Rail Accident and Incident Investigation Unit

Safety Notice

Incident with numerous vehicles on a level crossing
Moelingen - 3 March 2020

.be

January 2021

REPORT VERSION TABLE

Version number	Subject of revision	Date
1.0	First version	28/01/2021

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 Dutch version.

TABLE OF CONTENTS

1. SUMMARY

On 3 March 2020, at around 4:23pm, a major alert was raised at level crossing 28 in Moelingen. At around 4.57pm, the major alert was terminated. During this time, the red traffic lights were flashing in alternation, although the barriers remained open and there was no audible alarm signal. Despite the fact that the red traffic lights were flashing, many road users drove over the level crossing.

The incident of unauthorised presence on the tracks is catalogued as 'inadvertent third-party intrusion into the loading gauge of a railway track'.

The direct cause of the incident was the fact that the highway code was ignored. This code states that red traffic lights at level crossings must be respected at all times. Nevertheless, numerous road users drove over the malfunctioned level crossing. Given that it is evident that road users must respect the traffic rules, no recommendation is made regarding the direct cause.

The traffic rules were violated deliberately, but not maliciously. The indirect factor is the attitude of road users, attitudes that can be described, non-exhaustively, as:

- Instrumental attitude: people make a cost-benefit analysis. For example, when someone considers that waiting at a malfunctioned level crossing is pointless, or needs to be on time for an appointment, or has no idea how long they will have to wait, or has no explanation why they have to wait, road users may be more inclined to cross.
- Affective attitude: someone is influenced by how they (perceive they) feel. When a disciplined waiting manner of 'first in, first out' is disrupted by people 'pushing in', a person may feel unfairly treated and decide to cross the malfunctioned crossing.
- Informational social influence: in an unfamiliar situation where someone doesn't know how to react, they look at others to determine their own behaviour. Often there is first a *bystander effect*: if nobody reacts, it is not abnormal for you not to react either. If someone does take the initiative, the element of *social proof* comes into play. Because of the urge not to stand out from the crowd, one assumes that this is the appropriate behaviour to be exhibited. People therefore copied copy the other people crossing the malfunctioned level crossing.
- Familiarity: people may be so familiar with the timetable that they are convinced that there is no train traffic at the moment that the level crossing malfunctions. Moreover, if someone had a previous experience of needlessly waiting at a level crossing, they may be more inclined to cross a malfunctioned level crossing.
- Not being (fully) aware of the risks: people are convinced they have the situation under control and assume they can avoid an accident without knowing the risks of crossing a level crossing unauthorised. People are insufficiently aware of how quickly a train can arrive at that spot, or how long it takes for a train to come to a standstill.

Given that the infrastructure manager regularly organises campaigns to raise awareness, prevention and enforcement in order to keep road users permanently aware of the dangers of crossing level crossings unauthorised, no recommendation is made.

An underlying factor is the fact that there are level crossings. Removing a level crossing eliminates any risk of an accident. Given that not all intersections of railways and public roads can simply be removed, one alternative is to replace the crossing by a bridge, tunnel, bicycle path or parallel road, for instance. As the infrastructure manager is already making investments in this regard, no recommendation is made regarding this aspect.

Another underlying factor is the safety management of a level crossing accident. The infrastructure manager has a procedure in place for major alerts at level crossings. Given that road users need to take into account that a malfunctioned level crossing will remain inoperable for a certain period of time, no recommendation has been made.

An additional observation is that a shifted microswitch in the barrier mechanism caused the major alert. No recommendation has been made, the infrastructure manager has checklists for the inspection and maintenance of level crossings, which include an inspection of microswitches and their attachment.

A second additional observation is that bus drivers did not contact the dispatching office of the bus company, when the delay in question occurred. It is recommended that bus companies ensure that bus drivers are made more aware of the dangers of level crossings and that their bus drivers are more familiar with the procedures for contacting the dispatching office.


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2. IMMEDIATE FACTS

2.1. THE EVENTS

2.1.1. DESCRIPTION OF THE EVENTS

On 3 March around 4:23 pm, the operation of level crossing 28 on line 40 is disrupted: the red lights flash on and off alternately but the barriers on both sides of the level crossing are not closed. Despite the red flashing traffic lights, numerous road users cross the level crossing in both directions.

The road users showing such inadequate driving behaviour at the level crossing are drivers of both cars, vans, a school bus and a bus.

Screenshots as seen on RTL from an anonymous source

2.1.2. LOCATION

The Schansweg is an extension of the N602 regional road.

Exit 1 (Voeren) of the E25 motorway also joins the Schansweg.

From the level crossing of railway line 40, the regional road becomes a local road towards the village centre of Moelingen.

The village of Moelingen is situated in Flanders; to the north is the border with the Netherlands, to the south is the Walloon Region.

The speed limit on the asphalted Schansweg is 70 km/h on both sides of the level crossing.

2.1.3. THE DECISION TO OPEN AN INVESTIGATION

According to the law of 30 August 2013 on the Rail Code, the event does not meet the definition of a serious accident.

According to Article 111, paragraph 2 of this Law (translation), *"in addition to investigating serious accidents [...] the investigation body may also conduct investigations into accidents and incidents which, under slightly different circumstances, could have led to serious accidents, including technical defects in the structural subsystems or in the interoperability elements of the high-speed or conventional rail system. […]."*

In view of the possible consequences for railway safety, and in accordance with the said Article 111, paragraph 2, the Rail Accident and Incident Investigation Unit immediately decided to open an investigation into this incident[1], and informed the parties concerned.

2.1.4. CONDUCTING AN INVESTIGATION

The investigation looked into what caused the level crossing to go into major alert, and how it was resolved, based on a site visit and documents from the infrastructure manager.

Next, the reasons of the road users for crossing the level crossing unauthorised were investigated. Besides a literature study, the investigation is also based on interviews with bus drivers and managers of bus companies.

1 *In accordance with Article 3.31 of the Railway Code, an incident is described as "any occurrence, other than an accident or a serious accident, associated with the operation of trains and affecting the safety of operation."*

2.2. THE CIRCUMSTANCES OF THE EVENT

2.2.1. CONCERNED COMPANIES AND PERSONS

2.2.1.1. INFRASTRUCTURE MANAGER INFRABEL

Following the Royal Decree of 14 June 2004, Infrabel is the infrastructure manager. The infrastructure manager must ensure the correct application of the technical standards and rules relating to the safety and use of the railway infrastructure.

The following departments were involved in the incident:

- The signal box at Kinkempois, block 44. This manages the area where the incident occurred.
- RACOR[2] Southeast. This is responsible for the front-line handling of malfunctions in the relevant district.

2.2.1.2. PUBLIC TRANSPORT

2.2.1.2.1. DE LIJN

The Flemish transport company De Lijn is the Flemish Region's partner for urban and regional public transport in, from and to Flanders. Within the Mobility & Public Works policy domain De Lijn is an external autonomous agency and conducts regular services commissioned by the Flemish Region. About half of the bus services are outsourced to operators.

2.2.1.2.2. HEIDEBLOEM

The bus involved in the incident belongs to an operator of De Lijn, namely Heidebloem nv. This company was founded in 1950 and is based in Lanaken. Heidebloem is now part of the Belgian transport company group Hansea nv, the largest private transport company in Flanders. Heidebloem is active in school and staff transport, as a coach company, as a travel agency and also as an operator for the transport company De Lijn. The contract between the two parties runs until 30 June 2023.

Heidebloem has a transport licence, issued by the Flemish Government and valid until 14 January 2025, for access to the profession of road-based passenger transport operator for regular transport and special forms of scheduled transport. It is also licensed to supply international road-based passenger transport services on behalf of third parties by coach and bus.

The company is a member of the FBAA[3]. As a recognised professional federation, the FBAA looks after the interests of companies providing professional bus and coach transport for passengers by road.

2.2.1.2.3. TEC

The Wallonian transport company TEC[4] is the Walloon Region's partner for urban and regional public transport in, from and to Wallonia. Some of the bus routes are operated by operators.

2 *RACOR = Regional Asset Control and Operations Room.*
3 *FBAA = Federation of Belgian Bus and Coach Operators*
4 *TEC = Transport En Commun (this is their trading name; the legal and accounting entity is called OTW = Opérateur de Transport de Wallonie).*

2.2.1.2.4. JEAN-LUC CARS

The school bus involved in the incident belongs to Jean-Luc Cars, which organises school transport for the TEC as a subcontractor.

Jean-Luc Cars is based in Sprimont and organises trips to amusement parks, concerts and holiday destinations. The company also offers school transport and school excursions.

Jean-Luc Cars is a member of the FBAA.

2.2.1.3. OTHER ROAD USERS

In addition to the scheduled bus and a school bus, various other road users (drivers of cars and vans, with or without trailer) crossed the Schansweg level crossing while the red traffic lights were flashing in alternation.

2.2.1.4. TRAINING CENTRES

The VDAB[5] ensures that jobseekers and employers are matched on the job market. The VDAB offers 'Bus driver' training in its package of services. This course teaches participants how to drive a bus and obtain driving licence D with professional competence[6].

The FCBO[7] is the leading training institute for bus and coach drivers in Belgium, with the main objective of supporting Belgian bus and coach companies, and their drivers, in fulfilling the obligations of continuous training of professional drivers in compliance with the European regulations.

5 *VDAB = Vlaamse Dienst voor Arbeidsbemiddeling (= Flemish Service for Employment).*

6 *"Professional competence is a supplement to the driving licence that is compulsory for all professional drivers holding a licence for category groups C and D. It must be obtained in addition to the driving licence and the holder must undergo periodic training every 5 years in order to renew it. The proof of professional competence is indicated on the driving licence by the code 95 for the relevant categories". (Translation - FPS Mobility and Transport, undated).*

7 *FCBO = Formation Car & Bus Opleiding.*

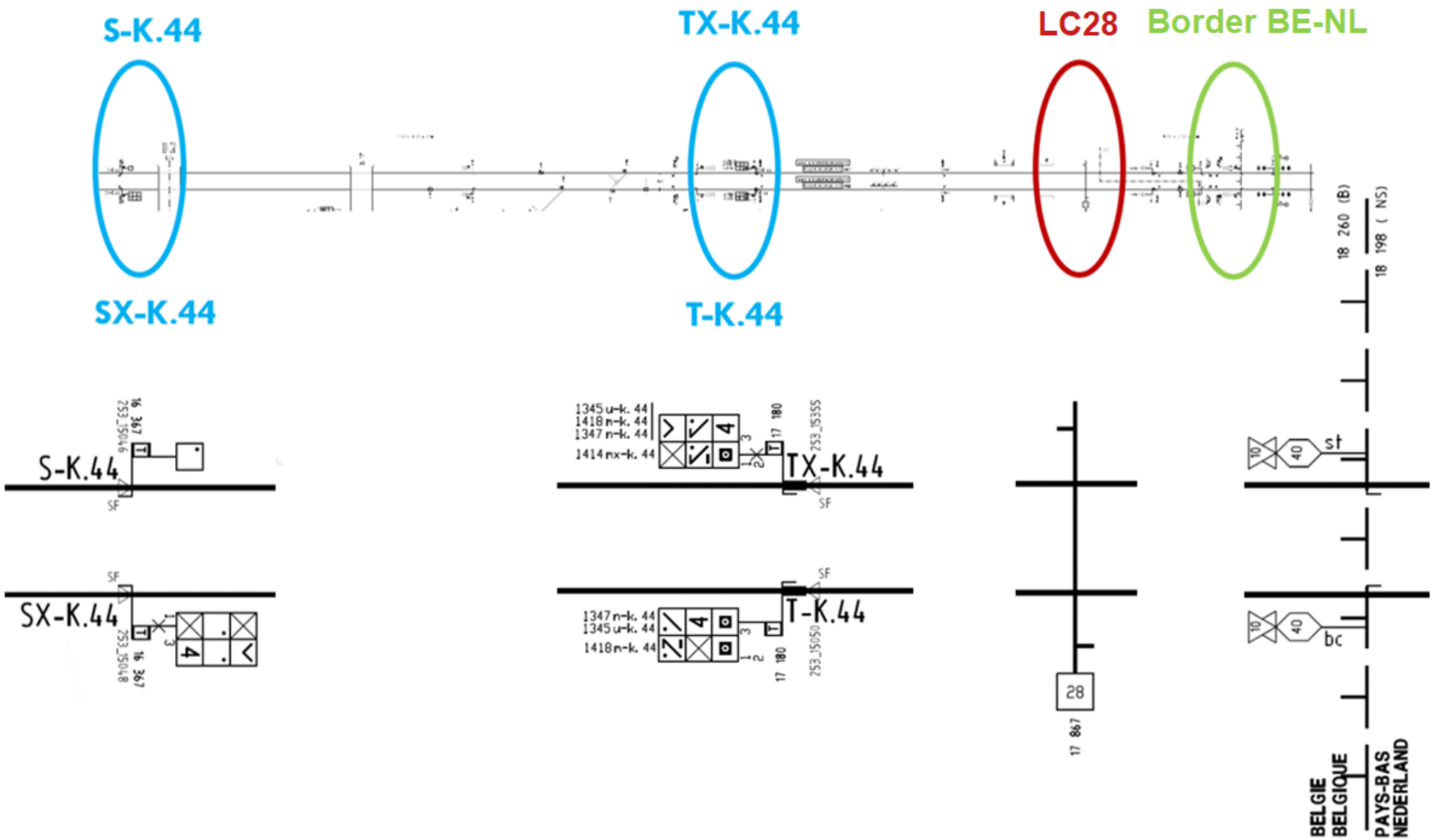
2.2.2. COMPOSITION OF THE TRAIN

Not a single train was involved in the incident.

2.2.3. DESCRIPTION OF THE INFRASTRUCTURE AND THE SIGNALLING INSTALLATIONS

2.2.3.1. SCHEMATIC SIGNALLING PLAN (SSP)

The signals S-K.44 + SX-K.44 and T-K.44 + TX-K.44 are situated on the Belgian side of level crossing 28. The schematic signalling plan of the level crossing in Moelingen shows where these signals are situated.


S-K.44
TX-K.44
LC28
Border BE-NL
SX-K.44
T-K.44
S-K.44
SX-K.44
TX-K.44
T-K.44
1345 u-k. 44
1418 n-k. 44
1347 n-k. 44
1414 nx-k. 44
1347 n-k. 44
1345 u-k. 44
1418 n-k. 44
28
st
bc
18 260 (B)
18 198 (NS)
BELGIE
BELGIQUE
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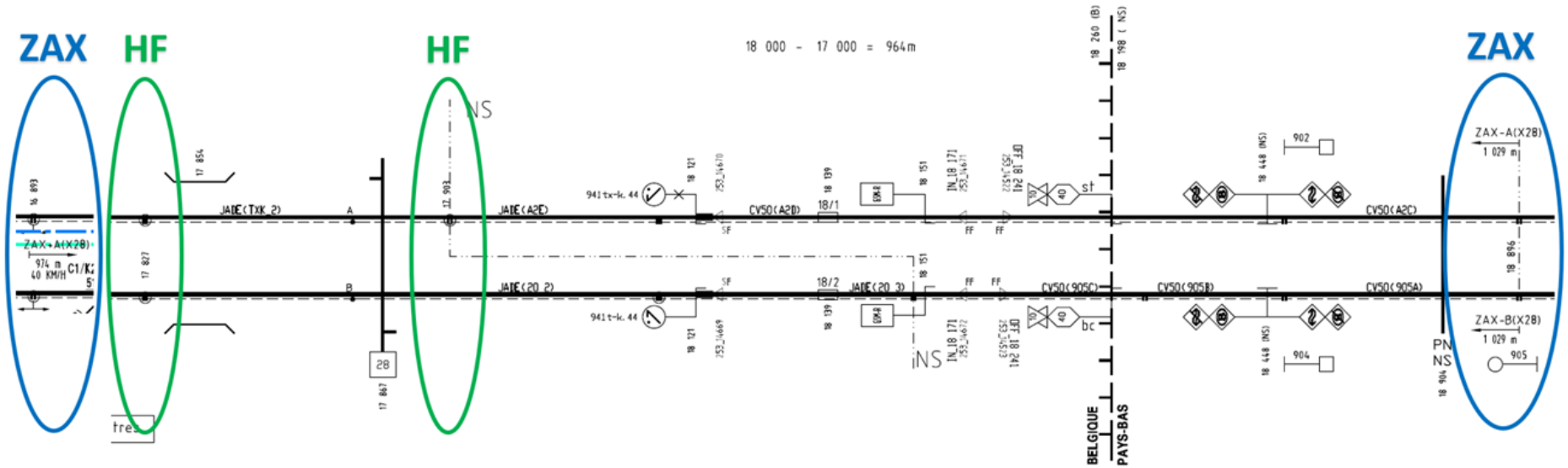
NEDERLAND

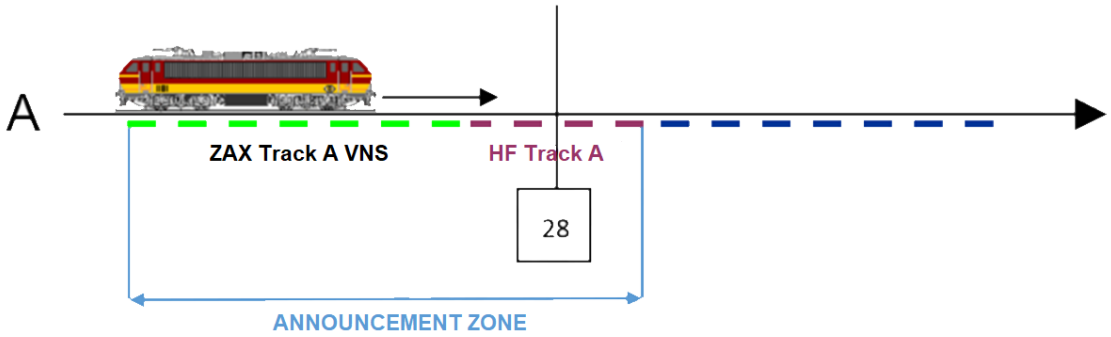
The announcement zones can be found on plan 002/99. *"The announcement ensures that the warning signal is triggered at the right time before the train passes through the level crossing, regardless of its speed, and it continues until the train has fully cleared the level crossing."* (RGE/ARE 727.2[8]).

In the direction from Maastricht to Visé the ZAX[9] is located at kilometre marker 18.896, which is 1,029 metres from the level crossing. The HF[10] is located at kilometre marker 17.827. In the direction from Visé to Maastricht the ZAX is located at kilometre marker 16.893, which is 974 metres from the level crossing. The HF is located at kilometre marker 17.903.



8 *RGE/ARE = Règlement Général d'Exploitation / Algemeen Reglement van de Exploitatie (= General Operating Rules).*
9 *The ZAX is a track circuit (TC) that detects the presence of trains on the tracks. This is where the announcement zone of a level crossing starts.*
10 *The HF (High Frequency) is also a track circuit. This is located on the level crossing itself and extends on both sides beyond the crossing. Its purpose is to reopen the level crossing.*

The ZAX announces a train at the level crossing and triggers the following actions:

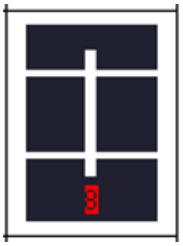


- The white traffic lights at the level crossing switch off.
- The red traffic lights switch on.
- An audible alarm is sounded.
  - This signal sounds immediately when there is a train in the announcement zone, both in normal track regime and counter-flow track regime;
  - The signal sounds until the barriers are completely closed.
- The barriers are then lowered.
  - When a train is in the announcement zone, the barriers are lowered after about 10 to 12 seconds (at this stage, the audible alarm is already sounding). After 15 seconds the barriers are in lowered position.
- If applicable, any track signals will open.
- The train passes the level crossing and the HF.
- After about 6 to 7 seconds, the barriers go up, after which the red traffic lights go out and the white traffic lights come on again.

2.2.3.2. ELECTRONIC CONTROL DESK (EBP)

The signal box of Kinkempois NK (block 44) is equipped with EBP technology. Chapter 13 of the professional instruction for operating signal boxes (Infrabel, 2019) states that (translation) *"level crossings are represented by a line that intersects the relevant track(s) at right angles."*

"The level crossing is identified above or below the line representing the level crossing." In principle, the identification is shown in yellow. In the event of a major alert ("MA") at the level crossing, the identification is shown as *"red inverse"*.[11]



"With the function 'MA':

- *the occurrence of a major alert is recorded; and [...]*
- *if the deck signals are closed during a major alert at a level crossing (DA), the EBP system will implement a table 3 on the level crossing in question."*

*"The function can be started/executed by a user with **control authority**."*

11 *Example taken from the Professional instruction for operating signal boxes. (Infrabel, 2019).*

2.2.3.3. LEVEL CROSSING 28

The level crossing in Moelingen is described in the Ministerial Decree of 12 May 2013 (see 3.3.1.1.).

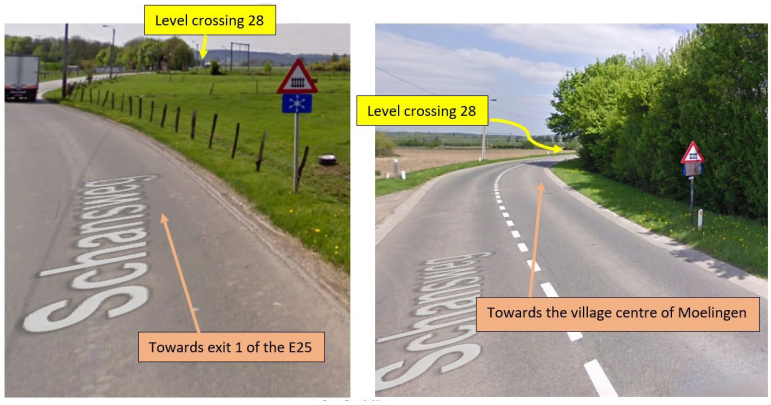
2.2.3.4. RAILWAY LINE 40

Level crossing 28 is located on the electrified railway line 40, which connects the cities of Liège and Maastricht over a distance of 28.8 kilometres. The nearest stops are Visé (Wezet) to the south and Eijsden (located in South Limburg, the Netherlands) to the north.

The reference speed on line 40 is 120 km/h.

2.2.3.5. ROAD INFRASTRUCTURE

The N602 regional road is marked with a broken line up to the level crossing. The local road from the level crossing to the village centre of Moelingen does not have any road markings.



The level crossing is announced on both sides by the road sign A41, 'level crossing with barriers'. From the village centre towards the E25, there is a sub-sign A15a[12].

The legally stipulated distance of approximately 150 metres is respected on both sides.

2.2.3.6. ROUTE BUS LINE 39B

The scheduled bus in question that serves the Schansweg is Line 39B. The line starts at the SGV Provincial School stop and ends at the Genoelselderen Boudewijnstraat stop.

From the site of the operator Heidebloem in Lanaken, a bus driver drives to the first stop which is situated on the Berneauweg at the Provincial Secondary School in Voeren. The scheduled departure time there is 4.05pm. Given the location of the stop, the passengers are primarily school students.[13] The next two stops in Moelingen are: MO Withuisstraat (4:14pm) and MO Centrum (4:15pm). The bus then continues to the Lixhe Halembay stop (4.27pm). It is between these two stops that the level crossing on the Schansweg is crossed.

12 *The road can be slippery due to sleet or snow.*

13 *The route in question is aimed primarily at school-age children and operates every day of the week except on Wednesdays: "A direct line bus provides transportation for pupils from Riemst and Voeren." (Provincial Secondary School Voeren, 2014).*

2.2.4. MEANS OF COMMUNICATION

Level crossing 28 is situated near the Dutch border. When a major alert is triggered at level crossing 28, the signal operator of block 44 has to notify the train dispatcher of ProRail[14]. This communication is via telephone.

2.2.5. WORKS CARRIED OUT AT OR IN THE VICINITY OF THE SITE

On 3 March 2020, there were no works in the immediate vicinity of level crossing 28.

In the nearby municipality of Voeren, sewerage works were being implemented on behalf of Aquafin. This resulted in diversions for vehicle traffic. Certain bus stops could not be served and the local timetable was changed.

2.2.6. ANNOUNCEMENT OF THE RAILWAY DISASTER PLAN AND THE SEQUENCE OF EVENTS

No railway or other disaster plan was put into operation.

14 *ProRail is the rail infrastructure manager of the Netherlands and is responsible for the construction, maintenance, management and safety of the entire railway network.*

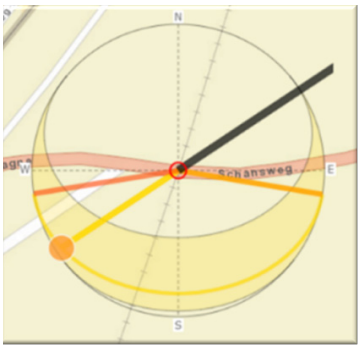
2.3. DEATHS, INJURIES AND MATERIAL DAMAGE

There were no casualties in this incident.

No damage was caused to infrastructure or rolling stock.

2.4. EXTERNAL CIRCUMSTANCES

2.4.1. WEATHER CONDITIONS



On 3 March at around 4:23pm, the sun was in the southwest.[15]

At the time of the incident, it was slightly overcast.

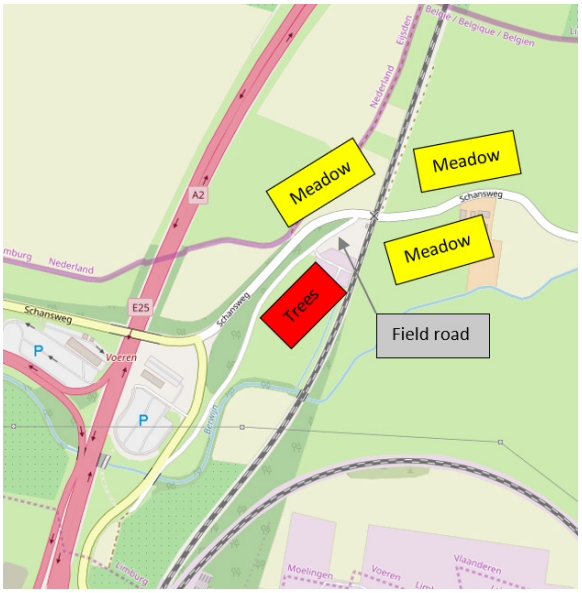
There was no rain or fog.

The condition of the road surface was dry.

2.4.2. GEOGRAPHICAL REFERENCES

When driving from the centre of Moelingen towards the regional road, meadows can be seen on both sides of the road. There are no trees along the road.

When driving on the regional road towards the centre of the village, there is a right turn before the level crossing. There are trees obstructing the view on this side. It is only from the point where a field road on the right hand side joins the Schansweg that road users have an open view and therefore also on the right hand side of the railway. The left side of the regional road is an open plain consisting of a meadow.[16]



15 *Note. Reprinted from (translation) "Meteo Gouda: Network of weather stations at Gouda". Consulted at https://www.meteo-gouda.nl/zonnestand.html*

16 *Note. Adapted from (translation) "StreetDir.be - Your street directory". Consulted at https://www.streetdir.be/nl-BE/*

3. SUMMARY INVESTIGATION

3.1. SUMMARY OF WITNESS STATEMENTS

During the course of the investigation, the Investigation Unit conducted several interviews. The information gathered during these interviews with drivers, managers, engineers and others has been incorporated into this safety report.

In order to protect the privacy of the relevant persons and to ensure the interviews are as open as possible, it is agreed before a safety interview that no names will be stated in the safety report, nor will transcripts of statements be included in the report.

3.2. SAFETY MANAGEMENT SYSTEM

3.2.1. LEADERSHIP

The infrastructure manager and transport companies are aware of the safety risks at level crossings. In this case, Infrabel's objective is (translation) *"to eliminate as much as possible physical crossings between our rail and road networks. Road users continue to behave dangerously at our level crossings."* (Infrabel, undated). Transport companies include level crossings in their training and examination programme.

In 2019, Infrabel launched 'Railspect', a national action plan with the overall objective of bringing about a change in behaviour: changing the dangerous behaviour of people on railway infrastructure, with the aim of having fewer people walking over tracks and fewer accidents at level crossings. Railspect is a portmanteau of Rail + Respect, and is based on the 3 strategic pillars of awareness, prevention and enforcement. The management of Infrabel sets aside the resources to develop these 3 pillars. Over the last 5 years, just over €100 million has been invested in safety at level crossings.[17]

Year	Investment in safety at level crossings
2019	€19.4 million
2018	€27.6 million
2017	€18.7 million
2016	€18 million
2015	€18.4 million

17 *Figures based on the annual safety reports of Infrabel.*

3.2.1.1. PREVENTION

Removing a level crossing removes any risk of an accident: *"The closure of a level crossing is the only true way to guarantee that risk had been eradicated and accidents cannot occur."* (Network Rail, 2019). This is therefore considered the best preventative measure: *"That the best level crossing is one that has been eliminated is recognized universally."* (Nelson, 2012).

Around two-thirds of the budget for safety at level crossings, or €66 million over the last 5 years[18], was spent on removing level crossings.[19]

Year	Investment in removing level crossings
2019	€15.6 million
2018	€11.6 million
2017	€10.4 million
2016	€14.8 million
2015	€13.6 million

When removing a level crossing is not possible, a very efficient alternative is to replace it with e.g. a bridge, tunnel, bicycle path or parallel road.[20]

Infrabel has also launched various prevention campaigns, including, recently, the identification of level crossings and the collaboration with a navigation app, and is also conducting a number of feasibility studies which could improve safety at level crossings. More information is provided in Annex 7.2.

18 *Figures based on the annual safety reports of Infrabel.*

19 *Setting aside a budget for removing a specific level crossing does not automatically mean that it will actually be removed, on account of possible resistance from the municipality. "The fact is that the municipalities involved often attach more importance to mobility than to safety." (Belgian Chamber of Representatives, 2018). "Local residents and other road users benefit from having as many locations as possible where they can cross the railway. In general, a municipality will therefore prefer a grade-separated or improved level crossing over removal or by-passing." (Dutch Safety Board, 2018, p44).*

20 *"Where road and rail intersect, there is always the potential for accidents. If the level crossing, a legacy of nineteenth-century railway builders, can be closed and replaced by a bridge or underpass, almost all of the risk can be eliminated." (Rail Accident Investigation Branch, 2020).*

3.2.1.2. RAISING AWARENESS

For the fourth consecutive year, Infrabel has increased its investment in safety campaigns and awareness-raising actions.[21]

Year	Investment in awareness raising
2019	€532,676
2018	€496,103
2017	€349,596
2016	€200,000
2015	€320,000

Infrabel has launched various campaigns to raise awareness and encourage people to change their behaviour at level crossings: Jeroom Slagboom, Crash Test, Ketnet Summer Tour, Sinterklaas campaign, Port of Antwerp truck campaign, The Floor, cooperation with 'Kijk Uit' and 'één' and educational tools have been developed for schools (school calendar, rail safety package, fun book, school visit). These awareness-raising campaigns are briefly outlined in Annex 7.1.

Awareness campaigns in the media have a positive effect. The media focus on accidents at level crossings (both fatal and non-fatal) creates social intolerance regarding this type of accident. In addition, it creates greater expectation that the government will take action to reduce the risk. (Nelson, 2012). The focus should not be limited to the conventional media of newspaper, television or radio, but campaigns also need to be run through social media, explaining how illegal behaviour at level crossings must be the subject of constant scrutiny. (Starčević et al., 2016; Nelson, 2012). For example, in recent years we have seen Infrabel post photos (2020) and videos (2020) on social media channels, such as Facebook, concerning unsafe situations and law-breaking at level crossings.

3.2.1.3. REPRESSION

When prevention and awareness-raising no longer help, there is still enforcement. Or as Nelson (2012) puts it, *"If education is the carrot then enforcement is the stick to be used in parallel."* Examples here include the possibility of safety checks and red light cameras at level crossings. More information is provided in Annex 7.3.

In Infrabel's annual safety report 2019, the infrastructure manager states that control actions by the railway police and Securail[22] are being continued (translation) *"The individuals who persist in breaking the law after all the campaigns need to be made to pay a financial price"*, Infrabel stated in the autumn of 2019. (Bauwens, Van Liefferinge, 2019).[23]

Observation:
The infrastructure manager Infrabel makes efforts in the areas of awareness-raising, prevention and enforcement so that road users behave (more) safely at level crossings.

21 *Figures based on the annual safety reports of Infrabel.*
22 *Securail = SNCB/NMBS security department.*
23 *During this period, Securail guards, railway police, local police and plain clothes officers carried out intensive checks at places where level crossing rules are often ignored. For example, the level crossing in Dilbeek next to the platforms. In the space of 1 hour, 8 people were caught accessing the tracks unauthorised. They were running late and crawled under the barrier to make a dash to the platform. (Luyckx, 2019).*

3.2.2. MONITORING

3.2.2.1. MONITORING AT INFRABEL

3.2.2.1.1. ARTWEB

Infrabel has the web application ARTWEB[24] at its disposal, which is part of the ARTEMIS[25] system. This manages the theoretical planning of trains and the implementation control of the real-time monitoring of train movements. The ARTWEB application has an archive in which all train journeys, detected by fixed detection points[26] in the infrastructure, are stored.

ARTWEB provides an overview of the train traffic at level crossing 28 based on the passage of trains through signals S-K.44 and T-K.44.

In the attached table, the Investigation Unit has listed the ARTWEB data for railway line 40 for 3 March 2020.

This is an overview of the number of trains that passed the level crossing on average per hour, in particular the number of times that road users had to stop at the level crossing on average per hour. In this case, there are approximately 2 to 3 train passages per hour.

Train passages LC 28 on 03/03/2020			
Time	Stop in station	Passing train	Total
0:00 - 1:00	2		2
6:00 - 7:00		1	1
7:00 - 8:00	1	1	2
8:00 - 9:00	1	1	2
9:00 - 10:00	2	1	3
10:00 - 11:00	1	2	3
11:00 - 12:00	1	2	3
12:00 - 13:00	1	1	2
13:00 - 14:00	1	2	3
14:00 - 15:00	1	1	2
15:00 - 16:00	1	1	2
16:00 - 17:00	1	1	2
17:00 - 18:00	2	1	3
18:00 - 19:00	1	1	2
19:00 - 20:00	1	1	2
20:00 - 21:00	1	1	2
21:00 - 22:00	1	2	3
22:00 - 23:00	1	1	2
23:00 - 0:00	2	1	3
Grand total	22	22	44

At 4.23pm, level crossing 28 went into major alert, until 4.57pm. From the ARTWEB data, we can see that no trains passed during the period of malfunction of the level crossing.

3.2.2.1.2. HISTORY ALARMS LEVEL CROSSING 28

The attached table shows the number of times there was an alert raised at level crossing 28 over the period April 2018 - March 2020.[27] On average, there were 4 major alerts and 2 minor alerts. From March 2019 through December 2019, 48 major alerts were recorded, twice the 23 major alerts in the same period in 2018. Infrabel primarily accounts for these figures by the dilapidated state of the pedestrian crossing on which the barrier mechanism was situated. Due to vibrations caused by the age of this pedestrian crossing, braking problems of the barrier were observed which caused the crossing to go into major alert. Following the increase in major alerts, Infrabel built a new pedestrian bridge. According to Infrabel, there are no significant differences in the amount of major alerts compared with other level crossings.

	Major Alert			Minor Alert			Total
Month	2018	2019	2020	2018	2019	2020	2 years
January		0	4		2	0	6
February		1	12		0	0	13
March		2	5		4	0	11
April	2	4		0	2		8
May	3	4		3	0		10
June	10	11		8	5		34
July	0	2		1	0		3
August	0	6		1	0		7
September	4	4		1	0		9
October	2	7		1	0		10
November	0	2		1	3		6
December	2	8		3	8		21
Total	**23**	**51**	**21**	**19**	**24**	**0**	
Grand Total		**95**			**43**		**138**

24 *ARTWEB = Advanced Railway Traffic WEB.*

25 *ARTEMIS = Advanced Railway Traffic Environment Management Information System.*

26 *A detection point is a "point on the track where the presence or passage of railway vehicles is detected by wheel detectors. This term corresponds to the location in the track where one finds insulating or electrical joints in the track for track circuits." (Infrabel, 2016).*

27 *Analysis by the Investigation Unit based on alert data from the 2 years prior to the major alert of 3 March 2020, as provided to us by Infrabel.*

In addition to a broken barrier, Infrabel also cites faulty coordination between the signal box and the on-site engineer responsible for supervision following the major alerts. During works (for repair or checks) there may be situations when the engineer has to trigger a major alert several times for the level crossing. The engineer communicates this to the signal box in advance. Nevertheless, these major alerts are still considered major alerts, and are included in the statistics.

The newly built pedestrian bridge to reduce the number of major alerts on level crossing 28. (Photo taken on 19 May 2020)

In the month prior to the incident, the level crossing had a major alert 12 times, 11 of which occurred on 26 February 2020, 6 days prior to the major alert of 3 March 2020. When engineers arrived on the scene that day after the first major alert, there was no longer an alert. They conducted various tests to determine the cause of the malfunction. It was during these tests that the level crossing went into major alert several times. Specifically, there was therefore one major alert (at 11.15am), while the other alerts (from 11.31am to 11.50am) were the result of diagnostic tests (see also comment above about coordination between the engineer and the signal box). The cause of the major alert on 26 February 2020 could not be determined during the tests. Between 26 February 2020 and 3 March 2020, there was no major alert at the level crossing. It is plausible that the issue of a shifting microswitch was already present, and caused a major alert, but was not detected earlier.

Date	Time	Type
26/02/2020	11:15:09	PN 28_L40 - Grande alarme
26/02/2020	11:31:04	PN 28_L40 - Grande alarme
26/02/2020	11:32:56	PN 28_L40 - Grande alarme
26/02/2020	11:33:59	PN 28_L40 - Grande alarme
26/02/2020	11:35:12	PN 28_L40 - Grande alarme
26/02/2020	11:43:42	PN 28_L40 - Grande alarme
26/02/2020	11:44:30	PN 28_L40 - Grande alarme
26/02/2020	11:47:09	PN 28_L40 - Grande alarme
26/02/2020	11:48:32	PN 28_L40 - Grande alarme
26/02/2020	11:49:09	PN 28_L40 - Grande alarme
26/02/2020	11:50:00	PN 28_L40 - Grande alarme

Observation:
The year before the incident, there was a noticeable increase in the amount of major alerts. The cause was attributed to the outdated pedestrian crossing. This has since been renewed.

Observation:
6 days before the major alert of 3 March 2020, there was a major alert on level crossing 28. It is plausible that this was also caused by the microswitch having already shifted position.

Observation:
Statistics of major alerts also contain 'false major alerts': depending on the tests, an engineer triggers a major alert at a level crossing, and although it is communicated, it is considered as a genuine major alert.

3.2.2.1.3. RIOC

Each intervention following a malfunction is registered by the RIOC[28]. This is the operational centre that remotely monitors and follows up the operation of the rail infrastructure, with the aim of identifying any malfunctions.

28 *RIOC = Rail Infrastructure Operations Center.*

3.2.2.2. MONITORING AT DE LIJN / HEIDEBLOEM

Article 19.3 of the specifications for regular transport between De Lijn and Heidebloem stipulates (translation): *"All incidents in the performance of the service (delays, minor accidents, traffic congestion, defects in the vehicle with an impact on the comfort of passengers, discussions with passengers, etc.) must be communicated by the transport company within 24 hours, in writing [...] to the management of the entity."*

Observation:
Incidents, including a delay of the bus route, must be reported by bus drivers to their management, in writing, within 24 hours.

3.2.3. PROCESSES FOR SUPPORT

3.2.3.1. COMPETENCE MANAGEMENT

3.2.3.1.1. TRAINING PROGRAMME BUS DRIVERS

Firstly, there is a theoretical part of up to 4 weeks which covers the highway code and professional competence, and secondly, a practical part lasting up to 28 days. There is simulator training with a bus simulator, focusing on basic skills, defensive, ecological and economic driving, and covering emergency situations. During the practical driving lessons, instructors give safety recommendations to prospective bus drivers, but these are not written down. After the training, participants follow a 10-day trainee course to gain practical experience.

In the training documents for obtaining the driving licence, the prospective bus driver is informed about the categorisation of levels of violations. The fourth (and most serious) level is defined herein as *"these violations directly endanger the safety of persons and almost inevitably result in physical harm in the event of an accident."*[29] The other levels are described as: *"these violations do 'not'/'indirectly'/'directly' endanger the safety of persons"* for violations of the first / second / third level respectively. For a fourth-level violation, two examples are given including *"accessing a level crossing when this is prohibited."*

Finally, the corresponding sanctions are listed: *"immediate fine collection is not possible; immediate revocation of driver's licence is possible; driving ban is possible."*

3.2.3.1.2. EXAM PROGRAMME BUS DRIVERS

An example of an exam question focuses on crossing at a level crossing.

This question reiterates to the prospective bus driver that traffic lights take precedence over barriers. Even if the train has passed and the barriers are raised, response B applies at such times: it is not allowed to drive on. The following question highlights the repercussions if a driver drives over the crossing: response A applies, the sanction of immediate revocation of the driving licence may be applied.

27. De trein is gepasseerd.
A Je mag nu verder rijden.
B Je mag nu niet verder rijden.
C Je mag nu verder rijden, als de bel niet meer rinkelt.

28. Kan je rijbewijs onmiddellijk worden ingetrokken als je verder rijdt?
A Ja.
B Neen.

Observation:
Safety at level crossings is covered in the training, manual and examination questions for bus drivers.

Observation:
Bus drivers may be asked a question in their examination that specifically tests their knowledge of a level crossing with red traffic lights.

29 *Art. 29§1 of the Law of 16 March 1968 defines this as: "The King may designate as level four violations [...] those which directly endanger the safety of persons and which are of such a nature that in the event of an accident they almost inevitably result in physical damage, and violations which consist in ignoring an instruction to stop from a competent person [...] as such."*

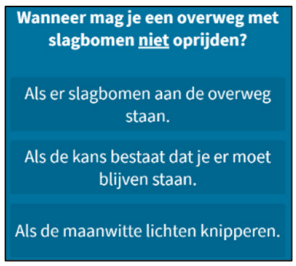
3.2.3.1.3. TRAINING PROGRAMME CAR DRIVERS

The Flemish government launched the digital platform mijnrijbewijs.be in 2019. Prospective drivers can use this website, set up by the Vlaamse Stichting Verkeerskunde (Flemish Foundation for Traffic Knowledge), to read through theoretical course material and then test their knowledge by doing exercises.

In the chapter on 'public roads', there is a section on level crossings which includes, inter alia, the guideline not to drive onto the level crossing when the red lights are flashing.

In the chapter on 'priority at intersections', the section on traffic lights focuses on flashing lights, more specifically the fact that drivers must stop, and must not go through the lights.

In the exercises, 2 questions cover level crossings, although they do not deal specifically with red flashing lights or what to do if there is a malfunction at the level crossing.



In the past, there were websites where individuals could learn and practise the theory for their driving licence, for free or for a fee. There is the website gratisrijbewijsonline.be which has existed for 15 years. In 'part F: right of way, lesson 22: train tram bus' there is, besides an explanation in a video clip, also a written focus on level crossings. Among other things, this includes red flashing lights.

Hoor je het **geluidssein** en/of **knipperen de rode lichten**, dan mag je je niet op de overweg begeven.

Nog vlug over een overweg rijden terwijl de slagbomen al naar beneden gaan is trouwens een ernstige overtreding, waarbij je rijbewijs onmiddellijk kan ingetrokken worden.

Observation:
Safety at level crossings is covered in the training for car drivers.

3.2.4. OPERATIONAL ACTIVITIES

3.2.4.1. OPERATIONAL REGULATIONS AND PROCEDURES

3.2.4.1.1. DE LIJN / HEIDEBLOEM

In the specifications for regular transport between De Lijn and Heidebloem, Article 19.2 stipulates (translation): *"Any deviation during the route (malfunction in the performance of the task, delay, defective vehicle, overloading or any other incident) is immediately communicated by the drivers via the on-board radio to the dispatching of the entity that manages the line in question."*

The term 'immediately' is interpreted internally by bus drivers as '5 minutes': 5 minutes standstill = contact dispatching immediately. Notifying dispatching after that is inadequate.

Without dispatching buses themselves, the dispatching office can visually see if a bus is delayed. However, it is up to the bus driver to report the delay after 5 minutes. If they forget, a fine may be imposed on the company. This did not happen in the case of the Moelingen incident.

Observation:
A procedure is in place as regards what bus drivers (of De Lijn / Heidebloem) must do in the event of a delay to their journey or other unforeseen circumstances. The instruction states that the bus driver must contact the dispatching office of De Lijn (and not the other way round).

3.2.5. RISK ASSESSMENT

A European study on causes of risk behaviour concludes, *"Almost 98% of all accidents at level crossings (at least in Europe) are caused by misuse of road users and pedestrians who do not respect traffic signs and signals."* (Community of European Railway and Infrastructure Companies, 2012).

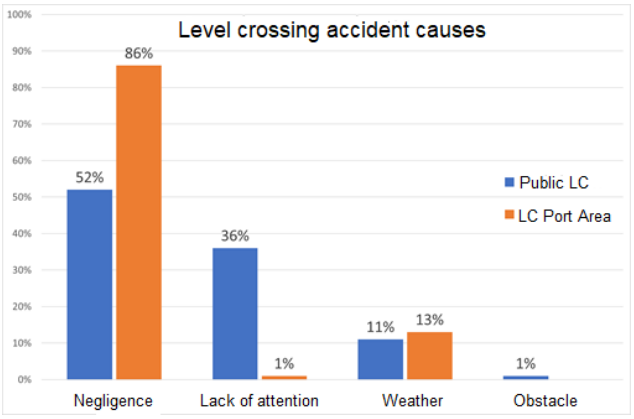
A study by Infrabel (2019) also found that 77% of people would ignore traffic rules at a level crossing if the opportunity arose. Based on the behaviour and attitude vis-à-vis careless behaviour at level crossings, 4 categories are defined:

1. Dangerous Doers (18 %). They are aware of risky behaviour at a level crossing, even though they do not consider their behaviour to be dangerous. These are largely young people who break the rules from time to time, and who can be prompted to act more responsibly through awareness-raising and warnings.

2. Unconscious Crossers (24 %). They consider that risky behaviour at a level crossing, and their own behaviour, is not dangerous. One scourge here are the so-called 'smartphone zombies': pedestrians who are absorbed by their smartphone when crossing. Their limited field of vision and lack of attention in traffic entails a higher safety risk and manifests itself, for example, in blindly crossing the tracks or ignoring red lights at a crossing. This category is also open to awareness-raising.

3. Opportunistic Crossers (35 %). They are aware of their risky behaviour at a level crossing, and know that what they are doing is illegal and life-threatening, but they do not care about this or about their dangerous behaviour. This group, primarily from the middle age group, deliberately break the traffic rules in order to save time, because others are doing it or because it suits them. Awareness-raising no longer works and enforcement is necessary.

4. Risk Avoiders (23 %). They consider risky behaviour at a level crossing to be more dangerous than the previous 3 categories. This group, mostly retired men, stick to the rules and set a good example.



The human causes[30] are first and foremost negligence, i.e. not respecting the red traffic lights and, for example, slaloming between the barriers.[31] Secondly, there is lack of attention, whereby people get trapped on a level crossing. This is due, among other things, to traffic jams, breakdowns, manoeuvres specific to the environmental configuration of the level crossing, a road accident further up from the level crossing, doing a U-turn on a crossing, etc. A portion of the accidents are caused by an external factor such as weather conditions (dazzling sun, fog, heavy rainfall) or an obstacle.

30 *Graph based on Infrabel data, 2019.*

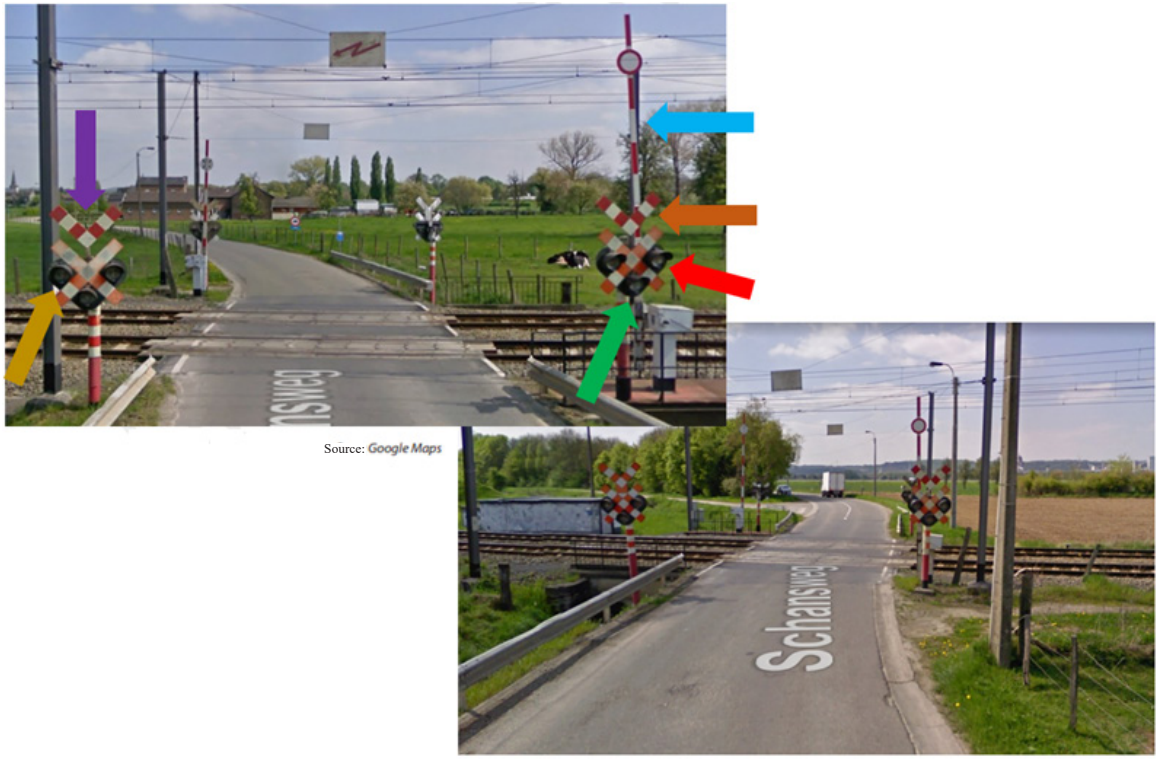
31 *This cause is significantly more common in port areas than at public level crossings. For the province of Antwerp, 60% of the accidents in 2015 occurred in the port area. And with the expansion of the port on the left bank of the Scheldt, two thirds of the accidents at level crossings in East Flanders occurred in the Waasland port. (Prinsen, 2016). There are no barriers at these level crossings (more than 200 crossings), although according to Infrabel in the Prinsen article, this is not the cause of the higher accident rate. Barriers appear to be broken more frequently at these points by road vehicles, with the result that neighbouring level crossings go into alert and the train traffic has to be halted. Barriers in the port area therefore not only entail an investment cost, but also a maintenance and repair cost.*

3.3. RULES AND REGULATION

3.3.1. APPLICABLE COMMUNITY AND NATIONAL PUBLIC RULES AND REGULATIONS

3.3.1.1. MINISTERIAL DECREE OF 25TH MAY 2013

This legal text describes level crossing 28.



Source: Google Maps

The LC is *"equipped with the safety devices provided for in Article 3, 1°, **traffic sign A47**[32] and 2° a) of the Royal Decree of 11 July 2011 on safety mechanisms at level crossings on the railways*[33]*."*

In addition, this level crossing is equipped with:

> *"1) the **partial-closure** system, on either side of the level crossing;*
> *2) an audible signal, on both sides of the level crossing;*
> *3) a **traffic sign A47 on the left** of the road, on both sides of the level crossing;*
> *4) on any **additional** traffic sign A47, a **traffic light that prohibits crossing**;*
> *5) on any traffic sign A47, a **traffic light that allows crossing**."*

32 *This traffic sign indicates that there is a level crossing for two or more tracks.*
33 *This is "the **traffic light that prohibits crossing**".*

3.3.1.2. ROYAL DECREE OF 1ST DECEMBER 1975

The highway code is the legal text that enshrines the Belgian traffic rules. Article 20.3 stipulates the situation for road users at level crossing 28 on the date of the Moelingen incident:

"It is prohibited to enter a level crossing:
1° when the barriers are moving or are closed;
2° when the red lights are flashing;
3° when the audible signal is sounding."

Article 64.2 reiterates the 2nd bullet point:

"Two alternately flashing red lights installed at level crossings signify to all road users that it is prohibited to drive past the stop line, or, if there is no stop line, to drive past or pass the traffic light itself."

3.3.1.3. ROYAL DECREE OF 30TH SEPTEMBER 2005

Various measures should ensure compliance with traffic rules set out in the highway code. There are different levels of violations, from 1 (least serious) to 4 (most serious).

In chapter 4 designating violations, level 4 violations are defined in article 4, 4 as:

"It is prohibited to enter a level crossing:
- *when the barriers are moving or closed;*
- *when the red lights are flashing;*
- *when the audible signal is sounding."*

3.3.1.4. EUROPEAN REGULATION OF 21ST OCTOBER 2009

This regulation lays down definitions for regular transport and special regular transport applicable to bus services.

- Regular transport: *"transport of passengers at specified times along specified routes, whereby passengers can get on and off at predetermined stops"*.

- Special form of regular transport: *"transport, irrespective of who organised it, for certain categories of passengers to the exclusion of other passengers"*.

3.3.2. OTHER RULES, SUCH AS OPERATING RULES, LOCAL INSTRUCTIONS, STAFF REQUIREMENTS, MAINTENANCE PRESCRIPTIONS AND APPLICABLE STANDARDS

3.3.2.1. PROCEDURE IN THE EVENT OF A MAJOR ALERT

In accordance with the RGE/ARE 727.2, indicating a malfunctioning (automatic) level crossing can be classified as a minor or major alert.

"It is a minor alert if:

- *1 red light of 1 or more road signals is out;*
- *the white light of 1 or more road signals is out;*
- *the battery is not charging;*
- *there is no AC power supply.*

It is a major alert if:

- *2 red lights of the same road signal are out;*
- *at least one barrier is not closed during the passage of the trains;*
- *at least one barrier is not closed within the envisaged time;*
- *road traffic is prohibited on the level crossing for more than 10 minutes (unless the announcement zones have been put out of service by the out-of-service installation TW);*
- *the monitoring switch on the level crossing is not in the 'AUTOM' position".*

The occurrence of a major or minor alert at an automatic level crossing requires action by the operator of the Infrabel signal box where the crossing is supervised. A major alert requires immediate action regarding the rail traffic.

The status of a level crossing in major alert is visually displayed on the EBP screen at the signal box: the feature of the level crossing turns red inverse on the screen and an alert message appears in the message box together with an audible signal. The transition from normal to abnormal status is logged. If the deck signals are closed during a major alert at a level crossing (DA[34]), the EBP system will place a table 3 on the level crossing in question. If the deck signals are not closed during a major alert at the level crossing (no DA), the EBP system will place a table 4 on the level crossing in question. If the EBP post is the control post, the MA function is automatically started by the user who has the control authority for the zone in which the relevant level crossing is situated. This user is informed via the dialogue in the function about the effect of the function on the other EBP system.

As soon as the operator of the signal box is informed of a malfunctioning of the barriers at a (road-rail) crossing, he or she has to call the maintenance operator "I-I-signalling"

Besides the general measures to be taken in the event of a malfunction as prescribed in the RGE/ARE 731, one of the following measures must be applied in the event of a major alert:

- either every train movement towards that level crossing must be via command SF 05;
- or the supervision of the crossing must be set up (RGE/ARE 727.4).

34 *DA system = "Dédoublement Alarme" (alarm duplication) system. It "means that the stop signals, which cover the level crossing in normal track regime and in counter-flow track regime, are closed in the event of a 'major alert' on a covered level crossing."*

SF 05

The command SF 05 stands for 'siffler/fluiten (whistle)/5 kilometres per hour' and the procedure, in accordance with RGE/ARE 727.2, requires the driver to:

- *"limit the speed to 5 km/h and sound the horn long and repeatedly when crossing the level crossing, i.e. from the announcement sign of the level crossing (if there is no sign, from 50 m before the crossing) until after the complete passing of the level crossing by the first vehicle;*
- *stop if traffic safety so requires."*

If the signals are equipped with a DA system, the command SF 05 is given by:

- either a form S 379, which is in the cabinet with 2 red bands of an automatic stop signal;
- or a combined form S 422[35] + S 379[36], which is located in the cabinet with a red T of an operated stop signal[37].

Level crossing 28 is equipped with a DA system and operated stop signals.

Supervision of the level crossing

Besides the procedure SF 05, supervision of the level crossing can be set up in accordance with the provisions of RGE/ARE 727.4: if the barriers cannot be closed electrically at the right time, the level crossing guard must close them manually.

3.3.2.2. CHECKLISTS FOR PREVENTIVE MAINTENANCE OF THE SIGNALLING INSTALLATIONS

3.3.2.2.1. CHECKLIST 4015I

An inspection of a level crossing is carried out by the Technical Deputy Head of Sector together with the Engineer for Electromechanics or the Mechanic for the Signalling Unit. Checklist 4015I is used for the inspection: 'OW: schouwing door TOS' ('LC: inspection by Technical Deputy Head of Sector').

In the section of the barriers, checkpoint number 15 is included: *"Check the condition of the end stops, the microswitches (working angle[38]), the wiring, the collector and brushes of the motor. Also check the condition of the main shaft, the gear assembly, the brakes, the diode* and the heater? (p. 2476)"*

Observation:
Microswitches are inspected.

35 *Form S 422 is the command whereby passing a level crossing is subject to the issuing of a pass command. It applies only to a one-off passing of one stop signal. As soon as the driver has brought his or her train to a standstill, they contact the signal box and only when the communication is completed according to procedure S 422, the signal box informs the driver that the stop signal in the closed position may be passed*

36 *Form S 379 is the command given when a level crossing is passed: limit the speed to 5 km/h and whistle and stop if the traffic safety so requires.*

37 *Passing an operated stop signal in the closed position requires, in certain cases, the permission of the signal operator. The stop signal is 'absolute' at that point. Passing an automatic stop signal in the closed position never requires the permission of the signal operator. The stop signal is 'not absolute'.*

38 *The working angle refers to the angle of the cam which must be +/- 30°.*

3.3.2.2.2. CHECKLIST 4041B AND 4041A

Preventive maintenance of a level crossing is done by the Engineer for Electromechanics or the Engineer for Electromechanics + the Mechanic for the Signalling Unit. Checklist 4041B: '1st and 2nd category LC' is used in this regard, together with checklist 4041A reliability: '1st and 2nd category LC'.

In checklist 4041B, in the microswitches section of the actuators, checkpoint 18 states, *"Check the smooth movement of the actuator cams, actuator pins, and idler rollers."*

In checklist 4041A, in the microswitches section of the sets, checkpoint 6 is: *"Check the attachment."*

Observation:
Inspection of microswitches and their attachment is included in the maintenance checklists of level crossings.

3.3.2.3. CIRCULAR OF 15TH APRIL 1991

In accordance with circular 15I of 15 April 1991 on the periodic inspection and adjustment of signalling installations, the industrial engineer *"is required to carry out an annual personal inspection of the light and sound signals and the road traffic signs at a distance; to ensure, by means of an operational test, that the barriers are opened and closed normally and that the prescribed times are observed"*.

In the section on barriers, point 6 states: *"What is the condition of the end stops, microswitches, collector and brushes of the motor, of axles and gears, of the brakes?"*

In accordance with this circular, the following is also stipulated: *"The maximum period between two inspections is set at 4 years for the various items of equipment. Level crossings are inspected every two years, except for track circuits, which are always inspected every four years"*.

Observation:
The inspection and maintenance of microswitches and their attachments have a stipulated periodicity.

3.3.2.4. INTERNAL DOCUMENTS INFRASTRUCTURE MANAGER

In the context of the investigation, documents were consulted and can only be found in Infrabel's business corner. This database is not publicly accessible and, given the confidentiality of the documents, they are not mentioned in the report.

3.3.2.5. MANUAL BUS DRIVERS

In the manual for line drivers (2011), Chapter VI - Guidelines, point 5, it is indicated that the highway code must be respected: *"the driver must act according to the signs. The driver of a vehicle for infrastructure-related operation on public roads must also act in accordance with the general road traffic regulations."*

Point 9 also stipulates: *"The driver must follow the journey sequence, in the event of problems he or she must contact the dispatcher and follow their orders."*

3.4. THE FUNCTIONING OF ROLLING STOCK AND TECHNICAL INSTALLATIONS

3.4.1. INFRASTRUCTURE

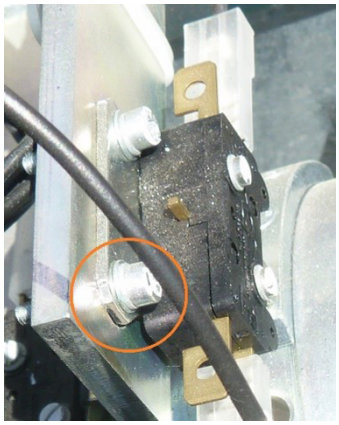
3.4.1.1. REASON FOR THE MAJOR ALERT AT LEVEL CROSSING 28 ON 3 MARCH 2020

When a train is in an announcement zone, relays in the barrier mechanism trigger the barriers to close, an audible signal to sound, the off-white lights to go out and the red lights to flash. When a train leaves the announcement zone, the relays ensure that the barriers open again, the red lights go out and the off-white lights come on.

However, the red lights remain on until the open position of the barriers is under control. When the corresponding relay is activated for this purpose at the 75-90° position of the barriers, the red lights go out. This is where the technical cause of the major alert on 3 March 2020 can be identified: the relay in question was without power.

The power supply to a relay depends on a microswitch. The microswitches of the barriers at level crossing 28 are the conventional Crouzet 83.106 model. (Infrabel, 2018).

With regard to the functional operation, the appearance and the contact resistance, the microswitches of the barrier mechanism at level crossing 28 were in good condition and, according to the infrastructure manager, premature replacement was not necessary.



Each microswitch includes an operating cam, mounted on the main shaft (which supports the barrier) via two attachment screws. The carrier of each microswitch has one bore that is too wide. This bored or slotted hole, which the attachment screw goes through, therefore has an opening of several millimetres. This allows the microswitch to be rotated around this attachment screw.

The positioning is configured in such a way that the microswitches are switched on and off in a specific sequence. However, the attachment screw of the relevant microswitch had shifted, with the result that when the cams were turned, its operating pin was not pressed in. The relay that controls the opening of the barriers at an angle of 75-90° remained without power, with the result that the red lights stayed on.

Consequently, the barriers were completely raised but the red traffic lights did not receive this information and kept flashing in alternation. When the major alert was triggered, the signal box was informed of the hitherto unknown position of the barrier. The signal box was alerted by the changing colour of the level crossing on the EBP screen to red inverse, the fact that a safety table was implemented on the stricken level crossing, as well as by an alert message in the message box and an audible signal.

The infrastructure manager generally does not have many issues with these types of microswitch, and this kind of malfunction rarely occurs.[39] In their experience, these microswitches need to be replaced approximately every three years, if one of the following elements is identified during preventive maintenance: a) abnormally high contact resistance and b) a worn out swivel castor that activates the contact of the microswitch.

The registered RIOC CALL, no. 17753226, was created on 3 March 2020 at 5:51 pm. In the RIOC CALL, the engineers noted the cause as *"Microswitch [...]" with the description "Batis [...] switch bouge au niveau de la fixation"*, i.e. the microswitch had shifted at the attachment screw.

To intervene, the engineers: *"réglé le switch et refixé le switch"*, adjusted and reattached the microswitch.

After the technical intervention, the engineers tested whether the barrier functioned correctly. Having done this, RACOR was informed of the cause of the major alert, and the repair work carried out. They also recorded this in the register of events, instructions and orders of the level crossing, also referred to as the 'logbook S 477'.

The intervention was recorded as terminating at 5:38pm.

Observation:
Level crossing 28 went into major alert due to a shifted microswitch.

3.4.1.2. ANNOUNCEMENT TRAIN

Using the kilometre markers and distances between the different track elements, it can be calculated how long it takes after the announcement of the train that the train passes the level crossing.

Maastricht → Visé: ***time*** *= (1,029 km)/(120 km/h) = (1029 m)/(33,33 m/s) =* ***30,87 seconds***
Visé → Maastricht: ***time*** *= (0,974 km)/(120 km/h) = (974 m)/(33,33 m/s) =* ***29,22 seconds***

Observation:
From the announcement of the train at the ZAX, it takes about 30 seconds (on both sides of the crossing) for the train to cross the level crossing at the permitted track speed of 120 km/h.

39 *For the Southeast district there have been a couple of incidents, mostly involving Siemens microswitches that subsequently were replaced with Crouzet microswitches. Previously recorded microswitch alerts were possibly due to the wind.*

3.5. DOCUMENTATION ON THE OPERATIONAL SYSTEM

3.5.1. MEASURES TAKEN BY STAFF TO CONTROL TRAFFIC AND SIGNALLING

The technical issue with the microswitch immediately triggered a major alert at the signal box. The incident, and especially the major alert, occurred on 3 March 2020 at 4.23pm.

The operator in the signal box ascertained the major alert at the level crossing both visually and audibly. As soon as he is informed of the malfunctioning of the barriers at a level crossing, he must call the 'I-I-signalling unit' maintenance operator. At 4:24pm, the operator at Block 44 alerted RACOR Southeast, which sent engineers to the scene.

At 4:38pm, 15 minutes after the alert was raised, the two engineers informed Block 44 that they were at the scene. Upon arrival, the engineers observed that the police were already there.

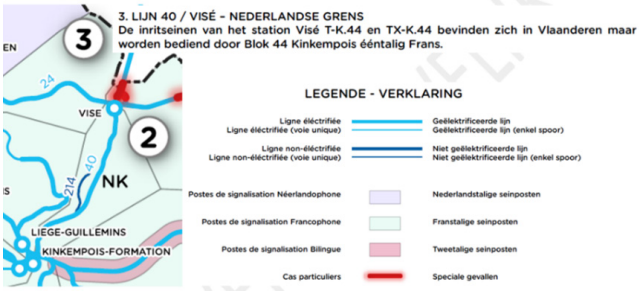
The engineers observed that the barriers of the level crossing were open, the red traffic lights were flashing in alternation, and there was no audible signal. One of the engineers manually lowered the barrier using the lever in the barrier mechanism.

The Infrabel engineer contacted the signal box at the scene, to verify whether any rail traffic was imminent. He was informed that the signals in the direction of level crossing 28 were closed and that the SF 05 procedure was in force.

Observation:
Block 44, RACOR Southeast, and the engineers responded to the major alert on level crossing 28 of 3 March 2020 in good time.

3.5.2. EXCHANGE OF VERBAL MESSAGES RELATING TO THE INCIDENT, INCLUDING DOCUMENTATION FROM RECORDINGS

Level crossing 28 is situated near the Dutch border. The local LIMA procedure (Infrabel, 2018) stipulates that in the event of a malfunction at the level crossing in question, the operator of Block 44 alerts the ProRail train dispatcher in Maastricht. This is done via the 'Overweg' (level crossing) form via notification L1.



1 Melding nr. Annonce n°	2 Aard van de melding Nature de l'annonce	3 Nederlandse Tekst Texte néerlandais	4 Franse tekst Texte français
L 1		*Overweg n° ..... is gestoord/bewaakt.* *Treinveiligheidsberichten ingesteld* *Aanwijzing aan alle treinen afgeven*	*PN n° ..... est dérangé/gardienné.* *Block par téléphone instauré* *Délivrez ordre à tous les trains.*

The map 'List-019-A - Communication exchange' (Infrabel, 2020) shows that the Kinkempois signal box is only French-speaking. The Maastricht rail traffic control centre is Dutch-speaking. Notification L1 was made in both French and Dutch (Infrabel, 2018).

At 4.26pm, the Infrabel signal box operator contacted the train dispatcher in Maastricht. In the recording of the communication, we hear that each person communicates in their mother tongue. The train dispatcher in Maastricht understands the instruction to start the LIMA procedure.

Observation:
Infrabel correctly informed the Dutch infrastructure manager ProRail, in good time, of the major alert at level crossing 28 on 3 March 2020.

3.5.3. MEASURES TAKEN TO PROTECT AND SAFEGUARD THE SITE OF THE OCCURRENCE

In accordance with the professional instruction for the operation of signal boxes (Infrabel, 2019), the EBP system implemented a protection table 3. This protection prevents unauthorised signal operation. Table 3 does not affect the operation of the level crossing, only the signals giving access to the level crossing.

"When a Table 3 case is applied:

- *the open stop signal to the zone in question must remain open until after a train has passed through the signal; and*
- *the automatic route and signalling control to the element concerned (switches, common crossings with points, etc.) is switched off.*

It is only possible to:

- *create the above-mentioned route to the zone in question manually;*
- *allow a train movement into the above-mentioned zone after the "FSO"[40] function is applied".*

Observation:
With the intervention measures procedure SF 05, level crossing supervision and safety table 3, Infrabel correctly applied the procedure for a major alert on 3 March 2020 at level crossing 28, and in good time.

40 *FSO: This command executes the auxiliary function to issue a pass command.*

3.6. MAN-MACHINE-OPERATION INTERFACE

3.6.1. INTERACTION INVOLVED ROAD USERS

3.6.1.1. HEIDEBLOEM

On 20 April 2016, the bus driver obtained his certificate of basic qualification.[41] The certificate contains the following applicable elements:

- Driving test on public roads.
- Practical test of professional competence.
- Test in an area away from traffic.
- The practical test was taken with a category D vehicle.

Category D is included in the bus driver's licence with a validity date from 21 April 2016 to 21 December 2020. The column 'additional entry' states the number 95 = professional competence with the validity date 19 April 2021.

After the VDAB training course, the bus driver drove a shuttle service for Heidebloem in Hasselt for around 6 weeks. In January 2017, he started at another bus company as a school bus driver, which he did for 1.5 years. During the summer holidays of 2017 and 2018, he also did the shuttle service for Heidebloem. In October 2018, he started at Heidebloem as a line driver.

The bus driver is familiar with route 39B and experiences it as a quiet line. On 3 March 2020, he had a split shift, i.e., a morning and evening shift. In the morning, his shift started at 6:26 am and ended at 11:27 am. The 2nd shift started at 3:23pm. Both at the station and at the first stop on the route, the bus driver commenced the journey without any problems.

Arriving at the malfunctioned level crossing[42], around five cars were waiting. The bus driver stopped at the level crossing. No-one was there to direct the traffic (e.g. police or Infrabel staff). While the bus driver was waiting at the level crossing, people in front and behind him were turning around. Given the length of the bus and the narrowness of the street, this was not possible for a bus.

Shortly thereafter, the stationary bus was passed by road users crossing the malfunctioned level crossing. The people behind did not flash their headlights, nor sound the horn, in order for the bus to move. The passengers on the bus were not too concerned about the situation. When there were about five or six cars waiting behind the bus, a fellow bus driver joined the back of the queue of the waiting vehicles. This colleague was operating another bus service that would normally pass by about eight minutes after the first bus driver.

The bus driver waited at least ten minutes. While waiting, the dispatching service was apparently not contacted. He started his bus, activated the left turn indicator, overtook two cars and headed for the level crossing. No-one was at the level crossing to direct traffic. As instructed during practical driving lessons, the driver stopped in front of the crossing, looked left and right, and then crossed.

41 *The bus driver from Heidebloem has followed bus driver training at the VDAB training centre in Bilzen.*
42 *It was the 1st time that the bus driver had arrived at a level crossing with red flashing lights and open barriers.*

Heidebloem was notified of the incident on 16 April 2020.[43] The bus driver was contacted and asked to draw up a report of the incident. The incident was also discussed at the Hansea CBPW TBE[44] meeting held on 7 May 2020. In the minutes of the meeting, it is noted (translation) *"that in such situations, dispatching must be called for further instructions. Important events like this must also be noted in the daily report."*

3.6.1.2. JEAN-LUC CARS

The driver of the school bus had worked for the company for 15 years and was familiar with the route along the Schansweg. He had made the journey four times a day over the last four to five years. The view around the level crossing was unobstructed, and no trains could be seen coming down the tracks. Possibly assuming that there were problems with the level crossing, the driver crossed it, possibly prompted by the sound of horns from the road users behind.

After the incident, the TEC banned the driver from school bus runs, and his employment contract was not renewed.

3.6.1.3. OTHER ROAD USERS

Various road users were involved in the incident. A number of road users made a U-turn before the crossing, others drove through the malfunctioned level crossing. Road users with a trailer or driving larger vehicles could not do a U-turn on the road in question.

With no number plates recorded, it was impossible to identify or interview the various drivers.

Observation:
Some of the road users made a U-turn at the malfunctioned level crossing. Other vehicles, too large to make this manoeuvre on the local Schansweg, drove through the malfunctioned level crossing.

Observation:
Drivers of public buses did not contact dispatching when they were held up at the level crossing, and they drove through the malfunctioned level crossing of their own accord.

43 *It was also the first time that Heidebloem had been confronted with such an incident.*
44 *CPBW TBE = Comité voor Preventie en Bescherming op het Werk van een Technische Bedrijfseenheid (Committee for Prevention and Protection at Work of a Technical Business Unit).*

3.6.2. MEDICAL AND PERSONAL CIRCUMSTANCES THAT INFLUENCED THE INCIDENT, INCLUDING PHYSICAL OR PSYCHOLOGICAL STRESS

Sewer works in the municipality of Voeren created diversions for vehicles. For buses, diversions may mean delays and missed connections. These circumstances can be a source of stress for bus drivers.

While waiting, the bus driver saw a bus driver colleague join the back of the queue of road users at the malfunctioned level crossing. If a driver is stressed due to delays on their route, which might mean passengers missing their connections, they may also feel worried on the part of a colleague that he or she will not be able to keep to the timetable if the delay at the malfunctioned level crossing persists.

3.6.3. DESIGN OF EQUIPMENT WITH IMPACT ON THE HUMAN-MACHINE INTERFACE

3.6.3.1. DISPATCHING

Every bus being operated for public transport contains an on-board radio. In the event of a delay on the route or other unforeseen circumstances, the bus driver must contact dispatching via this on-board radio.

Throughout the region, apart from the occasional poor connection via the radio system, communication with the dispatching is without any issues.

On 3 March 2020, the bus driver did not report the hold-up at level crossing 28 to the dispatching office of De Lijn. The driver's employer Heidebloem was not informed either. Given that Heidebloem was not aware of the situation, it could not, in accordance with Article 19.3 of the specifications for scheduled transport, inform De Lijn of the situation.

Observation:
Bus drivers can contact dispatching via an on-board radio. There are not really any problems in the region with this communication by radio.

3.7. SIMILAR EVENTS IN THE PAST

3.7.1. HISTORY OF ACCIDENTS AND INCIDENTS AT LEVEL CROSSING 28

Since 1 July 2007, Infrabel has used the SafeRail database.[45] The following registered incidents have occurred at level crossing 28:

- 23/07/2007: attempted theft of cables;
- 26/08/2007: attempted theft of cables;
- 13/07/2012: a truck crossed the level crossing before the white lights came back on. One barrier was broken, the other barrier was bent and cracked;
- 27/08/2019: a barrier was broken and blocked the road.

The level crossing is not listed as a hot spot by the railway police. There are no statistics available for level crossing 28 as regards major alerts due to cable theft on the railway line[46], nor as a result of incorrect configuration, nor as a result of the wind.

Observation:
Since 1 July 2007, 4 registered incidents have been identified on level crossing 28.

45 *This is a database in which all accidents and incidents on the railway network are registered and documented.*

46 *Moelingen is located in the border region with the Netherlands and Germany, which gives thieves escape routes. Thefts of cables result in breakdowns and consequently to major alerts.*

3.7.2. LINK WITH PREVIOUS INCIDENTS

3.7.2.1. COLLISION BETWEEN A BUS AND AN SNCB/NMBS PASSENGER TRAIN ON A LEVEL CROSSING IN PITTEM ON 25 NOVEMBER 2015

Following the investigation into the collision of a bus with an SNCB/NMBS passenger train at a level crossing in Pittem on 25 November 2015, De Lijn informed the Investigation Unit that an action plan had been drawn up, intended to be discussed by the management board. De Lijn's presentation to the board of directors took place on 22 June 2016. This was followed by discussions with the VRA[47] to adapt the specifications for operators. A reorganisation and retendering of contracts meant that the texts could not be finalised, although talks are due to start up again shortly. In the action plan of De Lijn, we see 7 pending action points regarding the subject 'supervision of operators - specifications for operators'. One action point has been achieved: the instruction 'what to do if radio does not work' was included in the specifications.

The contents of the training that operator drivers follow at the driving school of De Lijn has also been overhauled. The new lesson content includes a module that focuses on the use of the on-board radio and communicating with dispatching. The theoretical training includes as modules and learning objectives (De Lijn, undated):

- *"18.4. Radio communication*
  - *The driver knows the purpose of a dispatching office.*
  - *The driver knows how dispatching works (has visited dispatching).*
  - *The driver knows the different types of calls and can apply them.*
- *18.5. Use of intercom*
  - *The driver knows the tips and tricks to clearly communicate a message through the intercom."*

The FBAA has also implemented the recommendations of the study investigation by emphasising more explicitly to drivers the special conditions at level crossings for large vehicles in the training modules of the permanent training by the FCBO, where authorised by the FPS Mobility and Transport, as well as in the basic training by the Social Fund[48].

3.7.2.2. INCIDENTS WITH THE SAME MICROSWITCH

- 9 March 2015: in Lichtervelde, level crossing 54 went into major alert due to a malfunction in the motor system of the barrier. During the intervention, the microswitch was replaced and the situation was restored.
- 22 September 2016: Traffic Control[49] received a call that the red lights at level crossing 28 on railway line 12 in Kapellen continued to flash in alternation while the barriers were open. Upon inspection by the engineer, a problem with an outdated microswitch was identified. When the level crossing was opened, the relay did not have any power due to a malfunction in the microswitch. As a result, the barriers were open while the red lights continued to flash.

47 *VRA = Vlaamse Raad van Autobus- en Autocarondernemers (Flemish federation of coach and bus operators).*
48 *Social Fund = Social Fund for Employees of Public and Special Bus and Coach Undertakings.*
49 *The essential tasks of this service are the organisation of train traffic, the management of train traffic in real time and the supervision of signal boxes. It keeps a comprehensive overview of planned works, disruptions and other incidents on the railway network.*

4. ANALYSIS AND CONCLUSIONS

4.1. FINAL SUMMARY OF THE CHAIN OF EVENTS

On 3 March 2020, at 4:23pm, a major alert was raised at level crossing 28 on the Schansweg in Moelingen.

The signal operator of block 44 in Kinkempois saw the major alert on the EBP screen. The EBP system implemented a safety table 3. This prevents unauthorised signal operation. The signals in the direction of level crossing 28 closed and procedure SF 05 (siffler/fluiten(whistle)/5 kilometres per hour) took effect. At 4.24pm, the signal operator informed RACOR Southeast, which is responsible for the first line handling of malfunctions in the region in question. RACOR Southeast sent engineers to the scene. At 4:26pm, the signal operator of block 44 informed the dispatcher of ProRail.

The red lights on the malfunctioned level crossing were flashing, while the barriers on both sides of the crossing remained open. Nevertheless, various vehicles, i.e. cars, vans, a school bus and a normal bus, drove through the malfunctioned level crossing.

At 4.38 pm, Infrabel engineers arrived at the scene and oversaw the level crossing by manually closing the barriers. After they contacted the signal box, it was confirmed to them that the signals towards the level crossing were closed, and that the procedure SF 05 was in operation. If a train had announced itself unexpectedly, the ZAX would have detected it. The announcement system functioned normally: if rail traffic crossed the ZAX of the announcement zone, the actions to close the level crossing would have been triggered.

The Infrabel engineers pinpointed the cause of the major alert in the barrier mechanism. More specifically, the shifted position of a microswitch. The engineers adjusted and reattached this microswitch, and tested whether it worked properly. At 4.57pm, normal service was resumed at the level crossing and the major alert was terminated.

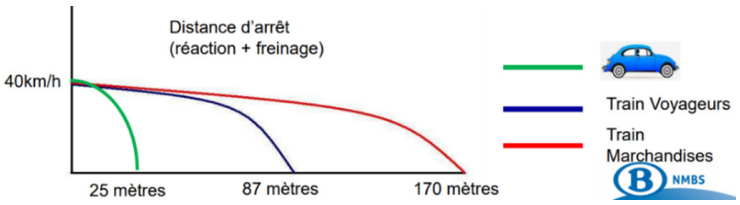
4.2. DISCUSSION

4.2.1. DANGER ANALYSIS

If a train travelling at the reference speed of the line, i.e. 120 km/h, passes the ZAX, which is approximately 1 km away from the level crossing (in Moelingen), it would pass the level crossing 30 seconds later. Due to environmental factors, it is possible that at the moment the train is announced, the road user cannot see the train. At a distance of 100 meters from the crossing, the train will pass within 3 seconds. It is therefore with good reason that there are red traffic lights, an audible signal and closed barriers to prohibit road users from crossing the level crossing unauthorised.

It should be borne in mind in this regard that the braking distance for rail transport is considerable, due to the low friction between the wheels of the trains and the rails. For example, the distance a train needs in order to stop can be 10 times that of a car. (Community of European Railway and Infrastructure Companies, 2012). The amount of locomotives, the amount of carriages, the amount of passengers, the goods transported, and friction influence the braking curve.

In 2016, a 'Lessons learned' seminar was held following the safety investigation carried out by the Investigation Unit into the accident at the level crossing at in Pittem. The braking curves of a train compared to those of a car were presented: at a speed of 40 km/h, the stopping distance (reaction + braking) for a car is 25 metres, for a passenger train 87 metres and for a freight train 170 metres. (SNCB/NMBS, 2016).



A 40-ton truck travelling at 89 km/h requires 1 football pitch, or 110 metres, in order to come to a standstill. For a freight train, this is 15 times longer. (International Union Of Railways, 2019).

Observation:
A train is much faster than many people realise. It requires much more time and distance than a car to come to a standstill. Moreover, a train cannot swerve from its route.

4.2.2. APPROACH ANALYSIS

4.2.2.1. RAISING AWARENESS

Infrabel organises awareness-raising campaigns to make road users aware of the dangers at level crossings and the investment budget has been increased for the 2nd year in a row. This awareness-raising is best pursued with a wide range of communication channels (traditional vs. social media).

However, at the societal level, this should not mean that incidents at level crossings are only a problem for the railway sector. Following the fourth edition of International Level Crossing Awareness Day, the Community of European Railway and Infrastructure Companies (2012) has stated that the sector is unable to manage all the risks associated with road users crossing level crossings.

Together with the road sector, the railway police and training centres, the railway sector is responsible for raising awareness: making road users aware of the dangers of level crossings and trying to make them aware of how to act safely at level crossings. However, (illegal) behaviour, such as the unauthorised crossing of the level crossing in Moelingen on 3 March 2020, is the responsibility of the road user. This is an absolute bottleneck, because according to Deutsche Bahn AG, 94% of accidents are caused by unlawful acts on the part of road users. (Schnieder, Grippenkoven, Wang & Lackhove, 2015).

4.2.2.2. PREVENTION

Infrabel is active in the area of prevention in order to limit the dangers at level crossings, and the investment budget has been increased for the 2nd year in a row. Where possible, it is desirable to continue working towards the removal of level crossings, or to avoid the crossing of level crossings by proposing alternatives.

However, it should be noted that, notwithstanding all preventive measures to increase alertness on the part of road users, it is the road user him or herself who crosses the level crossing and decides how they do this, safely or not. As Cairney (2003) states, *"The form of traffic control implemented at a railway level crossing greatly effects the decision that has to be made by the driver of the road vehicle and the safety of the crossing."*

The continuous improvements made to the infrastructure reduce the risk at level crossings. Reducing incidents requires more awareness of the consequences of inattentive or dangerous behaviour by and among road users. However, the range of preventive measures is limited. At some point, the system solutions provided, aimed at adding new types of alerts, reach a ceiling. Salmon et al. (2015) argue *"that reductionist approaches have achieved all that they can in areas such as road and rail."* They also find that the larger number of design changes to (parts of) the infrastructure only have a marginal impact on human behaviour and safety.

4.2.2.3. REPRESSION

For road users who deliberately disregard the traffic rules at level crossings and can hardly be made aware of them, traffic control and fines/penalties are a final but necessary step. The aim of a fine is to influence the behaviour of the penalised road user, and to influence the behaviour of all road users.

Imposing fines has a signal function: the road user belongs to a (small) group of offenders, a stigmatised group to which non-one wants to belong. A negative reaction from the circle of people around the penalised driver can also make him or her more inclined to adapt his or her behaviour. The aim of a fine is therefore to prevent a recurrence of the undesirable behaviour (which means that enforcement is also a specific form of prevention).

Punishment also sends a signal to all road users that there is an actual enforcement of the traffic rules, which coerces people to respect them. This coercion can be called the objective probability of being caught.

Although there are various forms of punishment, it should be borne in mind that not all of them have an equally lasting effect. The effects of a fine, for example, are short-lived: there is a nagging feeling that the road user has to pay an unnecessary and pointless penalty, but in the long term their road behaviour does not change much. Once the fine is a distant memory, there is a good chance that the road user reverts back to their previous behaviour. (Ddek, 2017). Increasing the fine appeals to the road user's extrinsic motivation: people abide by the highway code in order to avoid a fine, not because they think it is important. But here too, the effect on behaviour is limited in time and place.

The focus, for example in a campaign on safety at level crossings, should be on the subjective chance of being caught. As Hoekstra, Eenink & Goldenbeld (2017) argue (translation): the (size of the) fine has little influence on behaviour when people estimate the probability of receiving a fine for an offence to be low. Similarly, Molenaar (2014) argues that road users will only adapt their behaviour when *"the perceived risk of being caught is high."*

A higher chance of being caught also means more visible enforcement. This can be reflected in organising checks on a regular basis, both unannounced and announced.[50] When the results of the checks are also communicated (in a comparison with the results of previous campaigns) this increases the perceived chance of being caught.

Studies show that red light cameras reduce the number of accidents. A feasibility study has been implemented to install such cameras at certain level crossings. Which level crossings and how many are involved is not stated, although it seems that the infrastructure manager will follow the trend of other European countries.

50 *As regards unannounced checks, the infrastructure manager, police services and Securail could make agreements regarding the periodicity and hotspots. Announced checks can be organised, for example, in the context of a speed camera marathon at level crossings.*

4.2.2.4. SUMMARY

The infrastructure manager is active in the three pillars of prevention, awareness and enforcement. It is unrealistic to assume that figures relating to accidents, deaths and casualties at level crossings can be reduced to zero. Indeed, safety at level crossings is a problem which, despite prevention, awareness and enforcement measures, will not disappear as long as there are level crossings.

Campaigns are launched to influence the behavior and actions of car drivers, truck drivers, bus drivers, motorcyclists, moped riders, cyclists or pedestrians. Nevertheless, being realistic, the many attempts to make road users aware of the safety risks at level crossings do not mean that everyone is equally aware. The publication of The Rail Safety and Standards Board (2020) also states that despite the lowest number of fatalities at level crossings in the UK over the period 2018-2019 *"many level crossing users are unaware of the risks associated with level crossings and how to use them properly."*

We should also be realistic with regard to efforts made within the rail sector. Level crossings are a part of railways that are highly susceptible to incidents, *"be this involving user error, signaller error, incorrect usage, issues with sighting, or (less frequently) equipment failure." (The Rail Safety and Standards Board, 2020)*. It is also the case that the fatality rate of 0.29 in the European Union is 10 times higher for level crossing users than for road users, but the number of deaths at level crossings comprises 'only' 0.9% of the total number of deaths on the road: *"the number of road deaths is approximately one hundred times greater than the number of railway fatalities". (Delmonte & Tong, 2008)*. Level crossings are therefore a significant risk factor for safety in the railway sector, even though they only comprise a small part of road safety as a whole. This statistic also explains why the dialogue between road and rail authorities is not always easy as road infrastructure managers say they have other more important safety issues to focus their scarce resources on. (Nelson, 2012).

4.2.3. HUMAN FACTORS ANALYSIS

"It is widely recognised that human behaviour is the main factor for road collisions, with the vast majority of collisions at level crossings caused by drivers not observing the highway code, either deliberately or unintentionally." (Fonverne, 2020). It is not our intention to make a comprehensive analysis of why road users deliberately (but not maliciously) cross a malfunctioned level crossing. For the incident in Moelingen, we can possibly and in combination identify the following attitude-related reasons.

• **Instrumental attitude**: warning signals at a level crossing are subject to a cost-benefit analysis: when the costs of waiting (the journey takes a few minutes longer) outweigh the benefits (avoiding a possible penalty), the decision to cross becomes more plausible. (Picket and Grayson, 1996). Safety at level crossings is related to advantages (for example, it is advantageous/safe to respect level crossing warnings) or disadvantages (for example, time is lost waiting for a train).

Moreover, *"it's this idea that if you think you might get held up for 50 seconds then you're not bothered but if you think you might get held up for ten minutes your 'risk rating' changes."* (Delmonte & Tong, 2008).[51] If the situation at the malfunctioned level crossing 28 in Moelingen only lasted 50 seconds, it is plausible that road users would have acted in accordance with the highway code. The longer they had to wait, the more they were inclined to cross the level crossing, given that the threat of an approaching train decreased (unobstructed view of the railway).

Reactions to waiting differs from person to person, and depends on how the waiting time is perceived. In a primarily individualistic society, for example, people don't like to wait any longer than they have to. Moreover, the waiting must have a purpose, there must be a reason for the waiting. Needlessly waiting leads to irritation, it is a frustrating obstacle in reaching our goal. Uncertain waiting times (compared to waiting times known in advance) and inexplicable waiting times (compared to waiting times that are explained) will also feel longer.

Applied to the incident in Moelingen, it is plausible that road users were driving somewhere (for example, to pick up their children from school) and considered waiting to be a pointless waste of time. Or people may have had an appointment at a given time (for example, a medical appointment) and be late on account of the waiting. Moreover, the malfunctioned level crossing was unattended and the road users had no inkling of how long the wait would last. No-one knew what was happening either. The road users had no explanation as to why the red traffic lights were flashing, when no trains were coming. It is plausible that some road users judged that they could not wait any longer, wanted to wait, had to be somewhere on time, did not know why they were still waiting and therefore decided to cross the level crossing.

51 *Delmonte and Tong (2008) also link this to the growing climate concern: road users who wait a long time in their cars start worrying about their CO2 emissions: "if emissions become a recognised cost of traffic delays at level crossings, their costs could be offset against the cost of any potential solutions to the problem as a further route to justifying action." Road users who had been waiting for some time with their engine running at level crossing 28 in Moelingen, might have considered driving on (instead of switching off the engine) due to environmental considerations.*

• **Affective attitude**: safety at a level crossing is related to how someone feels in a situation. For example, Lawton, Parker, Manstead, and Stradling (1997) argue that road users feel silly or ridiculous when they do not cross a level crossing when the train has long passed but the red lights are still flashing. There is a link with how people handle waiting times, although here it is focused on how they feel when waiting. For example, longer waiting times are perceived as unfair, in comparison to reasonable waiting times. A road user will also feel irritated when someone further back in the queue, who has been waiting for less time or who has only just arrived, crosses the level crossing before the road user in question. The disciplined waiting conduct of first in, first out is therefore undesirably upended.

Applied to the incident in Moelingen, some road users witnessed other drivers, and people behind them, deciding not to stop at the level crossing. If a person has decided to wait, other road users overtaking and crossing the malfunctioned level crossing seems unfair. When a person reaches their frustration threshold, they may also decide to cross the malfunctioned level crossing as well.

• **Informational social influence**: people have the compulsion to adapt their behaviour to that of others, and this is automatic if a person identifies with those others. If we are in the same situation with others, we are more likely to trust these group members than non-group members, even in situations where it is clear that the group composition is completely arbitrary. (Stallen & Sanfey, 2013). Applied to the incident in Moelingen, road users are influenced by the power of the crowd: through 'social proof' (informational social influence), in a situation in which they do not know how to react themselves, they will look to others to determine their own behaviour. (Ligier, 2020).

If a person is in an unfamiliar situation, they will often take no action. This is called the bystander effect: no-one takes any initiative, and no-one can deviate from this either. However, if someone does take the initiative, then social proof comes into play: people unconsciously think 'oh, this is the behaviour that is expected of me' and go along with it in order not to fall out of the group.

In the case of the malfunctioned level crossing, people initially refrained from crossing, as this is also socially and legally undesirable. However, if after a while the lights do not change to white, people are more uncertain of the correct course of action to take. And if someone does decide to ignore the red lights, a radar of informational social influence is triggered, the psychological and social phenomenon whereby people copy the actions of others in an attempt to exhibit behaviour in a given situation, and thus jointly decide to cross the malfunctioned level crossing.

• **Familiarity**: if road users are familiar with the level crossing, they can reason 'I cross here several times a day', 'I already know the times when trains pass' and 'I know how long it takes before the barriers go back up'.[52] Road users address their previous experiences of waiting at level crossings more expansively: if they have already experienced the situation of having to wait needlessly at the red lights of a crossing, they are less likely to wait needlessly again in a similar situation: *"they may become predisposed not to look for a train on the crossing, if they are familiar with that crossing. Alternatively, drivers may transfer their experience of one crossing to a new crossing, reducing their vigilance."* (Pickett & Grayson, 1996).

Applied to the incident at in Moelingen, it may be that road users were familiar with the timetable and, relying on this, decided that it was safe to cross the malfunctioned level crossing: *"Local users can come to rely – wrongly – on the timetable. They'll memorise it and think that as long as they don't cross when the timetable says there's going to be a train, that they'll be safe […]."* (Delmonte & Tong, 2008).

• **Not (fully) aware of the risks**: road users believe they have enough competence to perform a given action. In accordance with an expectation of self-efficacy, the degree to which an individual thinks he or she has control over their own behaviour or thinks they can control it with some success, road users assume that they are capable of avoiding an accident themselves. No trains are coming, the level crossing is quickly traversed, so what's the risk of being hit? The external control expectations are overestimated in this regard. People think they have control over a train passing, or not, even though they cannot regulate or predict train traffic themselves. By extension, if a train does approach, people underestimate the risk of the speed at which a train can approach the level crossing at full speed, and the fact that it is unable to stop quickly.

The road users in Moelingen had an unobstructed view of the railway, which was not made less visible by rain, fog or dusk that day. The red traffic lights had been flashing for some time, the barriers were open, there was no audible signal and no trains were passing. This sensory information is not only acquired, it is also registered, organised, interpreted and analysed. This can create the perception that there is little risk in ignoring the red lights. If no trains are approaching and the level crossing has malfunctioned, a driver may decide that he or she has sufficient control over the situation and that there is no risk of an accident: they cross the level crossing.

52 *Infrabel (2019) also notes this in their study, noting that these road users live in the same or adjacent municipality to the level crossing.*

4.3. CONCLUSIONS

On 3 March 2020, at around 4:23pm, level crossing 28 in Moelingen went into full major alert. At around 4.57pm, the major alert was terminated. During this time, the red traffic lights were flashing in alternation, although the barriers remained open and there was no audible alarm signal. Despite the fact that the red traffic lights were flashing, many road users drove over the level crossing.

The incident of unauthorised presence on the tracks can be catalogued as 'inadvertent third-party intrusion into the loading gauge of a railway track'.

Direct cause
The direct cause of the incident was non-compliance with the highway code: many road users cross a level crossing when the red traffic lights are flashing in alternation.

Indirect factor
The traffic rules were violated deliberately, but not maliciously. The indirect factor is the attitude of road users. These include the instrumental attitude, affective attitude, informational social influence, familiarity and not being fully aware of the risks.

Underlying factors
An underlying factor is the fact that there are level crossings. Removing a level crossing eliminates any risk of an accident. Given that not all level crossings can simply be removed, one alternative is to replace the level crossing by a bridge, tunnel, bicycle path or parallel road, for instance.

Another underlying factor is the safety management of a level crossing incident. The infrastructure manager has a procedure in place for what to do in case of a major alert at level crossings. Road users must take into account that when a level crossing has malfunctioned, it remains unattended for a certain period of time (from the moment the malfunction occurs until the engineers arrive at the scene).

4.4. OTHER FINDINGS

A first additional observation is that a shifted microswitch in the barrier mechanism caused the major alert. The checklists used for the periodic inspection and maintenance of level crossings state that the microswitches and their attachments must be checked.

A second additional observation is that bus drivers did not contact the dispatching office of the transport company, and took the initiative themselves to cross the malfunctioned level crossing.

5. MEASURES TAKEN

After learning of the incident, Heidebloem had an interview with the bus driver, and brought the incident to the attention of Hansea's CPBW TE.

Infrabel signalled that, together with the FPS Mobility and Transport, it carries out annual checks on the safety equipment installed at each level crossing on the network. Based on these visits, extra safety provisions can be added to level crossings.

No additional safety provisions were reported for level crossing 28 after the incident.

6. RECOMMENDATIONS

No	Direct cause	Recommendation
1.	Road users ignored the highway code and crossed a level crossing when the red traffic lights were flashing in alternation.	The Investigation Unit does not make any recommendation. It is obvious that the traffic rules must be respected at level crossings.
No	**Indirect factors**	**Recommendation**
2.	Attitude of road users: instrumental attitude, affective attitude, informational social influence, familiarity and lack of awareness of the risks are conscious but not malicious factors that prompt road users to cross a level crossing unauthorised.	The Investigation Unit does not make any recommendation. The campaigns to raise awareness, prevention and enforcement organised by the infrastructure manager, must be continued in order to keep road users permanently aware of the dangers of crossing level crossings unauthorised.
No	**Underlying factors**	**Recommendation**
3.	Presence of level crossings.	The Investigation Unit does not make any recommendation. The infrastructure manager makes efforts to remove level crossings or replace them with, for example, a bridge, tunnel, bicycle path or parallel road.
4.	Management of level crossing incident.	The Investigation Unit does not make any recommendation. The infrastructure manager has a procedure in place for what to do in case of a major alerts at level crossings. Road users must take into account that when a level crossing has malfunctioned, it remains unattended for a certain period of time.
No	**Other findings**	**Recommendation**
5.	The investigation states that the major alert was caused by a shifted microswitch.	The Investigation Body Unit does not make any recommendation. The infrastructure manager has checklists for the inspection and maintenance of level crossings, which include an inspection of microswitches and their attachment.
6.	Bus drivers do not contact the dispatching office of the transport company in the event of a delay.	The Investigation Body Unit recommends that bus companies ensure that bus drivers are made more aware of the dangers of level crossings and that their bus drivers are more familiar with the procedures for contacting the dispatching office.

7. ANNEXES

7.1. AWARENESS-RAISING CAMPAIGNS INFRABEL

• "Jeroom Slagboom" (Flanders) or "Jean-Pierre Barrière" (Wallonia) is the mascot of the awareness campaign to change people's behaviour at level crossings. Non-compliance with the traffic rules is and remains the number one cause of accidents at level crossings. The campaign calls on people to respect red lights and barriers and to always be vigilant at level crossings. (Infrabel, 2019-2020). In the spring of 2019, the clip aired on TV and social media, with a re-run in the autumn, and it was also posted on YouTube. Infrabel also relaunched the clip in 2020, including on International Level Crossing Awareness Day[53] on 11 June 2020.

• Crash test: an empty, 85-ton locomotive at a speed of 75 km/h collides with a stationary, 1-ton car (containing 1 adult and 2 child crash test dummies) at a level crossing. The impact is filmed by 3 drones and 20 cameras, and is disseminated through social media and shown at various actions (training courses, lessons in schools, police and traffic days, events, etc.). Message: the chances of anyone surviving such a collision are practically zero. *"Je leven is echt het wachten waard: respecteer dus steeds het verkeersreglement"*. (Your life is really worth waiting for: so always respect the traffic rules). (Vias Institute & Infrabel, 2018).

• Ketnet Summer tour: a campaign aimed at young road users. A stand was set up in the Ketnet festival village, to make young people aware of the traffic rules at level crossings: *"We willen de kinderen (en hun ouders) op een luchtigere en positieve manier deze cruciale boodschap meegeven: "Stop aan een overweg zodra de rode lichten knipperen!"* (We want to give children (and their parents) this crucial message in a light-hearted and positive way: "Stop at a level crossing as soon as the red lights flash!") (Infrabel, 2019).

• 'Sinterklaas' campaign: every year, Sinterklaas (Saint Nicolas) visits a few railway level crossings to hand out a bag of sweets, but also to explain safety rules at level crossings. For example, in Buggenhout (De Rycke, 2019) where the barrier has been hit 16 times since 2000 and a serious accident occurred in 2012. Road users therefore drive though, even though this is not allowed. (Dooms, 2019).

53 *A safety awareness campaign at level crossings run by the UIC, the International Union of Railways. This is the global professional association representing the rail industry and promoting rail transport. Infrabel has been a member since 2014.*

• Trucks in the port of Antwerp: over the period 2010 to 2017, there was an average of 16 level crossing accidents per year in the port area. This means that the share of these accidents is 1/3 of the total number of level crossing accidents. (Infrabel, 2019). In December 2018, Infrabel organised a targeted awareness campaign in and with the support of the Port of Antwerp. The campaign to always respect the traffic regulations was aimed at truck drivers and was disseminated through the channels of the partners involved. There were also symbolic actions whereby the windscreens of the trucks were cleaned in the parking areas and drivers were given sunglasses to protect against sun dazzling. (Infrabel, 2018).

• 'Kijk Uit': in June 2020, Infrabel worked together with Kijk Uit, the Flemish television programme about traffic safety. In the episode 'Veilig over de spoorweg' (Crossing the railway safely), the Federal Railway Police explains the traffic and safety rules at a level crossing. (Belgian Federal Police, 2020).

• Television soap 'Thuis': In the 2019 season finale, one of the main characters puts his life in danger due to his reckless behaviour on a level crossing: 3 teenagers want to avoid being spotted by their parents while playing truant, go on the run and then someone crashes his bike on a closed level crossing with a train approaching. Besides the fatal accident, the financial, legal and administrative consequences are also explored. Between 19 to 28 June, the show was watched by around 2 million people in Flanders. The research department of the VRT ran a survey between 25 June and 3 July into the impact of the storyline: 53% of Flemish people were familiarised with the topic of accessing rail tracks unauthorised through the show 'Thuis', 31% would never have come into contact with the topic without 'Thuis', and 8% are more aware of the dangers of accessing rail tracks unauthorised thanks to the episode. (Infrabel, 2020).

• The Floor: through a virtual reality installation (vibrating stage, special glasses and sound effects), young people from secondary schools are made aware of the danger of impulsive decisions. As such, they are confronted with the experience of dashing over a railway line to catch a train. (Infrabel, undated) For 'The Floor', a new 360° virtual reality film was shot with the three young actors from 'Thuis'.

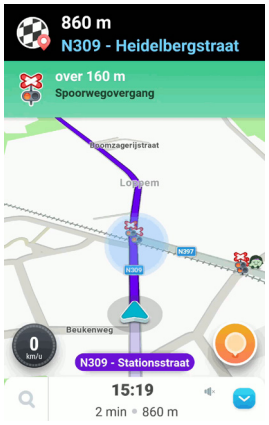
• Warning Box: an alarm system that detects inattentive or deliberate crossing of a closed level crossing by pedestrians and cyclists, and activates an alarm. The crossing alarm creates an immediate deterrent effect and warns the person concerned that danger is imminent. (Infrabel, 2020). A prototype was commissioned in Ottignies in September 2020, and the pilot project has since been extended to some 6 level crossings.

- Education
  - The sizeable school calendar of Infrabel (undated) teaches pupils a range of safety rules in stations, along tracks and at level crossings, in a light-hearted way using illustrations. As the second focus point, the calendar states (translation), *"At a level crossing, everyone must respect the red lights, the ringing signal, the barriers, and the traffic signs."*
  - Infrabel's rail safety package (undated) is an educational kit[54] through which the infrastructure manager teaches primary school children about rail safety. This school pack has a lot of focus on level crossings: what is a level crossing, which safety provisions are there, which rules of conduct must be observed, in which circumstances do most accidents happen[55], how long does it take for a train to pass after the barriers have been closed, how many metres does a train need to stop if it is driving 120 km/h, etc.
  - Infrabel's game book (2017) has 16 pages featuring crosswords, maze games, sudoku puzzles, a safety quiz, all on the theme of rail safety. The book also focuses on level crossings with, for example, interpretation of the traffic signs at a level crossing and when to stop.
  - Infrabel also visits schools: in 2018, safety lessons on safe behaviour on and around the railways were given to 15,200 pupils from primary and secondary schools.

54 It contains 5 modules: class trip, theoretical presentation, giant Goose Board game, 'Spoorzoekers' board game and safety posters.
55 Module 2 states (translation) "Emphasise the fact that traffic code violations are and will continue to be the primary cause of accidents."

7.2. PREVENTION CAMPAIGNS INFRABEL

• Identifying level crossings: in the summer of 2019, all public level crossings with active signalling were given an 'identity card', a sticker with specific information such as the official level crossing number and line number, the street name and the municipality. On the one hand, road users and local residents can provide information to the emergency services more quickly. On the other hand, the emergency services can pass on precise information to Traffic Control more quickly. This enables traffic control to pinpoint the correct location of incidents and immediately alert drivers of approaching trains. (Infrabel, 2020).



• Warning via navigation app: from 1 June 2020, Infrabel, with its Open Data platform, has worked with the navigation app Waze. If you approach a level crossing on a passenger line, you will see a warning sign in the shape of a Saint Andrew's Cross in Waze. This is intended to be an additional stimulus (on top of traffic signs, lights, barriers and audible signals) to be alert in the vicinity of level crossings. If it is a level crossing without barriers or not visible from 100 metres away, the driver will hear a notification. Around 1,200 level crossings are uploaded in the app as standard, and about 1.6 million drivers in Belgium use the app. The infrastructure manager does not rule out future collaborations with other similar companies or apps. (PUB, 2020).

• Level crossing hotspots: using a statistical method, a tool has been implemented to calculate a risk score for each level crossing in order to classify them into 1) level crossings with the highest potential risk of an accident, 2) level crossings with a high risk of blocking back and 3) level crossings with the worst visibility. The tool takes into account 1) the road[56], 2) the railway[57] and 3) the environment[58]. The database with the various parameters has been developed, the tool to group them and to calculate a risk score has been rolled out. Currently, data on the number of road vehicles at each level crossing is still being collected. (Infrabel, 2019).

• Installation of barriers, trip mats (anti-trespass panels whereby the unevenness makes it impossible to cross the tracks) and surveillance cameras.

• Equipping level crossings with additional audible signals, lights, Saint Andrew's Crosses, or providing for dynamic road signs or additional road markings in the Antwerp port area. There are more than 200 level crossings on the left and right banks of the Scheldt.

56 *Traffic density, average speed, number of roads leading to the level crossing, visibility, etc.*
57 *Traffic density, average speed, equipment at the level crossing, waiting time for road users, etc.*
58 *Population/km², number of schools, weather factors, etc.*

• Feasibility studies prevention

- Blocking back signs: blocking back is the phenomenon where a red light, roundabout, bus stop, etc. causes a traffic jam that runs back to a level crossing. If the barriers are lowered, the driver runs the risk of getting trapped and being hit by the oncoming train. At the end of 2019, blocking back signs were proposed as a warning to motorists not to enter a level crossing if they were not sure they could exit it quickly. (Infrabel, 2020). The signs are now subject of a study by the VIAS institute - can the presence of warning signs at level crossings have a positive influence on the behaviour of motorists - at 3 level crossings.

- Yellow road markings: in the Netherlands, ProRail has painted several level crossings yellow, where a train can hit the road user, to increase safety. ProRail tested this at the pilot site in Baarn and research by the Netherlands Organisation for Applied Scientific Research showed that a yellow level crossing enhances the feeling of safety and that road users are more alert when crossing. (Van Gompel, 2018). After an initial working group on "road markings at level crossings", Infrabel does not consider it appropriate to implement a "comprehensive colouring of level crossings" project.[59] The road marking option has not been completely abandoned: at the end of 2019, the options of 1) white reflective lines on the outer edge of the level crossing, 2) passive or active road surface reflectors and 3) lane guides, were kept open. (Infrabel, 2019).

- Concrete central reservation: to prevent slalom traffic between the barriers, a test set-up in Péruwelz installed a raised concrete central reservation before the crossing. Rail traffic is thus separated from the road traffic when the barriers are lowered. The length of the central reservation must be at least 10 metres from the barriers, although this may be longer depending on the local situation. (Starčević et al., 2016).

- LED lighting on barriers: to increase the visibility of the level crossing and the barrier, the barrier is equipped with LED lighting, red on the outside and blue on the inside.[60] On 14 July 2020, the LED system was put into service for the first time at the Comblain-la-Tour level crossing in Hamoir. (Giot, 2020).

59 *The return on investment is too low in budget terms; in terms of safety, it could create confusion for train drivers; it might lead to slippery road surfaces in rain and ice; and there are no proven long-term effects on people's behaviour.*

60 *This is effective both at night and during the day: analysis of UK statistics on near misses at level crossings suggests that the rate of reported incidents is lower when it is dark compared to daytime. (The Rail Safety and Standards Board, 2020).*

7.3. REPRESSIVE MEASURES

• Safety checks at (hotspot) level crossings. This concerns announced and unannounced checks by the Railway Police, the Local Police (both in uniform or civilian) and Securail. In an awareness-raising campaign by Infrabel at a level crossing in Buggenhout (see above), Securail had to fine 4 road users in one hour for not following the traffic rules at the tracks, despite the visibility of the inspectors. Various types of road users were fined: a cyclist, a pedestrian, a van driver and a car driver. (Dooms, 2019).[61]

• Red light cameras: in order to make the local traffic situation safer, Infrabel started a pilot project in 2017 in Oudegem, with red light cameras deployed at a railway crossing. (Vandepitte, 2017). These register the number plates when road users ignore the flashing red traffic lights and the closing barriers. Also in 2009, a speed camera was used in the municipality of Mol, where every month around 100 drivers were caught ignoring the barriers, especially at the point when the barriers were not yet completely lowered. (Rommers, 2017). One drawback is that pedestrians and cyclists who dart through the closed level crossing can evade this camera.

A study in the 1990s showed that red light cameras reduce violations at level crossings by about 20-30%. When used alongside speed cameras, the violation rate drops by another 20%. This decrease in violations can lead to fewer level crossing accidents and fatalities. (McKeever, 1998). Combined with police campaigns, an integrated programme of red light cameras has had the most success in reducing red light violations at level crossings. (Picket & Grayson, 1996).

61 *This is not an isolated case: in the period from 9 September 2019 to 9 October 2019, 151 official notices were issued in Belgium for unauthorised entry at level crossings and station stops. (Dooms, 2019).*

Recent figures in the UK still highlight the advantages of red light cameras. RLSE[62] was installed at 33 level crossings in the UK, with a significant improvement in situational alertness and people's behaviour. On average, safety-related incidents at these level crossings fell by 59% (Wainwright, 2018), and in some locations by as much as 90% (Network Rail, 2019).

Offenders identified using the RLSE are given two options: 1) possible prosecution resulting in a fine and points deduction from their driving licence; 2) following a 'Drivetech Driver Retraining Course' intended to change their behaviour. Enforcement is therefore linked to prevention-awareness raising through education. Driving behaviour, personal responsibility, risk perception and enhancing driving skills are the main focus of the training. Enforcement is therefore also linked to proactivity: the fact that they may be caught means that road users will adapt their behaviour at level crossings, according to Wainwright (2018). Although he points out the fact that this formula is successful with road users in vehicles, not pedestrians. This approach is called the deterrence theory. Pickett (1996, p40) writes: *"the threat of detection tends to be a more effective deterrent than the severity of the punishment."* The effectiveness of this theory has already been demonstrated in deterring motorists from drink-driving and speeding.

In 2020, Network Rail reaffirmed that a red light camera is a proven, cost-effective safety measure that makes motorists think twice about driving through red lights or slaloming between barriers, as this will lead to prosecution. The enforcement policy with speed cameras at level crossings is also increasingly seen in other European countries (Fonverne, 2020), such as in neighbouring Holland[63] and France[64].

62 *RLSE = Red Light Safety Equipment.*

63 *A camera system analyses the images and, if there is any violation, saves them and sends the driver a fine. On-site supervision is still necessary for pedestrians and cyclists. (ProRail, 2017).*

64 *At the start of 2020, cameras were installed at 6 level crossings on the Belfort-Delle line. The results will be compared after one year with the 7 other level crossings on the same line where no cameras were installed. The images will only be viewed in the context of an accident. There will be no fines. (Oblin, 2020).*

7.4. LITERATURE LIST

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