GISAF
Gabinete de Investigação de Segurança e de Acidentes Ferroviários
Office for the Investigation of Rail Safety and Accidents - NIB PT

Fatal accident at level crossing 324,964 Algarve line, Estômbar, on 28-01-2015

INVESTIGATION REPORT

- English extended summary -

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Reader's guide

All dimensions in this report are given using the International System of Units (SI units). Where the normal railway practice uses non standard units, these are mentioned in the report with the corresponding SI Unit is also given.

Descriptions and figures may be simplified in order illustrate concepts to non technical readers.

Preface

The *Gabinete de Investigação de Segurança e de Acidentes Ferroviários (GISAF) / Office for the Investigation of Rail Safety and Accidents*, is the Portuguese State national investigation body that conducts independent investigations into rail transportation accidents and incidents in the country.

GISAF investigates all serious accidents. According to Portuguese Law, a serious accident means any collision of trains or derailment, resulting in the death of at least one person or serious injuries to five or more persons or extensive damage to rolling stock, the infrastructure or the environment, and any other similar accident with an obvious impact on railway safety regulation or the management of safety.

GISAF may also investigate and report on accidents and incidents which under slightly different conditions might have led to a serious accident.

The purpose of GISAF investigations is to make safety recommendations, based on the findings of investigations, in order to prevent accidents and incidents in the future and improve railway safety.

An investigation conducted by GISAF (including its scope, methods, conclusions and recommendations) is independent of all other investigations, including those by the safety authority or railway industry.

Investigations are carried out in accordance with Decree-Law 394/2007, as modified by Decree-Law 151/2014, transposing the Railway Safety Directive 2004/49/EC.

It is not the purpose of such an investigation to establish blame or liability.

Accordingly, it is inappropriate that GISAF reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

Personal data of involved persons is protected during the investigation and in the report.

This document is an extended summary of the report in English language, intended to allow the international reader easy access to the facts of the accident/incident and to the investigation findings, conclusions and recommendations. In this way it is hoped to help disseminate internationally any relevant safety information.

Due to the effort involved, it is not possible to provide a full English translation of the investigation report, and therefore this document does not follow the structure of annex V of the Directive.

Any party interested in further information regarding the facts or the analysis of the investigation is invited to refer to the original report in Portuguese or to contact GISAF.

<u>Important notice</u>:

The English text of this document is given in good faith and "as is", to the best of the writer's knowledge. However, only the original report in Portuguese is binding.

GISAF cannot accept any responsibility for any error in translation or misinterpretation of the present document.

1. THE OCCURRENCE

On the 28th of January 2015, around 08:28h, a moped and its driver travelling on municipal road 25 (EM-25), at Estômbar village (Lagoa municipality, Faro district), collided with the lowered half-barrier of public level crossing 324,964 where the Algarve line crosses that road.

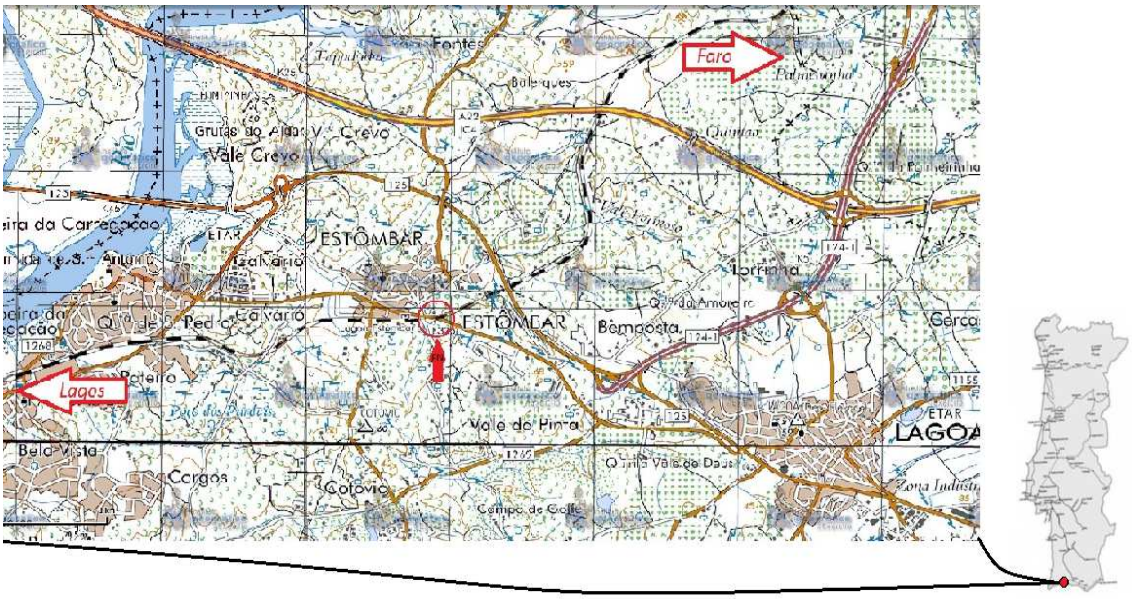


Figure 1: Accident location

The level crossing is composed of automatically activated half-barriers, flashing red lights for road vehicles and audible warning for pedestrians. At the moment it was activated by the approach of regional passenger train 5900 consisting of a DMU totalling two vehicles.

Figure 2: Level crossing viewed from the west

From the collision resulted the fall of the driver and its vehicle to the level crossing plank, between the running rails, being shortly after run over by the approaching train with fatal consequences.

The fatality was 82 years old, knew the location well and was a frequent user of the crossing.

After the emergency stop of the train, the rescue services were immediately requested by present members of the public and attended the location 12 minutes after the accident.

At the time of the accident the weather was clear and the sun had risen at 07:39h.

2. ORGANIZATIONS INVOLVED

The rail infrastructure is managed by the Infrastructure Manager (IM) IP - Infraestruturas de Portugal, S.A.[1].

The train was operated by the Railway Undertaking (RU) CP - Comboios de Portugal, E.P.E., who also employed the driver and train guard.

The road infrastructure is managed by Lagoa municipality.

3. THE TRAIN INVOLVED

The train involved was composed of a 2-car DMU, class 0450, built in 1965/65 by former Portuguese manufacturer Sorefame and refurbished in 1999/2000. The rolling stock is not relevant to the accident and its consequences.

4. THE INVESTIGATION

The investigation was decided after a preliminary examination of the evidence and additional information gathered regarding the occurrence history at the level crossing. It looked not only into the accident itself but also at the rescue operations.

5. MAIN FINDINGS AND CAUSAL TREE

This section only presents the main findings that were considered necessary and useful to explain and justify in this extended summary. Other relevant findings are mentioned in the causal tree at the end of this section, detailed in the original report and will be evident from the conclusions presented in section 6.

For the analysis purpose, the investigation considered two separate but consequential events: (*i*) a road accident consisting of the collision of the driver and moped with the

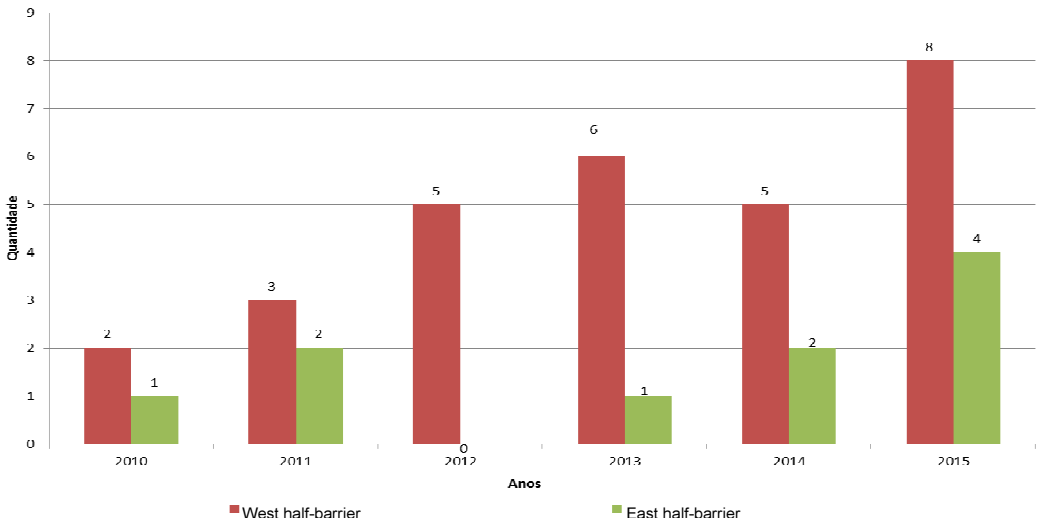
[1] At the time of the accident named REFER – Rede Ferroviária Nacional, E.P.E.

half-barrier and subsequent fall into the train path, and (*ii*) a rail accident consisting of the run over of the fallen road user by the train.

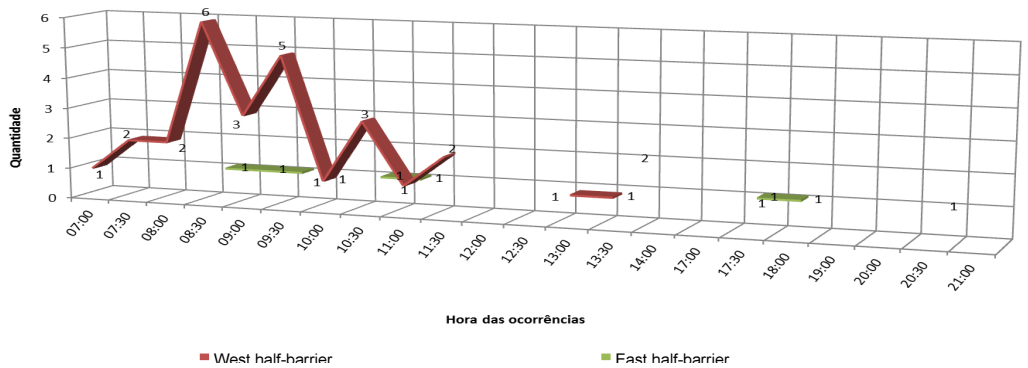
The investigation determined that the rail systems of the level crossing performed as designed; equally, the actions of the train driver were performed in accordance to the circumstances and the train behaved as expected.

The investigation focused on trying to understand why the moped driver didn't respond accordingly to the signalling of the activated level crossing.

Investigating the history of occurrences at the level crossing on the five years preceding the accident, it was determined the existence of an important number of past collisions with half-barriers, but without causing any fatality or involving any train. Investigating further, it became clear that there was a significant predominance of occurrences involving the half-barrier struck by the motorcyclist, most of them during the morning hours, as can be appreciated from the following graphs.



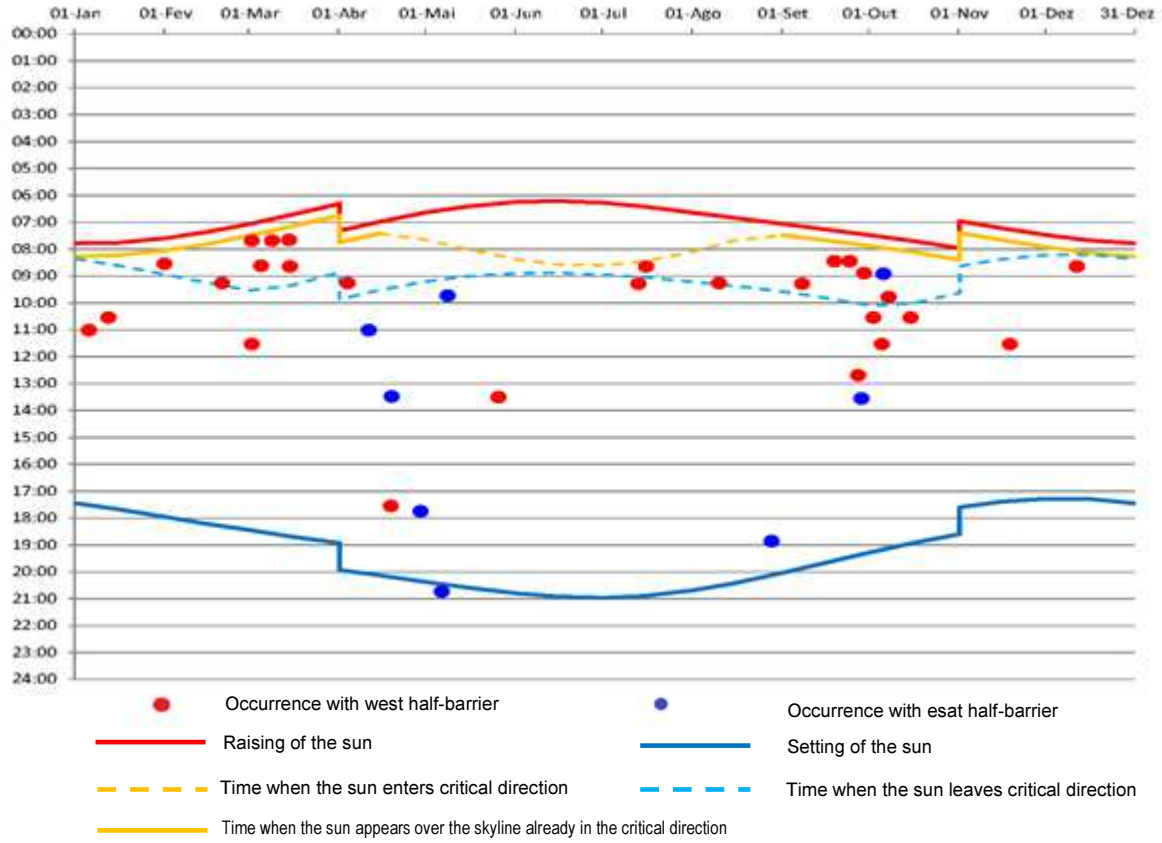
Graph 1: Collisions with half-barriers at the level crossing in the period 2010-2015, per year.



Graph 2: Collisions with half-barriers at the level crossing in the period 2010-2015, per hour of day.

The site examination by the investigation team and testimonial evidence from level crossing users all indicated that the facing sun, in the affected direction and at certain hours of the morning, could cause distraction and have a strong negative influence on the road users' ability to clearly see the lowered half-barrier and flashing warning lights.

Several published academic studies and other scientific works were considered and a computational tool for the calculation of sun azimuth and elevation was used, allowing GISAF to determine the moments of the day, along the year, in which the low sun is considered to affect road drivers at the location. The results are presented in the following graph, where the history of collisions with the half-barriers is also plotted.



Graph 3: Yearly hours when the sun is most likely to affect roads users travelling from west to the east and collisions with half-barriers at the level crossing in the period 2010-2015 when there was a clear sky.

Half-barrier west is the most struck in the morning period in a large proportion (24 against 3), so in the direction prone to be subjected to the effects of sun glare.

56% of collisions with the west half-barrier happen during the critical time-slot where it was determined that the sun causes significant glare (the area between the orange and light blue lines) [2], a period that represents only 11 % of the total sunlit period. This means that the frequency [3] of collisions with the West half-barrier in that short period

[2] If the four occurrences very close to the light blue line should be included, the percentage would be 70%.

[3] Determined in $\frac{nr.of\ occurrences}{sun\ hours \times year}$.

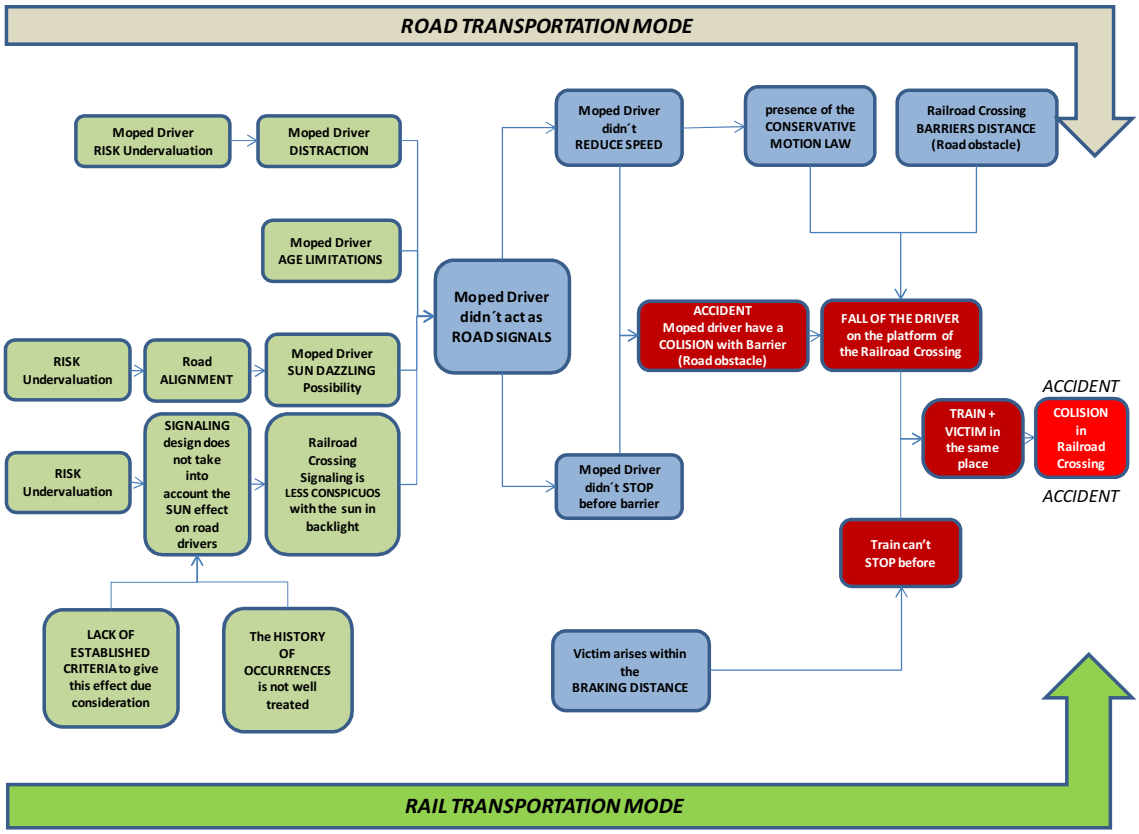
is ten times higher than a collision in the much larger remaining period, considering the fact that rail traffic is generally uniform along the day and that there is no evidence suggesting that the road traffic in the west-east direction and during the same small period is ten times higher to justify the larger frequecy.

The graph also clearly evidences the concentration of occurrences in the two yearly periods when the sun is longer in the position that was determined to cause glare (February, March, September and October). Consistently, in the months when the sun is for a very short period in the position where it causes glare (April to August and November to January) there are very few occurrences; there being no evidence to suggest that the road traffic pattern changes precisely in these periods so as to justify the pattern of occurrences.

It is also of note the fact that there is no registered collision before the raising of the sun.

Therefore, GISAF considers that there is strong evidence to conclude that the position of the sun at certain day periods variable along the year can (*i*) disturb the concentration and vision of road drivers, as well as (*ii*) cause the level crossing, its half-barrier and its signaling to be less conspicuous to road users, factors that combined have the effect of making it difficult for road drivers to see that the level crossing is activated. GISAF considers that there is a very high degree of probability that these effects are a relevant causal factor in the numerous collisions with barriers registered at this level crossing and of the fatal accident subject to the investigation.

Accident causal tree:



6. INVESTIGATION MAIN CONCLUSIONS

For clarity, conclusions are presented separately for the accident itself and for potentially relevant anomalies during the rescue and reestablishment operations.

6.1. Accident

The investigation established that the level crossing automatic systems performed accordingly to specifications and that the accident happened because of the road side of the crossing.

GISAF determined the following causes:

a) Immediate cause

The moped driver hitting the level crossing lowered half-barrier because he didn't stop before reaching it, and in consequence being projected to the crossing pavement, stopping over the track instants before the passage of the train.

b) Causal factors

The combined effect of the distance of the half-barrier to the track and the moped and driver velocity and mass, had the result of the fallen moped driver stopping over the track. [FCau-01]

Justification in section 4.2.1 of the report.

The moped and its driver appeared in front of the train within its braking distance, making it impossible for the train to stop before reaching them. [FCau-02]

Justification in section 4.2.1 of the report.

The moped driver didn't respond accordingly to the activated signals of the level crossing, not reducing its speed so as to stop short of the lowered half-barrier. [FCau-03]

Justification in section 4.2.1 of the report

The investigation determined that there is a variable annual time-slot, within which the time of the accident is included, when the low sun may cause significant glare and reduce the conspicuity of the half-barrier and level crossing signals to road users approaching from the west, due to the road orientation. [FCau-04]

Justification in section 4.2.1.1 of the report

Therefore, GISAF considers that there is a high probability that the moped driver didn't reduce its speed and stop because:

- He was momentarily distracted due to the visual disturbance caused by the facing sun; [Cau-05]

  Justification in section 4.2.1.1 of the report
- He didn't perceive the activated warning signal nor the lowered half-barrier of the level crossing due to the glare caused by the low sun illuminating them from behind. [FCau-06]

  Justification in section 4.2.1.1 of the report

c) Contributing factors

GISAF considers that it is possible that the following factors have contributed to the accident:

- Limitations related to the age of the moped driver, naturally reducing sensorial awareness and the capacity to adapt to disturbing factors during driving; [FCon-01]
  Justification in section 4.2.1 of the report
- Underestimation of the risk by the moped driver because of his familiarity with the location and route. [FCon-02]
  Justification in section 4.2.1 of the report

d) Underlying causes

The investigation has not identified any underlying causes.

e) Root causes

Despite the risk of sun glare having been identified by the rail Infrastructure Manager, no mitigating measure was defined nor implemented at the level crossing. [CPro-01]
Justification in section 4.2.1.2.3 of the report

The process for level crossings' risk analysis by the rail Infrastructure Manager does not guarantee that, in a consistent manner, each existing risk is assessed and that the corresponding control measures are defined and implemented. [CPro-02]
Justification in sections 4.2.1.2.2 e 4.2.1.2.3 of the report

The automation of the level crossing was not supported by an engineering project justifying the design of the layout and road signalling to the specific location risks, in particular not considering the risk of sun glare to the road users due to the alignment of the road approach. [CPro-03]
Justification in section 4.2.1.2.5 of the report

Notwithstanding the general dispositions of the national Level Crossings Regulation and the technical standards of the rail Infrastructure Manager, there is no national or industry standard or guidance that integrates the principles and good practice of road engineering relevant to level crossing design so as to give designers and technicians the necessary guidance regarding the use of technical solutions internationally proven as best practices relating, for example, (*i*) to the integrated design of the level crossing with its road approaches, (*ii*) to the layout and type of components and (*iii*) to the adequate measures to mitigate each identified risk, nor do Infrastructure Managers follow such foreign guidance. [CPro-04]
Justification in section 4.2.1.2.5 of the report

The processes of the rail IM Safety Management System relating to the introduction of prevention measures following safety related incidents have shown not to be sufficiently robust so as to ensure:

- That the classification of safety occurrences according to their causes is reliable; [CPro-05]
  Justification in section 4.2.1.3 of the report
- That the practical perception by the regional staff about the abnormal frequency of the half-barrier breaks at the level crossing resulted in a global critical analysis of the occurrences history; [CPro-06]

Justification in section 4.2.1.3 of the report

- That the history of occurrences was subjected to an analysis with the purpose of determining their causes, identify any risks evidenced by the use of the level crossing and implement the appropriate mitigating measures. [CPro-07]

Justification in section 4.2.1.3 of the report

On the other hand, the IM program for regular audits of its SMS wasn't effective to detect the above mentioned weaknesses in the processes. [CPro-08]

Justification in section 4.2.1.4 of the report

Also, the fact that the National Safety Authority, within its supervision obligations, has never audited the application of the Infrastructure Manager's SMS, particularly on its processes relevant to level crossings, one of the components responsible for most casualties on the national rail system, has contributed to the above mentioned weaknesses in the SMS not being identified nor subjected to improvement actions. [CPro-09]

Justification in section 4.2.1.4 of the report

Finally, the investigation also concludes that, in addition to the generally accepted fact of level crossing safety having to be treated in an integrated way between rail and road, the latter one is preponderant because only on the road approaches can most measures be introduced to induce drivers to adopt the necessary precautionary behavior when arriving at the level crossing. However, the existing regulations concerning level crossings aren't effective to favor or even compel the rail and road infrastructure managers to work jointly for designs, layouts and equipment that minimize risks to the users of either mode. [CPro-10]

Justification in section 4.2.1.2.4 of the report

An evident example of the lack of the mentioned multidisciplinary consideration to level crossing design is the fact that several technical solutions commonly applied on roads to mitigate the risk on approaching dangerous locations (e.g. road intersections or pedestrian crossings), are rarely applied on the approaches to level crossings.

6.2. Rescue and reestablishment phase

The investigation established the occurrence of two anomalies during rescue and reestablishment operations:

- Despite difficulties had in establishing verbal communication through the portable cell phone between the train guard and the IM Command Center, the fixed infrastructure communication systems available at the location weren't used, which led to not existing direct contact between the IM Command Center and the accident site for most of the emergency period;
- The train was instructed to proceed by a police officer attending to the emergency, without the previous knowledge and agreement of this order by the Rescue Operations Commander; this resulted in the train continuing its journey with traces of the collision with the casualty.

These anomalies didn't detract significantly from the rescue and reestablishment operations, however in different circumstances can have relevant consequences.

The analysis done by GISAF determined the following causes susceptible of improvement to prevent the repetition of the identified anomalies:

- The monitoring of the maintenance of competences of the train guard by the Railway Undertaking didn't guarantee sufficient proficiency for the use of all available communication systems between the accident location and the IM Command Center, and the understanding of the importance of such direct contact to the effective management of the emergency. [CPro-11]

  Justification in section 4.2.3.1 of the report

- The monitoring of competence acquisition during the training of the train guard by the Railway Undertaking didn't guarantee the sufficient understanding of the hierarchy of the rescue services at the emergency site. [CPro-12]

  Justification in section 4.2.3.2 of the report

- The existing procedures of the Guarda Nacional Republicana (national police) weren't sufficient to guarantee that their agents acted accordingly to the legally established hierarchy of the rescue services at the emergency site. [CPro-13]

  Justification in section 4.2.3.2 of the report

7. SUPPLEMENTARY OBSERVATIONS

In the course of the investigation, the following supplementary observations were made:

a) Inconsistency of rules and technical documents

The legal type of the level crossing (according to its traffic moment and equipment) is mentioned in national rules and internal technical documents of the IM either as type A or B. It was determined that this fact is not singular to the level crossing were the accident happened. This can, inadvertently lead to errors relevant to safety as certain criteria for road signs and warning delays are different for level crossings of type A or B. [OSup-01]

b) Reclassification of level crossings from type B to type A

Level crossings are legally classified by type accordingly to their traffic moment, among other criteria.

In the year 2006 the level crossing were the accident happened was reclassified from type B (traffic moment comprised between 10 000 and 24 000) to type A due to its traffic moment equal or greater than 24 000. According to national regulations, to this higher risk classification there is no change in any technical requirements or a higher level of protection. Thus, the change in classification didn't imply or require any change or reanalysis of the level crossing.

However, the international knowledge on this subject is clear that, besides the traffic moment, many other factors can influence the risk level of each crossing, which can determine the adequate design and equipments. Furthermore, the present principles for safety management required for the rail industry are based on the evaluation and control of the risks of its activities and, as far as reasonable, from third-parties, an approach that is not considered on the present national regulation for level crossings. [OSup-02]

c) Crew fitness after the occurrence and effects to their health

It is internationally recognized in the rail industry that fatal accidents consisting of people being run over by trains are a major cause of trauma to their crews.

The crew of the train involved in the accident continued in service until the end of their planned shift, as is normal practice in the RU.

The international practice on crew management after this type of events varies greatly among different countries and Railway Undertakings. However, the practice followed by the involved RU is not supported by any scientific study that takes in consideration the effect of trauma on the ability of the crews to perform safety functions and the possible inherent risk to safety. [OSup-03]

d) Anomalies in road signs on the approach to the level crossing

The signs on the approach road at 300 m from the level crossing do not conform to the road sign regulation. [OSup-04]

e) Estatística de sinistralidade nas PN

Accidents at level crossing are not considered as road accidents, even if their causes are exclusively due to the road component of the crossing. Thus, these accidents are not accounted on road accidents and fatalities statistics, a practice which is not consistent with other European countries.

This practice does not allow an accurate evaluation of the safety of roads whereLevel crossings exist, which can detract from the adequate determination of points for improvement in those roads. [OSup-05]

8. RECOMMENDATIONS

Following the investigation, **sixteen new safety recommendations** are issued, **twelve** relating to the causes of the accident and **four** to supplementary observations.

8.1. Safety recommendations relating to the accident

Adressee: **Instituto da Mobilidade e dos Transportes, I.P. (IMT)**, as National Safety Authority – 10 recommendations

Layout of the level crossing were the accident happened

Nr. 2016/08: IMT is recommended that, within a timeframe that it finds acceptable, the Infrastructure Manager Infraestruturas de Portugal, S.A. study and implements adequate improvements to level crossing 324,964 (Algarve line), based on good and best international practice on the subject, in order as to maximize the conspicuity to road users of the crossing and its road signals and signs, especially under adverse low sun conditions.

Justification: FCau-04, FCau-05, FCau-06, CPro-01

Criteria for the design of level crossings

Nr. 2016/09: IMT is recommended that, within a timeframe that it finds acceptable, the Infrastructure Manager Infraestruturas de Portugal, S.A. strengthens its requirements regarding the design procedure for level crossings, in order as to guarantee that the individual risks of each crossing under design are considered explicitly and that those risks are shown to be controlled by adequate technical solutions.

Justification: CPro-02, CPro-03

Level crossing design guidance

Nr. 2016/10: IMT is recommended to produce, within one year, a code or guide to be used as reference by rail and road infrastructure managers in designing, changing or improving level crossings and its road approaches, taking into consideration the relevant knowledge of road engineering, in order as to give guidance on using best international practice regarding, as a minimum, (*i*) an integrated design of the level crossings considering their road approaches, (*ii*) the layout and type of its components, (*iii*) the technical solutions adequate to mitigate identified risks.

Justification: CPro-04, CPro-10

Risk analysis

Nr. 2016/11: IMT is recommended that, within a timeframe that it finds acceptable, the Infrastructure Manager Infraestruturas de Portugal, S.A. strengthens their procedures regarding the risk analysis of level crossings, in order as to ensure that there are structured and documented procedures in the safety management system for the systematic analysis of risks at level crossings and the definition of the corresponding control measures.

Justification: CPro-01, CPro-02

Risk analysis

Nr. 2016/12: IMT is recommended that, within a timeframe that it finds acceptable, the Infrastructure Manager Infraestruturas de Portugal, S.A. establishes structured procedures in its safety management system for a systematic, regular and documented analysis of the history of safety occurrences at each level crossing, so as to identify evidenced potential safety risks.

Justification: CPro-06, CPro-07

Recording of safety relevant information

Nr. 2016/13: IMT is recommended that, within a timeframe that it finds acceptable, the Infrastructure Manager Infraestruturas de Portugal, S.A. strengthens the procedures in its safety management system to ensure the accuracy of the safety relevant information recorded in its data base as to the type of occurrences on level crossings.

Justification: CPro-05, CPro-06

Internal monitoring of the SMS

Nr. 2016/14: IMT is recommended that, within a timeframe that it finds acceptable, the Infrastructure Manager Infraestruturas de Portugal, S.A. reviews its internal audit plan to the safety management system, so that the processes relevant to level crossings are subjected to regular audits aiming at their effective monitoring and continuous improvement.

Justification: CPro-08

Supervision of SMS application

Nr. 2016/15: IMT is recommended to strengthen their supervision of the Infrastructure Manager and Railway Undertakings safety management systems, giving priority to the processes of the IM Infraestruturas de Portugal, S.A. relevant to level crossings and to their internal monitoring and continuous improvement.

Justification: CPro-09

Staff competence maintenance

Nr. 2016/16: IMT is recommended that, within a timeframe that it finds acceptable, the Railway Undertaking CP – Comboios de Portugal, E.P.E. establishes the necessary actions to guarantee the maintenance of competences of its staff susceptible to act as "Gestor de Emergência Local" (local emergency manager – Railway Undertaking), so as to be aware of the importance of direct contact, through any of the available means, with the command centers, for the effective management of the emergency while the local emergency manager – Infrastructure Manager is not present at the site.

Justification: CPro-11

Training

Nr. 2016/17: IMT is recommended that, within a timeframe that it finds acceptable, the Railway Undertaking CP – Comboios de Portugal, E.P.E. establishes the necessary actions to guarantee that its staff susceptible to act as "Gestor de Emergência Local" (local emergency manager – Railway Undertaking), are aware of the existence, role and authority of the operations theatre Rescue Operations Commander at the accident site, as well as of the interaction between them defined on national rule IET 96.

Justification: CPro-12

Adressee: **Câmara Municipal de Lagoa (Lagoa municipality)**, as road infrastructure manager and authority – 1 recommendation

Layout of the level crossing were the accident happened

Nr. 2016/18: Câmara Municipal de Lagoa is recommended to study and implement, within the shortest timeframe possible and in concertation with the rail Infrastructure Manager Infraestruturas de Portugal, S.A., adequate improvements to the road approaches to level crossing 324,964 (Algarve line), based on good and best international practice on the subject and relevant knowledge of road engineering, in order as to maximize to road users the conspicuity of the crossing and of its road signals, as well as to induce drivers to adopt the necessary precaution.

Justification: FCau-04, FCau-05, FCau-06, CPro-01

Adressee: **Comando-Geral da Guarda Nacional Republicana** (Command General of the National Republican Guard) – 1 recommendation

Procedures for emergencies in rail environment

Nr. 2016/19: Comando-Geral da Guarda Nacional Republicana is recommended to take the necessary actions to guarantee that their agents present on the site of a rail emergency comply to the operational hierarchy at the site defined in the Integrated System for Rescue and Protection Operations.

Justification: CPro-13

8.2. Safety recommendations relating to supplementary observations

Adressee: **Instituto da Mobilidade e dos Transportes, I.P.**, as national safety authority for rail transportation – 3 recommendations

Crew psychological fitness

Nr. 2016/20: IMT is recommended that, within a timeframe that it finds acceptable, the Railway Undertaking CP – Comboios de Portugal, E.P.E. study the impact on safety of the risks that accidents involving persons hit by trains may have on their crews psychological health when they continue on duty, and, if necessary according to the results of the study, implement the adequate mitigating measures.

Justification: OSup-03

Regulations concerning level crossings

Nr. 2016/21: IMT is recommended to make a general review of the legal and regulatory framework concerning level crossings, to ensure that the crossings and their road approaches are considered and managed in an integrated manner by the respective infrastructure managers, and that, without prejudice of the definition of minimum requirements, focus is made that the layout, equipments and signals of each level crossing and road approaches result from a safety risk assessment, thus harmonizing the legal framework regarding level crossings with the safety requirements legally established for the activity of infrastructure manager.

Justification: OSup-02

IM rules concerning level crossings

Nr. 2016/22: IMT is recommended that, within a timeframe that it finds acceptable, the Infrastructure Manager Infraestruturas de Portugal, S.A. reviews its internal rules and technical documents concerning level crossings, so as to ensure that there is uniformity and clear identification of level crossings' characteristics relevant to safety according to their defined types.

Justification: OSup-01

Addressee: **Autoridade Nacional de Segurança Rodoviária** (National Authority for Road Safety), as national safety authority for road transportation – 1 recommendation

Statistical treatment of accidents at level crossings

Nr. 2016/23: ANSR is recommended to consider integrating level crossing accidents and fatalities in the relevant road statistics, when the accidents aren't caused by a technical malfunction on the rail systems at the level crossings, in order as to allow for a more accurate analysis of road safety.

Justification: OSup-05

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