DiGIFeMa
Direzione Generale per le
Investigazioni Ferroviarie e Marittime

Ministry of Infrastructure and Transport

INVESTIGATION REPORT

DERAILMENT OF TRAIN 4132 OF THE EAV RAILWAY UNDERTAKING ON THE LINE NAPLES – TORRE ANNUNZIATA POGGIOMARINO, AT THE POMPEI SANTUARIO STATION, ON 07/11/2022

(ERAIL IDENTIFIER: IT-10335)

10 November 2023

Foreword

The General Directorate for Railway and Maritime Accident Investigation (DiGIFeMa), established at the Ministry of Infrastructure and Transport:

- constitutes the *National Investigating Body* (NIB) concerning railway accidents and incidents, the latter being understood as events affecting the safety of railway operations, pursuant to Art. 20 of Legislative Decree no. 50 of 14 May 2019, implementing Directive EU 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety;
- performs the duties of Investigating Body in relation to maritime casualties, pursuant to Legislative Decree no. 165 of 6 September 2011;
- also investigates accidents occurring on networks functionally isolated from the rest of the national railway system and used only for local, urban or suburban passenger services, and accidents occurring on all fixed transport systems and on national inland waterways, pursuant to article 15b(4)(a) of Decree-Law no. 148 of 16 October 2017, converted, with amendments, by Law no. 172 of 4 December 2017, and reiterated by paragraph 5 of Art. 20 of Legislative Decree no. 50 of 14 May 2019.

The sole objective of DiGIFeMa's work is to prevent future accidents and incidents through the identification of the technical causes that generated the event and the consequent formulation of safety recommendations to operators in the sector.

Pursuant to Art. 21(4), of Legislative Decree 50/2019, the investigation is not a substitute for those that could be carried out in this regard by the Judicial Authority and does not in any case aim to establish blame or liability.

Pursuant to Art. 26 of Legislative Decree 50/2019, the investigation report and the related safety recommendations do not in any case constitute a presumption of blame or liability for an accident or incident, in the context of the Judicial Authority's procedures.

This investigation report has been prepared in accordance with the format of the Commission Implementing Regulation (EU) 2020/572 of the European Commission of 24 April 2020 to be followed in railway accident and incident investigation reports. However, paragraphs pertaining to information that is not available or not useful due to the nature and/or circumstances of the event have been included in the body of the investigation report by inserting the words "*not relevant to this investigation*".

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Abbreviations and Acronyms

ACCM	Multistation Central Interlocking
ACEI	Central Electrically Controlled Routing
ACPF	Computerised Brake Test Equipment
AdC	Driver
ADT	Train Conductor
AFO	Audio Frequency Overlay
AG	Judicial Authority
ANSF	National Railways Safety Agency
ANSFISA	National Agency for railways and road and highway infrastructures safety
ATP	Automatic Train Protection
HS	High Speed
BAcc	Automatic Block with codified currents
Bca	Sleeper counting block
BM	Control Desk
CCS	Control-Command and Signalling
CdB	Track Circuit
CG	Main Pipe
CT	Train manager
CTC	Centralised traffic control
CTP	Expert of the party
CTU	Court expert
CUM	Head of Train Maintenance
CVR	Recorded Minutes Reports
DCCM	Movement Manager
DCE	Head of Operations
DCO	Train Dispatcher
DE	Operating Provision
DEIF	Railway Undertaking Operating Provision
DiGIFeMa	General Directorate for Railway and Maritime Accident Investigation
DL	Local Traffic Controller
DM	Movement Manager
DTP	Territorial Production Department
EAV	Ente Autonomo Volturno
ERA	European union Agency for Railways
ERAIL	European Railway accident Information Links
ERTMS	European Rail Traffic Management System
FL	Route Book
GEMS	General Error Modelling System
IM	Infrastructure Manager
RU	Railway Undertaking
ERTMS	European Rail Traffic Management System
ETCS	European Traffic Control System
ETR	Express Electric Train
EVN	European vehicle number
MIMS	Ministry of Sustainable Infrastructure and Mobility
OC	Civil Works
OdS	Operating Regulation
PdC	Drivers

PL	Level Crossing
PM	Public Prosecutor's office
POLFER	Railway Police
PRI	First Information Report
RCE	Chronological Event Recorder
RdC	Signaller
REC	Carriage Electric Heating
NVR	National Vehicle Register
SAMAC	Skills Acquisition and Maintenance System
SCMT	Train Running Control System
SIDAC	Dynamic Driver Training Simulator
SGI	Integrated Management System
SGS	Safety Management System
smt	train direction of traffic
SOAM	Systemic Occurrence Analysis Methodology
SPAD	Signal Passed At Danger
SRM	Entity in Charge of Maintenance
SSB	Onboard Subsystem
TSS	Ground Subsystem
TCMS	Train Control & Management System
ET	Electric Traction
UC	Circulation train
ZTE	Electronic Tachograph Zone

1. Summary

On 7 November 2022, at approximately 1:40 p.m., train no. 4132 of the EAV railway undertaking, consisting of the METROSTAR type ETRs (Express Electric Trains) no. 223 and no. 208, coming from Poggiomarino and bound for Naples, while arriving at the station of Pompei Santuario, on the functionally isolated line Naples – Torre Annunziata – Poggiomarino, derailed behind the switch no.4 of the two rear bogeys of the ETR 208.There were no injuries, neither among the staff, nor among the approximately 30 passengers on board the train, nor among the people present at station.

The accident was analysed using the *Systemic occurrence Analysis methodology (SOAM*), developed by the European Air Traffic Control Safety Agency EUROCONTROL[1]. Its main feature is to analyse human performance from a system perspective, observing it in the context in which it took place and taking into account all the factors that may have contributed to the occurrence of the accident, also in order to make it as objective as possible. In this context, the methodology has been adapted appropriately to the railway sector, while maintaining the aims described above.

The causal factors behind the accident, which emerged from the analysis, can be attributed to the following actions of the staff involved in the event:

- the DL (Local Traffic Controller) of the Pompei Santuario station has disregarded the provisions of Article 4(10), the *Regulation for the Circulation of single-manager trains* and chapter 6 of the *instructions for the operation of Central Electrically Controlled Routing with push-button and for the operation of Automatic Block* by modifying the configuration of switch 4 from a diverted to a normal switch, without first ascertaining that train 4132 had cleared the relevant detector track circuit, as would have been requested, since the latter had been out of service since approximately 10:00 a.m. on the same day as the accident occurred.

The causal factors behind the accident can be attributed to the following circumstances:

- degraded mode of traffic due to the failure of CdB 2 (Track Circuit) which excluded the automatisms normally provided by ACEI (Central Electrically Controlled Routing);

- the person responsible for the maintenance of the CCS (Control-Command and Signalling) subsystems did not ensure, after 13/08/2022, the monthly preventive maintenance of the ACEI and the track circuits of the Pompei Santuario station;

- the practice on the part of the DL not to ascertain in person the release of the damaged track circuit, but to use the ACEI light panel and, probably, the estimate of the time elapsed from the transition to the protection signal placed at the station entrance;

- exceeding the control speed by train 4132, which resulted in the emergency braking by ATP (Automatic Train Protection), in the consequent stopping of the train before its arrival at Pompei Santuario station, and in a delay of 20s in parking on platform 1 at the Pompei Santuario station. This circumstance contributed indirectly to the accident as the DL brought the switch no.4 back into its normal configuration while the relevant CdB was still occupied by train 4132, assuming that the time elapsed from the passage of the train to the protection signal at the train station entrance was sufficient for the completion of the parking phase;

- the DL and AdC (driver) perception of the pressure exerted by the passengers of the train 4132 increased by the need to accelerate the departure of the cross train that had been waiting for the departure signal for more than 20 minutes;

[1] EUROCONTROL's guidelines for the use of the SOAM methodology are available at https://www.skybrary.aero/bookshelf/books/275.pdf

- working hours of the DL, which had exceeded eight hours, of which approximately four hours dedicated to the management of traffic in degraded mode, due to the failure of the CdB 2;
- working space of the DL is open to third parties, which could have distracted the DL from his duties.

The systemic factors that may have affected the occurrence of the event can be attributable both to a lack of perception by the operators involved of the safety risks associated with non-compliance with regulatory provisions and to a management of working that does not take into account any additional workloads resulting from the need to ensure circulation in conditions of infrastructure degradation due to the occurrence of malfunctions.

The report concludes with four safety recommendations in which the National Agency for Railways and Road and Highway Infrastructure Safety is asked to:

- ensure that infrastructure managers comply with and monitor the implementation of activities provided for in the preventive maintenance plans of trains and equipment, assessing their effectiveness and adequacy in terms of the frequency of maintenance activities, also in relation to the age of the trains and equipment aim of the maintenance.
- ensure that infrastructure managers and railway undertakings carry out a review and a possible re-evaluation of working hours or re-modulation of the service, in relation to the exacerbate workloads resulting from operating conditions of circulation in conditions of infrastructure degradation due to the occurrence of malfunctions.
- ensure that the RU (Railway Undertaking) and IM (Infrastructure Manager) EAV (Ente Autonomo Volturno) rapidly revise their regulations based on the principles of clarity, precision, uniformity, simplicity and completeness, especially with regard to the safety procedures to be adopted to ensure that the circulation is operated in condition of infrastructure degradation due to the occurrence of malfunctions.
- consider the opportunity of requesting the RU and IM EAV to issue an internal measure clearly highlighting the importance, in terms of safety, of full compliance with the regulatory requirements, accompanied by an appropriate training of the operators involved, especially with regard to the safety procedures to be adopted in order to ensure that the circulation is operated in condition of infrastructure degradation due to the occurrence of malfunctions.
- ensure that the IM EAV takes measures aimed at inhibiting the access of unauthorised third parties to the work environment of the Local Manager.

2. Investigation and relevant context

2.1. Decision to open the investigation

In order to ascertain the causes of the accident, the General Directorate for Railway and Maritime Accident Investigation (DiGIFeMa), by D.D. prot. 3559 of 12/12/2022, appointed the writer for the investigative activity aimed at ascertaining the causes of the accident.

2.2. Reasons for the decision to open the investigation

The decision to open the investigation by DiGIFeMa is motivated by the need to improve safety and accident prevention in railway transport systems through the identification

of the causes of operating accidents and the definition of any safety recommendations to be addressed to the parties concerned, pursuant to the provisions of articles 20 and 21 of Legislative Decree no. 50/2019.

2.3. Scope and limitations of the investigation

The mandate given to the designated investigator for the investigation provides that the investigative activity shall be carried out in accordance with the principles of impartiality, transparency, confidentiality and secrecy of the investigative action established by:

a) Article 22 of Legislative Decree no. 50/2019 "Regulations for the investigation procedure";

b) the agreements between DiGIFeMa and the various Public Prosecutors' Offices of the Republic at the courts;

c) Directive no. 2567/M2 of 02/07/2002, issued by the Presidency of the Council of Ministers – Department of Public Service on inspection activities.

2.4. Technical and functional capabilities of the investigation team

The writer, a full professor of Converters, Machines and Electric Drives, has been carrying out teaching and scientific activities related to the field of transport systems for a long time and is on the list of investigators referred to in Article 20, paragraph 7 of Legislative Decree 50/2019. Therefore, he has the expertise required to carry out the safety investigation of the accident in question.

2.5. Communication and consultation with persons or entities involved

In the course of the investigation, the Commission had the opportunity to consult and communicate with EAV's Infrastructure and Railway Transport Directorates, in order both to collect the documentation and information deemed necessary and to interview some of the technical staff present on the plant at the time of the accident.

The staff interviewed were given anonymity, referring, where necessary, only to the tasks performed by the operators in the company and not to their personal details.

On 23/10/2023, DiGIFeMa submitted the draft final investigation report to ANSFISA, and to the RU and IM EAV. On 09/11/2023, a meeting was held in electronic mode to discuss and deepen the analysis carried out and the safety recommendations proposed by the investigation Commission. The meeting was attended by representatives of ANSFISA and the RU and IM EAV. This document takes account of the comments made at that meeting.

2.6. Level of cooperation offered by the actors involved

All parties involved in the investigation demonstrated an appropriate level of cooperation towards the investigator.

2.7. Investigation methods and techniques

The mandate was carried out by a initial inspection on 9 November 2022 on the event site followed by an analysis of the documentation requested by EAV with note of 22/11/2022 signed by the writer, which was made partially available on 09/01/2023 and completed on 11/09/2023, following a new request by the writer with a note dated 05/09/2023.

In particular, for the purpose of preparing this investigation report, the reference

documentation used is as follows:

- Document entitled *Instructions for the operation of Central Electrically Controlled Routing with push-button and for the operation of Automatic Block* (1998).
- *Regulations for the circulation of single-manager trains* (2010).
- *Signal Regulation* (2011).
- Investigation report "*Derailment of the EAV 432 train of 07/11/2022 at Pompei Santuario of the functionally isolated line Napoli – Scafati – Poggiomarino*", hereinafter, for brevity, referred to as the *EAV*[2] Investigation report.
- Electronic Tachograph Zones of ETRs 208 and 223 components of train 4132, relating to the day of the accident.
- RCE (Chronological Event Recorder) of ACEI of Pompei Santuario station.
- Maintenance plan for the equipment and the Signalling and Command-Control subsystem (CCS).

2.8. Difficulties and problems encountered during the investigation

No difficulties and/or problems were encountered during the investigation.

2.9. Interactions with judicial authorities

The interactions with the Public Prosecutor's Office at the Court of Torre Annunziata, which initiated criminal proceedings no. 5897/22 RGNR on the accident, have been constantly characterized by fruitful and synergistic cooperation, also through the Court expert, respecting reciprocal roles, and in full implementation of the agreement between the Public Prosecutor's Office at the Court of Torre Annunziata and the Ministry of Sustainable Infrastructure and Transport — DiGIFeMa, signed on 21/06/2017.

2.10. Other information

Not significant for the purposes of the investigation.

3. Description of the event

3.1. Event and background information

3.1.1. Description and type of the event

The event consisted of the derailment of train no. 4132 of the EAV railway undertaking at the switch no.4 at the Pompei Santuario station, on the functionally isolated line Naples – Torre

[2] In the title of the report, which is also given in the header of each page of the report, the train number is incorrectly stated as 432 instead of 4132. As regards the date of issue of the document, the header of each sheet of the report states "REV.0 19/11/2021". These are evidently typos. The report was received by the writer on 11 September 2023.

Annunziata - Poggiomarino managed by the EAV Infrastructure Manager.

In particular, train no.4132, consisting of the METROSTAR type ETRs no. 223 and no. 208, coming from Poggiomarino and bound for Naples, derailed behind the switch no.4 of the two rear bogies of the ETR 208.

The accident did not cause any injuries neither among the staff, nor among the approximately 30 passengers on board the train, nor among the people present at station.

Figure 1 - Static position of the train after the accident (*source: web*).

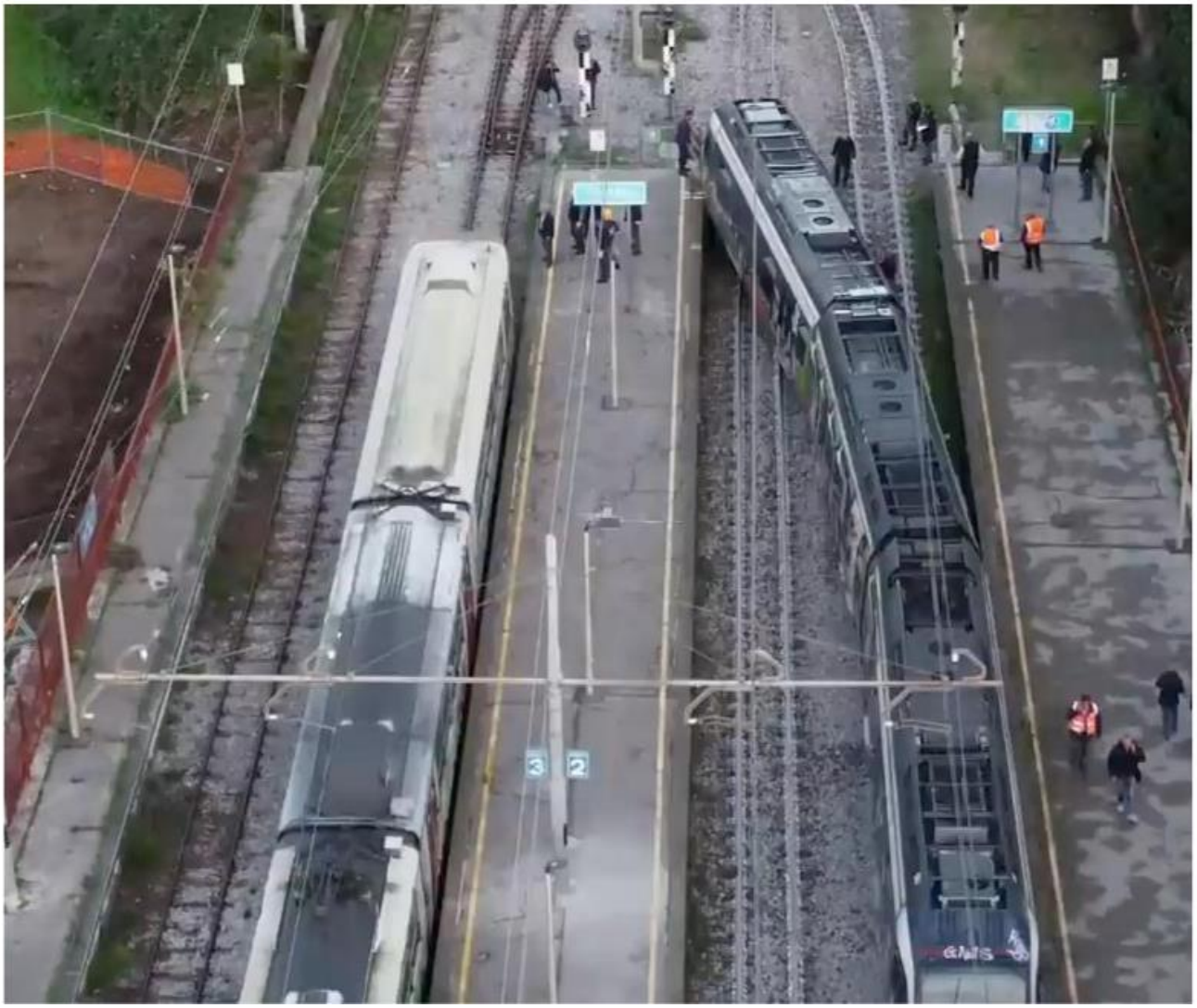

Figure 2 - Static position of the train after the accident (*source: web*).

3.1.2. Date, time, and place of the event

The event took place on 7 November 2022, at approximately 1:40 p.m., at the switch no.4 of the Pompei Santuario station.

3.1.3 Description of the place of the event, weather and geographical conditions, possible work in progress

The place of the event is the Pompei Santuario station, at the progressive km 6+235 of the functionally isolated line Napoli – Torre Annunziata – Poggiomarino, managed by the EAV Infrastructure Manager. The information collected does not reveal any critical issues arising from the weather conditions at the time of the event. On the other hand, the repair works of CdB 2 for the immobilisation of the switch no.4 were in progress, which had gone out of service around 10:00 a.m. on the same day, after the transit of train 4093, being permanently occupied even in the absence of trains transiting on it.

3.1.4. Deaths, injuries and material damage

The accident did not cause any injuries neither among the staff, nor among the approximately 30 passengers on board the train, nor among the people at the station.

The rolling stock and infrastructure were damaged as a result of the event. In particular, in addition to the derailed, seriously damaged trains, there were track buckles and damage to the switch no.4, without considering the indirect damage caused by the interruption of railway traffic on the route and the establishment of the replacement service.

In detail, the estimated damage to the railway infrastructure was quantified by the competent structure of the EAV at €21,948.54 divided as follows:

- € 2,777.74 total cost of staff employed;
- € 3,740.50 for materials;
- €15,430.30 for equipment repairs.

With regard to rolling stock, the derailment took place behind the switch no.4, and affected the two rear bogeys of ETR 208. The general finding of the damage caused by the derailment was carried out by visual investigation, downstream of the restitution of rolling stock by the judicial activities and is summarised in Table 1.

ETR 223	No damage
ETR 208	Right-hand buffer box M3 Right buffer Left-hand side profile axle height 6 bogey CV5 Fifth wheel coupling area M3 - M2 Safety exit glass case M2 right-hand side CV5 bogey in many of its parts

Table 1 - List of damage to rolling stock.

3.1.5. Other consequences

Following the event, the circulation between Poggiomarino and Torre Annunziata was interrupted from 1:45 p.m. until 12:00 p.m. on 8 November 2022. During the rest of the day, circulation resumed between Poggiomarino and Scafati, while a replacement bus service for the route between the stations of Scafati and Torre Annunziata was established.

3.1.6. People and actors involved

In the chain of events leading to the accident, the following entities were involved in various ways, without giving any consideration to their possible respective responsibilities:

- the CT (Train manager) in service on train 4132, in possession of ADT (Train Conductor) qualification, on the isolated narrow gauge Vesuvian railway lines operated by EAV, issued on 21/10/2022 without any medical restrictions;
- the AdC in service on train 4132, in possession of a train conductor license from 08/04/2021 expiring on 05/04/2031, assessed as physically fit for driving following a medical examination carried out on 12/01/2021;

- the DL in service at Pompei Santuario station at the time of the event, in possession of the license conferred by EAV as the Movement Manager Vesuvian lines, assessed as physically fit for circulation management following a medical examination carried out on 12/09/2022;
- the DU (Single Track Line Traffic Controller) in service at Naples Porta Nolana station at the time of the event;
- the person responsible for the maintenance of the CCS subsystems.

3.1.7. Rolling stock Each electric train type ETR 200 METROSTAR of the EAV railway undertaking consists of 3 bogeys.

In particular, train no. 4132 consisted of the METROSTAR type ETRs no. 223 and no. 208 identified as follows:

Internal serial number	Bogey identifier	EVN
ETR 223	RA1	948342000643
	RA2	948302000658
	RA3	948342000668
ETR 208	RA1	948342000221
	RA2	948302000237
	RA3	948342000247

Table 2 - Identifiers of ETRs forming train 4132 at the time of derailment.

The following table shows the main technical characteristics of each electric train:

Dimensions	40,000× 2,650× 3,850 mm
Gauge	950 mm
Centre distance	10,859/11,000 mm
Bogeys wheel base	2,100 mm
Mass in service	95.8 t
Empty mass	64.7 t
Running gear	Bo'2'Bo'Bo'
Continuous power	1,020 kW
Maximum approved speed	120 km/h (limited to 80 km/h for signalling)
Electricity supply	1,500 V dc

Table 3 - Main technical characteristics of METROSTAR-type ETRs.

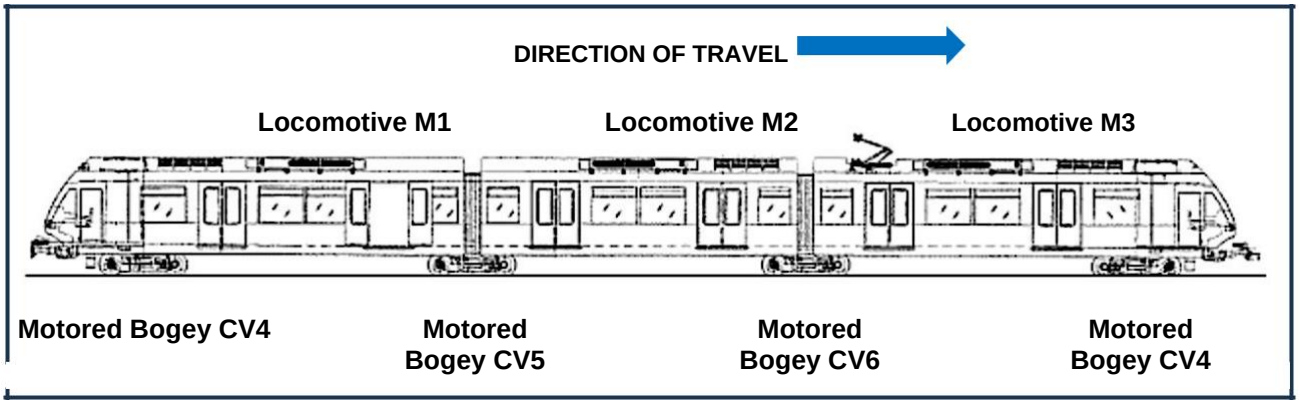

Figure 3 - Side view of a METROSTAR ETR.

Figure 4 - Side view of a METROSTAR series ETR (*Source: EAV – Processing:* DiGIFeMa).

The dates of entry into service, subject to a positive assessment by the competent USTIF (Special Department for fixed transport installations), are, respectively, 21 March 2009 for the ETR 208 and 30 June 2010 for the ETR 223.

3.1.8. Infrastructure and signalling system

The single track Poggiomarino – Torre Annunziata line (Figure 5), which includes the Scafati – Pompei Santuario route, has a track gauge of 950 mm, reaching 985 mm in sections with a minimum radius of curvature of 150 m, is electrified at 1,500 V dc, and it is equipped with a separation between trains system in automatic block mode with codified currents that allows the repetition of the signal in the car, on which the train running control system of type ATP is fitted.

The circulation regime on the line is regulated from one place (remote control unit) by means of the centralised block and the remote control. The remote-control system, which operates fully automatically, controls the switches and the main fixed signals of the entire line, forming the routes to be travelled by the trains. If necessary, a local control by the DL on the recommendation of the Signaller is possible.

The Pompei Santuario station, located at the progressive kilometre 6+235, is equipped with no.4 tracks, is attended by a DL whose district control office is located at the passenger building.

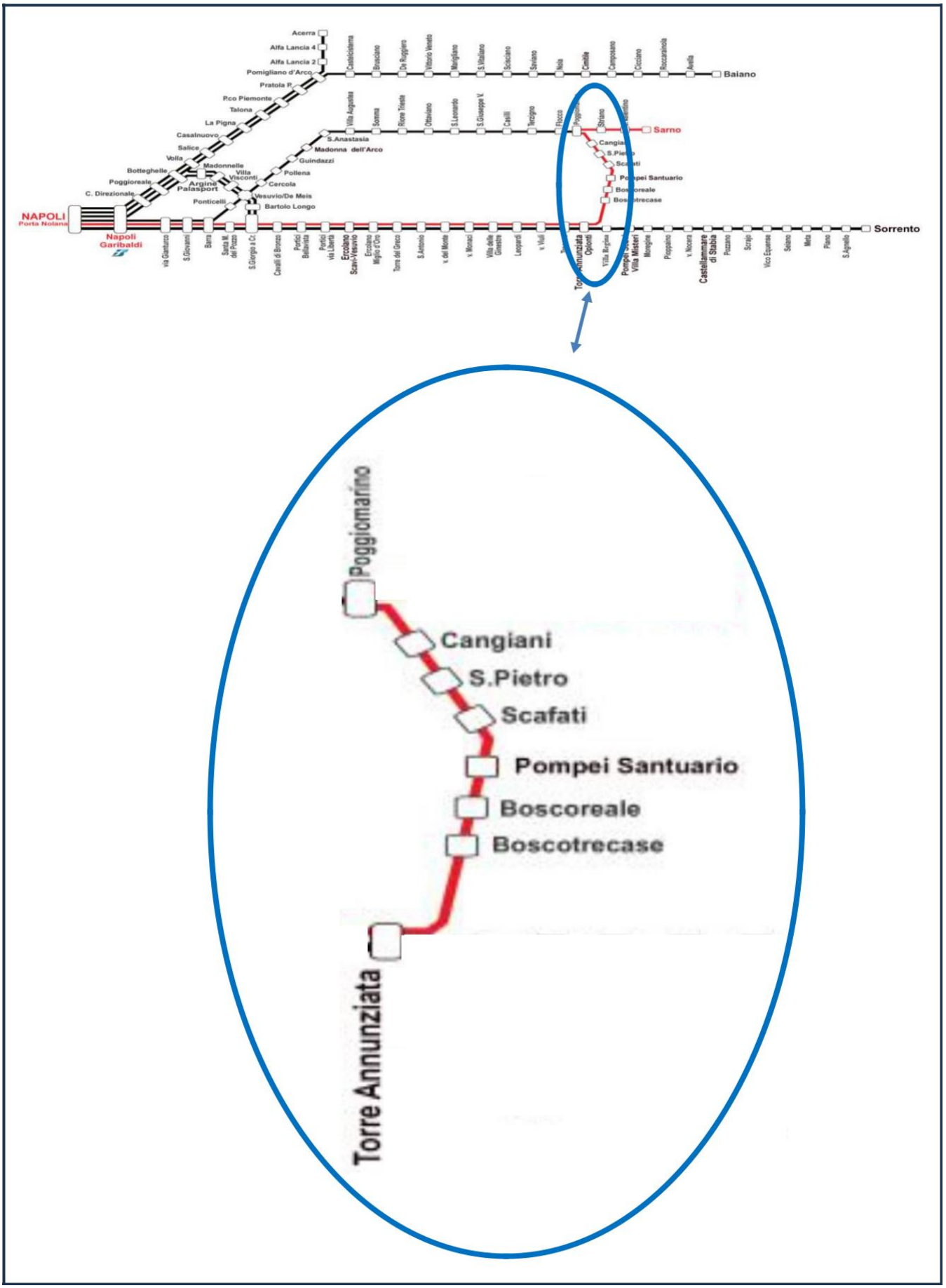

Figure 5 - File Line 104. Naples – Torre Annunziata – Poggiomarino – Sarno line (*source:* EAV – *elaboration:* DiGIFeMa).

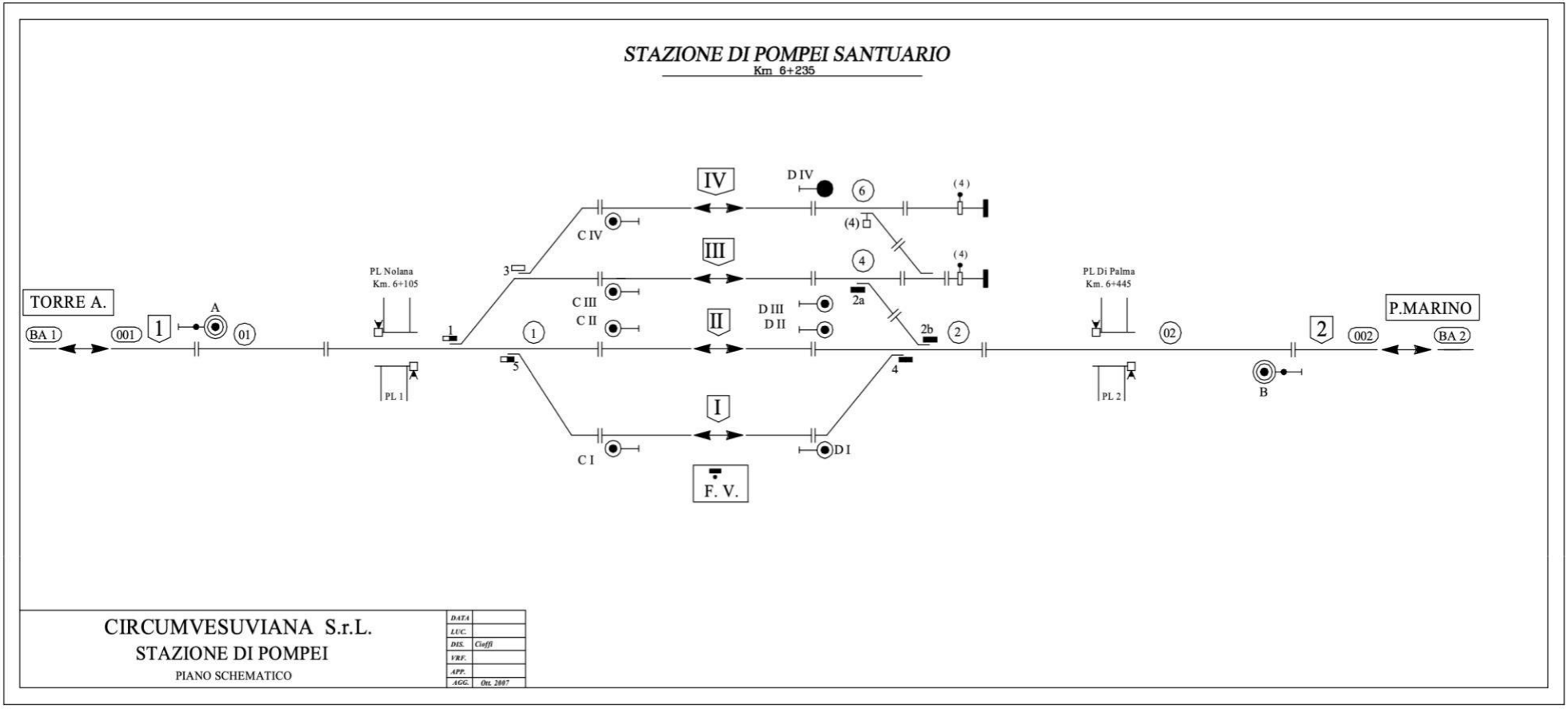

Figure 6 - Schematic plan of the POMPEI SANTUARIO Station (*source:* EAV).

SIMPLIFIED SIDE OF UP DIRECTION LINE

NAPLES - TORRE ANNUNZIATA - POGGIOMARINO

Progressive Chilometriche		Denominazioni	LINEA	Indicazioni di servizio	Indicatori di Max Velocità	Numero e capacità binario
Totali	Parziali					
38+381	----------	**SARNO**			30 70	3 (120)
36+110	2+271	**S. Valentino**			60 70	2 (120)
33+357	2+753	**Striano**			50 70	2 (120)
29+948	3+409	**POGGIOMARINO**		A		4+2 (120-80)
14+274	------	**POGGIOMARINO**			30 40 60	
12+139	2+135	*Cangiani*			70	
9+404	2+735	*S.Pietro*				
8+211	1+193	**Scafati**				2 (120)
6+235	1+976	**Pompei Santuario**			65 70 50	4 (120)
2+998	3+237	*Boscoreale*				
1+438	1+560	**Boscotrecase**			30	2 (120)
0+000	1+438	**TORRE ANNUNZIATA**		A		6 (120)
20+375	-----	**TORRE ANNUNZIATA**			70	
19+330	1+045	*Trecase*		PBI		
18+302	1+028	*Via Viuli*				
17+399	0+903	**Leopardi**		it		3 (120)
16+348	1+051	*Villa Delle Ginestre*				
15+544	0+804	*Via Dei Monaci*		PBI		
14+804	0+740	*Via Del Monte*				
13+847	0+957	*S. Antonio*		PBI		
12+277	1+570	**Torre del greco**				3 (120)
11+048	1+229	*Ercolano Miglio d'oro*				
10+115	0+933	**Ercolano Scavi -Vesuvio**				3 (120)
8+956	1+159	*Portici Via Libertà*				
8+262	0+694	*Portici Bellavista*		PBI		
7+546	0+716	*Cavalli di Bronzo*			40	
7+048	0+498	**S. GIORGIO A CREMANO**		A	70	6 (120)
5+832	1+216	*S. Maria del Pozzo*		PBI		
4+486	1+346	**BARRA**		A		5 (120)
3+209	1+277	**S. Giovanni**				3 (120)
1+988	1+221	*Via Gianturco*		PBI	40	
0.500	1+488	**NAPOLI GARIBALDI**		A		4 (120)
0.000	0+500	**NAPOLI PORTA NOLANA**		A		2+6+5 (40-80-120)

Figure 7 - File Line Vesuviana FL 104 - Chapter 19.2: Simplified side of up direction line Naples - Torre Annunziata – Poggiomarino (*source:* EAV – *elaboration:* DiGIFeMa).

Figure 8 – File line Vesuviana FL 104: Conventional signs and markings in the sides of the line (*source*: EAV - *elaboration*: DiGIFeMa).

3.1.9. Other

Not significant for the purposes of this investigation.

3.2. Objective description of the events

3.2.1. Chain of events leading to the event

On 7 November 2022, at around 1:40 p.m., the EAV 4132 train, consisting of the ETR serial number 223 (Master) and ETR serial number 208 (Slave) trains, departed at 1:26 p.m., with a 10 minutes delay, from Poggiomarino station and bound for Naples, was arriving at the Pompei Santuario station of the functionally isolated EAV Vesuviana line Naples – Torre Annunziata – Poggiomarino, located at the progressive kilometre (6+235). At that station, train 4125 was stopped on platform 2, waiting for the junction with train 4132. As soon as train 4132 engaged the AFO circuit of the Pompei Santuario station, the DM (Movement Manager) activated the call signal under Tb's regime because the immobilization CdB 2 was found to be fictitiously occupied, authorising train 4132 to enter platform 1. During this entrance, train 4132 derailed behind the switch no.4.

Figure 9 - ETR 208 after derailment (*source*: EAV).

Figure 10 - Bogey no.5 of the ETR 208 after derailment (*source*: EAV).

In particular, the last two bogeys, number 4 and number 5, of the ETR 208 rear electric train derailed from track 1, with truck no.4 routing on track 2.

The event occurred in a situation of infrastructure degradation. In fact, on the log sheet, which was delivered by the station manager of Poggiomarino, it was required that "BEA FROM SCAFATI TO POMPEI OUT OF SERVICE".

According to the Regulation in force on the Vesuvius lines, this condition requires the train to be stopped at the Scafati station in order to receive the movement provisions for the continuation of the journey. The CT of train 4132, at the Scafati station, received a phonogram from the Signaller with the following message, which was also written on the log sheet: "*For BEA malfunction you are authorised M.V. (run at sight) or E.M. (emergency). Depart with V.I. (at danger) cleared signal from Scafati to Pompei where you will couple*".

The CT, in the report annexed to the log sheet, stated that after receiving the phonogram in Scafati, communicated and countersigned by the AdC, upon arriving at the Pompei Santuario station, they found the protection signal at danger and the call signal flashing. After verifying the route on board the train, they continued their journey until they almost parked at platform 1 of the Pompei station. When approaching the platform, the train was travelling without code (C.A.) and the train driver operated the M.V. key, as required by the Regulation, to approach the departure signal.

Subsequently, according to the CT's statement, the train driver noted the signal indicating open doors and traction cut-off and the train manager on the control desk, after exiting the driver's cab door (platform side) to check the completeness of the train, he noticed the derailment and that people from the rear bogey were getting off the train safely on the platform after operating the emergency door opening handles.

3.2.2. Chain of events from the occurrence of the event

The traffic between Poggiomarino and Torre Annunziata was interrupted from 1:45 p.m. The police, the representative of the Railway Undertaking, and the Infrastructure Manager intervened on the spot. The Public Prosecutor's Office of Torre Annunziata ordered the seizure of train 4132 and the area of switch 4.

Subsequently, the traffic between Poggiomarino and Scafati was resumed, while a replacement bus service between the stations of Scafati and Torre Annunziata was established. Once the train was repositioned on track 1, after the checks on the equipment and the transit of a test train, the operation was resumed on the entire Poggiomarino – Torre Annunziata – Naples line from 12 p.m. on the day 8 November 2022, using platform 3 of the Pompei Santuario station.

Train 4132, after the initial checks and re-railing, so that it occupied only track one of the station, was seized by the judicial authority, together with track one and two, which were affected by switch 4. After the release from seizure, which took place on 14 December 2022, it was taken to the Ponticelli workshop for the necessary repairs.

4. Event Analysis

At around 10:00 a.m. on 7 November 2023, at the Pompei Santuario station, after the transit of the counter-running train 4093, there was a malfunction of the track 2 (CdB2) immobilising the switch no.4, which was permanently occupied. This is confirmed not only by the declarations of the DL of Pompei Santuario station, but also by the analysis of the RCE of the ACEI of the station. The switch no.4, when in normal position, routes the trains coming from Poggiomarino on track n.2 of the station of Pompei Santuario, and on track n.1 when it is in reverse position. The following figures show an excerpt from the RCE of the ACEI relating to a period of time on 6 November 2022 (12:37:15 p.m. - 15:52:37 p.m.), the day before the accident, in which the circulation of trains was regular. In order to facilitate data analysis, groups of events corresponding to the transit of certain trains are highlighted: the trains that travel from North to South are highlighted in yellow and the counter-running trains are highlighted in green. Following the departure of a train, it can be noted that the CdB 1 and 2 are released to secure the immobilisation of switches 1, 2, 4, and 5.

200	06/11/2022	16:32:40.350		Nessuna coppia in condizione di allarme
199	06/11/2022	16:32:40.350	101\ACR <	Segnale A a via impedita (R)
198	06/11/2022	16:32:38.970	101\ERR ?	Ingressi Sx e Dx attivi
197	06/11/2022	16:32:13.160	007\USC >	Blocco RH2 libero orient. in uscita
196	06/11/2022	16:32:08.200	007\OCC *	Blocco RH2 occupato
195	06/11/2022	16:32:07.710	101\ACV >	Segnale A a via libera (G o V)
194	06/11/2022	16:32:07.250	101\LSP *	Segnale A lampada spenta
193	06/11/2022	16:23:41.410	006\ING >	Blocco RH1 orientato in ingresso

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186	06/11/2022	15:50:14.360	001\ACV >	Segnale C (I - IV) a via libera (V)	Train 4156
185	06/11/2022	15:49:32.820	002\ACV >	Segnale B a via libera (G o V)	
184	06/11/2022	15:49:32.360	002\LSP *	Segnale B lampada spenta	
183	06/11/2022	15:07:46.260	006\USC <	Blocco RH1 libero orientato in uscita	
182	06/11/2022	15:02:21.150	006\OCC *	Blocco RH1 occupato	
181	06/11/2022	15:02:10.560	001\ACR <	Segnale C (I - IV) a via impedita (R)	Train 4148
180	06/11/2022	15:00:51.460	002\ACR <	Segnale B a via impedita (R)	
179	06/11/2022	15:00:02.410	001\ACV >	Segnale C (I - IV) a via libera (V)	
178	06/11/2022	15:00:00.000		Verfica data e ora	
177	06/11/2022	14:59:23.460	006\USC <	Blocco RH1 libero orientato in uscita	
176	06/11/2022	14:59:22.510	006\OCC *	Blocco RH1 occupato	
175	06/11/2022	14:59:21.100	002\ACV >	Segnale B a via libera (G o V)	
174	06/11/2022	14:59:20.620	002\LSP *	Segnale B lampada spenta	
173	06/11/2022	14:58:25.920	007\ING <	Blocco RH2 orientato in ingresso	
172	06/11/2022	14:58:25.460	007\OCC *	Blocco RH2 occupato	
171	06/11/2022	14:58:24.510	007\USC >	Blocco RH2 libero orient. in uscita	
170	06/11/2022	14:55:43.250	007\OCC *	Blocco RH2 occupato	
169	06/11/2022	14:55:32.200	003\ACR <	Segnale D (I - III) a via impedita (R)	Train 4141
168	06/11/2022	14:53:56.670	003\ACV >	Segnale D (I - III)a via libera (V)	
167	06/11/2022	14:53:55.760		Nessuna coppia in condizione di allarme	
166	06/11/2022	14:53:55.760	101\ACR <	Segnale A a via impedita (R)	
165	06/11/2022	14:53:54.360	101\ERR ?	Ingressi Sx e Dx attivi	
164	06/11/2022	14:53:17.260	007\USC >	Blocco RH2 libero orient. in uscita	
163	06/11/2022	14:53:12.570	007\OCC *	Blocco RH2 occupato	
162	06/11/2022	14:53:12.100	101\ACV >	Segnale A a via libera (G o V)	
161	06/11/2022	14:44:49.510	006\ING >	Blocco RH1 orientato in ingresso	
160	06/11/2022	14:44:49.050	006\OCC *	Blocco RH1 occupato	
159	06/11/2022	14:20:02.920	006\USC <	Blocco RH1 libero orientato in uscita	
158	06/11/2022	14:14:27.920	006\OCC *	Blocco RH1 occupato	
157	06/11/2022	14:14:17.360	001\ACR <	Segnale C (I - IV) a via impedita (R)	Train 4140
156	06/11/2022	14:12:44.150	002\ACR <	Segnale B a via impedita (R)	
155	06/11/2022	14:12:42.770	001\ACV >	Segnale C (I - IV) a via libera (V)	
154	06/11/2022	14:12:41.360	006\USC <	Blocco RH1 libero orientato in uscita	
153	06/11/2022	14:12:40.870	006\OCC *	Blocco RH1 occupato	
152	06/11/2022	14:11:05.820	002\ACV >	Segnale B a via libera (G o V)	
151	06/11/2022	14:10:05.250	007\ING <	Blocco RH2 orientato in ingresso	
150	06/11/2022	14:10:04.770	007\OCC *	Blocco RH2 occupato	
149	06/11/2022	14:10:03.360	007\USC >	Blocco RH2 libero orient. in uscita	
148	06/11/2022	14:07:04.720	007\OCC *	Blocco RH2 occupato	
147	06/11/2022	14:06:55.350	003\ACR <	Segnale D (I - III) a via impedita (R)	
146	06/11/2022	14:05:38.360	101\ACR <	Segnale A a via impedita (R)	

Figure 11 - Excerpt from the RCE of the Pompei Santuario station relating to the date of 6 November 2022 (*source*: EAV - *elaboration*: DiGIFeMa).

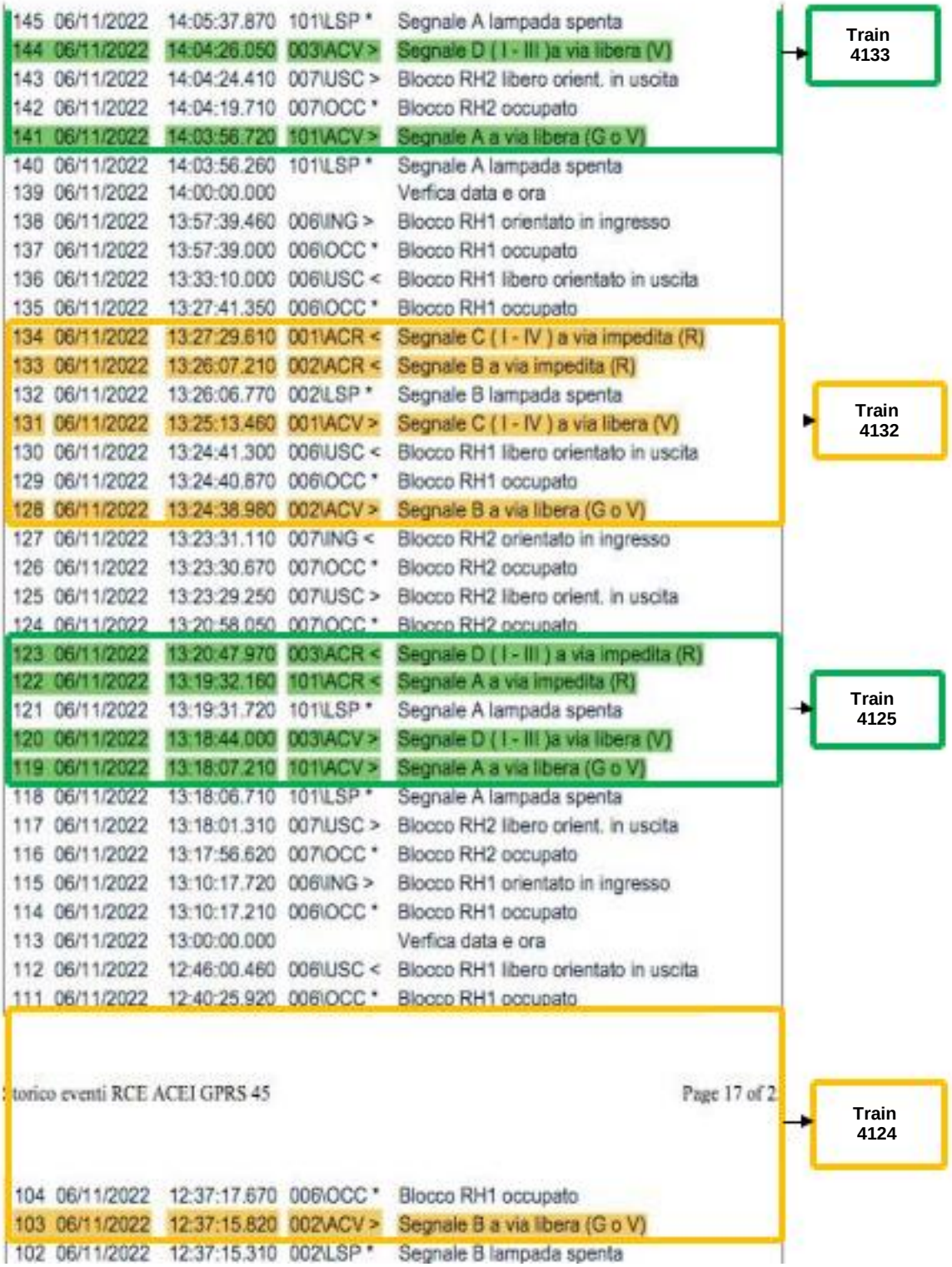
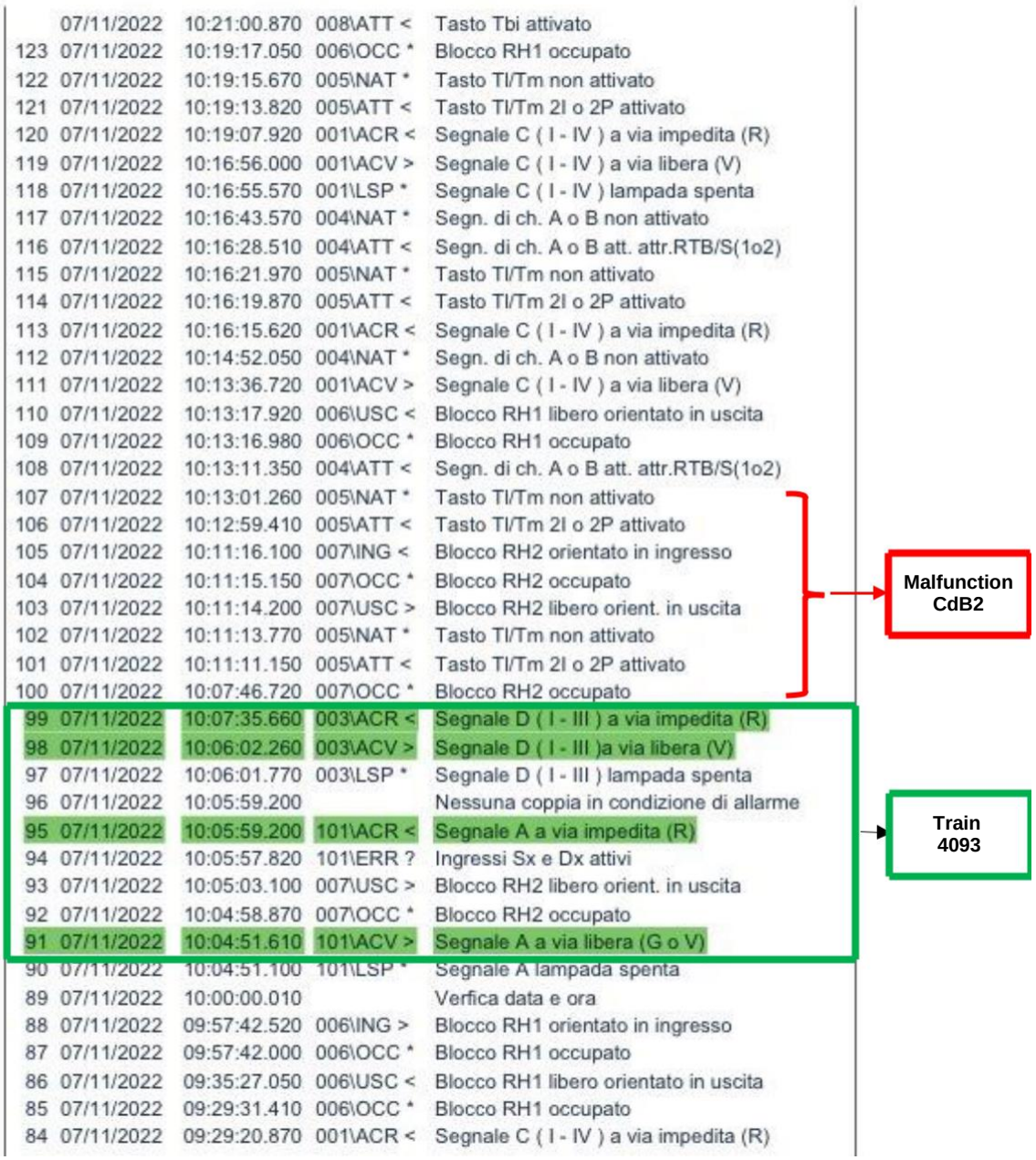


Figure 12 - Excerpt from the RCE of the Pompei Santuario station relating to the date of 6 November 2022 (*source*: EAV - *elaboration*: DiGIFeMa).

It should also be noted, for a correct interpretation of the data, that the time of events reported in the RCE does not necessarily coincide with the actual time of the events, or with the time of the tachograph zones, since the time bases used by the entities involved are different. In the present case, for example, the departure times of the trains considered in Figure 11 and Figure 12 are on average approximately 3 minutes earlier than those required by the official departure time at the time of the event. On the other hand, the following figure shows an excerpt from the RCE of the ACEI of the Pompei Santuario station on 7 November 2022 at around 10 p.m., at the transit of train 4093, from which the malfunction of CdB 2 is evident, which is occupied even in the absence of a train transiting on it.



	07/11/2022	10:21:00.870	008\ATT <	Tasto Tbi attivato
123	07/11/2022	10:19:17.050	006\OCC *	Blocco RH1 occupato
122	07/11/2022	10:19:15.670	005\NAT *	Tasto TI/Tm non attivato
121	07/11/2022	10:19:13.820	005\ATT <	Tasto TI/Tm 2I o 2P attivato
120	07/11/2022	10:19:07.920	001\ACR <	Segnale C (I - IV) a via impedita (R)
119	07/11/2022	10:16:56.000	001\ACV >	Segnale C (I - IV) a via libera (V)
118	07/11/2022	10:16:55.570	001\LSP *	Segnale C (I - IV) lampada spenta
117	07/11/2022	10:16:43.570	004\NAT *	Segn. di ch. A o B non attivato
116	07/11/2022	10:16:28.510	004\ATT <	Segn. di ch. A o B att. attr.RTB/S(1o2)
115	07/11/2022	10:16:21.970	005\NAT *	Tasto TI/Tm non attivato
114	07/11/2022	10:16:19.870	005\ATT <	Tasto TI/Tm 2I o 2P attivato
113	07/11/2022	10:16:15.620	001\ACR <	Segnale C (I - IV) a via impedita (R)
112	07/11/2022	10:14:52.050	004\NAT *	Segn. di ch. A o B non attivato
111	07/11/2022	10:13:36.720	001\ACV >	Segnale C (I - IV) a via libera (V)
110	07/11/2022	10:13:17.920	006\USC <	Blocco RH1 libero orientato in uscita
109	07/11/2022	10:13:16.980	006\OCC *	Blocco RH1 occupato
108	07/11/2022	10:13:11.350	004\ATT <	Segn. di ch. A o B att. attr.RTB/S(1o2)
107	07/11/2022	10:13:01.260	005\NAT *	Tasto TI/Tm non attivato
106	07/11/2022	10:12:59.410	005\ATT <	Tasto TI/Tm 2I o 2P attivato
105	07/11/2022	10:11:16.100	007\ING <	Blocco RH2 orientato in ingresso
104	07/11/2022	10:11:15.150	007\OCC *	Blocco RH2 occupato
103	07/11/2022	10:11:14.200	007\USC >	Blocco RH2 libero orient. in uscita
102	07/11/2022	10:11:13.770	005\NAT *	Tasto TI/Tm non attivato
101	07/11/2022	10:11:11.150	005\ATT <	Tasto TI/Tm 2I o 2P attivato
100	07/11/2022	10:07:46.720	007\OCC *	Blocco RH2 occupato
99	07/11/2022	10:07:35.660	003\ACR <	Segnale D (I - III) a via impedita (R)
98	07/11/2022	10:06:02.260	003\ACV >	Segnale D (I - III)a via libera (V)
97	07/11/2022	10:06:01.770	003\LSP *	Segnale D (I - III) lampada spenta
96	07/11/2022	10:05:59.200		Nessuna coppia in condizione di allarme
95	07/11/2022	10:05:59.200	101\ACR <	Segnale A a via impedita (R)
94	07/11/2022	10:05:57.820	101\ERR ?	Ingressi Sx e Dx attivi
93	07/11/2022	10:05:03.100	007\USC >	Blocco RH2 libero orient. in uscita
92	07/11/2022	10:04:58.870	007\OCC *	Blocco RH2 occupato
91	07/11/2022	10:04:51.610	101\ACV >	Segnale A a via libera (G o V)
90	07/11/2022	10:04:51.100	101\LSP *	Segnale A lampada spenta
89	07/11/2022	10:00:00.010		Verfica data e ora
88	07/11/2022	09:57:42.520	006\ING >	Blocco RH1 orientato in ingresso
87	07/11/2022	09:57:42.000	006\OCC *	Blocco RH1 occupato
86	07/11/2022	09:35:27.050	006\USC <	Blocco RH1 libero orientato in uscita
85	07/11/2022	09:29:31.410	006\OCC *	Blocco RH1 occupato
84	07/11/2022	09:29:20.870	001\ACR <	Segnale C (I - IV) a via impedita (R)

Figure 13 - Excerpt from the RCE of the Pompei Santuario station at around 10 a.m. on 7 November 2022 (*source*: EAV - *elaboration*: DiGIFeMa).

Pending the repair of the malfunction, the continuity of circulation, in accordance with the provisions of the document *Instructions for operation of Central Electrically Controlled Routing with push-button and for the operation of Automatic Block* (1998), was ensured by the use of the ACEI emergency keys, whose function is to allow the operation of the railway service even if, in the event of malfunctions and/or anomalies, not all the required safety conditions are met. In other words, the use of the emergency keys allows to exclude the missing conditions and therefore to carry out operations that would otherwise be prevented. In particular, an examination conducted by the RCE of the ACEI shows that the following emergency keys were used by the DL to allow trains to continue running even in degraded mode:

1) (Tl/Tm) key for artificial release and manual route block. The corresponding switch has three positions:

   - CENTRAL, normal: rest;

   - TURNED TO THE LEFT: (Tl) key artificial release;

   - TURNED TO THE RIGHT: (Tm) key, manual route lock.

   The left-hand position is reached after breaking of seal and is with spring return to the central position; right-hand rotation is free.

2) (Tbi) key for switch manoeuvre with the exclusion of immobilisation CdB (lead-lined). The corresponding switch, which is unique for all switches, can have two positions:

   - NORMAL: rest;

   - TURNED TO THE LEFT: exclusion of the immobilisation CdB for the individual manoeuvre.

Unlike the *EAV Investigation Report*, there is no evidence of the use the Tb and Tc emergency keys of the ACEI. Furthermore, the analysis of the RCE of the ACEI also found that the time gap between the activation and the deactivation of the T1/Tm keys is on average very small, resulting in fact incompatible with a *de visu* verification by the DL of the release of the track circuit. Therefore, it is likely to assume that manoeuvre of the lock keys was carried out by the DL, basing on the substantially empirical assessment of the average journey times of the trains on the track circuit concerned.

Obviously, the malfunction also caused that the BEA was out of service between the Scafati and Pompei Santuario stations. According to Article 20 of the document *Regulations for the circulation of single-manager trains* (2010), in case of failure of the BEA, the circulation of trains must be regulated by the station-to-station signalling block system. This condition therefore required the stopping of the trains from Scafati to Pompei Santuario in Scafati station in order to receive the movement provisions for the continuation of the journey.

Furthermore, since the malfunction prevented the scheduled crossings at Scafati station and since the Pompei Santuario station was manned by a DM, the DU ordered the crossings to be moved to the Pompei Santuario station and carried out in manual mode using the ACEI's emergency buttons.

As already mentioned in the previous paragraphs, in the present case the CT of train 4132 received, at Scafati station, a phonogram from the Signaller with the following instructions, which were also shown on the log sheet: "*For BEA malfunction you are authorised M.V. (run at sight) or E.M. (Emergency). Depart with V.I. (at danger) cleared signal from Scafati to Pompei where you will couple".*

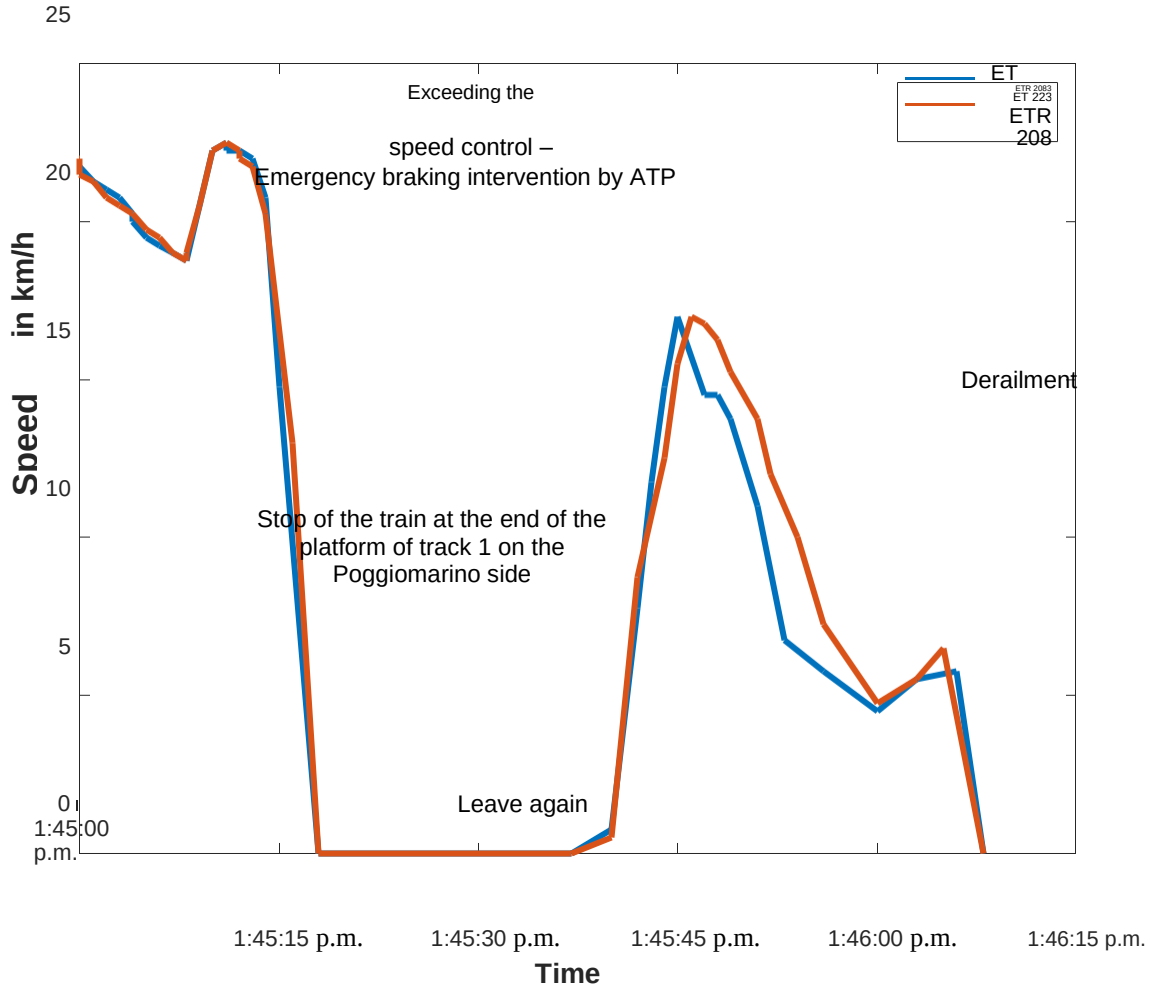
In the report attached to the log sheet the CT stated that, after receiving the phonogram in

Scafati, communicated and countersigned by the train driver, upon arriving at the Pompei Santuario

station, they found the protection signal at danger and the call signal flashing[3]. After verifying the route on board the train, they continued their journey until they almost parked at platform 1 of the Pompei station. When approaching the platform, the train was travelling without code (C.A.) and the train driver operated the M.V. key, as required by the Regulation, to approach the departure signal.

Subsequently, according to the CT's statement, the train driver noted the signal indicating open doors and traction cut-off and the train manager on the control desk, after exiting the driver's cab door (platform side) to check the completeness of the train, he noticed the derailment and that people from the rear bogey were getting off the train safely on the platform after operating the emergency door opening handles.

However, the analysis of the data provided by the tachograph zones of the two electric trains ETR 223 and ETR 208, which formed train 4132, provides a different reconstruction of the evolution of the facts. As evidence of this, see Figure 14, which shows the speed trend of the two electric trains at the entrance to the Pompei Santuario station, which is obtained from the processing of data provided by the tachograph zones.



From the analysis of that figure, it is immediately noted that train 4132:

[3] The document called the *EAV Investigation Report* states that this condition "*authorises entry to the station under TB regime*". In fact, the only EAV document in which the TB regime is mentioned is the *Signals Regulation*, but only limited to the case of the departure of a train from the Naples Porta Nolana and Naples Piazza Garibaldi stations.

- at 1:45:13 p.m., exceeds the speed control causing ATP emergency braking;
- at 1:45:17 p.m., stops at the entrance of the station at the end of the passenger platform of track 1 on the Poggiomarino side;
- at 1:45:37 p.m., leaves again to complete the parking at track 1;
- at 1:45:45 p.m., the derailment begins, as can be seen from the deviation between the speed profiles of the ETR 223 and the ETR 208;
- at 1:46:08 p.m., stops again, completing the parking at track 1.

Train 4132 then remained stationary for 20s with the front at the height of the Poggiomarino-side end of the passenger platform of track 1, before leaving again to complete the parking at track 1.
Moreover, this reconstruction of the facts is confirmed video surveillance camera footage of the Pompei Santuario station. The following Figure 15 shows the still images of the moment at which train 4132 stopped at the beginning of the platform on track 1 and the moment at which it left again. The analysis of these still images also shows that train 4132 remained stationary at the end of the passenger platform of track 1 on the Poggiomarino side for 20s, from 1:53 p.m. to 1:45:45:33 p.m. The difference in the time from the tachograph zones of ETR 223 and 208 is due to the fact that the time indicated by the camera differs by +16s from that of the tachograph zone of ETR 223.
On the other hand, Figure 16 shows the still image of the moment 1:46:24 p.m. when train 4132 completed the parking manoeuvre at the platform of track 1. This time is also consistent with the time obtained from the tachograph zones at less than a time shifting of 16s.

Figure 15 - Still images taken from the video camera footage of the video surveillance circuit at the station of Pompei Santuario relating to the instant when train 4132 stopped at the height of the beginning of the platform on track 1 and the instant when it left again (*elaboration*: DiGIFeMa).

Figure 16- Still images taken from the video camera footage of the video surveillance circuit at the station of Pompei Santuario relating to the instant when train 4132 completed its manoeuvre of parking at the platform on track 1 (*elaboration*: DiGIFeMa).

È It is thus confirmed that train 4132 then remained stationary for 20s with the front at the height of the Poggiomarino-side end of the passenger platform of track 1. In that position, the train, whose overall length is about 80 m, had not yet fully passed the switch no.4 which had been positioned, using the emergency keys, in a deviated configuration precisely to allow the arrival at track 1. The extremity of switch 4 was likely located between the two bogeys of the locomotive M2 of the ETR 208. During this time, switch no.4 was brought back to its normal configuration without checking that the train had passed completely over the switch, so that at the departure the CV6 and CV4 bogeys at the rear of ETR 208 derailed, with the CV6 bogey being routed on track 2, while the CV4 bogey was out of way between tracks 1 and 2.

The following figure shows the RCE of the ACEI in the time frame in which the derailment occurred, from which the sequence of manoeuvres made by the DL to regain control of the switch is detected.

#	Data	Ora	Ente	Descrizione
54	07/11/2022	14:08:35.560	006\USC <	Blocco RH1 libero orientato in uscita
53	07/11/2022	14:03:29.210	005\NAT *	Tasto TI/Tm non attivato
52	07/11/2022	14:03:27.820	005\ATT >	Tasto TI/Tm 1I o 1P attivato
51	07/11/2022	14:03:26.410	005\NAT *	Tasto TI/Tm non attivato
50	07/11/2022	14:03:25.460	005\ATT >	Tasto TI/Tm 1I o 1P attivato
49	07/11/2022	14:01:36.560	006\OCC *	Blocco RH1 occupato
48	07/11/2022	14:01:19.710	001\ACR <	Segnale C (I - IV) a via impedita (R)
47	07/11/2022	14:00:40.660	001\ACV >	Segnale C (I - IV) a via libera (V)
46	07/11/2022	14:00:00.000		Verfica data e ora
45	07/11/2022	13:46:05.310	005\NAT *	Tasto TI/Tm non attivato
44	07/11/2022	13:46:03.000	005\ATT >	Tasto TI/Tm 1I o 1P attivato
43	07/11/2022	13:45:51.260	001\ACR <	Segnale C (I - IV) a via impedita (R)
42	07/11/2022	13:42:38.770	008\NAT *	Tasto Tbi non attivato
41	07/11/2022	13:42:34.050	008\ATT <	Tasto Tbi attivato
40	07/11/2022	13:42:26.310	008\NAT *	Tasto Tbi non attivato
39	07/11/2022	13:42:16.200	008\ATT <	Tasto Tbi attivato
38	07/11/2022	13:42:12.000	008\NAT *	Tasto Tbi non attivato
37	07/11/2022	13:42:09.160	008\ATT <	Tasto Tbi attivato
36	07/11/2022	13:40:45.160	005\NAT *	Tasto TI/Tm non attivato
35	07/11/2022	13:40:43.250	005\ATT <	Tasto TI/Tm 2I o 2P attivato
34	07/11/2022	13:40:26.360	008\NAT *	Tasto Tbi non attivato
33	07/11/2022	13:40:22.610	008\ATT <	Tasto Tbi attivato
32	07/11/2022	13:40:12.050	008\NAT *	Tasto Tbi non attivato
31	07/11/2022	13:40:05.210	008\ATT <	Tasto Tbi attivato
30	07/11/2022	13:39:55.150	008\NAT *	Tasto Tbi non attivato
29	07/11/2022	13:39:46.460	008\ATT <	Tasto Tbi attivato
28	07/11/2022	13:39:44.560	008\NAT *	Tasto Tbi non attivato
27	07/11/2022	13:39:38.460	008\ATT <	Tasto Tbi attivato
26	07/11/2022	13:39:37.310	001\ACV >	Segnale C (I - IV) a via libera (V)
25	07/11/2022	13:39:35.410	005\NAT *	Tasto TI/Tm non attivato

Figure 17 - Excerpt from the RCE of the ACEI of the Pompei Santuario station at the time of derailment (*source*: EAV - *elaboration*: DiGIFeMa).

4.1. Roles and duties

Whereas, pursuant to Art. 20, paragraph 4 of Directive (EU) 2016/798, '*In no event may this investigation be concerned with appointing blame or liability*', the roles and tasks of the persons and the entities, who played a safety critical role in relation to the event, or in any activity that led to the event, are identified below.

4.1.1. Railway undertaking and infrastructure manager

- Railway Undertaking: EAV
  - the Driver (AdC) of train 4132;
  - the Train Manager (CT) of train 4132.
- Infrastructure Manager: EAV
  - the Signaller (DU);
  - the person responsible for the maintenance of the CCS subsystems.

4.1.2 Person responsible for maintenance

The EAV railway undertaking is also the entity in charge of the maintenance of the rolling stock, as certified on 09/09/2022 by the certifying Body ISARail S.p.A. in accordance with ANSF Decrees no.1/2019 and no.3/2019.

The EAV infrastructure manager is the entity responsible for the maintenance of the railway infrastructure.

4.1.3. Rolling stock manufacturer or supplier

AnsaldoBreda (not significant), FIREMA (not significant).

4.1.4. National authorities and/or European Union Agency for Railways

ANSFISA (not significant), ERA (not significant).

4.1.5. Notified bodies

Not significant for the purposes of the investigation.

4.1.6. Certified bodies

Not significant for the purposes of the investigation.

4.1.7 Other person or entity affected by the event

Not significant for the purposes of the investigation.

4.2. Rolling stock and technical installations

This section identifies the causal factors or consequences of the event recognised as related to the condition of the rolling stock or technical installations.

4.2.1. Factors attributable to design

Not significant for the purposes of the investigation.

4.2.2. Factors attributable to installation and putting into service Not significant for the purposes of the investigation.

4.2.3. Factors attributable to manufacturers or other suppliers Not significant for the purposes of the investigation.

4.2.4. Factors attributable to maintenance or modification of rolling stock or technical installations

The ACEI and the track circuits of the Pompei Santuario station were subject to preventive maintenance on a monthly basis. However, from the analysis of the document called *Plant Book Pompei Santuario* provided by EAV and shown in Figure 18, it emerges that the last maintenance on these

ID man.	Typology	CDL	Standard activity	Frequency	Entity	Location	Maintenance start date	Maintenance end date	Hours	Man hours	External company
77343	Preventive	Torre Annunziata CCS	IS-17-18-19 ACEI - Control Station	Monthly	Acei Pompei Santuario	KM 6+211	13/08/2022	13/08/2022	7:48	15.6	No
77342	Preventive	Torre Annunziata CCS	IS-12-13 ACEI & PL - Track Circuit	Monthly	Acei Pompei Santuario	KM 6+211	13/08/2022	13/08/2022	7:48	15.6	No
77341	Preventive	Torre Annunziata CCS	IS-07-08-09 ACEI and PL - Light Signal	Monthly	Acei Pompei Santuario	KM 6+211	13/08/2022	13/08/2022	7:48	15.6	No
77339	Preventive	Torre Annunziata CCS	IS-14-15-16 ACEI - Electric-motor operated switch	Monthly	Acei Pompei Santuario	KM 6+211	13/08/2022	13/08/2022	7:48	15.6	No
76994	Preventive	Torre Annunziata CCS	IS-14-15-16 ACEI - Electric-motor operated switch	Fortnightly	Acei Pompei Santuario	KM 6+211	13/08/2022	13/08/2022	7:48	15.6	No
64910	Preventive	Torre Annunziata CCS	IS-17-18-19 ACEI - Control Station	Monthly	Acei Pompei Santuario	KM 6+211	20/05/2022	20/05/2022	0:30	2	No
64909	Preventive	Torre Annunziata CCS	IS-14-15-16 ACEI - Electric-motor operated switch	Monthly	Acei Pompei Santuario	KM 6+211	20/05/2022	20/05/2022	0:30	2	No
64908	Preventive	Torre Annunziata CCS	IS-12-13 ACEI & PL - Track Circuit	Monthly	Acei Pompei Santuario	KM 6+211	20/05/2022	20/05/2022	0:30	2	No
64907	Preventive	Torre Annunziata CCS	IS-07-08-09 ACEI and PL - Light Signal	Monthly	Acei Pompei Santuario	KM 6+211	20/05/2022	20/05/2022	0:30	2	No
61540	Preventive	Torre Annunziata CCS	IS-12-13 ACEI & PL - Track Circuit	Monthly	Acei Pompei Santuario	KM 6+211	21/04/2022	21/04/2022	0:28	1.87	No
61538	Preventive	Torre Annunziata CCS	IS-07-08-09 ACEI and PL - Light Signal	Monthly	Acei Pompei Santuario	KM 6+211	21/04/2022	21/04/2022	0:28	1.87	No
61193	Preventive	Torre Annunziata CCS	IS-14-15-16 ACEI - Electric-motor operated switch	Monthly	Acei Pompei Santuario	KM 6+211	21/04/2022	21/04/2022	0:28	1.87	No
58482	Preventive	Torre Annunziata CCS	IS-24 ACEI - Cables and Shunting boxes	Annual	Acei Pompei Santuario	KM 6+211	17/03/2022	17/03/2022	7:48	7.8	Yes
58480	Preventive	Torre Annunziata CCS	IS-23 ACEI - Batteries/Battery Chargers	Biannual	Acei Pompei Santuario	KM 6+211	16/03/2022	16/03/2022	7:48	7.8	Yes
58478	Preventive	Torre Annunziata CCS	IS-20-21 ACEI - Relay Room or Rack	Annual	Acei Pompei Santuario	KM 6+211	16/03/2022	16/03/2022	7:48	7.8	Yes
58476	Preventive	Torre Annunziata CCS	IS-22 ACEI - Uninterruptible power supply (UPS)/rotating	Biannual	Acei Pompei Santuario	KM 6+211	16/03/2022	16/03/2022	7:48	7.8	Yes
58475	Preventive	Torre Annunziata CCS	IS-20-21 ACEI - Relay Room or Rack	Biannual	Acei Pompei Santuario	KM 6+211	16/03/2022	16/03/2022	7:48	7.8	Yes
58473	Preventive	Torre Annunziata CCS	IS-17-18-19 ACEI - Control Station	Annual	Acei Pompei Santuario	KM 6+211	17/03/2022	17/03/2022	7:48	7.8	Yes
58472	Preventive	Torre Annunziata CCS	IS-14-15-16 ACEI - Electric-motor operated switch	Biannual	Acei Pompei Santuario	KM 6+211	17/03/2022	17/03/2022	7:48	7.8	Yes
58471	Preventive	Torre Annunziata CCS	IS-12-13 ACEI & PL - Track Circuit	Annual	Acei Pompei Santuario	KM 6+211	24/03/2022	24/03/2022	7:48	7.8	Yes
58470	Preventive	Torre Annunziata CCS	IS-07-08-09 ACEI and PL - Light Signal	Annual	Acei Pompei Santuario	KM 6+211	24/03/2022	24/03/2022	7:48	7.8	Yes

entities was carried out on 13/08/2022. Therefore, in the last three months before the accident, both ACEI and the track circuits of Pompei Santuario station were not subject to the planned preventive maintenance.

4.2.5. Factors relating to the Entity in Charge of Maintenance

As already stated in the previous paragraph, ACEI and the track circuits of Pompei Santuario station were not subject to the planned preventive maintenance activities on a monthly basis from 13/08/2022.

4.2.6. Other factors

Not significant for the purposes of the investigation.

4.3. Human factors

This paragraph aims to identify the possible correlation with human actions of causal factors, concausal factors and consequences of the event. This shall take into account both the specific circumstances and the manner in which routine activities are carried out by staff during normal exercise, as well as the human and organisational factors that may influence actions and/or decisions.

In order to make the assessment of the incidence of human factors as objective and systematic as possible, the writer decided to use the SOAM (*Systemic occurrence Analysis methodology*) analysis methodology, described in detail in the following paragraph 4.6 and applied to the accident in question in paragraph 4.7.

4.3.1. Human and individual characteristics

See SOAM Analysis: § 4.6.3

4.3.2. Labour-related factors

See SOAM Analysis: § 4.6.4

4.3.3. Organisational factors and tasks

See SOAM Analysis: § 4.6.5

4.3.4. Environmental factors

See SOAM Analysis: § 4.6.4

4.3.5. Other factors significant to the investigation

See SOAM Analysis: § 4.6.5

4.4. Feedback mechanisms and control

4.4.1. Regulatory framework and provisions

- Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety (revision).

- Commission's Delegated Regulation (EU) 2018/762 of 8 March 2018 establishes Common Safety Methods relating to the requirements of the Safety Management System in accordance with Directive (EU) 2016/798 of the European Parliament and of the Council and abrogates the Commission Regulations (EU) no. 1158/2010 and (EU) no. 1169/2010.
- Legislative Decree no. 50 of 14 May 2019, "Implementation of Directive 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety".
- Commission Implementing Regulation (EU) 2020/572 of 24 April 2020 on the format to be followed in railway accident and incident investigation reports.
- Regulations for railway traffic (RCF), ANSF Decree no. 4/2012 of 09/08/2012, Annex B.
- Instructions for the operation of Central Electrically Controlled Routing with push-button and for the operation of Automatic Block, SFSM, 1998.
- Regulations for the circulation of single-manager trains, Circumvesuviana S.r.l., 2010.
- Signal Regulation, Circumvesuviana S.r.l., 2011.

4.4.2. Risk assessment and monitoring

Not significant for the purposes of the investigation.

4.4.3. Safety Management System for railway undertakings and the manager infrastructure

- EAV S.r.l., as RU, has implemented its own safety management system, as confirmed by the issue by ANSFISA of safety Authorisation no. IT2120190005 valid from 20/12/2021 to 11/06/2024.
- EAV S.r.l., as IM, has implemented its own safety management system accepted by ANSFISA with the issue of the Certificate of fitness to practice no. GI2021002, valid from 20/12/2021 to 11/06/2024, pursuant to Article 11 of Legislative Decree no.50 of 14 May 2019, "Implementing Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety".

It should be recalled that the safety authorisation certifies the acceptance of the safety management system of the infrastructure manager and contains the procedures and arrangements to meet the requirements necessary for the design, maintenance and operation of the railway infrastructure in safety conditions, including the maintenance and operation of the traffic control and signalling system.

4.4.4. Management system of the entity in charge of maintenance

The EAV RU is responsible for the maintenance of rolling stock. The EAV IM is the entity responsible for the maintenance of the railway infrastructure.

4.4.5. Supervision of national safety authorities

Supervision is exercised by ANSFISA pursuant to Article 17 of Legislative Decree no. 50 of 14 May 2019, in accordance with the principles and elements contained in Delegated Regulation (EU) 2018/761, which established the new Common Safety methods for supervision by national authorities.

4.4.6. Authorisations, certificates and reports issued by the Agency

As mentioned in the previous paragraph 4.4.3:

- the EAV IM holds the Certificate of fitness to practice no.GI2021002, valid from 20/12/2021 to 11/06/2024, issued by ANSFISA;
- the EAV RU holds the Security Authorisation no.IT2120190005 valid from 20/12/2021 to 11/06/2024, issued by ANSFISA.

4.4.7. Other systemic factors

Not significant for the purposes of the investigation.

4.5. Previous events of a similar nature

On the basis of the information and documentation acquired, no similar events occurred before the date of the accident (07/11/2022).

4.6. Analysis methodology

As mentioned above, the accident was analysed using the SOAM (*Systemic Occurrence Analysis Methodology)*, developed to analyse safe-critical events by the European Union Aviation Safety Agency EUROCONTROL. Originally, the methodology arose from the need to integrate human factors analysis into the investigation of incidents and accidents occurring in the context of air transport and in which an air traffic controller is at least partially involved. Its main feature is to analyse human performance from a system perspective, observing it in the context in which it took place and taking into account all the factors that may have contributed to the occurrence of the accident. On the other hand, its aim is to propose improvement measures that do not focus exclusively on any non-compliance in the behaviour of operating staff, but widen the view to all the elements on which it is possible to intervene in order to prevent or mitigate the effects of any future events, with elements similar to those of the event being analysed.

In this context, the methodology has been adapted appropriately to the railway sector, while maintaining the aims described above. In particular, it is based mainly on two widely known and strongly established theoretical models in human and organizational factors literature, the SHELL model[4] and the Swiss Cheese model[5].

The SHELL model originated in the aviation world in the 1970s and 1980s and is based on the identification of four different components within each system, with different complexity and criticality characteristics from a safety perspective:

- ***Software***: is the intangible component of the system, consisting of the knowledge that

[4] Hawkins, F. H., *Human factors in Flight*, Gower Publishing Company, London, 1987.

[5] Reason, J.T., *The Human Error*, Cambridge University Press, New York, 1990.
Reason, J. t., *Managing the risks of organizational accidents*, Ashgate Publishing Company, UK, 1997.

operators use to carry out their specialised activities. It can take the form of both written and formalised procedures and operational practices that are known to all members of the organisation in question but have not been included in official documents.

- ***Hardware***: represents the material component of the system, consisting of the tools, equipment, infrastructure elements used by operators to carry out their work.
- ***Liveware***: it is the human component of the system, represented by the colleagues with which each operator must collaborate and/or coordinate to carry out his work.
- ***Environment***: corresponds to the physical, social, economic and organisational environment within which the other components interact with each other.

The use of the SHELL model requires that the analysis of the mechanisms impacting human performance in any organisational system be carried out by identifying the elements that are part of the four components mentioned above and analysing the interactions between them. Figure 19 shows a graphical representation of the SHELL model, in which it is immediately noticeable that the human component of the system, *Liveware*, appears at the centre of the image as a component interacting with all the others, and among the components with which the human component itself can interact, in order to emphasise, among the possible interactions, that between the different human operators of a complex organisational system.

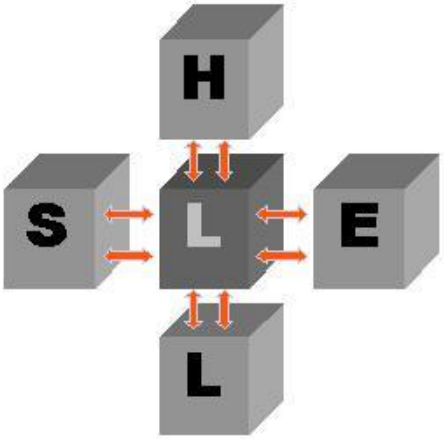


Figure 19 - Graphical representation of the SHELL model.

In contrast, the SWISS CHEESE model, which is graphically shown in Figure 20, emphasises the role of security systems within each organisational system as a barrier to prevent ordinary hazards from turning into accidents. Depending on the model, each barrier is represented by a slice of cheese.

è Since there is no absolute security, each barrier has flaws represented by the holes in the slices of cheese. These holes, considered individually, are not a problem in themselves. On the other hand, the can become a problem by causing accidents that can be very serious, when they begin to align themselves by combining the consequences of actions against safety committed by front-line operators (the “active errors”, typically committed by train drivers, pilots, operators of a nuclear power plant, etc.) with those due to possible systemic dysfunctions (the “latent conditions,” due to the choices made by managers and system designers), which can remain hidden even for a long time and unfurl their potential only when combined with active errors.

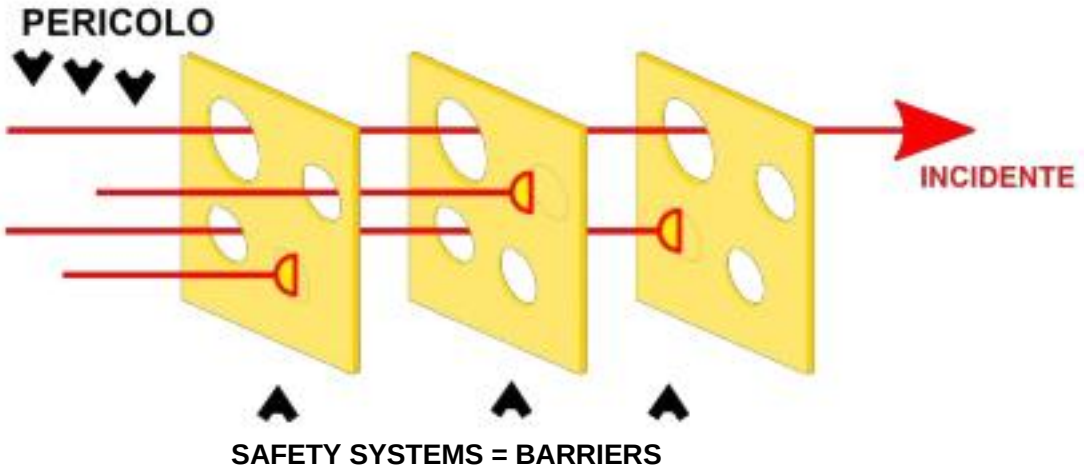


Figure 20 - Graphical representation of the SWISS CHEESE model.

The methodology is divided into several phases, which are outlined in the following diagram[6]:

Figure 21 - Schematic diagram of the different phases of SOAM methodology.

As you can see, a preliminary phase, which consists of collecting the elements that will be analysed, is followed by five central phases corresponding to as many levels of analysis. Finally, the last phase, which is the preparation of the SOAM diagram, aims to summarise the results of the analysis.

The following sub-paragraphs describe the objectives of each phase, while in the following paragraph 4.7 the SOAM methodology is applied to the accident subject of this investigation report.

[6] *EUROCONTROL Guidelines on the Systemic occurrence Analysis methodology (SOAM)*, Safety Regulation Commission, 2005, available at the following link: https://www.skybrary.aero/articles/systemic-occurrence-analysis-methodology-soam.

4.6.1. Preliminary phase: Collecting SHELL data

At this preliminary phase, the *Software*, *Hardware*, *Liveware*, *Environment* components, as defined above, which are believed to have played a major role in determining the accident, are identified. In particular,

- ***Software***: the regulations, procedures, operating provisions, manuals, significant for the execution of the tasks performed during the event.
- ***Hardware:*** the tools, equipment, workstations, infrastructures used by the staff involved in the event in carrying out their activities, who have played a direct or indirect role in the event itself.
- ***Liveware***: the staff members involved in the event either directly or indirectly, clearly identifying their role within the organization.
- ***Environment***: working conditions, physical and chemical environmental conditions, characteristics of the cultural, social, and organisational environment that are believed to have had an impact on the way events took place. By convention, this category includes elements that the organization involved in the event must consider as data and cannot be modified, whereas *Software*, *Hardware*, and *Liveware* are, at least in principle, modifiable by the organisation itself.

The elements identified for each category are placed in a simple table consisting of four columns and constitute the data available for the subsequent methodological phases. However, it should be noted that the realisation of such a table is necessarily an iterative process, since during the execution of the subsequent phases it is possible to return to this preliminary phase to add elements that were not identified as relevant at first, or exclude elements that were considered significant, but which in the course of subsequent analysis phases turn out to be of little importance.

4.6.2. Phase 1: Barriers Identification

At this phase, safety barriers that could have played a role in preventing or mitigating the adverse effects of the event but which for some reason were not present or could not adequately perform their function at the event are identified. Barriers are elements of the organisational system being analysed that have been designed only with safety objectives and do not perform any other function. The following are different categories of safety barriers, which differ according to their specific function:

- Barriers that help to become aware of a danger.
- Barriers that impose restrict on dangerous behaviour.
- Barriers that help to detect potentially dangerous events.
- Barriers that support the temporary management of a degraded condition.
- Physical protection and containment barriers against a hazard.
- Barriers that facilitate to escape or evacuate from a hazard.

The request for control for the inclusion of an element among the barriers is as follows:

Does the identified element describe a protection system, physical barrier, alarm system or operating procedure designed to prevent a security risk or mitigate its consequences?

4.6.3. Phase 2: Errors Identification and/or Violations

At this phase, unsafe actions committed individually by operators are analysed, classifying them according to the *General Error Modelling System* (GEMS) developed and proposed by James reason[7]. According to his model, unsafe actions are identified as errors or violations. These two categories of unsafe actions are also divided into a number of sub-types.

Errors can be classified into:

- **Skill based** (SB) can also be classified as:
  - ***Slip***: Execution errors due to an action performed differently than learned. The operator knows how he should perform a task, but nevertheless performs it incorrectly.
  - ***Lapse***: execution errors caused by forgetfulness.
- **Mistake**: Errors due to incorrect execution, despite the action being done as planned. They in turn can be classified as:
  - ***Rule-based*** (RB): errors due to the application of the incorrect rule due to a wrong perception of the situation.
  - ***Knowledge-based*** (KB): errors due to lack of knowledge or its incorrect application. The failure to act is determined by erroneous knowledge.

Violations can be classified according to two different criteria:

Reason for violation

- Optimising violations
- Violations of necessity
- Sabotages

Frequency of violation

- Routine violations
- Exceptional violations

The classification of each unsafe action is associated with a reason that explains what elements were considered to determine the type of classification. It is important to verify whether there are several unsafe actions that have combined with each other and never assume that there has been a single mistake or a single violation. For example, the error committed by one operator could have been added to the violation of another operator. Or the same operator may first have committed a violation and then an error, or vice versa.

Note that this methodology phase has been changed from the original SOAM methodology, in which unsafe actions performed at the individual level are analysed using the *Decision Ladder*[8] instead of the GEMS model. The main difference is that in the

[7] Reason, J. T., *The Human Error*, Cambridge University Press, New York, 1990.
[8] Rasmussen, J., *Outlines of a hybrid model of the process plant operator*, in T. B. Sheridan & G. Johannsen (Eds.),

Decision Ladder model errors that arise from perceptual issues are categorised in their own right, unlike in the GEMS model. This methodological choice is justified by the need to facilitate the use of the methodology in the Italian railway sector, in which GEMS has already been widely used, as well as by the lesser weight of perceptual errors in the railway sector.

The request for control for the inclusion of an element among errors or violation is:

Does the identified element describe an action (or non-action) of an operator that produces an unsafe result?

4.6.4. Phase 3: Contextual Conditions Identification

Contextual conditions describe the circumstances and preconditions at the time of the accident, which may have had a direct influence on the performance of operators in their working environment, including by favouring errors or violation by operators themselves.

The main categories of contextual conditions are as follows:

- working environment conditions;
- organisational climate;
- attitudes and personalities;
- performance limits;
- physiological and emotional factors.

The request for control for the inclusion of an element in the contextual conditions is:

Does the identified element describe an aspect of the local work context, organisational climate, physiological condition, performance limits of people, which is useful in explaining their behaviour in that context?

4.6.5. Phase 4: Organisational Factors Identification

Organisational factors are those factors that may have contributed to the occurrence of the accident, which existed before the event happened. They may have favoured or made possible contextual conditions that in turn influenced the actions (or lack of actions) of those on the front line.

The main categories of Organisational Factors are indicated in the following list:

- organisational culture;
- policies and procedures;
- training activities;
- staff management;
- equipment and infrastructure;
- risk management;
- internal communication;
- definition of responsibilities;

Monitoring behaviour and supervisory control, pp. 371-383, New York: Plenum, 1976.

- procurement and design of technological and infrastructure equipment;
- maintenance management.

The request for control for the inclusion of an element among Organizational factors is:

Does the identified element describe any aspect of the organisation, its procedures, its processes that existed before the critical event and that led to or made possible the contextual conditions underlying the event itself?

4.6.6. Phase 5: Other System Factors Identification

Other system factors are those elements external to the organisations involved in the event that have had an influence in determining the organisational factors and contextual conditions that in turn made the event possible or even favoured, such as:

- national and international rules, and regulations;
- relations with supervisory, and control authorities;
- relations with partners, customers, and suppliers;
- socio-economic factors.

Similar to what has already been described in relation to the *Environment*, in the SHELL model, "Other System Factors" are to be considered as data and not modifiable by the organisation involved in the event.

The request for control for the inclusion of an element among Other System Factors is:

Does the identified element describe an aspect of the regulatory framework or socio-economic context in which the organisation operates or its relationship with other organisations, which has had an influence on organisational choices?

4.6.7. SOAM Diagram Processing

The SOAM diagram of the event (SOAM *Chart*) summarises all the factors identified in the different phases. The event diagram consists of two main elements:

- the factors identified, which are grouped according to the five levels described above:
  1) Barriers Not Present or of Limited Effectiveness
  2) Errors and Violations
  3) Contextual Conditions
  4) Organizational Factors
  5) Other System Factors
- the horizontal *links* that combine factors that have been identified at different levels. For example, the *link* between individual Errors and Violations and the contextual conditions that favoured them, or the *link* between Contextual Conditions and the Organizational Factors that represented their antecedents.

4.7. SOAM analysis of the accident

This section describes the application of the SOAM methodology to the derailment of train 4132 of EAV which occurred at the Pompei Santuario station, on the line Naples-Torre Annunziata-Poggiomarino, on 07/11/2022. The section concludes with the SOAM diagram of the event, which summarises all elements considered in the analysis and the relationships that have been identified between those elements.

4.7.1. Preliminary phase: SHELL data collection for the accident

As illustrated above, all *Software*, *Hardware*, *Liveware* and *Environment* resources considered significant for the event must be identified in the preliminary phase of the SOAM analysis, according to the SHELL model. Their identification was the result of an initial analysis of the interactions observed in the event reconstruction described at the beginning of this chapter. In particular, the analysis took into account the roles of the staff members involved in the event either directly or indirectly (*Liveware*) and reconstructed the interactions between these roles and the other S-H-E-L resources (thus also including interactions with other *Liveware*). These are basically the interactions that occurred both during the event itself and earlier during the career of the individual operators. For example, the one between the AdC of train 4132 and the ETR223 electric train is an L-H interaction that certainly occurred during the event, but also concerns how the operator is used to interacting with that *hardware*. Similarly, the interaction between the DL in service at the Pompei Santuario station at the time of the event and the regulatory provisions contained in the *Regulation for the Circulation of single-manager trains* is an L-S interaction that occurred both during the training course to which the operator was subjected, and during any professional updates and during the event itself, as the regulatory provisions are used as a reference guide to carry out the activity.

è Finally, the interactions between DL and DU (but also those with all other operators) are L-L type interactions and concerned both the way in which operators got used to working together during their careers and communication coordination and exchanges that took place during the specific event.

It should be noted that, for reasons of synthesis, in this context, specific interactions are not analysed on the basis of the SHELL model, but all SHELL resources that have been considered relevant are simply listed and become the object of the five levels of analysis of the SOAM methodology that will be presented below (see paragraphs 4.7.2 to 4.7.6).

Table 4 – SHELL resources considered significant for SOAM analysis

Software	Hardware	Liveware	Environment
- Regulation for the circulation of single-manager trains (2010) - Signalling Regulation (2011) - Instructions for the operation of Central Electrically Controlled Routing with push-button and for the operation of Automatic Block (1998)	- ETR 208 - ETR 223 - Composition METROSTAR 208-223 - CdB 2 of Pompei Santuario station - Switch 4 of the Pompei Santuario station - ACEI of the Pompei Santuario station	- AdC train 4132 - DL Pompei Santuario station in service at the time of event - CT train 4132 in service at the moment of the event - DU in service at the time of the event - Responsible for the maintenance of the CCS subsystems	- Pressure exerted by travellers - Increased pressure exerted both by travellers waiting for train 4132, which was delayed, and those on train 4125 waiting to cross on platform 2 of the Pompei Santuario station - Working space of the DL open to third parties - Working hours of the DL

4.7.2. Phase 1: Identification of Barriers not Present or of Limited Effectiveness

An examination of the available documentation shows that the barriers that could have played a role in preventing the event are:

Barrier 1/Monthly preventive maintenance of track circuits.

From the available documentation, there is no evidence, after 13/08/2022, of the planned preventive maintenance carried out on a monthly basis by ACEI and of the track circuits of the Pompei Santuario station.

Barrier 2/ Regulations for the circulation of single-manager trains (2010).

In that Regulation, in point 10 of Art. 4 - *Routes and Safety Devices* it reads as follows:

Switches on the running track, which are facing met by trains and protected by a signal, must be equipped with a safety connection to the latter signal.

Where such connections are exceptionally lost due to the malfunction of the manoeuvring and control devices at the switches and for ACEI being out of service or switched off, these facing switches must be ensured by safety locks by the station staff.

In the absence or in the event of inefficiency of the safety locks, ***the facing switches must be present*** *and run at sight at speeds of less than 5 km/h, unless otherwise specified.*

No speed limitation or requirement is required if the switches are nailed in the proper position.

***Barrier 3/ Instructions for the operation of Central Electrically Controlled Routing with push-button and for the operation of Automatic Block* (1998).**

Paragraph 6.1 of that document states:

In the event that a switch is not controlled or, where it has failed, is not re-controlled, as will be explained below, it must be considered defective and without a lock.

while para. 6.2 states:

Except in the case of a power supply failure of the controls discussed below, the Operator must first ascertain whether the switch and the external manoeuvring parts are intact, ***either by going to the site or by using another agent****.*

In this case, the two barriers did not work because the DL of the Pompei Santuario station did not ensure its presence at switch no.4 as required by the documents mentioned.

4.7.3. Phase 2: Errors Identification and/or Violations related to the accident

The analysis of the unsafe actions committed by operators at individual level led to the identification of two violations and one error. It should be highlighted that these terms are used in a technical sense, taking into account their definition in the context of the GEMS model, and without any reference to value judgements or attribution of responsibility for the incident, which fall outside the aims of this report.

In particular, errors are actions committed by the operator that, according to reconstruction the facts, fail to achieve the objective that the operator himself had set himself. On the other hand, violations are actions committed in the knowledge that they are acting in a way that is not in accordance with the rules recognised in the specific working environment. The violations and errors identified are listed below, identifying who committed them and describing their circumstances.

Violation 1/DL of Pompei Santuario station

The DL of Pompei Santuario station changes the configuration of switch 4 from a diverted to a normal switch, without noting that train 4132 had cleared the relevant immobilisation circuit, as it would have been required, since the latter had been out of order since 10:00 a.m. on the same day as the accident occurred.

Violation 2/AdC of train 4132

The AdC of train 4132, when approaching the Pompei Santuario station, exceeded the speed control, causing ATP emergency braking to be applied and the train to stop with the front end at the end of the platform of track 1 on the Poggiomarino side, where it remained stationary for 20s. In that position, the train, whose overall length is about 80 m, had not yet fully passed the switch no.4 which had been positioned, using the emergency keys, in a deviated configuration precisely to allow the arrival at track 1 of the station. It is probably, with the train in this position, the extremity of switch 4 was located between the two bogeys of the locomotive M2 of the ETR 208. During this time the DL, without verifying *with his own eyes* the complete transit of the train over the switch (cf. Violation 1), but assuming that the time elapsed since train 4132 entered the station was sufficient for the completion of the parking phase, it brought switch no.4 to its normal configuration, so that at the departure the CV6 and CV4 bogeys at the rear of ETR 208 derailed, with the CV6 bogey being routed on track 2, while the CV4 bogey was out of way between tracks 1 and 2.

Error 1/ - The person responsible for the maintenance of the CCS subsystems

From the available documentation, there is no evidence of the planned preventive maintenance carried out on a monthly basis by ACEI and of the track circuits of the Pompei Santuario station after 13/08/2022. The consequences of this circumstance are also supported by what was declared by the DL of Pompei Santuario Station in its report on the event, which reads: "*As train 4132 passed, however, the switch 4 went out of control, a malfunction that had been recurring for some time, I followed the train route from the ACEI visual control panel and I had the perception that the train had cleared the entire route, as I was used to elastic clearance and also because not all the light bulbs of visual control panel were working*."

With regard to the identification of the specific types of violations and errors, based on the GEMS model subcategories, violations 1 and 2 are part of the case of optimising violations, as they appear to address only positive objectives of an individual nature, such as the ability to perform the necessary operations more quickly than is required by the procedures and not by organisational necessity. As regards the difference between exceptional and routine violations, it can only be assumed that none of the violations were of an exceptional nature, but there is insufficient evidence to show that they were routine violations in all cases.

Error 1, on the other hand, is part of the *Slip Skill based type*.

4.7.4. Phase 3: Contextual Conditions Identification related to the accident

As mentioned in paragraph 4.6.4, the contextual conditions are factors present at the specific location where the accident occurred, which may have been preconditions that made possible or favoured unsafe actions performed at the individual level. These preconditions may include the mental predispositions or psychological conditions of individual operators, the habits and beliefs spread among people working on site, and finally the aspects of the ergonomics of the working environment and the tools used by people that affect the way they work. The five contextual conditions that are believed to have affected the way in which the DL and AdC involved in the event operated are identified below.

CC1/ Pressure exerted by passengers at the station.

This condition, which was already present under normal operating conditions, due to the size of the catchment area that is not adequately reflected in the transport capacity of the infrastructure, was further exacerbated on the day of the accident by the pressure exerted both by passengers waiting for train 4132, which was delayed, and by those of train 4125 waiting to cross on platform 2 of the Pompei Santuario station.

***CC2/malfunction* of CdB2.**

From around 10 a.m. on the day of the accident, CdB 2, immobilising switch no.4, was out of service, and it was occupied even in the absence of a train transiting on it.

CC3/ Working space of the DL open to third parties.

The presence of other people in the working space of the DL can potentially affect the work of the latter.

CC4/ The DL had been working for more than 8 hours at the time of the accident.

This circumstance, together with the need to manage the traffic in degraded mode for about 50 % of the working time and the pressure exerted by travellers at the station, may have affected the quality of the DL's performance.

CC5/ DL's practice of not ascertaining the release of the damaged track circuit in presence.

In order to verify the release of the damaged track circuit, the DL used the ACEI visual control panel and the estimated time elapsed from the transit of the train to the protection signal, instead of performing the in presence check as required by the regulations in force.

4.7.5. Phase 4: Organisational Factors Identification related to the accident

As mentioned in paragraph 4.6.5, organizational factors are elements that may have contributed to the occurrence of the critical event, but which already existed even before the event happened. The only organisational factor that is considered to have played a role in determining the contextual conditions and unsafe actions, which are described above, is described below.

FO1/ Incompleteness and communicative obsolescence of the relevant regulatory provisions.

The reference regulation for operational safety reference regulations used by EAV, in its capacity as infrastructure manager and railway undertaking, are as follows:

- *Regulations for the circulation of single-manager trains* (2010);
- *Signal Regulation* (2011);

to which the document is to be added:

- *Instructions for the operation of Central Electrically Controlled Routing with push-button and for the operation of Automatic Block* (1998),

which, in addition to providing the technical instructions for the operation of ACEI, contains regulatory provisions on operational safety. As an example, consider what is stated in Chapter 6 for abnormalities relating to switches:

- Par.6.1: *In the event that a switch is not controlled or, where it has failed, is not re-controlled, as will be explained below, it must be considered defective and without a lock.*
- Par.6.2: *Except in the case of a power supply failure of the controls discussed below, the Operator must first ascertain whether the switch and the external manoeuvring parts are intact,* ***either by going to the site or by using another agent****.*

As can be seen, these documents are rather dated, unclear, especially in the instructions on the management of traffic in degraded mode, and even partially incomplete. For example, with reference to the TB regime in the station, which is mentioned in the EAV *Investigation Report*, the only EAV regulation in which this regime is mentioned is the *Signal Regulation*, but only limited to the case of the departure of a train from the Naples Porta Nolana and Naples Piazza Garibaldi stations.

It should be pointed out here that, in order to be effective and authoritative, a regulation, especially in the field of safety, must be based on five fundamental principles: clarity, precision, uniformity, simplicity, and completeness. In particular, a regulation:

- is clear, if it has certain contents, a clear structure, and a coherent development;
- is precise, if it does not lead to misunderstandings and avoids any semantic and syntactic ambiguity;
- is linguistically uniform, if it allows unequivocal recognition when referring to the same topic;
- is simple, if it gives preference to words known to most people and if it organises the sentences in a linear manner;

The above-mentioned documents do not appear to comply with these principles, especially with regard to cases of f traffic management in degraded mode.

4.7.6. Phase 5: Other System Factors Identification

No factors external to the organisation that are believed to have had an influence in determining the organisational factors and contextual conditions described in the previous paragraphs have been identified.

4.7.7. SOAM diagram of the accident Figure 22 shows the SOAM diagram of the accident.

It allows, firstly, to summarise all the elements of analysis described above, which have been identified as contributing factors or, at least, making possible the occurrence of the events leading to the accident. Secondly, the diagram facilitates the identification of conceptual and temporal *links* between all the elements identified at the different levels of analysis.

The diagram should be preferably read from the right side (that of the accident and the actions of the staff working on the front lines), to the left side (that of the factors physically and temporally more distant from the scene of the event which may nevertheless have played a role in determining it).

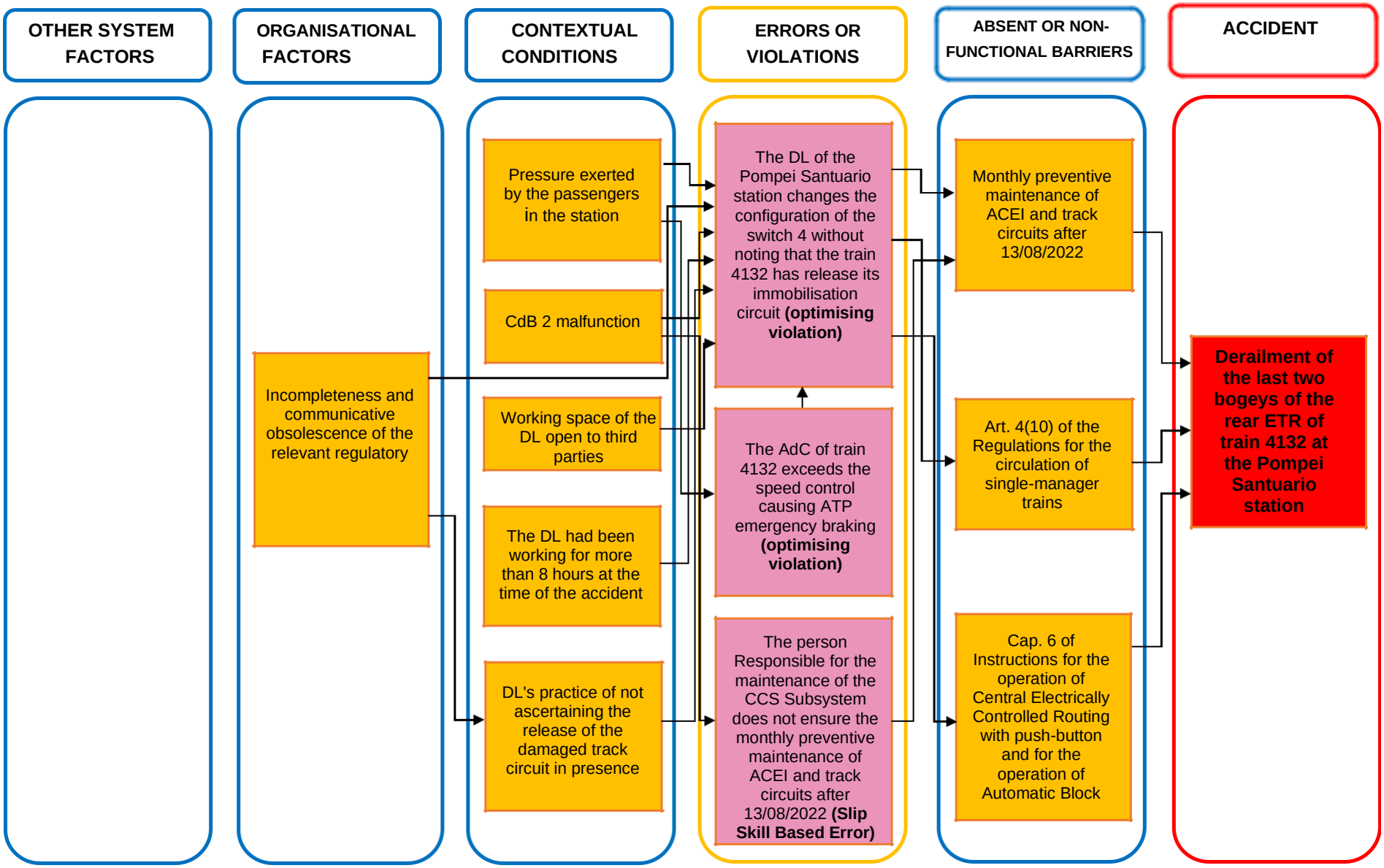
In the present case, starting from the right, the regulatory and procedural barriers that did not prevent the event from occurring are first highlighted, as they were not applied. In particular, Article 4(10) of the *Regulations for the circulation of single-manager trains*, chapter 6 of the *Instructions for the operation of Central Electrically Controlled Routing with push-button and for the operation of Automatic Block*, and the monthly predictive maintenance of the ACEI and the track circuits.

Immediately linked to them, further to the left, there is the individual action that represents the direct causal factor of the accident, represented by Violation 1 (DL of the Pompei Santuario station modifying the configuration of switch 4 without noting that train 4132 had released its immobilisation circuit). Added to this is Violation 2 (AdC of train 4132 exceeding the control speed, causing ATP emergency braking to be applied and the consequent stopping of the train): the 20s delay in the parking of train 4132 contributed indirectly to the accident as the DL brought turnout 4 back into its normal configuration while the related CdB was still occupied, assuming that the time elapsed since train 4132 entered the station was sufficient for the completion of the parking phase. Finally, among the actions that contributed to the occurrence of the event is certainly the failure to carry out monthly preventive maintenance of ACEI and track circuits after 13/08/2022, which can be classified as a *Slip Skill Based* error to be attributed to the person responsible for the maintenance of the CCS subsystems.

Observing the central part of the SOAM diagram, the role played by the identified contextual conditions is significant, with particular reference not only to the malfunction of CdB 2, but also to the DL's practice of not ascertaining the release of the damaged CdB in presence, favoured by the pressure of waiting travellers and probably excessive working hours, which are made even more burdensome by the operation of the traffic in degraded mode.

Finally, the indirect role played by the only organisational factor identified, represented by the incompleteness and communication obsolescence of the relevant regulatory provisions, all dating back more than a decade and requiring a thorough revision of language and content, should also be emphasised.

Figure 22-SOAM Diagram of the accident.



5. Conclusions

5.1. Summary of the analysis and conclusions regarding the causes of the event

The causal factors behind the accident, which emerged from the analysis, can be attributed to the following actions of the staff involved in the event:

- The DL of the Pompei Santuario station has disregarded the provisions of Article 4(10), the *Regulation for the Circulation of single-manager trains* and chapter 6 of the *instructions for the operation of Central Electrically Controlled Routing with push-button and for the operation of Automatic Block* by modifying the configuration of switch 4 from a diverted to a normal switch, without first ascertaining that train 4132 had cleared the relevant detector track circuit, as would have been requested, since the latter had been out of service since approximately 10:00 a.m. on the same day as the accident occurred;

The causal factors behind the accident can be attributed to the following circumstances:

- degraded mode of traffic due to the failure of CdB 2 which excluded the automatisms normally provided by ACEI;
- the person responsible for the maintenance of the CCS subsystems did not ensure, after 13/08/2022, the monthly preventive maintenance of the ACEI and the track circuits of the Pompei Santuario station;
- the practice on the part of the DL not to ascertain in person the release of the damaged track circuit, but to use the ACEI light panel and, probably, the estimate of the time elapsed from the transition to the protection signal placed at the station entrance;
- exceeding the control speed by train 4132, which resulted in the emergency braking by ATP, in the consequent stopping of the train before its arrival at Pompei Santuario station, and in a delay of 20s in parking on platform 1 at the Pompei Santuario station. This circumstance contributed indirectly to the accident as the DL brought the switch no.4 back into its normal configuration while the relevant CdB was still occupied by train 4132, assuming that the time elapsed from the passage of the train to the protection signal at the train station entrance was sufficient for the completion of the parking phase;
- the DL and AdC perception of the pressure exerted by the passengers of the train 4132 increased by the need to accelerate the departure of the cross train that had been waiting for the departure signal for more than 20 minutes;
- working hours of the DL, which had exceeded eight hours, of which approximately four hours dedicated to the management of traffic in degraded mode, due to the failure of the CdB 2;
- working space of the DL is open to third parties, which could have distracted the DL from his duties.

The systemic factors that may have affected the occurrence of the event are attributable to:

- a lack of perception by the operators involved of the safety risks associated with non-compliance with regulatory provisions;
- a management of working that does not take into account any additional workloads resulting from the need to ensure circulation in conditions of infrastructure degradation due to the occurrence of malfunctions;
- the incompleteness and communication obsolescence of the relevant regulatory provision.

5.2. Measures taken after the event

The DM of the station of Pompei Sanctuary in service at the time of the occurrence of the derailment was relieved from duty, with a prescription, pursuant to art. 4 annex C of ANSF Decree no. 4 of 2012, not to be reused in any safety activity pending the carrying out of the investigation. 5.3. Additional remarks

Not significant for the purposes of the investigation.

6. Safety recommendations

Recommendation no. IT-10335-01

It is recommended that the National Agency for Railway, Road Infrastructure and Motorway Safety ensure that infrastructure managers comply with and monitor the implementation of the activities envisaged in the preventive maintenance plans for facilities and equipment, assessing their effectiveness and adequacy in terms of the frequency of maintenance activities, also in relation to the age of the facilities and equipment being maintained.

Recommendation no. IT-10335-02

It is recommended that the National Agency for Railway, Road Infrastructure and Motorway Safety ensure that infrastructure managers and railway undertakings carry out an audit and a possible reassessment of working hours or remodelling of the service, in relation to the increased workloads resulting from the deterioration of the infrastructure due to the occurrence of breakdowns.

Recommendation no. IT-10335-03

It is recommended that the National Agency for Railway, Road Infrastructure and Motorway Safety ensure that the RU and the EAV IM proceed as soon as possible with a redrafting of their regulations inspired by the principles of clarity, precision, uniformity, simplicity and completeness, especially with reference to the safety procedures to be adopted to guarantee the operation of traffic in the event of infrastructure degradation due to the occurrence of breakdowns.

Recommendation no. IT-10335-04

It is recommended that the National Agency for Railway, Road Infrastructure and Motorway Safety consider the advisability of requesting the RU and the EAV IM to issue an internal measure clearly highlighting the importance of full compliance with the regulatory provisions for safety purposes, accompanied by an appropriate training action for the operators involved, especially with reference to the safety procedures to be adopted to ensure the operation of traffic in the event of infrastructure degradation due to the occurrence of breakdowns.

Recommendation no. IT-10335-05

It is recommended that the National Agency for Railway, Road Infrastructure and Motorway Safety ensure that the EAV IM takes measures to inhibit the access of unauthorised third parties to the working environment of the Local Manager.

(Prof. Ph.D. Ciro Attaianese, Engineer)