

Rail to Digital automated up to autonomous train operation

WP5.1 – Documentation of use cases for automating functions

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EXECUTIVE SUMMARY

In short, the objective of R2DATO is a successful development and demonstration of Digital & Automated (up to Autonomous) Train Operations. However, it is imperative that a clear understanding on the actual operational processes in relation to the technology under development, and how such technology may be used in the future (target) situation is established. Without this understanding, all the future projects are lacking clear guidance on how to reach the envisioned end goal.

When developing technological innovations, too often the problem statement is written from a technical standpoint. The objective of Work Package 5 of R2DATO is therefore to start the use case development from a more operational standpoint – leveraging the operational experience from the involved group of railway undertakings, infrastructure managers, rail supplier industry, research and innovation partners and expert user groups.

Starting from the state of the art, as captured in inputs from precursor projects such as X2Rail-4, TAURO, ARCC and relevant standards such as TSI CCS, between December 2022 and November 2023 the working group of 15 expert partner organisations contributing to task 5.1 focused on developing use cases and Operational Scenarios for Automating Functions, in the context of the Automation Process cluster of R2DATO.

Due to time constraints for the work package and delays in the delivery of formal inputs from other projects, the task 5.1 partners focused on simultaneously identifying the full set of potentially relevant operational scenarios and use cases based on the 'day in the life of' analysis. This analysis led to a total of over 1100 identified use cases and scenarios, which either were (or would soon become) available, or could potentially be developed within task 5.1 or other WP5 tasks.

From this relatively comprehensive identification, the team distilled the set of use cases and scenarios that would need development within the scope of task 5.1. This was done through a prioritization process, with input collected from the R2DATO demonstrator work packages and the group of railway undertakings on the basis of the objectives, innovative solutions, demonstrator context and impacts as defined in the Grant Agreement. These priorities were then matched with the scope of each identified use case, after which a relative ordering was made and matched with the available development capacity. To come to the final set of use cases for development, a final cut and sanity check was performed to ensure all use cases were aligned in level of detail and scope with the task 5.1 description of work.

To ensure that all use cases provided a similar result in terms of quality, considerable effort was spent during the development phase to align all development and review partners on topics such as templates, terminology and operational actors. Multiple rounds of informal and formal reviews, as well as workshops were organized, to ensure that all task partners were aligned on the final results of the development phase.

Resulting from this development phase, are a total of 74 use cases and 29 operational scenarios adding to the state of the art as input for the development of Automation Functions technology. These scenarios and corresponding use cases are described on basis of a 'day in the life of a train', resulting in a comprehensive set of use cases. The developed use cases need to be seen as additions to the already identified state of the art use cases.

By delivering these results within the agreed timeframe, task 5.1 fulfils the goals as stated in the Grant Agreement.

Constraints in available time and capacity have impacted the content of this deliverable, leading to limitations and unresolved issues. Ideally, the use cases and scenarios should have been standardized across all partners and their specific procedures. However, achieving this level of standardization within the 12-month timeframe of WP5 was not feasible. It is recommended that this objective be pursued in future projects, such as in the System Pillar. Additionally, due to the absence of formal inputs from other Flagship Projects and System Pillar by the defined milestone of M6, experts had to work with the information available informally. Further alignment with these areas is strongly advised and should be considered in the ongoing course of R2DATO.

The results of task 5.1, as contained in this deliverable, should be taken as a starting point for the development of specifications and functional and non-functional requirements, as mainly intended to be performed in Work Package 6 of R2DATO. They should also be used as a basis on which the demonstrators test the operational performance of the prototypes developed for the Automating Functions Technical Enabler. It is further recommended that future projects and specifically R2DATO work packages use the results of task 5.1, and the other WP5 tasks, as examples of how Automation Processes may be used in an operational environment, leveraging the extensive operational expertise that was captured in these use cases to come to an optimal design of the Technical Enablers.

ABBREVIATIONS AND ACRONYMS

In this report, the below abbreviations are used. Each abbreviation is noted the first time the term is used. Within task 5.1 where possible, terms were adopted from other Shift2Rail projects to maintain consistency. The main source used for this alignment is the ERTMS/ATO Glossary [7].

AD	ETCS Automatic Driving Mode
ADM	Automatic Driving Module
AoC	Area of Control
APM	Automatic Processing Module
ARCC	Automated Rail Cargo Consortium (Shift2Rail project)
ARS	Automatic Route Setting
ASPM	Automatic Stopping Point Management
ASR	Additional Speed Restriction
ATO	Automatic Train Operation
ATO-OB	ATO On-board
ATO-TS	ATO Trackside
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
ATSM	Automatic Train Stopping Management
AV	ATO Available
CBG	Centrally Controlled Area
CBTC	Communication Based Train Control
CCS	Command Control and Signalling
CCTV	Closed Circuit Television
CFR	Certified First Responder
CO	ATO Configuration
CT5	Cooperation Tool 5
DAC	Digital Automatic Coupler
DAS	Distributed Acoustic Sensing
DE	ATO Disengaging
ECM	Entity in Charge of Maintenance
EG	ATO Engaged
EMT	Emergency Medical Technician
EP	Emergency Plan

ETCS	European Train Control System
REMT	Remote Emergency Medical Technician
EU	European Union
EUG	ERTMS Users Group
FA	Failure
FMS	Fleet Management System
FP	Flagship project
FRMCS	Future Railway Mobile Communication System
FS	Full Supervision
GA	Grant Agreement
GoA	Grade of Automation
GSM-R	Global System for Mobile Communications – Railway
HMI	Human Machine Interface
HS	Handshake
HSAck	Handshake Acknowledgement
HSRej	Handshake Rejected
HSReq	Handshake Request
HVAC	Heating, ventilation, and air conditioning
ID	Identity
IEM	Incident Emergency Manager
IIS	Infrastructure [Passenger] Information System
IM	Infrastructure Manager
IMS	Incident Management System
IOM	Infrastructure Operations Manager
IPM	Incident and Prevention Management
ISM	Incident Solving Manager
IXL	Railway Interlocking System
JP	Journey Profile
JPAck	Journey Profile Acknowledgement
JPreq	Journey Profile Request
NA	ATO Not Available
NCBG	Non Centrally Controlled Area
NVR	National Vehicle Register

NP	ATO No Power
OA	Operational analysis
OAS	On board Automation System ¹
OCC	Operation Control Centre
OIS	On-board [Passenger] Information System
OLFD	On-line Fire Detection System
OM	Operations Manager
OMTS	On-board Multimedia and Telematic Subsystem
ORD	On-board Recording Device
PAS	Passenger
PDIU	Platform Door Interface Unit
PED	Platform Edge Doors
PER	Perception
PG	Platform Gates
PIS	Passenger Information System
PSD	Platform Screen Doors
PTI	Platform / Train Interface
R2DATO	Rail to Digital automated up to autonomous train operation
RBC	Radio Block Centre
RDR	Remote Driver
RE	ATO Ready
REP	Repository
RMS	Railway Mobile Staff
RST	Rolling Stock
RU	Railway Undertaking
RUS	Railway Undertaking Supervisor
S2R	Shift2Rail
SB	ATO Stand By
SP	System Pillar / Segment Profile ²

¹ Further defined in Annex 3: WP5 – Operational Actors for R2DATO WP5.

² In the ERTMS / ATO Glossary the abbreviation ‘SP’ refers to ‘Segment Profile’. In the context of WP5, the abbreviation is most often used to refer to ‘System Pillar’. In this deliverable, the abbreviation refers to ‘System Pillar’. In the included use cases, the reference is referring to ‘Segment Profile’. The context in which the abbreviation is mentioned will be uniform enough to provide clarity which of the two terms is used.

SPReq	Segment Profile Request
SR	Staff Responsible
SRS	System Requirement Specification
SSEM	Supervised Speed Envelope Management
STR	Status Report
TAURO	Technologies for the AUtonomous Rail Operations (Shift2Rail project)
TA	Train Attendant
TAS	Trackside Automation System
TBL	Traction/Brake Lever
TC	Temporary Constraint
TCMS	Train Control and Monitoring System
TDO	Train Door Operation
TDS	Train Display System
TE	Technical Enabler
TEN-T	Trans-European Transport Network
TMS	Traffic Management System
TP	Timing Point
TPS	Train Preparation Staff
TRN	Train Running Number
TS	Trackside
TSI	Technical Specifications for Interoperability
TSR	Temporary Speed Restriction
TTSM	Timetable Speed Management
TU	Train unit
UC	Use Case
WP	Work Package
WP5	Work Package 5, Automation Processes use cases and user requirements
X2R4	X2Rail-4 (Shift2Rail project)

Additional to the abbreviations above, specific definitions were created and aligned for the operational actors that are used in the WP5 use cases. The document containing these definitions can be found in Annex 3: WP5 – Operational Actors for R2DATO WP5.

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1 INTRODUCTION

The document presented is deliverable D5.1 - *“Documentation of use cases for automating functions”*. It is a result of the effort of all involved partners in task 5.1 *“Definition of use cases, operational parameters, and scenarios for automating functions”* within work package 5, as part of the Automation Processes Cluster of ERJU FP2 “R2DATO”.

The Automation Processes Cluster is tasked with the mission of architecting and developing Automation Processes through different Technical Enablers (TEs) – 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.

Within work package 5 *“Automation Processes Use Cases and user requirements”*, there are six tasks working in parallel to achieve this common goal of delivering use cases, user requirements, and review of ATO GoA3-4 specifications. These will be used as a starting point for the further specification, development, prototyping and eventually demonstration of the TEs in the Automation Processes Cluster. Each task has a specific focus related to a TE or operational domain. These tasks are:

Task	Title
5.1	Definition of use cases, operational parameters, and scenarios for automating functions
5.2	Definition of use cases, operational parameters and scenarios for safe perception systems
5.3	Review of specification for ATO GoA3-4 technology
5.4	Definition of use cases, operational parameters and scenarios for remote driving
5.5	Definition of freight specific user requirements
5.6	Definition of urban light rail use cases and operational rules

The work of WP5, task 5.1, was to focus on the ‘Automating Functions’ TE. This deliverable document illustrates this work and the outcome of use cases, operating parameters and scenarios. The content of this deliverable drew inspiration from the prior work completed in Shift2Rail – more specifically from the deliverables of X2Rail-4 and TAURO. These programs provided a set of existing use cases, that were further reviewed and included as input, against which a gap was established compared to the envisioned result for the Automating Functions use cases. This gap then became the basis for the development efforts of the task 5.1 partners, who provided their inputs in the form of use cases and operational scenarios based on their experience and expertise as railway undertaking, infrastructure managers, rail supplier industries and research groups.

The output of this deliverable forms an important foundation for the development of TEs that are to come from the further Work Packages in the Automation Processes Cluster. It provides with the operations scenarios and use cases that are important for realizing the Europe’s Rail vision in the area of Automation Processes. The work of task 5.1 will be further utilized and developed in multiple Work Packages, including but not limited to:

- **WP6 Automation Processes Specifications:** The objective of the tasks under WP6 is to derive a set of non-functional and functional requirements for automating functions, and to define architecture and interfaces for automating functions in passenger and freight application. It is intended to use the operational scenarios and use cases as a starting point.

- **WP7 GoA3/4 Data Factory Specifications and Implementation:** WP7 may benefit from the operational scenarios in order to refine the data factory requirements.
- **WP8 Safety Analysis and Risk Assessment:** The objective of the task under WP8 is to cover the Hazard identification, Safety Management Report and Hazard Log for Automating Functions.
- **WP9 Prototype development of automating functions:** WP9 is responsible for the development, testing and validation of functional prototypes for automating functions.
- **Demonstrator Cluster:** The Work Packages in the demonstrator cluster may use the operational scenarios and use cases as a basis for their test and validation scenarios.

The structure of the task 5.1 deliverable document is as follows:

- In chapter 2 the methodology and processes are described, explaining how the partners of task 5.1 came to the results contained in this deliverable. Relevant limitations to this approach and the remaining open points are listed in chapter 2.8.
- Chapter 3 introduces the main results of task 5.1, listing the scenarios on the basis of a 'Day In The Life Of' a train, and linking the developed use cases for each scenario. These developed use cases need to be seen as additions to the identified state of the art – as can be established from the complete identification done in the 'Use Case Index'. Further links with the X2Rail-4 scenarios are also included, resulting from a collaborative effort with the X2Rail-4 team.
- Conclusions and open points are summarized in chapter 4, followed by references and finally the annexes – in which the use cases themselves can be found attached.

2 DEVELOPMENT METHODOLOGY

In this section, the methodology on how this deliverable was developed is discussed. The methodology section is split out in eight chapters: 2.1 deliverable objectives, 2.2 existing and relevant deliverables, 2.3 scope definition, 2.4 identification of use case, 2.5 prioritizations of use cases, 2.6 development of use cases, 2.7 review of use cases and finally in chapter 2.8 the limitations of the approach and the open points are explained.

2.1 DELIVERABLE OBJECTIVES

This deliverable is created on the basis of the objectives as described in the 'Grant Agreement' (GA). To understand the goal of task 5.1, an in-depth analysis of the information described in the GA is provided in the chapter.

In the GA, there are three specific sections that discuss task 5.1. The first part provides the description for task 5.1 from the GA page 28, as shown below.

First, existing, and relevant deliverables from partner projects are examined. Relevant functions, related use cases and operational scenarios are collected. Additionally, this task will update a set of functions which currently are executed by the driver, train staff and maintenance personnel. These functions and tasks must be linked with a potential target component like ATO, TCMS or APM, and when applicable mapped to actual requirement specifications from Shift2Rail or the TSI standards. In this task, the use cases, and operational parameters for "automating functions" for passenger, freight, and tramway application will be defined in cooperation with System Pillar (SP) (first input from SP is necessary). This task is about the definition of modular, scalable, and configurable system and corresponding operational rules for nominal situation, and for degraded situation for GoA3/4 under consideration of different operational rules (e.g., calamity rules) at different operators, considering the corresponding general operational rules defined in the System Pillar. Resulting use cases will cover both operational aspects and functional aspects.

Inputs from Flagship Areas 5 & 6 and from the System Pillar will be considered until M6 (MS1 – Consolidation of external inputs milestone).

On basis of the description that was provided in the GA, the following can be concluded:

1. Relevant input from partner projects (X2Rail-4, ARCC and TAURO, other FAs and SP) needs to be collected, analysed and if relevant, included in the deliverable. Input from these partners project will be considered until month 6, June 2023, of the project.
2. Task 5.1 will create an overview of the functions that are currently performed by the driver, train staff and maintenance personnel and are linked to ATO, TCMS or APM. If possible, these functions are mapped to requirements specification from Shift2Rail (S2R) or Technical Specifications for Interoperability (TSI).
3. Task 5.1 will develop use cases and operational parameters for "Automating functions" for Passenger, freight, and tramway application. Development of these use cases and operational parameters will be developed in cooperation with the SP if input is received before the deadline in month 6. Otherwise, input will not be considered and use cases and operational parameters will be developed within task 5.1 context.

On basis of the description for task 5.1, a below deliverable description was created in the GA. This description was also included in the description for milestone #11: MCP3.

This deliverable [task 5.1] will contain a report about actual existing and specified automated functions, tasks, or related use cases with annotated target component as scope, a draft release for set of documents including analysis based on first input from SP and related FAs (e.g., regarding demonstrators) and definition for relevant use cases, operational parameters, and scenarios in scope of passenger/freight and tramway applications.

After analysing and comparing both the task and deliverable description, it can be concluded that the task 5.1 deliverable has three objectives:

1. Report about actual existing and specified automated functions, tasks, or related use cases with annotated target component as scope.
2. Report about draft release for set of documents including analysis based on first input from SP and related FAs (e.g., re definition for relevant use cases, operational parameters, and scenarios in scope of passenger/freight and tramway applications regarding demonstrators). Input from these partners project will be considered until month 6, June 2023, of the project.
3. Report about definition for relevant use cases, operational parameters, and scenarios in scope of passenger/freight and tramway applications.

A mapping of the deliverable objectives and where to find the results fulfilling these objectives can be found in the table below.

Objective location	Objective definition	Deliverable 5.1 result
Task 5.1 description, GA Page 28	First, existing, and relevant deliverables from partner projects are examined. Relevant functions, related use cases and operational scenarios are collected.	<ul style="list-style-type: none"> Methodology, chapter 2 Identification, chapter 2.4 Use Case Index, Annex 2
Task 5.1 description, GA Page 28	Additionally, this task will update a set of functions which currently are executed by the driver, train staff and maintenance personnel.	<ul style="list-style-type: none"> Use cases in chapter 3.1
Task 5.1 description, GA Page 28	These functions and tasks must be linked with a potential target component like ATO, TCMS or APM, and when applicable mapped to actual requirement specifications from Shift2Rail or the TSI standards.	<ul style="list-style-type: none"> Methodology, chapter 2 Scope definition 2.3 Use cases in chapter 3.1 Limitations 2.8.1
Task 5.1 description, GA Page 28	In this task, the use cases, and operational parameters for “automating functions” for passenger, freight, and tramway application will be defined in cooperation with System Pillar (SP) (first input from SP is necessary).	<ul style="list-style-type: none"> Scope definition 2.3 Use cases in chapter 3.1 Limitations 2.8.1
Task 5.1 description, GA Page 28	This task is about the definition of modular, scalable, and configurable system and corresponding operational rules for nominal situation, and for degraded situation for GoA3/4 under consideration of different operational rules	<ul style="list-style-type: none"> Use cases in chapter 3.1 Limitations 2.8.1

	(e.g., calamity rules) at different operators, considering the corresponding general operational rules defined in the System Pillar. Resulting use cases will cover both operational aspects and functional aspects.	
Task 5.1 description, GA Page 29	Inputs from Flagship Areas 5 & 6 and from the System Pillar will be considered until M6 (MS1 – Consolidation of external inputs milestone).	<ul style="list-style-type: none"> • Limitations 2.8.1
Deliverable 5.1 definition, GA Page 119	This deliverable [task 5.1] will contain a report about actual existing and specified automated functions, tasks, or related use cases with annotated target component as scope, a draft release for set of documents including analysis based on first input from SP and related FAs (e.g., regarding demonstrators) and definition for relevant use cases, operational parameters, and scenarios in scope of passenger/freight and tramway applications.	<ul style="list-style-type: none"> • Use Case Index • Task 5.1 deliverable document • Use cases in chapter 3.1 • Limitations 2.8.1 <p><i>See results of D5.3 as well, for analysis of X2RAIL-4 architecture</i></p> <p><i>For freight/tramway:</i></p> <p><i>Many 5.1 use cases apply for freight and tramway as well. Refer to D5.5 and D5.6 for more freight and tramway specific use cases.</i></p>

Table 1: Mapping of objectives to deliverable 5.1

2.2 INPUT FROM EXISTING AND RELEVANT DELIVERABLES

As input to the work package 5 process, the state of the art was considered and deliverables from past projects were identified and actively requested at work package level. For this process, input was collected from several relevant projects:

- Shift2Rail – IPX - TAURO 1st Release package (transfer date 06/02/2023) [1]
- Shift2Rail – IPX - TAURO 2nd Release package (transfer date 31/05/2023) [1]
- Shift2Rail – IP2 - X2Rail-4 Baseline 0 (transfer date 05/05/2023) [2]
- Shift2Rail – IP2 - X2Rail-4 Baseline 0.1 (transfer date 23/06/2023) [2]
- TSI CCS 2023 and relevant ATO subsets (informal drafts and 10/08/2023 release) [3]
- Shift2Rail - IP5 - ARCC Demonstrator – Deliverable 1.7 “Documentation and evaluation of GoA2 freight demonstrator test results in specified testing scenarios, proposal of next steps” (downloaded from project website 30/01/2023) [4]

Due to the variance in the receipt of formal inputs concerning the M6 deadline some intermediate deliverables were requested and provided on pertinent topics for WP5. In order to prevent further delays and ensure a viable outcome by the M12 deadline of WP5, the work package team initiated work based on these intermediate deliverables and draft documents. This allowed them to identify potential gaps with the intended WP5 results. This understanding of the gap was then utilized to

concentrate efforts within task 5.1 on drafting use cases for known open topics, while avoiding duplication of use cases that might be available in Shift2Rail projects.

Once the formal deliverables became available, an analysis was performed on the delta of these deliverables compared to the inputs used for the ongoing work in the WP5 tasks. Additionally, delivered use cases were processed into the use case index registering them as available input, with the specific topic of the use case no longer needing development within task 5.1.

As explained in the chapter 2.8, during the course of task 5.1 no timely deliverables were received as an input from the System Pillar and from other ERJU Flagship Projects.

2.3 SCOPE DEFINITION

During the initial phase of WP5 it became clear from discussions between the task leaders and between work package partners, that there was not a comprehensive definition available of the scope of each of the tasks for WP5. Of course, there were some generic clues on the scope of each task, providing some guidance on the boundaries between the tasks, but overall, many partners reported to be confused on the exact scope of each task. This was especially true for task 5.1, since it is focused on the 'Automating Functions' TE, which is a term not previously defined in other projects such as Shift2Rail.

To avoid future issues on the scope of the tasks, a series of discussions was planned during the initial phase of the project to gain an understanding of the scope for each task. After organizing three additional workshops in month 6, this process was formalized among a sub-group of stakeholders, and finally concluded by the task leaders of task 5.1, 5.2, 5.3 and 5.4. The results are captured in the internal document "*WP5 Scope Definition – Automating Functions, Perception, ATO Technologies, Remote Driving*". Below are the summarized results from this document, relevant for task 5.1.

The aim of this document was mainly to make a distinction of scope between the tasks, to be used to define and allocate the list of use cases for each task. It was meant to be a "mutual understanding and agreement on high level scope of each function, and the general work split between WP5 tasks". At the same time, the task leaders agreed the following:

- WP5 should focus on the operational rules and quantified conditions and should not aim to come to a detailed architecture.³
- Use cases may include several functions and TEs, in which case the work split would be according to the primary or initial actor of the use case (which ever was more relevant).
- The use cases should reflect a testable operational chain of events, where possible according to the "Sense / Think / Act" principle.
- Use case actor may be defined at a relatively high level, if from architectural work in previous projects it is not clear which actor is responsible.

³ Some exceptions apply, where a limited number of detailed use cases were highly prioritized and thus found very relevant, in spite of their level of detail. This was found to not be a problem, as long as the use case was relevant.

Specifically for task 5.1, the scope definition was formulated as defined below. As a reference, the Grades of Automation table as in IEC 62290-1:2014 was used.⁴ A copy of this table is included as Figure 1 below, with the scope of task 5.1 marked in the green box.

Automating functions in this context refers to functions required in GoA3/4 (DTO/UTO) systems compensating the absence of a driver or train attendant who would otherwise be responsible for some or all of train operation functions.

Excluded are train-borne functions supervising the guideway, preventing collisions or remote-controlled operations. Driving tasks are part of ATO Technologies (TE4).

Automating functions related use cases include but are not limited to:

- *Trigger train function, provide data / set mode.*
- *Supervise operations (monitoring brake, horn, sanding, incidents in train).*
- *Expected reaction on failures of train functions (WP5 will describe a representative set of responses – i.e., disable systems and requesting reduced speed – which will be non-exhaustive).*

Grades of automation as in EN 62267:2010, EN62290-1:2014						
Basic functions of train operation		On-sight train operation	Non-automated train operation	Semi automated train operation	Driverless train operation	Unattended train operation
		TOS	NTO	STO	DTO	UTO
		GOA0	GOA1	GOA2	GOA3	GOA4
Ensuring safe movement of trains	Ensure safe route	X (points command/control in system)	S	S	S	S
	Ensure safe separation of trains	X	S	S	S	S
	Ensure safe speed	X	X (partly supervised by system)	S	S	S
Driving	Control acceleration and braking	X	X	S	S	S
Supervising guideway	Prevent collision with obstacles	X	X	X	S	S
	Prevent collision with persons on tracks	X	X	X	S	S
Supervising passenger transfer	Control passengers doors	X	X	X	X or S	S
	Prevent person injuries between cars or between platform and train	X	X	X	X or S	S
	Ensure safe starting conditions	X	X	X	X or S	S
Operating a train	Set in/set off operation	X	X	X	X	S
	Supervise the status of the train	X	X	X	X	S
Ensuring detection and management of emergency situations	Perform train diagnostic, detect fire/smoke and detect derailment, handle emergency situations (call/evacuation, supervision)	X	X	X	X	S and/or staff in OCC
X = responsibility of operations staff (may be realised by technical system) S = realised by technical system						

Figure 1: IEC 62290-1:2014 Grades of Automation table – with task 5.1 scope ⁴

⁴ An update to this table has been published by X2Rail-4 [5] (table 2), which would reflect a change of the ‘X’ for ‘Operating a train’ in GoA3 to ‘X or S’ – which is in accordance with the scope of this deliverable.

This scope statement provided the basis for the further identification and development process of task 5.1, as described in the chapters below. Similarly, the other WP5 tasks used their scope statement (or available definition in case of task 5.5 and 5.6) as input to their own development process.

2.4 USE CASE IDENTIFICATION PROCESS

The first stage of task 5.1 was to set up an index file, generally referred to as the 'Use case index'. This stage of the project was finalized in March 2023 (see task 5.1 meetings notes⁵). Although at this point in time, the bulk of the use cases was identified, input could still be considered until M6 of the project. The use case index was used to capture inputs from below sources:

- Task 5.1 expert partners, specification partners and review partners
- Other Flagship Areas
- System Pillar
- Other Shift2Rail (S2R) projects such as X2Rail-4, TAURO and ARCC⁶
- Open source information

The use case index was first populated with input from the task 5.1 partners, followed by use cases from S2R projects. Input from other FAs and the SP could be considered until M6. Any input that was received after this point, was not formally considered. The input that was received from X2Rail-4 after M6 was only reviewed to determine critical inputs, which will be discussed more in depth in section 2.8 'Limitations'.

Once the index was populated, works started to structure the index and to resolve any redundancies. This process mostly took place in March 2023, after which the index consisted of a comprehensive list of use cases that had been identified and structured into scenarios.

2.5 USE CASE PRIORITIZATION

2.5.1 Identifying R2DATO priorities

Due to the successful identification of use cases in the first phase, the sheer number of use cases (more than 1100) required a next step in the development approach. To be able to achieve good quality use cases as deliverables, the identified set of use cases needed to be reduced to a viable number that could be developed with the available resources. The emphasis of the process therefore shifted to prioritization.

⁵ See meeting notes of 'WP Task 5.1 meeting 09-03-2023' slide 1')

⁶ While no formal input was received from ARCC before M6, the involvement of DB Cargo in both projects meant the results could be included informally in task 5.5.

To achieve an objective prioritization, a process was established at WP5 level to prioritize the use cases on the basis of relevant inputs in the R2DATO project. This process is illustrated in Figure 2 below.

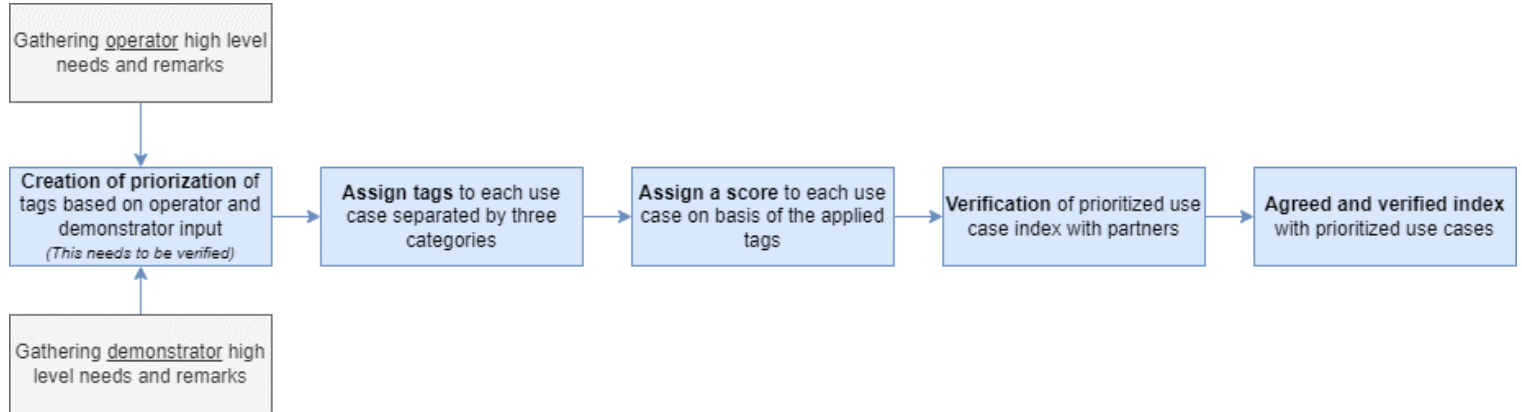


Figure 2: Use case prioritization process

As input to the prioritization process, the R2DATO objectives, innovative solutions, demonstrator context and impacts were used as a basis, visualized in Figure 3 below.

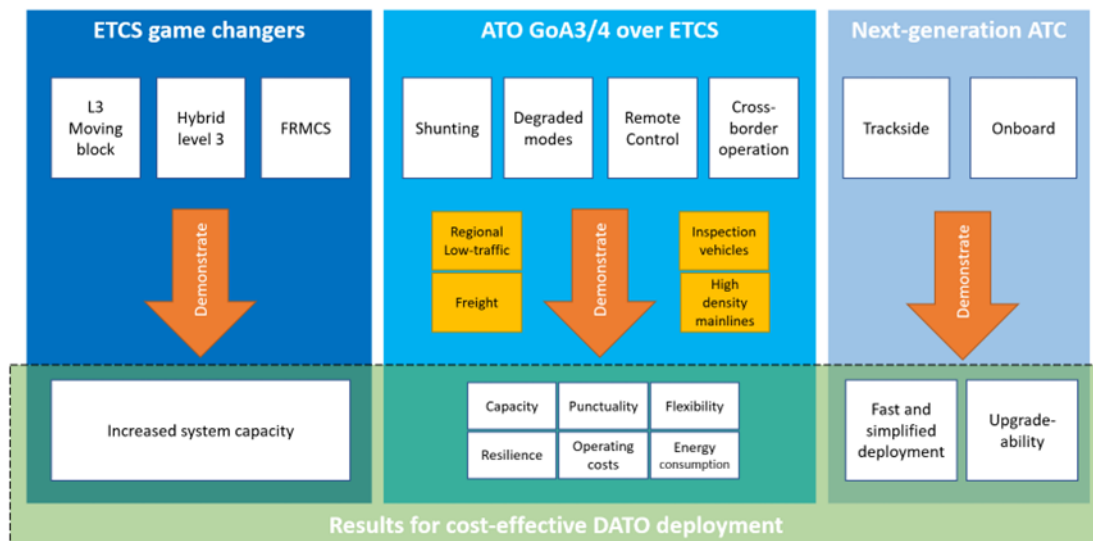


Figure 3: Input to the use case prioritization process

During multiple workshops with both the Railway Undertakings (RUs) and the Demonstrators, scorecards were created based on the schematic in Figure 3. As a result, each topic received a score based on how many RUs and demonstrators found it a priority for R2DATO. simultaneously, high level needs that explained what the RUs and demonstrators were looking for as important output of the WP5 use case development were also collected.

Resulting from these workshops, it became clear that the highest priority should be placed on use cases for:

- Remote control
- Shunting
- Degraded modes
- High density mainlines
- On-board
- Increasing capacity
- Fast and simplified deployment

Consecutively, the results of the workshops were made available to each task, as potential input to be used for setting priorities. Within task 5.1, these topics were used as explained in the chapters below. It is important to note however, that these results should be seen in the light of the defined scope of each task. In the case of task 5.1 for example, remote control is a topic that is out of scope and should be handled within task 5.4. Regarding the usage of these topics within task 5.1 is elaborated on in chapter 2.5.2.

In the later development phases of task 5.1, a further attempt by the WP Lead was made to again synchronize priorities between WP5 and the Demonstrator cluster. The aim of this exercise was to ensure that no major gaps would remain once the deliverables of WP5 would be made available, compared to the updated objectives of the R2DATO demonstrators. To organize such alignment, the WP leader contacted the Demonstrator Cluster leader in M9 in a joint effort to organise a workshop in M10 with the goal of explaining the current list of development priorities to the demonstrator leaders. After several reminders by the demonstrator cluster leader, it was concluded from the (lack of) response from the demonstrator leaders that no further alignment was necessary and that the resulting use cases of WP5 would remain the basis for the R2DATO project to work on. This also aligns with the linear flow of deliverables within the R2DATO project, as was outlined and accepted in D4.1 [1].

2.5.2 Identifying and tagging relevant objectives per use case

The next step in the process was to establish the value of each identified use case, according to its contribution to the R2DATO objectives and their established priority.

To achieve this, a tagging system was put in place where each partner was asked to tag a subset of use cases for alignment with goals from the different categories identified in the R2DATO objectives:

- Innovative solutions (i.e., remote control, shunting)
- Operational context (i.e., high density mainlines, inspection vehicles)
- Benefits of automation (i.e., increased system capacity, punctuality)

In two rounds, each use case was tagged at least two times, each round a different partner tagged the use case, to ensure the allocation of tags to each use case was representative.

As a final step, the tags that were given to a use case were combined with the relative priority of each tag (as shown in Figure 3 in section 2.5.1), added up for all the tags combined, and finally averaged across both scoring rounds – reducing the chance for incidental outliers. A manual sanity check was then performed to check if the results made sense against the original prioritization input from the RUs and demonstrator cluster. Any outliers were confirmed, or their scores marked for review where needed. The resulting list was then reviewed once more by all task 5.1 partners, to identify any unexplainably absent or unjustifiably included use cases.

The end result was a prioritised list where the most relevant use cases could be identified objectively against the R2DATO goals and objectives.

2.5.3 Reducing the number of use cases

With an overview with prioritised use cases, the final step was to reduce the number of use cases in order to come to a set of use case which could be developed within the available time. This process was done with multiple criteria:

- By establishing which use cases were meanwhile becoming available from Shift2Rail projects – i.e., from the X2Rail-4 SRS – and thus did not need further development in task 5.1.
- By removing any ‘use cases’ that were in fact a feature.
- By removing any ‘use cases’ that had a wrong granularity – i.e., describing a very detailed technical solution rather than the operational railway processes.
- By establishing which use cases would be out of scope of the ‘Automating Functions’ TE, potentially transferring them to the other WP5 tasks if relevant.
- Relative to each other based on their priority, where a final cut was made based on an achievable number of use cases.

As a result of this filtering, a total of 122 use cases were nominated for development in task 5.1. However, during the development process, this number saw a further reduction, ultimately, 74 use cases within task 5.1 were developed. The reduction from 122 to 74 use cases can be explained by gaining more in-depth knowledge of the contents of the use cases, resulting in a finer grained analysis of use cases that were duplicate, already available as input, out-of-scope, or a wrong granularity.

2.6 USE CASE DEVELOPMENT PROCESS

2.6.1 Allocation of use case development

After the prioritization process was completed, the use cases with the highest priority had to be developed. To develop these use cases, they were allocated to the partners within task 5.1. This was done by following the process as described below.

On basis of the person months, as described in the GA, an overview was created in which the persons months for each specification and expert input partner was translated to the percentual contribution to WP5 of each of these partners.

Taking the percentual contribution and the 122 use cases to be developed, it was then calculated how many use cases each partner had to develop. As can be seen in the table below, it has been calculated per partner what the number of use cases is that needed to be developed.

Partner	Person Months	Percentage	Number of UC
NSR	12,44	16%	20
GTSD	9	12%	14
CEIT	9	12%	14
Alstom	6,11	8%	10
DB	11,89	15%	19
Siemens	8,71	11%	14
SBB	19,92	26%	32
Total	77,07	100%	122

Table 2: Percentual contribution to development of use case in task 5.1

2.6.2 Alignment on development content

In order to guarantee that the use cases produced within the project would be uniform, a use case development guide was created by the WP lead. This guidance document had been developed with the aim to provide additional relevant information to the partners involved in the development of use cases in WP5.

In this document the following topics were discussed:

- *Terminology to be used in the use case* - A list of terms and definitions to align the development process with all partners involved. This list was adapted from X2Rail-4 with additional terms where needed.
- *How to develop a use case using the 'WP5 - Use Case Template'* - A step by step guide starting from using the use case template to uploading to finished use case.
- *Example use case* - A demonstration of what is asked while filling the template with information.

2.6.3 Definition of Operational actors

During the development process of the use cases, in addition to the development guide discussed in chapter 2.6.2, a further need to align on the definitions of the operational actors used across the different WP5 tasks was identified. Understanding and aligning on the actors to be used between the different use cases was an important process. This allowed for standardised usage of actors within task 5.1 as well as tasks 5.2 and 5.4. To achieve this, during several workshops, the partners involved in task 5.1, created document 'WP5 – Operational Actors for R2DATO WP5' [8].

This document aims at providing a reference for the operational entities/actors shared by the use-cases developed in task 5.1, 5.2, 5.4. The basis of the document was developed according to existing definitions in previous projects such as from Shift2Rail. In the developed document a discussion is provided with a chapter about how actors have been chosen.

All R2DATO WP5 partners have been requested to use the definitions in this document as a common ground for defining the WP5 use cases. Additionally, within task 5.1, during the formal review process of the use cases, a specific task was performed to ensure alignment of the operational actors with the definitions in this document.

To avoid duplication errors, these formulated definitions are not included in this document, but can be found in Annex 3: WP5 – Operational Actors for R2DATO WP5.

2.6.4 Document management process

Finally, the use case development guide also provided the document management approach to be used during the use case development process. This approach is described below.

Within task 5.1, there was a specific process agreed for the development of use cases. At a high level, the use case development process could be distinguished in two phases:

- In development (store on ProjectPlace)
- Finalized and ready for 'final acceptance' (store on CT5)

During the development phase there were six sub phases that needed to be completed, before a use case could be finalized. These steps were:

- 1. First development stage**
2. In review
- 3. Second development stage**
4. In formal review
- 5. Third development stage**
6. Finalized (store on CT5)

The phases in **bold** were the responsibility of the partner that was developing the use case. The phases in plain text were the responsibility of the review partner. These phases were put into practice as a matching folder structure in ProjectPlace. This setup was made for each task within WP5. By using the folder structure, a use case could 'physically' be moved into the next phase. By doing so, the task leaders could keep track of the status of all the use cases that were in the development process at each point in time, monitoring progress against the task- and work package planning.

2.7 USE CASE REVIEW PROCESS

Within task 5.1, the task leader has established a process for reviewing the use cases that has been used throughout the development process of task 5.1. This process is based on best practices from previous projects with a large group of stakeholders involved and facilitates both a rapid development process as well as a formalized approval. The review process can be distinguished between two types of review:

- Informal review
- Formal review

After the use case development process started, the review partners and their committed effort in Person Months to WP5, as listed in the GA, were identified. In total, there were 14 partners who were responsible for reviewing the developed use cases. On the basis of the provided person months per partner, an estimation of the review contribution per partner was made. The review partners were then requested to pick any use case they wanted to review, as long as all use cases had at least one of the partners reviewing it, and as long as they at least fulfilled their target number of reviews.

Taking the percentual contribution and the 122 use cases that were to be reviewed, it was calculated how many use cases each 'Review' partner had to review. As can be seen in the table below, it has been calculated per partner what the number of use cases is that needed to be reviewed.

During the development process, a more fine-grained review of the use cases was done, which resulted in a total of 74 developed use cases. In the column 'Reviewed use cases' the total number of reviewed use cases can be found.

Partner	Pmonths	Percentage	Planned use cases	Reviewed use cases
1. ProRail	2,3	2%	2	2
2. Adif	17	13%	16	12
3. Ferrovie dello Stato Italiane	5	4%	5	6
4. GTSD	9	7%	9	8
5. Hitachi	11	9%	11	7
6. AZD	3,8	3%	4	4
7. CAF	11,89	9%	11	9
8. NRD	5,9	5%	6	5
9. MerMec	6	5%	6	0
10. CEIT	9	7%	9	8
11. SBB	19,92	16%	19	2
12. Alstom	6,11	5%	6	6
13. DB	11,89	9%	11	0
14. Siemens	8,71	7%	8	6
Total	127,52	100%	122	74

Table 3: Percentual and actual contribution to reviewing of use case in task 5.1

In the two subsections below, an explanation of both types of reviews is provided.

2.7.1 Informal review process

The use cases that were ready for informal review were moved according to the previous discussed folder structure, into the “in review” folder. By doing so, the allocated review partners knew that the use case they had claimed was available and the informal review could be performed (see chapter 2.6.4 for an explanation of this process). In this stage, the R2DATO review template was not yet used.

Once the informal review was finished, the use case developer was then requested to process all the review comments that were placed in the document and improve the draft use case into a version suitable for formal reviewing. From this stage on, the process became more formalized, to ensure proper acceptance and approval, and for the paper trail to be available accordingly.

2.7.2 Formal review process

All informal review comments would have been processed, with the draft use case normally in a good shape once a use case was transferred to the “In formal review” folder by the use case developer. The formal review was mostly performed by the same partner who had previously assessed the use case informally, implying that the formal review was more of a check on the implementation of the informal review suggestions. However, all partners were invited to formally review any of the use cases, according to their own interest and relevance.

At this stage, the formal R2DATO use case review template also had to be used during the formal review. Reviewers needed to record their major comments in the review template and had the option to record minor comments in the word version of the use cases.

After finalizing the formal review, the developer of the use case was required to process all the comments and provide a response in the review template. Once this process was completed, the reviewer would then be informed of the updated use case, allowing for final remarks on the implementation of the review comments.

Once the use cases were finalized and uploaded to CT5, all task partners had five working days to comment on the uploaded version, before the use case was finalized (status from draft to issued). Having changed the status of the final use cases on CT5 from ‘draft’ to ‘issued’ on CT5, this concluded the development process of the use cases.

2.8 LIMITATIONS AND OPEN POINTS

During the course of WP5, many discussions took place about the intended scope of work and how the team of partners should ensure a good result that could be delivered timely. Already during the kick-off meeting many discussions were focused on what WP5 should and should not be doing to ensure these results. The main conclusion of these discussions was that WP5 needed strong focus to ensure delivering good results on a few use cases, rather than delivering many very mediocre use cases as a result. This has led to the first limitation mentioned in chapter 2.8.1 below and to the process of identifying and prioritizing use cases described further on in this document.

While the work was ongoing, several further issues and risks were encountered and mostly resolved by the work package and task leaders. Other risks remained a threat to the WP5 results and eventually materialized. These risks mainly applied to timely receipt of the input documentation from previous and parallel projects. One of these risks has led to the second limitation listed in chapter 2.8.1 below.

In chapter 2.8.1 these encountered limitations are described. The limitations are categorized in their respective stages they occurred in. Any further open points that are remaining after finalizing the deliverable are included in chapter 2.8.2.

2.8.1 Limitations compared to deliverable objectives

1. The first objective as described in section 2.1, refers to 'annotated target component as scope'. Which seems to suggest that WP5 will focus on an architecture level. During the Kick-off meeting in January 2023, with all partners represented, it was decided that WP5 should focus on capturing the operational procedures of the railways, rather than focusing on the architectural allocation to target components. This decision was also further guided by the fact that no stable reference architecture was available before the defined milestone of receiving first input from the System Pillar before M6.

Where the architectural allocation was already obvious due to previous work, a suggestion for allocation was included in the use case, which needs to be further standardized in the System Pillar. Within R2DATO, further allocation is expected to be needed by WP6 in during the specification process.

2. The second objective, as outlined in section 2.1, pertains to the incorporation of input from the SP and other FAs for the development of the use case within task 5.1. According to the objective description, input from the SP and other FAs was to be considered until M6 (June 2023) of the project. Post the M6 milestone, incorporating input from these sources became unfeasible due to time constraints. Consequently, this objective remained unfulfilled.

However, in month 9, one deliverable from 'FP6 FutuRe' was received by WP5. Due to the delayed delivery, there was no opportunity for processing these deliverables as input. However, to improve collaboration between the projects, the WP5 team did provide a review of the use cases focusing on alignment of the FP6 use cases in D2.2 and the WP5 use cases.

2.8.2 Open points

Due to time constraints, not all the identified and potentially relevant activities could be performed during the WP5 timeframe. Instead, priority had to be given to those topics most relevant for the R2DATO project results and the objectives as were set in the Grant Agreement. In this chapter the open points are listed that task 5.1 has considered relevant but could not be completed within the timeframe.

Standardization of operational processes

While the participants would have preferred to deliver a completely standardized set of operational procedures, realistically such an alignment across all the 20 partners involved in WP5 would take years rather than the 12 months available to the team. Instead, the approach was therefore taken to have one partner lead the drafting of each use case, with an additional partner (sometimes two or more) to review a use case. If alternative operational procedures were identified by peer-reviewers, these could be added as a variant of the use case within the same document. Across all use cases, the definitions of the operational actors have been aligned as is explained in chapter 2.6.3 Definition of Operational actors.

In this way, it was ensured that good set of quality use cases would be produced, reflecting actual operational procedures, as a basis for operational demonstrations of the Automation Processes TE prototypes to be performed within R2DATO. Meanwhile avoiding pitfalls of endless discussions on standardizing the operational procedures.

Recommendations

In future projects it is therefore the task to take the lessons learned from the R2DATO demonstrations based on this generation of prototypes and the drafted operational use cases. Future projects should work on full alignment between all involved RUs on standardized operational procedures, in order to facilitate an interoperable design of the eventually matured TEs.

Use cases for non-Automation Processes Technical Enablers

By R2DATO design, the WP5 activities were placed under the umbrella of the Automation Processes Cluster. Looking at the specific tasks in WP5, it becomes clear that the focus of the use case generation is on the TEs that are included in Automation Processes Cluster. While this seems logical, this also meant that during certain decision points in the project, clear scoping was needed where certain interesting and relevant use cases had to be placed out of scope – since they did not concern a TE included in Automation Processes Cluster .

From discussions with the broader R2DATO community, it became clear that this design choice was not obvious for all participants, and that there also are no further use case defining work packages in the other clusters.

Recommendations

While the nature of the operational use cases in WP5 allows for some relevant use cases to be specified slightly beyond the scope of Automation Processes Cluster, it is recommended that additional use case development work is performed within the demonstrator clusters, to ensure the operational usage of the railway is sufficiently captured for an effective demonstration of all Technical Enablers involved.

Use cases that were found relevant, but received a low priority

As explained in the chapter 2.5, priorities needed to be set in the development of use cases. According to the explained process, use cases that aligned best with the R2DATO demonstrators and RU priorities received a higher priority rating and were more often developed than use cases not aligning with those priorities. This does not necessarily align with the needs of future projects or the other R2DATO clusters.

Recommendations

For future projects and for other clusters of R2DATO, priorities may be perceived differently. It is advisable that the current selection of use cases is revisited for each future project, checking for missing operational processes for each project – rather than taking the task 5.1 results for an exhaustive set of use cases, which it is not.

As a starting point, the list of open use cases – defined as the gap between the identified relevant use cases, and the eventually delivered use cases – can be found in chapter 3.2.

New inputs received after M6 and further alignment

Due to the limited timeframe of WP5, a strict deadline was set on when received inputs could formally be processed. This deadline was clearly mentioned in the GA and was communicated often through the work package leadership. As was already mentioned in 2.8.1, not receiving these inputs timely has been a major risk for the project. While inputs from TAURO and X2Rail-4 were available (at least in concept) before that deadline, no other inputs were formally received before the deadline.

During the last months of the work package, further input was received with updates from X2Rail-4 and FP6. At this point in time, only limited adjustments could be made to ongoing and finalizing task 5.1 developments. While considerable effort has been invested in aligning the work with the X2Rail-4 team, the conceptual state of the scenarios and of some of the System Requirement Specification (SRS) use cases means the alignment was sometimes sub-optimal. Similarly, due to the late arrival of the FP6 deliverables, hardly any alignment could be made other than providing a commented table on the overlap of use cases between WP5 and FP6.

Recommendations

It is advisable for future projects to continue the integration of the deliverables of Shift2Rail projects, SP and other FP's with the final deliverables of task 5.1 and WP5 as a whole. While a best effort was made to align these deliverables during WP5, in practice the timelines of all projects were too much in parallel to fully incorporate all but the TAURO deliverables.

Specific alignment is advised to be sought between R2DATO WP6 and ongoing X2Rail-4 efforts on the definition of interfaces. In the final phase of the task 5.1 it was identified that these definitions potentially provide new insights compared to the task 5.1 results.

3 RESULTS

This chapter of the deliverable provides the results of task 5.1 from month 1 (December 2022) until month 12 (November 2023).

In chapter 3.1, the relevant scenarios from a 'Day in the life of' a train are listed, together with the use cases that were fully developed within task 5.1 for each scenario. Compared to the originally identified scenarios and use cases, not all scenarios are listed here – since several scenarios were already completely covered in the existing deliverables, or did not contain any priority use cases for development in task 5.1.

Chapter 3.2 lists the use cases that were identified and found relevant, but could not be developed within the task 5.1 timeframe or scope. Additionally, this chapter introduces the full set of use cases, operational rules and features that were identified during the task 5.1 identification phase. This result can be used by future work packages and projects to gain an understanding of the state of the art for Automation Function use cases, and even ATO use cases in general.

Finally in chapter 3.3 the link between the task 5.1 use cases and the X2Rail-4 scenarios and use cases is established, resulting from the alignment efforts between task 5.1 and X2Rail-4.

3.1 DEVELOPED USE CASES

This section provides insight in which use cases have been developed within task 5.1. The use cases have been categorized in 29 scenarios which present a 'Day in the life' of a Train. The scenarios represent both regular operational scenarios and non-regular scenarios.

For each scenario first a short description is provided to establish a common understanding of the specific scenario. Any exclusions for the scope of the developed use cases are then introduced. Next, a table is included with the linked use cases for each scenario, their unique identifier, and a brief summary of what operational process the use case is describing.

The complete use case document for each use case ID and name can be found in Annex 4: Use Cases for Automating Functions.

3.1.1 Train preparation

Train preparation is the process of getting a train prepared for a journey.

It includes both, automatic activities and manual activities like cleaning, refuelling in case of non-electric trains etc. The latter ones will not be considered in this scenario.

The process starts with waking up a parked train, which includes powering the vehicle, the on-board modules, and the auxiliaries. After receiving all necessary data from the trackside, on-board modules are initialized, and Self-tests/auto-tests are performed to determine if the system is fit for service.

In general terms, the train is ready for operation when:

- the train has received the relevant data to perform the mission;
- the train is prepared (power supply on, brake test done etc.);
- the train is configured (data entry performed).

Note:

'UC5.1-007 Preparation for departure' is applicable to remote driving operation, and the described process goes far beyond just "train preparation". In this use case, the locomotive is also moved and coupled. However, some aspects from this use case are relevant as automating function, hence why this use case is included in the task 5.1 deliverable.

ID	Use Case Name	Summary
UC5.1-001	"Wake-up" / Initialization and perform auto-tests/self-tests for normal operation in GoA 3&4	This use case describes the needs and the possible solution to switch on the train automatically.
UC5.1-002	Prepare passenger train (diesel)	This scenario outlines the process of getting a passenger train ready for operation, particularly one powered by diesel. The main goal of this train preparation is to guarantee the safety of the rail vehicles and ensure they are set up correctly to enter the rail network.
UC5.1-003	Prepare train unit for a mission - Configure GoA automatically	After Powering on the train, TAS provides OAS with all profiles needed for the mission. There are three sources for GoA level: 1. Static track plan data (static Segment Profile). 2. Dynamic information from dynamic Segment Profile from IM (OE). 3. Dynamic information from Mission Profile from RU
UC5.1-004	Prepare train unit for a mission – Select traction system automatically	The use case, Prepare Train unit for a Mission, normally happens after the X2R4 use case ""Awakening sequence of autonomous train" and the originally identified use case "Switch traction power supply to a train unit while stationary" is part of this use case. The selection or the switch of traction power supply is expected to be automatic to: Select voltage level. Select voltage type in the catenary. React on powerless section.

UC5.1-005	Determine and select travelling direction	<p>A change of the travelling direction can happen in two cases:</p> <ul style="list-style-type: none"> • train preparation, • a change in running direction requested by Mission Profile. <p>In both cases, it is also necessary to enter the ATP data automatically (see UC.5.1-006 Enter ATP data automatically)</p> <p>Select the correct cab:</p> <p>The change of cab is initiated by the On-board Automation System (OAS) using Mission Profile, Journey Profile and Segment Profile (Digital Map Information). The Serviceable train shall know its last orientation from last journey. Then it can select the correct cab based on the new Journey Profile and Segment Profile (Digital Map Information).</p>
UC5.1-006	Enter ATP data automatically	<p>A change of the front end can happen in two cases:</p> <ul style="list-style-type: none"> • train preparation, • a change in running direction requested by Mission Profile. <p>In both cases, it is necessary to enter the ATP data automatically.</p> <p>Enter the ATP data:</p> <p>If the correct cab is selected, or if the TCMS is connected to the waggon by using the Digital Automatic Coupler (DAC) a system can enter the train data in ATP.</p> <p>The train data is supplied by Fleet Automation System (FAS). OAS should check whether the input data from FAS has conflict with determined train local data. In EMUs this could be done by checking the inauguration data from TCMS. In freight trains it could be done by staff or by using the Digital Automatic Coupler (DAC).</p>
UC5.1-007	Prepare train for departure	<p>This use case defines the steps to be completed to remotely move the locomotive from the parking area to the wagon group. Two brake tests should be completed, the first locomotive should complete self-brake testing and once the locomotive is coupled with the wagon group a second brake test should be completed. Train integrity and train composition should be checked before departure.</p>

3.1.2 Periodic inspections and tests

In this group of use cases the inspections and tests are described that need to be conducted periodically, usually before the train is ready for departure. The identified inspections and tests currently need to be performed visually by a driver or as a functional system test, and are so far not included in the scope of the Perception TE. These are performed as part of the preparation process to ensure that the train is good operational order and can be cleared for departure.

Excluded from these use cases are exhaustive descriptions for tests and inspections of each single train system, which would need to be developed further once a standardized architecture has been agreed. These use cases can then be linked in with the developed high level operational use cases.

Further inspection and testing use cases were identified as part of the TAURO input, which have not been developed further in WP5.

ID	Use Case Name	Summary
UC5.1-008	Conduct visual inspections and tests	As part of the protocol to prepare the train for departure, the driver needs to perform visual inspections and tests. This use case only considers the visuals examinations. It is assumed that the visual inspection will be performed periodically before the train is cleared for automatic operation or RO operations by authorised personnel.
UC5.1-009	Conduct system and functional tests	As part of the protocol to prepare the train for departure, the driver needs to perform visual inspections and system functional tests. This use case only considers the system functional checks.

3.1.3 Train stabling

This group of use cases deal with train stabling, also known as train parking or train storage, and refers to the practice of temporarily placing a train in a designated area, typically a rail yard or siding, where it remains stationary and is not in active use for passenger or freight transportation.

Train stabling is a crucial part of railway operations, enabling efficient use of resources, maintenance, and adherence to safety and regulatory standards.

Particularly some specific functions about train stabling are addressed, such as when train arrives at the final destination and reports its end of shift, the clearance procedure of passengers before train is moved to a stabling position, the processes to change train modes between operating mode and standby/ready/sleep modes.

ID	Use Case Name	Summary
UC5.1-010	Report end of shift/assignment	<p>This use case describes the operational scenario of “end of shift/assignment”.</p> <p>The train arrives at the final destination, reports its end of shift and sets the train in the mode (or state) which specified by the mission profile.</p> <p>The states of the train in parking includes:</p> <ul style="list-style-type: none"> • Train is parking with shutdown mode. • Train is parking with service retention mode (or stand-by mode). • Train in parking with energy saving mode. • Other train states are notified in use case notes.
UC5.1-011	Stable a TU - Determine detrainment - automatic	The train has to be cleared from passengers, before the train will be operated to a stabling position and stabled.
UC5.1-012	Leave train in ready mode	<p>The Process to take train out of operating mode and into standby/ready mode. In standby/ready mode, the pantographs remain up and continue to provide power to the train.</p> <p>After 60 minutes of inactivity, the train automatically switches to sleep mode (see UC5.1-013).</p>
UC5.1-013	Leave train in sleep mode	Set train to sleep mode after putting the train in ready mode (see UC5.1-012). Sleep mode is a low-power state where the pantograph remains up, but certain accessories, such as the front and back train lights, are turned off.

3.1.4 Plan or replan speed profile / adapt to new or updated journey

This group of use cases describes the steps to be performed if a mission cannot be executed as planned due to unexpected events. Depending on the event, the mission is updated or cancelled.

Skipping stopping points can be done in real time by updating the Journey Profile.

Note:

- Journey Management by some might be considered in scope of the ‘ATO Technologies’ TE. During the scope definition process (chapter 2.3) it was agreed that the entering or updating a profile is in scope of Automating Functions, while the actual execution of the profile is in scope of ATO Technologies.
- UC5.1-015 describes the operational situation where a station is skipped, unless there is an emergency situation on board of the train which requires a stop.

ID	Use Case Name	Summary
UC5.1-014	Perform mission	This use case describes the process of carrying out a mission that has been previously defined. This is a general umbrella use case that describes the assignment of mission segments (journeys → perform mission movement as well as stopping segments → tasks to be conducted if train is stopped). The mission is considered complete when all the segments have been completed. If necessary (due to disruptions, emergencies etc.), a mission can be modified (if conditions for modifying the current mission are met) or aborted before all segments have been completed.
UC5.1-015	Skip station by passenger service	The train is scheduled to skip a station without a stop, considering a limited speed for passing through the station.

3.1.5 Passenger exchange

This group of use cases describes the process related to setting a train into service and executing a mission. It includes use cases related to stopping at platforms and the process of exchanging passengers, as well as processes if a train misses its target stopping or braking point.

For some operational domains, Platform Screen Doors (PSD) were identified as a feasible solution to overcome certain issues. A specific use case for such an operational process was therefore identified and added.

Excluded from this group of use cases are use cases for preparing the train unit for service like (automatic) tests. These will be listed as part of section 3.1.1 Train preparation. As an exception, UC5.1-018 is included here, since it is the first use cases in the 'day in the life' that considered operation with passengers.

The use cases that have been developed for this scenario are:

ID	Use Case Name	Summary
UC5.1-016	Implementing discretionary stops by regional services	<p>This use case describes the need of passengers on-board or travellers on platform to request stops at some stations. Those stations are usually in less frequency request to stop. When no request on stops, Serviceable train will skip those stops and continue the journey.</p> <p>In GoA1, this need is taken in charge by Driver. Starting from GoA2, this need can be taken in charge automatically by systems.</p>

UC5.1-017	Handle missed braking point or target point	<p>When a train missed its braking point or target point, two abnormal scenarios might happen:</p> <ul style="list-style-type: none"> • Train undershoots a Stopping point, • Train overshoots a Stopping point. <p>When these abnormal scenarios happen, the On-board Automation System and Trackside Automation System should coordinate automatically to handle the stopping anomaly and help passengers with embark and disembark.</p>
UC5.1-018	Set train into service	The train start from stabling track and approaches the scheduled platform, where it stops precisely. Passenger doors are prepared for opening and passengers are informed.
UC5.1-019	Stop at platform for passenger service	The train approaches the scheduled passenger exchange position, where it stops precisely. Passenger doors are prepared for opening and passengers are informed in order to achieve an efficient passenger exchange.
UC5.1-020	Manage Platform Screen Doors by ATO	Certain rail lines, such as Madrid's commuter network, predominantly pass through tunnels and experience substantial demand during peak hours. On these lines, it should be feasible to install Platform Screen Doors (PSD) to improve safety and streamline operations with Automatic Train Operation (ATO). Platform overcrowding is common, and despite the presence of a reliable safety system, the ATO may struggle to respond and stop the train promptly if a passenger accidentally falls from the platform onto the tracks.

3.1.6 Drive through a change of electrification system / Diesel Electric

Both use cases in this group describe a scenario where a train is coasting in a defined section of the line. In the case of encountering a voltage transition area, the traction system undergoes a change. In the case of a neutral section or passage of a bridge without an overhead contact line, the train is simply disconnected from the power supply in that specific section. Both cases have in common that the electric powered train has to coast and is unable to apply any traction effort.

The use cases developed within this group are:

ID	Use Case Name	Summary
UC5.1-021	Pass through voltage transition area or phase separation area	General passing of a stretch of track which requires a change in catenary voltage or phase lock.
UC5.1-022	Pass a bridge without overhead line	No high voltage is present during the passage of a bridge.

3.1.7 Technical center related processes

This group of use cases describes the processes that are related to the operations in the Technical Centre. It includes use cases that prepare the train set for performing maintenance and includes selected example use cases for tasks such as washing and anti-icing, since these differ from the generic process of preparing for maintenance.

Excluded are use cases that describe potential fully autonomous maintenance tasks since such use cases are not considered to be achievable within the R2DATO timeframe. Also excluded are exhaustive descriptions of every possible specific maintenance procedures – as it is assumed that the general use case of preparing a train for maintenance is adequate for a variety of specific maintenance procedure in the technical centre. Any specific deviations to this generic process shall be developed as needed in future projects.

The use cases that have been developed for this scenario are:

ID	Use Case Name	Summary
UC5.1-023	Manage daily interior cleaning, end of line	The interior of the Train Set is cleaned. The Train Set is ready to continue passenger service.
UC5.1-024	Prepare the train set for maintenance - Perform various maintenance tasks in parallel	To optimize lower downtimes due to maintenance and therefore aims to execute maintenance tasks in parallel without compromising safe working. The Train Set needs to enable safe working on individual electrical systems while other electrical systems may be under electric power.
UC5.1-025	Drive train through washing station	Driving a train through a washing station.
UC5.1-026	Drive train through anti-icing station	Driving a train to and through an anti-icing station in accordance with “handboek machinist” (operators handbook).

3.1.8 Stabling and shunting operations

Train stabling and shunting constitute critical functions within the realm of railway operations. This chapter describes the scenario for operations to be performed when stabling a train, or when shunting - moving a train to another location on a shunting yard while it is not in service.

The use cases contained in this chapter outline the autonomous operations of trains at low speeds (less than 30 km/h) in stabling yards or shunting areas. These operations may take place in areas with or without European Train Control System (ETCS). Furthermore, the process is described where a train is prepared for cleaning while shunting.

Other use cases for shunting were also identified during the identification process, but were mostly relevant for description of the Remote Driving process, and thus transferred to task 5.4.

ID	Use Case Name	Summary
UC5.1-027	Operate Full autonomous trains at low speed $\leq 30\text{km/h}$ in stabling yard or shunting Area equipped or not with ETCS infrastructure	Full autonomous operations of trains at low speed $< 30\text{km/h}$ in stabling yard or shunting Area equipped or not with ETCS infrastructure based on X2R SRS. The Vehicle moves from current position to demanded position and stops there.
UC5.1-028	Prepare train for cleaning during shunting	Move the train to a shunting position and prepare the train for cleaning by setting it in the correct operating mode “cleaning”.

3.1.9 Cross border operation

This group of use cases describe the applicable processes when a train needs to transition between two areas with different characteristics. In the operational ‘Day In The Life Of’ a train, such transitions will often be encountered – especially when operating on a longer (international) journey.

In these examples, this is the case when crossing geographical borders between countries for example, or between areas that have very different infrastructure characteristics – such as centrally controlled areas vs. non-centrally controlled areas. In both cases the main goal of the use cases is to describe the process for a safe transition to the destination area.

Further cross-border use cases were identified from the input of X2Rail-4 and TAURO, but these did not need further development within the scope of task 5.1.

ID	Use Case Name	Summary
UC5.1-029	Perform transition from CBG to NCBG	This use case describes the CBG-to-NCBG transition (centrally vs non centrally controlled), and only covers transition between CBG-NCBG (drive up to S-board and receive permission to enter NCBG).
UC5.1-030	Perform transition from NCBG to CBG	Transition from RD control inside an NCBG (non-centrally controlled area) to either ATO control or continued RD control in a CBG (centrally controlled area).
UC5.1-031	Border crossing	General passing of a geographical border; either to Belgium or Germany.

3.1.10 Inspection trains

This group of use cases focuses on automating functions that autonomous railway inspection vehicles will need to implement. In this way, new functions will be integrated, such as automating the elaboration of the mission profile with details about the inspection activity, such as the starting and ending points, as well as the inspection task itself, which will be associated with a specific type of vehicle.

Use cases also outline the actions that need to be carried out at the beginning and end of the inspection, such as checking inspection devices.

The use cases that have been developed for this scenario are:

ID	Use Case Name	Summary
UC5.1-032	Elaborate mission and journey profiles including inspection activities	Inspection Train: Elaborate mission and journey profiles including inspection activities.
UC5.1-033	Arriving to the starting point of the area to be inspected	This use case describes the actions to be completed once the inspection vehicle has arrived at the starting point of the area of inspection, before starting the inspection activities.
UC5.1-034	Finishing the inspection, save data and arrive to the end of the mission	This use case describes the actions to complete once the inspection vehicle has arrived at the finishing point of the area of inspection, after successfully completing the inspection activities.

3.1.11 During mission, process unexpected train conditions

Railway operations are highly vulnerable to delays and disruptions caused by various factors, such as emergencies or degraded situations, where the train must perform a non-scheduled stop during a current mission.

In certain emergency situations, a train can require remote operation. In this case, a remote driver should be ready and available to control the train and move it locally until the next Safe Stopping Point. However, when the train is running in the GoA4 mode and an emergency stop is triggered (i.e., a passenger triggers an alarm handle), the OAS should analyse and evaluate reactions and safety procedures.

In this context, this use case describes the procedures to consider when the train should operate in GoA3 or GoA4 mode because an incident or degraded situation occurs during the mission.

The use case that has been developed for this scenario is:

ID	Use Case Name	Summary
UC5.1-035	Perform automatic train shunting and "special" movements: Non-scheduled stop, stop at next emergency stop area.	This use case aims to illustrate the actions to be taken in case a train needs to perform a non-scheduled stop as a result of a degraded situation or emergency. For example, it could be needed to stop at a station after a passenger triggers an alarm handle.

3.1.12 Train-train collision

This operational scenario describes the steps to be performed after a train-train collision. It contains actions and procedures aimed at ensuring the safety and security of the site and passengers. These include reporting the collision with another train, initiating an emergency stop for all trains in the area, following country-specific emergency protocols, defining a secure perimeter around the collision site, updating plans for other trains, and coordinating the rescue of passengers involved in the collision.

The use case that has been developed for this scenario is:

ID	Use Case name	Summary
UC5.1-036	Manage Train – Train collision	This use case describes the steps to be performed after a train-train collision if this is still possible due to the damage.

3.1.13 Handle brake malfunction – Hot Wheel

The developed use case describes the processes to prevent damage and accidents when a hot box is detected on a train. While this use case is relatively specific compared to other higher-level use cases, this topic was found relevant during the use case prioritization process. In addition, it forms a good example of the sort of on-board processes that need to be automated within the Automation Function scope.

ID	Use Case Name	Summary
UC5.1-037	Handle hot wheel due to brake failure - Brake failure detected through hot boxes detector: continue to next station	<p>A hot wheel due to brake failure is detected through on-board hot boxes detector. The vehicle shall continue to the next station (or intervention station) and stops.</p> <p>Possible country-specific management: intervention stations are predefined stations where a vehicle that raised an alarm will be stopped and checked.</p>

UC5.1-038	Handle hot wheel due to brake failure - Brake failure through hot boxes detector: stop immediately	A hot wheel due to brake failure is detected through on-board hot boxes detector. The vehicle shall stop immediately, meant as soon as possible.
UC5.1-039	Handle hot wheel due to brake failure - Brake failure through train outside observation: stop immediately	A hot wheel due to brake failure is detected through trackside sensors. The vehicle shall stop immediately.

3.1.14 Fire related incidents

This group of use cases describes the processes that are related to fire detection in two scenarios: tunnels and passenger trains.

Use cases related to fire detection in tunnels include the procedures to be performed when a fire alarm is triggered to prevent the train unit(s) from entering the tunnel and ensure that the train unit(s) inside the tunnel can leave safely.

Use cases related to fire detection in passenger train(s) include the procedures to be performed when a fire alarm is triggered to guarantee the safety of passengers and travellers and reduce damage to trains and infrastructure.

The use cases that have been developed for this scenario are:

ID	Use Case Name	Summary
UC5.1-040	Manage fire on-board locomotive or empty passenger train	The detection of fire, i.e., the trigger of this use case can be: <ul style="list-style-type: none"> On-board device detection. Trackside device detection.
UC5.1-041	Handle fire accident on passenger train - in station (at standstill) - detected by train unit (e.g., PER / CCTV on-board)	This use case can be triggered not only by the detection from train unit, but also possible from trackside unit or people (railway staff, passengers, or travellers).

UC5.1-042	Handle fire accident on passenger train - running	This use case can be triggered not only by the detection from train unit, but also possible from trackside unit or people (railway staff, passengers, or travellers).
UC5.1-043	Handle fire alarm tunnel - Fire alarm systems Tunnel - no train unit run affected	This Use Case details the actions to be taken when a fire alarm in a tunnel is triggered without any train unit being immediately affected in the tunnel. Please note, that each tunnel (or tunnel complex) may have different characteristics covered in specific tunnel emergency and evacuation plans. This use case only aims at depicting a general procedure. Local rules apply.
UC5.1-044	Handle fire alarm tunnel - Fire alarm systems Tunnel - min. one train unit run affected	This use case details the actions to be taken when a fire alarm in a tunnel is triggered with at least one train unit inside affected tunnel. Please note, that each tunnel (or tunnel complex) may have different characteristics covered in specific tunnel emergency and evacuation plans. This use case only aims at depicting a general procedure. Local rules apply.

3.1.15 Rail vehicle defects

This scenario describes the processes to register and respond to vehicle defects as well as to recover from these defects. Vehicle defects refer, in this case, to both defective, damaged or misaligned system components or equipment that is on-board rolling stock (incl. but not limited to locomotives, train sets or carriages).

The impact of the defective, damaged or misaligned equipment might be safety-relevant (e.g., defective brake system), quality-relevant (e.g., defective passenger information system) or both (e.g., defective Heating, ventilation, and air conditioning (HVAC) in extreme weather conditions).

Defective or faulty equipment here refers to the equipment either being not usable at all or with limited functions. Damaged equipment might refer to physically damaged equipment impacting its functionality. Misaligned equipment can include equipment that is not functioning in its proper form and might pose a risk for others (e.g., loose equipment like a pipes or tarpaulin).

Vehicle defects can be either registered by on-board systems/actors or from outside the train unit e.g., by trackside equipment, other train units passing or actors trackside.

Within this scenario, multiple use cases were identified, as can be seen in the 'Use case index'. However, most of these defects have already been developed in other projects such as X2Rail-4. Excluded here are use cases handling traction power limitation (see 3.1.25), compartment related malfunctions (3.1.21) as well as security incidents (3.1.16). The side-effects or results from the impact of events like collisions (either train-train or with objects) are also not considered here.

The use cases that have been developed for this scenario are:

ID	Use Case Name	Summary
UC5.1-045	Handle failure of tilting technology infrastructure – Malfunction of tilting technology Infrastructure	This use case describes the procedure to restrict tilting trains due to failures of the infrastructure equipment (failure in data transmission from data point like balises or missing data point). The aim of the restriction is to avoid following tilting brakes to stop (forced brake) due to failures or missing data points and operate without interruption.
UC5.1-046	Handle failure of equipment or situations in passenger cabin - suspension failure - in station	This use case describes the needs and the possible solutions to handle failure of rolling stock equipment, specifically to the air suspension damage for passenger trains.

3.1.16 Security incidents

This group of use cases describes processes to register and respond to security-related incidents on-board train units as well as to recover from these.

Security incidents to be listed here are only related to processes in the context of autonomous train operations. In this regard it may cover only the response to requests (e.g., by passengers/personnel) or commands ordered (e.g., by security authorities or entities).

The use cases here may cover both physical as well as non-physical security attacks that have an impact or may have an impact on railway operations and where the system requires commands to comply with orders by security authorities or to protect passengers and personnel from physical harm.

Excluded here are occurrences that are quality-related leading to a deterioration of perceived security (e.g., anti-social behaviour), petty crime, administrative offences, verbal and physical assaults, fraud or other occurrences that do not lead to a change of the system's behaviour. Excluded are use cases describing processes to manage the impact of security-related events covered by other use cases. This means, that for the registration and response to an arson attack, two separate use cases describing the general procedures may be used. One for the registration and response to address the security incident (e.g. requesting police support) and at the same time a use case with the process to register and response to fire on-board a train unit. In many cases a security-related origin (cause) of an incident/accident cannot be immediately established but the measures to treat its impact may be the same or similar.

The use cases that have been developed for this scenario are:

ID	Use Case Name	Summary
UC5.1-047	Handle infrastructure restrictions ordered by authorities - Bomb alarm on train.	<p>This use case describes the procedure to handle a bomb alarm on a train unit in passenger's operations. The evacuation of the train unit is part of this use case.</p> <p>The bomb alarm was registered by the relevant police entities.</p> <p>The system under consideration can only support to implement measures. The overall handling strategy is subject to the relevant authorities (police) and the IM. The focus here is to handle infrastructure restrictions by the authorities and detail how the system behaves.</p>
UC5.1-048	Handle stop train unit due to security incidents on-board - Identification of personal details (violence against train personnel etc.)	One or several passengers or personnel are reporting a security incident on-board while the train is enroute (not stationary).

3.1.17 Overcrowded train unit

The use case developed for this scenario describes the situation where overcrowding is detected within a train set. It specifies the measures that need to be taken to ensure safe train operation when the number of passengers on a train exceeds capacity.

More hazardous, panic situations relating to overcrowding are included in chapter 3.1.18.

Overcrowding on the platform is not included in this chapter and can be found described in chapter 3.1.23.

ID	Use Case Name	Summary
UC5.1-049	Handle overcrowded train unit	<p>Legal Overcrowding: OAS must inform trackside of a possible impact on dwell time. Supervise the adapted dwell times of the Journey Profile.</p> <p>Illegal Overcrowding: Passengers are requested to leave the train until the train (and each vehicle) has an occupation smaller than maximum occupation.</p> <p>If not enough passengers leave the train, the police officer(s) is/are called to clear the train (i.e. reduce the number of people inside). If the police officer(s) did not succeed, the train is cancelled.</p>

3.1.18 Panic in compartment

This group of use cases describes processes to register and respond to hazardous overcrowding situations inside the train unit that (may) physically impact passengers leading to suffocation.

The situation described in these use cases may develop in crowded situations like during large-scale events (e.g. sport or music events or industrial fairs). Extreme weather situations, e.g. sudden hail or heavy rain leading persons to rush into train units, or security-related events, e.g. clashes between rival team supports or group of demonstrators, leading to persons rushing into train units and physically unhealthy conditions at bottlenecks.

Excluded here are use cases treating regular occurring overcrowded situations (see section 3.1.18).

ID	Use Case Name	Summary
UC5.1-050	Handle panic situation or riot in the train - in station detected by on-board systems	A sudden hazardous overcrowded situation inside a train unit (and/or at the platform next to the train unit) is detected by on-board means. No previous overcrowded report was filed and as such no crowd management measures were initiated as the situation quickly developed. The overcrowded situation can be described as hazardous due to the risk of a stampede with persons suffocating or being crushed.
UC5.1-051	Handle panic situation (stampede) or riot in the train - in station detected by external actor	One or several passengers are reporting a hazardous overcrowded situation inside a train unit and/or at the platform next to the train unit. No previous overcrowded report was filed and as such no crowd management measures were initiated as the situation quickly developed. The overcrowded situation can be described as hazardous due to the risk of a stampede with persons suffocating or being crushed.
UC5.1-052	Handle panic situation (stampede) or riot in the train - during train unit run detected by on-board systems	Within a crowded train unit, a situation develops where passengers (and personnel) are concentrating beyond a safe level leading to unhealthy conditions and persons requiring medical aid. The overcrowded situation can be described as hazardous due to the risk of a stampede with persons suffocating or being crushed.
UC5.1-053	Handle panic situation (stampede) or riot in the train - during train unit run detected by external actor	Within a crowded train unit a situation develops where passengers (and personnel) are concentrating beyond a safe level leading to unhealthy conditions and persons requiring medical aid. One or several passengers are reporting a security incident on-board while the train is enroute (not stationary). The overcrowded situation can be described as hazardous due to the risk of a stampede with persons suffocating or being crushed.

3.1.19 Emergency in passenger compartment

This group of use cases describes the processes to handle passenger alarms raised by passengers or personnel on-board usually via dedicated alarm buttons/handles installed in the passenger cabin.

Passenger alarm here refers to safety/security-related alarms from on-board devices. Service call requests where the reason for calling might be an emergency can be included in here as some train units or system environments might not differentiate between an emergency call and service call request by passengers (only one device with one button is installed).

Emergency calls from passengers or other persons trackside via third actors such as police / emergency services (European emergency number 112) can be included in here.

Handling the alarm includes the registration of the alarm, the processing of the alarm (response) and may include further steps to address the cause of the alarm (e.g., medical emergency on-board the train).

Excluded from the processes are service requests by passengers or emergency stop request.

For detailed process descriptions please refer the use cases in the table below:

ID	Use Case Name	Summary
UC5.1-054	Emergency on train - in station	A passenger initiates an emergency by pressing the button on the Passenger Alarm System. The scenario assumes a worst-case situation where a passenger on the platform becomes trapped in the closed train doors, possibly due to an item such as a purse obstructing the doors. This use-case allows all relevant parties to swiftly engage and respond with the urgency demanded by the situation.
UC5.1-055	Person in passenger cabin needing medical assistance, detected by actor	<p>Passenger has condition that needs urgent medical assistance.</p> <p>People in the train are instructed remotely how to perform first aid gestures. The most efficient place for emergency health care is coordinated – 2 stations after the call.</p> <p>The train skips a station and drives toward the rescue area with sustained speed.</p> <p>Passenger 1 is off-boarded. Further assistance is given to passenger 1 on the platform.</p>
UC5.1-056	Handle rescue operation affecting platform	Some rescue operation affects a platform, the train traffic along the platform is reduced to Vmax_RescueOnPlatform.

	- Rescue operation on platform/train	<p>To make this example practical, a trash burning on a platform is taken as example. It permits to illustrate:</p> <p>train traffic along the platform is reduced to Vmax_RescueOnPlatform.</p> <p>In this example, it allows safe work by the emergency team (fire brigade), avoids driving too fast along Person on platforms forced by the fire to edge of the platform.</p> <p>No more train is allowed to exchange Person on platform along the platform on which the trash lies.</p> <p>As the fire may narrow the width on the platform and, in case of big traffic on the platform, lead the people to fall on track (trying to avoid both heat and crowd pressure toward exit).</p> <p>The fire is considered little enough to apply those limitations only on one platform. Please considered that for other emergencies (terrorism, smoke emitting fires in underground stations), several platforms may be restricted.</p>
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3.1.20 Evacuate train

Several accidents in railway systems mean mass evacuations are often under time pressure due to critical situations such as fire detection or if the evacuation must take place in scenarios such as tunnels, underground structures (railway stations), or bridges.

In this context, this use case describes the processes that are related to managing the train doors (saloon and/or detrainment doors) for opening at a safe stopping point when an incident is detected and keeping passengers safe. The incident(s) occurs during the train mission, and it could be train anomalies, track anomalies, driving anomalies, or surrounding anomalies.

The use case that has been developed for this scenario is:

ID	Use Case Name	Summary
UC5.1-057	Evacuation and emergency procedures: Detrainment procedures	Some trains apart of the side saloon doors have end detrainment doors. Coordination between the ATO and the train doors in case of an emergency (e.g., a passenger triggers an alarm handle, fire is detected on-board, etc.).

3.1.21 Compartment related malfunction – doors, light, heating

It is not always possible to avoid the failure of technical components in the train. For components that have an impact on the wellbeing of passengers or on the operational process, measures are described that minimize the impact on passengers and the operational process.

Due to the different extent of damage, country specifics and influences on the railroad system, a general, identical handling tailored to all components is not aimed at for these use cases.

The aim is always to keep the impact of a failure as low as possible and to continue to ensure the safety of rail operations.

A specific addition was made to this group of use cases for cargo irregularities which, although different in nature, require similar processes to ensure the wellbeing of passengers and the operational process in general.

ID	Use Case Name	Summary
UC5.1-058	Handle emergency triggered by passenger doors not detected as closed and locked (at passenger exchange position)	A doors authorization for passenger exchange has been revoked at passenger exchange position to get ready for departure. However, not all passenger doors can be closed and locked, so that a departure is not possible.
UC5.1-059	Handle emergency triggered by passenger doors not detected as closed and locked (not at passenger exchange position)	Train is at interstation, while a passenger door is detected as not closed and locked.
UC5.1-060	Resolving detected open doors on moving passenger train (GoA3)	If a door opens during running a train, OAS (TCMS) immediately triggers traction cut-off. OAS must stop the train as soon as possible to prevent passengers from falling out of the train. The train stops even in areas which are not safe stopping areas like tunnels or bridges. In case if fire is detected, the rules for fire supersede this rule.
UC5.1-061	Resolving detected open doors on moving passenger train (GoA4)	If a door opens during running a train, OAS(TCMS) immediately triggers traction cut-off. OAS must stop the train as soon as possible to prevent passengers from falling out of the train. The train stops even in areas which are not safe stopping areas like tunnels or bridges. In case if fire is detected, the rules for fire supersede this rule.

UC5.1-062	React to cargo irregularities	<p>If a cargo irregularity is detected by the trackside detection system, the OAS is informed by the TAS/Railway Undertaking Supervisor about the necessary reaction (immediate stop or stop at the next station). OAS must implement the necessary reaction. Depending on the detected irregularity, the reaction might be safety relevant.</p> <p>After stopping the train, a check of the actual train conditions is carried out, by the staff (train driver GoA2, train attendant GoA3; trackside staff can support if necessary). During the check, constant communication with the technical expertise (intervention centre) shall be ensured.</p> <p>After assessing the actual train conditions, a decision is taken whether the train is fit to continue running.</p>
UC5.1-063	Handle door malfunction in Locomotive / Multiple	This use case details the actions to be taken in case a door failure is detected during door closing.
UC5.1-064	Resolving a detected HVAC failure at a platform	This use case details the actions to be taken in case of HVAC inside a carriage of a train unit fails while the train unit is at a platform (station).

3.1.22 React to derailment detection

This group of use cases describe the processes to register and respond to a derailment of a train unit.

The cause for the derailment might be due to:

- defective running gear components (e.g., wheel defects, wheel alignment).
- defective track conditions or misaligned track geometry (e.g., broken rails, buckled rails, sun kink, cyclic dips, or superstructure damage).
- the impact of other events (e.g., collisions with objects).
- mis coordinated operational handling trackside (e.g., points/derailers while train passing).
- (improper) train handling (e.g., over speeding, emergency brake, coupling surge).
- extreme environmental conditions (e.g., ice/snow build up or high wind forces).
- other reasons not listed here.

Excluded here are controlled derailments of defective vehicles or derailments due to flank protection at catch points or derailleurs (to avoid train-train collisions).

The use case that has been developed for this scenario is:

ID	Use Case Name	Summary
UC5.1-065	Restricting train operations when detecting derailment of another train	<p>This use case details the actions to be taken when one train unit detects the derailment of another train (while running).</p> <p>Remark: The scenario here describes a situation where one wagon / carriage of another train is derailed and not yet detected by the train unit itself while running. This might rather apply to (longer) freight trains where wagons could derail prior to detection by the train unit itself.</p>

3.1.23 Overcrowded platform

This scenario describes the situation when there are too many passengers on the platform of a station, detected either by a human actor or automation system, leading to overcrowding and potentially dangerous situations.

The use case developed within this scenario describes the measures that need to be taken when detecting such an overcrowding situation at the platform, to ensure continued safe train (station) operation when there are too many passengers on the platform.

ID	Use Case Name	Summary
UC5.1-066	Handle overcrowded platform in station detected by actor	<p>TAS or Operations Manager detects an overcrowding on a platform. People should leave the platform and trains should not depart or pass the platform at a lower speed.</p> <p>The overcrowding can happen at pax-ex or without a train at the platform.</p>

3.1.24 Handle platform door report

It is not always possible to avoid the failure of technical components in the train or on the track. For components that have an impact on the wellbeing of passengers or on the operational process, measures are described that minimize the impact on passengers and the operational process.

Due to the different extent of damage, country specifics and influences on the railroad system, a general, identical handling tailored to all components is not aimed at.

The use case developed in this scenario details the operational situation where not all PSD can be closed, and an emergency situation is potentially triggered.

ID	Use Case Name	Summary
UC5.1-067	Emergency triggered by PSD not detected as closed and locked (at passenger	<p>A doors release for passenger exchange has been revoked at passenger exchange position to get ready for departure. However, not all PSDs can be closed and locked, so that a departure is not possible.</p>

	exchange position)	
UC5.1-068	Emergency triggered by PSD not detected as closed and locked (not at passenger exchange position)	Train is at interstation, while a passenger screen door is detected as not closed and locked.

3.1.25 Degraded catenary use cases (bad current collection)

This use case describes the steps to performed if a bad current collection is detected due to bad weather conditions.

To ensure safe operation, the on-board automation system adapts the speed to the bad weather conditions.

Bad current collection due to a catenary or pantograph damage are not in the scope of this use case.

ID	Use Case Name	Summary
UC5.1-069	Handle bad current collection in case of weather conditions (wind, temperatures, etc.)	A bad current collection can be due to bad weather, or (not in scope of this use case) a defective catenary or pantograph. In case of a bad current collection due to bad weather, the train can continue driving at a reduced speed.

3.1.26 High wind situations

This group of use cases details the actions to be taken in case of high wind detection. To avoid incidents due to high wind, a temporary Speed Restriction is applied, followed by an update of the Journey Profile.

The use cases developed as part of this scenario are listed in the table below:

ID	Use Case Name	Summary
UC5.1-070	Apply temporary Speed Restrictions for High Winds	This use case describes the needs and possible solutions for applying temporary speed restrictions owing to high winds and avoiding some incidents. High winds TSRs are only applicable in areas where high-speed (HS) trains operate.

3.1.27 Tunnel light, escape doors and air flow determination

This group of use cases describes processes related to defective equipment in tunnels or alarms from external alert systems in tunnels such as escape door monitoring, trespassing alarm systems or fire detection systems.

Excluded here are use cases where process steps are not specific to tunnels e.g., medical incidents on-board a train unit, point failure.

The use case that has been developed for this scenario is:

ID	Use Case Name	Summary
UC5.1-071	Restricting train operations due to unauthorized escape door opening (in tunnel)	<p>This use case details the actions to be taken in case of an alarm from a trespassing detection system. Trespassing detection system can be installed in various parts of the infrastructure depending on the security specification of the respective infrastructure.</p> <p>This use case therefore refers only to trespassing systems of relevant infrastructure elements leading to the restriction of train movements.</p>

3.1.28 Bomb alarm, trespassing related to infrastructure

This group of use cases describes processes to register and respond to security-related incidents in the trackside with an impact on railway network operations as well as to recover from these.

Security incidents to be listed here are only related to processes in the context of autonomous train operations. In this regard it may cover only the response to requests (e.g., by passengers/personnel) or commands ordered (e.g., by security authorities or entities).

The use cases here may cover both physical as well as non-physical security attacks that have an impact or may have an impact on railway operations and where the system requires commands to comply with orders by security authorities or to protect passengers and personnel from physical harm.

Excluded here are occurrences that are quality-related leading to a deterioration of perceived security (e.g., anti-social behaviour), petty crime, administrative offences, verbal and physical assaults, fraud or other occurrences that do not lead to a change of the system's behaviour (e.g., assaults or theft on the platform or inside the station perimeter with no impact on railway operations).

Excluded are use cases describing processes to manage the impact of security-related events covered by other use cases. This means, that for the registration and response to an arson on a platform, two separate use cases describing the general procedures may be used. One for the registration and response to address the security incident (e.g., requesting police support) and at the same time a use case with the process to register and response to fire on a platform, where the platform and track capacity might need to be restricted. In many cases a security-related origin (cause) of an incident/accident cannot be immediately established but the measures to treat its impact may be the same or similar.

The use case that has been developed for this scenario is:

ID	Use Case Name	Summary
UC5.1-072	Restricting train operations due to detected trespassing	<p>This use case details the actions to be taken in case of an alarm from a trespassing detection system. Trespassing detection system can be installed in various parts of the infrastructure depending on the security specification of the respective infrastructure.</p> <p>This use case therefore refers only to trespassing systems of relevant infrastructure elements leading to the restriction of train movements.</p>

3.1.29 Schedule traffic

Railroad traffic is regulated by train schedules. Every train that is put into operation must be registered. Trains that are taken out of operation are deregistered.

In addition, schedules are affected by many unscheduled or scheduled events and must be corrected. Potential reasons for this are construction works, delays due to technology, passenger volume, weather conditions, etc. The example causes and procedures for setting and adjusting the traffic schedule are described. The use cases developed for this scenario are:

ID	Use Case Name	Summary
UC5.1-073	Set low adhesion conditions	Low adhesion conditions are given because of dirty weather, foliage on track or other reasons. In this case, expedition, brake retardation and maybe train speed needs to be limited.
UC5.1-074	Deregister a vehicle from operation in the AoC	<p>This use case details the actions to deregister a vehicle from operation within the area of control (AoC). The vehicle will remain in the AoC but will not be further recognised as an active vehicle and can therefore not be used in operations. The deregistration takes place for maintenance in the AoC. This use case does not cover the deregistration of the vehicle for stabling as this is covered in other use cases.</p>

3.2 USE CASES THAT HAVE NOT BEEN DEVELOPED

As described in chapter 2.5, originally 122 use cases were nominated for development. Due to several causes, the final resulting list of delivered use cases for task 5.1 totals the amount of 74 use cases. This chapter explains the difference between these figures.

Several reasons apply why use cases were not created during the development process; some were merged into other use cases, some were deemed redundant, some were transferred to another task, and some remain still open points.

The use cases that were merged were those that were closely related to one another. During the development it sometimes occurred that, due to the flow of the operational scenario, a use case would end up describing a broader scope than previously anticipated, thus including another smaller use case in its course. In other cases, there were several quite specifically split use cases identified for sub versions of one larger operational scenario. When the involved development and review partners agreed that combining use cases was possible, the steps of both use cases were processed into one use case (sometimes including several sub-use cases in one use case document).

Some use cases were declared redundant after the development process began, for example, because they were too specific on technical failures, focused on a single country or a duplicate description of events from another use case. In some cases, task 5.1 still provides use cases that are quite specific or focused on one country. This was decided if all partners deemed these use cases to be still relevant. Another reason for use cases being deemed redundant was whenever the use case became available in new deliveries from other projects, such as X2Rail-4 and TAURO. In this case those use cases were checked and aligned with the task 5.1 use case index to see what work had already been done, eliminating the need for development within task 5.1.

During the development process, for some use cases it became evident that they were outside the defined scope of task 5.1. These use cases could however still be relevant for other tasks. In such cases a discussion took place between the related task leaders, agreeing whether the use cases would be transferred between the tasks. If the transfer was agreed, these use cases were then not further developed within task 5.1. This process also was applied the other way around; one use case was moved from task 5.2 to task 5.1.

Finally, there are some open points for use cases that were planned to be developed but did not eventually get finished due to time or capacity constraints. These open use cases are limited to:

- "Avoid stop in powerless sections".
- "Handle infrastructure restrictions ordered by authorities - Closure ordered by authorities".

Following all of this, a final set of 74 use cases was developed within task 5.1, out of the original nominated 122, and are delivered as part of this deliverable D5.1.

3.3 TASK 5.1 USE CASES LINKED TO X2RAIL-4

This section aims to provide an overview of the relationship between the use cases developed in task 5.1, and the preliminary results of the X2Rail-4 project. It highlights which X2R4 Operational Scenarios [9] and which X2R4 Use Cases may be relevant to consider, when building upon the task 5.1 results in future projects.

Both project teams have made the effort to align the results of both projects and avoid overlaps and duplicates. For few specific instances the conscious choice was made to add to the available results to provide a more operational viewpoint. The linked X2R4 results should therefore mostly be seen as additional relevant information, that should be considered and brought in further alignment in future projects and work packages such as R2DATO WP6 and System Pillar.

The below table provides the task 5.1 use cases in numerical with the identified relevant X2Rail-4 scenarios and use cases that are encouraged to be considered.

Note:

- At the time of delivering this document, many X2R4 Operational Scenarios have not yet been finalized and are only available as a scenario title, for future development.
- It can occur that there is no mention of a linked X2Rail-4 scenario or X2Rail-4 use case. In this case, there was no match identified between the developed use case in task 5.1 and X2Rail-4.

Task 5.1 Use Cases	X2R4 Operational Scenarios	X2R4 SRS Use Cases
UC5.1-018 Set train into service	R2 Compose train R3 Prepare train for mission	13.2.1 Elaborate mission and journey profiles 13.2.7 Validate human interaction 13.3.2 Operations to test safety contributors 13.3.4 Train Protection configuration 13.4.3 Test brakes dynamically 13.4.4 Activate horn 13.5.1 Prepare freight train
UC5.1-002 Prepare passenger train (diesel)	R3 Prepare train for mission	13.2.1 Elaborate mission and journey profiles 13.2.7 Validate human interaction 13.3.2 Operations to test safety contributors 13.3.4 Train Protection configuration 13.5.1 Prepare freight train
UC5.1-001 "Wake-up" / Initialisation and perform auto-tests/self-tests for normal operation in GoA 3&4	R1 Awaken train	13.3.1 Awakening sequence of autonomous train
UC5.1-005 Determine and select travelling direction	R18 Change cabin R20 Change running direction	13.3.3 Initialization sequence for a multiple unit movement 13.3.4 Train Protection configuration 13.3.5 Determine and select travelling direction
UC5.1-006 Enter ATP data automatically	R19 Change of train running number R20 Change running direction	13.3.4 Train Protection configuration
UC5.1-007 Prepare train for departure	R4 Prepare train for departure	13.2.1 Elaborate mission and journey profiles

		<p>13.3.3 Initialisation sequence for a multiple unit movement</p> <p>13.3.4 Train Protection configuration</p> <p>13.4.2 Check departure conditions except signalling</p> <p>13.4.6 Authorize departure of autonomous train</p> <p>13.5.2 Supervise departure of autonomous freight train</p>
<p>UC5.1-008</p> <p>Conduct visual inspects & tests</p>	R3 Prepare train for mission	<p>13.2.1 Elaborate mission and journey profiles</p> <p>13.2.7 Validate human interaction</p> <p>13.3.2 Operations to test safety contributors</p> <p>13.3.4 Train Protection configuration</p> <p>13.4.3 Test brakes dynamically</p> <p>13.4.4 Activate horn</p> <p>13.5.1 Prepare freight train</p>
<p>UC5.1-009</p> <p>Conduct system and functional tests</p>	<p>R3 Prepare train for mission</p> <p>R4 Prepare train for departure</p>	<p>13.2.1 Elaborate mission and journey profiles</p> <p>13.2.7 Validate human interaction</p> <p>13.3.2 Operations to test safety contributors</p> <p>13.3.3 Initialisation sequence for a multiple unit movement</p> <p>13.3.4 Train Protection configuration</p> <p>13.4.2 Check departure conditions except signalling</p> <p>13.4.3 Test brakes dynamically</p> <p>13.4.4 Activate horn</p> <p>13.4.6 Authorize departure of autonomous train</p> <p>13.5.1 Prepare freight train</p> <p>13.5.2 Supervise departure of autonomous freight train</p>
<p>UC5.1-010</p> <p>Report end of shift/assignment</p>	<p>R11 Ending journey</p> <p>R12 Ending mission</p>	<p>13.2.5 Park autonomous train</p> <p>13.2.6 Switch to retention of service</p>
<p>UC5.1-011</p> <p>Stable a TU - Determine detrainment - automatic</p>	<p>R10 Train stops at stopping point</p> <p>R13 Shutdown train</p>	<p>13.2.5 Park autonomous train</p> <p>13.4.7 Determine stopping point for a freight or passenger train</p> <p>13.4.9 Request holding brake</p> <p>13.6.7 Door closing at the end of passenger service (passenger train)</p>
<p>UC5.1-012</p> <p>Leave train in ready mode</p>	<p>R4 Prepare train for departure</p> <p>R13 shutdown train</p>	<p>13.2.6 Switch to retention of service</p>
UC5.1-013	R13 shutdown train	13.2.5 Park autonomous train

Leave train in sleep mode		
UC5.1-014 Perform mission	R5 Drive according to journey R7 React to mission update	13.3.6 Deactivate vigilance 13.4.1 Move autonomous train 13.4.3 Test brakes dynamically 13.4.8 Traction and brake control 13.4.9 Request holding brake 13.6.1 Manage passenger information systems 13.7.7 Update mission
UC5.1-015 Skip station by passenger service	NR3 Driver initiated "Stopping point Skip"	*X2R4 GoA2 scenario
UC5.1-017 Handle missed braking or target point	NR1 Train stops short of a stopping point NR2 Train overshoots a stopping point	13.11.3 Passenger train only stops partially at a platform
UC5.1-003 Prepare train unit for a mission - Configure GoA automatically	R3 Prepare train for mission R21 GoA transitions	13.2.1 Elaborate mission and journey profiles 13.2.7 Validate human interaction 13.3.2 Operations to test safety contributors 13.3.4 Train Protection configuration 13.5.1 Prepare freight train
UC5.1-004 Prepare train unit for a mission - select traction system automatically	R3 Prepare train for mission	13.2.1 Elaborate mission and journey profiles 13.2.7 Validate human interaction 13.3.2 Operations to test safety contributors 13.3.4 Train Protection configuration 13.5.1 Prepare freight train
UC5.1-016 Implementing discretionary stops by regional services	R6 React to journey update	13.4.7 Determine stopping point for a freight or passenger train 13.6.1 Manage passenger information systems 13.8.1 React after misrouting
UC5.1-019 Stop at platform for passenger service	R10 Train stops at stopping point	13.4.7 Determine stopping point for a freight or passenger train 13.4.9 Request holding brake 13.11.3 Passenger train only stops partially at a platform
UC5.1-020 Manage Platform Screen Doors by ATO	R10 Train stops at stopping point R14 Passengers embark and disembark	13.4.7 Determine stopping point for a freight or passenger train 13.4.9 Request holding brake 13.6.4 Supervise departure of a passenger train 13.6.5 Door opening (passenger train) 13.6.6 Door closing (passenger train)

		13.6.7 Door closing at the end of passenger service (passenger train) 13.11.3 Passenger train only stops partially at a platform
UC5.1-021 Pass through voltage transition area or phase separation area	R26 Neutral or Powerless Sections	13.4.5 Cut current, lower and change pantograph 13.8.9 unforeseen stop in de-energized section
UC5.1-022 Pass a bridge without overhead line	R26 Neutral or Powerless Sections	13.4.5 Cut current, lower and change pantograph 13.8.9 unforeseen stop in de-energized section
UC5.1-023 Manage daily interior cleaning, end of line	R31 Automatic cleaning (washing machine) R32 Manual cleaning at standstill	13.2.4 Perform train maintenance or cleaning
UC5.1-024 Prepare the train set for maintenance - Perform various maintenance tasks in parallel	R33 Perform train maintenance	13.2.4 Perform train maintenance or cleaning
UC5.1-025 Drive train through washing station	R30 Drive inside depot, stabling or maintenance facility R31 Automatic cleaning (washing machine)	13.2.4 Perform train maintenance or cleaning
UC5.1-026 Drive train through anti-icing station	R30 Drive inside depot, stabling or maintenance facility	13.2.2 Entry in technical centre 13.2.3 Exit from technical centre
UC5.1-027 Operate Full autonomous trains at low speed <= 30km/h in stabling yard or shunting Area equipped or not with ETCS infrastructure	R30 Drive inside depot, stabling or maintenance facility	13.2.2 Entry in technical centre 13.2.3 Exit from technical centre
UC5.1-028 Prepare train for cleaning during shunting	R30 Drive inside depot, stabling or maintenance facility	13.2.4 Perform train maintenance or cleaning
UC5.1-029 Perform transition from CBG to NCBG	R28 Transition from ATP Class B area to Class A area	13.2.2 Entry in technical centre
UC5.1-030 Perform transition from NCBG to CBG	R29 Transition from ATP class A area to Class B area	13.2.3 Exit from technical centre
UC5.1-031 Border crossing	R22 TM handover R23 TMS handover	13.2.2 Entry in technical centre 13.2.3 Exit from technical centre
UC5.1-032 Elaborate mission and journey profiles including inspection activities	R5 Drive according to journey NR8 Equipment fault ATO Trackside Systems	13.3.6 Deactivate vigilance 13.4.1 Move autonomous train 13.4.3 Test brakes dynamically 13.4.8 Traction and brake control

		13.4.9 Request holding brake 13.6.1 Manage passenger information systems
UC5.1-033 Arriving to the starting point of the area to be inspected	R3 Prepare train for mission R4 Prepare train for departure	13.2.1 Elaborate mission and journey profiles 13.2.7 Validate human interaction 13.3.2 Operations to test safety contributors 13.3.3 Initialisation sequence for a multiple unit movement 13.3.4 Train Protection configuration 13.4.2 Check departure conditions except signalling 13.4.3 Test brakes dynamically 13.4.4 Activate horn 13.4.6 Authorize departure of autonomous train 13.5.1 Prepare freight train 13.5.2 Supervise departure of autonomous freight train
UC5.1-034 Finishing the inspection, save data and arrive to the end of the mission	R11 Ending journey R12 Ending mission	13.2.5 Park autonomous train 13.2.6 Switch to retention of service
UC5.1-035 Perform automatic train shunting and "special" movements: Non-scheduled stop, stop at next emergency stop area.	R36 Train stops by signalling NR4 Hold train at next Stopping Point	13.7.2 Unexpected stop 13.7.5 Request immobilisation 13.7.12 Stop at next station or rescue point
UC5.1-036 Manage train-Train collision	NR16 Rescue Passengers NR18 Securing accident site	13.7.10 Recover after stop 13.7.11 Organize Rescue 13.7.13 Move passenger to safer zone 13.7.14 Monitor passengers 13.8.4 Unusual impact 13.8.7 Uncontrollable movement of uncontrollable vehicles 13.11.1 Human accident involving injury or death 13.11.2 Human accident involving injury or death - Body discovered
UC5.1-037 Handle hot wheel due to brake failure - Brake failure detected through hot boxes detector: continue to next station	NR11 Equipment Fault Rolling Stock NR24 Handle hot box alarm	13.8.6 Uncontrollable movement by Emergency Brake failure 13.9.6 Hot Box Alarm from trackside 13.9.7 Hot Box Alarm from on board sensor
UC5.1-040 Manage fire on-board locomotive or empty passenger train	NR19 Fire on-board in station NR20 Fire on-board while running	13.9.2 Fire on Board in station 13.9.3 Fire on Board while running 13.10.9 Fire on embankment

UC5.1-045 Handle failure of tilting technology infrastructure - Malfunction of tilting technology Infrastructure	NR12 Equipment fault infrastructure	13.10.1 Sudden lack of catenary voltage 13.10.4 Point failure with movement permission 13.10.5 Point failure without movement permission 13.10.6 Damage to catenary passable with reduced speed 13.10.7 Damage to Level Crossing 13.10.8 Damage to Level crossing passable with caution speed
UC5.1-046 Handle failure of equipment or situations in passenger cabin - suspension failure - in station	NR11 Equipment fault Rolling Stock	13.9.18 Incident with configurable reaction
UC5.1-047 Handle infrastructure restrictions ordered by authorities - Bomb alarm on train	NR17 Handle restriction on infrastructure ordered by authority or infrastructure Manager NR26 Handle Emergency Alarm	13.7.3 Set local alarm 13.9.9 Use of Passenger Alarm in station 13.9.10 Use of Passenger Alarm when train is starting (train still along platform) 13.9.11 Use of Passenger Alarm during train run
UC5.1-048 Handle stop train unit due to security incidents on-board - Identification of personal details (violence against train personnel etc.)	NR4 Hold train at next Stopping Point NR17 Handle restriction on infrastructure ordered by authority or infrastructure Manager NR23 Handle Passenger Call for Aid	13.7.5 Request immobilisation 13.7.12 Stop at next station or rescue point 13.9.12 Use of Call for Aid
UC5.1-050 Handle panic situation or riot in the train - in station detected by on-board systems	NR22 Handle Passenger Alarm NR23 Handle Passenger Call for Aid	13.7.14 Monitor passengers 13.9.9 Use of Passenger Alarm in platform 13.9.10 Use of Passenger Alarm when train is starting (train still along platform) 13.9.11 Use of Passenger Alarm out of platform 13.9.12 Use of Call for Aid
UC5.1-051 Handle panic situation (stampede) or riot in the train - in station detected by external actor		
UC5.1-052 Handle panic situation (stampede) or riot in the train - during train unit run detected by on-board systems		
UC5.1-053 Handle panic situation (stampede) or riot in the train - during train unit run detected by external actor		
UC5.1-054 Emergency on train – in station	NR18 Securing accident site NR20 Fire on-board while running	13.7.10 Recover after stop 13.7.11 Organize Rescue

		13.8.4 Unusual impact 13.9.2 Fire on Board in station
UC5.1-055 Person in passenger cabin needing medical assistance, detected by actor	NR23 Handle Passenger Call for Aid	13.9.9 Use of Passenger Alarm in platform 13.9.10 Use of Passenger Alarm when train is starting (train still along platform) 13.9.11 Use of Passenger Alarm out of platform 13.9.12 Use of Call for Aid
UC5.1-056 Handle rescue operation affecting platform - Rescue operation on platform/train	NR16 Rescue Passengers NR18 Securing accident site	13.7.10 Recover after stop 13.7.11 Organize Rescue 13.7.13 Move passenger to safer zone 13.7.14 Monitor passengers 13.11.1 Human accident involving injury or death 13.11.2 Human accident involving injury or death - Body discovered
UC5.1-057 Evacuation and emergency procedures: Detrainment procedures	NR16 Rescue Passengers NR18 Securing accident site	13.7.10 Recover after stop 13.7.11 Organize Rescue 13.7.13 Move passenger to safer zone 13.7.14 Monitor passengers 13.11.1 Human accident involving injury or death 13.11.2 Human accident involving injury or death - Body discovered
UC5.1-058 Handle emergency triggered by passenger doors not detected as closed and locked (at passenger exchange position)	NR30 Obstacle in doors NR31 Handle on-board abnormal situation	13.9.14 Door failure during train run 13.9.15 Door failure during closing sequence 13.9.16 Obstacle when door is closing
UC5.1-059 Handle emergency triggered by passenger doors not detected as closed and locked (not at passenger exchange position)		
UC5.1-060 Resolving detected open doors on moving passenger train (GoA3)	NR11 Equipment fault Rolling Stock NR15 Abnormal movement NR31 Handle onboard abnormal situation	13.9.14 Door failure during train run
UC5.1-061 Resolving detected open doors on moving passenger train (GoA4)	NR11 Equipment fault Rolling Stock NR15 Abnormal movement NR31 Handle onboard abnormal situation	13.9.14 Door failure during train run

UC5.1-062 React to cargo irregularities	NR11 Equipment fault Rolling Stock	13.7.2 Unexpected stop 13.7.4 Restart after unexpected stop 13.7.10 Recover after stop 13.7.11 Organize rescue
UC5.1-063 Handle door malfunction in Locomotive / Multiple	NR11 Equipment fault Rolling Stock NR31 Handle onboard abnormal situation	13.9.14 Door failure during train run 13.9.15 Door failure during closing sequence 13.9.16 Obstacle when door is closing
UC5.1-064 Resolving a detected HVAC failure at a platform	NR11 Equipment fault Rolling Stock	13.9.4 HVAC default in station 13.9.5 HVAC default while running
UC5.1-065 Restricting train operations when detecting derailment of another train	NR5 Emergency brake application commanded by ETCS or other safety system NR16 Rescue Passengers NR18 Securing accident site	13.7.10 Recover after stop 13.7.11 Organize Rescue 13.7.13 Move passenger to safer zone 13.7.14 Monitor passengers 13.8.4 Unusual impact 13.11.1 Human accident involving injury or death 13.11.2 Human accident involving injury or death - Body discovered
UC5.1-066 Handle overcrowded platform - overcrowded platform in station detected by actor	NR17 Handle restriction on infrastructure ordered by authority or infrastructure Manager	13.7.14 Monitor passengers 13.9.14 Use of Passenger Alarm in station 13.9.15 Use of Passenger Alarm when train is starting (train still along platform) 13.9.17 Use of Call for Aid in station
UC5.1-068 Emergency triggered by PSD not detected as closed and locked (at passenger exchange position)	NR17 Handle restriction on infrastructure ordered by authority or infrastructure Manager	*PSD is out of the X2R4 scope
UC5.1-069 Handle bad current collection in case of weather conditions (wind, temperatures etc)	NR13 Traction power supply peak issues NR25 Handle restriction due to weather conditions	13.8.10 Speed restriction due to weather conditions 13.9.18 Incident with configurable reaction 13.10.2 Impassable flooding 13.10.3 Flooding passable with reduced speed
UC5.1-070 Apply temporary Speed Restrictions for High Winds	NR25 Handle restriction due to weather conditions	13.8.10 Speed restriction due to weather conditions
UC5.1-071 Restricting train operations due to unauthorized escape door opening (in tunnel)	NR12 Equipment fault Infrastructure NR26 Handle Emergency Alarm	13.7.3 Set local alarm 13.9.9 Use of Passenger Alarm in station 13.9.10 Use of Passenger Alarm when train is starting (train still along platform)

		13.9.11 Use of Passenger Alarm out of platform
UC5.1-043 Handle fire alarm tunnel - Fire alarm systems Tunnel - no train unit run affected	NR18 Securing accident site NR20 Fire on-board while running NR26 Handle Emergency Alarm	13.7.10 Recover after stop 13.7.11 Organize Rescue 13.8.4 Unusual impact 13.9.3 Fire on Board while running 13.11.1 Human accident involving injury or death 13.11.2 Human accident involving injury or death - Body discovered
UC5.1-044 Handle fire alarm tunnel - Fire alarm systems Tunnel - min. one train unit run affected		
UC5.1-072 Restricting train operations due to detected trespassing	NR17 Handle restriction on infrastructure ordered by authority or infrastructure Manager	13.7.3 Set local alarm 13.9.9 Use of Passenger Alarm in station 13.9.10 Use of Passenger Alarm when train is starting (train still along platform) 13.9.11 Use of Passenger Alarm during train run 13.11.6 Inappropriate behaviour in train in station 13.11.7 Inappropriate behaviour in train during operation
UC5.1-073 Set low adhesion conditions	R6 React to journey update R27 Change in adhesion condition NR17 Handle restriction on infrastructure ordered by authority or infrastructure Manager	13.8.11 Manage adhesion problems
UC5.1-074 Deregister a vehicle from operation in the AoC	R13 Shutdown train	13.2.5 Park autonomous train

4 CONCLUSIONS

Delivering the results from 12 months of intensive collaboration between 15 expert partner organisations, this deliverable meets the objectives for D5.1 as set out in the Grant Agreement. At the start of the work package, the task 5.1 partners set out to capture the high level operational scenarios and use cases relevant for the Automating Functions Technical Enabler, aiming to capture the operational rules and quantified conditions and the available experience among the Railway Undertakings.

This is achieved by delivering a total of 74 newly developed use cases and corresponding scenarios within the defined scope of 'Automating Functions'. Depending on the needs and priorities that were established against the state of the art, some use cases provide the intended high level processes, while few others provide insight in more detailed processes. This is a result of the combination of methodology chosen, already available high level use cases and priorities as set by the Railway Undertakings and the R2DATO demonstrator work package leaders.

As a further result, a full identification of available use cases and scenarios from previous projects was done in the 'Use Case Index' (Annex 2), identifying more than 1100 use cases, features and scenarios and their sources. While not originally intended as a deliverable, due to its relevance in establishing the state of the art, this document is also made available as a working document for future projects. Based on this identification work and the collaboration with the X2Rail-4 team, specific links are included in chapter 3.3 between the task 5.1 use cases and the deliverables from X2Rail-4, especially with regular and non-regular scenarios and the SRS use cases.

Some limitations apply to the results of task 5.1, such as not being able to fully standardize the operational processes and architectural mapping within the available timeline, or incorporate the anticipated System Pillar and other Flagship Project inputs due to lack of deliveries by the defined milestone M6. These are further highlighted in chapter 2.8.

The output of this deliverable forms an important foundation for the development of TEs that are to come from the further Work Packages in the Automation Processes Cluster. It provides with the operations scenarios and use cases that are important for realizing the Europe's Rail vision in the area of Automation Processes. It is recommended that future projects, such as the System Pillar and other Flagship Projects, and future R2DATO work packages such as WP6, WP9 and the Demonstrators, use the results of task 5.1, and the other WP5 tasks, as examples of how Automation Processes may be used in an operational environment, leveraging the extensive operational expertise that was captured in these use cases to come to an optimal design of the TEs.

In addition, the 'Use Case Index' can be used as a valuable source of information for determining other relevant use cases or getting an insight in the available use cases from various sources that were considered in this project. At the same time, further alignment and standardisation will be necessary (for example by the System Pillar) to align all currently existing variants of operational processes across all European stakeholders.

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- [4] S2R-CFM-IP5-02-2015, “ARCC”, Automated Rail Cargo Consortium: Rail freight automation research activities to boost levels of quality, efficiency and cost effectiveness in all areas of rail freight operations
- [5] ERTMS/ATO Operational Principles, EUG 12E108, version 3-, 2024-02-13
- [6] FP2-T4_2-D-CAF-002-06 - D4.1 - Automation Processes Collaboration Map, 22/08/2023
- [7] ERTMS/ATO Glossary, version 13E154 2-, 2023-07-05
- [8] WP5 – Operational Actors for R2DATO WP5, Revision 01, 10/07/2023
- [9] ERTMS/ATO Operational Scenarios, version 13E151 2b, 2023-12-14

ANNEXES

The annexes below can be found in separate documents, which have been delivered jointly with this deliverable in a compressed file.

ANNEX 1: USE CASE TEMPLATE

ANNEX 2: USE CASE INDEX

ANNEX 3: WP5 – OPERATIONAL ACTORS FOR R2DATO WP5

ANNEX 4: USE CASES FOR AUTOMATING FUNCTIONS
