerpen-Berchem and the surveillance agent concerned immediately contacted the train driver.

When the train driver answered the GSM-R call, he spontaneously declared that he had been wrongly routed.

Upon request by block 12, he initiated the brake. The train came to a standstill 556m before signal A491. The train driver confirmed that the train was stopped.

Following the overrunning of the signal, 250 passengers had to be evacuated and several trains had to be cancelled.

After the first overrunning of a signal, the train entered the points 03AR and, after the second overrunning of a signal, the points 04BR, 01BR and 02AR, without causing any damage.

No train was travelling in the immediate vicinity of Antwerpen-Luchtbal: the situation created no immediate danger.

11. ANALYSIS

According to the hypothesis retained by the Investigation Body, the moment that the train driver acknowledged the restrictive signal A455 was the moment of the loss of control.

Pressing the button late is, in itself, without consequence, but can provide an indication of the level of vigilance of the driver. To the extent that the signal A455 was preceded by a repeating signal, we expect in principle that the button should be pressed in time, before passing the signal.

- The signal A455 was clearly visible. It is placed at the end of the tunnel in a shaded transition zone, specially intended for this purpose, which makes the switch from dark to light easier. Therefore pressing the button late cannot be explained by a lack of visibility or by the fact that the driver was surprised by the aspect of the signal.

Upon seeing the restrictive double yellow signal A455, the driver should adapt the speed of the train so as to be able to stop in time, specifically before the signal at danger G-R.12 which followed. As the speed of the train was over 40 km/h, the driver must initiate the brake at the latest when passing the signal A455.
The driver did not react in the expected way and did not brake.

- In normal conditions, train drivers have more than sufficient time to stop the train after pressing the button. Multiple route analyses revealed that drivers sometimes tend to slightly delay braking, for example so as to reduce delays. The potential decision to delay braking is against the rules. Railway undertakings will draw attention to these practices in their training and monitoring. The rest of the analysis shows that it was improbable that the driver intended to delay his braking.

The fact of increasing his speed instead of braking makes the hypothesis of a violation (delaying braking) unlikely.

- Confirmation of the restrictive signal does not necessarily imply that the information shown was taken on board by the driver, or that his memory handles it correctly:
  - a confirmation can be made "unconsciously";
  - the information of the signal can be wrongly understood;
  - the information of the signal can be wrongly handled;
  - the information of the signal can be deleted from the memory;
  - the information of the signal can be dependent on other information, even imaginary.

The analysis of the route data seems to show that the train driver reacted in a state of automatism to light or sound signals generated in the driving post by the Memor system, rather than signalling information along the track. As the Memor signal only goes off after passing the signal A455, the aspect of the signal can no longer be checked.

The driver must therefore interpret the Memor signal to give it the response required, thus slow down. Instead, the train driver recorded the information on the speed limit sign immediately following and which allowed an increase in speed, all the while being subordinate to the information given by the signal A455. The driver of the train operated the traction control and the train accelerated.

The driver also did not "see" the information given by two successive signals at danger. The sequence of events lets it be supposed that the driver was letting himself be guided by an automatic reflex which guides him "as usual" from the L.25 to the L.12, at a limited speed of 90 km/h, which allows him to cross the points leading from one line to another. He then accelerated up to 90 km/h.

The driver said he had not seen the (first) signal at danger as he was distracted by another action (getting a drink out of his bag).

According to the hypothesis retained by the Investigation Body, the events demonstrate another problem: the analysis of the route data leads to a conclusion that the loss of control results from a weakened capacity for concentration, due to tiredness. The driver's tiredness existed at the beginning of the workday.

- The events reveal cognitive mechanisms, as described by D. Norman (1981)[9] and which are activation loss (capture slips or sequencing errors) or action slips (spoonerism, action confusion).

  Capture slips come from a dominant routine (here most frequent route, line-clear signals) which overrides the activated routine which starts in the same way (departure with a green light in Antwerpen-Centraal).

  The driver expected to be sent "as usual" from the L.25 to the L.12 (dominant routine), in passing points "as usual" at a maximum speed of 90 km/h. The aspect of the signals and speed limit signs corresponded in his mind to his expectations and experience.

- The train driver did not take advantage of the information from the restrictive signal (activated routine): an attentive train driver would have concluded, on seeing the restrictive signal, that the following signal risked being at danger and would have delayed his action.

Tiredness is a risk which had already been identified in the rail sector and the sector has taken a series of measures and enacted some rules to deal with it.

On the one hand, the railway system expects that train drivers have good sleep health and that they are in a condition to correctly evaluate their level of tiredness at the start of the day and to decide if they are fit for service.

On the other hand, railway undertakings use preventive measures such as planning of service time taking into account adapted sequences of work and rest as foreseen in the legislation in force. Thus, a driver's potential level of tiredness is only partially taken into account.

A first finding that appears from the investigation is that there is too little account taken of the factors of self-diagnosis and self-medication. Interviews reveal that the phenomenon of "driving under the influence" after taking medication is well-known but that only the possible negative side-effects of certain medications on reaction capacity are taken into account (drowsiness, dazed feeling, etc.). These side-effects are mentioned in the instructions for use.

9 *Norman, Donald A. "Categorization of Action Slips," Psychology Review 88:1, pp. 1-15 (1981). See Investigation report on the Buizingen accident p.107*

The investigation showed that taking medication can also have a pernicious effect on driving. This effect is identified in the investigation as a real risk. The train driver engaged in self-diagnosis and self-medication. Under the influence of this medication, he considered, at the start of his workday, to be sufficiently well to carry out his duty. In reality, some time after taking the medication, a plasma peak was reached, which gave the impression of being well. After the plamsa peak, the effect of the medication reduced progressively and without realising it the feeling of tiredness took over. This resulted in concentration problems. The interviews show that train drivers and their hierarchy are not sufficiently aware that the effect of medication is temporary.

When a train driver reports himself as being unfit, the railway undertakings - as far as possible - call upon a substitute driver or cancel the service.

A second finding is that railway undertakings have not developed a system of Last Minute Risk Analysis which could help the managers and train drivers to recognise being unfit before or during the execution of daily tasks.

A third finding is that internal regulations leave the responsibility of deciding on fitness with the driver. The current system, in other words, requires the weakest link to make this decision. And this is not easy: arrival of tiredness and the progressive loss of vigilance which results from it comes on gradually and, in a first stage, without the train driver being conscious of it. Supposing that the train driver is conscious of his condition, it is not excluded that social pressure (colleagues, professional pride, management, etc.) creates a certain feeling of embarrassment regarding unfitness for work.

A deterioration of the capacity to concentrate, being not always predictable or occurring without the driver realising it, can lead to a loss of control. Railway undertakings anticipate these situations for example by developing corrective measures that balance out a process.

A corrective measure would for example be to timely detect the loss of control (not slowing down of a train) and to slow the train down, even stop it completely, automatically.

The train was equipped with the Memor system. This requires the train driver to confirm what he sees and constitutes a memory aide as it reminds the train driver of the restrictive nature of the signal received. It is only in the case that the driver fails to confirm his vigilance and does not press the Memor button, that it intervenes and stops the train. This system does not react if a train driver automatically confirms his vigilance but does not follow-up on the information received.

Except if the driver corrects himself at the last minute, the situation can degenerate into an incident or even an accident. Seeing the Memor light illuminated can provoke corrective action but many incidents, including that on 1 November 2015, and accidents like in Wetteren in 2013 have shown that the Memor system offers insufficient guarantees in these circumstances.

More effective corrective measures have been developed, such as the TBL1+ and ETCS. TBL1+ and ETCS require the infrastructure as well as the trains to be equipped with the necessary equipment. In the zone Antwerpen-Luchtbal, the lines 25, 12 and 4 are equipped with ETCS, lines 25 and 12 with TBL1+. TBL1+ or ETCS technologies on board the train E9227 would in other words have prevented the overrunning of the signal G-R.12. In addition, the second overrunning of the signal would not have occurred and no danger point would have been reached.

It would only have required slightly different circumstances to turn the fact that these technologies were not present in the overrunning of the signal on 1 November 2015 into a serious accident. The locomotives in service for the Intercity between Brussels and Amsterdam are only equipped with Memor. They are however equipped with the ATB system which, on the Dutch network, plays an equivalent role to the TBL1+ system.

After its departure from Antwerp, the train crossed the signal G-R.12 at danger. In usual operating conditions, international trains have priority and the driver expects to find a clear-line signal here. This does not mean that he does not have to be able to stop at an unexpected signal at danger!

If the risk of finding a signal at danger is reduced, logically, the risk of SPAD is reduced. The risk of encountering a signal at danger may be reduced by ensuring the elimination of conflicts in the planning and maintenance of timetables. This means for example that the train is given priority or that it cannot restart before the signal at danger clears.

12. CONCLUSION AND RECOMMENDATIONS

Direct cause

According to the hypothesis retained by the Investigation Body, the double overrunning of a signal results directly from a lack of concentration linked to the driver being tired. The lack of concentration explains why the train driver neglected the driving information received several times. Also, according to the hypothesis retained by the Investigation Body, the driver had taken authorised medication and started his service with a false sense of fitness for service. Once the effect of the medication had passed the plasma peak, it developed into a sub-therapeutic zone where the capacity for concentration gradually reduced to a reduced state of concentration or hypovigilance which is difficult to self-diagnose.

Recommendation No 1
The DRSI should ensure that railway undertakings take into account the identified risk linked to the taking, prior to driving, of medicines not considered as unsafe but, which have an effect over a limited time, and which can nonetheless have a negative effect on driving.
The DRSI should ensure that railway undertakings make drivers aware of the fact that the effect of a medicine is limited over time and risks giving them a false sense of their ability to perform their service.

Indirect cause 1

According to the hypothesis retained by the Investigation Body, the first indirect cause of the overrunning of a signal was the lack of a driving assistance mechanism of type TBL1+ or ECTS cab signalling Level 1 or 2 on board the locomotive.
In the given circumstances (speed of the train), the presence of TBL1+ and ECTS technologies on board the train would have allowed the train to be stopped in time and avoided any overrunning of signals.
The DRSI confirmed the authorisation for entry into service of locomotives of a TRAXX type with configuration 7D and 7D1 (ed. 2 September 2016) allowing the use of TBL1+ and ECTS L1 technologies. Locomotives with this equipment have since been put into service on the IC links Brussels-Amsterdam.

Recommendation No 2
The DRSI should ensure that all railway undertakings take the necessary measures to adapt all the locomotives to configuration 7D or 7D1.

Indirect cause 2

According to the hypothesis retained by the Investigation Body, the second indirect cause of the overrunning of signals was the fact that the route was not exempt of conflicts.
If the risk of finding a signal at danger is reduced, logically, the risk of SPAD is reduced. The risk of encountering a signal at danger may be reduced by ensuring the elimination of conflicts in the planning and maintenance of timetables.
The Infrastructure Manager is currently studying a safe planning system, in particular by ensuring that conflicts are avoided in the planning and maintenance of the timetable.

Recommendation No 3
The DRSI should ensure that the Infrastructure Manager implements as quickly as possible the project which is currently being studied, aiming to eliminate conflicts in the planning and maintenance of timetables.

Underlying cause

The underlying cause of the double overrunning of signals was the absence of an LMRA or a vigilance detection system for train drivers. The implementation of a quality FRMS (Fatigue Risk Management System) increases the probability of timely detection of unfitness of a driver as well as problems linked to a potential vigilance slip during his service.

Recommendation No 4

The DRSI should ensure that railway undertakings deploy an efficient FRMS that is not only based on strict application of the rules but also on elements such as training and driving awareness, service planning, introduction of hypovigilance detection systems, etc.

Investigation Body for Railway Accidents and Incidents
http://www.mobilit.belgium.be