Rail to Digital automated up to autonomous train operation

D5.2 – Documentation of use cases for Perception system

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EXECUTIVE SUMMARY

The objective of Flagship Project (FP) 2 is to provide Digital & Automated (up to Autonomous) Train Operations for the Rail industry and hence it is named R2DATO. It is important to realize that the term Rail industry is quite wide and includes the operators, infrastructure managers, rail supplier industries, research & innovation and expert user groups. Any new technology being developed needs to start with a problem statement and the use cases that the technology can cater to. As part of Work Package 5, the workgroup consisting of the above rail experts have focussed on the use case and operational scenario development. This deliverable provides the foundation for the Perception technical enabler.

X2Rail-4 has permitted to craft an architecture for the autonomous train ([SRS X2Rail-4 v0.3] [1] in X2Rail-4 delivery v0.1). A return on experience was that an operational analysis would further refine the outcome. In successor project R2DATO, WP5 addresses this need. WP5.2 focuses on perception-related use-cases: those dealing with unplanned obstacles or events in the track and train vicinity.

In a first step, WP5 collected use-cases potentially pertaining to an autonomous train out of predecessor projects TAURO and X2Rail-4. Partner companies ALSTOM, CAF, CEIT, DB, NS, RENFE, SBB, SIEMENS completed these lists with use-cases internally identified. After synthesis, WP5.2 took over those related to perception. Through a prioritization methodology created by the workgroup, 59 use cases were identified for evaluation. Each use-case was then drafted according to a template common to WP5: a.o. purpose, summary, pre-conditions, steps, post-conditions. Further consolidation was performed resulting in the final 21 detailed use cases.

The use-cases are all considered starting with a train up and running in GoA3-4 operations (WP 5.1), with or without some monitoring by a remote driver (WP 5.4).

The work permitted to identify and detail key use-cases for the autonomous train. For all use-cases, a reaction chain for the train was defined. This permits to focus X2Rail-4's variablility (functions emulate Action from Driver, define evaluated reaction depending on incident, define reflexive reaction depending on incident) and sets the foundation for later european harmonization. Next list gives an overview of these use-cases according to the grant agreement's general areas:

1. **Obstacle Detection**: A generic obstacle avoidance use-case could be synthesized, followed by some Human accident involving injury or death, Wandering livestock/objects, Human injury or death – on track or in the vicinity, defining the train's own track.
2. With regards to the **signal reading** functionality, four use-cases have been issued to cover the need for ATO in areas without ERTMS/ETCS. Three use cases reflect regular operations: from long range detection of signals, driving regularly according to lineside signals, to the transition between ETCS fitted and lineside signaling equiped areas. Another use case for non regular operations has been defined in describing the reaction to non permanent signals such as temporary speed restrictions.
3. **Surveillance of locations associated with an increased risk for collision**: Use-cases introduced by the autonomous train itself were elicited, adapting the train's maximum speed to its visibility. It shall be considered during architecture together with the remote-control specific degraded use-cases. An use case details the need to monitor the horn's availability (safety).

4. **Detection of infrastructure defects and anomaly** : Fire on embankment , Flooding, Broken or Buckled rail, Damage to catenary, Rail adhesion estimation, Unusual impact or movement are detected. Diverse temporary speed restrictions are processed.
5. Standard operations key use case **automatic coupling** was precised based on urban experience, including coordination by trackside and taking into account the opportunities offered by main line's obstacle-driven perception capability. Driving inside depots have also been included.

Although addressed in the grant agreement, two use-cases were extended under the light of obstacle coordination by track-side: On Line People Detection, Fire on embankment. Especially, managing humans beyond the line of sight of a train, although not specifically about its own perception, seamed of great importance for later safety demonstrability of the complete system.

A prioritization has been assigned while starting elaboration of use-cases. Priority 1 and Priority 2 use cases have been documented and addressed, while few of them may be continued in future projects. Some use-cases may deserve tuning in safety concepts of their own (e.g., pedestrian behaviour analysis).

Overall, the work sets up a sound structure to handle obstacle management in operations. It permits to refine, also focus, X2Rail-4's architecture in the succeeding WP6 and to plan efficiently validation and testing in the various demonstrators covering mainline (freight and stabling/shunting operations) and regional lines. Similarly, a detailed risk assessment and safety analysis is foreseen to be done in the succeeding WP8 which will provide the relevant safety aspects.

ABBREVIATIONS AND ACRONYMS

ADM	Automatic Driving Module
APM	Automatic Processing Module
ATO	Automatic Train Operation
ATP	Automatic Train Protection
BAMS	Brake-Adhesion Management System
BG	Balise Group
CCS	Control, Command and Signalling
CCTV	Closed circuit television
DMU	Diesel Multiple Unit
EB	Emergency Brake
EMC	Electromagnetic Compatibility
EMU	Electric Multiple Unit
EN	European Standard
EoA	End of Authority
ERA	European Union Agency for Railways
ERJU	Europe’s Rail Joint Undertaking
ERTMS	European Rail Traffic Management System
ETCS L1 LS	European Train Control System - Level 1 – Limited Supervision
ETCS	European Train Control System
ETCS-OB	European Train Control System – Onboard
EU	European Union
EVC	European Vital Computer
FMS	Fleet Management System
FP	Flagship Project

GoA	Grade of Automation
IEM	Emergency Manager
IIM	Incident Manager
IM	Infrastructure Manager
IMS	Incident Management System
IOM	IM Operations Manager
IPM	Incident and Prevention Manager
IPM-OB	Incident and Prevention Manager – Onboard
IPX	Innovation Programme X (Shift2Rail)
IT	Information Technology
JP	Journey Profile
LC	Level Crossing
LOC	Localization
LOC & PAS TSI	Rolling Stock – Locomotives and Passengers Technical Specification for Interoperability
MA	Movement Authority
OAS	Onboard Automation System
OCC	Operations Control Center
OM	Operations Manager
OMTS	Onboard Multimedia and Telematic Subsystem
OPE / TSI OPE	Operation and Traffic Management Technical Specification for Interoperability
OS mode	On sight mode
PER	Perception
PTU	Physical Train Unit
R2DATO	Rail to Digital automated up to Autonomous Train Operation
REP	Repository

RO	Railway Operator
RU	Railway Undertaking
RUS	Railway Undertaking Supervisor
SCV	Signal Converter
S2R	Shift2Rail Joint Undertaking
SIL	Safety Integrity Level
SRS	System Requirements Specification
SL	Line side signalling
TAS	Trackside Automation System
TAURO	Technologies for Autonomous Rail Operation
TCMS	Train Control Management System
TE	Technical Enabler
TM	Traffic management
TMS	Traffic Management System
TR	Technical Report
TRL	Technology Readiness Level
TS	Train system
TSI CCS	Control, Command and Signalling Technical Specification for Interoperability
TSR	Temporary Speed Restriction
UC	Use Case
UIC	Union Internationale des Chemins de fer (International Union of Railway)
WP	Work Package
X2Rail-4	Advanced signalling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers

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1 INTRODUCTION

The document constitutes the Deliverable D5.2 'Documentation of use cases for Perception system' in the framework of WP5, Task 5.2 of FP2 R2DATO.

The Automation Processes Cluster of the FP2 R2DATO is tasked with the mission of architecting and developing Automation Processes through different technical enablers – Automating Functions, Perception, ATO Technology, and Remote Driving. To enable this, it is critical to start with the definition of the use cases and operational scenarios that need to be addressed. The work of WP5, Task 5.2 focuses on the Perception technical enabler and this deliverable document illustrates this work and the outcomes of use cases, operating parameters, and scenarios.

The work content of this deliverable drew inspiration from prior work completed in Shift2Rail, more specifically, from the deliverables of X2Rail-4 and TAURO. These programs provided a set of use cases, that were further progressed and refined through this work package deliverable. The inputs of operational scenarios and use cases were also provided by various partners, based on their experience and expertise as operators, infrastructure managers, rail supplier industries, and research groups.

The work content of this deliverable forms an important foundation for the development of Technical enablers that are to come from the further Work Packages in the Automation Processes Cluster. It provides the operational scenarios and use cases that are important for realizing Europe's Rail vision in the area of Automation Processes. The content will further be utilized and developed in multiple Work Packages, including but not limited to

- **WP6 Automation Processes Specifications:** The objective of this work package is to derive a set of requirements based on the analysis of work package WP5. Then these requirements will be used to specify a System Architecture Specification (SAS) to support the evolution of DATO up to GoA3/4 in cooperation with the System Pillar, the System Coherence (WP3) and the Automation Processes System Architecture consolidating activity in WP4.
- **WP7 GoA3/4 Data Factory Specifications and Implementation:** The goal of this WP is setting the framework for a collaborative solution in the rail sector, the "Data Factory", to jointly collect, store and annotate sensor data and build up all required infrastructure for processing the data as a prototype. WP7 may benefit from the use cases in order to refine the data factory requirements.
- **WP8 Safety Analysis and Risk Assessment:** The objective of WP8 is to centrally cover aspects of safety in the Automation Processes subproject. This activity requires close cooperation with System Pillar and the System Coherence (WP3). It covers the five Technical Enablers (Automating functions, ATO technologies, Perception & Data Factory and Remote Driving), and the activities carried out in previous Shift2Rail projects, such as X2Rail-4 and TAURO will be considered as a relevant baseline. The objective of the task under WP8 is to cover the Safety and Hazard Analysis for Perception technical enabler.
- **WP11 Prototype development of Perception Systems:** This Work Package will focus on the detailed design, development, and validation of the Perception system (TE-06) defined in the Perception Architecture and System Specification in Task 6.4 up to TRL4/5. The scope shall also include the interfaces between the Perception System and its dependent technical enablers. At the validation side of the V-model, the interface testing needs coordination with

the various technical enablers. The perception functions that need to be covered by the perception system are (non-exhaustive list), with additional identified use cases in WP5:

   - 1. Obstacle Detection
   - 2. Signal Reading
   - 3. Surveillance of locations associated increased risk for collision
   - 4. Detection of infrastructure defects and anomaly detection.

- **Demonstrator Cluster:** The demonstrators may use the operational scenarios as a basis for their test and validation scenarios.

The use cases described in this deliverable have been categorized into 5 different categories based on operational scenarios. This is intended to align with the expectations of the Grant Agreement and in parallel provide insight into the scope that is addressed by this deliverable. Further, these categories are expected to align with the work packages that follow, dealing with the development and validation of the Perception technical enabler.

To help with easy readability of the deliverable D5.2, the document is structured as follows:

- Chapter 2 provides the list of operational actors and a brief description of each of the actors that have been used in the detailed use cases
- Chapter 3 provides the detailed development process that has been leveraged by the workgroup. It starts with listing the Grant Agreement objectives, how these objectives are achieved, a description of the prior work inspiration and limitations of the deliverable
- Chapter 4 contains the list of use cases developed, categorized into 5 sections
- Conclusions from the work is summarized in Chapter 5

2 OPERATIONAL ACTORS

This Chapter lists the Operational actors that have been used in WP5.2 during the use case development process and also contains a brief description of each actor. A common set of actors [6] have been used across the work package to be consistent.

#	Actor	Description
1	On-board Automation System (OAS)	On-board Automation System provides all on-board automation functions. It ranges from performing the operational tasks of a train, including control and supervision of the train speed and position, down to control of passenger doors and passenger information system. OAS gathers all on-board logical components including ADM, APM, ETCS-OB, OMTS, PER, REP, LOC, SCV, PIS and TCMS.
2	Trackside Automation System (TAS)	Trackside Automation System owned by the infrastructure manager provides all the trackside automation functions from scheduling a train run down to setting routes and points in the right direction and issuing movement authorities for each train run.
3	Remote Supervision and Control Center	Remote Supervision and Control Center form a part of railway undertaking operations, comprising an organization, facility, personal, and IT environment hosting the remote operations of trains.
4	Remote Driver	Remote driver is part of the Railway Undertaking and supervises and controls the train remotely and drives the train when required from a remote workplace.
5	On-board Driver	On-board driver is part of the Railway Undertaking and drives the train from its physical cabin. On-board drivers may be driving at the journey level (GoA2: engage ATO) or manually (GoA1: manage doors, traction, and braking) with assistance (automatically raise/lower pantographs, automatic coupling, etc.).
6	Fleet Management System (FMS)	The Fleet Management System owned by the railway undertaking provides all central automation functions from gathering and supervising the status of each train down to controlling commands for each train.
7	Operations Manager (OM)	The Operations Manager represents a person responsible for the railway operation of the System in a given geographic area. The operations manager synthesized classic roles ‘dispatcher’ and ‘signaler’. This person is part of the Infrastructure Management entity. Therefore, if the Operations Manager is employed by a railway undertaking, this railway undertaking acts on behalf of the

		infrastructure manager and is considered having replaced the role of the infrastructure manager in this case. The Operations Manager supervises the normal operation performed automatically by Traffic Management and manages specific actions that cannot be executed automatically.
8	Energy Manager	Energy Manager is part of the Infrastructure Management and manages from a control center the electrical power distribution along the track, to overhead lines and third rails.
9	Pedestrian on track	A pedestrian on track, shortened pedestrian if the context is clear, lies the vicinity of the track vicinity. He stands or is walking on railway ground, in the area constituted by the track and its surroundings. The main characteristic of this pedestrian is that he/she may lie in the loading gauge of a track, or enter it without motion other than walk, jog, run, jump. He / she does not need to climb a fence or jump from artefact hanging over the railway ground (adjacent building, bridge). This pedestrian may rely on mature life-saving skills in the vicinity of trains (track maintenance staff, shunting staff, other infrastructure manager staff, train maintenance staff), middle life-saving skills in the vicinity of trains (medical assistance teams, police officers) or not (trespasser). Pedestrians may be found at pedestrian hot-spots (platform, level-crossing) or in the open track.
10	Incident Manager	This person is part of the Infrastructure Management entity, acting in the Incident management process area. The Incident Manager is a person dedicated to the solving of incidents, defined as unexpected events impeding operations. Unlike Emergency managers, Incident managers act from a control center. Their task routinely comprises contracting RU-incident management, Emergency Managers, railway security acting for the infrastructure manager, police force, fire brigade, health assistance staff and sometimes other miscellaneous emergency services such as water and waste management, armed forces, maritime institutions, civil engineering. Incident managers interfaces with Operations managers all along the life-cycle of the incident to help optimize the traffic in spite of degraded conditions while enabling the safe deployment of personal and assets along the track.
11	Police officer(s)	In the R2DATO context, police officer(s) are members of police implied in railway processes when public security authorities are needed. Important in this definition is that the police

		officer(s) are not part of the railway system, unlike security officers. A single police institution may fulfill several roles (criminal, policing, customs). According to the situation, a use-case may require one or more officers. Current actor covers all roles, independently of local institutions and their lawful responsibilities towards railways. The use-cases do not specify how many officers are required.
12	Incident Management System (IMS)	The incident management system is the system supporting the process area Infrastructure Incident Management. As such, it covers the Incident manager's workflow aspects related to incidents. The Infrastructure Incident management is the process area dedicated to the solving of incidents during operations. It comprises incident managers (coordination/remote), emergency manager (coordination/field). Incident Management System is also system trackside responsible for automated detection and handling of non-regular situations (incidents/accidents/failures) in railway operation on the trackside.
13	Physical Train Unit	The Physical Train Unit conveys passengers or freight to its destination. The Physical Train Unit functions come from EN 15380-4 (5.3.1 and 5.3.2) [5].
14	Infrastructure Manager (IM)	Defined by EU Directive 2012/34 as 'any body or firm responsible for the operation, maintenance, and renewal of railway infrastructure on a network, as well as responsible for participating in its development as determined by the Member State within the framework of its general policy on development and financing of infrastructure.'
15	Serviceable Train	The serviceable train is the physical train unit with its On-board Automation System (OAS).
16	Railway Undertaking Supervisor (RUS)	The Railway Undertaking Supervisor represents an employee of the railway undertaking, coordinating the operations of the railway undertaking: - Allocates train consists to train unit runs to fulfill transport demand. - Allocates on-board and remote drivers to train units - Attends train passengers - Acts as incident managers for railway undertakings.

17	Emergency Manager	This person is part of the Infrastructure Management entity, acting in the Incident management process area. Like the incident manager, the Emergency Manager is a person dedicated to the solving of incidents. Unlike Emergency managers, Incident managers act from the field. They may need some delay until they reach the location of an incident. Their task may comprise all those of an incident manager, plus non-automated emergency functions which require local human actions. Like Incident manager, Emergency managers interface with Operations managers all along the life-cycle of the incident to help optimize the traffic in spite of degraded conditions while enabling the safe deployment of personal and assets along the track. The Emergency Manager can also act remotely as a remote driver (X2Rail).

3 DELIVERABLE DEVELOPMENT PROCESS

3.1 DELIVERABLE OBJECTIVES

Deliverable D5.2 is created on the basis of the guidelines as described in the Grant Agreement. Below is the excerpt of the description for WP5.2 from the Grant Agreement:

Task 5.2: Definition of use cases, operational parameters, and scenarios for safe perception systems (Leader: FT; Participants: ATSA, AZD, CAF, GTSD, SNCF, ADIF, NS, SMO, DB, CEIT, HITACHI, NRD, MERMEC, SBB)
(Duration: M1 to M12)

This task shall focus on the use cases definition for safe perception systems for the applications targeted by the automation processes subproject: mainline (including freight and stabling/shunting operations), and regional. Inputs from Flagship Areas 5 and 6 will be considered until M6 (MS1 – Consolidation of external inputs milestone).

As is evident from the excerpt, the task for the workgroup was to focus on the definition of use cases for Perception system in the Automation Processes subproject/cluster. Since the deliverable objective has been described at a global level with a focus on the technical enabler of Perception, it was important to ensure that a robust methodology be created, and a process established for the development of the use cases. The next section provides details on the methodology that was used during the development of the use cases.

3.2 METHODOLOGY FOR USE CASE DEVELOPMENT

The deliverable 5.2 is one of the early deliverables inside the Automation Processes Cluster of R2DATO. This work group relied on deliverables from the Shift2Rail programs of X2Rail-4 and TAURO. In parallel, inputs were also sourced through the partners of the workgroup. These became the fundamental inputs to start the process of input collection. This was an iterative process between the two sources of input to ensure consistency and reduce redundancy (illustrated in Figure [1]) with a circular arrow.

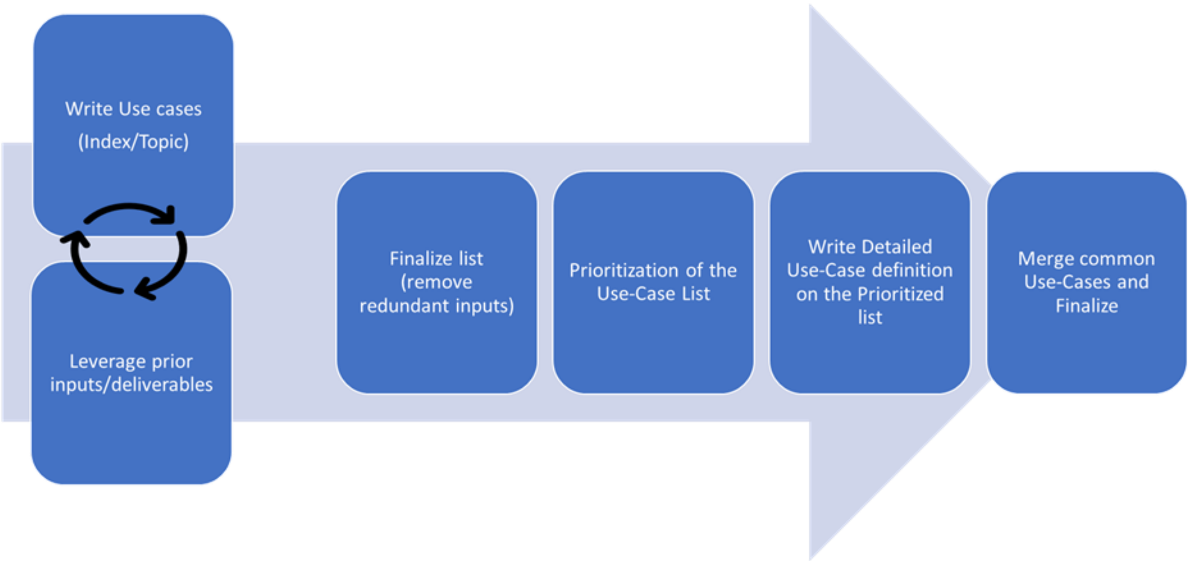

Figure 1: Use Case Development Methodology

The use cases were discussed and approved for inclusion with the partners of WP5.2. The list was then checked for redundancy. The next step of the process was the prioritization of the use case list, with the goal to identify the right priority levels so that the available time and personnel would be effectively used to focus on describing the prioritized use cases. Three levels of priority were defined, as enumerated below:

- Priority 1: Required for higher levels of GoA + inspiration from X2Rail-4/TAURO + feasible in First Call
- Priority 2: Required for higher levels of GoA + feasible in First Call
- Priority 3: Value-add (Nice-to-have) for higher levels of GoA

where conditions stated for each priority are defined in following way:

- Required for higher levels of GoA: The use cases that are required to be defined and developed for achieving higher levels of GoA (GoA3 and GoA4)
- Inspiration from X2Rail-4/TAURO: As the use cases from Shift2Rail were leveraged at the beginning of this workgroup, this defines the list leveraged from X2Rail-4 or TAURO. WP5.2 would expand and refine the work to describe the operational scenarios and use cases
- Feasible in First call: The feasibility is purely defined here based on the workgroup's understanding of the use case at an operational level. As the workgroup may not consist of all the technical experts in this domain, it is simply an indicative proposal

At the final step of this process, the workgroup agreed to develop the Priority 1 and Priority 2 use cases which were 59 in total. These use cases were then distributed among the partners and further developed by the respective parners. During the development, the workgroup also leveraged the Operational Actors developed for the Work Package 5 (further description and the list of actors available in Chapter 2: Operational Actors) and the use case template that was agreed upon by the group for use case development. Leveraging these common templates provided with consistency across the various Technical Enablers and enabled further collaboration on these closely linked Technical Enablers.

Once the use cases were drafted, the workgroup found opportunities to merge use cases that were catering to similar operational scenarios and consolidated accordingly. This enables thoroughness in the defined steps of the use cases to capture the various scenarios inside the use case and would help the further development process of the technical enabler. As an example, many of the Signal detection use cases were merged into a single use case which simplified the development approach. The outcome of this final step resulted in the 21 use cases that are delivered as part of this document.

The workgroup followed a structured approach from the point of drafting the use case to finalizing the use cases with the required consensus and approval. The following 6 steps illustrate this process:

1. First development stage – responsibility of partner writing the use case
2. Review – responsibility of partner reviewing the use case
3. Second development stage – responsibility of partner writing the use case
4. Formal review – responsibility of partner reviewing the use case
5. Third development stage – responsibility of partner writing the use case
6. Finalized (stored in Cooperation Tool) – responsibility of partner writing the use case

As can be seen in the process described, it provided with a good collaboration among the partners for writing and reviewing the use cases before agreeing on the finalized use case.

3.3 Prior Work Inspiration

As described in Chapter [3.2] Methodology for Use Case Development, the workgroup leveraged inputs from prior work done in Shift2Rail. This section provides details of the prior work and its source.

The following Shift2Rail inputs were formally provided to R2DATO for the benefit of WP5:

- Shift2Rail – IPX - TAURO 1st Release package (transfer date 06/02/2023)
- Shift2Rail – IPX - TAURO 2nd Release package (transfer date 31/05/2023)
- Shift2Rail – IP2 - X2Rail-4 Baseline 0 (transfer date 05/05/2023)
- Shift2Rail – IP2 - X2Rail-4 Baseline 0.1 (transfer date 23/06/2023)

The main input for the work conducted in WP 5.2 comes from Shift2Rail, which treated both GoA 2 and GoA 3 and 4. The following 2 sections illustrate this in further detail.

3.3.1 GoA 2

The work conducted in the Shift2Rail on GoA 2 led to an interoperable architecture which was endorsed by ERA and has been published in 2023 in the TSI CCS.

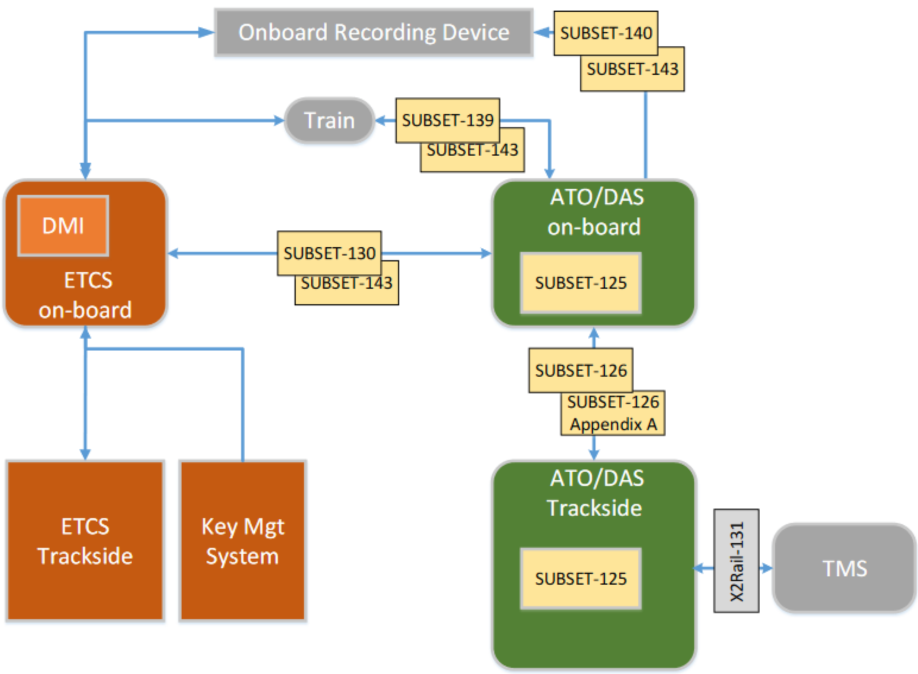

Figure 2: GoA 2 Logical Architecture

3.3.2 GoA 3 and 4

Given the absence of a train driver, the automation in GoA 3 and 4 takes over the same scope of functionality regarding a lot of incidents and scenarios, such as obstacle detection, signal reading, observation of the environment etc., both levels are often mentioned together. Moreover, the technical enabler of this task, the Perception module is similar, if not identical between GoA 3 and 4.

3.3.2.1 X2Rail-4

The work on GoA 3 and 4 architecture was conducted in Shift2Rail within the group 'ATO up to GoA 3 and 4' of the IP2 project X2Rail-4 that took place between 2019 and 2023[1]. In its System Requirement Specification deliverable, the project details the Automatic Train Operation on-board system architecture for ATO over ETCS. Its 4 main modules contain the perception module (PER), which replaces the train driver's vision, as well as the Automatic Processing Module (APM), the on-board Repository (REP) and the Automatic Driving Module (ADM)[2].

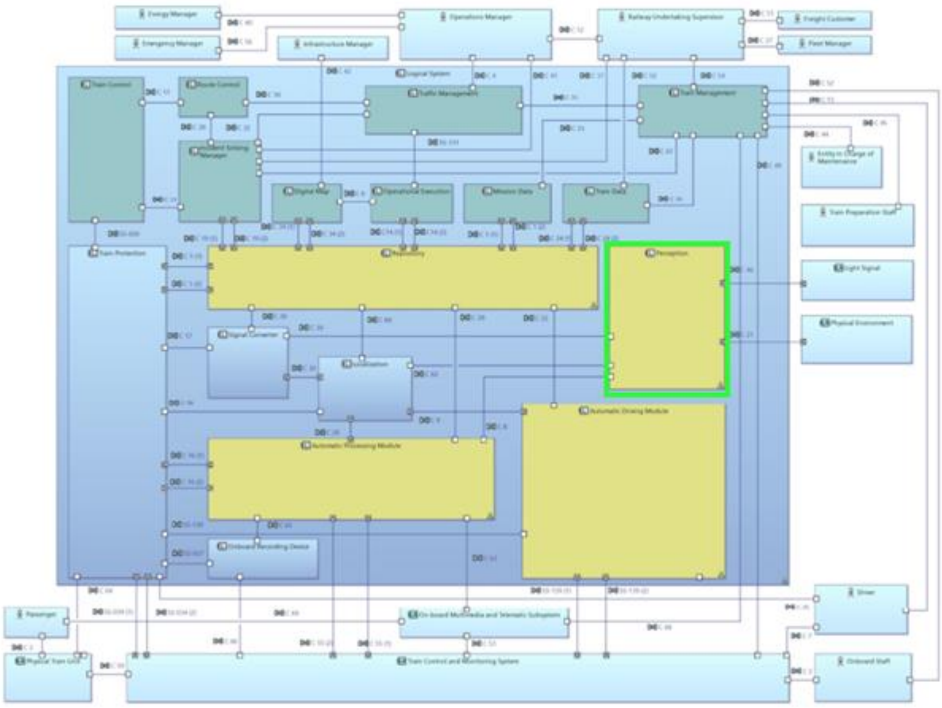

Figure 3: GoA 3/4 Logical Architecture

The central deliverable for the R2DATO WP5.2 was the Deliverable 5.2 'ATO up to GoA 3/ 4' of IP2 WP5. It introduces the central new emerging notions of GoA 3/ 4 (such as perception, the mission profile), defines the main modules, actors, and interfaces. It, furthermore, lists a number of use cases for GoA 3/4 operations.

[1] https://projects.shift2rail.org/s2r_ip2_n.aspx?p=X2Rail-4

[2] System Requirement Specifications: S2R IP2 WP5 Deliverable 5.2 'ATO up to GoA 3 and 4'

3.3.2.2 TAURO

The Shift2Rail IPX project TAURO, which took place between 2020 and 2023[3] set out to complete the work conducted in X2Rail-4 regarding the technologies that are necessary for Automatic Train Operation by investigating 4 main areas:

- Environment Perception (WP1): this work package defined the necessary developments for perception technologies, which includes the certification of Perception systems with AI, the construction of databases for the validation of perception systems and the definition of a sequence of use cases for perception systems (on-board and trackside).
- Remote Driving (WP2): this technology constitutes a complement for the operation of ATO, e.g., as a fallback solution for ATO, but also for the driving in depots and urban rail.
- Automatic monitoring and diagnostics of the status of autonomous trains (WP3): this work package investigated all technological dispositions for the self-diagnostics on the train.
- ATO Migration technologies (WP4): this work included especially the concept for perception-based lineside signal reading technology, as a way of deploying ATO beyond the existing ETCS fitted areas.

3.4 LIMITATIONS

The deliverable D5.2 captures the work completed over the last 12 months to address the objectives defined in the Grant Agreement. While the workgroup has delivered the required objectives, it is also important to capture the limitations and the corresponding recommendations on the future improvement.

Use Case Focus

The focus area that has been considered in this deliverable is on outdoor/environmental monitoring including Object detection, Signal reading, Surveillance of locations associated with increased risk for collision, Detection of infrastructure defects and anomaly detection. This is inline with the Grant Agreement and provides with a prioritized set of use cases that need to be developed to shape the R2DATO vision. Indoor monitoring is not part of the scope of this deliverable. In the future projects, it is expected that the creation of new use cases will continue thereby further enhancing the automation of operational processes in GoA 3 & 4, including the addition of use cases pertaining to indoor monitoring.

Inputs from Flagship areas 5 & 6

As specified in the Grant Agreement, the inputs from Flagship areas of 5 & 6 were expected by Month 6, however they did not arrive by the due date. It was the point in time where the workgroup was finalizing the prioritization of the use cases and taking in further inputs beyond this point would impact the deliverable deadlines. Timely inputs could have yielded a deliverable that included use cases from these Flagships. Based on the late arrival of FP6 input deliverable, the deliverable was

[3] https://projects.shift2rail.org/s2r_ipx_n.aspx?p=tauro

briefly reviewed and comments provided on the use cases overlapping with Perception technical enabler. It is expected that FP6 reviews the deliverable D5.2 and further enhances the use cases to suit their operational scenarios in a future project. As an example, there are use cases involving level crossings which are already included in D5.2 list from the standpoint of detecting objects/humans at level crossings and the corresponding reaction. It is foreseen that FP6 takes these use cases and adapts/enhances them to suit their specific use cases on level crossings in a future project.

Standardized Operational Procedures

On a large-scale project like R2DATO, it would have been beneficial for all clusters to make use of a standardized operational procedure with defined operational actors and interfaces. However, since this was lacking, the work package created templates and actor list that were used within the work package. In future projects, the standardized operational procedures would be valuable that can be co-developed by the System Pillar and Demonstrators.

4 USE CASES FOR PERCEPTION SYSTEMS

The final results of WP5.2 are documented in this chapter. The results are categorized into 5 different sub-chapters.

Chapter 4.1 captures the use cases that focus on the detection of objects/obstacles on the track or in the environment/vicinity of the track. It also contains the reaction to the detection of objects.

Chapter 4.2 contains the use cases related to signal reading, which covers lateral signalling and the transition between signalling systems.

Chapter 4.3 are the use cases related to handling of reduced visibility and the activation of horn in areas associated with higher risk of collision.

Chapter 4.4 lists the use cases developed in the context of detecting infrastructure defects and associated anomalies.

Chapter 4.5 contains the use cases in depots and maintenance facilities.

4.1 Object Detection

4.1.1 UC5.2-0003: On track detection system – On Line People Detection

Use Case field	Description
ID	UC.5.2-0003
Use Case name	On Track Detection System- On Line People Detection
Main actor	Trackside Automation System and Pedestrian on track
Other actors	• Operations Manager • Energy Manager • Incident Manager • Incident Management System • Emergency Manager • Infrastructure Manager • On-board Automation System • On-board driver • Police Officer
Use Case summary	Trackside Automation System may be equipped to detect unexpected human behaviour on the tracks. In that case, safety mitigation shall be deployed, and potentially police officer intervention may be requested. Traffic shall resume afterwards if it has been interrupted.
Applicability	• Geographical: European level • System level: Railway System • Operational category: passenger, freight, urban, regional, mainline and inspection vehicles
Main goal	Manage operational situation where people are detected on track.

Preconditions	People have trespassed into a track area.	
Termination outcome	**Successful outcomes**	• No more people on track and traffic resumes normally
	Unsuccessful outcomes	• Outcome 2: Traffic cannot resume
Condition affecting termination outcome	**Outcome 2**	Dedicated use case for major traffic incident shall be followed.
Use Case description	**Step 1**	Trackside Automation System detects Pedestrian on track (shortened pedestrian) or in the vicinity.
	Step 2	Trackside Automation System informs Operations Manager or Incident Management System or Incident Manager of the trespassing.
	Step 3	Trackside Automation System or Operations Manager or Incident Management System or Incident Manager apply mitigation depending on the immediate danger: • Interruption of traffic near and in the corresponding area • Energy cut-off of Catenary or third rail (optionally performed by the Energy Manager) • Restriction of speed • Rule to operate only with a “running on sight” principle near and in the area (as per definition from TSI OPE Appendix B) The area is selected by the Trackside Automation System with a combination of selected tracks and distance around the incident.
	Step 4a	Trackside Automation System communicates this mitigation(s) to equipped trains (equipped with a compatible Onboard Automation System, depending on the mitigation to apply).
	Step 4b	Operations Manager communicates this mitigation(s) to on-board drivers of unequipped trains via a dedicated communication procedure.
	Step 4c	Onboard Automation System and on-board drivers apply the mitigation(s).
	Step 5	If applicable, Trackside Automation System or Operations Manager and Onboard Automation System or on-board driver communicate about a delay to passengers in station or in the trains.

	Step 6	Incident Management System or Incident Manager take decision to call the police officer.
	Step 6.1	If called, Police officer intervene to take care of the situation and to free the area.
	Step 7a	Incident Management System or Incident Manager (with camera) or Emergency Manager (on the site) performs visual inspection to confirm the absence of people on tracks.
	Step 7b	If required, Operations Manager or Incident Manager decides and carries-out maintenance activities before resuming traffic (in coordination with Infrastructure Manager if required).
	Step 7c	If required, Energy Manager re-establishes Catenary or third-rail energy.
	Step 7.1	If one of these steps is not successful, it might be required to reroute or evacuate the trains. [Outcome 2]
	Step 8	Operations Manager (if required in coordination with Incident Manager) indicates to Trackside Automation System that operation may resume normally.
	Step 9a	Trackside Automation System communicates this end of mitigation(s) to equipped trains (equipped with a compatible Onboard Automation System, depending on the mitigation to apply).
	Step 9b	Operations Manager communicates this end of mitigation(s) to on-board drivers of unequipped trains via a dedicated communication procedure.
	Step 10	Onboard Automation System and on-board drivers resume driving, Traffic resumes normally.
Postcondition	None	
Use Case notes	None	
Related UCs	None	

Table 1: Use Case "On Track Detection System- On Line People Detection"

4.1.2 UC5.2-0017: Human accident involving injury or death

This use case details the actions to be taken if a person is injured or killed in relation with the movement of the train.

Use Case field	Description

ID	UC5.2-0017	
Use Case name	Human accident involving injury or death	
Main actor	OAS (On-board Automation System)	
Other actors	• OM (Operations Manager) • IIM (Incident Manager)	
Use Case summary	This use case details the actions to be taken in case of human accident involving injury or death caused by the ego train*. When a human accident involving injury or death occurs, the train will stop and inform the supervisor. **Ego train - the train itself; the vehicle which is an object or the performer of the Use Case (the term is used to distinguish from the other trains in the vicinity).*	
Applicability	• Geographical: European level • System level: Perception system, APM • Operational category: All	
Main goal	The main goal of this use case is to provide a reaction to the human accident involving injury or death, and to inform about that OM and IIM.	
Preconditions	1. The UC5.2-0019 - React to obstacle is performed. 2. The train has had a collision with a human.	
Termination outcome	**Successful outcomes**	• OAS informed OM/IIM about accident and train stopped.
	Unsuccessful outcomes	• OAS failed to inform OM/IIM about human accident or did not stop.
Condition affecting termination outcome	**Outcome 2**	Communication failure or unsuccessful recognition by PER.
	Step 1	Immediately stop the train with respect to national operational rules.
	Step 2	Inform OM/IIM about human accident involving injury or death, including information of time, and precise location of the accident.
	Step 3	Inform passengers (if applicable) about reason of train immobility.
	Step 4	Terminate use case.
Postcondition	Train informed supervisor/dispatcher about human accident involving injury or death. Train is not moving.	

Use Case notes	This use case considers that a collision occurred with the train involved in the use-case. To detect an injured body without collision (e.g., outside the loading gauge), please see UC5.2-0029.
Related UCs	None

Table 2: Use Case "Human accident involving injury or death"

4.1.3 UC5.2-0029: Human accident involving injury or death - Body discovered

This use case details the actions to be taken if human body was detected in vicinity of the train by PER system. The realization of the UC is dependent on the exact position of the body. The UC is in close relation to UC5.2-0017: Human accident involving injury or death.

Use Case field	Description	
ID	UC5.2-0029	
Use Case name	Human accident involving injury or death – Body discovered	
Main actor	OAS (On-board Automation System)	
Other actors	• OM (Operations Manager) • IIM (Incident Manager)	
Use Case summary	This use case details the actions to be taken in case of detection of human body in vicinity of the track, but not being obstacle to the operated train. When a human body is discovered (detected) by the train, it is assumed that potential injury or death occurred without influence of the train operated in the use case. Due to this fact, the train shall maintain normal operation but shall inform OM about the discovered body.	
Applicability	• Geographical: European level • System level: Perception system, APM • Operational category: All	
Main goal	The main goal of this use case is to provide a reaction to the detected potential injured or dead human in vicinity of the track, and to inform about that OM and IM.	
Preconditions	1. Train is in operational mode GoA3/4. 2. Train is operating in a mission. 3. Train is moving. 4. Human body is detected by OAS in vicinity of the tracks. 5. There is a storage device on board for storing the video sequence of incidents.	
Termination outcome	**Successful outcomes**	• OAS informed supervisor about detected human body with the possibility of injury or death.

	Unsuccessful outcomes	• OAS failed to recognize or inform supervisor about detected body.
Condition affecting termination outcome	**Outcome 2**	Communication failure or unsuccessful recognition by PER.
	Step 1	OAS decides: Is detected human body in a place, where people can be expected (level crossing, platform)? If yes, continue with Step 4.
	Step 2	OAS decides: Is this human body lying or hanging? If not, continue with Step 4.
	Step 3	OAS informs OM and IIM about potentially injured or dead human in vicinity of the train, including information of time, and precise location of detected body relative to the track position. OAS records and stores to on-board permanent memory (non-volatile memory device) video sequence from the moment the body appears in the train's field of view to the moment it disappears (also rear camera video if possible). The video sequence contains information about current position and speed of the train, area of detected incident is highlighted.
	Step 3.1	The information about body discovery is sent by OAS (Repository) with localization data.
	Step 4	Terminate use case.
Postcondition	Train informed OM about discovered potentially injured or dead human.	
Use Case notes	Some memory management of device mentioned in Step 3 is expected (delete the records older than [X] days, inform OM of limited space left, …). To distinguish a normal from an abnormal behaviour (i.e., body that really needs to be reported) is complicated and may not be feasible for the current PER system.	
Related UCs	None	

Table 3: Use Case "Human accident involving injury or death – Body discovered"

4.1.4 UC5.2-0030: Wandering livestock, animals or other objects on or close to the Tracks

In ATO GoA3-4 there will be no driver in the cabin and hence observations and actions taken by driver need to be implemented in a technical manner through an automatic perception system. An important operational scenario that should be handled by this system is named as a **"obstacle on and close to the track"** where intruding objects (**livestock, animals, moving objects such as cars)** are present along or on the ego track, and where their presence might affect train operation depending on size (but maybe also speed and other detectable characteristics).

Perception (PER) is the subsystem enabling perception of environmental observations like obstacles. Depending on the detection location of the objects, different functions are required:

On the track, the animals, if big enough, constitute an obstacle for the train, and, thus, obstacle detection with a high level of safety is required. Obstacle classification may be done as well.

Along the track, animals or cars are mobile elements belonging to the physical environment of the train and, thus, observation of the environment is the necessary function. It should require a safety level that is significantly lower. The question of obstacle tracking with anticipation of movement is a complex question which may be treated in further investigations.

OAS/APM (Automatic Processing Module) is the subsystem that will evaluate the impact of the present of animals and in this case if it is passable or not, if the train should slow down, signal, or go to a halt and if this can have consequences to other trains in the area.

ATP is the subsystem will activate emergency brake in case the emergency brake is necessary, or slow down if needed.

The infrastructure manager database may store the presence, location, and time of animals in the database.

In the SRS document from Shift2Rail project X2Rail-4 a list of reactions has been developed. This list may serve as a base for a commonly developed sequence of events in the operational scenario in question.

At first, we shall draw a distinction between an object and an obstacle as not every object in the train environment should qualify as an obstacle. It is clear that an obstacle is linked to a risk for the train and the passengers/freight, and, thus, to its physical characteristics and its position relatively to the train. Currently, there does not exist any generally admitted and shared definition of what constitutes an obstacle (size, volume, composition, number of entities, speed) but we shall, as a working definition, assume the obstacle to be an object of sufficiently large volume, e.g., 50 cm x 50 cm of orthogonal projected surface on the ego track. We shall also note that other edge cases of objects may exist which do not fall into this description so easily but still occur regularly e.g., fallen tree across the track. In X2Rail-4 a first classification for possible objects in or close to the track has been defined [1].

An obstacle may be passable or impassable depending on its velocity (animal leaving the ego track zone), continuous presence on the ego track (ex: bird flying through the 3D gauge of the train) and further criteria of that nature to be defined.

An obstacle detection system needs, thus, to draw these two distinctions:

- discerning whether an object is an obstacle
- distinguishing whether the obstacle is passable or requires a brake.

Use Case field	Description
ID	UC5.2-0030
Use Case name	Wandering livestock, animals, or other objects on or close to the Tracks
Main actor	OAS (Onboard Automation System): Perception, ADM, APM, Automatic Train Protection (ATP)
Other actors	• TAS (Trackside Automation System) • OM (Operation Manager) • Incident manager (IM) • Incident Management System (IMS)
Use Case summary	This use case details the actions to be taken in case of objects are situated closely along or on the ego track**.

<table>
<tr><td></td><td colspan="2">The presence of such objects can also be on tracks in vicinity of the ego track of the train itself. The OAS/PER system must be able to detect the present of one or more objects, and estimate their location, volume and if possible, a bounding box if there are several objects or a flock. Furthermore, OAS/PER may classify the objects into types.

In addition, the OAS/PER should be able to exclude the presence of mobile objects where there are natural or man-made structures that will prevent the livestock or animals from entering or approaching the ego track (fences, walls, canal, etc.). Such information should be available from the Infrastructure Management System.

OAS/PER needs to distinguish the objects into obstacles, which may pose a risk and be safety critical.

When obstacles are detected by the OAS/PER system a message will be sent to the OAS/APM system.

The OAS/APM system will decide on what kind of action is needed to be taken.

• If the OAS/APM evaluates this as an impassable obstacle and, thus, an urgent incident, an emergency stop-command gets sent to the OAS/ATP who will activate emergency stop. OAS/APM then sends a message to Operation Manager who may evaluate the need for delays of the other trains in the area.
• If the OAS/APM evaluate this as passable with slow speed, it will send a message to OAS to slow down, and if possible, activate any reaction that could scare animals or humans off or away from the track. The train would them proceed with slow speed until OAS/PER system reports ego track free of wandering intruders when it is safe to proceed.
• In case the objects are observed on or along another track than the ego track, the train will proceed without interruption, but the observation will be reported to Operation Manager.
• If the OAS/APM evaluates this as passable at full speed, no action is taken, but the observation will be reported to Operation Manager.

**Ego track – the track occupied by the train or already chosen and set for the train (the term is used to distinguish the track in a path of the train from adjacent track or other tracks in the vicinity).</td></tr>
<tr><td>Applicability</td><td colspan="2">All over Europe but the reaction can be nationally chosen.</td></tr>
<tr><td>Main goal</td><td colspan="2">The main goal of this use case is to fit the GoA3-4 with the same or better perception and actions as a driver perform today in case detected objects.</td></tr>
<tr><td>Preconditions</td><td colspan="2">1. Train is in operational mode GoA3/4.
2. Train is operating in a mission.
3. Train is moving.
4. OAS/PER module is monitoring the area of interest.
5. Objects are in vicinity of the train.</td></tr>
<tr><td rowspan="2">Termination outcome</td><td>Successful outcomes</td><td>• Outcome 1: Objects are correctly detected as obstacles and subsequently as impassable or passable and evaluated in time for any emergency brake or slow down reaction.</td></tr>
<tr><td>Unsuccessful outcomes</td><td>• Outcome 2: Objects are classified as passable or impassable obstacles and/or detected too late for emergency brake to stop the train.</td></tr>
</table>

Condition affecting termination outcome	Outcome 2	Management of a collision should be managed by UC5.2-0019 React to obstacle
	Step 1	OAS/PER system detects the presence of an obstacle and sends information to OAS/APM. The OAS/PER system should report the presence of one or more animals (or other mobile obstacles), and estimate their locations relative to the train, their volume, and if possible, a bounding box if there are several objects or a flock.
	Sub case A.1	In case the obstacles (e.g. livestock or animals) are observed on the ego track and OAS/APM decide that the obstacles are too close for normal breaking, it sends an emergency brake command to OAS/ATP system.
	A.2	OAS/ATP system activates emergency stop.
	A.3	OAS/APM send a message informing Incident manager
	A.4a	Train is stopped before the objects. Proceed to Step 2a
	A.4b	Train hits the obstacle. [Outcome 2]
	Sub case B.1	In case the obstacles are observed **on or along the ego track**, but far enough ahead to avoid a collision by braking and OAS/APM decides that the animals are passable at slow speed, OAS/APM send command to slow down train to ATO.
	B.2	OAS/ADM system slows down the train.
	B.3	OAS/APM send a message informing Incident Manager
	B.4	OAS/ADM will proceed at slow speed, and if needed OAS/APM activates measures to scare animals/humans off the track, until OAS/PER system reports 'ego track free' of obstacles and it is safe to proceed at normal speed taking the length of the train into consideration to ensure the entire train has passed the risk points.
	Sub case C	In case the mobile objects, e.g., wandering livestock or animals are observed on or along **another track than the ego track,** proceed to Step 2
	Sub case D	In case the mobile objects, e.g., wandering livestock or animals presents no danger to train operation (outside of the tracks, or the rules are they can be run over avoiding a delay?), proceed to Step 2
	Step 2a	OAS/APM sends information about the observed objects and its details to the TAS and Incident Management System (IMS), as other trains may be affected by the present of wandering animals.
	Step 2b	Optionally, TAS inform other OAS of trains in the area of the possible presence of wandering animals
	Step 2c	Optionally, depending on the TAS information, OAS of trains in the area may slow down.

	Step 3	OAS sends information to TAS (infrastructure manager database) or Incident Management System (IMS) about the detection and handling of wandering animals and if emergency brake and slow-down was a necessity as it might affect train traffic.
	Step 4	OAS/PER system reports 'ego track free' of obstacles and OAS may restart the movement.
Postcondition	None	
Use Case notes	None	
Related UCs	• UC5.2-0019: React to obstacle: The reaction to the observed critical object on or along the track constitutes the next piece in a sequence of scenarios related on the presence of a foreign object on the tracks. • UC5.2-0017 Human accident involving injury or death: The actions to be taken if a person is injured or killed in relation with the movement of the train.	

Table 4: Use Case "Wandering of livestock and animals"

4.1.5 UC5.2-0019: React to obstacle

4.1.5.1 General Context

This use case details the actions to be taken in case of obstacle detection.

In line with the X2Rail-4 use case, when an obstacle is detected, APM sends an obstacle End of Authority (EoA) to ETCS via C16 and informs the Incident Manager which causes a delay in operation. This use case describes actions (activities) that need to be taken in order to execute the correct reaction of the autonomous train following the detection of an obstacle on, or in the vicinity of the track. In principle, the goal of this UC is to take actions that matches the reaction of human train driver in order to be insertable into the existing operations in the simplest way possible, or elsewise as defined by the operator of the autonomous train.

It is important to note, that UC "React to obstacle" assumes that the detected object was already assessed as an obstacle to the train. In other words, the following description of the operational scenario takes over at the moment where the perception system has detected an object on the train trajectory (or in its vicinity) and classified the object as an obstacle*. Furthermore, it is assumed, that for this use case to be applicable, the train must be "in motion" meaning its velocity has a nonzero value. A standing train does not need to react to the obstacle by braking, but rather its departure must be disabled due to the existence of obstacle.

4.1.5.2 Recurring Specific Cases

Due to its complexity, this use case in the "Operational scenario" part can be divided into 3 variations of the 'React on obstacle' UC.

4.1.5.2.1 Variation A – Live obstacle – human

This variation of the "React on obstacle" use case is applicable when obstacle is classified as a human being or obstacle where human being can be expected (car, bus). In such case, further behaviour and reaction of the train is very strict. Its reaction shall always lead to protection of the human on/near the tracks.

*4.1.5.2.2 Variation B – Live obstacle – non-human***

In this variation the reaction of the train is fairly complex and multilevel relatively to the variation A. Firstly, the train shall try to scare potential intruders or announce its presence by the means of horn before deciding on further action. This subsequent action is further dependent on the size of the animal, which may involve different consequences of the potential impact (clash).

*4.1.5.2.3 Variation C – Non-live obstacle***

In this version of the UC, no trial of communication or alarming the obstacle is taken. Unlike the variant B, the determination of an object's size does not provide enough information to determine the potential consequences of an impact with sufficient confidence as even small object made of stone or some metal object can result in pretty serious consequences and may even cause the train to derail.

**Note: The distinction between object and obstacle is assumed (see UC5.2-0030 'General Context'), where an obstacle is a subset of objects that can be detected. Sometimes, a specific object class (e.g., a vehicle) can be an object or an obstacle depending on the specific circumstances of detection. A vehicle standing near a railway track at the active and secured level crossing is considered an object, while a vehicle standing on the tracks is an obstacle. Similarly, a vehicle standing or traveling near the tracks on the parallel road is an object, while vehicle present near the railway tracks without the road shall be considered a potential obstacle.*

*** The mentioned distinction between alive vs non-alive; human vs non-human requires classification which is a complex technical problem as e.g., a crouched human may appear to be an object or an animal to an algorithm. As such, this operational scenario may require a default reaction mechanism or an acceptable heuristic such as a restrictive reaction beyond a certain size of the obstacle in order to account for this uncertainty.*

Use Case field	Description
ID	UC5.2-0019
Use Case name	React to obstacle
Main actor	OAS (Automatic Processing Module (APM))
Other actors	• OAS/TCMS (actuating horn) • OAS/ADM (Automatic Driving Module) • OAS/ATP • OAS/PER • OAS (Odometry (localization)) • Physical train unit
Use Case summary	This use case details the actions to be taken in case of obstacle detection. When an obstacle is detected, APM (according to X2Rail-4 architecture, which will be the objective of WP6 - sends an obstacle EOA to ETCS via C16) informs Incident Manager (delay in operation). When the train is stopped, the feedback loop with the trackside permits to identify the problem and to restart when the problem is solved (false alarm for example). In case of obstacle EOA, if the train is stopped without trip, onboard ETCS will request a new MA to Train Control when the obstacle EOA is removed by APM. This removal can be done automatically if the obstacle has disappeared or via a

<table>
<tr><td></td><td colspan="2">confirmation of Incident Manager. If the obstacle is still present, the track must be closed until recovery.</td></tr>
<tr><td>Applicability</td><td colspan="2">Geographical: European level
System level: Perception system
Operational category: All</td></tr>
<tr><td>Main goal</td><td colspan="2">The main goal of this use case is to provide a reaction to the obstacle on or in the vicinity of track in a way that respects current operational rules for the train drivers. Specifically, (if possible) to prevent train accident by clashing with an obstacle during operation, or (if prevention is not possible) to minimalize the results (both legal and economical) of such clash.</td></tr>
<tr><td>Preconditions</td><td colspan="2">Train is in operational mode GoA3/4.
Train is operating in a mission.
Train is moving.
An object in front of train was classified as an obstacle.</td></tr>
<tr><td rowspan="2">Termination outcome</td><td>Successful outcomes</td><td>Obstacle is cleared in time to continue the mission and no injuries occur among passengers.
Train stopped before obstacle and no injuries occur among passengers.</td></tr>
<tr><td>Unsuccessful outcomes</td><td>Clash with obstacle occurred.
The obstacle is not cleared in time and clash occurs:
The collision with the obstacle does not affect the behaviour of the train and it could continue with the mission and not human injuries among the passengers occurs.
The collision with the obstacle does not affect the behaviour of the train and it could continue with the mission, but human injuries occurred among the passengers.
The collision with the obstacle prevents the train from continuing with the mission (with or without passenger injuries)</td></tr>
<tr><td>Condition affecting termination outcome</td><td>Outcome 2</td><td>In case of unsuccessful outcome system was not able to prevent the train from the clash with obstacle, with the result of a moderate or heavy damage inflicted on train.</td></tr>
<tr><td rowspan="2"></td><td>Step 1</td><td>Determination if detected obstacle is alive, or it is an obstacle controlled by human being. (Positive outcome of UC 5.2.0002 or UC 5.2.0003).</td></tr>
<tr><td>Step 1.1</td><td>If obstacle is alive, train shall activate warning signal according to local rules (UC 5.2.0031). If it is not alive continue with step 1.2</td></tr>
</table>

	Step 1.1.1	Determination whether obstacle is a human (Deploy UC 5.2.0003). If yes, continue with Step 1.1.2 if no, move to Step 1.2.
	Step 1.1.2	Predict the position of clash with obstacle.
	Step 1.1.3	Send obstacle EOA to ATP in order to stop train before clash position.
	Step 1.1.4	Check if train passed predicted clash position. If no, check train speed. If yes go to Step 2.1
	Step 1.1.4.1	If train speed is not 0, return to Step 1.1.2 If train stopped, go to Step 3.
	Step 1.1.5	If human impact (clash) occurred, send to ATP request for emergency stop and proceed with UC 5.2.0017.
	Step 1.2	Decide if obstacle needs a reaction.
	Step 1.2.1	If no reaction is needed remove obstacle from the list of observed obstacles and continue train ride – end UC.
	Step 1.3	Are predicted consequences of forecasted clash serious? If not, go to Step 1.4.
	Step 1.3.1	Send obstacle EOA to ATP.
	Step 1.3.2	Check if clash position is passed.
	Step 1.3.2.1	If no, check train speed.
	Step 1.3.2.2	If train speed is not 0, return to Step 1.3.1 If train stopped, go to Step 3.
	Step 1.3.3	If train passed predicted clash position, check if clash occurred and continue at step 1.5.
	Step 1.4[1]	If consequences are not serious, maintain train speed below 50 km/h and continue until collision point was passed.
	Step 1.5	Perform the health check of the train sensors. If train is able to proceed go to step 2.1, if not go to step 2.
	Step 2	If clash occurred stop the train and go to Step 3.
	Step 2.1	Return to operational speed and go to Step 4.
	Step 3	Inform OOC (Operation Control Centre): the train is stopped + reason for stopping + its position.
	Step 4	Terminate use case.

Postcondition	The obstacle is no more detected in front of the train in motion. Train either clashed with obstacle, or successfully stopped in front of the obstacle. Alternatively, the alive obstacle was scared from the track vicinity.
Use Case notes	Exact parameters and detailed description of conditions needs further specification and development. InWP8 a specific case where classification of the obstacle type and distance to the obstacle failed must be analysed, as correct classification of obstacle type and distance is crucial for results of this UC.
Related UCs	• **UC5.2-0030: Wandering Livestock, animals or other objects on or close to the tracks:** o As mentioned, this UC is the previous action in the sequence of the operational scenario of an obstacle on or close to the track. • **UC5.2-0017 Human accident involving injury or death:** o A discovered human on the track is a crucial scenario that needs to be handled by the perception system. The observation usually leads to an investigation and a prolonged stop. • **UC5.2-0029 Human accident involving injury or death – Body discovered:** o A discovered human in the vicinity of the track is a crucial scenario that needs to be handled by the perception system. This observation needs to either be signalled and depending on the location may lead to a prolonged stop.

Table 5: Use Case "React to obstacle"

[1] *Step 1.4 is optional and might be implemented or omitted based on the requirements of the Railway Operator (RO). In such case, the speed limit in case of expected clash shall be defined by the RO.*

4.1.6 UC5.2-0041: Evaluating ego track

Use Case field	Description
ID	UC5.2-0041
Use Case name	Evaluating Ego Track
Main actor	Onboard Automation System (OAS)
Other actors	• Trackside Automation System (TAS) • Remote Supervision and Control Centre • Remote driver • On-board driver
Use Case summary	The train is running on a track or approaching a switch. The OAS must know where in the field of view of perception the train will continue to run through (ego track) to ensure an obstacle free passageway. The ego track zone corresponds to the track zone taken by the ego train according to the route

	setting while the adjacent track zones correspond to the other tracks in the vicinity of the ego track. This use case should also work for 3-rail tracks (dual gauge tracks).	
Applicability	• Geographical: European level • System level: GoA1/2 (for assistant systems) GoA3/4 (ATO operation) • Operational category: passenger, freight, urban, regional, mainline and inspection vehicles.	
Main goal	The ego track zone corresponds to the track zone taken by the ego train according to the route setting while the adjacent track zones correspond to the other tracks in the vicinity of the ego track. Based on perception (Camera, filtering etc.) the system can determine the ego track within the visibility range. Note: This use case applies in different scenarios: Combination of weather (Fog, Rain, direct sunlight etc.), location (f. ex. different tunnels, free Track) and operational procedures. Safety constraint: Safety is a central and important point in this use case. The SIL-Level of the function must be defined and confirmed.	
Preconditions	Train runs, Perception system is operational.	
Termination outcome	**Successful outcomes**	• Outcome1: OAS evaluates the correct ego track in the field of view of PER.
	Unsuccessful outcomes	• Outcome 2: OAS evaluates the ego track only until a short distance. The (GoA3/4) train may break, decelerate, or stop. On the GoA1/2 scenario the driver (GoA1/2) is alerted (warning). • Outcome 3: OAS evaluates the ego track of the train but in the wrong direction/place/location or the wrong track at switches which can lead to crash or unwanted stoppings of the train.
Condition affecting termination outcome	**Outcome 2**	**Conditions:** • Outcome 2: This could happen in Poor visibility, bad conditions or bad track layout. • Outcome 3: OAS cannot prevent a possible crash with an obstacle or person outside the ego track leading to an unwanted stop. **Postconditions:** • Outcome 2: OAS is going on with determining the ego track.

		• Outcome 3: Remote driver or train driver on the train continues to drive the train.
Use Case scenario	**Step 1**	OAS is gathering information from TAS (segment profile), digital map, localisation and perception and starts function to evaluate its ego track.
	Step 2	Case 1: OAS can evaluate the ego track of the train within the complete defined visibility range.
	Step 3.1.1	Case 2: OAS can evaluate the ego track of the train only until to a short distance.
	Step 2.1.2	OAS breaks and decelerates the train to a speed, where the distance of the ego track evaluation is sufficient to ensure safe driving (GoA3/4). OAS warns the driver about the short distance of ego track evaluation (GoA1/2)
	Step 2.2.3	OAS reports to TAS about slow running of the train due the "short distance detection" of the ego track (GoA3/4)
	Step 2.2.4.1	Case 2.1: OAS can evaluate again the ego track of the train within the complete defined visibility range. (GoA3/4)
	Step 2.2.4.2	Continue with Step 3 (GoA3/4).
	Step 2.2.5.1	Case 2.2: Train continues to run with reduced speed (GoA3/4) (if the reduced ego track evaluation persists)
	Step 2.3.1	Case 3: OAS cannot detect the ego track of the train.
	Step 2.3.2	OAS breaks and stops the train. (GoA3/4) OAS warns the driver about the failure of ego track evaluation (GoA1/2)
	Step 2.3.3	Report to TAS about stop of the train because of failure to evaluate ego track.
	Step 2.3.4	OAS informs passengers about emergency brake, because of failed ego track evaluation.
	Step 2.3.4.1	Case 3.1: OAS can evaluate again the ego track of the train within the complete defined visibility range. (GoA3/4)
	Step 2.3.4.2	Continue with Step 3 (GoA3/4)
	Step 2.3.5.1	Case 3.2: The TAS decides the further procedure to enable the continuation of the journey (e.g., send local driver, activate remote driver, …).
	Step 3	Train runs normal without restrictions.

Postcondition	OAS can evaluate ego track of the train until the complete defined visibility range to detect if objects are on the passageway of the train or near it.
Use Case notes	SIL of the function “ego track evaluation” must be defined. Required sufficient distance of successful ego track evaluation for different speeds should be defined.
Related UCs	None

Table 6: Use Case “Evaluating Ego Track”

4.2.1 UC5.2-0036: Long range detection and recognition of signals applicable to train route

Use Case field	Description	
ID	UC5.2-0036	
Use Case name	Long range detection and recognition of signals applicable to train route	
Main actor	OAS (onboard Automation System)	
Other actors	• TAS (Trackside Automation System) • FMS (Fleet Management System)	
Use Case summary	This use case describes the train driving over a CCS Class-B system with the additional lateral signalling information. The additional lateral signalling information can be provided: • by perception systems which can interpret the signals on the line side • or it could be done also (or in addition) with data from a SIL4 interlocking which can be transmitted in a dynamic layer “signal aspects” in Digital Map.	
Applicability	• Geographical: European level • System level: GoA3 & GoA4 with perception System • Operational category: All	
Main goal	GoA 3 & 4 train can safely run over Lineside signaling system	
Preconditions	• The train is driving over Lineside signaling system. • Train is equipped with line side signalling detection. • Track is equipped with line side signals. • OAS (train protection) is in a mode in which it can drive with lateral signals (ETCS L1 LS or a national ATP). • The train has an own reliable, accurate (and safe) localization. • TAS includes Digital Map and Digital Map contains all necessary information about the signals. • OAS (PER) is monitoring the ego track zone + buffer zones	
Termination outcome	**Successful outcomes**	• Outcome 1: Train is able to detect the signal aspects and convert them into an MA. Train adapts accordingly.
	Unsuccessful outcomes	• Outcome 2: Systems fails to detect lateral signals aspects. Train stops.

Condition affecting termination outcome	**Outcome 2**	**Explanation:** OAS (SCV) fails to detect the aspect of signals. **Postconditions:** • Train stops. • OAS informs TAS about failure of detecting signals.
Use Case scenario	**Step 1**	OAS requests the signal position from TAS.
	Step 2	TAS sends the requested signal data (e.g., location) to OAS.
	Step 3	OAS detects the lateral signals.
	Step 4	OAS (PER) detects the aspects of the signals
	Step 5	OAS (PER) detects the signals, OAS (SCV) converts the aspect of signals, OAS(ATO) drives the train according to the signal restrictions, OAS (SCV) informs TAS the detected aspect of signal.
	Step 5.1	OAS detects a failure in signal aspect detection. OAS stops train. OAS informs TAS about failure
	Step 5.2	The TAS decides the further procedure to enable the continuation of the journey (e.g., send local driver, activate remote driver, etc.). Go To Outcome 2
Postcondition	Physical train unit continues according to Journey Profile (JP).	

Use Case notes	• Safety analysis necessary to determine the necessary SIL Level of signal aspect detection. The result of this analysis will show whether a detection with perception systems is safe enough or if additional data from interlocking systems are necessary.
	• The Digital Map static layer contain the information which signals are relevant for a train at a specific location. This means localization will be safety relevant too.
	• The ego track zone corresponds to the track zone taken by the ego train according to the route setting while the adjacent track zones correspond to the other tracks in the vicinity of the ego track.
	• Detection of the signals applicable for the train route might be difficult at the following scenarios:
	    o Multiple tracks in parallel where the applicability of the signals is clarified by block markers.
	    o Multiple tracks in parallel where the signals are hanging from catenary gantries.
	    o Signals at the left side.
	    o Signals that cannot be seen due to external influences (fog, covered by snow, signals destroyed due to vandalism).	

Related UCs	None	

Table 7: Use Case "Long range detection and recognition of signals applicable to train route"

4.2.2 UC5.2-0055: Transition from/to ATP Lineside signalling area / Class A area

4.2.2.1 General Context

- Currently ERTMS is being deployed progressively over the coming decades in Europe according to the different National Implementation Plans (reference).
- For GoA 2, an already existing technology defines ATO over ETCS.
- Migration solutions are investigated to enable ATO over ETCS on areas not equipped with ERTMS/ETCS. This creates the need for an automatic reading of the currently existing lineside signals (legacy systems)
- This functional need has been considered within the Shift2Rail project TAURO, especially in work package 'Technologies supporting migration to ATO over ETCS'.
- The work package proposed a concept for a technical solution that relies on visual perception of lineside signals to determine the Movement Authority. To be compatible with ETCS equipped lines this concept uses a translation of the signal information into an ETCS compatible format through a converter module (SCV).
- An important case that arises when one tries to deploy ATO over larger areas that include both ETCS-equipped and non-equipped lines, is the transition between both.
- This use case should manage both the situation:
    - Transition from ETCS Equipped to non-equipped line (Lineside signalling area)
    - Transition from Non equipped Line (Lineside signalling area) and ETCS
- It seems that this transition does not lead to additional challenge to the perception system as comparatively with regular lineside signal reading.
- In fact, the only change is the transition moment in which the ATP switches from ETCS to lineside signal reading (PER-SCV-EVC) mode.

4.2.2.2 Operational Context

During regular operations, not all lines are equipped with ETCS. To be, however, capable of deploying Automatic Train Operation beyond the current deployment of ETCS, a management of the transitions between domains with ETCS and legacy systems is needed.

4.2.2.3 Recurring Specific Cases

Due to its complexity, this use case in the "Operational scenario" part can be divided into 2 variations of the 'Transition from/to ATP Lineside signalling area / Class A area' UC.

4.2.2.3.1 Variant A : Transition from ETCS- to Perception-based ATP

1. If the train is operating at GoA 3/4, all perception functions, except lineside signal reading need to be active (e.g., obstacle detection, Observation of the environment).
2. Transition Announcement based on a balise detected by the physical train unit.
3. Nowadays this transition is operated by the EVC which informs the driver (via DMI) that the transition is in order. The train driver subsequently acknowledges the transition.

    A plausible way to handle this transition in the absence of a driver could be the APM compiles the information from the EVC and transmits this via the dedicated interface to the PER module.

"Perception- Lineside signalling reading function" needs to be made ready (state functional)

4. "Perception- Lineside signalling reading" function.

As soon as the "Lineside signals reading" function is activated, the PER function shall inform about its state to the APM and SCV modules in order to active the whole functional chain.

This function "Lineside signals recognition" is described in the use case description "UC5.2-0058 Driving according to journey based on lateral signalling".

4.2.2.3.2 Variant B : Transition from Perception-based ATP to ETCS

1. If the train is operating at GoA 3/4, all perception functions, except lineside signal reading need to be kept active (e.g., obstacle detection, Observation of the environment).
2. Transition Announcement based on a balise detected by the physical train unit.
3. Nowadays this transition is operated by the EVC which informs the driver (via DMI) that the transition is in order. The train driver subsequently acknowledges the transition.

   A plausible way to handle this transition in the absence of a driver could be the APM compiles the information from the EVC and transmits this via the dedicated interface to the PER module.

4. "Perception- Lineside signalling reading function" needs to be deactivated (state functional)

5. "Perception- Lineside signalling reading" function

As soon as the "Lineside signals reading" function is deactivated, the PER function shall inform about its state to the APM and SCV module in order to deactivate the whole functional chain.

Use Case field	Description
ID	UC5.2-0055-1
Use Case name	Transition from ATP Lineside signalling area to ATP Class A area
Main actor	OAS (On-board Automation System including ATP (Automatic Train Protection), ADM (Automatic Driving Module), APM (Automatic Processing Module), LOC(Localization), TCMS (Train Control and Monitoring System))
Other actors	• PTU (Physical train unit) • TAS (Trackside Automation System)
Use Case summary	This operational scenario details the process to switch from driving a train according operated in an ATP Lineside signalling area to an ATP Class A Area. The perception system detects and reads the signal, and the signal converter module translates it into an ETCS-compatible package in order to define the ATP supervised speed profile.
Applicability	• Geographical: European level • System level: Perception system • Operational category: All

Main goal	The main goal of this use case is to keep providing a movement authority to the train during an ATP transition	
Preconditions	1. Physical train unit is in operational mode Goa 1 (?), 2 or 3/4. Within the operational mode a sub-mode for the signalling system configuration ("ATO over ETCS" vs ATO migration towards ETCS) may be specified. 2. Physical train unit is operating according to its journey. 3. Trackside is fitted with a set of balise groups to manage the transition to ETCS operation.	
Termination outcome	**Successful outcomes**	• Transition managed properly and on-board system set to the new ATP configuration. • Movement authority is given by the ETCS system.
	Unsuccessful outcomes	Outcome 1: Unsuccessful transition lead to a train still operated under lineside reading. Outcome 2: EB Brake applied as no ATP supervision set (lineside reading function deactivated and ETCS supervision is not set properly).
Condition affecting termination outcome	**Outcome 2**	None
	Step 1	OAS (ATP): Detect and read announcement balise group for ATP transition from lineside signalling area to ATP Class A (ETCS) Note: This transition shall be compliant with current specification Subset 026
	Step 1a	BG not detected: Unsuccessful transition. OAS: EB brake applied as the transition hasn't been properly performed
	Step 1b	In parallel, TAS: send information to OAS related to ATP Transition
	Step 2	OAS: Prepare for transition
	Step 3	OAS(ATP): Detect and read Execution Balise Group
	Step 3.1	BG not detected: Unsuccessful transition. OAS: EB brake applied as the transition hasn't been properly performed
	Step 4	OAS(ATP): Switch to ATP configuration ""ATO over ETCS"
	Step 5	OAS(ATP): Update data to OAS(ADM)

	Step 6	OAS(PER/SCV): Switch off lineside reading configuration
	Step 7	OAS(ADM): adapt speed profile according to the ATP instruction
Postcondition	The physical train unit continues its journey according to the movement authority and speed profile determined through the signal reading.	
Use Case notes	None	
Related UCs	• UC5.2-0057: Drive inside depot / stabling or maintenance facility	

Table 8: Use Case "Transition from ATP Lineside signalling area to ATP Class A area"

Use Case field	**Description**
ID	UC5.2-0055-2
Use Case name	Transition from ATP Class A area to ATP Lineside signalling area
Main actor	OAS (Perception module (PER); Signal Converter (SCV); ATP (Automatic Train Protection))
Other actors	• OAS (On-board Automation System including ADM (Automatic Driving Module), APM (Automatic Processing Module), LOC(Localization), TCMS (Train Control and Monitoring System) • PTU (Physical train unit) • TAS (Trackside Automation System)
Use Case summary	This operational scenario details the process to switch from driving a train according operated in an ATP Class A area to an ATP Lineside signalling Area. The perception system detects and reads the signal, and the signal converter module translates it into an ETCS-compatible package in order to define the ATP supervised speed profile.
Applicability	• Geographical: European level • System level: Perception system • Operational category: All
Main goal	The main goal of this use case is to keep providing a movement authority to the train during an ATP transition
Preconditions	1. Physical train unit is in operational mode Goa 1 (?), 2 or 3/4. Within the operational mode a sub-mode for the signalling system configuration ("ATO over ETCS" vs ATO migration towards ETCS compatible) may be specified. 2. Physical train unit is operating according to its journey. 3. Trackside is fitted with a set of balise groups to manage the transition to ETCS operation.

	4. the portion of the track where Lineside signalling is to be used should be described in the TAS with the list, position, and characteristics of signals	
Termination outcome	**Successful outcomes**	• Transition managed properly and on-board system set to the new ATP configuration. • Movement authority is given by the ATP system.
	Unsuccessful outcomes	Outcome 1: Unsuccessful transition leads to a train still operated under lineside reading. Outcome 2: EB Brake applied as no ATP supervision set (lineside reading function deactivated and ETCS supervision is not set properly).
Condition affecting termination outcome	**Outcome 2**	None
	Step 1	OAS(ATP): Detect and read announcement balise group for ATP class A (ETCS) transition to ATP Lineside signalling area
	Step 1.1	BG not read: Unsuccessful transition. OAS: EB brake applied as the transition hasn't been properly performed.
	Step 2	OAS(PER/SCV): Set on the on-board system including the Lineside signal reading of PER
	Step 2.1	System Failure: Unsuccessful transition OAS: EB brake applied as the transition hasn't been properly performed.
	Step 3	OAS(ATP): Detect and read Execution Balise Group
	Step 3.1	BG not read: Unsuccessful transition. OAS: EB brake applied as the transition hasn't been properly performed.
	Step 4	OAS(ATP): Switch to ATP configuration ""ATO over LS" ETCS compatible"
	Step 4.1	System Failure: Unsuccessful transition OAS: EB brake applied as the transition hasn't been properly performed.
	Step 5	TAS: Provide OAS the list, position, and characteristics of signals to recognize.

	Step 5.1	OAS(PER): Detect and recognize lineside signal using data from TAS
	Step 5.2	OAS: no data from TAS or incorrect data from TAS OAS: EB brake applied as all condition are not gathered to operate under lineside signalling
	Step 6	OAS(SCV): Convert information from PER into ETCS telegram to OAS(ATP)
	Step 7	OAS(ATP): Update data to OAS(ADM)
	Step 8	OAS(ADM): adapt its speed profile according to the ATP instruction
Postcondition	The physical train unit continues its journey according to the movement authority and speed profile determined through the signal reading.	
Use Case notes	None	
Related UCs	UC5.2-0057: Drive inside depot / stabling or maintenance facility	

Table 9: Use Case "Transition from ATP Class A area to ATP Lineside signalling area"

4.2.3 UC5.2-0058: Driving according to journey based on lateral signalling

4.2.3.1 General Context

- As ETCS is not deployed on all lines, migration solutions are investigated to enable ATO over ETCS on areas not equipped with ERTMS/ETCS but equipped with Lineside signaling systems.
- At least in GoA 3 and 4, this creates the need for an automatic reading of the currently existing lineside signals (legacy systems).
- This functional need has been considered within the Shift2Rail project TAURO work package 'Technologies supporting migration to ATO over ETCS'.
- The work package proposed a concept for a technical solution that relies on visual perception of lineside signals to determine the Movement Authority. To be compatible with ETCS equipped lines this concept uses a translation of the signal information into an ETCS compatible format through a converter module (SCV).

4.2.3.2 Functional Requirement

4.2.3.2.1 UC1: Signal and panel detection/identification

Step A – Signal detection – static:

- Physical signal panel detection
- Other signal aspects (indication elements, colour)
- Other fixed signals (including indicators of LC) and markers detection.

Step B – Dynamic signal aspect detection – static or blinking/flashing:

Step C – Identification of other dynamic indications such as 'Speed (number) dynamic panel':

4.2.3.2.2 UC2: Signal applicability:

As multiple signals may exist in similar locations (especially with regards to perspective vision), the perception system needs to identify which signal is the signal that shall be respected and read by the train.

4.2.3.3 Recurrent specific cases

As the lineside signal system is a legacy system, there exists a naturally high variability between different country's signalling systems. It is, thus, neither feasible nor desirable, to give an exhaustive list of the signals in different countries. As there are still common rules and systems, we may, however, give the following – necessarily incomplete - list of recurring cases:

- Detection of signals indicating the train to stop.
- Detection of signals indicating the train to proceed with caution / to be prepared to stop at the next signal.
- Detection and recognition of light blinking signals. An example from Spain: A yellow signal announces caution / prepare to stop while a blinking yellow signal announces prepare for immediate stop.
- Detection and recognition of numeric dynamic panel indicating temporary speed restriction.
- Detection and recognition of level crossing signals (LC), i.e.:
    - Protected LC
    - Unprotected LC ahead (fixed signal or malfunction of the system)
    - Malfunction of the LC
- Detection and recognition of level crossings used by pedestrians between platforms:
    - Protected LC between platforms.
    - Unprotected LC between platforms ahead (fixed signal or malfunction of the system)
    - Malfunction of the LC between platforms
- Detection and recognition of plates/panels and block markers accompanying light signals:
- Detection of fixed signals and markers indicating:
    - Speed limits and significant speed transitions.
    - Information about the contact line system (e.g., neutral sections, transitions between systems, etc.).
    - Information about the track (e.g., transition between track gauges).
    - Location markers.
    - Level crossing ahead.

Use Case field	Description
ID	UC.5.2.0058
Use Case name	Driving according to journey based on lineside signalling
Main actor	OAS (Perception module (PER); Signal Converter (SCV); ATP)
Other actors	• OAS (TCMS (actuating horn)) • OAS (ADM (Automatic Driving Module)) • OAS (APM) • OAS (Odometry (localization) > Localisation) • Physical train unit

	• OAS (Passenger information System)	
Use Case summary	This operational scenario details the process of driving of a train according to lineside signal. The perception system detects and reads the signal, and the signal converter module translates it into an ETCS-compatible package to define the ATP supervised speed profile.	
Applicability	• Geographical: European level • System level: Perception system • Operational category: All	
Main goal	The main goal of this use case is to provide a movement authority to the train without having to rely on ETCS-equipped line.	
Preconditions	1. Physical train unit is in operational mode Goa 1 (?), 2 or 3/4. Within the operational mode a sub-mode for the signalling system configuration (ATO over ETCS vs ATO migration towards ETCS) may be specified. 2. Physical train unit is operating according to its journey. PER module is monitoring the area of interest the system recognizes a signal in the area of interest.	
Termination outcome	**Successful outcomes**	All the relevant aspects of the correct signal are detected by the system and its state is converted into a Movement Authority (according to ETCS package definitions) by the SCV. The train adapts its speed in accordance.
	Unsuccessful outcomes	The train detection system makes an incorrect detection by: 1 - not detecting the signal 2 - detects the wrong signal 3 - detects the correct signal but A – misclassifies the type of signal (e.g., wrong signal frame) B – misclassifies the state of the signal (e.g., wrong spot)
Condition affecting termination outcome	**Outcome 2**	None
	Step 1	Determine whether a lineside signal is present
	Step 1.2	Determine the state of the signal
	Step 2	Translate signal into ETCS-compatible package with a movement authority for the ATP. Depending on the national legacy system rules multiple reactions are possible (stop, continuing, speed decrease, ...).
	Step 3	ATP sends instruction to ADM
	Step 4	ADM adapts its speed profile according to the ATP instruction

Postcondition	The physical train unit continues its journey according to the movement authority and speed profile determined through the signal reading.
Use Case notes	Due to the UC complexity, I attach the activity diagram of the UC. Exact parameters and detailed description of conditions needs further specification and development.
Related UCs	• UC 5.2 -0055: Transition from ATP Lineside signalling area to Class A area • UC 5.2 -0059: Train stops by signalling • UC 5.2 -0057: Drive inside depot / stabling or maintenance facility.

Table 10: Use Case "Drive according to journey based on lineside signalling"

4.2.4 UC5.2-0059: Train stops by signalling

4.2.4.1 General Context

- Currently ERTMS is being deployed progressively over the coming decades in Europe according to the different National Implementation plans (reference).
- For GoA 2, an already existing technology defines ATO over ETCS.
- Migration solutions are investigated to enable ATO over ETCS on areas not equipped with ERTMS/ETCS. This creates the need for an automatic reading of the currently existing lineside signals (legacy systems)
- This functional need has been considered within the Shift2Rail project TAURO, especially in work package 'Technologies supporting migration to ATO over ETCS'.
- The work package proposed a concept for a technical solution that relies on visual perception of lineside signals to determine the Movement Authority. To be compatible with ETCS equipped lines this concept uses a translation of the signal information into an ETCS compatible format through a converter module (SCV).
- In addition to the nominal signals the train needs to respect to guarantee safe circulations, other non-regular signals exist, such as temporary speed restrictions. These signals are not permanent but signal an important change in the operations, usually following an incident or unplanned event.

4.2.4.2 Operational Context

Driving on the track while respecting the signals is a nominal task, but the reaction to non-regular signals such as temporary speed restrictions is a non-regular operational scenario.

4.2.4.3 Functional Requirements

In GoA3 and GoA4 operation, Perception functions are required to execute a safe circulation while respecting non regular signals.

- Lineside signal reading to detect the non-regular signals.
- Environment observation (e.g., for workers along the tracks)

4.2.4.4 Recurrent Specific Cases

- Temporary Speed Restrictions

Use Case field	Description	
ID	UC.5.2.0059	
Use Case name	Drive according to non-regular signals	
Main actor	OAS (Perception module (PER); Signal Converter (SCV); ATP)	
Other actors	• OAS/ TCMS • OAS/ADM (Automatic Driving Module) • OAS/APM (Automatic Execution Module) • OAS/Odometry (localization) > Localization • Physical train unit	
Use Case summary	This operational scenario details the driving while respecting non regular lineside signals. The perception system detects and reads the signal, and the signal converter module translates it into an ETCS-compatible package in order to define the ATP supervised speed profile.	
Applicability	• Geographical: European level • System level: Perception system • Operational category: All	
Main goal	The main goal of this use case is to keep providing a movement authority to the train during an OAS/ATP transition	
Preconditions	1. Physical train unit is in operational mode Goa 1 (?), 2 or 3/4. Within the operational mode a sub-mode for the signalling system configuration ("ATO over ETCS" vs ATO migration towards ETCS compatible) may be specified. 2. Physical train unit is operating according to its journey. OAS/PER module is monitoring areas of interest. The system recognizes a signal in the area of interest.	
Termination outcome	**Successful outcomes**	Train Stops According to the signal and adapts its speed.
	Unsuccessful outcomes	None
Condition affecting termination outcome	**Outcome 2**	None
	Step 1	OAS/ APM: Collect Mission Profile
	Step 2	OAS/ APM: Collect data for journey
	Step 3	OAS/ ADM: Drive according to Journey
	Step 4	OAS/ PER: Monitor environment during the journey

	Step 5	OAS/ PER: Detect Signal, Interpret Signal information
	Step 6	OAS/ ATP: Adapt train speed profile
Postcondition	The physical train unit continues its journey according to the movement authority and speed profile determined through the signal reading.	
Use Case notes	The ego track zone corresponds to the track zone taken by the ego train according to the route setting while the adjacent track zones correspond to the other tracks in the vicinity of the ego track.	
Related UCs	• UC 5.2 -0055: Transition from ATP Lineside signalling area to Class A area • UC 5.2 -0058: Driving according to journey based on lineside signals. • UC 5.2 -0057: Drive inside depot / stabling or maintenance facility	

Table 11: Use Case “Drive according to non-regular signals”

4.3 Surveillance of Location Associated With Increased Risk of Collision

4.3.1 UC5.2-0016: Handle reduced visibility and detection capabilities

Use Case field	Description	
ID	UC.5.2-0016	
Use Case name	Handle reduced visibility and detection capabilities	
Main actor	Onboard Automation System	
Other actors	• Fleet Management System	
Use Case summary	If diagnostic information indicates degraded capability of one or more sensors, the reduced capability needs to be taken into account. Note: This use case applies in different scenarios: Combination of: • weather (Fog, Rain, direct sunlight etc.) • technological impact (disturbances, failure) • location, track layout and corresponding surroundings (e.g., tunnels, walls, trees or building near the tracks, train on adjacent track)	
Applicability	• Geographical: European level • System level: Railway System • Operational category: passenger, freight, urban, regional, mainline and inspection vehicles	
Main goal	Ensure that the Onboard Automation System is able to operate in case of reduced visibility and detection capabilities	
Preconditions	Onboard Automation System is working with nominal visibility and detection capabilities.	
Termination outcome	**Successful outcomes**	• Outcome 1: The Onboard Automation System is recovering full visibility and detection capabilities.
	Unsuccessful outcomes	• Outcome 2: The Onboard Automation System indicates it has no more visibility or detection capabilities.
Condition affecting termination outcome	**Outcome 2**	Onboard Automation System may be unable to continue to drive the train (see use case notes).
	Step 1a	Weather, light environment, or element external to the Onboard Automation System (waterdrop, windscreen wiper, unexpected EMC, ...) may have an impact on sensor performance.

	Step 1b	The Onboard Automation System shall, based on its sensor data, be able to measure its residual visibility and detection capabilities under these conditions. It means also that the Onboard Automation System is still able to operate with a reduced domain of visibility and detection. (Refer to higher level use case)
	Step 1b.1	The Onboard Automation System indicates it has no more visibility or detection capabilities. [Outcome 2]
	Step 2a	Onboard Automation System internal failure may have an impact on global sensor performance (sensor failure, loss of communication, loss of power).
	Step 2b	The Onboard Automation System shall, based on its sensor data, be able to measure its residual visibility and detection capabilities under these conditions. It means also that the Onboard Automation System is still able to operate with a reduced domain of visibility and detection. (Refer to higher level use case)
	Step 2b.1	The Onboard Automation System indicates it has no more visibility or detection capabilities. [Outcome 2]
	Step 3a	Because of track arrangement, surroundings (walls, tunnels, gradient), train on adjacent track, occlusions may temporarily prevent the Onboard Automation System from full visibility of the train gauge.
	Step 3b	The Onboard Automation System shall, based on computation coming from track knowledge (curve, tunnels), train location, and potential train on adjacent track, measure its visibility and detection capabilities. Note: might be out of use case since it is nominal operation. There is no unsuccessful outcome for this step because the visibility is never fully blocked due to these conditions (gauge standard). Visibility might be strongly reduced though.
	Step 4a	If required, after Step 1 or Step 2, specific alarm with detailed diagnostic information is sent by On-Board Automation System to Fleet Management System for maintenance activity to perform (cleaning, component replacement, ...)
	Step 4b	Railway Undertaking Supervisor perform maintenance activity on the train. A workshop and appropriate tools may be required.

	Step 5	The Onboard Automation System is recovering full visibility and detection capabilities.
Postcondition	None	
Use Case notes	If the Onboard Automation System is driving in an operational mode where "driving-on-sight" attention is required, the Onboard Automation System shall adapt it speed accordingly. This is out of the scope of this use case and shall be managed by higher level use cases.	
Related UC	None	

Table 12: Use Case "Handle reduced visibility and detection capabilities"

4.3.2 UC5.2-0031: Activate horn triggered by onboard perception or trackside information

Use Case field	**Description**
ID	UC5.2-0031
Use Case name	Activate Horn triggered by onboard perception or trackside information
Main actor	On Board Automation System OAS
Other actors	• Trackside Automation System TAS
Use Case summary	Perception-related situations when the horn should be activated.
Applicability	• Geographical national level / European level (some rules might be country specific). • System level: GoA3, GoA4 • Operational category: passenger, freight, urban, regional, mainline and inspection vehicles
Main goal	Several situations require the horn to be activated. Some are position related, i.e., railway crossings in some countries or leaving a tunnel. Other are situation dependent like passengers on platforms or people/objects on railway crossings. We focus on these situations. See S2R SRS requirement: (APM-2.1) APM shall activate horn at predefined horn activation locations or following a horn request from APM in case of incident for which this reaction is required. This use case lists possible situations which shall be detected by OAS and/or TAS.
Preconditions	Train is running in GoA3 or GoA4

Termination outcome	**Successful outcomes**	• Outcome 1: the horn is activated during the sensitive situation and the train continuous without braking or deceleration.
	Unsuccessful outcomes	• Outcome 2: the horn is activated, and the sensitive situation is still present. Train decelerates or stops.
Condition affecting termination outcome	**Outcome 2**	Explanation: despite of activation of the horn, the situation is not resolved. Depending on the situation the train may continue with low speed (people on platform) or must stop (big animals on track). See UC5.2-0002/ UC5.2-0003. If stop is necessary: post-conditions: wait until situation resolves or activate staff to resolve the situation. Inform TAS about delay.
Use Case scenario	**Step 1**	OAS or TAS detects a sensitive situation.
	Step 1a	The sensitive situation includes: • Wandering livestock • Objects or person on level crossing • People on platform who are near to the tracks (less than 2.2m from track centre) or move towards an unsafe area. • Passing train on another track (France) • Railway agents on the track inside the gauge • Railway agents on the track outside the gauge • People on the track • People near the track In addition, there are cases in which to horn is needed without using perception. It is triggered due to data from digital map: • Unprotected level crossing • Other locations defined in the digital map (today solved by signs along trackside)
	Step 2	If TAS detected a critical situation: TAS informs OAS about the situation
	Step 3	OAS activates the horn (short, long, or multiple) considering the restriction for the current time/area. See use case S2R SRS 13.4.4 Activate horn.
	Step 3.1	In case OAS doesn't receive status of the horn, there is a retry of the activation of the horn and an information to TAS is triggered.

	Step 4	The detected object solves the sensitive situation. In case the TAS has the knowledge/detection of issue, the OAS will be informed. In case the OAS has detected the issue, the train continuous automatically.
	Step 4.1	The detected object remains in critical situation. OAS informs TAS about ongoing critical situation. Go to Outcome 2
	Step 5	The train continues its journey.
Postcondition	TAS calculates new timetable if necessary.	
Use Case notes	In addition: if horn is not working properly, there are restrictions: Additional note for Step 1a: The maximum distance (e.g., distance from the track that should be considered as criteria to avoid false positive detection due to animals in a garden or in a field) is currently not defined.	
Related UC	None	

Table 13: Use Case "Activate Horn triggered by onboard perception or trackside information"

4.4 DETECTION OF INFRASTRUCTURE DEFECTS AND ANAMOLY DETECTION

4.4.1 UC5.2-0008: Rail Adhesion Estimation using Perception

<table>
<tr><th>Use Case Field</th><th colspan="2">Description</th></tr>
<tr><td>ID</td><td colspan="2">UC5.2-0008</td></tr>
<tr><td>Use Case name</td><td colspan="2">Rail Adhesion Estimation using Perception</td></tr>
<tr><td>Main actor</td><td colspan="2">OAS: On-Board Automation System</td></tr>
<tr><td>Other actors</td><td colspan="2"></td></tr>
<tr><td>Use Case Summary</td><td colspan="2">This use case details the flow of events that need to be performed for the PER actor to collect the information to estimate the wheel to rail adhesion of the current track that the train is traversing.

The scope is to make the estimate and provide this information to other actors that would further take action for improving the Braking performance, including:

• Tune the braking curve.
• Improve braking performance.
• Provide ability to indicate the adhesion level in GoA3/4 operation</td></tr>
<tr><td>Applicability</td><td colspan="2">All over Europe</td></tr>
<tr><td>Main Goal</td><td colspan="2">Providing the Wheel to Rail adhesion estimation allowing the Braking-Adhesion Management System (BAMS) for better Braking estimation and management. This estimation includes:

1. Dry/wet rail condition
2. Rain condition (ON/OFF – scale of intensity)
3. Snow condition (ON/OFF – scale of intensity)</td></tr>
<tr><td>Precondition</td><td colspan="2">1. Train is in operational mode GoA3/4
2. PER module is active</td></tr>
<tr><td rowspan="2">Termination outcome</td><td>Successful outcomes</td><td>PER is able to estimate the track condition and provide this information</td></tr>
<tr><td>Unsuccessful outcomes</td><td>PER is not able to estimate the track condition and hence unable to provide this information</td></tr>
<tr><td>Condition affecting termination outcome</td><td>Outcome 2</td><td>Unavailability of PER to detect environmental conditions, which impacts the track condition estimation</td></tr>
<tr><td rowspan="2">Use Case description</td><td>Step 1</td><td>PER collects and processes the required sensor data</td></tr>
<tr><td>Step 2</td><td>PER performs the detection of the wheel to rail adhesion based on the sensor data processing. This includes detecting the factors that impact the wheel to rail adhesion like rain, snow, and its intensity.</td></tr>
</table>

	Step 3	The adhesion level is continuously communicated to the other sub-systems responsible for the braking
	Step 3a	The sub-systems use this information for improving the performance, including: • Tune the braking curve. • Improve braking performance. • Provide ability to indicate the adhesion level in GoA3/4 operation
	Step 3b	In case this information is not estimated for any failure reason, this inability is also communicated to ensure that there is a fall-back option
Postcondition	PER continuously communicates the wheel to rail adhesion estimation information	
Safety relation	Safety relevant if BAMS providing adhesion information to ATP	
Use Case Notes	None	
Related UC	None	

Table 14: Use Case "Rail Adhesion Estimation using Perception"

4.4.2 UC5.2-0018: Unusual impact or movement

Use Case field	Description
ID	UC.5.2.0018
Use Case name	Unusual impact or movement
Main actor	Physical Train Unit (PTU)
Other actors	• Trackside Automation System (TAS), • Operations Manager (OM), • Railway Undertaking Supervisor (RUS), • Emergency Manager (IEM)
Use Case summary	This use case details the actions to be taken in case of impact or bogie instability. This use case is limited to an impact detected by PER or a bogie instability detected by TCMS. Incident must be transmitted through APM.
Applicability	Geographical: European level System level: up to GoA4 Operational Category: passenger, freight, urban, regional, mainline and inspection vehicles
Main goal	Verify a detected irregularity at an early stage and then react to it appropriately, to prevent harm to third parties.

Preconditions	Train is running at speed between stations.	
Termination outcome	**Successful outcomes**	• Irregularity was identified and responded to appropriately.
	Unsuccessful outcomes	• Irregularity wasn´t detected. Time at risk for derailment increases. • The probability that the result of an impact will be noticed first in a station increases.
Condition affecting termination outcome	**Outcome 2**	None
Use Case scenario	**Step 1**	PTU: Apply brakes until standstill (if impact is detected at front bogie).
	Step 1.1	PTU: Apply brakes (if instability of any bogie is detected).
	Step 1.1.1	PTU: Inform trackside automation system about speed reduction by instability.
	Step 1.1.2	PTU: Release brakes (if stability of each bogie is gained again).
	Step 1.1.3	PTU: Apply traction as necessary to reach envisaged speed profile. Continue with step 9.
	Step 2	PTU: Immobilize train.
	Step 3	PTU: inform trackside automation system about 'impact detected'.
	Step 4	PTU: inform and advice passengers on board about 'intermediate stop and not to leave the train'.
	Step 5	TAS: Alert Operations Manager about impact detected.
	Step 6	RUS: Request video stream before and after incident.
	Step 7	RUS: Evaluates the situation based on video stream.
	Step 8	RUS: Command reset the impact detection alarm and release brakes (if it was obviously determined as a false alarm).
	Step 8.1	RUS: send IEM for further investigation on site and inform other entities in case of emergency (if not sure that there is no obstacle or that the train has not been damaged).
	Step 8.1.1	IMS: Clarifies the situation on site and reports to the Operations Manager accordingly.
	Step 8.1.2	RUS: Command reset the impact detection alarm and release brakes.

	Step 9	PTU: Reset impact detection alarm, release emergency brake, and apply horn to indicate start of movement.
	Step 10	PTU: Continue trip.
Postcondition	Train moves at interstation.	
Use Case notes	None	
Related UC	None	

Table 15: Use Case "Unusual impact or movement"

4.4.3 UC5.2-0020: Fire on Embankment

The use-cases in this paragraph intend to

- enable prototyping the recognition of some fire by the train's perception systems,
- elicit the train's reactions, so that the autonomous train's architecture can be consolidated.

They are organized as follows:

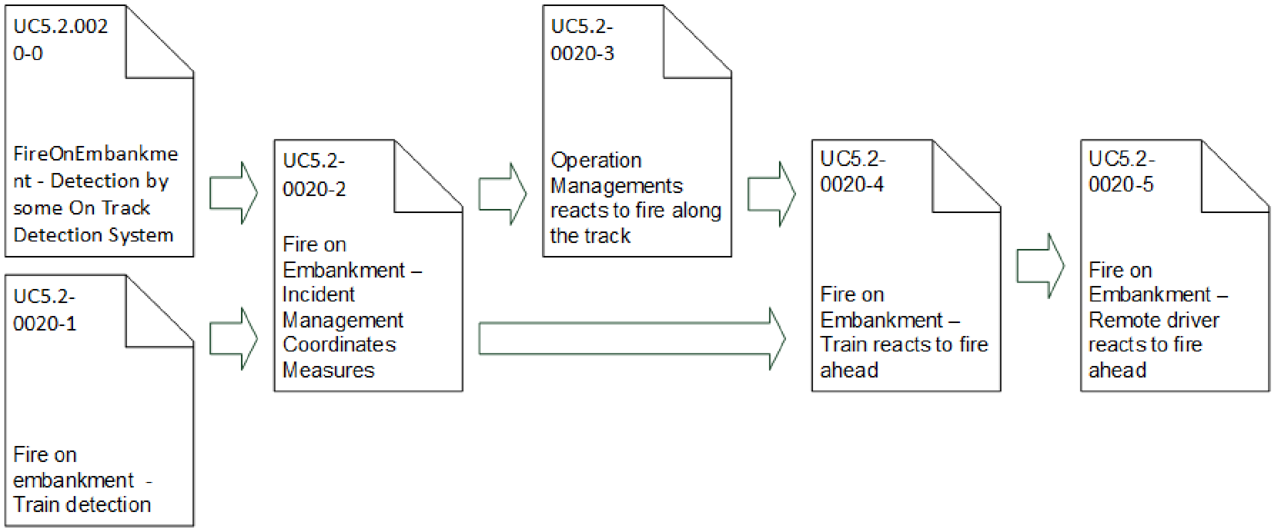

Figure 4: Fire on Embankment

4.4.3.1 UC5.2-0020-0 Fire on Embankment – Detection by some On Track Detection System

Use Case field	Description
ID	UC5.2-0020-0
Use Case name	Fire On Embankment – Detection by some On Track Detection System
Main actor	Incident Manager (Incident Management System)
Other actors	• Operations manager • Physical train unit,
Use Case summary	This use case details the actions that shall be taken when a fire is detected on the line by some online fire detection system.
Applicability	• Geographical: European level • System level: ATO-Incident Management System, APM, ATP

	• Operational category: All	
Main goal	The main goal of this use case is that the fire is reported to the organization responsible for mitigating its consequences – operations, remote supervision centre.	
Preconditions	1. Online Fire Detection System (track-side equipment) up and running. 2. Incident Manager running	
Termination outcome	**Successful outcomes**	The Incident Manager is notified about the fire – the use-case is continued by UC5.2.0020-2.
	Unsuccessful outcomes	The fire is not reported to the Incident Manager or to the Operations Manager.
Condition affecting termination outcome	**Outcome 2**	None
	Step 1	The Fire detection System detects a fire ahead. It assesses the fire category and location. • TrackAreaFire: closest 2 points on the track centre line to the fire's extremities points. If the fire is smaller than grown, the area may be reduced to a single point. • DTrackFire: shortest distance of any point of TrackAreaFire to the fire. • FireCategory: fire category as defined in Appendix 1: Minor, Grown, Restricted, HeatWall It archives its sensor recordings about the fire, especially video, also infra-red if existing.
	Step 2	The Fire Detection System alarms its Incident Manager about the fire. To this intend, it sends a fire report to the Incident management system: • TrackAreaFire, DTrackFire, FireCategory • Video recordings about the fire also Infra-red
	Step 3.x	From this moment, the Fire Detection System refreshes periodically its report about the fire progression.
	Step 4	The scenario ends when the sensor reporting a fire assessed as extinguished.
Postcondition	The fire is reported to ISM, see UC5.2-0020-2.	
Use Case notes	See Appendix 1, Disclaimer about safety	
Related UC	• UC5.2-0020-1 • UC5.2-0020-2 • UC5.2-0020-3 • UC5.2-0020-4 • UC5.2-0020-5	

Table 16: Use Case "Fire on Embankment– Detection by some On Track Detection System"

4.4.3.2 UC5.2-0020-1: Fire on Embankment - Train detection

Use Case field	Description	
ID	UC5.2-0020-1	
Use Case name	Fire on embankment - Train detection	
Main actor	Serviceable Train	
Other actors	• Operations manager • Incident Manager	
Use Case summary	This use case details the actions that shall be taken when a fire is detected in an embankment.	
Applicability	• Geographical: European level • System level: ATO-IPM-ATP • Operational category: All	
Main goal	The main goal of this use case is that the train remains safe at all times. If possible, it reaches the next stopping point, leaving the fire behind itself. If not, it shall stay away from the fire.	
Preconditions	1. Train is in operational mode GoA3/4 2. Train is operating in a mission. 3. Train has typically a nonzero velocity, but it is not necessary. In case the train is at standstill, the braking part of the use-case is skipped. 4. The train is not yet notified that a fire lies ahead. 5. A fire is detected on the embankment by the train	
Termination outcome	**Successful outcomes**	The train and its passengers or load have remained safe during the use-case. If the fire size and location allowed the train to pass safely, they have passed the fire. The operations centre is notified about the fire.
	Unsuccessful outcomes	The train has been exposed to the fire in a way that is not safe. Or The operations centre is not notified about the fire. Or Critical outcome: the fire has propagated to the train.
Condition affecting termination outcome	**Outcome 2**	The train and its passengers or load have remained safe during the use-case. The train did not pass the fire. The operations centre is notified about the fire.
	Step 1	The train detects a fire ahead. The train assesses the fire category and location. • TrackAreaFire: closest 2 points on the track centre line to the fire's extremities points. If the fire is littler than grown, the area may be reduced to a single point. • DTrackFire: shortest distance of any point of TrackAreaFire to the fire. • FireCategory: fire category as defined in Appendix 1: Minor, Grown, Restricted, HeatWall It archives its recorded measures about the fire.

	Step 2	The train alarms the Incident Manager responsible for the fire location about the fire. It reports: • TrackAreaFire, DTrackFire, FireCategory • Video recordings about the fire also Infra-red
	Step 3	From now on, the train will refresh its report about the fire every 25 meters, until its rear cannot detect the fire anymore.
Postcondition	The Fire is burning. The Incident Manager is notified. The train pursues with UC5.2-0020-4.	
Use Case notes	See Appendix 1, Disclaimer about safety	
Related UC	• UC5.2-0020-0 • UC5.2-0020-2 • UC5.2-0020-3 • UC5.2-0020-4 • UC5.2-0020-5	

Table 17: Use Case "Fire on Embankment - Train detection"

4.4.3.3 UC5.2-0020-2: Fire on Embankment – Incident Manager Coordinates Measures

Use Case field	Description	
ID	UC5.2-0020-2	
Use Case name	Fire on Embankment – Incident Manager Coordinates Measures	
Main actor	Incident Manager	
Other actors	• Operations manager, • Serviceable Train	
Use Case summary	This use case details the actions that shall be taken when a fire is detected in an embankment.	
Applicability	• Geographical: European level • System level: ATO-IPM-ATP • Operational category: All	
Main goal	The main goal of this use case is that a notified fire is extinguished. In the meantime, operations have been given the opportunity of adapting the traffic to avoid jeopardizing trains.	
Preconditions	This use-case pre-requisite a location where a fire takes place. 1. The Incident Manager responsible for this location is running. 2. Some Fire Detection System is running, that covers the location at the start of the use-case: a. UC5.2-0020-0 Online Fire Detection b. UC5.2-020-1 On-board Fire detection system c. Other fire detection system d. Any combination of the above 3. A fire appears on the track embankment at the location	
Termination outcome	**Successful outcomes**	1. The measures to extinguish the fire have been triggered. 2. Operations Manager is notified if operation is opened on the track (Night)

	Unsuccessful outcomes	1. The measures to extinguish the fire are delayed. 2. Operations is not notified
Condition affecting termination outcome	**Outcome 2**	None
	Step 1	A human or a Fire Detection System, either on-line, on-board, or other, notifies an Incident Prevention Manager of a fire, incl. fire report to the Incident Management System: • TrackAreaFire, DTrackFire, FireCategory • Video recordings about the fire also Infra-red
	Step 2	The incident Manager assesses whether the fire it is already known to him/it/her. • If not, a fire incident is opened. • If so, the notification is added in the workflow of the already existing fire incident. Note: this assessment can be performed by a human, automatically, or both.
	Step 3	A fire manager assesses the notification new information. Especially, the Incident Manager may reassess the FireCategory. If the FireCategory is estimated to 'FalseAlarm', the use-case ends with success. If the FireCategory is [Minor, Restricted, Grown, HeatWall], Jump to step 4 If the FireCategory is Extinguished, jump to step 6
	Step 4.0	[the FireCategory is Minor, Restricted, Grown, HeatWall] The Incident Manager takes all 4.x measures in parallel
	Step 4.1	The Incident Manager notifies the local firefighting teams of the fire: • TrackAreaFire, DTrackFire, FireCategory • Video recordings about the fire also Infra-red • Closest point of entry on the track from the road network • Track area allocated to Fire-Fighting teams to fight the fire. Note: this track area may change along the incident solving process. Fire-Fighting teams may report need for more space vocally, or by digital interface, may be equipped with personal or vehicle location devices, … Current use-case does not intend to specify those interactions. Instead, the new value of the track area is repeated along sub-sequent reports.
	Step 4.2	It notifies operations about of the fire. • TrackAreaFire, DTrackFire, FireCategory • Video recordings about the fire also Infra-red • Closest point of entry on the track from the road network • Expected time of entry of firefighting teams

		• Track area allocated to Fire-Fighting teams to fight the fire.
	Step 4.3	It notifies all trains in approach of the fire, d<= 5km, about of the fire • TrackAreaFire, DTrackFire, FireCategory • Video recordings about the fire also Infra-red • Expected time of entry firefighting teams • Track area allocated by Fire-Fighting teams to fight the fire
	Step 5.x	From this moment on, Step 4 is repeated periodically or on change of status.
	Step 6.0	[the fire is Extinguished] The incident manager notifies all related parties about the end of the incident. Note: The order of 6.x is not specified by this use-case, nor if other tasks must be evaluated before the incident is really close. Current use-case is a simplified use-case to enable demonstrator.
	Step 6.1	notifies operations about of the fire. • FireCategory=Extinguished • Video recordings about the fire also Infra-red • Fire-Fighting Teams have left the track
	Step 6.2	It notifies all trains that had been informed about the fire: • FireCategory=Extinguished • Video recordings about the fire also Infra-red • Fire-Fighting Teams have left the track
Postcondition	After step 4: • Fire is burning. • Incident Manager manages the fire incident (not scope of WP5). • Firefighters Fight (not scope of WP5). • Operations react – *See starting use-case UC5.2.0020-3* • Trains start modulating Speed – *See starting use-case UC5.2.0020-4.* After step 6: • Operations and trains resume to normal traffic.	
Use Case notes	See Appendix 1, Disclaimer about safety	
Related UC	• UC5.2-0020-0 • UC5.2-0020-1 • UC5.2-0020-3 • UC5.2-0020-4 • UC5.2-0020-5	

Table 18: Use Case "Fire on Embankment – Incident Manager Coordinates Measures"

4.4.3.4 UC5.2-0020-3: Fire on Embankment – Operation Manager reacts to fire along the track

Use Case field	Description	
ID	UC5.2-0020-3	
Use Case name	Operation Manager reacts to fire along the track	
Main actor	Operations Manager	
Other actors	Serviceable Trains in approach of the fire area TrackAreaFire	
Use Case summary	The operations manager adapts traffic in the area in approach of a fire, according to fire category and extend of the firefighter's deployment.	
Applicability	• Geographical: European level • System level: ATO-IPM-ATP • Operational category: All	
Main goal	Ensure that train speeds in the vicinity of the fire and firefighters' deployment is permanently adequate until incident is solved. To this intend, it issues Temporary Speed Limits for: TrackAreaFire, TrackAreaFireFighterDeployment, potentially also 0. Care is taken that the first train, if impacted by a shortened movement authority, does not stop, and remains along the fire. Instead, it shall be given the opportunity to drive back.	
Preconditions	UC5.2-0020-2	
Termination outcome	**Successful outcomes**	The fire generates no damages to the rolling stock, firefighting squad, vehicles, and assets. Running trains generate no damages to the infrastructure even if weakened by the heat. The traffic speed is maintained as far as possible, also at reduced speed. It is stopped if not possible anymore. If the track is suspended for traffic, Movement Authorities of the first stopping train remain protected in rear of the train so it can leave the fire area driving backwards.
	Unsuccessful outcomes	Trains drive too fast, are not able to avoid some collision with firefighters. Traffic is unnecessarily stopped. A train is exposed to a fire.
Condition affecting termination outcome	**Outcome 2**	-
	Step 1	Operations is notified about of a fire (see pre-conditions for preceding scenarios) • For each track close to the fire: TrackAreaFire, DTrackFire, FireCategory • Video recordings about the fire also Infra-red • Closest point of entry on the track from the road network • Expected time of entry firefighting teams • Track area TrackAreaFireFighterDeployment allocated by Fire-Fighting teams to fight the fire.

	Step 2	Operations declare TrackAreaFire and TrackAreaFireFighterDeployment as area that shall not be entered if it cannot be driven through without stop. According to the DTrackFire, FireCategory and Appendix 1 “Fire classification and associated distance to the loading gauge”, operations define fire related minimum speed and maximum speed (also 0) for TrackAreaFire. Should the resulting Minimum and Maximum speed not be compatible, the area is suspended for traffic. The resulting ‘Desirable MRSP’ is computed and inserted in the movement authority associated to the track.
	Step 3	‘Desirable MRSP’ are assessed for the trains in approach. For all train that can implement it – no MA yet received about the area where MRSP changes, the MRSP is decided (it will be sent when the track sends to the train his MA containing the track along the fire).
	Step 4	For the train that had already received a MA containing the changed MRSP, assessment is made whether this would generate an EBI, that might stop the train in front of the fire. If not, go to 4.1. If so, go to 4.2
	Step 4.1	The train would either drive along the fire a safe speed or stop before the fire. The use-case ends successfully here. See UC5.2-0020-4 for continuation.
	Step 4.2	The train would stop along the fire. The operations manager is asked whether the train shall stop or drive through. A decision assistance system may help him/her, for instance by displaying that the rules in Appendix 1 would lead to, if DTrackFire or FireCategory were different. If the operations manager decides to lead the train through, go to step 5. If the operations manager decided to stop the train along the fire (the track is supposed blocked ahead), go to step 6.
	Step 5	The operations manager decides a maximum speed that the train can apply. The trains’ LMA is improved. The use-case ends. See UC5.2-0020-4 for continuation.
	Step 6	The train’s operation manager decides a shortening at the first reachable point. The train’s LMA behind in rear of the fire is maintained for the train, so if can later drive backwards. See UC5.2-0020-4 for continuation.
Postcondition	The first approaching train’s movement authority has been amended. Successors will get an adapted MA.	
Use Case notes	See Appendix 1, Disclaimer about safety	
Related UC	• UC5.2-0020-0 • UC5.2-0020-1	

	• UC5.2-0020-2 • UC5.2-0020-4 • UC5.2-0020-5

Table 19: Use Case "Fire on Embankment – Operation Manager reacts to fire along the track"

4.4.3.5 UC5.2-0020-4: Fire on Embankment – Train reacts to fire ahead

Use Case field	**Description**	
ID	UC5.2-0020-4	
Use Case name	Fire on Embankment – Train reacts to fire ahead	
Main actor	Operations Manager	
Other actors	• Serviceable trains in approach of the fire area TrackAreaFire, • On Board Driver or Remote Driver	
Use Case summary	The train adapts its driving according to the restrictions set by operations, due to the fire in UC5.2-0020-3.	
Applicability	• Geographical: European level • System level: ATO-IPM-ATP • Operational category: All	
Main goal	Ensure that train speeds in the vicinity of the fire and firefighters' deployment is permanently adequate until incident is solved. To this intend, it issues Temporary Speed Limits for: TrackAreaFire, TrackAreaFireFighterDeployment, potentially also 0. Care is taken that the first train, if impacted by a shortened movement authority, does not stop, and remains along the fire. Instead, it shall be given the opportunity to drive back.	
Preconditions	UC5.2-0020-1 or -2.	
Termination outcome	**Successful outcomes**	The fire generates no damages to the rolling stock, firefighting squad, vehicles, and assets. Running trains generate no damages to the infrastructure even if weakened by the heat. The speed of the train in the scenario is maintained as far as possible, also at reduced speed, also stopped if not possible anymore. If the traffic is stopped (track is suspended for traffic), Movement Authority of the first stopping train remain protected in rear of the train so it can leave the fire area driving backwards.
	Unsuccessful outcomes	Trains drive too fast, are not able to avoid some collision with firefighters. Traffic is unnecessarily stopped. A train is exposed to a fire.
Condition affecting termination outcome	**Outcome 2**	-
	Step 1	The train is notified about a fire, out of scenario (see pre-conditions for the preceding scenario) • TrackAreaFire, DTrackFire, FireCategory

		• Video recordings about the fire, also Infra-red/thermal sensors • Closest point of entry on the track from the road network • Expected time of entry firefighting teams • Track area TrackAreaFireFighterDeployment allocated by Fire-Fighting teams to fight the fire.
	Step 2	The train notifies its controlling driver about the fire notification. • TrackAreaFire, DTrackFire, FireCategory • Video recordings about the fire also Infra-red • Closest point of entry on the track from the road network • Expected time of entry firefighting teams • Track area TrackAreaFireFighterDeployment allocated by Fire-Fighting teams to fight the fire.
	Step 3	According to the notification report, the principles in 'Operational definitions', and existing movement authority, the train defines a strategy about driving toward TrackAreaFire: Stop before, DriveAlong, DriveThrough (without stop), Drive back. To precise this strategy, the train defines for every location of TrackAreaFire: • A minimum speed V_{min}, • A maximum speed, V_{max} from 0 km/h (drive through forbidden) to VMaxTrain (no specific restriction due to the fire) • A property 'Lasting stop safe' according to the distance to the fire For TrackAreaFireFighterDeployment, it defines VMaxDrivingAlongFireFighters.
	Step 4	The train defines a speed profile implementing the strategy decided in step 3 and the associated constraint. Potentially, this speed profile contains a backward manoeuvre to exit the fire area.
	Step 5	The train applies this speed profile.
Postcondition	The train has driven along the fire area. It safely stands ahead of it. The train has stopped before the fire area. It lies safely and waits for instructions from Operations. The train has stopped along the fire area. It has driven backwards to a safe haven. It lies safely and waits for instructions from Operations.	
Use Case notes	See Appendix 1, Disclaimer about safety	
Related UC	• UC5.2-0020-0 • UC5.2-0020-1 • UC5.2-0020-2 • UC5.2-0020-3 • UC5.2-0020-5	

Table 20: Use Case "Fire on Embankment – Train reacts to fire ahead"

4.4.3.6 UC5.2-0020-5: Fire on Embankment – Remote driver reacts to fire ahead

<table>
<tr><th>Use Case field</th><th colspan="2">Description</th></tr>
<tr><td>ID</td><td colspan="2">UC5.2-0020-5</td></tr>
<tr><td>Use Case name</td><td colspan="2">Fire on Embankment – Remote driver reacts to fire ahead</td></tr>
<tr><td>Main actor</td><td colspan="2">Remote Driver</td></tr>
<tr><td>Other actors</td><td colspan="2">Serviceable Train</td></tr>
<tr><td>Use Case summary</td><td colspan="2">A remote driver supervising a train is notified that its train approaches a fire.</td></tr>
<tr><td>Applicability</td><td colspan="2">• Geographical: European level
• System level: ATO-IPM-ATP
• Operational category: All</td></tr>
<tr><td>Main goal</td><td colspan="2">Support the incident with human decision plasticity by preparing human support of the incident.</td></tr>
<tr><td>Preconditions</td><td colspan="2">UC5.2-0020-4</td></tr>
<tr><td rowspan="2">Termination outcome</td><td>Successful outcomes</td><td>Train passengers or goods have remained safe from the fire all along the use-case. No passenger panic</td></tr>
<tr><td>Unsuccessful outcomes</td><td>Trains were not safe along the complete use-case.
Passengers panic in the compartment.</td></tr>
<tr><td>Condition affecting termination outcome</td><td>Outcome 2</td><td>None</td></tr>
<tr><td rowspan="7"></td><td>Step 1</td><td>The Supervising Remote Driver is alarmed about of a fire.
• TrackAreaFire, DTrackFire, FireCategory
• Video recordings about the fire also Infra-red
• Closest point of entry on the track from the road network
• Expected time of entry firefighting teams
• Track area TrackAreaFireFighterDeployment allocated by Fire-Fighting teams to fight the fire.</td></tr>
<tr><td>Step 2</td><td>He/she takes control of the train, becoming the single point of contact for operations.
➔ Several drivers may have been supervising
➔ This does not mean that the train leaves Goa4, just that it now drives a supervised Goa4</td></tr>
<tr><td>Step 3</td><td>He/she assesses the fire, the driving strategy by ATO (UC5.2-0020-4)</td></tr>
<tr><td>Step x</td><td>At any time, the remote driver may
• reassess the fire category.
• disengage ATO</td></tr>
<tr><td>Step y</td><td>At any time, the remote driver may
• inform passengers about incident development</td></tr>
<tr><td>Step 5.0</td><td>(The train passes the fire area, or traffic resumes normally due to incident solving)
The use-case ends successfully.</td></tr>
<tr><td>Postcondition</td><td colspan="2">The train has driven along the fire area. It safely stands ahead of it.</td></tr>
</table>

	The train has stopped before the fire area. It lies safely and waits for instructions from Operations, e.g., get back to former station. The train has stopped along the fire area. It drove backwards to a safe haven. It lies safely and waits for instructions from Operations, e.g. also get back to former station.
Use Case notes	See Appendix 1, Disclaimer about safety
Related UC	• UC5.2-0020-0 • UC5.2-0020-1 • UC5.2-0020-2 • UC5.2-0020-3 • UC5.2-0020-4

Table 21: Use Case "Fire on Embankment – Remote driver reacts to fire ahead"

4.4.4 UC5.2-0021: Flooding

This use case details the actions to be taken in case of flooding identified as passable with reduced speed or impassable flooding in the track in proximity of the train.

4.4.4.1 UC5.2-0021-1: Impassable flooding

Use Case field	Description	
ID	UC.5.2-0021-1	
Use Case name	Impassable flooding	
Main actor	OAS (Onboard Automation System)/PER (Perception)	
Other actors	• TAS (Trackside Automation System) • FMS (Fleet Management System) • IMS (Incident Management System)	
Use Case summary	This use case details the actions to be taken in case of flooding identified as impassable in the track in proximity of the train.	
Applicability	• Geographical: European • System level: Infrastructure System (GoA3/4) • Operational category: passenger, urban, regional, mainline, freight, tram	
Main goal	The main goal of this use case is to fit the GoA3/4 with perception and actions with at least the same performance that a driver has today in case of catenary damage identified as impassable in track in proximity of the train.	
Preconditions	• Train is operating in a mission. • Train has a nonzero velocity. • Flooding is in proximity of the train. • OAS (PER) system is monitoring the area of interest	
Termination outcome	**Successful outcomes**	Outcome 1: Conditions for success: • Flooding is correctly detected as impassable. • Train avoided incident. • Train in safe area. • IMs Control Centres and RUs Control Centres are notified of the impassable flooding location and train location. • Mission profile of train units in vicinity of impassable flooding and affected train is updated.

		• On board Multimedia and Telematic Subsystem informs to passengers about situation. All conditions must be met in order to achieve Outcome 1
	Unsuccessful outcomes	Outcome 2: One or more conditions for successful Outcome 1 is not met. Outcome 3: Train is unable to avoid flooding area, is stuck there and needs rescue and evacuation procedure.
Condition affecting termination outcome	**Outcome 2**	None
	Step 1	OAS/PER detect impassable flooding in the track in proximity of the train.
	Step 1.1	Flooding is passable. ➔ Unsuccessful outcome 2
	Step 1.2	Flooding is not detected. ➔ Unsuccessful outcome 2. If train derails. ➔ Unsuccessful outcome 3.
	Step 2	OAS/PER identify distance to danger area. OAS determine safe area.
	Step 3	OAS stops the train ahead of danger area.
	Step 3.1	OAS is unable to stop train ahead of danger area. OAS determine appropriate action in accordance with detected flooding levels.
	Step 3.1.1	OAS try to stop train in danger area and drive back to safe area. ➔ If this succeeds, go to step 4. ➔ If this fail, go to step 3.2
	Step 3.1.2	OAS try to drive train through danger area with reduced speed. ➔ If this succeeds, go to step 4. ➔ If this fail, go to step 3.2
	Step 3.1.3	OAS try to stop train in danger area and stay in position. ➔ Go to step 3.2
	Step 3.2	OAS is unable to stop train ahead of danger area and the train is stuck there. OAS informs TAS and FMS, which informs IMS, which informs Incident/Emergency Manager about the incident.
	Step 3.3	OM and FMS with IMS updates mission profile of train units in vicinity of impassable flooding and affected train.
	Step 3.4	Incident/Emergency Manager organizes rescue and evacuation procedure. ➔ Unsuccessful Outcome 2

	Step 4	OAS drive to or keep the train in safe area until mission profile is updated.
	Step 5	OAS informs TAS and FMS, which informs OM about the impassable flooding location, train location and sequence of events.
	Step 5.1	OAS is unable to inform FMS and IMS about the situation. On board Multimedia and Telematic Subsystem informs to passengers about situation. ➔ Unsuccessful Outcome 2
	Step 6	OM and FMS with IMS updates mission profile of train units in vicinity of impassable flooding and affected train.
	Step 6.1	FMS with IMS is unable to update mission profile of trains in vicinity of impassable flooding and affected train. ➔ Go to step 5. ➔ Unsuccessful Outcome 2
	Step 7	On board Multimedia and Telematic Subsystem informs to passengers about situation. ➔ Successful Outcome 1
Postcondition	• If affected train went through danger area, the train is to be checked at next station for damage. • If journey cannot continue, rescue and evacuation are executed. • Passengers are informed about new mission profile or rescue and evacuation.	
Use Case notes	The terms *Danger area* and *Safe area* needs to be defined at a more detailed level. This is considered outside the scope of this UC. References from document X2R4-WP05-D-ALS-010-009: • 13.10.2 Impassable flooding	
Related UC	None	

Table 22: Use Case "Impassable flooding"

4.4.4.2 UC5.2-0021-2: Passable flooding with reduced speed

Use Case field	Description
ID	UC.5.2-0021-2
Use Case name	Passable flooding with reduced speed
Main actor	OAS (Onboard Automation System)/PER (Perception)
Other actors	• TAS (Trackside Automation System) • FMS (Fleet Management System) • IMS (Incident Management System)
Use Case summary	This use case details the actions to be taken in case of flooding identified as passable with reduced speed in the track in proximity of the train.
Applicability	• Geographical: European • System level: Infrastructure System (GoA3/4) • Operational category: passenger, urban, regional, mainline, freight, tram

<table>
<tr><td>Main goal</td><td colspan="2">The main goal of this use case is to fit the GoA3/4 with perception and actions with at least the same performance that a driver has today in case of catenary damage identified as impassable in track in proximity of the train.</td></tr>
<tr><td>Preconditions</td><td colspan="2">• Train is operating in a mission.
• Train has a nonzero velocity.
• Flooding is in proximity of the train.
• OAS (PER) system is monitoring the area of interest</td></tr>
<tr><td rowspan="2">Termination outcome</td><td>Successful outcomes</td><td>Outcome 1: Conditions for success:
• Flooding is rightly detected as passable with reduced speed.
• Train avoided incident and continue to the designated stop area.
• IMs Control Centres and RUs Control Centres are notified of the incident and flooding location.
• On board Multimedia and Telematic Subsystem informs to passengers about situation.</td></tr>
<tr><td>Unsuccessful outcomes</td><td>Outcome 2: One or more conditions for successful Outcome 1 is not met.
Outcome 3: Train derails and needs rescue and evacuation procedure. Passengers are notified.</td></tr>
<tr><td>Condition affecting termination outcome</td><td>Outcome 2</td><td>-</td></tr>
<tr><td rowspan="8"></td><td>Step 1</td><td>OAS/PER detects passable flooding in the track in proximity of the train.</td></tr>
<tr><td>Step 1.1</td><td>Flooding is impassable.
➔ Unsuccessful Outcome 2
If train derail.
Incident/Emergency Manager organize rescue and evacuation procedure.
➔ Unsuccessful Outcome 3</td></tr>
<tr><td>Step 1.2</td><td>Flooding is not detected.
➔ Unsuccessful outcome 2
If train derail.
Incident/Emergency Manager organize rescue and evacuation procedure.
➔ Unsuccessful outcome 3</td></tr>
<tr><td>Step 2</td><td>OAS/PER identify distance to danger area.</td></tr>
<tr><td>Step 3</td><td>OAS reduces the speed of the train an appropriate amount ahead of danger area.</td></tr>
<tr><td>Step 3.1</td><td>OAS is unable to reduce the speed of the train an appropriate amount ahead of danger area with service brakes.
OAS activates emergency brakes to stop ahead of danger area.</td></tr>
<tr><td>Step 3.1.1</td><td>OAS is unable to reduce speed or stop train ahead of the danger area with emergency breaks.</td></tr>
</table>

		➔ If train derails, Unsuccessful outcome 3 ➔ If train is fine, go to step 3.2.
	Step 3.2	OAS drives out of danger area.
	Step 3.3	OAS drive to or keeps the train in safe area until mission profile is updated. ➔ Unsuccessful Outcome 2.
	Step 4	OAS informs TAS and FMS about the passable flooding location, train location and sequence of events.
	Step 4.1	OAS is unable to inform TAS and FMS about the situation. OAS continue according to Mission profile, until end of movement authority. ➔ Go to step 4. ➔ Unsuccessful Outcome 2
	Step 5	TAS impose TSR and updates mission profile of train units in vicinity of passable flooding.
	Step 5.1	TAS and FMS is unable to update mission profile of trains in vicinity of impassable flooding and affected train. ➔ Go to step 5. ➔ Unsuccessful Outcome 2
Postcondition	IMS and Incident/Emergency manager monitors the situation closely. • IMS and Incident/Emergency manager monitors the situation closely. • Train continues with the mission.	
Use Case notes	The terms Danger area and Safe area needs to be defined at a more detailed level. This is considered outside the scope of this UC. References from X2R4-WP05-D-ALS-010-009: • 11.11.5 Manage temporary speed restriction. • 13.10.3 Flooding passable with reduced speed	
Related UC	None	

Table 23: Use Case "Passable flooding with reduced speed" description

4.4.5 UC5.2-0024: Impassable Broken or Buckled Rail

Use Case field	Description
ID	UC.5.2-0024
Use Case name	Broken or Buckled Rail passable with reduced speed or with stop
Main actor	Incident Management System (IMS)
Other actors	• Operations Manager (OM), • Trackside Automation System (TAS), • On-board Automation System (OAS)
Use Case summary	A broken or buckled rail is reported from infrastructure management IM to OAS and TAS
Applicability	Geographical: European level

	System level: GoA2, GoA3, GoA4 Operational Category: passenger, freight, urban, regional, mainline and inspection vehicles	
Main goal	Stop in front of a broken or buckled rail	
Preconditions	Train operates at interstation.	
Termination outcome	**Successful outcomes**	Outcome 1a: Speed adjustment is applied before and after the slow speed section. Outcome 1b: Train is stopped before buckled or broken rail
	Unsuccessful outcomes	Outcome 2: Train was not able to adjust speed or stop before buckled or broken rail
Condition affecting termination outcome	**Outcome 2**	Messages were sent too late. Train adjusted speed or stopped too late. Postcondition: check if train was derailed. Inform TAS about late stop. See also remarks about Outcome 2 in use case notes.
Use Case scenario	**Step 1**	IMS: Determine broken or buckled rail section from external information. OAS: If equipped with a rail quality detection system, contribute information about the state of the rail and the ensuing risk
	Step 2	IMS: Provide information about broken or buckled rail section to the IM and Operations Manager OM.
	Step 3a	If the section is passable at lower speed. OM: Set a temporary speed restriction on respective section in the trackside automation system TAS.
	Step 3b	If the section is unpassable and stop is required. OM: Set a temporary MA restriction before the respective section in the trackside automation system TAS.
	Step 4a	If the section is passable at lower speed. TAS: Consider temporary speed restriction for movement authorities and journey profiles.
	Step 4b	If the section is unpassable and stop is required. TAS: Consider temporary MA restriction for movement authorities and journey profiles.
	Step 5a	If the section is passable at lower speed. OAS: Respect temporary speed restriction for control and supervision of train speed.
	Step 5b.1	If the section is unpassable and stop is required. OAS: If possible: stop just before the MA restriction.
	Step 5b.2	If the section is unpassable and stop is required. OAS: If a stop before the MA restriction is not possible, stop as early as possible. Go To Outcome 2.

	Step 6	OAS: Inform passengers about situation and expected delay.
	Step 7a	If the section is passable at lower speed. OAS: Resume to line speed after temporary speed restriction is passed with entire train length.
	Step 8	TAS calculates and sends to OAS new timetable because of speed restriction or closed route.
Postcondition	a) Train has passed the broken or buckled rail with appropriate speed b) Train is stopped before the broken or buckled rail section. Train will be evacuated or drives backwards. Rail will be repaired. If maintenance is successful, normal operation can resume.	
Use Case notes	[X2R4 SRS 0.3.0 chapter 11.11.3 (OM.3.3) The risk of a broken or buckled rail is mitigated by IM. Rationale: it is assumed that track quality is high and well maintained. Process for prevention is available] Optionally the trains could be equipped with rail quality sensors (in the simplest case an acceleration sensor) and monitor the quality of the track. They report the measurements to TAS which can detect worsening track conditions. Perception could also be used to detect and/or predict broken and buckled rail. A specific use case could focus on the detection of broken and buckled rail and report the findings to TAS. Remarks to the Outcome 2 (Postcondition): check if train was derailed. Inform TAS about late speed adjustment or late stop. For this condition (derailment) a derailment detection system or device is needed.	
Related UC	None	

Table 24: Use Case "Broken or Buckled Rail with reduced speed or with stop"

4.4.6 UC5.2-0025: Damage to catenary

This use case details the actions to be taken in case of catenary damage identified as passable with reduced speed or impassable catenary damage in the track in proximity of the train.

4.4.6.1 UC.5.2-0025-1: Impassable catenary damage

Use Case field	Description
ID	UC.5.2-0025-1
Use Case name	Impassable catenary damage
Main actor	OAS (Onboard Automation System)/PER (Perception)
Other actors	• TAS (Trackside Automation System) • FMS (Fleet Management System) • IMS (Incident Management System)
Use Case summary	This use case details the actions to be taken in case of catenary damage identified as impassable in the track in proximity of the train.
Applicability	• Geographical: European • System level: Infrastructure System (GoA3/4) • Operational category: passenger, urban, regional, mainline, freight, maintenance, tram.

Main goal	The main goal of this use case is to fit the GoA3/4 with perception and actions with at least the same performance that a driver has today in case of catenary damage identified as impassable in track in proximity of the train.	
Preconditions	• Train is operating in a mission. • Train has a nonzero velocity. • Catenary damage is in proximity of the train. • OAS (PER) system is monitoring the area of interest	
Termination outcome	**Successful outcomes**	Outcome 1: Conditions for success • Catenary damage is correctly detected as impassable. • Train avoided incident. • Train in safe area. • TAS, IMs Control Centres and RUs Control Centres are notified of the impassable catenary damage location and train location. • Mission profile of train units in vicinity of impassable catenary damage and affected train is updated. • On board Multimedia and Telematic Subsystem informs to passengers about situation. All conditions must be met in order to achieve Outcome 1
	Unsuccessful outcomes	Outcome 2: One or more conditions for successful Outcome 1 is not met. Outcome 3: Train is unable to avoid catenary damage area, is stuck there and needs rescue and evacuation procedure.
Condition affecting termination outcome	**Outcome 2**	None
	Step 1	OAS/PER detect impassable catenary damage in the track in proximity of the train.
	Step 1.1	*Catenary damage is passable.* ➔ Unsuccessful outcome 2
	Step 1.2	*Catenary damage is not detected.* ➔ Unsuccessful outcome 2.
	Step 2	OAS/PER identify distance to danger area. OAS determine safe area.
	Step 3	OAS stops the train ahead of danger area.
	Step 3.1	*OAS is unable to stop train ahead of danger area.* OAS determine appropriate action.
	Step 3.1.1	OAS try to stop train in danger area and drive back to safe area. According to National operational rules. ➔ If this succeeds, go to step 4. ➔ If this fail, go to step 3.2

	Step 3.1.2	OAS try to drive train through danger area with reduced speed. ➔ If this succeeds, go to step 4. ➔ If this fail, go to step 3.2
	Step 3.1.3	OAS try to stop train in danger area and stay in position. ➔ Go to step 3.2
	Step 3.2	*OAS is unable to stop train ahead of danger area and the train is stuck there.* OAS informs TAS and FMS, which informs IMS, which informs Incident/Emergency Manager about the incident.
	Step 3.3	OM and FMS with IMS updates mission profile of train units in vicinity of impassable flooding and affected train.
	Step 3.4	Incident/Emergency Manager organize rescue and evacuation procedure. ➔ Unsuccessful Outcome 3
	Step 4	OAS drive to or keeps the train in safe area until mission profile is updated.
	Step 5	OAS informs TAS and FMS, which informs OM about the impassable catenary damage location, train location and sequence of events.
	Step 5.1	*OAS is unable to inform FMS and IMS about the situation.* On board Multimedia and Telematic Subsystem informs to passengers about situation. ➔ Unsuccessful Outcome 2
	Step 5	OM and FMS with IMS updates mission profile of train units in vicinity of impassable flooding and affected train.
	Step 5.1	FMS with IMS is unable to update mission profile of trains in vicinity of impassable catenary damage and affected train. ➔ Go to step 5. ➔ Unsuccessful Outcome 2
	Step 6	On board Multimedia and Telematic Subsystem informs to passengers about situation. • Successful Outcome 1
Postcondition	• If catenary damage was identified as impassable, and the affected train went through danger area, the train is to be checked at next station for damage. • If journey cannot continue, rescue and evacuation are executed. • Passengers are informed about new mission profile or rescue and evacuation.	
Use Case notes	The terms *Danger area* and *Safe area* needs to be defined at a more detailed level. This is considered outside the scope of this UC. References from document X2R4-WP05-D-ALS-010-009: • 13.10.6 Damage to catenary	
Related UC	None	

Table 25: Use Case “Impassable catenary damage”

4.4.6.2 UC.5.2-0025-2: Passable catenary damage with reduced speed

Use Case field	**Description**	
ID	UC.5.2-0025-2	
Use Case name	Passable catenary damage with reduced speed	
Main actor	OAS (Onboard Automation System)/PER (Perception)	
Other actors	TAS (Trackside Automation System) FMS (Fleet Management System) IMS (Incident Management System)	
Use Case summary	This use case details the actions to be taken in case of catenary damage identified as passable with reduced speed in the track in proximity of the train.	
Applicability	• Geographical: European • System level: Infrastructure System (GoA3/4) • Operational category: passenger, urban, regional, mainline, freight, maintenance, tram.	
Main goal	The main goal of this use case is to fit the GoA3/4 with perception and actions with at least the same performance that a driver has today in case of catenary damage identified as impassable in track in proximity of the train.	
Preconditions	• Train is operating in a mission. • Train has a nonzero velocity. • Catenary damage is in proximity of the train. • OAS (PER) system is monitoring the area of interest	
Termination outcome	**Successful outcomes**	Outcome 1: Conditions for success: • Catenary damage is rightly detected as passable with reduced speed. • Train avoided incident and continue to the designated stop area. • TAS, IMs Control Centres and RUs Control Centres are notified of the incident and catenary damage location. All conditions must be met in order to achieve Outcome 1
	Unsuccessful outcomes	Outcome 2: One or more conditions for successful outcome 1 is not met. Outcome 3: Train needs rescue and evacuation procedure. Passengers are notified.
Condition affecting termination outcome	**Outcome 2**	None
	Step 1	OAS/PER detect passable catenary damage in the track in proximity of the train.
	Step 1.1	*Catenary damage is impassable.* ➔ Unsuccessful Outcome 2

		Incident/Emergency Manager take control of the train and organize rescue and evacuation procedure. ➔ Unsuccessful Outcome 3
	Step 1.2	*Catenary damage is not detected.* ➔ Unsuccessful outcome 2 Incident/Emergency Manager take control of the train and organize rescue and evacuation procedure. ➔ Unsuccessful outcome 3
	Step 2	OAS/PER identify distance to danger area.
	Step 3	OAS reduce the speed of the train an appropriate amount ahead of danger area.
	Step 3.1	*OAS is unable to reduce the speed of the train an appropriate amount ahead of danger area with service brakes.* OAS activate emergency brakes to stop ahead of danger area.
	Step 3.1.1	*OAS is unable to reduce speed or stop train ahead of the danger area with emergency breaks.* ➔ Unsuccessful outcome 3 ➔ If train is fine, go to step 3.2.
	Step 3.2	OAS drive out of danger area.
	Step 3.3	OAS drive to or keep the train in safe area until mission profile is updated. OAS informs TAS and FMS, which informs IMS about the incident. ➔ Unsuccessful Outcome 2.
	Step 4	OAS informs TAS and FMS about the passable catenary damage location, train location and sequence of events.
	Step 4.1	*OAS is unable to inform TAS and FMS about the situation.* OAS continue according to Mission profile, until end of movement authority. ➔ Go to step 4. ➔ Unsuccessful Outcome 2
	Step 5	TAS impose TSR and updates mission profile of train units in vicinity of passable catenary damage.
	Step 5.1	TAS and FMS is unable to update mission profile of trains in vicinity of impassable catenary damage and affected train. ➔ Go to step 5. ➔ Unsuccessful Outcome 2
Postcondition	• IMS and Incident/Emergency manager monitors the situation closely. • Train continues with the mission	

Use Case notes	The terms *Danger area* and *Safe area* needs to be defined at a more detailed level. This is considered outside the scope of this UC. References from document X2R4-WP05-D-ALS-010-009: • 11.11.5 Manage temporary speed restriction. • 13.10.7 Catenary damage passable with reduced speed.
Related UC	None

Table 26: Use Case "Passable catenary damage with reduced speed"

4.4.7 UC5.2-0027: Speed restriction due to weather conditions

This use case contains two individual sub cases. The first (UC5.2-0027-1) concern the speed restriction due low visibility in OS On Sight mode affecting only one train (local) and the second (UC5.2-0027-2) due to weather conditions and initiated by the TAS affecting all the trains in this area (central).

4.4.7.1 UC5.2-0027-1: Speed restriction due to visibility issues while driving on sight - local

Use Case field	Description	
ID	UC5.2-0027-1	
Use Case name	Speed restriction due to visibility issues while driving on sight - local	
Main actor	On-board Automation System (TCMS, ATO, ETCS)	
Other actors	Operation Manager	
Use Case summary	OAS (PER, APM) detects bad weather conditions. OAS (APM) ensures that the train may always stop at the point of maximal visible distance.	
Applicability	• Geographical European level • System level GoA34 • Operational category: passenger, freight, urban, regional, mainline and inspection vehicles	
Main goal	Main goal is a safe driving in driving-on-sight in bad weather conditions. An example could be coupling in fog. The train reduces the speed to a value which always allows braking to the point of visibility. This ensures that the train can break for an obstacle which "appears out of the fog" or allows OAS to detect a line side signal aspect on time.	
Preconditions	Driving-on-sight mode (OS mode with the specified speed limit) is activated. Vehicle may be at standstill or running.	
Termination outcome	**Successful outcomes**	Outcome 1: Vehicle drives without accident in bad weather conditions
	Unsuccessful outcomes	• Outcome 2: Vehicle stopped
Condition affecting termination outcome	**Outcome 2**	Explanations for unsuccessful outcomes:

		• Vehicle is stopped because visibility is essential 0m or PER detects falsely a visibility of 0m. Post-conditions for unsuccessful outcomes: • If visibility is 0m: wait for better weather. • If visibility is falsely detected as 0: send message to central, start remote driving.
Use Case scenario	**Step 1 a**	OAS (PER) measures the visibility range. Depending on the speed and breaking capability of the train, OAS calculates a minimal visibility range for driving-on-sight mode.
	Step 1 b	If the actual visibility range of OAS (PER) is larger than the minimal visibility range, remove TSR or obstacle MA and go to 1a. Remark: remove only TSR/MA related to bad visibility. All other TSR and MA remain in action.
	Step 1 c	OAS (PER) detects a visibility range which is smaller than the minimal visibility range.
	Step 2	OAS (APM) sets a protection (for example a TSR or an obstacle MA to the limit of visibility range) to ensure that the supervised speed/distance allows a sufficient distance to break the train before the limit of visibility range: • if the position of the limit of visibility does not change (while the train continue to move in this direction) • if an obstacle appears at the limit of the visibility distance. If other systems demand lower TSR/MA, they remain in action.
	Step 3	Train continues journey under new restrictions
	Step 3a	If visibility is 0m, OAS stops the train.
	Step 3b	OAS sends a message to TAS to indicate that the train is stopped.
	Step 3c	Operation Manager checks if visibility may be falsely detected as 0m, and in that case Operation Manager may launched appropriate procedure: Remote driving for example.
	Step 3.1	If visibility is 0, go to Outcome 2

	Step 4	OAS informs TAS about weather conditions and new MA/TSR. TAS calculates new timetable and sends timetable update to OAS.
	Step 5	Go to Step 1a. Reason: the train moves and visibility changes, so the restriction must be updated in "real time".
Postcondition	This should be an ongoing process until end of mission or end of journey. Therefore, there are no postconditions	
Use Case notes	• This use case requires driving-on-sight mode (OS mode). • The speed reduction may be enforced by setting a TSR=0 km/h or an obstacle MA at the point of maximal visibility. • This use case is related to X2R4 SRS use case: ○ SRS 13.12.2Bad visibility in OS mode	
Related UC	None	

Table 27: Use Case "Speed restriction due to visibility issues while driving on sight - local"

4.4.7.2 UC5.2-0027-2: Speed restriction due to weather conditions - central

Use Case field	**Description**
ID	UC5.2-0027-2
Use Case name	Speed restriction due to weather conditions - central
Main actor	Operations Manager TAS: Trackside Automation System
Other actors	• OAS: On-board Automation System (TCMS, ATO, ETCS)
Use Case summary	Operation Manager or TAS (trackside system) detects bad weather conditions. TAS sends temporary speed restriction (TSR) to OAS. OAS ensures that the train is running not faster than TSR. TAS calculates new timetable and sends it to OAS.
Applicability	• Geographical European level • System level GoA34 • Operational category: passenger, freight, urban, regional, mainline and inspection vehicles
Main goal	Main goal is a safe driving in bad weather conditions. An example could be lateral wind (train behaviour), heavy snow, fog or heat (track impact). The train drives not faster than the TSR. See X2Rail-4 SRS 13.8.13 Speed restriction due to weather conditions
Preconditions	GoA34 is activated. Vehicle may be at standstill or running.

Termination outcome	**Successful outcomes**	Vehicle drives without accident in bad weather conditions and does not exceed the TSR. If the bad weather disappears, TAS or Operation manager withdraws the TSR.
	Unsuccessful outcomes	Outcome 2: vehicle drives faster than TSR. This leads to an emergency brake.
Condition affecting termination outcome	**Outcome 2**	Application of Emergency brake because train was too fast. Postcondition: TAS and OAS allow resumption of traffic if the situation is safe. TAS sends new timetable because of delay.
Use Case scenario	**Step 1**	Operation Manager or TAS detect bad weather, or a weather forecast warns of bad weather. Bad weather situations are: • Heavy rain • Heavy Hail • Strong Snowfall / Heavy snow • Dense Fog • Smoke • Lateral wind
	Step 2	Operation Manager or TAS compute a Speed restriction on a defined area
	Step 3	TAS sends TSR to OAS of every train approaching and already in the area
	Step 4	OAS receives TSR and activates the TSR.
	Step 5	OAS supervises TSR
	Step 5.1	If OAS drives faster than TSR, go to Outcome 2
	Step 6	TAS calculates new timetable due to reduced speed and sends it to OAS.
	Step 7	TAS or Operation Manager informs the passengers waiting for the train at the next station(s) of possible delay
	Step 8	Each OAS of the affected trains informs the passengers in the trains of possible delay
	Step 9 a	If bad weather conditions change, go to Step 1
	Step 9 b	If the bad weather disappears, the operation Manager or TAS withdraws the TSR, and the trains continues with full speed. TAS calculates new timetable.
Postcondition	Train continues with timetable and no weather related TSR.	

Use Case notes	• This use case is related to X2rail-4 SRS use case: ○ SRS 13.12.2Bad visibility in OS mode
Related UC	None

Table 28: Use Case "Speed restriction due to weather conditions - central"

4.5.1 UC5.2-0028: Automatic joining of electric and/or diesel multiple units

The following references have been used:

- Subset 026 v3.6.0 §5.14.1.2 Definitions for joining and §5.14.3 Procedure "Joining".
- LOC & PAS TSI §4.2.2.2
- OPE TSI §4.2.2.5
- X2Rail-4 ATO GoA3/4 SRS 0.3.0 §13.6.2 Coupling EMU
- X2Rail-4 ATO GoA3/4 SRS 0.3.0 §11.14.3 Prepare the Coupling
- X2Rail-4 ATO GoA3/4 SRS 0.3.0 §7.3.6 Coupling.
- TR 50610 - Railway applications - Train Modes functional interface specification
- UIC Leaflet 612-1 §3.1.6.2 and Appendix B scenario coupling.

Use Case field	Description
ID	UC.5.2-0028
Use Case name	Automatic Joining of Electric and/or Diesel Multiple Units (EMU/DMU)
Main actor	Operations Manager (OM) and Trackside Automation System (TAS)
Other actors	• Serviceable train • Railway Undertaking Supervisor (RUS) • Fleet Management System (FMS) • On-board Automation System (OAS)
Use Case summary	The process starts with a standing train unit stopped at the intended joining location with holding brakes applied, continues with another train approaching to couple this stopped train, and ends when both train units are physically coupled. The solution for joining two autonomous train units must cover two high-level functions: • It must allow the joining only if both train units are ready to join; otherwise, it must stop the approaching train at a defined distance to the standing train unit. • It must allow the approaching train unit to travel until the coupler makes contact, even though this is not possible in regular driving in full supervision mode. This is done at a reduced speed.

Applicability	• *Geographical:* European level
	• *System level:* Railway system
	• *Operational category:* passenger, urban, regional, mainline and inspection vehicles. Freight considered not applicable, as joining of Traction Unit and railway vehicles is outside of the scope of this use case. This use case does not cover:
	  ○ joining of 2 locomotives
	  ○ joining of locomotive with an EMU/DMU

	○ joining of a locomotive with a freight train (locomotive with wagons, joined by another locomotive with/without wagons) ○ joining of locomotives with wagons	
Main goal	Ensure automatic joining of two trains (it can be Train Consists and/or Train Units)	
Preconditions	1) One train ("train to be joined") is stopped at the position where the joining is meant to occur. The other train ("joining train") is on an adjacent block. 2) Trains are both equipped with Automatic Couplers (EN 16019)[4], and compatible for coupling: electrical connections interface, clearance around the coupler head, height above top of rail for the coupler are position of the pivot point of the coupler are compatible 3) Optionally, for each train, coupler heating shall be performed automatically by TCMS when train is awakened if outside temperature is below a given threshold. 4) TCMS shall offer a coupling mode where TCMS automatically drives the train unit at coupling speed until it senses physical contact of the couplers (or using automatic pneumatic/hydraulic actions on brakes) and stops the train. (TR 50610)[3] 5) The train to be joined shall not move by more than 10 centimetres if its brakes are applied, and a joining train has collided with it at the maximum coupling speed (to be confirmed by Operation and Rolling Stock experts). This is to avoid risk on passenger exchange if train doors are not closed. If doors are closed, this value may be increased to cover only "point of danger"-related issues (buffer or switch after the train) 6) Trains are both equipped with GoA4 capabilities.	
Termination outcome	**Successful outcome**	• Outcome 1: Trains are joined, forming a new Train Unit, able to communicate with the TAS
	Unsuccessful outcomes	• Outcome 2: Trains are unable to join (too low speed, remaining gap between the trains, train not able to reach the location chosen by the RUS to perform the joining) • Outcome 3: Collision of the trains at a too high speed • Outcome 4: coupling partially performed (mechanical or electrical issue for example)
Condition affecting termination outcome	**Outcomes 2 and 4**	Situation shall be assessed by the OM, and new journey may be agreed between OM and RUS.
	Outcome 3	There is a risk of mechanical breakage, or movement of train to be joined. Refer to use case "Train-Train collision" from D5.1.

Use Case description	**Step 1**	Conditions before joining shall be verified:
	Step 1a	RUS or FMS shall select the trains to join according to the expected Timetable agreed with IM or TAS.
	Step 1b	RUS or FMS shall verify that: • the two trains consist are compatible for joining (coupling system, OAS, ...) • the two trains are healthy for joining (no anomaly on coupler or OAS detected) • the joining is to be performed is an appropriate location for joining (gradient, curve, ...)
	Step 1c	As in TSI OPE, § 4.2.2.5, RUS or FMS shall check that for the train to be formed after joining, «the composition of the train is compatible with the route and the path».
	Step 1c.1	If one of the previous steps is not fulfilled, RUS or FMS must reconsider or replan the objective of joining. [Outcome 2]
	Step 1d	RUS or FMS shall communicate to OM or TAS the request to form a new Train Unit from 2 trains (for example though Mission Profile).
	Step 1e	TAS (automatically or on OM request) sets a route such that the joining train can reach the position of the train to be joined.
	Step 1f	TAS (automatically or on OM request) assigns a journey to the joining train, to reach a destination point near the train to be joined. This point may or may not be a stopping point, it may otherwise be point to transition to next journey for final coupling (step 6). The destination points to be reached is set based on the known position of the train to be joined, or the expected position of where joining should take place. The journey shall indicate: • the accuracy and confidence level of the position indication to reach. • That this is for a future joining, for the joining train to prepare for it.
	Step 1f.1	If any of the 2 previous steps is not possible, OM or TAS shall inform the RUS or FMS that the operation is not possible.
	Step 1f.2	The RUS or FMS shall analyse the issue and reconsider or replan the objective of joining and agree with OM or TAS (§7.3.6.1.1 of X2Rail-4 SRS). [Outcome 2]
	Step 2	The joining train receive this journey.

	Step 2a	The OAS of the joining train shall: • If required, activate coupler heating (winter conditions), • If the functionality is available, open the coupler cover.
	Step 2b	If the OAS of the joining train knows its position, is able to cross a restrictive signal, and if the position to reach is known accurately, the OAS shall drive the train to achieve its journey autonomously.
	Step 2b.1	If the train reaches standstill before step 5.x are achieved, and if the OAS of the joining train is too far from the train to be joined (for example through a check of localisation error greater than a threshold), the OAS should follow Step 2c to reach a closer position for joining.
	Step 2c	Otherwise (i.e., if the OAS of the joining train does not know its position, or is not able to cross a restrictive signal, or if the position to reach is not known accurately), the joining train shall follow the use case "Entering an occupied block with a signal showing a restrictive aspect". Note: this probably means using a "driving-on-sight" procedure.
	Step 2.1	If the train is not able to achieve its journey, refer to 1f.1 and 1f.2 steps. [Outcome 2]
	Step 3	If the joining train is coming near a station or a depot, staff or passengers in train, in station or depot shall be warned if required by operational rules.
	Step 3a	If the joining train is coming near a station, the OAS of the joining train communicate a message to passengers of the train that a joining operation will occur (they may experience a sudden movement due to the joining), and that the passengers shall not try to open the doors.
	Step 3b.1	If the joining train has a known position, coming near a station, the OM or TAS, based on its position and journey, shall inform Passenger on the platform of an incoming train in movement on the platform. Refer to use case "Stop at platform for passenger service" from D5.1.
	Step 3b.2	If the joining train has not a known position, coming near station, the OM or TAS, based on its assigned itinerary/platform and on a timer, or a visual observation

		(direct or CCTV), shall inform Passenger on the platform of an incoming train in movement on the platform. Refer to use case "Stop at platform for passenger service" from D5.1.
	Step 3c	If the joining train is coming near a depot, depot safety procedure shall be applied. (For example: horn activation at specific location, TAS warning system, specific speed restriction)
	Step 4	Optionally, the train is stopped near the train to join (refer to step1f). Note: if the joining train is capable to monitor the distance to the coupler to be joined (for example thanks to TAS or visual information), this step may be skipped, i.e., if the conditions provided by step 5.x are given, the train may proceed to step 6 without stop.
	Step 4.1	If the joining train collided with the train to be joined before steps 5, the joining train shall detect this error. Refer to use case "Train-Train collision" from D5.1. [Outcome 3]
	Step 5	The train to be joined shall prepare for joining. Eventually these steps have begun in parallel.
	Step 5a	If required, FMS shall automatically or on RUS request wake up the train to be joined.
	Step 5b	TAS shall automatically or on OM request: - send a journey to train to be joined to prepare for joining - indicate if the train to be joined will become the leading train for the next journey, to be able to continue communication after joining.
	Step 5c	Upon reception of the journey, the OAS of the train to be joined shall: • If required, activate coupler heating (winter conditions) • If the functionality is available, open the coupler cover, • apply appropriate brake for joining. • communicate a message to passenger of the train that a coupling operation will occur. • Optionally, close of the doors

	Step 5d	If these steps are successful, the OAS of the train to be joined shall communicate to TAS that the train is ready to be joined.
	Step 5e	If required, staff near the trains or remote staff that have access to video supervision (RUS) shall perform a visual check of both couplers (sand, ice) or removal of coupler cover. Optionally, OAS may perform the task itself. In that case, mutual OAS exchange between both trains might be required.
	Step 5f	If this check is successful, and if the conditions are fulfilled to perform (no one on track, no danger detected), the OM (or the OAS) shall then provide the authorisation to perform joining to TAS.
	Step 5.1	If one of these steps fails, refer to 1e.1 steps. [Outcome 2]
	Step 6	The joining train continue with the final joining phase.
	Step 6a	Upon confirmation from the train to be joined and from the OM that it is ready for joining, TAS shall send to the joining train the authorisation to move for joining. TAS: • sends a journey to joining train. • indicates if the train will become the leading train for the next journey, to be able to continue communication after joining.
	Step 6b	Optionally, if the joining is occurring in a station, the OM or TAS shall inform Passenger on the platform that a joining operation is occurring.
	Step 6c	Upon reception of the message from TAS, the OAS of the joining train shall drive at coupling speed (TCMS Coupling Mode) up to reaching the train to be joined.
	Step 6d.1	OAS shall supervise train speed during this phase. The speed to supervise may be determined by speed threshold and/or monitoring of remaining distance to the coupler to be joined.
	Step 6d.2	Optionally, OM shall supervise the operation to prevent from people (staff in a yard, or passenger in station) approaching the gap between the two trains.
	Step 6d.3	Optionally, OM shall be able to stop the joining train during the coupling process, by communication through the TAS and OAS, or by other means.
	Step 6d.4	Optionally, the OAS of the joining train shall ensure there are no objects on track between itself and the train to be joined.

	Step 6e	Upon reaching the train to be joined, the joining train shall apply the brakes. Note: this might be performed pneumatically thanks to coupling, or by the OAS.
	Step 7.1a	If joining operation is successful, the OAS of the joining train shall communicate to the TAS (and then to OM optionally) that the coupling has been successfully performed. See use case "train initialisation" for the reconfiguration activities.
	Step 7.1b	TAS shall communicate to the OAS of the train that was joined that it may release the brake that were required for joining procedure.
	Step 7.1c	OAS of the train that was joined may release the brake applied during joining operation. Note: other brake command is still applied during reconfiguration process.
	Step 7.2	If the joining operation has failed, with coupling partially performed, go to step 7.2.1a. If coupling is not performed at all due to remaining gap between the two trains, go to step 7.2.2.
	Step 7.2.1a	The joining train shall inform the TAS, and the RUS or FMS of this failure, with the detail of the failure (for example, mechanical, pneumatic, electrical, communication).
	Step 7.2.1b	The RUS or FMS shall take appropriate measure to manage a train not successfully joined, depending on the information received, and coordinate with OM and TAS. [Outcome 4]
	Step 7.2.2	The joining train shall inform the OM or TAS, and the RUS or FMS of this failure, with the detail of the failure (for example, system not responding, estimated remaining distance, no movement possible due to obstacle, or brake application). Refer to 1f.x steps. [Outcome 2]
	Step 8	Upon confirmation of successful joining by the new leading train, TAS shall inform OM of the successful joining.
Postcondition	The automatic joining of the two trains was successful. OAS of the designated leading train resume communication with TAS For further steps after joining, refer to use cases "Passenger train preparation", and "Perform mission" from D5.1	
Use Case notes	To be aligned with potential discussion occurring in TSI Operation Working group	

Related UC	None

Table 29: Use Case "Automatic Joining of Electric and/or Diesel Multiple Units"

4.5.2 UC5.2-0057: Drive inside depot / stabling or maintenance facility

4.5.2.1 General Context

- To deploy ATO in all relevant operational scenarios, the particular use case of Depots is crucial as it comes with specific constraints on speed and sometimes special signals (no ERTMS).
- Today these different constraints are handled by the train driver through his vision and experience.
- If one wants to deploy ATO in Depots, these functions need to be implemented by an automatic system. In particular, the perception functions in GoA 3 and 4 need to be carried out with the right sensors and algorithms.
- This functional need has been considered within the Shift2Rail project TAURO, especially in work package 'Environment Perception'.
- Other than Perception, the technical enabler Remote Driving may as well be important to guarantee a reliable ATO deployment in depots.
- Special Operational context implies the following specific constraints:
  - No ATP trackside system (Depots are not equipped with an ETCS system)
  - Low speed (on-sight)
  - Workers in the surroundings
  - IM/RU roles are merged.

4.5.2.2 Functional Requirements

In GoA3 and GoA4 operation, Perception functions are required to fulfil all the functions currently performed by the train driver. These functions include, in particular: lineside signal reading, obstacle detection and environment monitoring beyond the ego track (e.g., people in the vicinity of the train, ...).

Use Case field	Description
ID	UC.5.2-0057
Use Case name	Drive inside depot, stabling or maintenance facility
Main actor	OAS (Perception module (PER); Signal Converter (SCV); ATP (Automatic Train Protection)
Other actors	• OAS (TCMS (Train Control and Monitoring System), ADM (Automatic Driving Module), APM (Automatic Processing Module), LOC (Localisation)) • PTU (Physical train unit) • Operations Manager (OM), • Trackside Automation System (TAS),
Use Case summary	This operational scenario details the management of a train movement in a depot.

	The perception system detects and reads the signal, and the signal converter module translates it into an ETCS-compatible package in order to define the ATP supervised speed profile.	
Applicability	• Geographical: European level • System level: Perception system • Operational category: All	
Main goal	The main goal of this use case is to allow automatic movement of a Rolling Stock within a depot	
Preconditions	1. PTU is at standstill, immobilized by train parking brake. 2. Depot environment is secured by dedicated rules applied on train movement and depot staff. 3. Depot environment may be secured by dedicated trackside system such as warning bell, energy protection system... 4. Train movements are regulated by OM (Operation Management)	
Termination outcome	**Successful outcomes**	Train reaches the Stopping Point specified
	Unsuccessful outcomes	Outcome 1: Train Stopped due to obstacle. Outcome 2: Train Stopped due to signalling. Outcome 3: Train didn't reach the Stopping Point
Condition affecting termination outcome	**Outcome 2**	
	Step 1	OM: Receive the information "Train Ready for service" meaning that all maintenance activities are completed on the PTU, and no presence of equipment forbid PTU movement such as scotches (brake shoe), red flag, catenary in service (powered and not isolated) …
	Step 2	OM: Give information "Execute Journey" to TAS
	Step 1	TAS: Send the allocated journey to the OAS of the train
	Step 2	OAS/APM+ADM: Collect and process data. OAS: Set the appropriate operational mode GoA 1, 2 or 3/4. Within the operational mode a sub-mode for the signalling system configuration ("ATO over ETCS" vs "ATO over Lateral Signalling" ETCS compatible) may be specified.
	Step 3	OAS/PER: Monitor environment (obstacle detection) OAS/PER: Monitor Lineside Signalling
	Step 4	OAS/ADM: Drive According to Journey OAS/ATP: Ensure speed supervision and ensure EoA limit

	Step 5	OAS/PER: Monitor environment (obstacle detection) OAS/LOC: Localize train in the Digital Map
	Step 5.1	OAS/PER: Obstacle on-track detected (and track is no cleared) OAS: Request immediate stop OAS: Inform trackside about the situation. Note: See UC UC5.2-0019: React on obstacle
	Step 5.2	OAS/PER: Detect Train stop requested by signalling. OAS: Request immediate Stop *Note: See UC5.2-0059: Train stops by signalling*
	Step 5.3	OAS: Detect Inconsistency between train current position and journey planned. OAS: Request immediate Stop OAS: Inform TAS and wait for journey update
	Step 6	Train stopped at the Stopping Point OAS/APM: Inform Trackside about the stage
Postcondition	Train stopped and waited for next task	
Use Case notes	None	

Related UC	• UC5.2-0019: React to obstacle.
	    ○ The perception module needs to be able to react to the observation of an obstacle on the track (or a critical object in the vicinity)
	• UC5.2-0024: Impassable Broken or Buckled Rail
	• UC5.2-0030: Wandering Livestock, animals or other objects on or close to the tracks
	    ○ In order to be guarantee a safe circulation within the confines of the depot, the perception module needs to be able to detect (and classify) critical objects on or in the vicinity of the track.
	• UC5.2-0058: Driving according to journey based on lateral signalling.
	    ○ The train needs to be able to respect the signals of the depot.
	• UC5.2-0059: Train reacts to non-regular signalling.
	    ○ In case of special activities, non-regular signals may be installed. The train needs to recognize and read these signals.
	• UC5.2-0055: Transition between ATP class A and lineside signalling area	

	○ In order to drive from a class an area to depots which do, in general, not have class A systems, the transition between both needs to be handled by the train.

Table 30: Use Case "Drive inside depot / stabling or maintenance facility"

5 CONCLUSIONS

The foundational step in defining the areas of focus for the development of Perception systems to enable the Europe's Rail vision is an arduous task and the D5.2 deliverable attempts to provide the required details and clarity. Due to the collaboration of partners ranging from operators, infrastructure managers, supplier industrials and research groups, the final deliverable brings a culmination of results developed over the last 12 months through their expertise. The definition of use cases, operational parameters and scenarios for Perception Systems will be an important input for work packages that succeed WP5 and offers the right operational scenarios to focus for further development.

Deliverable D5.2 takes into account the relevant contributions from Shift2Rail, and further refines the details of these contributions. In parallel, new use cases have also been added to prepare a comprehensive list. Each of the use cases provides a perception detection mechanism, incident definition based on the detection and a reactionary response to the incident to complete the entire operational scenario. The knowledge gained through this deliverable will be valuable for framing the system functional requirements and the architecture for the Perception technical enabler. Further, the use cases defined in Deliverable D5.2 will provide the required information for the Demonstrator Cluster in identifying the use cases that each of the Demonstrator would test and validate the operational scenarios.

During the definition and development of the use cases, the level of detail already available on each of the use cases varied. As a result, on some of the use cases, the logical blocks have been referenced while on others it was not possible to be defined. Similarly, the safety aspect of these use cases has not been considered in detail. These aspects have been identified in respective use cases, which will further need to be detailed in the scope of WP6 and WP8 of the Automation Processes Cluster. WP11 will further perform the development and validation for Perception system.

The results of this deliverable will be valuable for stakeholders outside R2DATO as well. System Pillar can benefit from the use case definitions and can form a basis for standarizing operational processes across clusters. FP5 and FP6 can leverage the use cases from D5.2 and further enhance them to suit their specific needs in future projects.

The scope established for the deliverable has been addressed over the last 12 months and the workgroup feels confident of the future work that will embark based on the results achieved here. This will pave the way for achieving Digital & Automated (up to Autonomous) Train Operations for the Rail industry.

REFERENCES

[1] [SRS X2Rail-4 v0.3] X2Rail-4, WP5 GoA3/4 Specification version 0.3.0. Call S2R-CFM-IP2-01-2019, Deliverable D5.1, X2R4-WP05-D-ALS-010-009.

[2] [EN 50126-1:2017] Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Generic RAMS Process. Oct 17th 2017

[3] CLC/TR 50610:2014 – Railway applications – Train Modes functional interface specification

[4] EN 16019:2014 – Railway applications – Automatic coupler – Performance requirements, specific interface geometry and test method

[5] EN 15380-4 (5.3.1 and 5.3.2) Railway applications - Classification system for railway vehicles

[6] Operational Actors for R2DATO WP5, Annexe 4 of R2DATO WP5 D5.1

APPENDIX 1: Informative Definitions About Fires on Embankment

Use-cases about fires on embankment (UC5.2-0020-x) sketch the behavior of trains when a fire is detected along the track. A fire classification is provided in support (Minor, Restricted, Grown, 'HeatWall'). The intent is to elicit the different behaviors of a train towards a fire:

- Drive along or drive through
- Stop ahead
- Drive backwards

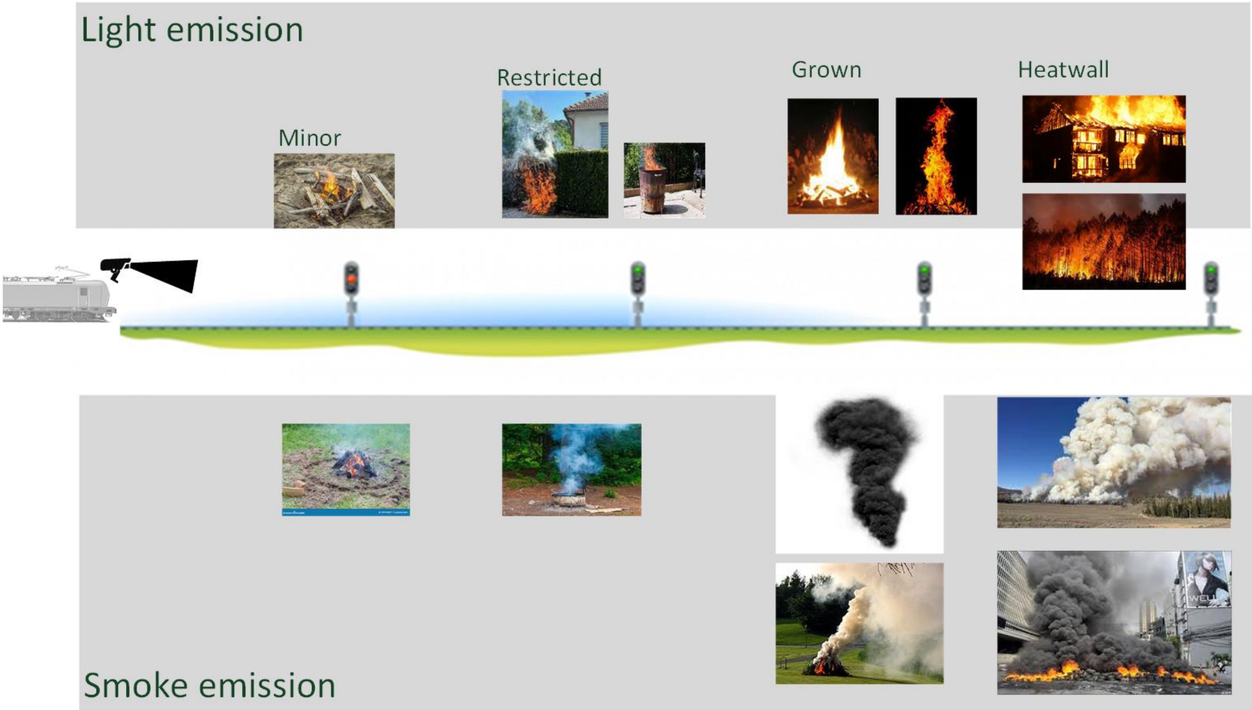

Figure 5: Fire Classification

Speeds and Distances associated to fires

Some speeds and distances are introduced to help define the fire classification below:

- D_FireSpreadingVertices: Distance sufficient for a train to drive along a fire and its vertices not to spread fire, independently of the train's speed.

  In this use-case, 5 m is assumed. If a more realistic value is required for prototypes, some very pragmatic tests may be made, with 5cmx5xm thick papers distributed from the centerline to the embankment. Those papers that move for more than 1 m are inside D_FireSpreadingVertices,

- V_FireSpreadingVertices: Speed that contains the air vertices of a train enough for it to drive above a fire without spreading it – I.e., without vertices lifting embers out of the gauge.

  In this use-case, 15 km/h is assumed. If a more realistic value is required for prototypes, some very pragmatic tests may be made, that show which speed moves some thick 5cmx5cm paper from train gauge to embankment: just distribute those papers perpendicularly to the gauge, let the train drive at your target speed and see which papers have moved dangerously.

- *D_HeatRadiationGrown*: Distance a train shall leave between itself and a grown fire.

  In this use-case, 5m is assumed. On the long term, a safety case is necessary, not scope about current proposal.

- D_HeatRadiationWallOfFire: Distance a train shall leave between itself and a HeatWall to avoid damage to some of its components.

  In this use-case, 100 m is assumed. Should a more realistic distance be necessary, a safety case is required, not scope of current proposal.

- Vmax_HotInfra: maximum speed a train shall drive through some infrastructure weakened by temperature, in order to avoid permanent damage.
- In this use-case, 50 km/h is assumed. Should a more realistic distance be necessary, a safety case is required, not scope of current proposal.

Fire classification

Following categories of fires are defined, according to their intensity:

- Minor: Fire typically limited to a surface less than 10 cm^2 radiating surface, for instance a starting wild fire. Smoke emission is so light it can hardly be detected unless the train is already close to the fire.
  - If a Minor fire's distance to the track is > D_FireSpreadingVertices,
    - the train can drive along this fire at any speed.
    - The train can stop along this fire without danger of propagation to the vehicle, as soon as it lies outside the track gauge, e.g., to alight people in emergency. In that case, a monitoring shall ensure that it does not grow in intensity (also by human).
  - If a Minor fire is in the gauge or distant from the gauge by less than D_FireSpreadingVertices,
    - The train shall not stop above this fire.
    - If the fire lies below the gauge, the train may drive at any speed above it without damage.
    - the train shall drive at most at V_FireSpreadingVertices to avoid spreading the fire further

- Restricted: Any fire that is not minor anymore, and not yet grown. For instance, the content of a big trash can or a wood quantity corresponding to a sleeper, a single bush burning. Some emission blurs the background landscape from 50 m already.

  If a Restricted fire lies in the gauge,

  - the train shall avoid, as far as possible, to drive above the fire, I.e., shall stop before the fire.
  - if impossible to avoid (emergency braking distance too long), the train shall drive at sustained speed over the fire without stopping.

  If a Restricted fire's distance to the gauge is < D_FireSpreadingVertices, the train shall drive along the fire no faster than V_FireSpreadingVertices. It shall not stop.

If the fire's distance to the gauge is > D_FireSpreadingVertices, the train shall drive along this fire without stopping and without restriction of speed.

- Grown: A fire grown enough to radiate strong heat to a distance *D_HeatRadiationGrown*. For instance, a burning stack of logs. The smoke density is enough to create a flow in the air oblivious to light. Note that a little fire emitting a little quantity of very dark smoke may be a grown fire already.

If a Grown fire lies on the track,

- If possible, the train shall stop at least *D_HeatRadiationGrown* ahead of the fire
- *Otherwise*, if possible, the train shall stop at a distance between 0 and *D_HeatRadiationGrown* ahead of the fire. It shall then drive back to a distance > *D_HeatRadiationGrown*
- *Otherwise*, if the fire lies in the train's emergency braking path, the train shall drive at Vmax_HotInfra as long as its entirety has not reached a place behind the fire's location. It shall stop in no case.

  Rational: Such a fire, too close to the track may have weakened the infrastructure. Therefore, driving along the fire at high speed is considered inappropriate.

If a Grown fire's distance to the gauge is > 0 and < *D_HeatRadiationGrown*, the fire track location is defined as the closest point of the fire located on the track center line.

- If possible, the train shall stop at least *D_HeatRadiationGrown* ahead of the fire track location
- If possible, the train shall stop at a distance between 0 and *D_HeatRadiationGrown* ahead of the fire track location. It shall then drive back to a distance > *D_HeatRadiationGrown*
- If the fire track location lies in the train's braking path, the train shall drive at Vmax_HotInfra as long as its entirety has not reached a place behind the fire's location. It shall not stop.

  Rational: Such a fire, too close to the track may have weakened the infrastructure. Therefore, driving along the fire at high speed is considered inappropriate.

If a Grown fire's distance to the track is > *D_HeatRadiationGrown*, the train shall drive at sustained speed along it.

HeatWall: Typically, a forest fire, or a big building burning along the track: a fire that covers a distance long enough along the embankment, to consider that a point of the train perpendicular to the middle of the fire line is irradiated by a linear but linear/surface source of heat. The associated decay in heat radiation, function of the distance d to the fire is square (d^2) rather than cubic (d^3) as for a punctual source. This decay, associated to the size of the fire, induces a different order of magnitude in received heat radiation density, by both vehicle and infrastructure. Typically, in a forest fire, the fire front can ignite a fire on the other side of a road without contact: the trees on the apparently safe side are first heated by radiation until their surfaces have been heated to their ignition temperature. Flames break out almost at once over the surface several trees (flash over phenomenon). The smoke can be detected from afar.

D_HeatRadiationWallOfFire is a distance defined between the gauge and the fire for which the train is allowed to drive along the fire at a speed Vmax_HotInfra, supposed to be acceptable on an infrastructure weakened by heat.

This definition is considered a sufficient pre-condition to exclude direct damage to the train due to heat radiation while driving at Vmax_HotInfra along a fire distance from the gauge by more than D_HeatRadiationWallOfFire, also for an undefined period of time[1].

According to considerations in "Safety Disclaimer", a HeatWall within a distance < *D_HeatRadiationGrown* from the gauge is not considered.

If a HeatWall lies at a distance of the track within *D_HeatRadiationGrown* and D_HeatRadiationWallOfFire,

- If possible, the train shall stop at least D_HeatRadiationWallOfFire ahead of the fire
- If possible, the train shall stop at a distance between 0 and D_HeatRadiationWallOfFire ahead of the fire. It shall then drive back to a distance > *D_HeatRadiationGrown*
- If the fire's closest point in the track lies in the train's braking path, the train shall drive at Vmax_HotInfra as long as it has not left the fire's location. It shall not stop.

If a HeatWall lies at a distance of the track > D_HeatRadiationWallOfFire,

- The train shall drive along the fire at Vmax_HotInfra. The train shall not stop.

- Extinguished: In general, a fire is Extinguished if it does not burn anymore. In this document's context, it is extinguished if the firefighting squad notifies the Incident Manager that its work is successfully accomplished: the fire does not burn any more and is not expected to reappear.

Disclaimer about safety

The safety relevance of the Fire on Embankment (UC5.2-0020-x) use-cases and operational definition in this chapter are roughly estimated SIL2 ([EN 50126-1:2017] [2], no dramatic damage):

- In all cases but 'HeatWall', the consequences are max a few injuries, or some damage on the rolling stock in a magnitude that fits SIL2 (component).
- Damages by fire to the infrastructure are another use case unless they occur while executing the use-case itself.
- The damages to the infrastructure, even if occurring during use-case execution, are estimated low enough not to cause a SIL4-relevant damage on the train or human on-board.
- The consequences of some 'HeatWall' (see below) along the track may fit SIL4. Among others, the infrastructure may be so damaged that the execution of the use-case causes some derailment, for instance at sustained speed. Having to off-board a full train along a heatwall is catastrophic enough to enter SIL-4-level damage.
- However, a fire of this magnitude needs time to develop. Before a fire reaches HeatWall, former trains or civil authorities are likely to have notified the infrastructure manager of the danger. Once such a fire is reported, no more train is sent to drive along the fire. In other words, the likelihood that a train is confronted with the 'Heatwall' fire is very low, due to external measures: only undetected big fires would trigger this use-case.

- A 'HeatWall' in the gauge is not considered: The track is not supposed to generate a HeatWall while burning, by design
    - Fallen trees burning across the track, as a result of a very close forest fire, supposing a poor maintenance of the close-track vegetation, are addressed by last point
    - A preceding train burning up to a HeatWall would be a special goods train, e.g., in a tunnel. This is another use-case.

The reader is warned that this perception, although bona fide, does not replace a dedicated safety concept created by knowledgeable professionals (fire brigade for fire classification, operations for likelihood, physicists for distance estimations, Rolling stock specialists for fire tolerance, Infrastructure specialists …). Especially, existing norms shall be considered!

In other words, as stated in this appendix's introduction, following use-cases intend to permit the assessment of sensor technologies and a basis for architectural sketching. From the point of view of safety, it may trigger the design of some harmonized safety concept.