Grant Agreement Number: 101101962
Project Acronym: FP6 - FutuRe
Project title: Future of Regional Rail

DELIVERABLE D4.1

REQUIREMENTS SPECIFICATION FOR WAYSIDE ASSETS REPORT

Project acronym:	FP6 - FutuRe
Starting date:	01/12/2022
Duration (in months):	48
Call (part) identifier:	Call: EU-RAIL JU Call Proposals 2022-01 (HORIZON-ER-JU-2022-01) Topic HORIZON-ER-JU-2022-FA6-01
Grant agreement no:	101101962
Grant Amendments:	NA
Due date of deliverable:	26/11/2024
Actual submission date:	22/11/2024 Resubmission 02/10/2025 after request for revision
Coordinator:	Alessandro Mascis, FT
Lead Beneficiary:	ÖBB-INFRA
Version:	2.1
Type:	Report
Sensitivity or Dissemination level	[Public]
Taxonomy/keywords:	[Wayside Assets, Level Crossing, Switch, Obstacle Detection]

This project has received funding from the Europe's Rail Joint Undertaking (JU) under grant agreement 101101962. The JU receives support from the European Union's Horizon Europe research and innovation programme and the Europe's Rail JU members other than the Union.

Document History

Version	**Date**	**Name**	**Affiliation**	**Position/Project Role**	**Action/ Short Description**
0.1	06/10/2023	MO	ÖBB	Task Leader of T4.1	Created and prepared the Deliverable based on template (Defined the structure of the Deliverable (Definition of the sections and responsibilities))
0.2	14/10/2023	MO	ÖBB	Task Leader of T4.1	Filled the Document with Input (Added information and description in every section)
0.3	27/10/2023	MO	ÖBB	Task Leader of T4.1	Filled the Document with Input (Added high-level Requirements)
0.4	30/10/2023	MO	ÖBB	Task Leader of T4.1	Prepared the Document for Submission intermediate Release 1
0.5	24/04/2024	MB	TRV	Author, ST4.1.3	Added Sect. Benchmarking of alternative sensors + references (i.e. sections 3.5.2, 3.5.4 and 5)
0.6	28/05/2024	NMB	ENYSE	Subtask Leader of T4.1.1 and T4.1.2	Completion of sections 1 and 2. and 5. Reallocation of content in section 3 into an Excel file.
0.7	06/06/2024	MO	ÖBB	Task Leader of T4.1	Reviewed and prepared for submission for Intermediate Release 2
0.8	09/08/2024	FI	MER	Subtask Leader of ST4.1.3	Added Content for ST4.1.3 (Adding overall information and description for context; adding section about Safety Aspects of ML/AI components, Expanded dedicated section with FSM Scheme of the LCOB, Finalizing the

					Requirements)
0.9	02/09/2024	MO	ÖBB	Task Leader of T4.1	Finalized the Document (Adding missing descriptions and improving of formulations/wordings)
1.0	07/10/2024	MO	ÖBB	Task Leader of T4.1	Checked Comments and prepare for internal review
1.1	21/10/2024	MO	ÖBB	Task Leader of T4.1	Improved version with smaller changes in wording
1.2	23/11/2024	MO	ÖBB	Task Leader of T4.1	Cleaned Version for external Review
1.3	14/11/2024	MO	ÖBB	Task Leader of T4.1	Prepared version of Deliverable for final submission by closing the comments of internal and external review
1.4 (final Version for SteCo submission)	21/11/2024	MO	ÖBB	Task Leader of T4.1	Last Check of final version for submission to SteCo
1.5	02/12/2024	FB	FT	WP1 Leader	Quality check
2.0	14/07/2025	RW FI MH NMB	SC ÖBB MER SC ÖBB ENYSE	Subcontractors ÖBB-INFRA and Sub-task leaders	Changes after request for revision of 24/06/25: One integrated document (header, TOC, etc.) + revisions
2.0	14/07/2025	FB	FT	WP1 Leader	Quality check
2.1	02/10/2025	RW FI NMB	SC ÖBB MER ENYSE	Subcontractors ÖBB-INFRA and Sub-task leaders	Changes after EU-RAIL comments: introduction/innovation potential, LCOB, REQ update
2.1	02/10/2025	FB	FT	WP1 Leader	Quality check

Document Contributions

Name	Company	Details of Contribution
Mats Bengtsson (MB)	TRV	Expert Input (T4.1.3)
Fabrizio Burro (FB)	FT	Reviewer
Javier García Castaño (JGC)	ATSA	Reviewer (T4.1.1/T4.1.3), Follower (T4.1.2)
Francesco Inzirillo (FI)	MERMEC	Reviewer (T4.1.1), Author (T4.1.3)
Libor Lochman	FT	Reviewer
Noelia Medrano Buendía (NMB)	ENYSE	Author (T4.1.1/T4.1.2)
Markus Hofer (MH)	ÖBB	Author
Amirreza Tahamtan (AT)	ÖBB	Follower
Maximillian Obermeier (MO)	ÖBB	Author (T4.1.1/T4.1.2), Follower (T4.1.3)
Rainer Widmann (RW)	ÖBB	Author (Doc integration)
Virginie Taillandier (VT)	SNCF	Expert Input (T4.1.1)

I. Table of contents

II. Executive Summary

The present document represents the Deliverable D4.1 with the title "Requirement Specification for Wayside Assets Report".

This primary objective of this Deliverable is to outline a set of requirements that reflect the operational and functional behaviour of three specific Wayside Assets when deployed at Regional Lines: Level Crossings, Switches and Obstacle Detection Systems. In addition to specifying these requirements, the document also includes various analysis and developments related to the Wayside Assets.

Before developing the requirements, a series of reference Use Cases were defined to:

- provide a foundation for the development and derivation of the requested requirements,
- serve as a reference for activities planned later in the project in context of demonstrator development (in further WP9).

Additionally, this deliverable encompasses sections that provide context and background of the work. These sections describe the methodology used to derive the requirements from the Use Cases and detail how the requirements are managed. The document also discusses the social-economic benefits targeted by the requirements specification, which are considered achievable through its successful implementation.

The present document counts as a version for final submission in M24, November 2024 with preceding intermediate releases in M11, November 2023 and M18, May 2024.

III. List of abbreviations, acronyms, and definitions

Abbreviation / Acronym	Definition
AE	Affiliated Entity
BEN	Beneficiary
CT5	Cooperation Tool 5
ERA	European Railways Association
ERJU	Europe's Rail Joint Undertaking
ERTMS	European Rail Traffic Management System
EU	European Union
FA	Flagship Area
FP	Flagship Project
G1	Group 1 Lines
G2	Group 2 Lines
GA	Grant Agreement
ID	Identifier
IM	Infrastructure Manager
IPR	Intellectual Property Rights
IXL	Interlocking
JU	Joint Undertaking
LCOB	Level Crossing Obstacle Detection
LX	Level Crossing
LXA	Level Crossing Area
LXC	Level Crossing Control Unit
M	Month
OPEX	Operational Expenditures
R&D	Research & Development
RBC	Radio Block Centre
Req.	Requirement
SEO	Social Economic Objective
SP	System Pillar
TCO	Total Cost of Ownership
TSI	Technical Specification for Interoperability
UC	Use Case
WP	Work Package

IV. List of figures

V. List of tables

1 Introduction

1.1 Document Scope

This document represents Deliverable D4.1 entitled “Requirement Specification for Wayside Assets Report” and has been developed by Task4.1 “Requirement specification for Wayside Assets” within the technical Work Package 4 “Regional Rail Assets Requirements & Specifications” as essential part of the FP6 “FutuRe – Future of Regional Lines”. The Deliverable D4.1 provides a comprehensive report on functional and non-functional requirements of Wayside Assets. The Task4.1 is organisationally divided into three different Subtasks, which are assigned according to the Wayside Assets to be addressed. The individual Subtasks therefore deal with the respective Requirement Specification of the assigned Wayside Assets. The Deliverable D4.1 is the consolidation of content from each Subtask and integrates these outputs into a comprehensive framework.

Table 1: Organization of Task4.1 "Requirement Specification of Wayside Assets"

Task 4.1: Requirement Specification for Wayside Assets	
Subtask 4.1.1:	Requirement Specification for wireless enabled energy self-sufficient level crossings
Subtask 4.1.2:	Requirement Specification for wireless enabled energy self-sufficient switches
Subtask 4.1.3:	Requirement Specification for Obstacle Detection

1.2 Purpose

The purpose of this deliverable is to provide a valid set of requirements that reflect the operational and functional behaviour of three specific Wayside Assets when deployed at Regional Lines as well as performing additional analysis and deployments related to the Wayside Assets.

The requirements are drawn up against the background of cost reduction (reduction of Total Cost of Ownership) to achieve enhanced rentability and attractiveness of regional lines. The Wayside Assets represent a major cost factor in construction, expansion, and operation of these lines, so this is why the focus of the innovation is applied mainly to achieve this cost reduction rather than on the adding of new features to the existing Assets.

A few introductory examples of innovations to existing features that support cost reduction are:

- Energy Efficiency: Energy consumption cannot be reduced to zero since a certain amount of energy is always necessary for asset operation, the focus of FutuRe is on enhancing energy efficiency through better energy sourcing. The goal is to configure the energy supply for these assets in a hybrid model. Traditionally, assets rely solely on grid power, however, after FutuRe, the objective is to enable energy procurement from both the grid and renewable sources, such as solar panels. In such configurations, grid consumption will decrease as the utilization of renewable sources increases.

- Wireless communication: The fact of adding wireless networks as a transmission medium (which is by itself an innovation) will bring a clear reduction in the CAPEX.
- Diagnosis and Maintenance: The difference to existing solutions is that the “exchange of data” can be done in three different ways (under demand, dump and subscription) and the data itself can be of three different natures (raw data, config data, events). The innovation for example is that fact of having such number of possibilities. Currently, very often the maintenance and diagnosis are only about dump transmission of raw data)

More concretely by subtasks:

The Subtask 4.1.1 “Requirement Specification for wireless enabled energy self-sufficient level crossings” develop Requirements for Level Crossings, which shall be:

i. able to be controlled either from the Interlocking or from the Radio Block Centre (for Group 1 lines) or via IP-protocol communication (for Group 2 lines),
ii. wireless enabled, i.e. controlled by wireless communication technologies by following the Requirements of Task4.2 “Requirement Specification for Communication”,
iii. energy self-sufficient, i.e. without the need for external power supply and/or cabling,
iv. able to generate and transmit diagnosis data and perform maintenance remotely.

The Subtask 4.1.2 “Requirement Specification for wireless enabled energy self-sufficient switches” develop Requirements for Switches, which shall be:

i. configurable and work at any track gauge,
ii. wireless enabled, i.e. controlled by wireless communication technologies by following the Requirements of Task4.2 “Requirement Specification for Communication”,
iii. energy self-sufficient, i.e. without the need for external power supply and/or cabling,
iv. able to generate and transmit diagnosis data and perform maintenance remotely.

The Subtask 4.1.3 “Requirement Specification for Obstacle Detection” develop Requirements for an Obstacle Detection System at Level Crossings. The scope of the Subtask includes:

i. Benchmarking of alternative sensors
ii. Analysis of the use of machine learning and artificial intelligence components regarding safety aspects of the system
iii. Requirements specification of the Obstacle Detection System
iv. Interfaces specification.

Based on the defined requirements, specific demonstrators for the considered Wayside Assets will be implemented in the subsequent FP6 Work Package 9 “Regional Rail Assets Demonstrators”. This Work Package will assess the feasibility of the Wayside Assets and identify potential vulnerabilities at an early stage.

1.3 Document Structure

The Deliverable D4.1 “Requirement Specification for Wayside Assets Report” consists of two interconnected parts, as visualized in Figure 1:

- Word Document (present document): This part provides the introduction, explains the methodology, describes reference use cases, includes subtask specific content not explicitly formulated as requirements, addresses the objective of cost reduction and concludes the requirements-related information.
- Excel Document: This part compiles all requirements in tabular form, greatly facilitating the management of requirement attributes and enabling easy navigation through the requirements. The requirements defined in Excel are listed in section 5.6 of this document.

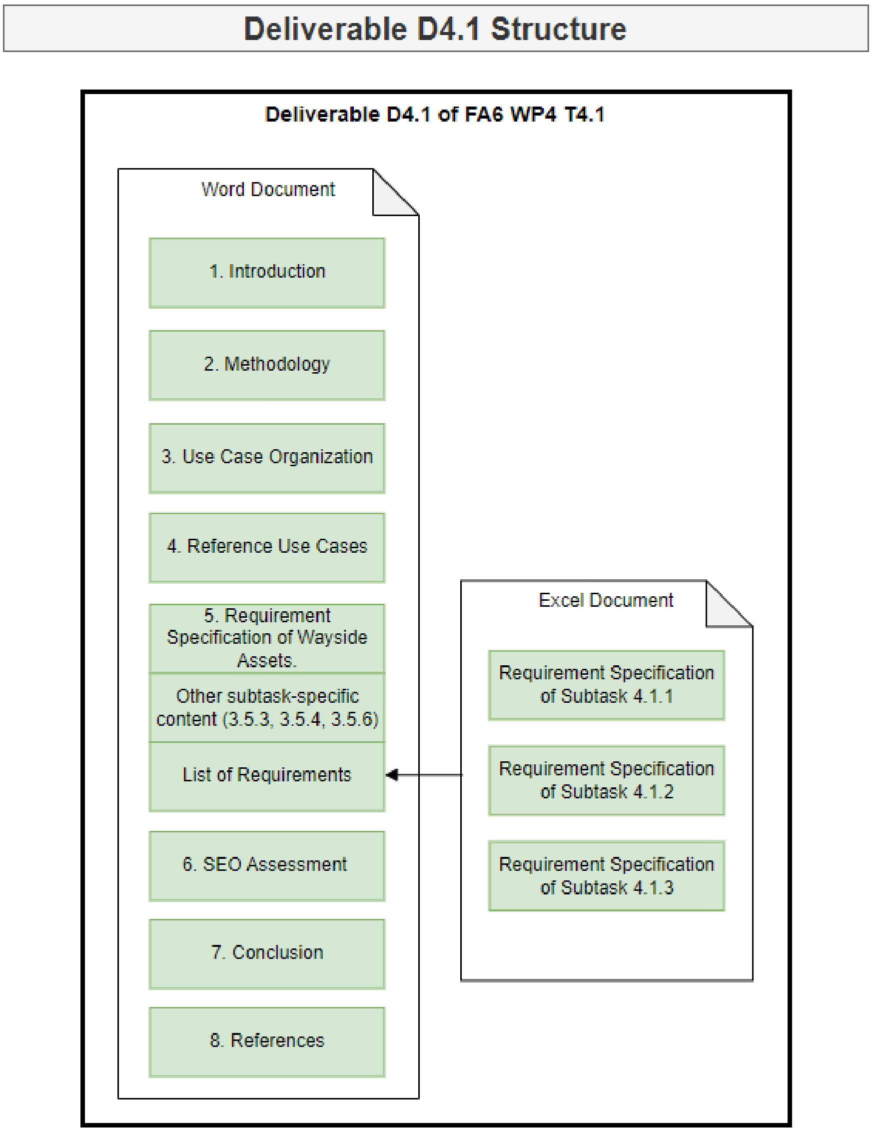


Figure 1: Structure of Deliverable D4.1

In this present document (Word Document), the chapters are summarized as follows:

- Chapter 1: Provides a general introduction to the deliverable.
- Chapter 2: Describes the methodology used to derived requirements from the reference Use Cases described in [Ref.13], and explains how the accompanying Excel Document, which compiles the Requirement Specifications of the Subtasks, should be interpreted.
- Chapter 3: Describes the organization of the reference use cases defined in Chapter 4
- Chapter 4: Contains a comprehensive collection of Use Cases, focusing on wireless-enabled and energy self-sufficient Level Crossings, Switches and Obstacle Detection Systems. While the creation of the Use Cases is not explicitly required by the Grand Agreement for this task, their inclusion provides a logical foundation for developing requirements and supports later project phases, including demonstrator development in FP6 WP9.
- Chapter 5: Offers general insights into the requirements and includes subtask-specific content, such as analyses and developments, that are not explicitly formulated as requirements.
- Chapter 6: Highlights and discusses social economic impacts related the Requirement Specifications of the Subtasks.
- Chapter 7: Concludes the document with the most significant findings.
- Chapter 8: Lists the references cited or used as a basis for the creation of this document.

The Excel Document contains the requirement specifications of Task4.1 for each Subtask in a detailed listing format. It includes specific attributes essential for the documentation and tracking of each requirement. The Table 2 describes the attributes, providing a clear structure for managing and monitoring the requirements both within Task4.1 and across Work Package 4.

Table 2: Explanation of the Requirements Attributes in the Excel Document

Attribute	Description
Subtask	Assignment of the defined requirement to the specific Subtask, i.e. 4.1.1, 4.1.2, 4.1.3
Asset	Assignment of the defined requirement to the specific Wayside Asset, i.e. Level Crossing, Switch, Obstacle Detection System
Function/ Feature	Assignment of the defined requirement to the specific function or feature addressed within the Subtask
Owner	Responsible project partner of the defined requirement
Req ID	Unique identification of the requirement according to the defined nomenclature in section 5.2 to ensure traceability
Req Description	Detailed description of the requirement, including its objectives, scope and expected outcome
Req Type	Classification of the requirements, i.e. functional, non-functional, safety, etc.)
Safety?	Indicates whether the defined requirement is safety-related, i.e. Yes, No

Rationale	Justification or motivation for the defined requirement, including additional context to enhance understanding
UC Source (from WP4)	Associated Use Case from Work Package 4 to which the defined requirement is assigned
UC Source (from Other WPs)	Associated Use Case from other technical Work Packages to which the requirement is linked
Req Source (from Other WPs)	Associated (high-level) requirement of other Work Packages, if available
Req Status (from Other WPs)	Current status of the requirement within other Work Packages, i.e. New, Inherted, Refined, etc.

2 Development Methodology

The requirements described in the present document has been derived from a set of reference Use Cases. To create both outputs, Use Cases and Requirements, the below steps have been followed.

The mean of applying such methodology is to follow a sensitive, conclusive, and clear approach with the final aim of identifying a coherent and justified set of requirements:

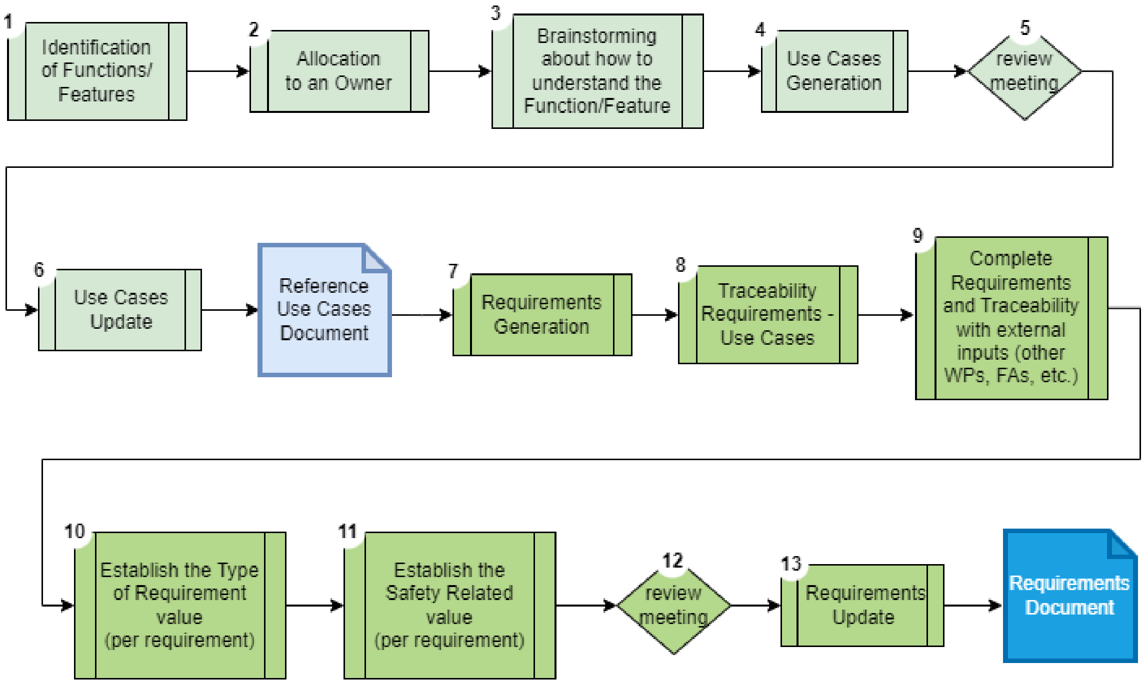


Figure 2: Development Methodology

The steps can be described as follows:

1) Identification of Functions/Features: The list of functions per each asset is to be extracted from the subtask description in the Grant Agreement. Being those:

- For Subtask 4.1.1, Level Crossings, “Control Management (G1 and G2 separately)”, “Wireless Connection Management”, “Energy Self-sufficient Management” and “Remote Maintenance Management”.
- For Subtask 4.1.2, Switches, “Configurability for different track gauges”, “Wireless Connection Management”, “Energy Self-sufficient Management” and “Remote Maintenance Management”.
- For Subtask 4.1.3, Obstacle Detectors, no functions split, just considered as a whole.

2) Allocation to an Owner: Among the contributors the different functions are to be assigned to concrete owners/authors:

- For Subtask 4.1.1, Level Crossings:
    - Control Management (G1): ÖBB.
    - Control Management (G2): FT.
    - Wireless Communication Management: ÖBB – Quite likely reuse of requirements described in Task 4.2 will be done.

  - Energy Self-sufficient Management: ENYSE.
  - Remote Maintenance Management: ENYSE.
- For Subtask 4.1.2:
  - Configurability for different track gauges: ÖBB.
  - Wireless Connection Management: ÖBB – Quite likely reuse of requirements described in Task 4.2 will be done.
  - Energy Self-sufficient Management: ENYSE.
  - Remote Maintenance Management: ENYSE.
- For Subtask 4.1.3, Obstacle Detectors, MERMEC is fully in charge.

3) Brainstorming: Among the contributors and during several follow-up meetings the different ideas to explain the functions are to be discussed. The aim is to find the best way to explain how the functions/features must behave in their application to Regional Lines.

4) Use Cases Generation: A first draft of the reference Use Cases is to be created. The Use Cases are to be created by the different owners and then consolidated by one of them.

5) Review Meeting: That first draft of Uses Cases is to be reviewed at least by other participants in the Task 4.1.

6) Use Cases Update: The reference Uses Cases are to be updated with the review comments.

7) Requirements Generation: From the reference Uses Cases, each owner has the responsibility to derive a first draft of requirements. The requirements should be singular, unambiguous, traceable and verifiable by means of the future demonstrator.
The requirements are to be stored in Excel file that belongs to this deliverable (as explained in section 1.3). For each requirement, next attributes are to be filled-in:

- Task / Subtask (mandatory)
- Asset (mandatory)
- Function / Feature (mandatory)
- Owner (mandatory)
- Requirement ID (mandatory): See section 5.2.
- Requirement Description (mandatory): Piece of text (singular, unambiguous, traceable and verifiable) that forms the core of the requirement.
- Rationale (optional): When considered as necessary, short explanation that justifies the need of the requirements.

8) Traceability Requirements – Use Cases: The below attributes are to be filled-in:

- Use Case(s) Source (from WP4) (mandatory): Trace/link to the Reference Use Case(s) from where the requirement is derived.
  Please note that one (1) given requirement may be derived from several (N) Use Cases.

9) Complete Requirements and Traceability: To identify additional requirements which may come from external sources (other WPs, FAs, etc.) and to complete the next attributes:
   - Use Case(s) Source (from Other WPs) (optional): When considered as necessary, trace/link to the Reference Use Case(s) in other WPs used as inspiration to define the requirement.
   - Requirement(s) Source (from Others WP) (optional): When considered as necessary, trace/link to requirement(s) in other WPs used as inspiration to define the requirement.
   - Requirement(s) Status (from Others WP): When a requirement from other WP is traced, it mut be indicated whether such requirement is:
     - Completely "Inherited" by the WP4 requirement, or
     - Somehow "Redefined" by the WP4 requirement.

10) Type of Requirement: For all the requirements, the next attribute is to be filled-in:
   - Requirement Type (mandatory):
     - ArchDes: Related to a design or architecture matter.
     - Assumption: Not a requirement but an assumption needed to satisfy the requirements.
     - Configuration: Related to a configuration matter, e.g. concrete values (timers, distances, lengths, etc.).
     - Definition: Not a requirement but a definition needed to understand the requirements.
     - Functional: Related to an internal behaviour, describing how the asset/function must behave.
     - Non-Functional: Related to system attributes such as performance, security, reliability, and usability
     - Operational: Related to an operational condition that the asset/function shall require/provide from/to externals.

11) Safety Related: For all the requirements, the next attribute is to be filled-in:
   - Safety? (mandatory):
     - YES: The non-fulfilment of the requirement may have safety consequences.
     - NO: The non-fulfilment of the requirement does not have any safety consequences.

12) Review Meeting: That first draft of Requirements is to be reviewed at least by other participants in the Task 4.1.

13) Requirements Update: The Requirements (the present deliverable) are to be updated with the review comments.

It is worth noting that the document structure is already defined to include specific requirements for the G2 Lines context. The first official release of the present document, coherently with the coeval release of D2.1 and D2.2, keeps G2 lines as "concept" postponing the definition of requirements to a further stage.

3 Use Case Organization

This chapter introduces the reference use cases presented in the next chapter. The first subchapter documents the evolution history of the use cases. The following subchapters describe the FP6/WP4 use case template applied and the use case nomenclature and tracking.

3.1 Use Case Evolution History

Version	Date	Name	Affiliation	Position/Project Role	Action/ Short Description
0.1	06/11/2023	MO	ÖBB	Task Leader of T4.1	Creating and preparing the Deliverable
0.2	14/11/2023	MO	ÖBB	Task Leader of T4.1	
0.3	13/02/2024	NMB	ENYSE	Subtask Leader of ST4.1.1 and ST4.1.2	UC about LX/Switch energy self-sufficient added & UC about LX/Switch about Remote Maintenance added
0.4	05/03/2024	MO	ÖBB	Task Leader of T4.1	UC about Control Management of LC added; General Information; Preparing for Reviewing
0.5	08/04/2024	MO	ÖBB	Task Leader of T4.1	Add information of Control Mng. based on reviewing comments
0.6	08/04/2024	NMB	ENYSE	Subtask Leader of ST4.1.1 and ST4.1.2	All comments from review closed – this version tracks all comments and answers. Look and feel harmonization among all the sections.
0.7	16/04/2023	FB	WABTEC / FT	Contributor of ST4.1.1 and ST4.1.2	Section 3.2.2 added.
0.8	22/04/2024	NMB	ENYSE	Subtask Leader of ST4.1.1 and ST4.1.2	Minor in the UC about Energy and Remote Maintenance for LX and Switch. Pending paragraphs highlighted in grey.
0.9	08/10/2024	MO	ÖBB	Task Leader of T4.1	Update Use Case Nomenclature of

					Reference Use Cases of T4.2/T4.4
1.0	21/10/2024	MO	ÖBB	Task Leader of T4.1	Prepare for external Review
1.1	21/11/2024	MO	ÖBB	Task Leader of T4.1	Insert Use Cases of Subtask 4.1.3 based on the submission of Subtaskleader 4.1.3. Add Document Structure
1.2 (final version for SteCo submission)	21/11/2024	MO	ÖBB	Task Leader of T4.1	Last Check of finale version for submission to SteCo
1.3	02/12/2024	FB	FT	WP1 Leader	Quality Check
1.4	26/06/2025	FI	MERMEC	Subtask Leader of ST4.1.3	Revision of Section 4.4

3.2 Use Case Template

The following template (Reference Table) is used in this document for the uniform creation of use cases, which was provided by WP2 and represents the official template in FP6/WP4.

The template contains both formal and technical-related information and in addition provides clarifications and guidance to fill in the template for the use cases.

Table 3: Use case template with guidance of attributes

Use Case Group	Brief name of the use case (UC) group *Note: Recommendation to have in advance numbered list of all UC groups to be defined.*
Use Case	Brief name of the specific UC *Note: Name should refer to the main goal of the UC.*
UC ID	UC_XX_YYY *Note: ID of each UC should be unique.* *(XX=number of UC group, YYY=number of specific UC)* *Example: UC_02_104* *(02 = WP4, 1="Communication", 04="instauration of the communication")* *Note: Numbering of UC groups (XX) is defined firmly in advance. Numbering of specific UC's (YYY) is in charge of the WPs leader WPs task responsible for specific UC.*
Main actor	Actor that initiates the UC.
Other actors	List of all actors that play any role during UC scenario in any event of the UC. *Note: Recommendation to have in advance list of all possible actors to be used (e.g. ATO, dispatcher, RBC…).*
Main goal	ID of the UC main goal: G_UC_02_104 Description of the UC main goal – what operational scenario (concept) is provided. *Example: "ensure train end of operation procedure including inspection everything is performed properly".* *Note: It is not easy to define all possible operational scenarios, but at least for those which are already defined there should exist some relationship between them to help a reader better understand the operational.*
Assumptions	List of indicated generic assumptions which are needed for performing the UC in an intended way (and e.g. nowadays some system or interface is not available yet). *Example: "interface between system A and B exists (or will be developed")."*
Precondition	Defines all conditions that have to be fulfilled before the UC is started. *Example: "specific system is switched on; specific environment condition is available".*
Flow of events	Numbered sequence of UC scenario events (step by step from the start of the UC to its successful end) – "what shall happen to fulfil UC goal". *Note: Proposal: In first stage to write UC's in "sunny day" way – it means that the goal of the UC will be achieved successfully without any disruption.* *Note: Recommendation to describe all events on the same level of detail.* *Proposal: Not to be too much specific. Operational scenario should be*

	described, not a technical solution (system here is more like a black box which performs some action and interacts with other systems or operational environment). Example of the event sequence: 1. First (initial) event (Main actor initiates something) 2. Second event 3. XY event 4. … 5. Final event (after the last event is done, the main goal of the UC is successfully fulfilled) *Note: Proposal: Number of events should not exceed approximately 10 events.*
Postcondition	Defines all conditions that have to be fulfilled when the UC is successfully completed or the condition where we go in failed case. *Example: "specific system is switched off; some actor is in specific operational status".*
Safety relation	Defines, if any event in the use case has any relation to safety and a function made by an actor is supposed to be safety relevant.
Open topics / consideration	Whatever you find interesting to note which has already not been written above.

3.3 Tracking and Nomenclature of Use Cases

As can be seen in the line two of the template, the informal information regarding a use case identification has been included. However, this nomenclature does not provide enough information required for comprehensive collaboration within WP4. In particular, the unique referencing of use cases along WP4 should be possible and established. Therefore, following nomenclature as unambiguous identification of the use cases is used in this reference document instead of the nomenclature provided.

The used nomenclature includes certain identifiers to represent the affiliation to the WP4, the identification of the Subtask and an increasing numeration. In addition, the numeration is subdivided into subranges relating to the main objectives for each subtask.

Nomenclature: **UC_WP4_ST*ID_UC*ID**

Table 4: Nomenclature of Use cases with guidance of attributes

IDs	Description	Information
UC_WP4	Affiliation of Use Case (belonging to WP4)	*permanent*
ST*ID	Identification of the Subtask	*[4.1.1, 4.1.2, 4.1.3]*
UC*ID	Numeration of the Use Cases	*[Starting at beginning of range and increment by 1]* ***For Subtask 4.1.1**, use next subranges:* *001 to 050: about Control Mng. G1* *051 to 099: about Control Mng. G2* *101 to 199: about Wireless Connection* *201 to 299: about Energy Self-Sufficient* *301 to 309: about Remote Maintenance* ***For Subtask 4.1.2**, use next subranges:* *001 to 099: about Configurability* *101 to 199: about Wireless Connection* *201 to 299: about Energy Self-Sufficient* *301 to 309: about Remote Maintenance* ***For Subtask 4.1.3**, use next subranges:* *001 to 099: General*

4 Reference Use Cases

4.1 Table of Use Cases

Table 5: Use Cases of Subtask 4.1.1, 4.1.2, 4.1.3

Identifier	Owner	Description	WP2 Reference
Subtask 4.1.1 – Level Crossing			
Control Management			
UC_WP4_4.1.1_001	ÖBB	(G1) Activation of Level Crossing Protection Facilities	
UC_WP4_4.1.1_002	ÖBB	(G1) Deactivation of Level Crossing Protection Facilities	
UC_WP4_4.1.1_010	ÖBB	(G1) Report Protection Facilities Status: Monitoring Parameters	
UC_WP4_4.1.1_011	ÖBB	(G1) Report Protection Facilities Status: Obstacle Detection	
UC_WP4_4.1.1_012	ÖBB	(G1) Report Protection Facilities Status: Train Detection Element	
UC_WP4_4.1.1_020	ÖBB	(G1) Report Irregularities: Timers Overrun	
UC_WP4_4.1.1_021	ÖBB	(G1) Report Irregularities: Report of detected failures	
UC_WP4_4.1.1_030	ÖBB	(G1) Level Crossing Operation Mode: Enabling Local Operation	
UC_WP4_4.1.1_031	ÖBB	(G1) Level Crossing Operation Mode: Disabling Local Operation	
UC_WP4_4.1.1_032	ÖBB	(G1) Level Crossing Operation Mode: Enabling Autonomous Operation	
UC_WP4_4.1.1_033	ÖBB	(G1) Level Crossing Operation Mode: Disabling Autonomous Operation	
UC_WP4_4.1.1_051	FT	(G2) Activation of Level Crossing Protection Facilities	
UC_WP4_4.1.1_052	FT	(G2) Deactivation of Level Crossing Protection Facilities	
UC_WP4_4.1.1_060	FT	(G2) Report Protection Facilities Status: Monitoring Parameters	
UC_WP4_4.1.1_061	FT	(G2) Report Protection Facilities Status: Obstacle Detection	
UC_WP4_4.1.1_070	FT	(G2) Report Irregularities: Timers Overrun	
UC_WP4_4.1.1_071	FT	(G2) Report Irregularities: Report of Detected Failures	
UC_WP4_4.1.1_080	FT	(G2) Level Crossing Operation Mode: Enabling Local Operation	
UC_WP4_4.1.1_081	FT	(G2) Level Crossing Operation Mode: Disabling Local Operation	
Wireless Connection			
UC_WP4_4.2.2_*	ÖBB	Reference Use Cases from Task 4.2.2 and Task 4.4	
Energy Self-Sufficient			
UC_WP4_4.1.1_201	ENYSE	Battery (only source of energy) – LX in Stand-by	
UC_WP4_4.1.1_202	ENYSE	Battery (only source of energy) – LX in Operation	
UC_WP4_4.1.1_203	ENYSE	Renewable (working) + Battery (backup) – LX in Stand-by	
UC_WP4_4.1.1_204	ENYSE	Renewable (working) + Battery (backup) – LX in Operation	
UC_WP4_4.1.1_205	ENYSE	Renewable (not working) + Battery (backup and working) – LX in Stand-by	
UC_WP4_4.1.1_206	ENYSE	Renewable (not working) + Battery (backup and working) – LX in Operation	
UC_WP4_4.1.1_207	ENYSE	Grid (working) + Battery (backup) – LX in Stand-by	
UC_WP4_4.1.1_208	ENYSE	Grid (working) + Battery (backup) – LX in Operation	
UC_WP4_4.1.1_209	ENYSE	Grid (not working) + Battery (backup and working) – LX in Stand-by	
UC_WP4_4.1.1_210	ENYSE	Grid (not working) + Battery (backup and working) – LX in Operation	
UC_WP4_4.1.1_211	ENYSE	Renewable (working) + Grid (as complement) + Battery (backup) – LX in Stand-by	
UC_WP4_4.1.1_212	ENYSE	Renewable (working) + Grid (as complement) + Battery (backup) – LX in Operation	

Identifier	Owner	Description	WP2 Reference
UC_WP4_4.1.1_213	ENYSE	Renewable (not enough) + Grid (complementing) + Battery (backup) – LX in Stand-by	
UC_WP4_4.1.1_214	ENYSE	Renewable (not enough) + Grid (complementing) + Battery (backup) – LX in Operation	
UC_WP4_4.1.1_215	ENYSE	Renewable (not working) + Grid (not working) + Battery (backup and working) – LX in Stand-by	
UC_WP4_4.1.1_216	ENYSE	Renewable (not working) + Grid (not working) + Battery (backup and working) – LX in Operation	
UC_WP4_4.1.1_217	ENYSE	No energy source available – LX in Stand-by	
UC_WP4_4.1.1_218	ENYSE	No energy source available – LX in Operation	
Remote Maintenance			
UC_WP4_4.1.1_301	ENYSE	Non-remote Maintenance – Use Manual Command	
UC_WP4_4.1.1_302	ENYSE	Diagnosis – Acquisition of data Under Demand	
UC_WP4_4.1.1_303	ENYSE	Diagnosis – Acquisition of data through Dump Transmission	
UC_WP4_4.1.1_304	ENYSE	Diagnosis – Acquisition of data through Subscription	
UC_WP4_4.1.1_305	ENYSE	Maintenance – Maintenance through Update	
Subtask 4.1.2 – Switch			
Configurability for different Track Gauges			
	ÖBB	No Uses Cases identified	
Wireless Connection			
UC_WP4_4.2.2_*	ÖBB	Reference Use Cases from Task 4.2.2 and Task 4.4	
Energy Self-Sufficient			
UC_WP4_4.1.2_201	ENYSE	Battery (only source of energy) – Switch Set and Locked	
UC_WP4_4.1.2_202	ENYSE	Battery (only source of energy) – Switch Moving	
UC_WP4_4.1.2_203	ENYSE	Renewable (working) + Battery (backup) – Switch Set and Locked	
UC_WP4_4.1.2_204	ENYSE	Renewable (working) + Battery (backup) – Switch Moving	
UC_WP4_4.1.2_205	ENYSE	Renewable (not working) + Battery (backup and working) – Switch Set and Locked	
UC_WP4_4.1.2_206	ENYSE	Renewable (not working) + Battery (backup and working) – Switch Moving	
UC_WP4_4.1.2_207	ENYSE	Grid (working) + Battery (backup) – Switch Set and Locked	
UC_WP4_4.1.2_208	ENYSE	Grid (working) + Battery (backup) – Switch Moving	
UC_WP4_4.1.2_209	ENYSE	Grid (not working) + Battery (backup and working) – Switch Set and Locked	
UC_WP4_4.1.2_210	ENYSE	Grid (not working) + Battery (backup and working) – Switch Moving	
UC_WP4_4.1.2_211	ENYSE	Renewable (working) + Grid (as complement) + Battery (backup) – Switch Set and Locked	
UC_WP4_4.1.2_212	ENYSE	Renewable (working) + Grid (as complement) + Battery (backup) – Switch Moving	
UC_WP4_4.1.2_213	ENYSE	Renewable (not enough) + Grid (complementing) + Battery (backup) – Switch Set and Locked	
UC_WP4_4.1.2_214	ENYSE	Renewable (not enough) + Grid (complementing) + Battery (backup) – Switch Moving	
UC_WP4_4.1.2_215	ENYSE	Renewable (not working) + Grid (not working) + Battery (backup and working) – Switch Set and Locked	
UC_WP4_4.1.2_216	ENYSE	Renewable (not working) + Grid (not working) + Battery (backup and working) – Switch Moving	
UC_WP4_4.1.2_217	ENYSE	No energy source available – Switch Set and Locked	

Identifier	Owner	Description	WP2 Reference
UC_WP4_4.1.2_218	ENYSE	No energy source available – Switch Moving	
Remote Maintenance			
UC_WP4_4.1.2_301	ENYSE	Non-remote Maintenance – Use Manual Command	
UC_WP4_4.1.2_302	ENYSE	Diagnosis – Acquisition of data Under Demand	
UC_WP4_4.1.2_303	ENYSE	Diagnosis – Acquisition of data through Dump Transmission	
UC_WP4_4.1.2_304	ENYSE	Diagnosis – Acquisition of data through Subscription	
UC_WP4_4.1.2_305	ENYSE	Maintenance – Maintenance through Update	
Subtask 4.1.3 – Obstacle Detector			
UC_WP4_4.1.3_001	MERMEC	Level Crossing Obstacle Detector in normal condition with signalling system	UC_2_301
UC_WP4_4.1.3_002	MERMEC	Level Crossing Obstacle Detector in normal condition without signalling system	
UC_WP4_4.1.3_003	MERMEC	Level Crossing Obstacle Detector in degraded condition without train, LX connected to the signalling system	
UC_WP4_4.1.3_004	MERMEC	Level Crossing Obstacle Detector in degraded condition without train, LX stand alone	
UC_WP4_4.1.3_005	MERMEC	Level Crossing Obstacle Detector in degraded condition with train, LX connected to the signalling system	
UC_WP4_4.1.3_006	MERMEC	Level Crossing Obstacle Detector in degraded condition with train, LX stand alone	

4.2 Reference Use Cases of wireless enabled energy self-sufficient LX (Subtask 4.1.1)

4.2.1 About Control Management (G1 Lines)

Assumptions and Rationale

Three different scenarios of Controlling Entities were identified for G1 Lines:

a. Level Crossing is controlled by Interlocking
b. Level Crossing is controlled by Radio Block Centre
c. Level Crossing is controlled by Interlocking with connected Radio Block Centre

Table 6: Comparison of controlling entities scenarios for Control Management of LX

	IXL	RBC	Conclusion
a.	X		The scenario where the Interlocking is in charge of controlling and monitoring Wayside Assets like Level Crossings corresponds to its intended purpose and represents the usual setup. For this reason, using only the Interlocking as Controlling Entity defines the most cost-efficient scenario.
b.		X	The RBC is an essential component for ETCS functions, which is intended for the control and monitoring of trains and controls the communication for this purpose. According to the current specification, the RBC has no integrated functions that are intended for controlling of Wayside Assets like Level Crossing. The scenario in which the Level Crossing is only controlled by RBC therefore does not correspond to the purpose of the RBC and does not occur, especially for regional lines. The scenario, where the RBC is the only Controlling entity is not considered very promising in terms of cost reduction.
c.	X	X	The combination of Interlocking and RBC represents the complete controlling setup for G1 lines, where the Interlocking is in responsible for controlling the Wayside Assets and provide status and information to the RBC with its intended functionalities and vice versa. The scenario is aimed at in the long-term but does not represent the most cost-efficient case for regional lines, as in many locations' RBCs are not fully available or implemented.

Based on this, the term "controlling entities" is used in the following to cover all scenarios. The validation of use cases for only one specific scenario is specified.

NOTE: The following Use Cases regarding the Control Management of Level Crossing (G1) aim at new Level Crossing Deployments and do not include existing Level Crossing Systems. Therefore, the backward compatibility of existing Level Crossing Systems is not envisaged or included. Furthermore, the identified use cases are based on the EULYNX specification [REF.22], as this was identified as a key technology or standard for the controlling of level crossings.

<u>Concepts</u> (alphabetical order)

- AUTONOMOUS MODE: Operational Mode in which the Level Crossing is isolated to the CCS Architecture and acts independently without the control of the Controlling Entities.
- CONTROLLING ENTITIES: Central Component in the CCS Architecture, that is in charge of controlling and monitoring the Level Crossing System, i.e. Interlocking and/or Radio Block Centre for G1 lines
- FALLBACK MODE: Operational Mode/State of the Level Crossing that is activated when the regular functions are no longer working properly due to malfunctions, disruptions, or unexpected conditions. The functionality of the Fallback Mode can be implemented differently and depends on national specifications and standards, i.e. complete standstill, limited functionality or defined safety protocol performed by the Level Crossing.

<u>Use Cases Groups</u>

For the Controlling Management (G1) of the Level Crossing four different Use Case Groups have been identified:

a) Activation and Deactivation of Protection Facilities
b) Report Protection Facilities status
c) Report Irregularities
d) Level Crossing Operation Modes

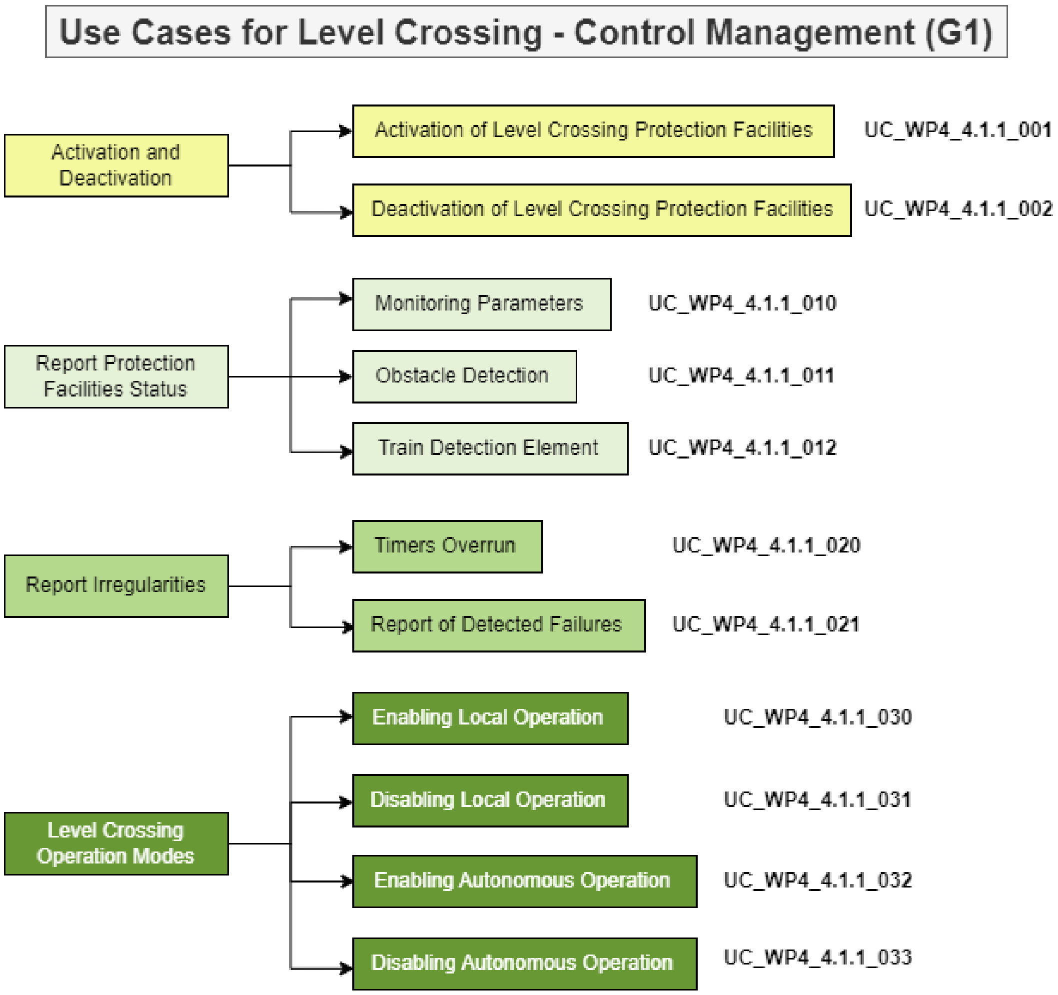


Figure 3: Use Cases for LX – Control Management (G1)

Use Cases for G1 Lines

a) Activation and Deactivation of Protection Facilities

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Activation of Level Crossing Protection Facilities for G1 Lines
UC ID	UC_WP4_**4.1.1_001**
Main actor	Control Management of Level Crossing
Other actors	Controlling Entities (IXL, RBC, etc.) Protection Facilities of Level Crossing System
Main goal	Activation of the protection facilities by the controlling entities in a safely manner.
Assumptions	Usage of a standardized Interface specification to establish interoperability for G1 lines (i.e. EULYNX SCI-LC Interface, others.).
Precondition	• Level Crossing System is in Operational State. • Level Crossing System is not protected. • If operate with local Power Supply System, Power Management of Level Crossing System ensures that sufficient energy is available to activate the protection facilities.
Flow of events	Activation of Protection Facilities: 1) Level Crossing System receives from Controlling Entities to activate the Protection facilities. 2) Level Crossing System activates the Protection facilities (switch on visual and acoustic signals, switch on motors of barriers, etc.). 3) If configured, the Level Crossing System starts defined Timers (i.e. Closure Timers) for monitoring. 4) Level Crossing System receives Status of Protection Facilities (visual and acoustic signals on, Barriers in End Positions, etc.). 5) If configured, the Level Crossing System stops defined Timers (i.e. Closure Timers). 6) Detection of Irregularities. 7) Level Crossing System reports to Controlling Entities that Level Crossing is protected.
Postcondition	Level Crossing is protected and safe train passing is ensured.
Safety relation	YES
Open topics / consideration	-

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Deactivation of Level Crossing Protection Facilities for G1 Lines
UC ID	UC_WP4_**4.1.1_002**
Main actor	Control Management of Level Crossing
Other actors	Controlling Entities (IXL, RBC, etc.) Protection Facilities of Level Crossing System
Main goal	Deactivation of the protection facilities by the controlling entities in a safely manner.
Assumptions	Usage of a standardized Interface specification to establish interoperability for G1 lines (i.e. EULYNX SCI-LC Interface, others.).
Precondition	• Level Crossing System is in Operational State. • Level Crossing System is protected. • Level Crossing System ensures, that the train fully left the Level Crossing Area. • If operate with local Power Supply system, Power Management of Level Crossing ensures, that there is sufficient energy to deactivate the Protection Facilities.
Flow of events	Deactivation of Protection Facilities: 1) Level Crossing System receives from Controlling Entities to deactivate the Protection facilities. 2) Level Crossing System deactivates the Protection facilities (switch off visual and acoustic signals, switch on motors of barriers, etc.). 3) If configured, the Level Crossing System starts defined Timers (i.e. Opening Timers) for monitoring. 4) Level Crossing System receives Status of Protection Facilities (visual and acoustic signals off, Barriers in End Position, etc.). 5) If configured, the Level Crossing System stops defined Timers (i.e. Opening Timers). 6) Detection of Irregularities. 7) Level Crossing System reports to Controlling Entities that Level Crossing is unprotected.
Postcondition	Level Crossing is unprotected and Protection Facilities are in initial state
Safety relation	YES
Open topics / consideration	-

b) Report Level Crossing status

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Report Protection Facilities Status: Monitoring Parameters for G1 Lines
UC ID	UC_WP4_**4.1.1_010**
Main actor	Control Management of Level Crossing
Other actors	Controlling Entities (IXL, RBC, etc.) Protection Facilities of Level Crossing
Main goal	Report to Controlling Entities the change of Monitoring Parameters of Protection Facilities.
Assumptions	Usage of a standardized Interface specification to establish interoperability for G1 lines (i.e. EULYNX SDI-LC Interface, others.).
Precondition	• Level Crossing is configured to monitor the change of selected Monitoring Parameters. • Level Crossing System is in Operational State.
Flow of events	1) Level Crossing System receives the change of Monitoring Parameters from Protection facilities (i.e. Barriers Position, Barrier Movement, Road light status, Power Supply Status, etc.). 2) Level Crossing System reports monitoring status of each facility to Controlling Entities.
Postcondition	-
Safety relation	Depending on Configuration and Monitoring Parameters.
Open topics / consideration	Which parameters must be monitor and must be reported to Controlling Entities depend on configuration and national regulations.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Report Protection Facilities Status: Obstacle Detection for G1 Lines
UC ID	UC_WP4_**4.1.1_011**
Main actor	Control Management of Level Crossing
Other actors	Obstacle Detection System Controlling Entities (IXL, RBC, etc.)
Main goal	Monitoring Obstacle Detection System and Reporting to Controlling Entities.
Assumptions	Usage of a standardized Interface specification to establish interoperability for G1 lines (i.e. EULYNX SCI-LC Interface, others.).
Precondition	• Level Crossing System is configured to use obstacle detection. • Level Crossing System is in Operational State.
Flow of events	1) Level Crossing System receives status from Obstacle Detection System (obstacle/no obstacle in conflict area). 2) Level Crossing System reports status to Controlling Entities.
Postcondition	-
Safety relation	YES
Open topics / consideration	Use Case is listed for consistency reasons but is considered and dealt in WP4 Subtask4.1.3 & WP4 Task4.4

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Report Protection Facilities Status: Train Detection Element for G1 Lines
UC ID	UC_WP4_**4.1.1_012**
Main actor	Control Management of Level Crossing
Other actors	Train Detection Element Controlling Entities (IXL, RBC, etc.)
Main goal	Reporting to Controlling Entities the status of Train Detection Elements.
Assumptions	Usage of a standardized Interface specification to establish interoperability for G1 lines (i.e. EULYNX SCI-LC Interface, others.).
Precondition	• Level Crossing System is configured to use Train Detection Elements. • Level Crossing System is in Operational State.
Flow of events	1) Level Crossing System receives status from Train Detection Element (occupied, vacant, failed). 2) Level Crossing System reports status to Controlling Entities.
Postcondition	-
Safety relation	YES
Open topics / consideration	-

c) Report Irregularities

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Report Irregularities: Timers Overrun for G1 Lines
UC ID	UC_WP4_**4.1.1_020**
Main actor	Control Management of Level Crossing
Other actors	Controlling Entities (IXL, RBC, etc.)
Main goal	Detection of occurrence of Timer Overruns and Report to Controlling Entities, i.e. Closure Timer of Level Crossing.
Assumptions	Usage of a standardized Interface specification to establish interoperability for G1 lines (i.e. EULYNX SCI-LC Interface, others.)
Precondition	• Level Crossing System is configured to use certain Timers for Controlling. • Level Crossing System is in Operational State.
Flow of events	Detection and report of Timer Overruns: 1) Level Crossing System detects that Timers periods has exceeded. 2) Level Crossing System reports to Controlling Entities, that the Timers has exceeded. 3) Level Crossing System validate if certain Timer Overrun is critical or non-critical. 4) Level Crossing System reports to Controlling Entities the result of validation.
Postcondition	If Timer Overrun is critical, the Level Crossing system goes into Fallback-Mode
Safety relation	YES
Open topics / consideration	Validation of what is critical and non-critical depends on national regulations.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Report Irregularities: Report of Detected Failures for G1 Lines
UC ID	UC_WP4_**4.1.1_021**
Main actor	Control Management of Level Crossing
Other actors	Protection Facilities Controlling Entities (IXL, RBC, etc.)
Main goal	Inform Controlling Entities about occupied failures of Protection Facilities.
Assumptions	Usage of a standardized Interface specification to establish interoperability for G1 lines (i.e. EULYNX SCI-LC Interface, others.).
Precondition	Level Crossing System is in Operational State
Flow of events	General Flow of events for reporting of detected failures: 1) Level Crossing System receives status of protection facilities. 2) Level Crossing System evaluates the received statuses and determines if statuses are properly or improperly. 3) If one or more statuses are improperly, the Level Crossing System derives a critical or non-critical fault condition from this. 4) Level Crossing System reports to Controlling Entities the failure with information about cause and categorisation of failure.
Postcondition	If the failure is critical, the Level Crossing System changes into Fallback-Mode
Safety relation	YES
Open topics / consideration	Evaluation of what is critical and non-critical failure depends on national regulations. Power Management of Level Crossing by local energy supply system.

d) Level Crossing Operation Modes

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Level Crossing Operation Mode: Enabling Local Operation for G1 Lines
UC ID	UC_WP4_**4.1.1_030**
Main actor	Control Management of Level Crossing
Other actors	Local Operator Controlling Entities (IXL, RBC, etc.)
Main goal	Enabling Local Operation Mode, which implies the handover from controlling Entity-controlled mode to Local Operation Mode.
Assumptions	Usage of a standardized Interface specification to establish interoperability for G1 lines (i.e. EULYNX SCI-LC Interface, others.)Local Operator, who is the initiator of the Local Operation, is in immediate surrounding of the system.
Precondition	• Level Crossing System is configured to use Local Operation. • Level Crossing System is in Operational State and controlled by a Controlling Entity.
Flow of events	Enabling Local Operation Mode: 1) Level Crossing System receives the request to handover of Local Operation Mode by Local Operator. 2) Level Crossing System reports the request of handover to Controlling Entities. 3) Level Crossing System receives the establishment for handover by Controlling Entity. 4) Level Crossing System reports the establishment for handover to Local Operator.
Postcondition	Local Operation Mode is enabled. Local Operator is in charge of activating and deactivating the protection facilities of Level Crossing
Safety relation	YES
Open topics / consideration	-

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Level Crossing Operation Mode: Disabling Local Operation for G1 Lines
UC ID	UC_WP4**_4.1.1_031**
Main actor	Control Management of Level Crossing
Other actors	Controlling Entities (IXL, RBC, etc.) Local Operator
Main goal	Disabling Local Operation Mode, which implies the return of handover from Local Operation Mode to (IXL, RBC, etc.)-controlled mode.
Assumptions	Usage of a standardized Interface specification to establish interoperability for G1 lines (i.e. EULYNX SCI-LC Interface, others.)Local Operator, who is the initiator of the return of handover, is in immediate surrounding of the system.
Precondition	• Level Crossing System is configured to use Local Operation. • Level Crossing System is in Operational State and in Local Operation Mode.
Flow of events	Disabling Local Operation Mode: 1) Level Crossing System receives the input from Local Operator to return handover of the local operation. 2) Level Crossing System reports to the Controlling Entity, that the Local Operator has returned the handover of local operations. 3) Level Crossing System receives the confirmation from Controlling Entity, that the handover of local operation is returned. 4) Level Crossing System reports to Local Operator, that the handover of the local operation has returned.
Postcondition	Local Operation Mode is disabled and Level Crossing System is controlled by Controlling Entities. Local Operator isn’t in charge of activating and deactivating the protection facilities anymore.
Safety relation	YES
Open topics / consideration	-

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Level Crossing Operation Mode: Enabling Autonomous Operation for G1 Lines
UC ID	UC_WP4_**4.1.1_032**
Main actor	Control Management of Level Crossing
Other actors	Controlling Entities (IXL, RBC, etc.)
Main goal	To increase the operational availability of Level Crossings during scheduled maintenance work of Controlling Entities (IXL, RBC, etc., where a deactivation of the Controlling Entities is needed. Enabling Autonomous Mode of Level Crossing in order to operate the line during that time period for deactivation.
Assumptions	Usage of a standardized Interface specification to establish interoperability for G1 lines (i.e. EULYNX SCI-LC Interface, others.).
Precondition	• Level Crossing System is configured to use Autonomous Mode • Level Crossing System is in Operational State
Flow of events	Enabling Autonomous Mode: 1) Level Crossing System receives the command to enable the Autonomous Mode by Controlling Entity. 2) Level Crossing System enable the Autonomous Mode. 3) Level Crossing System reports to Controlling entity the establishment of the Autonomous Mode.
Postcondition	Autonomous Operation Mode is enabled.
Safety relation	YES
Open topics / consideration	-

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Level Crossing Operation Mode: Disabling Autonomous Operation for G1 Lines
UC ID	UC_WP4_**4.1.1_033**
Main actor	Control Management of Level Crossing
Other actors	Controlling Entities (IXL, RBC, etc.)
Main goal	To increase the operational availability of Level Crossings during scheduled maintenance work of Controlling Entities (IXL, RBC, etc., where a deactivation of the Controlling Entities is needed. Disabling Autonomous Mode of Level Crossing.
Assumptions	Usage of a standardized Interface specification to establish interoperability for G1 lines (i.e. EULYNX SCI-LC Interface, others.).
Precondition	• Level Crossing System is configured to use Autonomous Mode • Level Crossing System is in Operational State and Autonomous Operation Mode is enabled.
Flow of events	Disabling Autonomous Mode: 1) Level Crossing System receives the command to disable the Autonomous Mode by Controlling Entities. 2) Level Crossing System disable the Autonomous Mode. 3) Level Crossing System reports to Controlling entity the removal of the Autonomous Mode.
Postcondition	Autonomous Operation Mode is disabled.
Safety relation	YES
Open topics / consideration	-

4.2.2 About Control Management (G2 Lines)

Assumptions and Rationale

Based on the definition provided at level of WP2 (D2.1 deliverable), the G2 Lines concept leverages on full radiocommunication technologies and on the integration of Interlocking and Radio Block Centre in a single platform as “controlling entities”.

The scenarios identified for G2 Lines are:

a. Level Crossing controlled by integrated Interlocking/Radio Block Centre
b. Switches controlled by integrated Interlocking/Radio Block Centre (There are no UCs for Switches G2)

NOTE: The following Use Cases regarding the Control Management of Level Crossing (G2) aim at new Level Crossing Deployments and do not include existing Level Crossing Systems. Therefore, the backward compatibility of existing Level Crossing Systems is not envisaged or included.

The Use Cases for G1 and G2 lines are partly similar. However, the G2 CCS is under the development as an entire system, not as a derivative of the G1 system. Therefore, the use cases for the G2 system must be listed comprehensively, rather than as an addition to or in difference from the G1 line use cases.

Concepts (alphabetical order)

- AUTONOMOUS MODE: Operational Mode in which the Level Crossing is isolated from the CCS Architecture and acts independently without the control of the Controlling Entities.
- CONTROLLING ENTITIES: Central Component in the CCS Architecture, that is in charge of controlling and monitoring the Level Crossing System, i.e. Interlocking + Radio Block Centre integrated in a single platform for G2 lines
- FALLBACK MODE: PENDING.

Use Cases Groups

For the Controlling Management (G2) of the Level Crossing four different Use Case Groups have been identified:

a) Activation and Deactivation of Protection Facilities
b) Report Protection Facilities status
c) Report Irregularities
d) Level Crossing Operation Modes

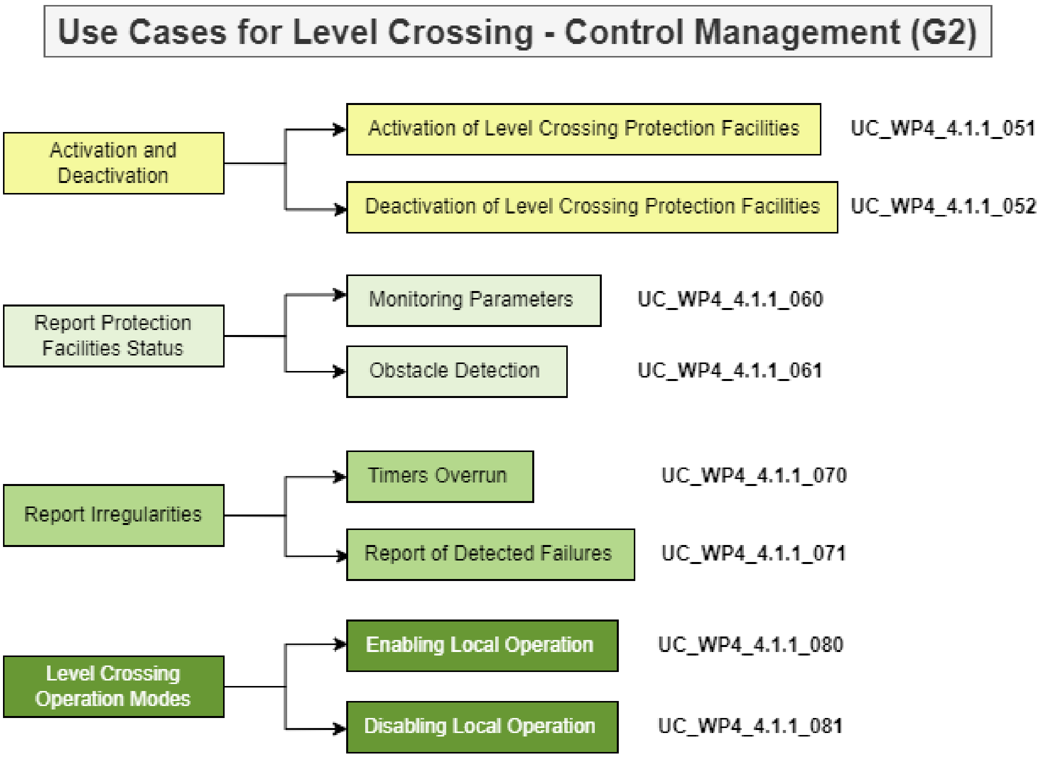


Figure 4: Use Cases for LX – Control Management (G2)

Use Cases for G2 Lines

a) Activation and Deactivation of Protection Facilities

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Activation of Level Crossing Protection Facilities for G2 Lines
UC ID	UC_WP4_**4.1.1_051**
Main actor	Control Management of Level Crossing
Other actors	Controlling Entities (integrated IXL+RBC, etc.) Protection Facilities of Level Crossing System
Main goal	Activation of the protection facilities by the controlling entities in a safely manner.
Assumptions	Usage of an open standardized G2 Lines Interface specification (including EULYNX SCI-LC, if required by the Infrastructure Manager).
Precondition	• Level Crossing System is in Operational State. • Level Crossing System is not protected. • If operated with local Power Supply System or with self-powering level crossings equipment, Power Management of Level Crossing System ensures that sufficient energy is available to activate the protection facilities.
Flow of events	Activation of Protection Facilities: 1) Level Crossing System receives from Controlling Entities a command to activate the Protection facilities. 2) Level Crossing System activates the Protection facilities (switch on visual and acoustic signals, switch on motors of barriers, etc.). 3) If configured, the Level Crossing System starts defined Timers (i.e. Closure Timers) for monitoring. 4) Level Crossing System receives Status of Protection Facilities (visual and acoustic signals on, Barriers in End Positions, etc.). 5) If configured, the Level Crossing System stops defined Timers (i.e. Closure Timers). 6) Detection of Irregularities. 7) Level Crossing System reports to Controlling Entities that Level Crossing is protected.
Postcondition	Level Crossing is protected and safe train passing is ensured.
Safety relation	YES
Open topics / consideration	-

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Deactivation of Level Crossing Protection Facilities for G2 Lines
UC ID	UC_WP4_**4.1.1_052**
Main actor	Control Management of Level Crossing
Other actors	Controlling Entities (integrated IXL+RBC, etc.) Protection Facilities of Level Crossing System
Main goal	Deactivation of the protection facilities by the controlling entities in a safely manner.
Assumptions	Usage of an open standardized G2 Lines Interface specification (including EULYNX SCI-LC, if required by the Infrastructure Manager).
Precondition	• Level Crossing System is in Operational State. • Level Crossing System is not protected. • If operated with local Power Supply System or with self-powering level crossings equipment, Power Management of Level Crossing System ensures that sufficient energy is available to activate the protection facilities.
Flow of events	Deactivation of Protection Facilities 1) Level Crossing System receives from Controlling Entities a command to deactivate the Protection facilities. 2) Level Crossing System deactivates the Protection facilities (switch off visual and acoustic signals, switch on motors of barriers, etc.) 3) If configured, the Level Crossing System starts defined Timers (i.e. Opening Timers) for monitoring. 4) Level Crossing System receives Status of Protection Facilities (visual and acoustic signals off, Barriers in End Position, etc.). 5) If configured, the Level Crossing System stops defined Timers (i.e. Opening Timers). 6) Detection of Irregularities. 7) Level Crossing System reports to Controlling Entities that Level Crossing is unprotected.
Postcondition	Level Crossing is unprotected and Protection Facilities are in initial state.
Safety relation	YES
Open topics / consideration	-

b) Report Level Crossing status

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Report Protection Facilities Status: Monitoring Parameters for G2 Lines
UC ID	UC_WP4_**4.1.1_060**
Main actor	Control Management of Level Crossing
Other actors	Controlling Entities (integrated IXL+RBC, etc.) Protection Facilities of Level Crossing
Main goal	Report to Controlling Entities the change of Monitoring Parameters of Protection Facilities.
Assumptions	Usage of an open standardized G2 Lines Interface specification (including EULYNX SCI-LC, if required by the Infrastructure Manager).
Precondition	• Level Crossing is configured to monitor the change of selected Monitoring Parameters. • Level Crossing System is in Operational State.
Flow of events	1) Level Crossing System receives the change of Monitoring Parameters from Protection facilities (i.e. Barriers Position, Barrier Movement, Road light status, Power Supply Status, etc.). 2) Level Crossing System reports monitoring status to Controlling Entities.
Postcondition	-
Safety relation	Depending on Configuration and Monitoring Parameters.
Open topics / consideration	Which parameters must be monitor and must be reported to Controlling Entities depend on configuration and national regulations.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Report Protection Facilities Status: Obstacle Detection for G2 Lines
UC ID	UC_WP4_**4.1.1_061**
Main actor	Control Management of Level Crossing
Other actors	Obstacle Detection System, Controlling Entities (integrated IXL+RBC, etc.),
Main goal	Monitoring Obstacle Detection System and Reporting to Controlling Entities
Assumptions	Usage of an open standardized G2 Lines Interface specification (including EULYNX SCI-LC, if required by the Infrastructure Manager).
Precondition	• Level Crossing System is configured to use obstacle detection. • Level Crossing System is in Operational State.
Flow of events	1) Level Crossing System receives status from Obstacle Detection System (obstacle/no obstacle in conflict area) 2) Level Crossing System reports status to Controlling Entities
Postcondition	-
Safety relation	YES
Open topics / consideration	Use Case is listed for consistency reasons but is considered and dealt in WP4 Subtask4.1.3 & WP4 Task4.4.

c) Report Irregularities

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Report Irregularities: Timers Overrun for G2 Lines
UC ID	UC_WP4_**4.1.1_070**
Main actor	Control Management of Level Crossing
Other actors	Controlling Entities (integrated IXL+RBC, etc.)
Main goal	Detection of occurrence of Timer Overruns and Report to Controlling Entities, i.e. Closure Timer of Level Crossing.
Assumptions	Usage of an open standardized G2 Lines Interface specification (including EULYNX SCI-LC, if required by the Infrastructure Manager).
Precondition	• Level Crossing System is configured to use certain Timers for Controlling. • Level Crossing System is in Operational State.
Flow of events	Detection and report of Timer Overruns: 1) Level Crossing System detects that Timers periods has exceeded. 2) Level Crossing System reports to Controlling Entities, that the Timers has exceeded. 3) Level Crossing System validate if certain Timer Overrun is critical or non-critical. 4) Level Crossing System reports to Controlling Entities the result of validation.
Postcondition	If Timer Overrun is critical, the Level Crossing system goes into Fallback-Mode.
Safety relation	YES
Open topics / consideration	Validation of what is critical and non-critical depends on national regulations.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Report Irregularities: Report of Detected Failures for G2 Lines
UC ID	UC_WP4_**4.1.1_071**
Main actor	Control Management of Level Crossing
Other actors	Protection Facilities, Controlling Entities (integrated IXL+RBC, etc.)
Main goal	Inform Controlling Entities about failures of Protection Facilities.
Assumptions	Usage of an open standardized G2 Lines Interface specification (including EULYNX SCI-LC, if required by the Infrastructure Manager).
Precondition	Level Crossing System is in Operational State.
Flow of events	General Flow of events for reporting of detected failures: 1) Level Crossing System receives status of protection facilities 2) Level Crossing System evaluates the received statuses and determines if statuses are properly or improperly 3) If one or more statuses are improperly, the Level Crossing System derives a critical or non-critical fault condition from this 4) Level Crossing System reports to Controlling Entities the failure with information about cause and categorisation of failure
Postcondition	If the failure is critical, the Level Crossing System changes into Fallback-Mode.
Safety relation	YES
Open topics / consideration	Evaluation of what is critical and non-critical failure depends on national regulations for roads traffic management and safety. Power Management of Level Crossing by local energy supply system.

d) Level Crossing Operation Modes

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Level Crossing Operation Mode: Enabling Local Operation for G2 Lines
UC ID	UC_WP4_**4.1.1_080**
Main actor	Control Management of Level Crossing
Other actors	Local Operator, Controlling Entities (integrated IXL+RBC, etc.)
Main goal	Enabling Local Operation Mode, which implies the handover from controlling Entity-controlled mode to Local Operation Mode.
Assumptions	Usage of an open standardized G2 Lines Interface specification (including EULYNX SCI-LC, if required by the Infrastructure Manager).
Precondition	• Level Crossing System is configured to use Local Operation. • Level Crossing System is in Operational State and controlled by a Controlling Entity.
Flow of events	Enabling Local Operation Mode: 1) Level Crossing System receives the request to handover of Local Operation Mode by Local Operator. 2) Level Crossing System reports the request of handover to Controlling Entities. 3) Level Crossing System receives the establishment for handover by Controlling Entity. 4) Level Crossing System reports the establishment for handover to Local Operator.
Postcondition	Local Operation Mode is enabled. Local Operator is in charge of activating and deactivating the protection facilities of Level Crossing.
Safety relation	YES
Open topics / consideration	-

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Level Crossing Operation Mode: Disabling Local Operation for G2 Lines
UC ID	UC_WP4_**4.1.1_081**
Main actor	Control Management of Level Crossing
Other actors	Controlling Entities (integrated IXL+RBC, etc.),Local Operator
Main goal	Disabling Local Operation Mode, which implies the return of handover from Local Operation Mode to (integrated IXL+RBC, etc.)-controlled mode.
Assumptions	Usage of an open standardized G2 Lines Interface specification (including EULYNX SCI-LC, if required by the Infrastructure Manager).
Precondition	• Level Crossing System is configured to use Local Operation. • Level Crossing System is in Operational State and in Local Operation Mode.
Flow of events	Disabling Local Operation Mode: 1) Level Crossing System receives the input from Local Operator to return handover of the local operation. 2) Level Crossing System reports to the Controlling Entity, that the Local Operator has returned the handover of local operations. 3) Level Crossing System receives the confirmation from Controlling Entity, that the handover of local operation is returned. 4) Level Crossing System reports to Local Operator, that the handover of the local operation has returned.
Postcondition	Local Operation Mode is disabled and Level Crossing System is controlled by Controlling Entities. Local Operator isn't in charge of activating and deactivating the protection facilities anymore.
Safety relation	YES
Open topics / consideration	-

4.2.3 About Wireless Connection

The following Use Cases deal with the use of wireless communication technology in the context of specific Wayside Assets. These Use Cases were identified and aligned in collaboration with Task4.2 about track-to-track communication and track-to-field communication [REF.4, REF.5]

Rationale and Assumptions:

The use of wireless communication technology for Wayside Assets like Level Crossings and Switches varies depending on the deployment type and integration options, leading to following assumption.

- In brownfield deployments, existing wayside assets are generally connected through wired connections such as copper or fibre optics. For financial and sustainability reasons, wireless communication technology is not intended to replace these wired connections. Instead, it serves as a fallback solution in case of cable failures, disruptions, or theft, ensuring higher availability and reliability of the Wayside Assets. This approach can help to reduce OPEX by minimize costs associated with the failure and maintenance of the existing wired connections.
- In greenfield deployments, where any existing installations are not present, the wireless communication technology is promoted as the preferred and primary transmission method. This approach can help to reduce CAPEX and OPEX to mitigate the drawbacks and vulnerabilities of wired transmission, such as the higher costs associated with installation, construction and maintenance.

Due to the lack of sufficient information regarding the potential impact of implementing wireless communication technology in the retrofitting of brownfield deployments on actual OPEX cost reduction, it is assumed that the focus will be directed towards greenfield deployments, where a significantly greater cost reduction is anticipated.

It is further assumed that the Object Controller, responsible for controlling and monitoring the field devices, is positioned in close proximity to the field devices. Based on this assumption, wired transmission remains the preferred and utilized for communication between these components. Consequently, wireless communication technology should primary be employed for communication between the Controlling Entity (Interlocking for G1 lines and combined Interlocking and Radio Block Centre for G2 lines) and the Object Controller, as these components are typically situated at greater distances, leading to higher cost for wired implementation.

Based on these assumptions, the following architectures for G1 lines and G2 lines are derived from those defined in Task4.2

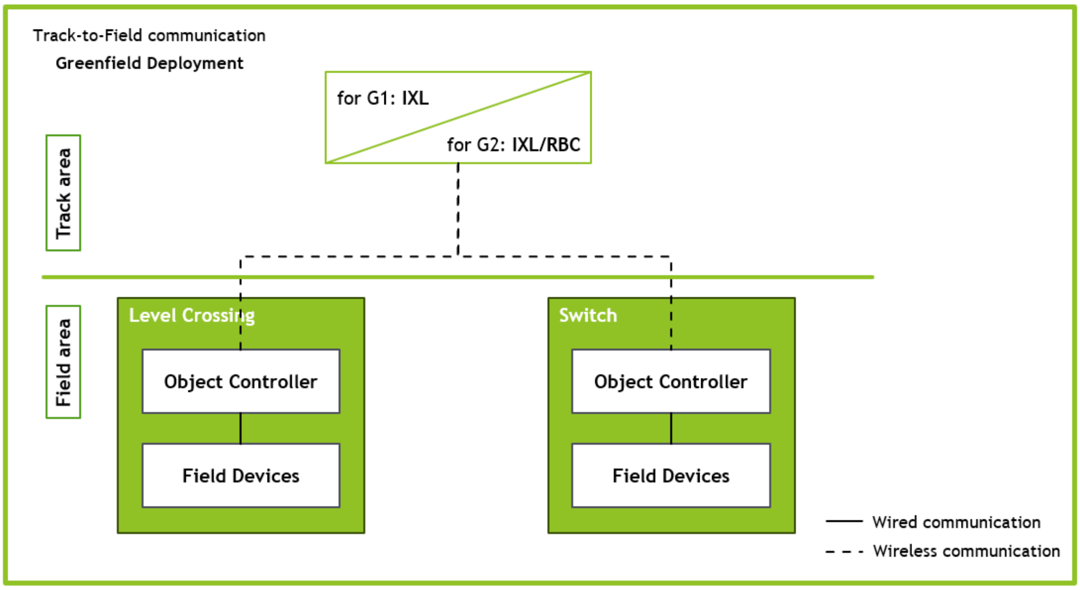


Figure 5: Envisioned architecture for wireless communication technology at Greenfield Deployment

Based on these assumptions, the following use cases have been identified as relevant for Task4.1, with the referenced use cases having been developed by Task4.2:

Table 7: Identified Use Cases from Task 4.2 as relevant for Task4.1

Identifier	Description
From Task4.2.2 [2]	
UC_WP4_4.2.2_006	Level Crossing is set to a defined state
UC_WP4_4.2.2_001	Point Machine is set to a defined position

4.2.4 About Energy Self-Sufficient

Assumptions and Rationale

1. Three **potential sources of energy** are considered:
    - Grid
    - Renewable Source (e.g. solar panels)
    - Batteries

   The possible combination of these 3 sources have been analysed, concluding as the next table summarises:

Table 8: Assumptions & Rational for Subtasks 4.1.1 and 4.1.2 (Energy Self-Sufficient)

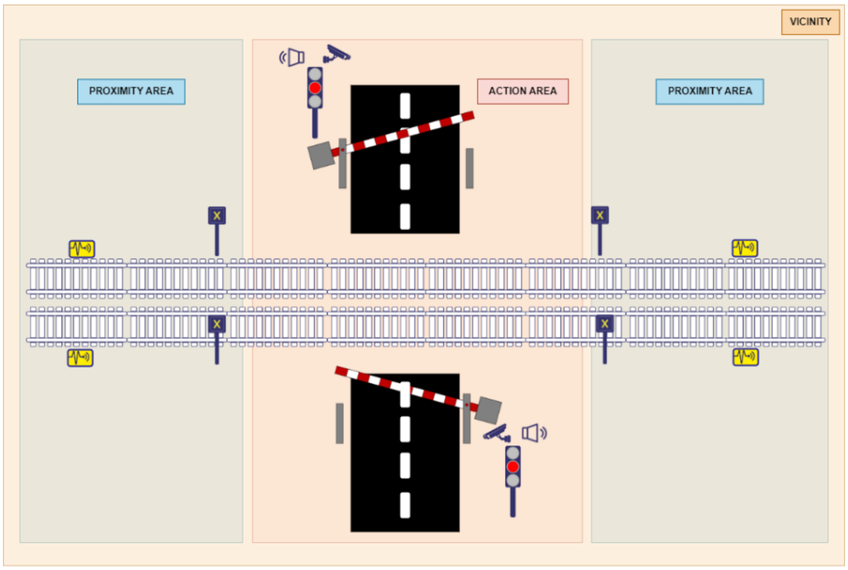
	Grid	Renewable	Battery	Conclusion
a.			X	Not recommended option, although some UC and requirements will be proposed. The batteries are intended to provide energy as backup during a determined period of time (e.g. 24h, 48h, etc.). Whether they are to be used as the only source of energy, they will have to be robust enough because if the battery is discharged, it has to be replaced by another one, which would significantly increase the maintenance costs of the product.
b.		X	X	Most preferable option. The asset is to be powered by renewable energy as its primary source, complemented by a backup from the battery. Typically, the asset relies on renewable energy, seamlessly switching to the battery as an alternative source if renewable energy becomes unavailable.
c.	X		X	The asset is to be powered by the grid as its primary source, complemented by a backup from the battery. Typically, the asset relies on the grid, seamlessly switching to the battery as an alternative source if grid energy becomes unavailable.
d.	X	X	X	The asset is to be powered by a combination of grid and renewable energy, with renewable energy as the primary source. In case of insufficient renewable energy, it is complemented with grid energy. If this combination of grid and renewable energy becomes unavailable, the system seamlessly switches to the battery as a backup power source.
e.		X		Not considered option. Always a battery (as backup) will need to be installed.
f.	X			
g.	X	X		

2. The LX are to be installed **always with battery** because in low density traffic areas, issues with the power grid may occur.

3. The **battery is charged constantly** from the energy provided by the grid and/or by the renewable sources.
4. The LX does always use as first the source of energy (whatever it is, either grid or renewable) and if not available, then uses the **battery as backup**.
5. LX **safe state** implies to lay down the barriers ((if barriers are installed), due to the gravity) and to switch-off the light signals.
   In case LX does not have barrier(s), the light signals must be equipped with their own battery as a backup to ensure the lights remain switched on.
6. LX in **stand-by** implies to keep the barriers open (if installed) and to switch-off the light signals.

Concepts (alphabetical order)

- ACTION AREA: Area where the LX is located; its length that covering the crossing area between the road and the railway line.
- BACKUP (SOURCE OF ENERGY): Refers to the role that the battery plays as source of energy.
- COMPLEMENTARY SOURCE OF ENERGY: Source of energy that provides additional power to the primary one, when necessary.
- PRIMARY SOURCE OF ENERGY: First source of energy providing power to the asset.
- PROXIMITY AREA: Area in the surroundings of the LX, where a train is identified as approaching to the LX.
- VICINITY: Surrounding, proximity, etc. of the LX.



Use Cases Groups

The Use Cases have been defined using three main criteria:

a) the combination of sources of energy, coming from the table above (from row a to d), and
b) the source of energy working as primary, and
c) the LX status, either in stand-by (no train in the vicinity) or in operation (because of a train in the vicinity)

The next picture presents all the Use Cases identified for this function. These UC will be used as basis to derive requirements.

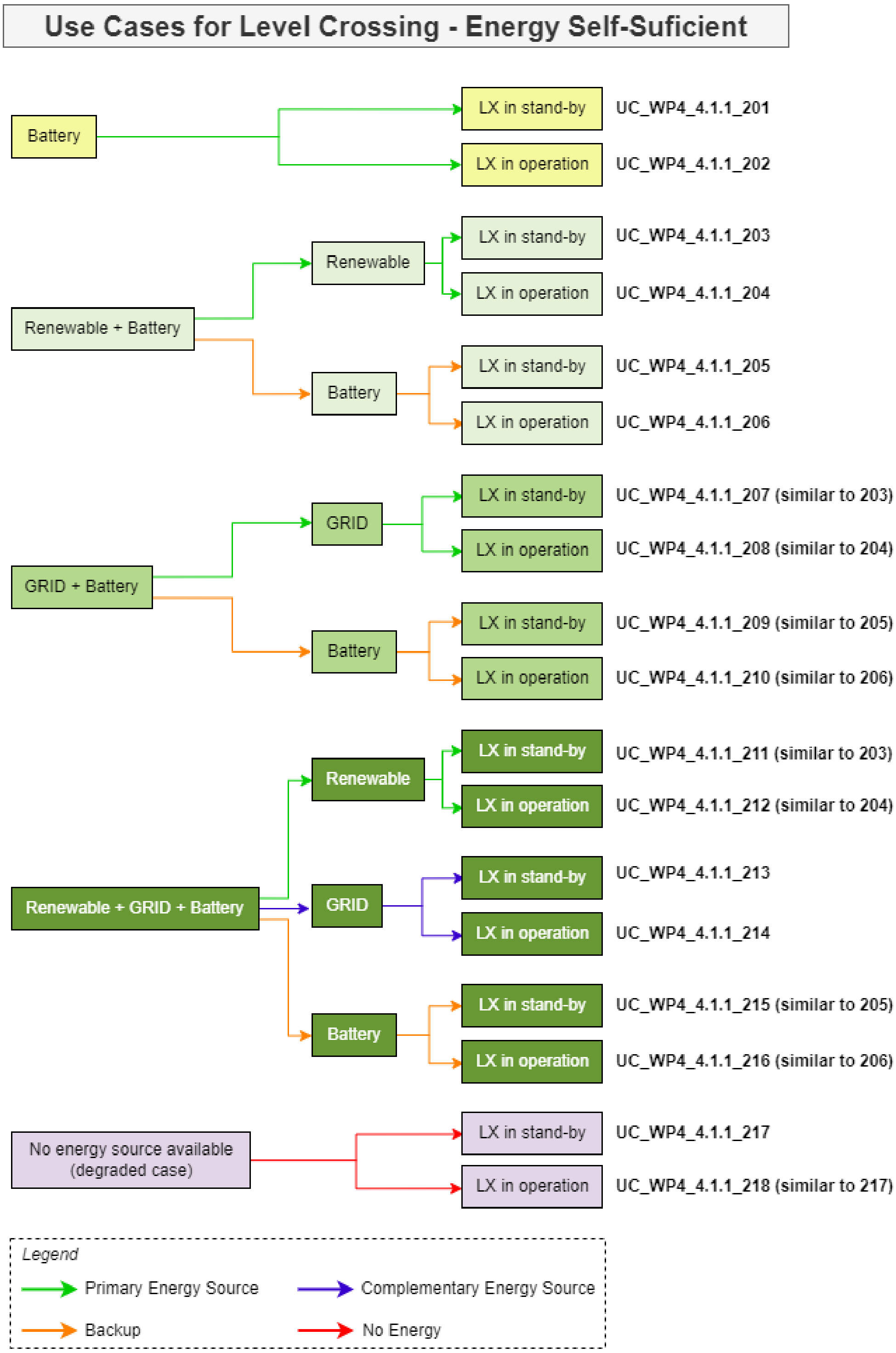


Figure 6: Use Cases for LX – Energy Self-Sufficient

Use Cases

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Battery (only source of energy) – LX in Stand-by
UC ID	UC_WP4_**4.1.1_201**
Main actor	LX
Other actors	None
Main goal	LX remains in stand-by using the energy stored in the battery.
Assumptions	LX only is configured only with battery.
Precondition	Battery is enough charged.
Flow of events	1. LX gets the sufficient energy to remain in stand-by from the battery.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	Remark: UC and requirements will be defined for this scenario, but this situation will not be further implemented in the demonstrator of WP9. Among others, the reasons are: • The type/technology of batteries (UPS) for signalling installations require more time for charging that the autonomous use that they provide – around 5 times more: for example, for 2h of autonomous use, may be needed 10h of charging); • At then, to recharge the battery is needed another source of energy, so if that source of energy is available, it can be used as primary source at the same time that is charging the batteries.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Battery (only source of energy) – LX in Operation
UC ID	UC_WP4_**4.1.1_202**
Main actor	LX
Other actors	Train
Main goal	LX operates properly using the energy stored in the battery.
Assumptions	LX only is configured only with battery.
Precondition	Battery is enough charged.
Flow of events	1. LX gets the sufficient energy from the battery to perform the appropriate actions (e.g. lay down the barriers, raise the sounding system, switch-on signals, etc.) depending on the train position.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	Equal to UC_WP4_**4.1.1_201**.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Renewable (working) + Battery (backup) – LX in Stand-by
UC ID	UC_WP4_**4.1.1_203**
Main actor	LX
Other actors	None
Main goal	LX remains in stand-by using renewable energy.
Assumptions	LX only is configured with 2 energy sources, renewable energy that comes from solar panels and a battery.
Precondition	• Solar panels are working (it is a sunny day) and there is no need of battery. • No train in the vicinity.
Flow of events	1. Renewable energy continuously charges the battery while this is not fully charged. 2. LX gets the sufficient energy to remain in stand-by for the solar panels.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	None.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Renewable (working) + Battery (backup) – LX in Operation
UC ID	UC_WP4_**4.1.1_204**
Main actor	LX
Other actors	Train
Main goal	LX operates properly using renewable energy.
Assumptions	LX only is configured with 2 energy sources, renewable energy that comes from solar panels and a battery.
Precondition	• Solar panels are working (it is a sunny day) and there is no need of battery. • There is a train in the vicinity, so the LX needs to operate.
Flow of events	1. Renewable energy continuously charges the battery while this is not fully charged. 2. LX gets the sufficient energy from the renewable source to perform the appropriate actions (e.g. lay down the barriers, raise the sounding system, switch-on signals, etc.).depending on the train position.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) When the train is in the proximity area. b) When the train is in the action area. c) When the train has left the action area.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Renewable (not working) + Battery (backup and working) – LX in Stand-by
UC ID	UC_WP4_**4.1.1_205**
Main actor	LX
Other actors	None
Main goal	LX remains in stand-by using the energy stored in the battery.
Assumptions	LX only is configured with 2 energy sources, renewable energy that comes from solar panels and a battery.
Precondition	• Solar panels are not working (e.g., during nights or because of an incident), so there is need of using the battery. • Battery is enough charged. • No train in the vicinity.
Flow of events	1. LX gets the sufficient energy to remain in stand-by from the battery. 2. If the renewable source starts providing energy but this is insufficient, the LX shall continue using the battery as complement; while if the renewable energy is enough, then the behaviour shall transit to UC_WP4_**4.1.1_203**.
Postcondition	Same as “Main goal”.
Safety relation	Not identified.
Open topics / consideration	None.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Renewable (not working) + Battery (backup and working) – LX in Operation
UC ID	UC_WP4_**4.1.1_206**
Main actor	LX
Other actors	Train
Main goal	LX operates properly using the energy stored in the battery.
Assumptions	LX only is configured with 2 energy sources, renewable energy that comes from solar panels and a battery.
Precondition	• Solar panels are not working (e.g., during nights or because of an incident), so there is need of using the battery. • Battery is enough charged. • There is a train in the vicinity, so the LX needs to operate.
Flow of events	1. LX gets the sufficient energy from the battery to perform the appropriate actions (e.g. lay down the barriers, raise the sounding system, switch-on signals, etc.).depending on the train position. 2. If the renewable source starts providing energy but it is insufficient, the LX shall continue using the battery as complement; while if the renewable energy is enough, then the behaviour shall transit to UC_WP4_**4.1.1_204**.
Postcondition	Same as “Main goal”.
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) When the train is in the proximity area. b) When the train is in the action area. c) When the train has left the action area.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Grid (working) + Battery (backup) – LX in Stand-by
UC ID	UC_WP4_**4.1.1_207**
Main actor	LX
Other actors	None
Main goal	LX remains in stand-by using grid energy.
Assumptions	LX only is configured with 2 energy sources, grid energy and a battery.
Precondition	• Grid is working and there is no need of battery. • No train in the vicinity.
Flow of events	1. Grid energy continuously charges the battery while this is not fully charged. 2. LX gets the sufficient energy to remain in stand-by from the grid.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	None.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Grid (working) + Battery (backup) – LX in Operation
UC ID	UC_WP4_**4.1.1_208**
Main actor	LX
Other actors	Train
Main goal	LX operates properly using grid energy.
Assumptions	LX only is configured with 2 energy sources, grid energy and a battery.
Precondition	• Grid is working and there is no need of battery. • There is a train in the vicinity, so the LX needs to operate.
Flow of events	1. Grid energy continuously charges the battery while this is not fully charged. 2. LX gets the sufficient energy from the grid to perform the appropriate actions (e.g. lay down the barriers, raise the sounding system, switch-on signals, etc.).depending on the train position.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) When the train is in the proximity area. b) When the train is in the action area. c) When the train has left the action area.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Grid (not working) + Battery (backup and working) – LX in Stand-by
UC ID	UC_WP4_**4.1.1_209**
Main actor	LX
Other actors	None
Main goal	LX remains in stand-by using the energy stored in the battery.
Assumptions	LX only is configured with 2 energy sources, grid and a battery.
Precondition	• Grid is not working, so there is need of using the battery. • Battery is enough charged. • No train in the vicinity.
Flow of events	1. LX gets the sufficient energy to remain in stand-by from the battery. 2. If the grid source becomes available, then the behaviour shall transit to UC_WP4_**4.1.1_207**.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	None.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Grid (not working) + Battery (backup and working) – LX in Operation
UC ID	UC_WP4_**4.1.1_210**
Main actor	LX
Other actors	Train
Main goal	LX operates properly using the energy stored in the battery.
Assumptions	LX only is configured with 2 energy sources, grid and a battery.
Precondition	• Grid is not working, so there is need of using the battery. • Battery is enough charged. • There is a train in the vicinity, so the LX needs to operate.
Flow of events	1. LX gets the sufficient energy from the battery to perform the appropriate actions (e.g. lay down the barriers, raise the sounding system, switch-on signals, etc.).depending on the train position. 2. If the grid source becomes available, then the behaviour shall transit to UC_WP4_**4.1.1_208**.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) When the train is in the proximity area. b) When the train is in the action area. c) When the train has left the action area.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Renewable (working) + Grid (as complement) + Battery (backup) – LX in Stand-by
UC ID	UC_WP4_**4.1.1_211**
Main actor	LX
Other actors	None
Main goal	LX remains in stand-by using renewable energy.
Assumptions	LX only is configured with 3 energy sources, renewable energy that comes from solar panels, grid as complementary source and a battery.
Precondition	• Solar panels are working (it is a sunny day) and there is no need of grid or battery. • No train in the vicinity.
Flow of events	Equal to UC_WP4_**4.1.1_203**.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	None.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Renewable (working) + Grid (as complement) + Battery (backup) – LX in Operation
UC ID	UC_WP4_**4.1.1_212**
Main actor	LX
Other actors	Train
Main goal	LX operates properly using renewable energy.
Assumptions	LX only is configured with 3 energy sources, renewable energy that comes from solar panels, grid as complementary source and a battery.
Precondition	• Solar panels are working (it is a sunny day) and there is no need of grid or battery. • There is a train in the vicinity, so the LX needs to operate.
Flow of events	Equal to UC_WP4_**4.1.1_204**.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) When the train is in the proximity area. b) When the train is in the action area. c) When the train has left the action area.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Renewable (not enough) + Grid (complementing) + Battery (backup) – LX in Stand-by
UC ID	UC_WP4_**4.1.1_213**
Main actor	LX
Other actors	None
Main goal	LX remains in stand-by using a combination of renewable and grid.
Assumptions	LX only is configured with 3 energy sources, renewable energy that comes from solar panels, grid as complementary source and a battery.
Precondition	• Solar panels are not providing as many energy as necessary, so the grid complements to get the required amount; there is no need of battery. • No train in the vicinity.
Flow of events	1. The combination of renewable and grid energy continuously charges the battery while this is not fully charged. 2. LX gets the sufficient energy from that combined sources to remain in stand-by.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	None.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Renewable (not enough) + Grid (complementing) + Battery (backup) – LX in Operation
UC ID	UC_WP4_**4.1.1_214**
Main actor	LX
Other actors	Train
Main goal	LX operates properly by using a combination of renewable and grid.
Assumptions	LX only is configured with 3 energy sources, renewable energy that comes from solar panels, grid as complementary source and a battery.
Precondition	• Solar panels are not providing as many energy as necessary, so the grid complements to get the required amount; there is no need of battery. • There is a train in the vicinity, so the LX needs to operate.
Flow of events	1. The combination of renewable and grid energy continuously charges the battery while this is not fully charged. 2. LX gets the sufficient energy from that combination of sources to perform the appropriate actions (e.g. lay down the barriers, raise the sounding system, switch-on signals, etc.).depending on the train position.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) When the train is in the proximity area. b) When the train is in the action area. c) When the train has left the action area.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Renewable (not working) + Grid (not working) + Battery (backup and working) – LX in Stand-by
UC ID	UC_WP4_**4.1.1_215**
Main actor	LX
Other actors	None
Main goal	LX remains in stand-by using the energy stored in the battery.
Assumptions	LX only is configured with 3 energy sources, renewable energy that comes from solar panels, grid as complementary source and a battery.
Precondition	• Solar panels are not working (e.g., during nights or because of an incident), and the grid is not available to complement the demanded energy so there is need of using the battery. • Battery is enough charged. • No train in the vicinity.
Flow of events	1. LX gets the sufficient energy to remain in stand-by from the battery. 2. If only grid or both grid and renewable energy become available, then the behaviour shall transit to UC_WP4_**4.1.1_211** or UC_WP4_**4.1.1_213** depending on the situation. 3. If only renewable energy becomes available, the LX shall use the battery to complement the remain energy if necessary.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	None.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Renewable (not working) + Grid (not working) + Battery (backup and working) – LX in Operation
UC ID	UC_WP4_**4.1.1_216**
Main actor	LX
Other actors	Train
Main goal	LX operates properly using the energy stored in the battery.
Assumptions	LX only is configured with 3 energy sources, renewable energy that comes from solar panels, grid as complementary source and a battery.
Precondition	• Solar panels are not working (e.g., during nights or because of an incident), and the grid is not enough to complement the demanded energy so there is need of using the battery. • Battery is enough charged. • There is a train in the vicinity, so the LX needs to operate.
Flow of events	1. LX gets the sufficient energy to remain in stand-by from the battery. 2. If only grid or both grid and renewable energy become available, then the behaviour shall transit to UC_WP4_**4.1.1_212** or UC_WP4_**4.1.1_214** depending on the situation. 3. If only renewable energy becomes available, the LX shall use the battery to complement the remain energy if necessary.
Postcondition	Same as “Main goal”.
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) When the train is in the proximity area. b) When the train is in the action area. c) When the train has left the action area.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	No energy source available – LX in Stand-by
UC ID	UC_WP4_**4.1.1_217**
Main actor	LX
Other actors	None
Main goal	From stand-by, go to safe state.
Assumptions	Any of the four (a-d) described in the "Open topics / consideration" row.
Precondition	No train in the vicinity.
Flow of events	1. Suddenly, all the sources of energy stop working. 2. LX goes to safe state. 3. When any/all source of energy is available again, the LX shall transit to the appropriate UC based on its configuration.
Postcondition	Same as "Main goal".
Safety relation	Yes.
Open topics / consideration	The case must be proven under the following circumstances: a) For only Battery available. b) For Renewable + Battery configuration. c) For Grid + Battery configuration. d) For Renewable + Grid + Battery configuration.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	No energy source available – LX in Operation
UC ID	UC_WP4_**4.1.1_218**
Main actor	LX
Other actors	Train
Main goal	From operation, go to safe state.
Assumptions	Any of the twelve (a-d) described in the “Open topics / consideration” row.
Precondition	There is a train in the vicinity, so the LX needs to operate.
Flow of events	Equal to UC_WP4_**4.1.1_217**.
Postcondition	Same as “Main goal”.
Safety relation	Yes.
Open topics / consideration	The case must be proven under the following circumstances: a) For only Battery available: i. When the train is in the proximity area. ii. When the train is in the action area. iii. When the train has left the action area. b) For Renewable + Battery configuration: i. When the train is in the proximity area. ii. When the train is in the action area. iii. When the train has left the action area. c) For Grid + Battery configuration: i. When the train is in the proximity area. ii. When the train is in the action area. iii. When the train has left the action area. d) For Renewable + Grid + Battery configuration: i. When the train is in the proximity area. ii. When the train is in the action area. iii. When the train has left the action area.

4.2.5 About Remote Maintenance

Assumptions and Rationale

Remote maintenance can be used for 2 different purposes:
- Diagnosis
- Maintenance

1. About **diagnosis**, 4 different types of data can be accessed:
   - Memory Data (Raw)
   - Configuration Data (Processed)
   - On-time Events Data (Processed)
   - Historical Events Data (Processed)
   Note: 'Raw' data refers to unprocessed or original data as it was initially collected, while 'Processed' data has been transformed for easier interpretation and use.

   These types of data can be transmitted through the following 3 mechanisms:
   - Under Demand
   - Dump Transmission
   - Subscription

2. About **maintenance**, 3 types of items can be updated:
   - Software
   - Software Data
   - Operational Data

   There is only one mechanism to update items; it is mainly to send the information from a Maintenance Terminal; optionally, the asset may acknowledge the reception of such information.

In short, the next figure and the next table, summaries the possible combinations related to remote maintenance; please note the meaning of the X in the table as:
- X : Asset shall mandatorily implement such combination
- [X]: Asset shall optionally implement such combination

Table 9: Assumptions & Rational for Subtasks 4.1.1 and 4.1.2 (Remote Maintenance)

	Mechanism	Types of Data				Types of Item		
		Memory Data	Configuration Data	On-time Events Data	Historical Events Data	SW	SW Data	Operational Data
Diagnosis	Under Demand	X	X	X	X			
	Dump Transmission	[X]	[X]	X				
	Subscription			X	[X]			
Maintenace	Update					X	X	X

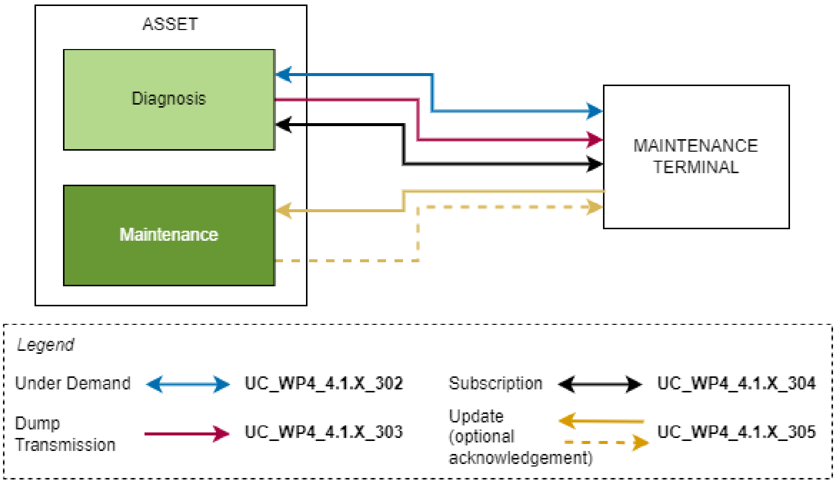


Figure 7: Assumptions and Rational for Subtasks 4.1.1 and 4.1.2 (about Remote Maintenance)

Concepts (alphabetical order)

- CONFIGURATION DATA: Processed data, answering a given demand; e.g., current SW version installed in the asset.
- DUMP TRANSMISSION: Asset provides data constantly (either at regular time intervals or when an event happens).
- HISTORICAL EVENTS DATA: Same than On-time, but between two dates/times.
- MEMORY DATA: Raw data, without any type of interpretation. Usually is to be demanded between two memory addresses.
- ON-TIME EVENTS DATA: Processed data, providing any of the events previously agreed with the Maintenance Terminal; e.g., current asset state, current temperature, etc.
- OPERATIONAL DATA: Set of variables used to express the state of the asset; e.g., number of movements performed, number of manual interventions, current energy consumption, etc.
- SOFTWARE: Compiled source code that execute a given function.
- SOFTWARE DATA: Data to configure the SW and let it works correctly; e.g., IP address, number of elements to control, etc.
- SUBSCRIPTION: Asset provides data on a scheduled basis.
- UNDER DEMAND: Asset provides data when the Maintenance Terminal asks for it.
- UPDATE: The Maintenance Terminal send information to update any item to the asset.

Use Cases Groups

The Use Cases have been defined using three main criteria:

a) distinguishing between either diagnosis or maintenance, and
b) the type of data/item to be provided/updated, and
c) identifying the mechanism used

The next picture presents all the Use Cases identified for this function. These UC will be used as basis to derive requirements.

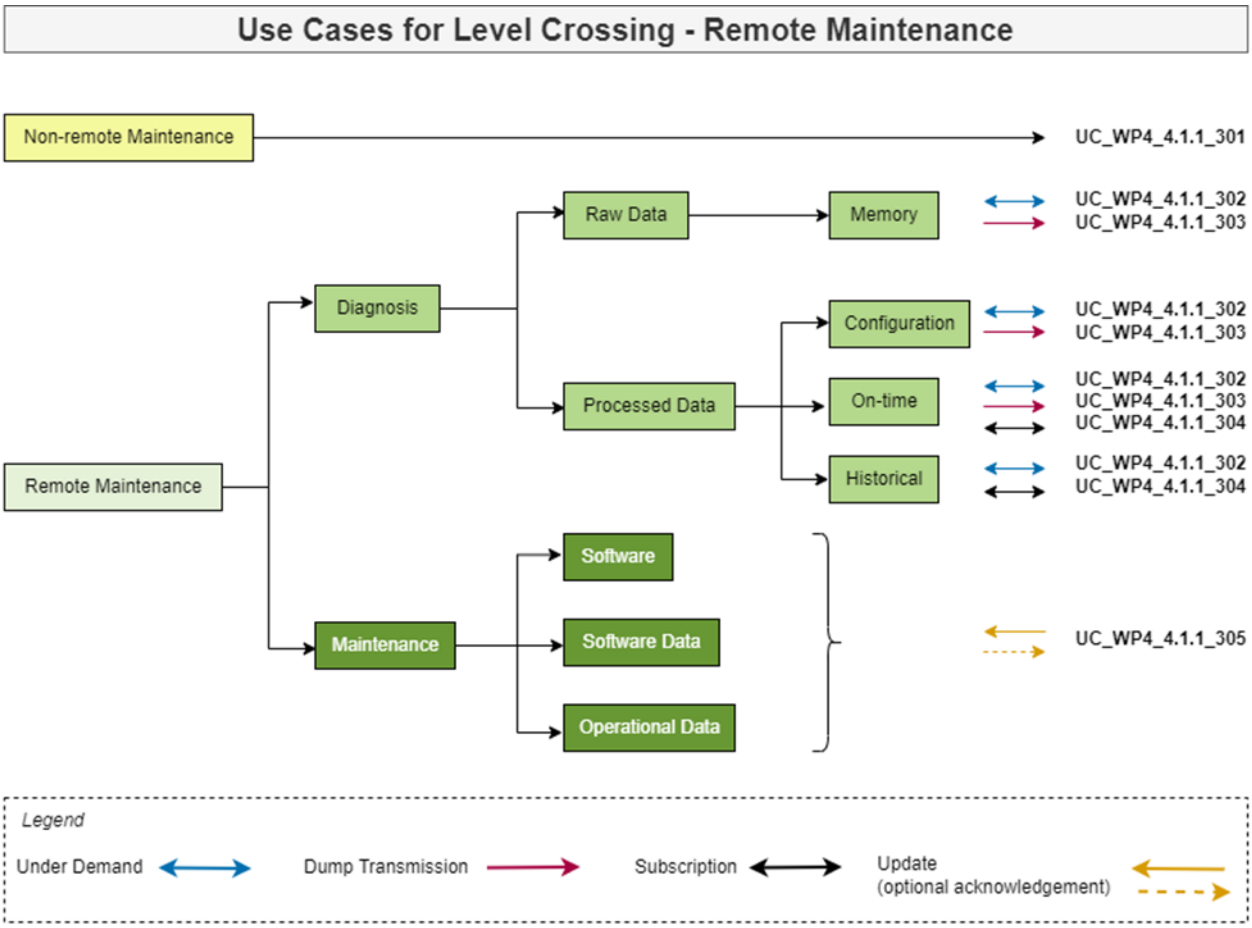


Figure 8: Use Cases for LX – Remote Maintenance

Use Cases

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Non-remote Maintenance
UC ID	UC_WP4_**4.1.1_301**
Main actor	LX
Other actors	Maintenance Terminal
Main goal	No-remote maintenance serves as the backup for not having remote maintenance. No-remote maintenance should allow to perform the same actions than the ones allowed by the remote facility.
Assumptions	There is no possibility to perform any remote maintenance.
Precondition	There is no possibility to perform any remote maintenance.
Flow of events	Out of the scope of this document.
Postcondition	None.
Safety relation	Not identified.
Open topics / consideration	Remark: UC and requirements will be defined for this scenario, but this situation will not be further implemented in the demonstrator of WP9.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Diagnosis – Acquisition of data **Under Demand**
UC ID	UC_WP4_**4.1.1_302**
Main actor	LX
Other actors	Maintenance Terminal
Main goal	LX provides data for diagnosis under demand.
Assumptions	LX is configured to provide the following types of data under demand: • Memory (Raw) • Configuration (Processed) • On-time Events (Processed) • Historical Events(Processed)
Precondition	The LX and the Maintenance Terminal are previously and well configured and both know the data to be exchanged.
Flow of events	1. Maintenance Terminal demands memory data for diagnosis, between two memory addresses. 2. LX provides Memory Data.
Postcondition	Same as “Main goal”.
Safety relation	Not identified.
Open topics / consideration	The case must be proven with the LX providing the following data: a) Configuration (requesting concrete data) b) On-time Events (requesting concrete events) c) Historical Events (requesting concrete events between two dates/times)

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Diagnosis – Acquisition of data through **Dump Transmission**
UC ID	UC_WP4_**4.1.1_303**
Main actor	LX
Other actors	Maintenance Terminal
Main goal	LX provides data for diagnosis through dump transmission.
Assumptions	• LX must be configured to provide on-time events data through dump transmission. • LX optionally can be configured to provide the following types of data through dump transmission: - Memory (Raw) - Configuration (Processed)
Precondition	The LX and the Maintenance Terminal are previously and well configured and both know the data to be sent by the asset and so received by the Maintenance Terminal.
Flow of events	1. LX continuously provides on-time events data through dump transmission.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	The case must be proven with the switch providing the following type of data if it is configured: a) Memory (Raw) b) Configuration (Processed)

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Diagnosis – Acquisition of data through **Subscription**
UC ID	UC_WP4_**4.1.1_304**
Main actor	LX
Other actors	Maintenance Terminal
Main goal	LX provides data for diagnosis through subscription.
Assumptions	• LX must be configured to provide on-time events data through subscription. • LX optionally can be configured to provide historical events data.
Precondition	• A subscription process shall have previously performed. • So, the LX and the Maintenance Terminal are previously and well configured and both know the data to be exchanged.
Flow of events	1. Maintenance Terminal subscribes to receive on-time event data for diagnosis. 2. LX provides on-time data based on the subscription.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	The case must be proven with the LX providing historical event data if it is configured.

Use Case Group	WP4 – Subtask 4.1.1
Use Case	Maintenance – Maintenance through **Update**
UC ID	UC_WP4_**4.1.1_305**
Main actor	LX
Other actors	Maintenance Terminal
Main goal	LX updates the following: - Software - Software Data - Operational Data
Assumptions	• LX must be configured to update the Software. • The LX can optionally be configured to provide an acknowledgement indicating that it has been updated successfully.
Precondition	The LX and the Maintenance Terminal are well configured and know the data to be exchanged.
Flow of events	1. Maintenance Terminal updates the Software. 2. Internally, the LX updates its Software. 3. If configured, the LX acknowledges the Software update.
Postcondition	Same as “Main goal”.
Safety relation	Not identified.
Open topics / consideration	The case must be proven updating the following: a) Software Data b) Operational Data

4.3 Reference Use Cases of wireless enabled energy self-sufficient Switches (Subtask 4.1.2)

4.3.1 About Configurability for different Track Gauges

No Uses Cases identified.

4.3.2 About Wireless Connection

See Section 3.2.2, which already includes the information for Switches.

4.3.3 About Energy Self-Sufficient

Assumptions and Rationale

1. Three **potential sources of energy** are considered (same as section 4.2.44.2.4)
2. The Switches are to be installed **always with battery** because in low density traffic areas, issues with the power grid may occur.
3. The **battery is charged constantly** from the energy provided by the grid and/or by the renewable sources.
4. The Switch does always use as first the source of energy (whatever it is, either grid or renewable) and if not available, then uses the **battery as backup**.
5. Switch **restricted state** implies that the point is marked as "Unlocked".

Concepts (alphabetical order)

- BACKUP (SOURCE OF ENERGY): Described in section 4.2.44.2.4.
- COMPLEMENTARY SOURCE OF ENERGY: Described in section 4.2.44.2.4.
- PRIMARY SOURCE OF ENERGY: Described in section 4.2.44.2.4.
- SET AND LOCKED: The Switch is able to guarantee its position.
  a. NOMINAL:

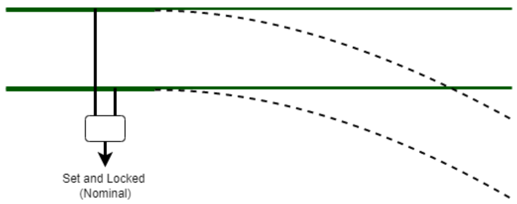


Figure 9: Switch Set and Locked NOMINAL

  b. REVERSE:

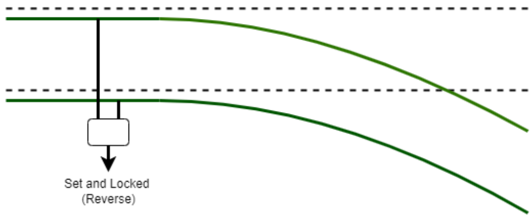


Figure 10: Switch Set and Locked REVERSE

- SWITCH MOVING: The Switch is not able to guarantee its position, because it is moving to reach one:

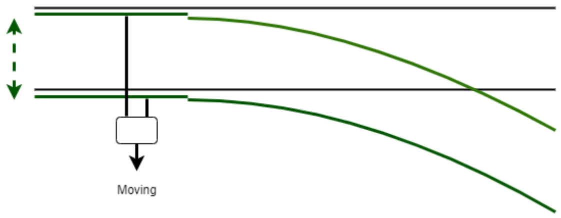


Figure 11: Switch MOVING

- UNLOCKED: The Switch is not able to guarantee its position, because of any unknow reason. This is considered the restricted state as well:

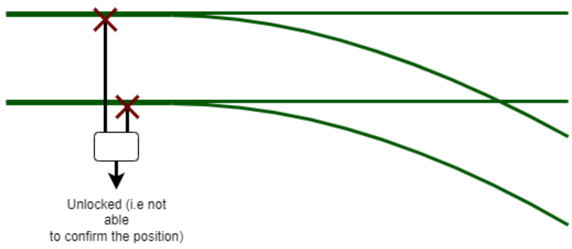


Figure 12: Switch UNLOCKED

<u>Use Cases Groups</u>

The Use Cases has been defined using three main criteria:

a) the combination of sources of energy, coming from the Table 8 (from row a to d), and
b) the source of energy working as primary, and
c) the Switch status (Nominal/Reverse or Moving).

The next picture presents all the Use Cases identified for this function. These UC will be used as basis to derive requirements.

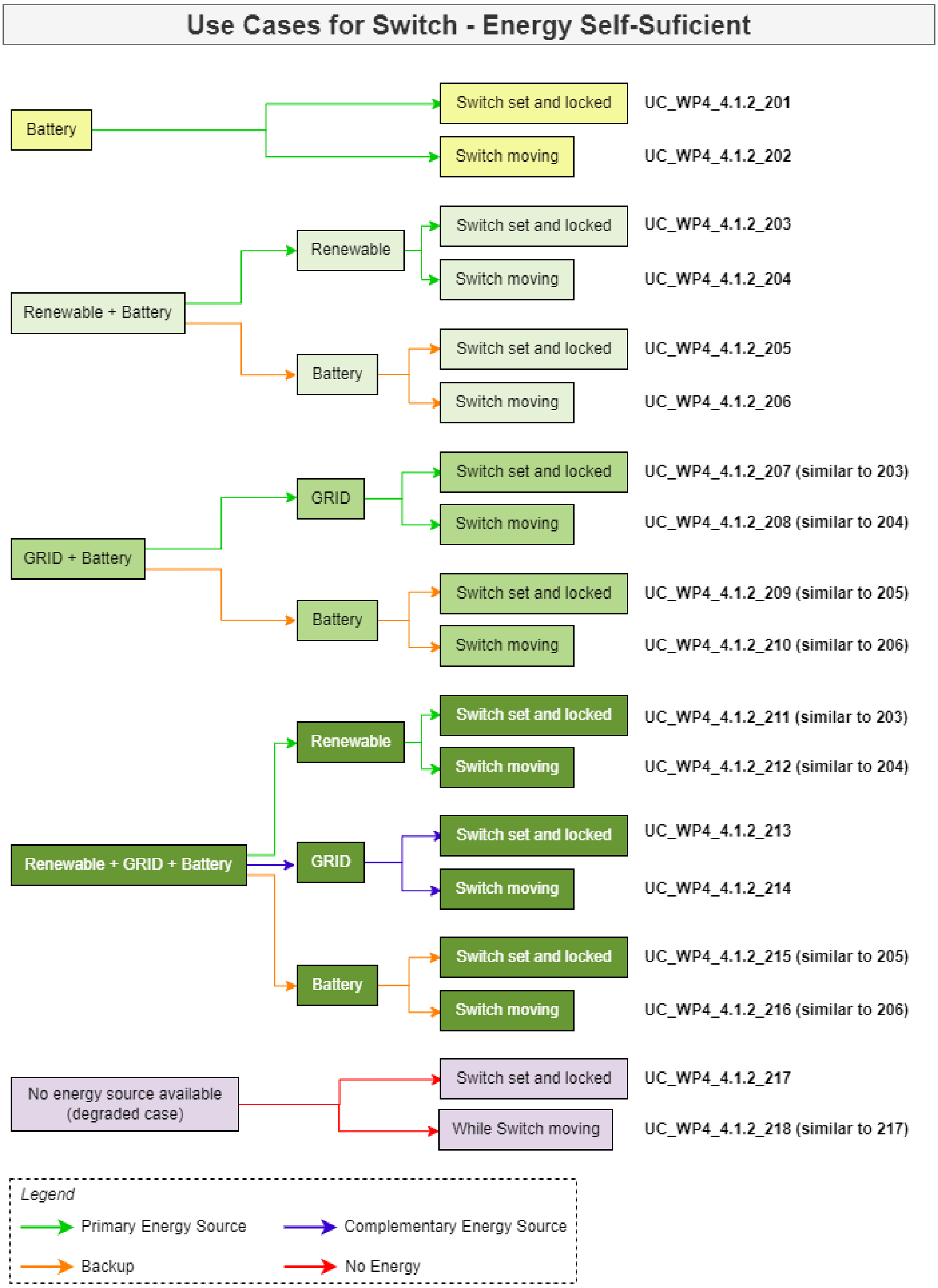


Figure 13: Use Cases for Switch – Energy Self-Sufficient

Use Cases

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Battery (only source of energy) – Switch Set and Locked
UC ID	UC_WP4_**4.1.2_201**
Main actor	Switch
Other actors	None
Main goal	Switch remains in set and locked position using the energy stored in the battery.
Assumptions	Switch is configured only with battery.
Precondition	Battery is enough charged.
Flow of events	1. Switch gets the sufficient energy to remain in the set and locked position from the battery.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	Equal to UC_WP4_**4.1.1_201**.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Battery (only source of energy) – Switch Moving
UC ID	UC_WP4_**4.1.2_202**
Main actor	Switch
Other actors	None
Main goal	Switch changes the position properly using the energy stored in the battery.
Assumptions	Switch is configured only with battery.
Precondition	Battery is enough charged.
Flow of events	1. Switch gets the sufficient energy to change its position from the battery.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	Equal to UC_WP4_**4.1.1_201**.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Renewable (working) + Battery (backup) – Switch Set and Locked
UC ID	UC_WP4_**4.1.2_203**
Main actor	Switch
Other actors	None
Main goal	Switch remains in set and locked position using renewable energy.
Assumptions	Switch only is configured with 2 energy sources, renewable energy that comes from solar panels and a battery.
Precondition	Solar panels are working (it is a sunny day) and there is no need of battery.
Flow of events	1. Renewable energy continuously charges the battery while this is not fully charged. 2. Switch gets the sufficient energy to remain in set and locked position for the solar panels.
Postcondition	Same as “Main goal”.
Safety relation	Not identified.
Open topics / consideration	In addition, the case must be proven when the switch is unlocked.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Renewable (working) + Battery (backup) – Switch Moving
UC ID	UC_WP4_**4.1.2_204**
Main actor	Switch
Other actors	None
Main goal	Switch changes the position properly using renewable energy.
Assumptions	Switch only is configured with 2 energy sources, renewable energy that comes from solar panels and a battery.
Precondition	Solar panels are working (it is a sunny day) and there is no need of battery.
Flow of events	1. Renewable energy continuously charges the battery while this is not fully charged. 2. Switch gets the sufficient energy to change its position from the battery.
Postcondition	Same as “Main goal”.
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) Switch changes from Reverse to Nominal position. b) Switch changes from Nominal to Reverse position.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Renewable (not working) + Battery (backup and working) – Switch Set and Locked
UC ID	UC_WP4_**4.1.2_205**
Main actor	Switch
Other actors	None
Main goal	Switch remains in set and locked position using the energy stored in the battery.
Assumptions	Switch only is configured with 2 energy sources, renewable energy that comes from solar panels and a battery.
Precondition	• Solar panels are not working (e.g., during nights or because of an incident), so there is need of using the battery. • Battery is enough charged.
Flow of events	1. Switch gets the sufficient energy to remain in set and locked position from the battery. 2. If the renewable source starts providing energy but this is insufficient, the switch shall continue using the battery as complement; while if the renewable energy is enough, then the behaviour shall transit to UC_WP4_**4.1.2_203**.
Postcondition	Same as “Main goal”.
Safety relation	Not identified.
Open topics / consideration	In addition, the case must be proven when the switch is unlocked.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Renewable (not working) + Battery (backup and working) – Switch Moving
UC ID	UC_WP4_**4.1.2_206**
Main actor	Switch
Other actors	None
Main goal	Switch changes the position properly using the energy stored in the battery.
Assumptions	Switch only is configured with 2 energy sources, renewable energy that comes from solar panels and a battery.
Precondition	• Solar panels are not working (e.g., during nights or because of an incident), so there is need of using the battery. • Battery is enough charged.
Flow of events	1. Switch gets the sufficient energy to change its position from the battery. 2. If the renewable source starts providing energy but this is insufficient, the switch shall continue using the battery as complement; while if the renewable energy is enough, then the behaviour shall transit to UC_WP4_**4.1.2_204**.
Postcondition	Same as “Main goal”.
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) Switch changes from Reverse to Nominal position. b) Switch changes from Nominal to Reverse position.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Grid (working) + Battery (backup) – Switch Set and Locked
UC ID	UC_WP4_**4.1.2_207**
Main actor	Switch
Other actors	None
Main goal	Switch remains in set and locked position using the grid energy.
Assumptions	Switch only is configured with 2 energy sources, grid energy and a battery.
Precondition	Grid is working, so there is no need of using the battery.
Flow of events	1. Grid energy continuously charges the battery while this is not fully charged. 2. Switch gets the sufficient energy to remain in set and locked position from the grid.
Postcondition	Same as “Main goal”.
Safety relation	Not identified.
Open topics / consideration	In addition, the case must be proven when the switch is unlocked.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Grid (working) + Battery (backup) – Switch Moving
UC ID	UC_WP4_**4.1.2_208**
Main actor	Switch
Other actors	None
Main goal	Switch changes the position properly using grid energy.
Assumptions	Switch only is configured with 2 energy sources grid energy and a battery.
Precondition	Grid is working and there is no need of battery.
Flow of events	1. Grid energy continuously charges the battery while this is not fully charged. 2. Switch gets the sufficient energy to change its position from the grid.
Postcondition	Same as “Main goal”.
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) Switch changes from Reverse to Nominal position. b) Switch changes from Nominal to Reverse position.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Grid (not working) + Battery (backup and working) – Switch Set and Locked
UC ID	UC_WP4_**4.1.2_209**
Main actor	Switch
Other actors	None
Main goal	Switch remains in set and locked position using the energy stored in the battery.
Assumptions	Switch only is configured with 2 energy sources, grid and a battery.
Precondition	• Grid is not working, so there is need of using the battery. • Battery is enough charged.
Flow of events	1. Switch gets the sufficient energy to remain in set and locked position from the battery. 2. If the grid source becomes available, then the behaviour shall transit to UC_WP4_**4.1.2_207**.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	In addition, the case must be proven when the switch is unlocked.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Grid (not working) + Battery (backup and working) – Switch Moving
UC ID	UC_WP4_**4.1.2_210**
Main actor	Switch
Other actors	None
Main goal	Switch changes the position properly using the energy stored in the battery.
Assumptions	Switch only is configured with 2 energy sources grid and a battery.
Precondition	• Grid is not working, so there is need of using the battery. • Battery is enough charged.
Flow of events	1. Switch gets the sufficient energy to change its position from the battery. 2. If the grid source becomes available, then the behaviour shall transit to UC_WP4_**4.1.2_208**.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) Switch changes from Reverse to Nominal position. b) Switch changes from Nominal to Reverse position.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Renewable (working) + Grid (as complement) + Battery (backup) – Switch Set and Locked
UC ID	UC_WP4_**4.1.2_211**
Main actor	Switch
Other actors	None
Main goal	Switch remains in set and locked position using renewable energy.
Assumptions	Switch only is configured with 3 energy sources, renewable energy that comes from solar panels, grid as complementary source and a battery.
Precondition	Solar panels are working (it is a sunny day) and there is no need of grid or battery.
Flow of events	Equal to UC_WP4_**4.1.2_203**.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	In addition, the case must be proven when the switch is unlocked.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Renewable (working) + Grid (as complement) + Battery (backup) – Switch Moving
UC ID	UC_WP4_**4.1.2_212**
Main actor	Switch
Other actors	None
Main goal	Switch changes the position properly using renewable energy.
Assumptions	Switch only is configured with 3 energy sources, renewable energy that comes from solar panels, grid as complementary source and a battery.
Precondition	Solar panels are working (it is a sunny day) and there is no need of grid or battery.
Flow of events	Equal to UC_WP4_**4.1.2_204**.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) Switch changes from Reverse to Nominal position. b) Switch changes from Nominal to Reverse position.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Renewable (not enough) + Grid (complementing) + Battery (backup) – Switch Set and Locked
UC ID	UC_WP4_**4.1.2_213**
Main actor	Switch
Other actors	None
Main goal	Switch remains in set and locked position using a combination of renewable and grid.
Assumptions	Switch only is configured with 3 energy sources, renewable energy that comes from solar panels, grid as complementary source and a battery.
Precondition	Solar panels are not providing as many energy as necessary, so the grid complements to get the required amount; there is no need of battery.
Flow of events	1. The combination of renewable and grid energy continuously charges the battery while this is not fully charged. 2. Switch gets the sufficient energy from that combined sources to remain in set and locked position.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	In addition, the case must be proven when the switch is unlocked.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Renewable (not enough) + Grid (complementing) + Battery (backup) – Switch Moving
UC ID	UC_WP4_**4.1.2_214**
Main actor	Switch
Other actors	None
Main goal	Switch changes the position properly using a combination of renewable and grid.
Assumptions	Switch only is configured with 3 energy sources, renewable energy that comes from solar panels, grid as complementary source and a battery.
Precondition	Solar panels are not providing as many energy as necessary, so the grid complements to get the required amount; there is no need of battery.
Flow of events	1. The combination of renewable and grid energy continuously charges the battery while this is not fully charged. 2. LX gets the sufficient energy from that combination of sources to change its position.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) Switch changes from Reverse to Nominal position. b) Switch changes from Nominal to Reverse position.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Renewable (not working) + Grid (not working) + Battery (backup and working) – Switch Set and Locked
UC ID	UC_WP4_**4.1.2_215**
Main actor	Switch
Other actors	None
Main goal	Switch remains in set and locked position the energy stored in the battery.
Assumptions	Switch only is configured with 3 energy sources, renewable energy that comes from solar panels, grid as complementary source and a battery.
Precondition	• Solar panels are not working (e.g., during nights or because of an incident), and the grid is not enough to complement the demanded energy so there is need of using the battery. • Battery is enough charged.
Flow of events	1. Switch gets the sufficient energy to remain in set and locked position from the battery. 2. If only grid or both grid and renewable energy become available, then the behaviour shall transit to UC_WP4_**4.1.2_211** or UC_WP4_**4.1.2_213** depending on the situation. 3. If only renewable energy becomes available, the switch shall use the battery to complement the remain energy if necessary.
Postcondition	Same as “Main goal”.
Safety relation	Not identified.
Open topics / consideration	In addition, the case must be proven when the switch is unlocked.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Renewable (not working) + Grid (not working) + Battery (backup and working) – Switch Moving
UC ID	UC_WP4_**4.1.2_216**
Main actor	Switch
Other actors	None
Main goal	Switch changes the position properly using the energy stored in the battery.
Assumptions	Switch only is configured with 3 energy sources, renewable energy that comes from solar panels, grid as complementary source and a battery.
Precondition	• Solar panels are not working (e.g., during nights or because of an incident), and the grid is not enough to complement the demanded energy so there is need of using the battery. • Battery is enough charged.
Flow of events	1. Switch gets the sufficient energy to change its position from the battery. 2. If only grid or both grid and renewable energy become available, then the behaviour shall transit to UC_WP4_**4.1.2_212** or UC_WP4_**4.1.2_214** depending on the situation. 3. If only renewable energy becomes available, the switch shall use the battery to complement the remain energy if necessary.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	The case must be proven under the following circumstances: a) Switch changes from Reverse to Nominal position. b) Switch changes from Nominal to Reverse position.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	No energy source available – Switch Set and Locked
UC ID	UC_WP4_**4.1.2_217**
Main actor	Switch
Other actors	None
Main goal	From Set and Locked, go to restricted state.
Assumptions	Any of the four (a-d) described in the "Open topics / consideration" row.
Precondition	None
Flow of events	1. Suddenly, all the sources of energy stop working. 2. Switch goes to restricted state. 3. When any/all source of energy is available again, the switch shall transit to the appropriate UC based on its configuration.
Postcondition	Same as "Main goal".
Safety relation	Yes.
Open topics / consideration	The case must be proven under the following circumstances: a) For only Battery available. b) For Renewable + Battery configuration. c) For Grid + Battery configuration. d) For Renewable + Grid + Battery configuration.

Use Case Group	WP4 – Subtask 4.1.2
Use Case	No energy source available – Switch Moving
UC ID	UC_WP4_**4.1.2_218**
Main actor	Switch
Other actors	None
Main goal	From moving, go to restricted state.
Assumptions	Any of the four (a-d) described in the "Open topics / consideration" row.
Precondition	None
Flow of events	Equal to UC_WP4_**4.1.2_217**.
Postcondition	Same as "Main goal".
Safety relation	Yes.
Open topics / consideration	The case must be proven under the following circumstances: a) For only Battery available. i. Switch changes from Reverse to Nominal position. ii. Switch changes from Nominal to Reverse position. b) For Renewable + Battery configuration. i. Switch changes from Reverse to Nominal position. ii. Switch changes from Nominal to Reverse position. c) For Grid + Battery configuration. i. Switch changes from Reverse to Nominal position. ii. Switch changes from Nominal to Reverse position. d) For Renewable + Grid + Battery configuration. i. Switch changes from Reverse to Nominal position. ii. Switch changes from Nominal to Reverse position.

4.3.4 About Remote Maintenance

Assumptions and Rationale

See section 4.2.54.2.5 – it is fully applicable to the Switches.

Additionally, please bear in mind that the switch does not have any functional software, meaning it lacks software to control its operation. However, it does have software for maintenance purposes.

Concepts (alphabetical order)

See section4.2.5 4.2.5 – it is fully applicable to the Switches.

Use Cases Groups

See section 4.2.54.2.5 – it is fully applicable to the Switches.

The next picture presents all the Use Cases identified for this function. These UC will be used as basis to derive requirements.

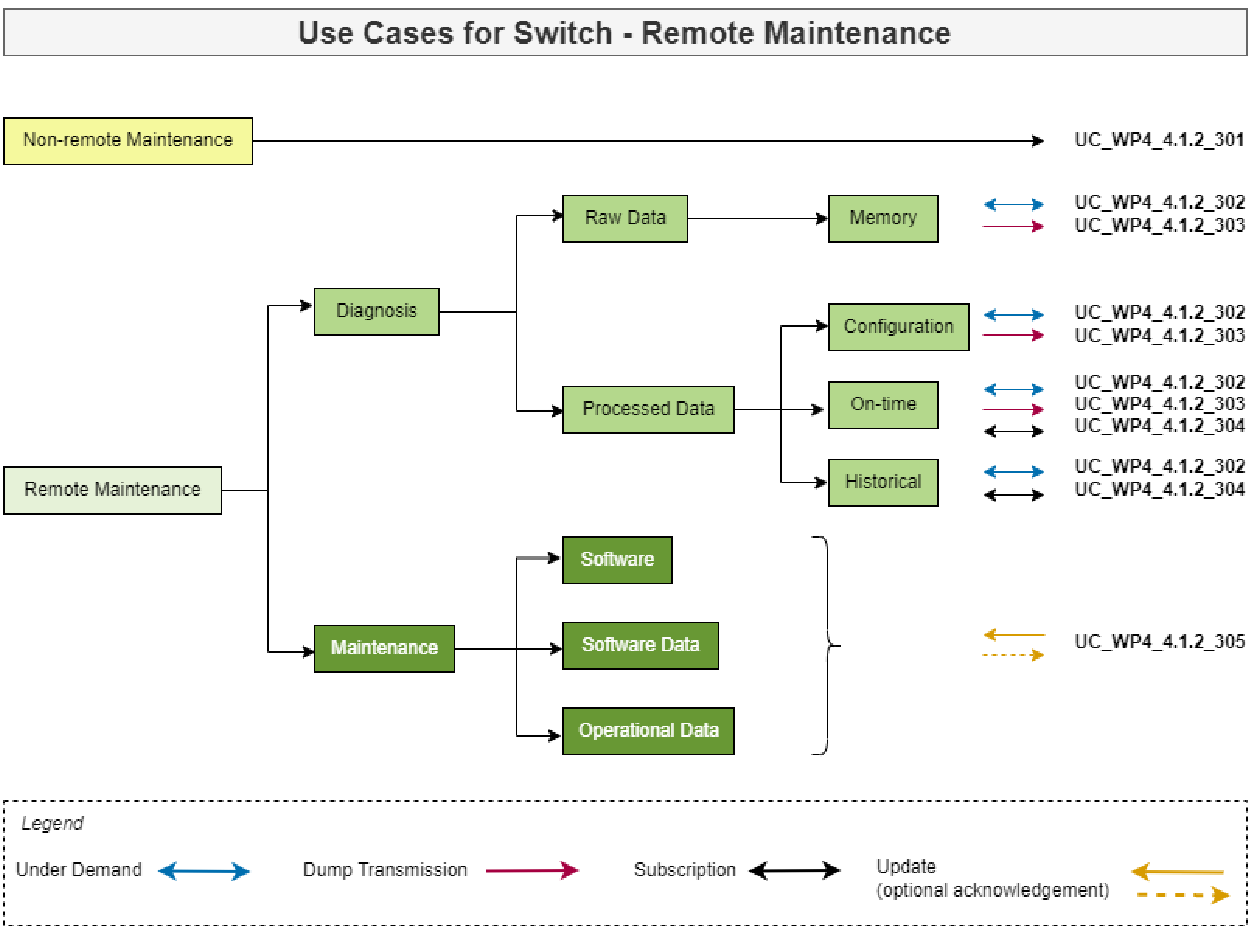


Figure 14: Use Cases for Switch – Remote Maintenance

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Non-remote Maintenance
UC ID	UC_WP4_**4.1.2_301**
Main actor	Switch
Other actors	Maintenance Terminal
Main goal	Equal to UC_WP4_**4.1.1_301**
Assumptions	There is no possibility to perform any remote maintenance.
Precondition	There is no possibility to perform any remote maintenance.
Flow of events	Out of the scope of this document.
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	Equal to UC_WP4_**4.1.1_301**

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Diagnosis – Acquisition of data **Under Demand**
UC ID	UC_WP4_**4.1.2_302**
Main actor	Switch
Other actors	Maintenance Terminal
Main goal	Switch provides data for diagnosis under demand.
Assumptions	Equal to UC_WP4_**4.1.1_302** (replace LX by Switch)
Precondition	Equal to UC_WP4_**4.1.1_302** (replace LX by Switch)
Flow of events	Equal to UC_WP4_**4.1.1_302** (replace LX by Switch)
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	Equal to UC_WP4_**4.1.1_302** (replace LX by Switch)

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Diagnosis – Acquisition of data through **Dump Transmission**
UC ID	UC_WP4_**4.1.2_303**
Main actor	Switch
Other actors	Maintenance Terminal
Main goal	Switch provides data for diagnosis through dump transmission.
Assumptions	Equal to UC_WP4_**4.1.1_303** (replace LX by Switch)
Precondition	Equal to UC_WP4_**4.1.1_303** (replace LX by Switch)
Flow of events	Equal to UC_WP4_**4.1.1_303** (replace LX by Switch)
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	Equal to UC_WP4_**4.1.1_303** (replace LX by Switch)

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Diagnosis – Acquisition of data through **Subscription**
UC ID	UC_WP4_**4.1.2_304**
Main actor	Switch
Other actors	Maintenance Terminal
Main goal	Switch provides data for diagnosis through subscription.
Assumptions	Equal to UC_WP4_**4.1.1_304** (replace LX by Switch)
Precondition	Equal to UC_WP4_**4.1.1_304** (replace LX by Switch)
Flow of events	Equal to UC_WP4_**4.1.1_304** (replace LX by Switch)
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	Equal to UC_WP4_**4.1.1_304** (replace LX by Switch)

Use Case Group	WP4 – Subtask 4.1.2
Use Case	Maintenance – Maintenance through **Update**
UC ID	UC_WP4_**4.1.2_305**
Main actor	Switch
Other actors	Maintenance Terminal
Main goal	Equal to UC_WP4_**4.1.1_305** (replace LX by Switch)
Assumptions	Equal to UC_WP4_**4.1.1_305** (replace LX by Switch)
Precondition	Equal to UC_WP4_**4.1.1_305** (replace LX by Switch)
Flow of events	Equal to UC_WP4_**4.1.1_305** (replace LX by Switch)
Postcondition	Same as "Main goal".
Safety relation	Not identified.
Open topics / consideration	Equal to UC_WP4_**4.1.1_305** (replace LX by Switch)

4.4 Reference Use Cases of Obstacle Detection (Subtask 4.1.3)

The Use Cases reported in this section are related to the Level Crossing Obstacle Detector applied in the Regional Lines. The obstacle detector is always connected to a level crossing.
These Use Cases also cover the regional line conditions where is possible that a level crossing isn't connected to the signalling system.

4.4.1 Obstacle detector in normal condition, LX connected to the signalling system.

Use Case Group	WP4 – Subtask 4.1.3
Use Case	Level Crossing Obstacle Detector in normal condition with signalling system
UC ID	UC_WP4_4.1.3_001
Main actor	Obstacle Detectors
Other actors	LX (level Crossing) (it includes the LX Control) Obstacle Train Signalling system Energy
Main goal	If there is an obstacle in the level crossing area the signalling system is informed.
Assumptions	The trains and the wayside are equipped with signalling system, the wayside signalling system is connected to the LX
Precondition	The Obstacle Detector is connected to the Level Crossing Control
Flow of events	1. The Obstacle detector is working correctly (internal test are ok). 2. The LX are working correctly (internal test are ok). 3. The train is running to the level crossing. 4. The signalling system recognises that the train is approaching. 5. The Obstacle Detector wakes up from low power. 6. LX is informed that the train is approaching starts the lights, ring the bell, and lowers the barriers if are present. 7. The LX Control sends the command to scan the area to the Obstacle Detector. 8. The Obstacle Detector scans the area and sends to the LX Control the status of the LX area: 9. No obstacle in the LX area then jump to 9) 10. Obstacle in the LX area then jump to 10) 11. The LX Control sends clear condition to the signalling system Jump to 13) 12. The LX Control sends occupied condition to the signalling system. 13. The Signalling System stops the Train before the LX.

	14. As long as the LX Area isn't clear the signalling system in cooperation with the LX Control keeps the train stationary. 15. When the LX area is clear the signalling system sends the authorization to run at the train 16. The Train can run
Postcondition	The Obstacle Detector switches to energy-saving (sleep) mode
Safety relation	YES
Open topics / consideration	The signalling system, as it is connected with the level crossing, has the task of harmonizing and controlling the entire operation.

4.4.2 Obstacle detector in normal condition, LX standalone (Autonomous LX)

Use Case Group	WP4 – Subtask 4.1.3
Use Case	Level Crossing Obstacle Detector in normal condition without link to CCS signalling system (autonomous LX)
UC ID	UC_WP4_4.1.3_002
Main actor	Obstacle Detectors
Other actors	LX (level Crossing) (it include the LX Control) Obstacle Train Energy
Main goal	If there is an obstacle in the level crossing area the LX system is informed.
Assumptions	No signalling CCS system is connected to the LX
Precondition	The Obstacle Detector is connected to the Level Crossing control
Flow of events	1. The Obstacle detector is working correctly (internal test are ok). 2. The LX are working correctly (internal test are ok). 3. The train is running to the level crossing. 4. The LX recognises that the train is approaching to the level crossing area. 5. The LX starts the lights, rings the bell, and lowers the barriers if are present. 6. The Obstacle Detector wake up from low power. 7. The LX Control sends the command to scan the area to the Obstacle Detector. 8. The Obstacle Detector scans the area and sends to the LX Control the status of the LX area: 9. No obstacle in the LX area then jump to 11) 10. Obstacle in the LX area then jump to 12)

	11. The LX Control sends clear condition to the train (if there is a radio connect with the train or change the status of the signals) Jump to 14) 12. The LX Control sends occupied condition to the train (if there is a radio connect with the train or change the status of the signals). 13. The Train is stopped before the LX. 14. As long as the LX Area isn't clear the LX Control keeps the train stationary. 15. When the LX area is clear the LX Control sends the authorization to run at the train (if there is a radio connect with the train or change the status of the signals). 16. The Train can run
Postcondition	The Obstacle Detector switches to energy-saving (sleep) mode
Safety relation	YES
Open topics / consideration	Since the level crossing is not connected to the CCS signalling system, management is resolved locally. In the case of an occupied area, it is necessary to verify that the other trains are informed of the stopped train before the level crossing. This depends on the CCS signalling system adopted in the line.

4.4.3 Obstacle detector in fault, LX connected to the CCS signalling system.

Use Case Group	WP4 – Subtask 4.1.3
Use Case	Level Crossing Obstacle Detector in degraded condition without train, LX connected to the signalling system
UC ID	UC_WP4_4.1.3_003
Main actor	Obstacle Detectors
Other actors	LX (level Crossing) Obstacle Train Signalling system Energy
Main goal	If there is a fault in the obstacle detector this must be managed.
Assumptions	The train and the wayside are equipped with CCS signalling system. The Signalling System is based on Radio ETCS.
Precondition	No train is approaching. The Obstacle Detector is connected to the Level Crossing control.
Flow of events	1. The Obstacle detector is working correctly (internal test are ok). 2. The LX are working correctly (internal test are ok). 3. The Obstacle Detector recognise a fault.

	4. The LX Control sends this condition to the Signalling System. 5. The signalling system manages this faulty condition. 6. Until the Obstacle detector fault isn't solved the train circulation is manage in the way managed by the CCS signalling system
Postcondition	The Obstacle Detector is in faulty mode until this isn't solved.
Safety relation	YES
Open topics / consideration	The CCS signalling system can manage the Obstacle Detector fault, it is out the scope of this task identify in which way it is managed. The add value is that in this scenario the trains can run.

4.4.4 Obstacle detector in fault, LX stand alone (autonomous LX)

Use Case Group	WP4 – Subtask 4.1.3
Use Case	Level Crossing Obstacle Detector in degraded condition without train, LX stand alone
UC ID	UC_WP4_4.1.3_004
Main actor	Obstacle Detectors
Other actors	LX (level Crossing) Obstacle Train Energy
Main goal	If there is a fault in the obstacle detector this must be managed.
Assumptions	The LX isn't connected to the CCS signalling system.
Precondition	No train is approaching. The Obstacle Detector is connected to the Level Crossing control.
Flow of events	1. The Obstacle detector is working correctly (internal test are ok). 2. The LX are working correctly (internal test are ok). 3. The Obstacle Detector recognises a fault. 4. The LX Control sends occupied condition changing the status of the signals that are connected. 5. A diagnostic message could be sent to the maintenance manager. 6. Until the Obstacle detector fault isn't solved the LX is waiting for the next train for communicate the fault.
Postcondition	The Obstacle Detector is in faulty mode until this isn't solved.
Safety relation	YES
Open topics / consideration	The train circulation is only managed locally so no measures are taken to mitigate the effect of the fault. It is in charge of the local Railway Manager.

4.4.5 Obstacle detector in fault, LX connected to the CCS signalling system.

Use Case Group	WP4 – Subtask 4.1.3
Use Case	Level Crossing Obstacle Detector in degraded condition with train, LX connected to the signalling system
UC ID	UC_WP4_4.1.3_005
Main actor	Obstacle Detectors
Other actors	LX (level Crossing) (it include the LX Control) Obstacle Train Signalling system Energy
Main goal	If there is a fault in the obstacle detector this must be managed.
Assumptions	The trains and the wayside are equipped with CCS signalling system, the CCS wayside signalling system is connected to the LX
Precondition	The Obstacle Detector is connected to the Level Crossing Control
Flow of events	1. The Obstacle detector is working correctly (internal test are ok). 2. The LX are working correctly (internal test are ok). 3. The Obstacle Detector is in fault. 4. The train is running to the level crossing. 5. The CCS signalling system recognises that the train is approaching. 6. LX informed about the train is approaching switches on the road lights, rings the bell, and lowers the barriers if present. 7. The LX Control sends the faulty condition to the CCS Signalling System. 8. The CCS signalling system manage this faulty condition. 9. The CCS signalling system manage the incoming train following its rules. 10. Until the Obstacle detector fault isn't solved the train circulation is manage in the way managed by the CCS signalling system
Postcondition	The Obstacle Detector is in faulty mode until this isn't solved.
Safety relation	YES
Open topics / consideration	The CCS signalling system can manage the Obstacle Detector fault, it is out the scope of this task identify in which way it is managed. The add value is that in this scenario the trains can run under the CCS signalling supervision.

4.4.6 Obstacle detector in fault, LX stand alone (Autonomous LX)

Use Case Group	WP4 – Subtask 4.1.3
Use Case	Level Crossing Obstacle Detector in degraded condition with train, LX stand alone
UC ID	UC_WP4_4.1.3_006
Main actor	Obstacle Detectors
Other actors	LX (level Crossing) Obstacle Train Energy
Main goal	If there is a fault in the obstacle detector this must be managed.
Assumptions	The LX isn't connected to the CCS signalling system. (autonomous LX)
Precondition	train is approaching. The Obstacle Detector is connected to the Level Crossing control.
Flow of events	1. The Obstacle detector is working correctly (internal test are ok). 2. The LX are working correctly (internal test are ok). 3. The Obstacle Detector recognise a fault. 4. The train is running to the level crossing. 5. The LX recognises that the train is approaching to the level crossing area. 6. The LX switches on the road lights, rings the bell and lowers the barriers if are present. 7. The LX Control sends occupied condition to the train (if there is a radio connect with the train or change the status of the light signals). 8. The Train is stopped before the LX. 9. A diagnostic message could be sent to the maintenance manager. 10. As long as the fault is present LX Control keeps the train stationary. 11. A manual operation can help the train movements. 12. Until the Obstacle detector fault isn't solved the LX is waiting for the next train for communicate the fault.
Postcondition	The Obstacle Detector is in faulty mode until this isn't solved.
Safety relation	YES
Open topics / consideration	The train circulation is only managed locally so no measures are taken to mitigate the effect of the fault.

5 Requirement Specification of Wayside Assets

5.1 References

In addition to the task internally developed Use Cases, the following documents were considered for the development of the requirements. The following Figure 15 contains a graphical overview. The task-external reference documents contain framework definitions and interfaces/reference points for the Task 4.1, which were considered and used as a basis in the development of the requirements.

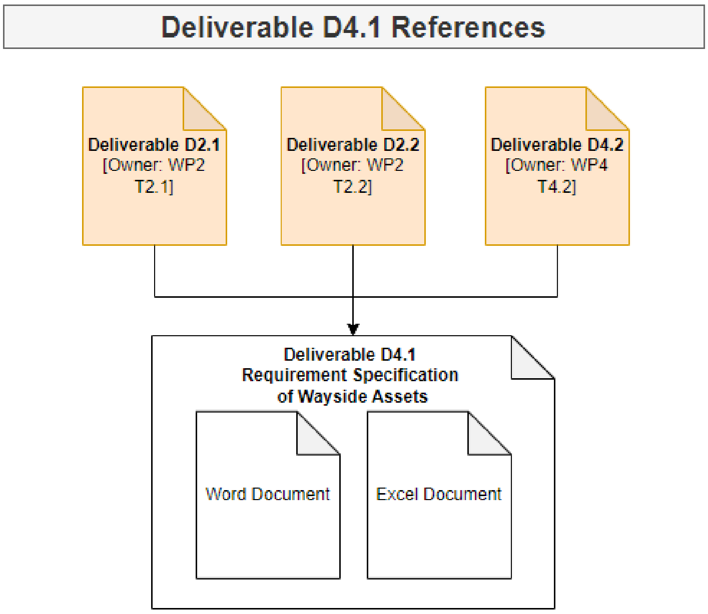


Figure 15: Deliverable D4.1 Reference Documents

5.1.1 General Requirements

Reference Document for Deliverable D4.1 “Deliverable D2.2: Regional lines operational and functional requirements” [REF.3].

Reference Document for Deliverable D4.1 “Deliverable D4.2: Interface_Specification_Track-Field” [REF.4].

5.1.2 Architecture

Reference Document for Deliverable D4.1 “Deliverable D2.1: Regional lines Architecture” [REF.6].

5.2 Global Tracking and Nomenclature of Requirements

Due to the absence of a unified nomenclature for requirements labelling within either FP6 or WP4, Task 4.1 has developed and implemented its own defined and standardized nomenclature for requirements. This ensures consistent referencing across the Work Packages, facilitating seamless coordination and integration during the requirement specification and development phase as well as ensuring an unambiguous tracking and tracing of the requirements within Work Package 9, particularly for the development of demonstrators.

The requirements of Task 4.1 labels each requirement according to the following nomenclature, ensuring clarity and consistency in the requirements management. The nomenclature includes certain identifiers to represent the affiliation to the Work Package 4, the identification of the Subtask, the type of the requirement, a sequential numbering within a designated range, and an index for any subdivided requirements.

Nomenclature: **REQ_WP4_ST*ID_REQ-TYPE_REQ*ID_REQ_SUB**

Table 3: Nomenclature of Requirements with guidance of attributes

IDs	Description	Information
REQ_WP4	Affiliation of Requirement (belonging to WP4)	permanent
ST*ID	Identification of the Subtask	[4.1.1, 4.1.2, 4.1.3]
REQ-TYPE	Identification of the Requirement Type	[According to Requirement Types defined in the Development Methodology] AD: Architecture/Design AS: Assumption C: Configuration Def: Definition F: Functional Requirement NF: Non-functional Requirement O: Operational Requirement
REQ*ID	Numeration of the Requirements	[Starting at beginning of range and increment by 1] **For Subtask 4.1.1, use next subranges:** 0001 to 1000: about Control Mng. G1 1001 to 2000: about Control Mng. G2 2001 to 3000: about Wireless Connection 3001 to 4000: about Energy Self-Sufficient 4001 to 5000: about Remote Maintenance **For Subtask 4.1.2, use next subranges:** 0001 to 2000: about Configurability 2001 to 3000: about Wireless Connection

		3001 to 4000: about Energy Self-Sufficient 4001 to 5000: about Remote Maintenance **For Subtask 4.1.3, use next subranges:** 0001 to 2000: General
REQ_SUB	Subdivision of the Requirement (if necessary)	[Starting at “a” and increment according to alphabet]

5.3 Requirement specification for wireless enabled energy self-sufficient LX (Subtask 4.1.1)

The following chapter presents the “Requirement Specification for wireless enabled energy self-sufficient Level Crossings” of Subtask 4.1.1, defining the functional and operational requirements to ensure cost efficiency for regional lines. According to [REF.1], these level crossings should be controllable either through the Interlocking, Radio Block Centre (for Group 1 lines), or via IP-protocol communication (for Group 2 lines), as discussed in section 3.3.1 on Command and Controlling. Additionally, the level crossings must be wireless enabled, in line with the specifications outlined in Task 4.2 “Requirement Specification for Communication”, covered in section 3.3.2 on Wireless Communication. Furthermore, the level crossings should be energy self-sufficient, eliminating the need for external power supply or cabling, as addressed in section 3.3.3 on Power Management. They should also be capable of generating and transmitting diagnostic data and supporting remote maintenance, as detailed in section 3.3.4 on Remote Maintenance.

5.3.1 Command and Controlling

5.3.1.1 Operational and Functional Requirements for G1 Lines

As presented in Chapter 1.3 the corresponding content can be found in the Excel Document. The associated requirements related to the Command and Controlling for the G1 Lines are from *REQ_WP4_4.1.1_F_0001* till *REQ_WP4_4.1.1_F_0053* and are based on the EULYNX specification [REF.23].

5.3.1.2 Concept Development for G2 Lines

Based on the definition provided at level of WP2 D2.1 [REF.6], the G2 Lines concept leverages on full radiocommunication technologies and on the integration of Traffic Management, Interlocking and Radio Block Centre in a single platform as Controlling entities.

G2 Lines Level Crossing is then controlled by integrated Interlocking/Radio Block Centre; detailed specification of such concept will be provided at level of D5.2. “Specification of CCS for Group 2” [REF.7].

As set in the WP D2.1, Level Crossing is considered, as well as switch control, an essential wayside element. Based on such G2 lines concept as strongly radiocommunication oriented, the Level Crossing in G2 lines works totally as wireless (and self-powered) subsystem. Traditional wired subsystem for G2 can be considered only if strictly imposed by a brownfield revamping approach that would be adopted by the IM.

From the architecture point of view, the Level Crossing in the G2 Lines can be generally conceived as the wayside electromechanical equipment and the electronic object controller associated to it.

Coherently to “internal to G2 Lines interface” concept reported in D2.1 [REF.6, sect. 3.1.3.6] the elements communicate via radio through IP standard messaging. The adoption of such kind of standardised protocol allows transparently managing the case of electronic object controller as physically embedded (and co-located) with the Level Crossing.

The above proposed concept is coherent with the specification of the operation modes and use cases defined in chapter 4.

5.3.2 Wireless Communication

5.3.2.1 Operational and Functional Requirements

The requirements for wireless communication were developed, as stated in the proposal, in harmonisation with Task 4.2 “Requirement Specification for Communication” [REF.4]. In particular, the track-to-field communication described in Subtask 4.2.2 “Requirement specification for wireless connection between trackside/trackside and trackside/field devices”, is intended and referenced here. The approach involved collecting all requirements, assessing their significance and relevance, and subsequently transferring them for Task 4.1 perspective.

As presented in Chapter 1.3, the corresponding content can be found in the Excel Document. The associated requirements related to the Wireless Communication are from *REQ_WP4_4.1.1_Def_2001* till *REQ_WP4_4.1.1_F_2028.*

5.3.3 Power Management

5.3.3.1 Operational and Functional Requirements

As presented in Chapter 1.3, the corresponding content can be found in the Excel Document. The associated requirements related to the Power Management are from *REQ_WP4_4.1.1_AS_3001* till *REQ_WP4_4.1.1_AD_3026.*

5.3.4 Remote Maintenance

5.3.4.1 Operational and Functional Requirements

As presented in Chapter 1.3, the corresponding content can be found in the Excel Document. The associated requirements related to the Remote Maintenance are from *REQ_WP4_4.1.1_AS_4001* till *REQ_WP4_4.1.1_F_4026_c.*

5.4 Requirement specification for wireless enabled energy self-sufficient switches (Subtask 4.1.2)

The following chapter presents the "Requirement Specification for wireless enabled energy self-sufficient Switches" of Subtask 4.1.2, defining the functional and operational requirements to ensure cost efficiency for regional lines. According to [REF.1], these switches should be configurable and able to work with any track gauge, including UIC and national gauges, as discussed in section 3.4.1 on Configuration. Additionally, the switches must be wireless enabled, in line with the specifications outlined in Task 4.2 "Requirement Specification for Communication", covered in section 3.4.2 on Wireless Communication. Furthermore, the switches should be energy self-sufficient, eliminating the need for external power supply or cabling, as addressed in section 3.4.3 on Power Management. They should also be capable of generating and transmitting diagnostic data and supporting remote maintenance, as detailed in section 3.3.4 on Remote Maintenance.

5.4.1 Configuration

5.4.1.1 Requirements

As presented in Chapter 1.3, the corresponding content can be found in the Excel Document. The associated requirements related to the Remote Maintenance are from *REQ_WP4_4.1.2_C_0001* till *REQ_WP4_4.1.2_C_2022.*

5.4.2 Wireless Communication

5.4.2.1 Operational and Functional Requirements

The requirements for wireless communication were developed, as stated in the proposal in harmonisation with Task 4.2 "Requirement Specification for Communication" [REF.4]. In particular, the track-to-field communication described in Subtask 4.2.2 "Requirement specification for wireless connection between trackside/trackside and trackside/field devices", is intended and referenced here. The approach involved collecting all requirements, assessing their significance and relevance, and subsequently transferring them for Task 4.1 perspective.

As presented in Chapter 1.3, the corresponding content can be found in the Excel Document. The associated requirements related to the Wireless Communication are from *REQ_WP4_4.1.2_Def_2001* till *REQ_WP4_4.1.2_F_2028.*

5.4.3 Power Management

5.4.3.1 Operational and Functional Requirements

As presented in Chapter 1.3, the corresponding content can be found in the Excel Document. The associated requirements related to the Power Management are from *REQ_WP4_4.1.2_AS_3001* till *REQ_WP4_4.1.2_AD_3027.*

5.4.4 Remote Maintenance

5.4.4.1 Operational and Functional Requirements

As presented in Chapter 1.3, the corresponding content can be found in the Excel Document. The associated requirements related to the Remote Maintenance are from *REQ_WP4_4.1.2_AS_4001* till *REQ_WP4_4.1.2_F_4026_c.*

5.5 Requirement specification for Obstacle Detection (Subtask4.1.3)

The Level Crossing Obstacle Detector (LCOB) system is an assistance system for level crossings, which is intended to detect obstacles within the Level Crossing Area.

The added value of this project can be described by the following points:

It provides a set of requirements that must be adopted across the board, regardless of the technologies used.
It produces a SIL4-compliant solution.
It uses a mix of technologies that can fill any gaps that might arise from using a single one.

This section contains the content applicable to the LCOB system.

The work done in subtask 4.1.3 was done following the following guidelines which then became sections of the document.

This is the contribution of the FutuRe WP4 task 4.1.3 and is structured in the following sub-sections:

- Common Definitions, this is to have a single interpretation of the different terms associated with the topic
- Introduction, for providing an overview of the operating environment
- Benchmarking of alternative sensors, to provide an overview of the technologies currently involved and their strengths and weaknesses.
- Requirement Specification, to have a common basis of applicable requirements
- Interface Specification, to define the essential interfaces that the system must have

Everything related to the development of the demonstrators and their description is concentrated in WP9. The reference requirements will be implemented and the technologies deemed suitable by each partner will be used to achieve the objective of creating a Level Crossing Obstacle detector compliant with the provisions of this document.

The requirements are not designed for a specific technology but must refer to the function. The scope of this job is to have a set of requirements relate to thfunctionon only instead of a specific technology.

The highly ambitious task is precisely that of identifying obstacles of configurable size under all operating conditions.

Regardless of the technologies used in WP9, the requirements will remain applicable and will be usable by others who wish to attempt to build these systems in the future. Therefore, the work conducted in subtask 4.1.3 can be considered as valid preparatory work for all future LCOBs.

5.5.1 Common Definitions

This paragraph contains the definitions of objects that are used within the developed content, which can be interpreted differently.

Table 10: Common Definitions of Obstacle Detection

Object	Definition
Level Crossing Obstacle Detector (LCOB)	All hardware and software, including the physical sensor(s) required to detect if an obstacle is present or not, with an interface to the Level Crossing Control Unit (LXC).
Level Crossing Recovery Area (LXRA)	Area within the railway area that can be used as a safety area where you can take refuge when you are unable to leave the level crossing area with closed barriers.
Level Crossing Area (LXA)	The LXA area is that area which has the base of the barriers and its supports as its vertices. This area therefore includes the part that cars and pedestrians must follow to cross the level crossing.
Level Crossing Control Unit (LXC)	The system that controls the level crossing and interacts with the signalling system. Typically, with the interlocking but this depends on the chosen architecture and national regulations.

5.5.2 Introduction

The LCOB is a Safety system designed for avoiding incident between the train and potential obstacle in the level crossing area LXA.

There are operational rules that depend on national regulations and infrastructure managers.

The aim of this work is to collect requirements for a solution that is possibly applicable in every context and configurable according to the locally applicable rules. For example, not all countries have the same minimum dimensions on what should be considered an obstacle or not. In some countries the aim is to prevent accidents with humans even when lying down, while in others the aim is to avoid accidents with cars that may have remained stuck in the level crossing area.

To respond to different needs, it is not always possible to adopt the same technology and sometimes it is necessary to have more than one at the same time. The benchmark paragraph allows the reader to have an overview of the current state of the art and the technologies currently applied. Performance in terms of resolution and response time depends on the technology used.

The LCOB system cooperates with the level crossing controller by providing the LXA status information. It is designed as a system that can be added to existing level crossing controllers. For this reason, the type of physical interface to the LXC can change depending on how the LXC has been implemented. There may be configurations where the LXC is standing alone and therefore not connected to a structured signalling system. In these cases, for example, LXC could drive signals that allow or deny the approach of the passing train to the level crossing.

The LCOB needs a trigger command to start scanning activities in the LXA area. Following this command, it returns the status of the area.

The LXC knows when to close the barriers because a train is about to arrive, and the information is provided in advance to allow all operations to be concluded before the train can pass safely. The presence of the LCOB is included in this procedure and the LXC declares the scanning activities concluded when the LXA area is also declared clear.

The impact of the introduction of the LCOB in the level crossing management chain can be intrusive if the time to determine the status of the LXA increases the travel time of the train.

5.5.3 Benchmarking of alternative sensors

This benchmarking study is based on a thorough literature review of existing technologies used today around the world, as well as technologies that have been proposed and tested in experimental studies.

This study, although not directly connected to the requirements, allows us to give a state of the art of the activities carried out in this area. The benchmark traces the current availability of technologies that can be used for the realization of the LCOB.

5.5.3.1 Performance criteria

An ideal obstacle detector should provide high detection performance in all different conditions (weather, light, …), low life-cycle cost, high reliability, safety, and security, and be applicable in all different kind of level crossings.

The statistical detection performance of a detector is typically characterized by the probability of false alarm (stating that there is an obstacle when no obstacle is present) and the probability of missed detection (stating that there is no obstacle when an obstacle is present). By adjusting the sensitivity threshold of the detector, a trade-off between these two measures is obtained. For an obstacle detector, these characteristics could only be validated in highly controlled test environments, which however only provides little information on the actual performance in field, due a magnitude of external factors, such as the layout of the specific level crossing, type of obstacle, weather conditions, …).

Also, the events to be detected are very rare and it is even rarer that a missed detection or false alarm is noticed and recorded in the event logs of an actual deployment. Therefore, the only possibility to compare and evaluate different sensor types would be to use a controlled test environment. To the best of our knowledge, not internationally accepted such test conditions have been defined and as already pointed out, such test would only provide limited information on the performance in other conditions. For the same reason, it is very hard to judge and compare numeric results reported in the literature.

The exact definition of what obstacles should be detected varies between countries. Also, the size and layout of the level crossing may differ between sites. Therefore, the detector should be configurable, both on the area to be covered and on what objects should be detected.

Most sensor types are at least somewhat affected by weather conditions such as heavy rain, snow, ice, fog and sandstorms. Vision based sensors also depend on the light conditions.

The life-cycle cost can be broken down into installation cost, cost of the equipment and final deposal/recycling, energy and other operational costs, the need for regular maintenance, and lifetime of the components. Some sensor types require computationally heavy processing to analyse the raw sensor data, which may influence the cost.

5.5.3.2 Main sensor types

Three main physical principles are used for obstacle detection; inductive/magnetic sensing of metallic objects, radiated beams that are blocked by the obstacle and beams that are reflected by the obstacle. For the two latter options, it is most common to use electromagnetic waves, either in the visible spectrum, infrared spectrum, or microwave spectrum (radar), but ultrasound has also been proposed in the literature.

5.5.3.2.1 Radar

Radar systems estimate the distance to objects by measuring the delay of emitted radio waves, reflected by the object. The emitted signals are either short pulses (pulse radar) or continuous signals where the instantaneous frequency increases with time (Frequency Modulated Continuous Wave FMCW radar). For road traffic monitoring, there is also a third type of radar, Continuous Wave (CW) radar, that uses a more narrowband signal and only can estimate the velocity of an object using the Doppler principle. Such CW radars are unsuitable for detecting static objects and therefore not of interest for level crossings. FMCW radar is less sensitive to electromagnetic interference than pulse radar and allows for simpler post-processing since the delay translates into a frequency shift that easily can be estimated by multiplying the received signal with the transmitted signal and using a fast Fourier transform. FMCW radar is therefore the most popular technology for automotive radar, as used on modern road vehicles. Such radar units are therefore mass-produced resulting in low price per unit, even though the targeted safety level and life-length is not the same as a typical railway sensor.

Estimating the direction (bearing) of the obstacle is either done by physically rotating a directive antenna or using so-called MIMO radar or phased array radar, with an array of antenna elements where the radio beam is electronically steered by controlling the relative phase shift between the antenna elements, and where similarly the relative phases between the received signals provide directional information. The angular resolution is determined by the antenna aperture, i.e. the physical size of the antenna (array).

Radar systems are used for level crossing obstacle detection for example in Germany [REF.8] and have also been tested in several other countries. The radar is typically mounted near ground (German system) or on a mast in a corner of the LXA. In some cases, a second radar unit in the diagonally opposite corner is needed to get full coverage of the area. Some systems use reflectors mounted at the boarder of the area, as reference objects, to help the system determine if an object is within the LXA or not. The most used frequency spectra are 24GHz and 77GHz, i.e. a wavelength of 1.3mm or 0.4mm, respectively. Radio waves at these frequencies are less affected by weather conditions, than signals in the visible or IR spectrum. Also, the radar sensor can be mechanically shielded, making it less sensitive to unintentional or intentional damage (vandalism), compared to LiDAR and cameras. For the same reason, if a mechanically rotating antenna is used for bearing estimation, the mechanism will be less exposed to wear and tear, compared to a similar implementation of LiDAR. Still, an implementation using MIMO radar will typically be more robust since it does not involve any moving parts.

Another consequence of the frequency spectrum is that the resolution is lower than camera-based solutions. For this LCOB applications this can even be an advantage since no concerns about personal privacy can be raised. The resolution is still sufficient to detect objects of the required size and shape.

To be able to distinguish between objects to be detected and objects that belong to the fixed installations, the system typically involves a self-calibration function that learns the background “image” and detects when the reflected ranges in different directions differ from the normal background. Radar systems are also able to estimate movements, exploiting the Doppler effect, making it easier to track the position of different vehicles and other objects as they move around in the area, which can help to early predict possibly dangerous situations. However, this requires the obstacle detector to be continuously activated and is incompatible with low-power sleep-mode implementations.

To be “visible” to a radar, an object needs a sufficient radar cross section. Measurements of the radar cross section of pedestrians have been reported in [REF.9] showing a reflection intensity some 15-20dB below that of the rear of a vehicle. Related measurements of pedestrians, e-scooters and e-scooters including the driver, are available in [REF.10] but are hard to compare to the numeric results in [REF.9].

The expected lifetime of a radar installation is 20-25 years for the systems currently used in Germany [REF.8].

5.5.3.2.2 LiDAR

The basic principle of LiDAR (Light Detection and Ranging) is very similar to radar but using visible light or infrared light instead of millimetre-wave radio. Also, a laser source and optical detector is used instead of the transmitting and receiving antennae of a radar. LiDAR technology has developed significantly in recent years thanks to the road vehicle industry, that is starting to adopt LiDAR as a complement to radar. Like Frequency-Modulated-Continuous-Wave (FMCW) radars, it can therefore be expected that the cost per unit goes down.

The beam direction can be fixed, but mostly the laser source is rotated in a 2 dimensional or 3-dimensional pattern, to provide a so-called point cloud of distance measurements in many different directions. Similarly to radar, the most common solution is a rotor based mechanical LiDAR. However, there are primarily three alternative implementations available to avoid the rotating parts,

- Solid-state LiDAR, using micro-electromechanical (MEMS) mirrors that reflect the laser beam in different directions. Similar MEMS mirrors are in use in video projectors since more than 25 years.
- Optical phased array (OPA) LiDAR, using an array of laser emitters where the relative phase can be adjusted, like phased array radar, thus completely eliminating the need of moving parts.
- Flash LiDAR, where the emitted laser passes through an optical diffuser that spreads the light in multiple direction, thus acting more similarly to a flashlight of an ordinary camera. Also, the receiver end is similar to an ordinary camera, using an array of optical sensors.

More details about LiDAR technology can be found in [REF.11] and [REF.12], which also lists features of several LiDAR sensors available on the market. However, many of these products are very recent and the technical maturity may differ.

Similarly to radar systems, a LiDAR based object detection system can learn the background environment using self-calibration and detect objects by comparing the instantaneously estimated point cloud to that of the background. As pointed out in [REF.13], even objects that are “black”, i.e. that have very low reflectivity at the specific frequency, can be detected since they appear as “holes” in the point-cloud, as compared to the background.

SIL 4 LiDAR sensors for obstacle detection in level crossings are available on the market. They are typically placed elevated on a mast next to the LXA, to provide a view over the full area. However, a 2-dimensional LiDAR sensor would typically be placed at ground level, scanning along a horizontal plane a few decimetres above the ground (sufficiently low to detect low objects, sufficiently high to see trucks and other vehicles with greater ground clearance. Such a placement requires that the full level crossing area is sufficiently flat.

As compared with radar, the much shorter wavelength used in LiDAR makes it more sensitive to rain, snow, and other weather conditions, where the precipitation both can dampen the light beam, resulting in lower contrast, and reflect the beam, potentially resulting in false detections.

5.5.3.2.3 Cameras

Cameras are dependent on ambient light. To use cameras for obstacle detection at nighttime, some additional illumination would be needed. A standard (video) camera provides a 2-dimensional projection of the scene, so the presence and position of an obstacle would need to be obtained by analysing the image, like how a human would try to interpret the image. Similarly to radar and LiDAR based solutions, an image of the static background would be used as a reference. However, when clouds come and go and the sun moves over the sky, colours, light intensities, and the shape of shadows change, making it more difficult to know what changes in an image emanate from an additional object and what changes are just a shadow or some other natural change of the background environment. Another difficult scenario is when strong sun light is reflected directly into the camera. Therefore, advanced image processing techniques are needed to try to identify foreign obstacles. General techniques for object detection, recognition and classification in images have improved significantly during the last 10 years, thanks to the introduction of deep learning methods [REF.14], and several research articles have appeared recently on using such methods for obstacle detection. However, to the best of our knowledge, none of these have resulted in any products so far.

Cameras can operate both in the regular visible spectrum and in the infrared spectrum, where the difference in temperature between an obstacle and the background can be exploited.

Compared with radar and LiDAR, cameras are more sensitive to weather conditions and collected dirt and dust on the lens. A study of the need for cleaning the lens and on possible automated solutions to reduce the need of manual maintenance, is provided in [REF.15]. There is also another open point, analyses in the Project VAL2020 (automation with a shunting Loco) showed that on hot days the person can melt visual to the background using infrared. This must be solved.

On the other hand, a camera provides much higher resolution than radar and LiDAR, and provides colour information, which provides much better possibilities to distinguish between different types of objects. However, for privacy reasons, the use of cameras comes with some restriction in public areas. Even though the output of an obstacle detector is completely anonymous, this aspect may still put some extra requirements on what kind of data may be stored for development and maintenance purposes, for example.

Some level crossings are already equipped with a CCTV camera for traffic monitoring, which in principle could be used also for obstacle detection, if it is combined with suitable image processing. Like LiDAR systems, the typical camera placement would be elevated on a mast in a corner of the level crossing.

Camera based image processing solutions have also been proposed for obstacle detection systems placed on-board trains.

5.5.3.2.4 Stereo/depth camera

By placing two (or more) cameras at some distance from each other, depth information can be obtained by comparing the two images, just as our brain obtains stereo information from our two eyes. Similarly to radar and LiDAR, such depth information can be used to distinguish obstacles more accurately from shadows or other image phenomena, especially when combined with other image features.

Recently, other technologies have appeared to extract depth information using a single lens camera, such as Kinect or Intel Realsense. The trick used is to illuminate the scene with a specific pattern, which is then used to extract depth information. These techniques first appeared for video games and are primarily applicable indoors, even though there are some outdoor products available. However, the range is limited, and they can be expected to be even more sensitive to poor weather conditions, compared with standard stereo cameras.

5.5.3.2.5 Ultrasound

Ultrasound sensors work in principle as radar but using reflected ultrasonic signals instead of radio waves to estimate the distance (and/or velocity from the Doppler). Such sensors are commonly used to activate gates and count vehicles at parking areas. Another common use case is back sensors and other proximity sensor on road vehicles. If they are to be used at a level crossing, the best placement from a sensing point of view would be above the trail, i.e. close to the catenary lines, which would make installation and maintenance complicated and expensive. The sensing range is limited; even though some products are claimed to have a range of up to 15m, this only holds for large and reflective objects. Also, ultrasonic sensors for vehicle detection are explicitly marketed as ignoring pedestrians, which is an undesirable feature for an LCOB. Moreover, there are some side effects in condition like heavy water and snow. This point must be taken into account.

5.5.3.2.6 Optical beam sensors

Optical beam sensors have been used in Japan for obstacle detection [REF.8]. Several fixed laser beams are irradiated at photoelectric sensors (possibly combined with reflectors). When an obstacle blocks one of the beams the receiving sensor detects the absence of incoming light. The technology is simple, low-cost, and mature, but also has several drawbacks. Many emitters/receiver pairs may be needed to cover the full LXA, careful alignment is needed during installation, the maintenance cost is high ([REF.8] even reports daily maintenance to clean the lenses), and the system is sensitive to weather conditions such as heavy snow.

The same basic idea can in principle also be applied using other parts of the electromagnetic spectrum, such as the radio frequencies normally used for radar [REF.8], but bulkier antennas would be required to obtain sufficiently narrow beams.

A variation of the same basic idea is proposed in [REF.16], using a combination of infrared and ultrasound beams, and exploiting that each of the beams is wide enough to illuminate several receivers. However, the proposed scheme requires coordination between transmitting and receiving units and at least the sensor geometry proposed in the paper is not applicable in level crossings, but rather at railway sections where there is a risk of rocks falling on the track.

5.5.3.2.7 Inductive loops

Inductive loops have been used for obstacle detection at least since the 1990s, for example in Sweden [REF.8] and in the US [REF.2012] and are also commonly used in road traffic, for example at traffic lights. The basic principle is that the inductance of a loop wire changes when a metallic object passes above it. Therefore, only objects that contain a sufficient amount of metal can be detected. The coils can be mounted below ground or be mounted on the rails. Several coils may be needed to cover a full LX area. The main advantages are that the technology is simple and mature, and that the detector is insensitive to weather conditions. Even though the equipment itself is cheap, the installation and maintenance cost can be fairly high since the traffic has to be stopped during the work. The minimum lifetime is reported as 4-10 years [Hilleary 2012]. Since only metallic objects can be detected, inductive loops alone do not fulfil the requirements *REQ_WP4_4.1.3_F_0011* but may be used as part of a multi-sensor solution.

5.5.3.2.8 Magnetometers

Magnetometers buried under ground could potentially be used in a similar way as inductive loops and are sometimes used for road traffic monitoring. However, they can only detect objects with magnetic properties (iron, …) and each sensor can only cover a small area. They are therefore not so interesting for level crossings.

5.5.3.2.9 Combinations of sensors

As explained above, all sensor types come with both advantages and disadvantages. It is therefore of interest to combine different sensor types. One advantage is that it provides additional redundancy and thereby additional safety. The additional sensors may in some situations also be used to detect and eliminate false alarms. In [REF.8] it is reported that trial experiments have done in the US with laser+video imaging, and with downward pointing infrared+ultrasonic sensors placed above the level crossing. A trial in the UK used a combination of radar and LiDAR [REF.18]. Several other combinations have been proposed in the research literature.

Conceptually, there are three main options to combine the output of the different sensors into a single detection. The easiest is to let each sensor take its own binary decision (obstacle present/absent) and then combine these using and AND or OR operation. Better detection performance is obtained if each separate detector provides a numeric value indicating the level of confidence for its own detection conclusions. These confidence levels can then be used to weigh together the individual detector outputs when taking the joint decision. The final alternative, which provides the highest detection performance but at the cost of a higher computational complexity, is to collect the raw data from each of the sensors and do the full processing jointly based on all available data. One example of the latter option is stereo cameras, where images from the two cameras are processed jointly to obtain the depth information. Such joint processing requires procedures to align measurement values from the different sensors to a joint geographical coordinate system (this process is called “registration” in image processing).

5.5.3.3 Summary and conclusions

A summary of the different sensor types is listed in Table 11 Ultrasound sensors and magnetometers have been excluded from the table since they do not seem relevant for the application, except possibly as part of a multi-sensor solution.

The options that seem best suited for obstacle detection are radar and LiDAR. However, both may be affected by weather conditions such as heavy snow and it may therefore be interesting to consider combinations with other sensor types, for example with inductive loops that are very insensitive to weather conditions but are unable to detect humans and non-metallic objects.

It is very hard to judge the life-cycle cost. Some numbers can be found in the open literature, but it is challenging to compare numbers from different sources, and it is not fully clear how much of the full life-cycle cost is included in these numbers. Installation costs should be of similar orders for radar, LiDAR, and camera if they are placed on a mast. Previously deployed LCOB radar systems, however, are placed at ground level close to the track. Similar deployments have also been used for trials with 2D LiDAR technology. Placement close to the ground would increase the need for regular cleaning but would also simplify such maintenance. Inductive loops have relatively high costs for installation and repair. The cost of the sensor hardware is typically lower than the installation and maintenance cost.

Table 11: Summary of different obstacle detector types.

Sensor type	Types of objects	Sensitivity to weather conditions	Maturity for obstacle detection	Typical installation	Maintenance
Radar	All with sufficient radar cross section.	Better than LiDAR or camera	SIL3 products deployed 15+ years	1-2 units at ground level or on a mast, in a corner of the area	Infrequent
LiDAR	All non-transparent.	Better then camera	SIL4 products on the market. Basic technology still under rapid development	1-2 units at ground level (2D LiDAR) or on a mast (3D LiDAR), in a corner of the area	Regular cleaning (frequency?).
Camera	All	High sensitivity	Field trials	1-2 units on a mast, in a corner of the area	Regular cleaning (frequency?).
Infrared camera	All with temperature difference to the surroundings.		Field trials	1-2 units on a mast, in a corner of the area	Regular cleaning (frequency?).
Stereo camera	All	Same as camera	Research studies	1-2 units on a mast, in a corner of the area	Regular cleaning (frequency?).
Optical beams	All sufficiently large.	Slightly better than LiDAR	Deployed 25+ years.	Several transmitting and receiving units at ground level	Frequent cleaning
Inductive loop	Only metallic.	Insensitive	Non-SIL products deployed 25+ years	One or several loops under ground or on the rail.	Repair/replacement
Sensor combinations	All that can be detected by at least one sensor.	As the best of the sensors.	Field trials		

5.5.4 Safety Aspects of Using Machine Learning/Artificial Intelligence Components

Machine learning (ML) techniques, often based on deep learning, have revolutionised many fields of data analysis in recent years, especially in image processing and recognition. For example, the accuracy of image-based face recognition has improved significantly with the introduction of deep learning networks, compared to using classical image processing techniques. These methods have also been implemented in automotive applications for assisted or even autonomous driving.

Despite these successes, several main concerns remain regarding these technologies, not the least in safety-critical scenarios. Even if a deep neural network has been trained and validated using thousands or even millions of data samples, there are no guarantees that the obtained "competence" generalises to new or unforeseen situations. Recent research has also shown several examples of how for example an image classification algorithm can be fooled into providing completely erroneous classification results by modifying only a few of the pixels in an image. This is accompanied by a lack of explainability, where it is impossible for a human to understand and analyse what features are used by the algorithm. See for example [REF.19], for a more extensive discussion on these concerns. It has not yet been resolved how to validate, following the traditional methods used up to now, the applications that use these algorithms. This remains an open point.

However, there also recent results on the possibility to use machine learning approaches as an ingredient in safety-critical systems and provide safety certificates using formal methods, see [REF.20, REF.21]. In short, the idea is that that the machine learning algorithm is used as a first stage in the processing chain, outputting not only a tentative detection and classification result, but also information that can be checked using a traditional non-AI algorithm, In the particular scenario analysed in [REF.20], the ML algorithm outputs the bounding box of an identified traffic sign, and classical image processing techniques are used to verify that it indeed is the correct traffic sign.

A similar approach would be possible in the context of level crossing obstacle detection, were a machine learning based component could be used as a pre-processing step to quickly detect and locate tentative obstacles, that then are verified using certifiable image/data processing techniques. An alternative would be to use ML algorithms to provide additional information on the obstacle (type of obstacle), that is not needed for the safety critical components but can be used by the infrastructure manager to collect statistics.

5.5.5 Requirement specification LCOB

This section reports the requirements applicable to the LCOB. these are divided into Operational requirements, Functional requirements, and Non-Functional requirements.

Before addressing the requirements, however, it is important to clarify the reasons for the requirements indicated. The assumptions paragraph is intended to better clarify the context and the reasons for the choices made.

5.5.5.1 Assumptions

The purpose of the LCOB is to provide the level crossing Area status to the signalling system when a train is approaching the level crossing.

One assumption is based on the fact that when the barriers are closed, it should be "difficult" or almost "impossible" for an unintentional event of occupation of the level crossing area to occur.

This aspect is very important, because it is linked to the ability of the train to stop before the level crossing area in the event of an obstacle being present.

Therefore, this assumption is linked to the management of the level crossing, and when it should be closed to vehicular passage.

This aspect is therefore also crucial to be able to regulate rail traffic and define, based on the maximum speed of the line, when the functions of closing the level crossing and detecting any obstacles should be activated before the train arrives.

The reason for declaring to use full barriers instead of half barriers is only that theoretically with barriers that cover the entire area, access to the area is more appropriately prevented.

With half barriers, however, a potential risk of access, for example by a car, inside the level crossing area cannot be ignored. An advantage of using half barriers is that when a vehicle needs to be inside the area it can easily exit.

Each infrastructure manager is responsible for choosing the most suitable level crossing solution for their country and the valid railway regulations.

For the LCOB what matters is having the trigger moment for which to start checking the status of the level crossing area.

Depending on the national rules, the start of the LXA scan can happen at any time, this has no impact on the LCOB. This is also applicable for barrier-free level crossings.

What has to be taken into account in the operational rules is the reconciliation of the train braking curve with the information of LXA occupied.

5.5.5.2 LCOB Finite State Machine

The Finite State Machine of the LCOB is shown. It has the following states:

- PO Power On: This is achieved when the system is switched on.
- IT Internal Test: In this state all possible system tests are performed. These are essential to declare the system working correctly.
- SB Stand By: In this state, the necessary tests are performed to evaluate the functioning of the sensors, the system is waiting for the command to perform the scan.
- OD Obstacle Detection: In this state, scanning is performed to provide the LXA status.
- FB Fallback: LCOB goes into this state when a safety-compromising issue is recognized. It is a degraded condition where no safety issues are provided.

The Figure 16 shows the FSM scheme applicable for LCOB.

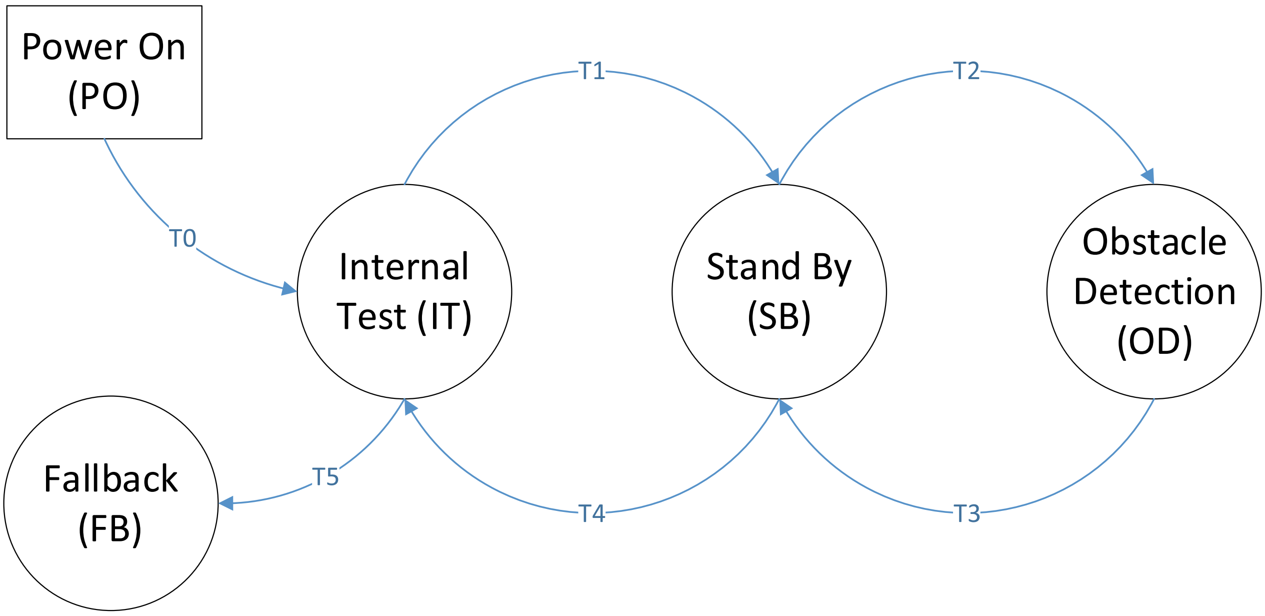


Figure 16 LCOB Finite State Machine

The Table 12 shows the possible transitions from one state to another.

Table 12: LCOB FSM Transitions

PO				
T0 >	IT	T4 <		
	T1 >	SB	T3 <	
		T2 >	OD	

	T5 >			FB

The following Table 13 reports the transition conditions necessary for moving from one state to another one and the LCOB actions in the new state.

Table 13: LCOB FSM Transitions conditions

Condition	Transition conditions from State X to State Y	Action in Y state
T0	**Transition from PO to IT** The LCOB is switch On	LCOB send to LXC: • State IT. • LXA unknow
T1	**Transition from IT to SB** Successful competition of Initialization activities. All the tests are successful performed	LCOB send to LXC: • State SB and tests result • LXA unknow
T2	**Transition from SB to OD** LCOB receives from LXC the start command	LCOB send to LXC: • State OD • Status of LXA
T3	**Transition from OD to SB** LCOB receives from LXC the stop command	LCOB send to LXC: • State SB and tests result • LXA unknow
T4	**Transition from SB to IT** LCOB periodic tests recognise something wrong	LCOB send to LXC: • State IT. • LXA unknow
T5	**Transition from IT to FB** LCOB detects an unrecoverable fault, it is final state	LCOB send to LXC: • State FB. • LXA unknow

5.5.5.3 Operational Requirements

These requirements come mainly from the world of users, therefore mainly from the infrastructure managers. They do not see the single component but analysed the railway system, the requirements reported have an impact on the LCOB system. As presented in Chapter 1.3, the corresponding requirements can be found in the Excel Document from *REQ_WP4_4.1.3_O_0001* till *REQ_WP4_4.1.3_O_0002.*

5.5.5.4 Functional Requirements

These requirements report the behaviour of the LCOB regardless of the applied technology and the type of signalling applied. As presented in Chapter 1.3, the corresponding requirements can be found in the Excel Document from *REQ_WP4_4.1.3_F_0003* till *REQ_WP4_4.1.3_F_0041.*

5.5.5.5 Non-functional Requirements

As presented in Chapter 1.3, the corresponding requirements can be found in the Excel Document from *REQ_WP4_4.1.3_NF_0044* till *REQ_WP4_4.1.3_NF_0045.*

5.5.6 Interface specification

This section contains the functional aspects of the LCOB interface.

The LCOB system must be able to be applied to any type of level crossing depending on the needs of the IM. For this reason, the physical interface may change from case to case. Obviously, for new solutions, depending on the needs of the IM, it is advisable to adopt solutions described in the other paragraphs of the document.

In all cases, the information that the LCOB system must provide to the LXC is described below. In this scheme it is the LXC that has the responsibility to connect to the existing signalling system using the available communication lines. The connection between LCOB and LXC is the purpose of this paragraph.

The LCOB interfaces with the Level Crossing (LX Controller) mainly.

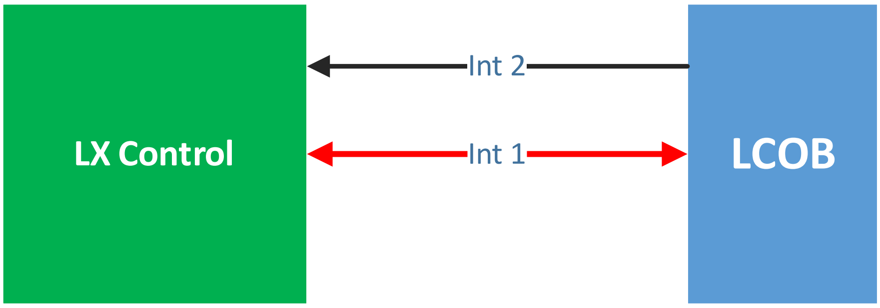


Figure 17: LCOB Interfaces

There are two main functional interfaces between the LCOB and the LX Controller as showed in the Figure 17.

- Int 1: The LCOB receive a command to scan the area, the LCOB returns the status of the area whether free or occupied by an obstacle.
- Int 2: The LCOB informs the LX Controller of its operating status by transferring the results of the tests performed periodically. This interface also provides for the transfer of maintenance information from LCOB to LXC.

Depending on the type of LXC present, a relay or serial interface will be possible using the available connection type.

Especially for stand alone level crossings of the older generation a relay interface is conceivable, especially when it is not possible to intervene with modifications to the LXC.

5.6 List of Requirements

Note: Where there is no UC linked to the requirement, it could be because of several reasons: first, the requirements are not functional, they are of other nature as configuration, non-functional, etc (see column Req Type), and second because they are added by the supplier (in the case of LX and Switches by ENYSE) to provide completeness to the description of the requested functionalities as per the GA (control, wireless control and energy self-sufficient management).

Sub-task	Asset	Function / Feature	Owner	Req ID	Req Description	Req Type	Safety	Rationale	UC Source (from WP4)	UC Source (from Other WPs)	Req Source (from Others WP)	Req Status (from oth WP)
4.1.1	**LX**	**Command and Controlling G1 lines**	**ÖBB**	Req ID	Req Description	Req Type	Safety?	Rationale	UC Source (from WP4)	UC Source (from Other WPs)	Req Source (from Others WP)	Req Source (from Others WP)
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0001	The Level Crossing shall be controlled by the following controlling entities for G1 Lines:	Functional						New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0001_a	*Interlocking (IXL)	Functional					[FA6, WP2, D2.2] FRWA 4;	Refined
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0001_b	*Interlocking (IXL) and Radio Block Centre (RBC)	Functional						New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0002	The Control Management of the Level Crossing shall control and monitor the protection facilities to establish safe and secure train passing	Functional	YES					New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_Def_0003	The term [Protection Facilities] describes the field devices like visual road signals, acoustic signals, barriers, train detection elements, etc. , that are connected to of the Level Crossing Object Controller. The selection of field devices depends on national regulations and standards	Definition	NO					New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_C_0004	The Configuration of the Level Crossing shall include an (logical) Interfaces for Controlling of the Level Crossing for Interlocking and Radio Block Centre	Configuration	NO					New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_C_0005	The (logical) Interface for the Controlling of the Level Crossing should be implemented with standardized interface specifications like EULYNX SCI-LC Interface to establish interoperability	Configuration	NO				[FA6, WP2, D2.2] FRWA 5;	Inherited
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_C_0006	The (logical) Interface for the Controlling of the Level Crossing should be implemented with national specifications and standards	Configuration	NO					New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_C_0007	The Configuration of the Level Crossing shall include a priorization of the (logical) Interface for Controlling against other (logical) interfaces of the Level Crossing	Configuration	YES					New

4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_C_0008	The Configuration of the Level Crossing shall include a priorization of the control entities by setting a primary controlling entity and a secondary/fallback controlling entity to establish higher availability	Configuration	YES					New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_C_0009	The Configuration of the Level Crossing shall include the connected Protection Facilities	Configuration	NO					New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_O_0010	The Control Management of the Level Crossing shall include different Operational States (i.e. booting, initialization, operational, fallback, etc.)	Operational	NO					New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_O_0011	The Level Crossing shall only be controlled in the Operational State: OPERATIONAL, when the booting and initialization was successfully	Operational	YES		UC_WP4_4.1.1_001; UC_WP4_4.1.1_002; UC_WP4_4.1.1_010; UC_WP4_4.1.1_011; UC_WP4_4.1.1_012; UC_WP4_4.1.1_020; UC_WP4_4.1.1_030; UC_WP4_4.1.1_031; UC_WP4_4.1.1_032; UC_WP4_4.1.1_034;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0012	The Control Management of the Level Crossing shall activate the Protection Facilities after receiving the command from the control entity	Functional	YES		UC_WP4_4.1.1_001;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0013	The Control Management of the Level Crossing shall deactivate the Protection Facilities after receiving the command from the control entity	Functional	YES		UC_WP4_4.1.1_002;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0014	The Control Management of the Level Crossing shall include Functional states, that define the current action and safety state of the Level Crossing:	Functional	YES		UC_WP4_4.1.1_001; UC_WP4_4.1.1_002;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0014_a	* Deactivated and unprotected	Functional	YES		UC_WP4_4.1.1_001; UC_WP4_4.1.1_002;			New

4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0015_b	* Activated and unprotected	Functional	YES		UC_WP4_4.1.1_001; UC_WP4_4.1.1_002;				New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0016_c	* Activated and protected	Functional	YES		UC_WP4_4.1.1_001; UC_WP4_4.1.1_002;				New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0017_d	* Autonomous Operation Mode	Functional	YES		UC_WP4_4.1.1_032; UC_WP4_4.1.1_033;				New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_Def_0018	The terms [Deactivated and Activated] descibes the process of	Definition	NO						New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_Def_0018_a	* Deactivated: The Control Management of the Level Crossing is currently deactivating the Protection Facilities	Definition	NO						New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_Def_0018_b	* Activated: The Control Management of the Level Crossing is currently activating the Protection Facilities	Definition	NO						New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_Def_0019	The terms [Unprotected and protected] describes the safety state of the Level Crossing:	Definition	NO						New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_Def_0019_a	* Unprotected: The Level Crossing is not safe for train passing	Definition	NO						New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_Def_0019_b	* Protected: The Level Crossing is safe for train passing	Definition	NO						New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_Def_0020	The term [Autonomous Mode] describes the functional state, that the Level Crossing is currently working autonomously and is not be controlled by any controlling entitiy.	Definition	NO						New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0021	When the functional state of the Level Crossing changes, the Control Management of the Level Crossing shall report the new functional status to the controlling entity	Functional	YES		UC_WP4_4.1.1_001; UC_WP4_4.1.1_002;				New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0022	The Control Management of the Level Crossing shall have Monitoring Parameters to track the state and condition of the Protection Facilites	Functional	YES		UC_WP4_4.1.1_010; UC_WP4_4.1.1_011; UC_WP4_4.1.1_012;				New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_C_0023	The Configuration of the Level Crossing shall include the selection of monitoring parameters	Configuration	NO						New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_C_0024	The selection of monitoring parameters depends on the nationals regulations and standards.	Configuration	NO						New

4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0025	Following Monitoring Parameters should be included:	Functional	NO					New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0025_a	* State of the Barriers: top end position, bottom end position, no end position, not applicable	Functional	NO		UC_WP4_4.1.1_010;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0025_a	* Barrier Movement: barrier movement downwards, barrier movement upwards, barriers not moving, not applicable	Functional	NO		UC_WP4_4.1.1_010;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0025_b	* State of the road light signals: signals on, signals off, not applicable	Functional	NO		UC_WP4_4.1.1_010;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0025_c	* State of acoustic signals: signals on, signals off, not applicable	Functional	NO		UC_WP4_4.1.1_010;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0025_d	* state/values of generic I/O: active, not active, not applicable	Functional	NO		UC_WP4_4.1.1_010;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0025_e	* State of power supply: working correctly, not fully available, not applicable	Functional	NO		UC_WP4_4.1.1_010;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0025_f	* State of connected Obstacle Detection System: no obstacle detected in the conflict area, obstacle detected in the conflict area, not applicable	Functional	NO		UC_WP4_4.1.1_011;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0025_g	* Sate of train detection elements: vacant, occupied, failed	Functional	NO		UC_WP4_4.1.1_012;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0026	When the Monitoring Parameters of the Level Crossing changes, the Control Management of the Level Crossing shall report the change to the controlling entity	Functional	YES		UC_WP4_4.1.1_010; UC_WP4_4.1.1_011; UC_WP4_4.1.1_012;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0027	The Control Management of the Level Crossing shall include functions, mechanism and methods to detect irregulations in the operation of the Level Crossing (i.e. Closing Timers to monitor the closing time of the barriers)	Functional	YES		UC_WP4_4.1.1_020; UC_WP4_4.1.1_021;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_Def_0028	The term [irregulations] describes the deviation in the intended and correct operation of the Level Crossing	Definition	NO					New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_C_0029	The selection and implementation of the functions, mechanism and methods to detect irregulations shall relay on national regulations and standards	Configuration	NO					New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0030	The Control Management of the Level Crossing shall report detected irregulations to the controlling entitiy (i.e. Closing Timer Overrun)	Functional	YES		UC_WP4_4.1.1_020;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0031	The Control Management of the Level Crossing shall include functions, mechanism and methods to detect failures in the operation of the Level Crossing	Functional	YES		UC_WP4_4.1.1_021;			New

4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_C_0032	The selection and implementation of the functions, mechanism and methods to detect failures shall relay on national regulations and standards	Configuration	NO					New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0033	The Control Management of the Level Crossing shall evaluate and categorize detected failures based on the status of the Protection Facilities in:	Functional	YES		UC_WP4_4.1.1_021;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0033_a	* critical failure	Functional	NO		UC_WP4_4.1.1_021;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0033_b	* non-critical failure	Functional	NO		UC_WP4_4.1.1_021;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_Def_0034	The definition of critical failures and non-critical failures depends on national regulations and standards	Definition	NO					New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0035	The Control Management of the Level Crossing shall report detected critical and non-critical failures to the controlling entity	Functional	YES		UC_WP4_4.1.1_021;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0036	The Control Management of the Level Crossing shall switch into Operational State: FALLBACK, when a critical failures is detected.	Functional	YES		UC_WP4_4.1.1_020; UC_WP4_4.1.1_021;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0037	The Level Crossing shall include an Operational Mode for Local Operation	Configuration	YES		UC_WP4_4.1.1_030; UC_WP4_4.1.1_031;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_AD_0038	The Level Crossing shall include an Interface for the Local Operator to control and monitor the Level Crossing	ArchDes	YES		UC_WP4_4.1.1_030; UC_WP4_4.1.1_031;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0039	The Control Management of the Level Crossing shall request the handover to Local Operation Mode to the controlling entitiy, after receiving the request from the Local Operator	Functional	YES		UC_WP4_4.1.1_030;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0040	The Control Management of the Level Crossing shall establish the handover to Local Operation Mode after the confirmed release from the controlling entitiy	Functional	YES		UC_WP4_4.1.1_030;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0041	In Operational Mode Local Operation the Protection Facilities of the Level Crossing shall be controlled locally by the Local Operator	Functional	YES		UC_WP4_4.1.1_030;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0042	In Operational Mode Local Operation the Protection Facilities of the Level Crossing shall not be controlled by the controlling entity	Functional	YES		UC_WP4_4.1.1_030;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0043	In Operational Mode Local Operation the Control Management of the Level Crossing shall report/visualize the functional states and monitoring parameters to/at the Interface for the Local Operator	Functional	YES		UC_WP4_4.1.1_030;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0044	In Operational Mode Local Operation the Control Management of the Level Crossing should report the functional states and monitoring parameters to the controlling entity	Functional	YES		UC_WP4_4.1.1_030;			New

4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0045	The Control Management of the Level Crossing shall request the removement of the handover, after receiving the request from the Local Operator	Functional	YES		UC_WP4_4.1.1_031;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0046	The Control Management of the Level Crossing shall establish the removement of the handover after the confirmed release from the controlling entity	Functional	YES		UC_WP4_4.1.1_031;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0047	The Control Management of the Level Crossing shall report/visualize the removement of the handover to the Local Operator	Functional	YES		UC_WP4_4.1.1_031;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_C_0048	The Level Crossing shall include an Operational Mode for Autonomous Operation	Configuration	NO		UC_WP4_4.1.1_032;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0049	The Control Management of the Level Crossing shall establish the handover to Autonomous Operation after receiving the command from the controlling entity	Functional	YES		UC_WP4_4.1.1_032;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0050	In Operational Mode Autonomous Operation the Protection Facilities of the Level Crossing shall function autonomously without the controlling of a controlling entity	Functional	YES		UC_WP4_4.1.1_032; UC_WP4_4.1.1_033;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0051	In Operational Mode Autonomous Operation the Protection Facilities of the Level Crossing shall not be controlled by the controlling entity	Functional	YES		UC_WP4_4.1.1_032;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0052	The Control Management of the Level Crossing shall establish the removement of the handover after the confirmed release from the controlling entity	Functional	YES		UC_WP4_4.1.1_033;			New
4.1.1	LX	Command and Controlling G1 lines	ÖBB	REQ_WP4_4.1.1_F_0053	The Control Management of the Level Crossing shall report the establishment and removement of the handover to the controlling entity	Functional	YES		UC_WP4_4.1.1_033;			New

4.1.1	**LX**	**Command and Controlling G2 lines**	**FT**	Req ID	Req Description	Req Type	Safety?	Rationale	UC Source (from WP4)	UC Source (from Other WPs)	Req Source (from Others WP)	Req Source (from Others WP)
4.1.1	LX	Command and Controlling G2 lines	FT	NULL	The control management requirements for G1 lines do apply except of the functions relating to "autonomous mode"			Even if capable of supporting direct/wired connections, G2 concept primarily sees level crossings commanded via cloud based communication connected with combined Interlocking/RBC monitoring train movement. Cloud exploitation supports reduction of CAPEX and OPEX.				
4.1.1	**LX**	**Wireless Communication**	**ÖBB**	Req ID	Req Description	Req Type	Safety?	Rationale	UC Source (from WP4)	UC Source (from Other WPs)	Req Source (from Others WP)	Req Source (from Others WP)
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_Def_2001	The Level Crossing shall use wireless communication technology as primary transmission technology at greenfield deployments	Definition	NO					New
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_Def_2002	The Level Crossing shall be use wireless communication technology as alternative transmission technology at brownfield deployments to the wired communication.	Definition	NO					New
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_AD_2003	The Level Crossing shall communicate wirelessly with the following partners through a wireless communication module integrated at the object controller of the Level Crossing	ArchDes	NO		UC_WP4_4.2.2_006			New
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_AD_2003_a	* Interlocking for G1 lines	ArchDes	NO		UC_WP4_4.2.2_006			New
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_AD_2003_b	* combined Interlocking/RBC for G2 lines	ArchDes	NO		UC_WP4_4.2.2_006			New
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2004	The Level Crossing machine shall be able to use any communication system that is intended for communication with command sources.	Operational	NO	Supports OPEX reduction by providing flexibility in choosing cost-effective solutions.	UC_WP4_4.2.2_006		[FA6, WP2, D2.2] ORWA 1;	Inherited
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2005	The wireless communication module of the Level Crossing shall be compatible to communicate with existing installed communication infrastructure.	Operational	NO	To reduce costs, the new systems should use as much as possible what is already present in terms of infrastructure.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 2.	Refined

4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2006	The wireless communication module of the Level Crossing shall possess the capability to utilize public, prive and/or hybrid solutions of communication infrastracutre while offering the required QoS.	Operational	NO	Supports OPEX reduction by providing flexibility in choosing cost-effective solutions.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 20.	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2007	The wireless communication module of the Level Crossing shall be compatible to communication infrastructures designed according to European standard EN50159.	Operational	NO	Aligning with OPEX reduction, the system's compatibility with the European Standard EN 50159 streamlines compliance processes for railway applications, encompassing communication, signalling, and processing systems, specifically focusing on safetyrelated communication in transmission systems.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 3.	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2008	The functionality of the wireless communication of the Level Crossing shall be independent of the Level Crossing's power source.	Operational	NO	To decrease OPEX and CAPEX by providing flexibility in power infrastructure, minimizing installation costs, and ensuring adaptability to diverse energy supply scenarios cost-effectively.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 14.	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_F_2009	The wireless communication of the Level Crossing shall be energy-efficient, particularly when powered by a local energy supply system, to minimize power consumption and reduce strain on the energy source.	Functional	NO	To minimize power consumption and reduce strain on the energy source.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 14, ORWA 2., ORWA 3., ORWA 4., ORWA 8.	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_F_2010	The wireless communication module of the Level Crossing shall be designed with Commercial-off-the-Shelf (COTS) solutions for Hardware and Software, while allowing the development of customized solutions, specific:	Functional	NO	Costs Reduction. Easier implementation.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 16.	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_F_2010_a	* the configuration of the intented national frequency bands and the adaptation of future radio options with new communication requirements.	Functional	NO		UC_WP4_4.2.2_006			New
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_AD_2011	The wireless communication module of the Level Crossing shall be designed redundantly to ensure high availability data transmission	ArchDes	NO	Contributing to both OPEX and CAPEX reduction. This approach minimizes the risk of disruptions, ensures continuous operation, and optimizes resource utilization, resulting in a cost-effective and resilient communication infrastructure.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] ORCM 3.	Refined

4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_F_2012	The wireless communication module of the Level Crossing shall support wireless communication with both terrestrial and non-terrestrial radio systems, adhering to IEEE, 3GPP, ITU and ISO standards	Functional	NO	Aligning with OPEX and CAPEX reduction by promoting a standardized and cost-effective approach to wireless communication technology.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 10.	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_F_2013	The wireless communication module of the G1 Level Crossing shall be compatible with the latest FRCMS specification and easy to upgrade to ensure future TSI compatibility.	Functional	NO	Reducing both OPEX and CAPEX by fostering interoperability and supporting seamless integration with evolving railway technologies. G2: due the nature of the concept, TSI and mandatory compatibility with FRMCS are not applicable to this lines group	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCMG1 1., NFRCMG1 2.	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2014	The wireless communication module of the Level Crossing should utilize standardized interface specifications, ensuring compatibility and interchangeability across different manufactors/vendors	Operational	NO	Aligning with OPEX and CAPEX reduction by promoting a standardized and cost-effective approach to wireless communication technology.	UC_WP4_4.2.2_006			New
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_F_2016	The wireless communication module of the Level Crossing shall have the capability to detect failures in the communication or connection	Functional	NO	Equipping the wireless communication system with fault detection capabilities aligns with both OPEX and CAPEX considerations by reducing downtime, minimizing operational disruptions, and facilitating cost-effective maintenance through proactive fault identification.	UC_WP4_4.2.2_006			New
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_F_2017	The wireless communication of the Level Crossing shall support network management policies, including the ability to implement VLANs or similar concepts for network partitioning and traffic segregation	Functional	NO	This will allow a better network management like usual private networks used by IM and aligns with both OPEX and CAPEX considerations by enhancing security, promoting efficient resource utilization, and minimizing potential operational disruptions cost-effectively.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 18	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2018	The wireless communication module of the Level Crossing shall support standardized network addressing with:	Operational	NO	Aligns with both OPEX and CAPEX considerations by ensuring compatibility, minimizing upgrade costs, and fostering long-term operational efficiency.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 15	Refined

4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2018_a	* IPv4 according to IETF RFC 791 specification	Operational	NO		UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 15	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2018_b	* IPv6 according to IETF RFC 2460 specification	Operational	NO		UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 15	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_C_2019	The wireless communication module of the Level Crossing shall be configurable based on the IP network adressing in use	Configuration	NO	Aligns with both OPEX and CAPEX considerations by ensuring compatibility with latest technology	UC_WP4_4.2.2_006			New
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2020	The wireless communication module of the Level Crossing shall support connection oriented and connectionless oriented protocols	Operational	NO	Aligns with both OPEX and CAPEX considerations by enhancing operational efficiency, reducing the risk of service disruptions, and promotes cost-effective resource utilization by tailoring communication parameters to the specific requirements of each application.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2021	The wireless communication module of the Level Crossing should use Transmission Control Protocol (TCP) according to:	Operational	NO	Aligning with OPEX and CAPEX, supporting TCP protocols enhances operational flexibility, reduces disruptions, and ensures cost-effective communication through widely used, standardized protocols.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2021_a	* RFC 9293 when TCP runs over IPv4	Operational	NO		UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2021_b	* RFC 2460 when TCP runs over IPv6.	Operational	NO		UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2022	The wireless communication module of the Level Crossing should use User Datagram Protocol (UDP) according to:	Operational	NO	Aligning with OPEX and CAPEX, supporting UPD protocols enhances operational flexibility, reduces disruptions, and ensures cost-effective communication through widely used, standardized protocols.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined

4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2022_a	* RFC 9124 when UDP runs over IPv4.	Operational	NO		UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_20022_b	* RFC 2460 when UDP runs over IPv6.	Operational	NO		UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2023	The wireless communication module of the Level Crossing shall use an interoperable Safety Layer for all UDP-TCP/IP communication for authentications, integrity, message ordering and timelineness	Operational	YES	Implementing an interoperable Safety Layer for all UDP-TCP/IP connections in the communication system aligns with both OPEX and CAPEX considerations by ensuring standardized safety protocols, reducing integration costs, and fostering long-term operational efficiency in a cost-effective manner.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 12.	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_C_2024	The Safety Layer of the wireless communication module shall fulfill the current level of safety characteristics defined by national regulations and rules	Configuration	YES		UC_WP4_4.2.2_006			New
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_F_2025	The wireless communication module of the Level Crossing shall incorporate an authentication algorithm	Functional	NO	To provide secure and trustworthy on-board to trackside communications.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] ORCM 6.	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_O_2026	The wireless communication of the Level Crossing shall fulfill Quality-of-Service parameters (latency, jitter, reliability, data rate), defined by the Infrastructure managers.	Operational	NO	Contributing to OPEX reduction by ensuring reliable communication.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] ORCM 1	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_F_2027	The wireless communication of the Level Crossing shall support different priority classes for vital and non-vital communication.	Functional	NO	Aligns with both OPEX and CAPEX considerations by ensuring optimal resource allocation, reducing latency for vital functions, and enhancing overall system reliability cost-effectively	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 13, FRCM 14.	Refined
4.1.1	LX	Wireless Communication	ÖBB	REQ_WP4_4.1.1_F_2028	The wireless communication of the Level Crossing shall support multiple operational modes, which shall be compatible with the operational modes of the Level Crossing's Control Management.	Functional	NO	Supports OPEX reduction by ensuring efficient resource allocation based on specific operational needs.	UC_WP4_4.2.2_006		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] ORCM 1	Refined

4.1.1	**LX**	**Power Management**	**ENYSE**	Req ID	Req Description	Req Type	Safety?	Rationale	UC Source (from WP4)	UC Source (from Other WPs)	Req Source (from Others WP)	Req Source (from Others WP)
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_AS_3001	Three potential **sources of energy** are considered: - Grid, and - Renewable Source (e.g. solar panels), and - Batteries.	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.			[FA6, WP2, D2.2] ORWA 8;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_AS_3002	The Level Crossing are to be installed always with battery.	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_AS_3003	The Level Crossing power management module shall have **batteries** sized to supply power for **at least 12 hours**.	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_Def_3004	**BACKUP** (SOURCE OF ENERGY): Refers to the role that the battery plays as source of energy.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_Def_3005	**COMPLEMENTARY SOURCE OF ENERGY**: Source of energy that provides additional power to the primary one, when necessary.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_Def_3006	**PRIMARY SOURCE OF ENERGY**: First source of energy providing power to the asset.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_Def_3007	SAFE STATE: State that the Level Crossing must transit to, in case of a degraded behaviour. It implies to lay down the barriers (due to the gravity) and to switch-off light signals.	Definition	YES	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3008	The **battery is charged constantly** from the energy provided by the grid and/or by the renewable sources.	Functional	NO	Efficient use of energy.	None.			New
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3009	The Level Crossing does always use as first the source of energy (whatever it is, either grid or renewable) and if not available, then uses the battery as backup.	Functional	NO	Efficient use of energy.	None.			New
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_AD_3010	The Level Crossing shall provide a specific **module for power management**, that operates in an environment class compatible with the IM needs (e.g. range temperature -20°C to +45°C, IP 54, etc.).	ArchDes	NO	LX to provide a modular design.	None.		[FA6, WP2, D2.2] ORWA 2; [FA6, WP2, D2.2] ORWA 3;	Inherited
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_AD_3011	The Level Crossing shall have a **renewable energy source integrated by default** in the power management module. Note: The renewable energy source can be removed.	ArchDes	NO	LX to satisfy carbon footprint reduction tendency.	None.		[FA6, WP2, D2.2] ORWA 8;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_C_3012	The Level Crossing power management module shall have the capability to be configured by the following **combinations** of energy sources:	Configuration	NO	See sub-requirements.	See sub-requirements.		[FA6, WP2, D2.2] ORWA 8;	Refined

4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_C_3012_a	Renewable + Grid + Battery, or	Configuration	NO	See UCs.	UC_WP4_4.1.1_211; UC_WP4_4.1.1_212; UC_WP4_4.1.1_213; UC_WP4_4.1.1_214; UC_WP4_4.1.1_215; UC_WP4_4.1.1_216; UC_WP4_4.1.1_217; UC_WP4_4.1.1_218;		[FA6, WP2, D2.2] ORWA 8;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_C_3012_b	Renewable + Battery, or	Configuration	NO	See UCs.	UC_WP4_4.1.1_203; UC_WP4_4.1.1_204; UC_WP4_4.1.1_205; UC_WP4_4.1.1_206; UC_WP4_4.1.1_217; UC_WP4_4.1.1_218;		[FA6, WP2, D2.2] ORWA 8;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_C_3013_c	Grid + Battery, or	Configuration	NO	See UCs.	UC_WP4_4.1.1_207; UC_WP4_4.1.1_208; UC_WP4_4.1.1_209; UC_WP4_4.1.1_210; UC_WP4_4.1.1_217; UC_WP4_4.1.1_218;		[FA6, WP2, D2.2] ORWA 8;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_C_3014	Battery. Note: The configuration 'd)' is not recommended due to its limited duration of operation time.	Configuration	NO	See UCs.	UC_WP4_4.1.1_201; UC_WP4_4.1.1_202; UC_WP4_4.1.1_217; UC_WP4_4.1.1_218;		[FA6, WP2, D2.2] ORWA 8;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3015	The Level Crossing power management module shall allow to **return** from the battery energy to:	Functional	NO	See sub-requirements.	See sub-requirements.		[FA6, WP2, D2.2] FRWA 1;	Inherited

4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3015_a	Renewable energy or,	Functional	NO	See UCs.	UC_WP4_4.1.1_205; UC_WP4_4.1.1_206;		[FA6, WP2, D2.2] FRWA 1;	Inherited
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3015_b	Grid energy or,	Functional	NO	See UCs.	UC_WP4_4.1.1_209; UC_WP4_4.1.1_210;		[FA6, WP2, D2.2] FRWA 1;	Inherited
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3015_c	Renewable and grid energy combination.	Functional	NO	See UCs.	UC_WP4_4.1.1_215; UC_WP4_4.1.1_216;		[FA6, WP2, D2.2] FRWA 1;	Inherited
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3016	The Level Crossing power management module, when integrated with a renewable energy source, shall use renewable energy as the **primary source of energy**.	Functional	NO	See UCs.	UC_WP4_4.1.1_203; UC_WP4_4.1.1_204; UC_WP4_4.1.1_211; UC_WP4_4.1.1_212; UC_WP4_4.1.1_213; UC_WP4_4.1.1_214;		[FA6, WP2, D2.2] FRWA 1;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3017	The Level Crossing power management module configured with renewable, grid, and battery energy sources shall use grid energy to **supplement** the remaining energy of the Level Crossing in case of renewable energy is insufficient. Note: Renewable energy must be compatible with grid energy.	Functional	NO	See UCs.	UC_WP4_4.1.1_213; UC_WP4_4.1.1_214;		[FA6, WP2, D2.2] FRWA 1;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3018	The Level Crossing power management module configured with renewable, grid, and battery energy sources shall use battery energy to **supplement** the remaining energy of the Level Crossing in case of grid energy is unavailable and renewable is insufficient.	Functional	NO	See UCs.	UC_WP4_4.1.1_215; UC_WP4_4.1.1_216;		[FA6, WP2, D2.2] FRWA 1;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3019	The Level Crossing power management module configured with renewable and battery energy sources shall use the battery to **supplement** the remaining energy of the Level Crossing in case renewable energy is insufficient.	Functional	NO	See UCs.	UC_WP4_4.1.1_205; UC_WP4_4.1.1_206;		[FA6, WP2, D2.2] FRWA 1;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3020	The Level Crossing power management module configured with grid and battery energy sources shall use grid as the **primary source of energy**.	Functional	NO	See UCs.	UC_WP4_4.1.1_207; UC_WP4_4.1.1_208;		[FA6, WP2, D2.2] FRWA 1;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3021	The Level Crossing power management module, when configured only with battery, shall utilize it as the **primary source of energy**.	Functional	NO	See UCs.	UC_WP4_4.1.1_201; UC_WP4_4.1.1_202;		[FA6, WP2, D2.2] FRWA 1;	Refined

4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3022	The Level Crossing power management module shall use the battery when the primary and, if applicable, complementary source of energy are **unavailable**.	Functional	NO	See UCs.	UC_WP4_4.1.1_205; UC_WP4_4.1.1_206; UC_WP4_4.1.1_209; UC_WP4_4.1.1_210; UC_WP4_4.1.1_215; UC_WP4_4.1.1_216;		[FA6, WP2, D2.2] FRWA 1;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3023	The Level Crossing power management module shall **continuously charge the battery** if it is not full, with the primary source of energy. Note1: In case of having a unique source of energy the battery, this requirement does not apply. Note2: In case of having power management module configuration with renewable (primary) + grid (complementary) + battery (backup), to charge the battery, renewable energy shall be used first, and if it is insufficient, it shall be supplemented with grid energy.	Functional	NO	See UCs.	UC_WP4_4.1.1_205; UC_WP4_4.1.1_206; UC_WP4_4.1.1_209; UC_WP4_4.1.1_210; UC_WP4_4.1.1_215; UC_WP4_4.1.1_216;		[FA6, WP2, D2.2] FRWA 2;	Refined
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3024	The Level Crossing shall go to **safe state** if all energy sources including the battery are unavailable.	Functional	YES	See UCs.	UC_WP4_4.1.1_217; UC_WP4_4.1.1_218;			New
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3025	For maintenance and diagnostics purposes, the Level Crossing shall **notify** from the power management module:	Functional	NO	See sub-requirements.	See sub-requirements.		[FA6, WP2, D2.2] FRWA 3;	Inherited
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3025_a	The consumption to renewable energy.	Functional	NO	Necessary for maintenance/diagnosis purposes.	UCs about maintenance/diagnosis.		[FA6, WP2, D2.2] FRWA 3;	Inherited
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3025_b	The consumption to grid energy.	Functional	NO	Necessary for maintenance/diagnosis purposes.	UCs about maintenance/diagnosis.		[FA6, WP2, D2.2] FRWA 3;	Inherited
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3025_c	The usage of the battery.	Functional	NO	Necessary for maintenance/diagnosis purposes.	UCs about maintenance/diagnosis.		[FA6, WP2, D2.2] FRWA 3;	Inherited
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_F_3025_d	The health status of the battery such as the level of charge of the battery, expected lifetime, etc.	Functional	NO	Necessary for maintenance/diagnosis purposes.	UCs about maintenance/diagnosis.		[FA6, WP2, D2.2] FRWA 3;	Inherited
4.1.1	LX	Power Management	ENYSE	REQ_WP4_4.1.1_AD_3026	The Level Crossing shall allow a **reduced hardware** configuration that operates only with batteries. Note: How those batteries shall be recharged is out of the scope.	ArchDes	NO	Light LX - Less HW.	None.		[FA6, WP2, D2.2] ORWA 4;	Inherited

4.1.1	**LX**	**Remote Maintenance**	**ENYSE**	Req ID	Req Description	Req Type	Safety?	Rationale	UC Source (from WP4)	UC Source (from Other WPs)	Req Source (from Others WP)	Req Source (from Others WP)
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_AS_4001	Remote maintenance can be used for 2 different **purposes**: - Diagnosis, and - Maintenance.	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_AS_4002	About <u>diagnosis</u>, 4 different **types of data** can be accessed: - Memory Data (Raw) - Configuration Data (Processed) - On-time Events Data (Processed) - Historical Events Data (Processed)	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_AS_4003	The above mentioned **types of data can be transmitted through** the following **3 mechanisms**: - Under Demand, and - Dump Transmission, and - Subscription.	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_AS_4004	About <u>maintenance</u>, 3 **types of items** can be updated: - Software - Software Data - Operational Data	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_AS_4005	There is only **one mechanism to update items**; it is mainly to send the information from a Maintenance Terminal; optionally, the asset may acknowledge the reception of such information.	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_Def_4006	**CONFIGURATION DATA**: Processed data, answering a given demand; e.g., current SW version installed in the asset.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_Def_4007	**DUMP TRANSMISSION**: Asset provides data constantly.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_Def_4008	**HISTORICAL EVENTS DATA**: Same than On-time, but between two dates/times.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_Def_4009	**MEMORY DATA**: Raw data, without any type of interpretation. Usually is to be demanded between two memory addresses.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_Def_4010	**ON-TIME EVENTS DATA**: Processed data, providing any of the events previously agreed with the Maintenance Terminal; e.g., current asset state, current temperature, etc.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_Def_4011	**OPERATIONAL DATA**: Set of variables used to express the state of the asset; e.g., number of movements performed, number of manual interventions, current energy consumption, etc.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New

4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_Def_4012	**SOFTWARE**: Compiled source code that execute a given function.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_Def_4013	**SOFTWARE DATA**: Data to configure the SW and let it works correctly; e.g., IP address, number of elements to control, etc.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_Def_4014	**SUBSCRIPTION**: Asset provides data on a scheduled basis.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_Def_4015	**UNDER DEMAND**: Asset provides data when the Maintenance Terminal asks for it.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_Def_4016	**UPDATE**: The Maintenance Terminal send information to update any item to the asset.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_AS_4017	Level Crossing shall implement remote maintenance facilities throughout the **wired or wireless** connection.	ArchDes	NO	External Communications.	None.		[FA6, WP2, D2.2] ORWA 5;	Inherited
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_AS_4018	The Ethernet based wired or wireless connections of the Level Crossing shall implement the EULYNX **SDI-LC** diagnostics protocol, among others.	ArchDes	NO	External Communications.	None.		[FA6, WP2, D2.2] ORWA 6; [FA6, WP2, D2.2] FRWA 5;	Inherited
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4019	The Level Crossing maintenance module shall support **2 different purposes**:	Functional	NO	See sub-requirements.	See sub-requirements.			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4019_a	Diagnosis and,	Functional	NO	See UCs.	UC_WP4_4.1.1_301; UC_WP4_4.1.1_302; UC_WP4_4.1.1_303;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4019_b	Maintenance.	Functional	NO	See UCs.	UC_WP4_4.1.1_304; UC_WP4_4.1.1_305;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_C_4020	The Level Crossing shall provide the capability to **configure** the type of data and the way in which that data is going to be provided.	Configuration	NO	See UCs.	UC_WP4_4.1.1_301; UC_WP4_4.1.1_302; UC_WP4_4.1.1_303; UC_WP4_4.1.1_304; UC_WP4_4.1.1_305;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4021	The Level Crossing maintenance module shall have **non-remote maintenance as backup**.	Functional	NO	See UCs.	UC_WP4_4.1.1_301;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4022	(Diagnosis) The Level Crossing maintenance module shall provide all the following data **under demand**:	Functional	NO	See sub-requirements.	See sub-requirements.			New

4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4022_a	Memory.	Functional	NO	See UCs.	UC_WP4_4.1.1_302;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4022_b	Configuration.	Functional	NO	See UCs.	UC_WP4_4.1.1_302;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4022_c	On-time Events.	Functional	NO	See UCs.	UC_WP4_4.1.1_302;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4022_d	Historical Events.	Functional	NO	See UCs.	UC_WP4_4.1.1_302;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4023	(Diagnosis) The Level Crossing maintenance module shall provide the following data **through dump transmission**: Note: a) and b) are optionally provided according to the asset configuration.	Functional	NO	See sub-requirements.	See sub-requirements.			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4023_a	Memory.	Functional	NO	See UCs.	UC_WP4_4.1.1_303;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4023_b	Configuration.	Functional	NO	See UCs.	UC_WP4_4.1.1_303;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4023_c	On-time Events.	Functional	NO	See UCs.	UC_WP4_4.1.1_303;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4024	(Diagnosis) The Level Crossing maintenance module shall provide the following data **through subscription**: Note: b) is optionally provided according to the asset configuration.	Functional	NO	See sub-requirements.	See sub-requirements.			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4024_a	On-time Events.	Functional	NO	See UCs.	UC_WP4_4.1.1_304;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4024_b	Historical Events.	Functional	NO	See UCs.	UC_WP4_4.1.1_304;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4025	(Maintenance) The Level Crossing maintenance module shall **update** the following items when ordered by maintenance terminal: Note: It must be proven that each item can be updated, either individually or concurrently.	Functional	NO	See sub-requirements.	See sub-requirements.			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4025_a	Software.	Functional	NO	See UCs.	UC_WP4_4.1.1_305;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4025_b	Software Data.	Functional	NO	See UCs.	UC_WP4_4.1.1_305;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4025_c	Operational Data.	Functional	NO	See UCs.	UC_WP4_4.1.1_305;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4026	(Maintenance) The Level Crossing maintenance module shall provide optionally an **acknowledgement** indicating successful updated of some or all the following items: Note: This acknowledgement is optional.	Functional	NO	See sub-requirements.	See sub-requirements.			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4026_a	Software.	Functional	NO	See UCs.	UC_WP4_4.1.1_305;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4026_b	Software Data.	Functional	NO	See UCs.	UC_WP4_4.1.1_305;			New
4.1.1	LX	Remote Maintenance	ENYSE	REQ_WP4_4.1.1_F_4026_c	Operational Data.	Functional	NO	See UCs.	UC_WP4_4.1.1_305;			New

4.1.2	**Switch**	**Configurability**	**ÖBB**	Req ID	Req Description	Req Type	Safety?	Rationale	UC Source (from WP4)	UC Source (from Other WPs)	Req Source (from Others WP)	Req Source (from Others WP)
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0001	The point machine (as component of a Switch) shall be capable of adapting to the different turnout types (defined by the different curve radius applicable to reverse movements).	Configuration	NO				[FA6, WP2, D2.2] ORWA 7;	Inherited
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0002	The point operating mechanism and the point monitoring device for verifying the end positions of a switch shall operate completely independently of each other	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_AD_0003	The Switch shall be designed modular	ArchDes	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0004	The configuration of the Switch shall include the operating principle of the actuating force generation (i.e. electromechanical, electrohydraulic)	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0005	The configuration of the Switch shall include to option to use additional monitoring devices for the point machine.	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0006	The Switch shall be able to replace individual modules at the location without any special tools and equipments	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0007	The Switch shall have the configuration of a left and right arrangement of the switch drive	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0008	The Switch shall have the configuration of being converted to the left-hand or right-hand drive at the installation location	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0009	The configuration of the Switch shall include the setting of the switching force of the point machine	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0010	The maximum switching force shall not be exceeded and shall remain constant over the lifecycle	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0011	The minimum switching force shall not fall below and shall remain constant over the lifecycle	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0012	The configuration of the Switch shall include the setting of the switch throw of the point machine	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0013	The configuration of the Switch shall include the setting of the switching time of the point machine	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0014	The configuration of the Switch shall include the setting of the inspection path of the point machine	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0015	The configuration of the Switch shall include the setting the holding force of the point machine	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0016	The configuration the point operating mechanism of the the Switch shall fulfil national specifications and standards	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0017	The configuration of the switching force and the holding force of the point machine shall be independently	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0018	The configuration of the Switch shall include the option of connecting and operating a manual switch throw mechanism/ manual switch lever	Configuration	NO					New

4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0019	The configuration of the Switch shall include the option of seperate monitoring devices for each point blade	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0020	The configuration of the Switch shall include the option of additional monitoring devices for the frog of the switch	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0021	The configuration of the Switch shall include the setting of the wireless communication Management	Configuration	NO					New
4.1.2	Switch	Configurability	ÖBB	REQ_WP4_4.1.2_C_0022	The configuration of the Switch shall consider the ambient conditions and applications classes according to EN 60721-3-4 (IEC 721)	Configuration	NO					New
4.1.2	**Switch**	**Wireless Communication**	**ÖBB**	Req ID	Req Description	Req Type	Safety?	Rationale	UC Source (from WP4)	UC Source (from Other WPs)	Req Source (from Others WP)	Req Source (from Others WP)
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_Def_2001	The Switch shall use wireless communication technology as primary transmission technology at greenfield deployments	Definition	NO					New
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_Def_2002	The Switch shall be use wireless communication technology as alternative transmission technology at brownfield deployments to the wired communication.	Definition	NO					New
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_AD_2003	The Switch shall communicate wirelessly with the following partners through a wireless communication module integrated at the object controller of the Switch	ArchDes	NO		UC_WP4_4.2.2_001			New
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_AD_2003_a	* Interlocking for G1 lines	ArchDes	NO		UC_WP4_4.2.2_001			New
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_AD_2003_b	* combined Interlocking/RBC for G2 lines	ArchDes	NO		UC_WP4_4.2.2_001			New
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2004	The Switch machine shall be able to use any communication system that is intended for communication with command sources.	Operational	NO	Supports OPEX reduction by providing flexibility in choosing cost-effective solutions.	UC_WP4_4.2.2_001		[FA6, WP2, D2.2] ORWA 1;	Inherited
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2005	The wireless communication module of the Switch shall be compatible to communicate with existing installed communication infrastructure.	Operational	NO	To reduce costs, the new systems should use as much as possible what is already present in terms of infrastructure.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 2.	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2006	The wireless communication module of the Switch shall possess the capability to utilize public, prive and/or hybrid solutions of communication infrastracutre while offering the required QoS.	Operational	NO	Supports OPEX reduction by providing flexibility in choosing cost-effective solutions.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 20.	Refined

4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2007	The wireless communication module of the Switch shall be compatible to communication infrastructures designed according to European standard EN50159.	Operational	NO	Aligning with OPEX reduction, the system's compatibility with the European Standard EN 50159 streamlines compliance processes for railway applications, encompassing communication, signalling, and processing systems, specifically focusing on safetyrelated communication in transmission systems.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 3.	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2008	The functionality of the wireless communication of the Switch shall be independent of the Switch's power source.	Operational	NO	To decrease OPEX and CAPEX by providing flexibility in power infrastructure, minimizing installation costs, and ensuring adaptability to diverse energy supply scenarios cost-effectively.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 14.	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_F_2009	The wireless communication of the Switch shall be energy-efficient, particularly when powered by a local energy supply system, to minimize power consumption and reduce strain on the energy source.	Functional	NO	To minimize power consumption and reduce strain on the energy source.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 14, ORWA 2., ORWA 3., ORWA 4., ORWA 8.	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_F_2010	The wireless communication module of the Switch shall be designed with Commercial-off-the-Shelf (COTS) solutions for Hardware and Software, while allowing the development of customized solutions, specific:	Definition	NO	Costs Reduction. Easier implementation.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 16.	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_F_2010_a	* the configuration of the intented national frequency bands and the adaptation of future radion options with new communication requirements.	Functional	NO		UC_WP4_4.2.2_001			New
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_AD_2011	The wireless communication module of the Switch shall be designed redundantly to ensure high availability data transmission	ArchDes	NO	Contributing to both OPEX and CAPEX reduction. This approach minimizes the risk of disruptions, ensures continuous operation, and optimizes resource utilization, resulting in a cost-effective and resilient communication infrastructure.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] ORCM 3.	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_F_2012	The wireless communication module of the Switch shall support wireless communication with both terrestrial and non-terrestrial radio systems, adhering to IEEE, 3GPP, ITU and ISO standards	Operational	NO	Aligning with OPEX and CAPEX reduction by promoting a standardized and cost-effective approach to wireless communication technology.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 10.	Refined

4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_F_2013	The wireless communication module of the G1 Switch shall be compatible with the latest FRCMS specification and easy to upgrade to ensure future TSI compatibility.	Functional	NO	Reducing both OPEX and CAPEX by fostering interoperability and supporting seamless integration with evolving railway technologies. G2: due the nature of the concept, TSI and mandatory compatibility with FRMCS are not applicable to this lines group	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCMG1 1., NFRCMG1 2.	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2014	The wireless communication module of the Switch should utilize standardized interface specifications, ensuring compatibility and interchangeability across different manufactors/vendors	Operational	NO	Aligning with OPEX and CAPEX reduction by promoting a standardized and cost-effective approach to wireless communication technology.	UC_WP4_4.2.2_001			New
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_F_2016	The wireless communication module of the Switch shall have the capability to detect failures in the communication or connection	Functional	NO	Equipping the wireless communication system with fault detection capabilities aligns with both OPEX and CAPEX considerations by reducing downtime, minimizing operational disruptions, and facilitating cost-effective maintenance through proactive fault identification.	UC_WP4_4.2.2_001			New
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_F_2017	The wireless communication of the Switch shall support network management policies, including the ability to implement VLANs or similar concepts for network partitioning and traffic segregation	Functional	NO	This will allow a better network management like usual private networks used by IM and aligns with both OPEX and CAPEX considerations by enhancing security, promoting efficient resource utilization, and minimizing potential operational disruptions cost-effectively.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 18	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2018	The wireless communication module of the Switch shall support standardized network addressing with:	Operational	NO	Aligns with both OPEX and CAPEX considerations by ensuring compatibility, minimizing upgrade costs, and fostering long-term operational efficiency.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 15	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2018_a	* IPv4 according to IETF RFC 791 specification	Operational	NO		UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 15	Refined

4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2018_b	* IPv6 according to IETF RFC 2460 specification	Operational	NO		UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 15	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_C_2019	The wireless communication module of the Switch shall be configurable based on the IP network adressing in use	Configuration	NO	Aligns with both OPEX and CAPEX considerations by ensuring compatibility with latest technology	UC_WP4_4.2.2_001			New
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2020	The wireless communication module of the Switch shall support connection oriented and connectionless oriented protocols	Operational	NO	Aligns with both OPEX and CAPEX considerations by enhancing operational efficiency, reducing the risk of service disruptions, and promotes cost-effective resource utilization by tailoring communication parameters to the specific requirements of each application.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2021	The wireless communication module of the Switch should use Transmission Control Protocol (TCP) according to:	Operational	NO	Aligning with OPEX and CAPEX, supporting TCP protocols enhances operational flexibility, reduces disruptions, and ensures cost-effective communication through widely used, standardized protocols.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2021_a	* RFC 9293 when TCP runs over IPv4	Operational	NO		UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2021_b	* RFC 2460 when TCP runs over IPv6.	Operational	NO		UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2022	The wireless communication module of the Switch should use User Datagram Protocol (UDP) according to:	Operational	NO	Aligning with OPEX and CAPEX, supporting UPD protocols enhances operational flexibility, reduces disruptions, and ensures cost-effective communication through widely used, standardized protocols.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2022_a	* RFC 9124 when UDP runs over IPv4.	Operational	NO		UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined

4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_20022_b	* RFC 2460 when UDP runs over IPv6.	Operational	NO		UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 12	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2023	The wireless communication module of the Switch shall use an interoperable Safety Layer for all UDP-TCP/IP communication for authentications, integrity, message ordering and timeliness	Operational	YES	Implementing an interoperable Safety Layer for all UDP-TCP/IP connections in the communication system aligns with both OPEX and CAPEX considerations by ensuring standardized safety protocols, reducing integration costs, and fostering long-term operational efficiency in a cost-effective manner.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] NFRCM 12.	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_C_2024	The Safety Layer of the wireless communication module shall fulfill the current level of safety characteristics defined by national regulations and rules	Configuration	YES		UC_WP4_4.2.2_001			New
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_F_2025	The wireless communication module of the Switch shall incorporate an authentication algorithm	Functional	NO	To provide secure and trustworthy on-board to trackside communications.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] ORCM 6.	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_O_2026	The wireless communication of the Switch shall fulfill Quality-of-Service parameters (latency, jitter, reliability, data rate), defined by the Infrastructure managers.	Operational	NO	Contributing to OPEX reduction by ensuring reliable communication.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] ORCM 1	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_F_2027	The wireless communication of the Switch shall support different priority classes for vital and non-vital communication.	Functional	NO	Aligns with both OPEX and CAPEX considerations by ensuring optimal resource allocation, reducing latency for vital functions, and enhancing overall system reliability cost-effectively	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] FRCM 13, FRCM 14.	Refined
4.1.2	Switch	Wireless Communication	ÖBB	REQ_WP4_4.1.2_F_2028	The wireless communication of the Switch shall support multiple operational modes, which shall be compatible with the operational modes of the Switch's Control Management.	Functional	NO	Supports OPEX reduction by ensuring efficient resource allocation based on specific operational needs.	UC_WP4_4.2.2_001		[FA6, WP4, D4.2 Interface Specification Track-Field, v4.3] ORCM 1	Refined
4.1.2	**Switch**	**Power Management**	**ENYSE**	Req ID	Req Description	Req Type	Safety?	Rationale	UC Source (from WP4)	UC Source (from Other WPs)	Req Source (from Others WP)	Req Source (from Others WP)
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_AS_3001	Three potential **sources of energy** are considered: - Grid, and - Renewable Source (e.g. solar panels), and - Batteries.	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.			[FA6, WP2, D2.2] ORWA 8;	Refined
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_AS_3002	The Switch are to be **installed always with battery**.	Assumption	NO	If the assumptions are not met, the correct system functionality				New

								described in the use cases cannot be guaranteed.				
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_AS_3003	The Switch power management module shall have **batteries** sized to supply power for **at least 12 hours**.	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_Def_3004	BACKUP (SOURCE OF ENERGY): Refers to the role that the battery plays as source of energy.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_Def_3005	COMPLEMENTARY SOURCE OF ENERGY: Source of energy that provides additional power to the primary one, when necessary.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_Def_3006	PRIMARY SOURCE OF ENERGY: First source of energy providing power to the asset.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_Def_3007	**RESTRICTED STATE**: State that implies the Switch is marked as "Unlocked".	Definition	YES	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_Def_3008	**SET AND LOCK**: The Switch is able to guarantee its position, either "Nominal" or "Reverse".	Definition	YES	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_Def_3009	**SWITCH MOVING**: The Switch is not able to guarantee its position, because it is moving to reach one.	Definition	YES	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_Def_3010	**UNLOCKED**: The Switch is not able to guarantee its position, because of any unknow reason.	Definition	YES	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3011	The **battery** is charged constantly from the energy provided by the grid and/or by the **renewable sources**.	Functional	NO	Efficient use of energy.	None.			New
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3012	The Switch does always use as **first the source of energy** (whatever it is, either grid or renewable) and if not available, then uses the battery as backup.	Functional	NO	Efficient use of energy.	None.			New
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_AD_3013	The Switch shall provide a specific **module for power management,** that operates in an environment class compatible with the IM needs (e.g. range temperature -20°C to +45°C, IP 54, etc.).	ArchDes	NO	Switch to provide a modular design.	None.		[FA6, WP2, D2.2] ORWA 2; [FA6, WP2, D2.2] ORWA 3;	Inherited
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_AD_3014	The Switch shall have a **renewable energy source integrated by default** in the power management module. Note: The renewable energy source can be removed.	ArchDes	NO	Switch to satisfy carbon footprint reduction tendency.	None.			New
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_C_3015	The Switch power management module shall have the capability to be configured by the following **combinations** of energy sources:	Configuration	NO	See sub-requirements.	See sub-requirements.		[FA6, WP2, D2.2] ORWA 8;	Refined

4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_C_3015_a	Renewable + Grid + Battery, or	Configuration	NO	See UCs.	UC_WP4_4.1.2_211; UC_WP4_4.1.2_212; UC_WP4_4.1.2_213; UC_WP4_4.1.2_214; UC_WP4_4.1.2_215; UC_WP4_4.1.2_216; UC_WP4_4.1.2_217; UC_WP4_4.1.2_218;		[FA6, WP2, D2.2] ORWA 8;	Refined
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_C_3015_b	Renewable + Battery, or	Configuration	NO	See UCs.	UC_WP4_4.1.2_203; UC_WP4_4.1.2_204; UC_WP4_4.1.2_205; UC_WP4_4.1.2_206; UC_WP4_4.1.2_217; UC_WP4_4.1.2_218;		[FA6, WP2, D2.2] ORWA 8;	Refined
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_C_3015_c	Grid + Battery, or	Configuration	NO	See UCs.	UC_WP4_4.1.2_207; UC_WP4_4.1.2_208; UC_WP4_4.1.2_209; UC_WP4_4.1.2_210; UC_WP4_4.1.2_217; UC_WP4_4.1.2_218;		[FA6, WP2, D2.2] ORWA 8;	Refined
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_C_3015_d	Battery. Note: The configuration 'd)' is not recommended due to its limited duration of operation time.	Configuration	NO	See UCs.	UC_WP4_4.1.2_201; UC_WP4_4.1.2_202; UC_WP4_4.1.2_217; UC_WP4_4.1.2_218;		[FA6, WP2, D2.2] ORWA 8;	Refined
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3016	The Switch power management module shall allow to **return** from the battery energy to:	Functional	NO	See sub-requirements.	See sub-requirements.		[FA6, WP2, D2.2] FRWA 1;	Inherited

4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3016_a	Renewable energy or,	Functional	NO	See UCs.	UC_WP4_4.1.2_205; UC_WP4_4.1.2_206;		[FA6, WP2, D2.2] FRWA 1;	Inherited
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3016_b	Grid energy or,	Functional	NO	See UCs.	UC_WP4_4.1.2_209; UC_WP4_4.1.2_210;		[FA6, WP2, D2.2] FRWA 1;	Inherited
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3016_c	Renewable and grid energy combination.	Functional	NO	See UCs.	UC_WP4_4.1.2_215; UC_WP4_4.1.2_216;		[FA6, WP2, D2.2] FRWA 1;	Inherited
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3017	The Switch power management module, when integrated with a renewable energy source, shall use renewable energy as the **primary source of energy**.	Functional	NO	See UCs.	UC_WP4_4.1.2_203; UC_WP4_4.1.2_204; UC_WP4_4.1.2_211; UC_WP4_4.1.2_212; UC_WP4_4.1.2_213; UC_WP4_4.1.2_214;		[FA6, WP2, D2.2] FRWA 1;	Refined
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3018	The Switch power management module configured with renewable, grid, and battery energy sources shall use grid energy to **supplement** the remaining energy of the Level Crossing in case of renewable energy is insufficient. Note: Renewable energy must be compatible with grid energy.	Functional	NO	See UCs.	UC_WP4_4.1.2_213; UC_WP4_4.1.2_214;		[FA6, WP2, D2.2] FRWA 1;	Refined
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3019	The Switch power management module configured with renewable, grid, and battery energy sources shall use battery energy to **supplement** the remaining energy of the Level Crossing in case of grid energy is unavailable and renewable is insufficient.	Functional	NO	See UCs.	UC_WP4_4.1.2_215; UC_WP4_4.1.2_216;		[FA6, WP2, D2.2] FRWA 1;	Refined
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3020	The Switch power management module configured with renewable and battery energy sources shall use the battery to **supplement** the remaining energy of the Level Crossing in case renewable energy is insufficient.	Functional	NO	See UCs.	UC_WP4_4.1.2_205; UC_WP4_4.1.2_206;		[FA6, WP2, D2.2] FRWA 1;	Refined
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3021	The Switch power management module configured with grid and battery energy sources shall use grid as the **primary source of energy**.	Functional	NO	See UCs.	UC_WP4_4.1.2_207; UC_WP4_4.1.2_208;		[FA6, WP2, D2.2] FRWA 1;	Refined
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3022	The Switch power management module, when configured only with battery, shall utilize it as the **primary source of energy**.	Functional	NO	See UCs.	UC_WP4_4.1.2_201; UC_WP4_4.1.2_202;		[FA6, WP2, D2.2] FRWA 1;	Refined

4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3023	The Switch power management module shall use the battery when the primary and, if applicable, complementary source of energy are **unavailable**.	Functional	NO	See UCs.	UC_WP4_4.1.2_205; UC_WP4_4.1.2_206; UC_WP4_4.1.2_209; UC_WP4_4.1.2_210; UC_WP4_4.1.2_215; UC_WP4_4.1.2_216;		[FA6, WP2, D2.2] FRWA 1;	Refined
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3024	The Switch power management module shall **continuously charge the battery** if it is not full, with the primary source of energy. Note1: In case of having a unique source of energy the battery, this requirement does not apply. Note2: In case of having power management module configuration with renewable (primary) + grid (complementary) + battery (backup), to charge the battery, renewable energy shall be used first, and if it is insufficient, it shall be supplemented with grid energy.	Functional	NO	See UCs.	UC_WP4_4.1.2_205; UC_WP4_4.1.2_206; UC_WP4_4.1.2_209; UC_WP4_4.1.2_210; UC_WP4_4.1.2_215; UC_WP4_4.1.2_216;		[FA6, WP2, D2.2] FRWA 2;	Refined
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3025	The Switch shall go to **restricted state** if all energy sources including the battery are unavailable.	Functional	YES	See UCs.	UC_WP4_4.1.2_217; UC_WP4_4.1.2_218;			New
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3026	For maintenance and diagnostics purposes, the Switch shall **notify** from the power management module:	Functional	NO	See sub-requirements.	See sub-requirements.		[FA6, WP2, D2.2] FRWA 3;	Inherited
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3027_a	The consumption to renewable energy.	Functional	NO	Necessary for maintenance/diagnosis purposes.	UCs about maintenance/diagnosis.		[FA6, WP2, D2.2] FRWA 3;	Inherited
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3026_b	The consumption to grid energy.	Functional	NO	Necessary for maintenance/diagnosis purposes.	UCs about maintenance/diagnosis.		[FA6, WP2, D2.2] FRWA 3;	Inherited
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3026_c	The usage of the battery.	Functional	NO	Necessary for maintenance/diagnosis purposes.	UCs about maintenance/diagnosis.		[FA6, WP2, D2.2] FRWA 3;	Inherited
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_F_3026_d	The health status of the battery such as the level of charge of the battery, expected lifetime, etc.	Functional	NO	Necessary for maintenance/diagnosis purposes.	UCs about maintenance/diagnosis.		[FA6, WP2, D2.2] FRWA 3;	Inherited
4.1.2	Switch	Power Management	ENYSE	REQ_WP4_4.1.2_AD_3027	The Switch shall allow a **reduced hardware** configuration that operates only with batteries. Note: How those batteries shall be recharged is out of the scope.	ArchDes	NO	Light Switch - Less HW.	None.		[FA6, WP2, D2.2] ORWA 4;	Inherited

4.1.2	**Switch**	**Remote Maintenance**	**ENYSE**	Req ID	Req Description	Req Type	Safety?	Rationale	UC Source (from WP4)	UC Source (from Other WPs)	Req Source (from Others WP)	Req Source (from Others WP)
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_AS_4001	Remote maintenance can be used for 2 different **purposes**: - Diagnosis, and - Maintenance.	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_AS_4002	About diagnosis, 4 different **types of data** can be accessed: - Memory Data (Raw) - Configuration Data (Processed) - On-time Events Data (Processed) - Historical Events Data (Processed)	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_AS_4003	The above mentioned **types of data can be transmitted** through the following **3 mechanisms**: - Under Demand, and - Dump Transmission, and - Subscription.	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_AS_4004	About maintenance, **3 types of items** can be updated: - Software - Software Data - Operational Data	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_AS_4005	There is only **one mechanism to update items**; it is mainly to send the information from a Maintenance Terminal; optionally, the asset may acknowledge the reception of such information.	Assumption	NO	If the assumptions are not met, the correct system functionality described in the use cases cannot be guaranteed.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_Def_4006	**CONFIGURATION DATA**: Processed data, answering a given demand; e.g., current SW version installed in the asset.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_Def_4007	**DUMP TRANSMISSION**: Asset provides data constantly.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_Def_4008	**HISTORICAL EVENTS DATA**: Same than On-time, but between two dates/times.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_Def_4009	**MEMORY DATA**: Raw data, without any type of interpretation. Usually is to be demanded between two memory addresses.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_Def_4010	**ON-TIME EVENTS DATA**: Processed data, providing any of the events previously agreed with the Maintenance Terminal; e.g., current asset state, current temperature, etc.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_Def_4011	**OPERATIONAL DATA:** Set of variables used to express the state of the asset; e.g., number of movements performed, number of manual interventions, current energy consumption, etc.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_Def_4012	**SOFTWARE**: Compiled source code that execute a given function.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_Def_4013	**SOFTWARE DATA:** Data to configure the SW and let it works correctly; e.g., IP address, number of elements to control, etc.	Definition	NO	Definition included to ensure correct understanding of				New

								functional, architectural and configuration requirements.				
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_Def_4014	**SUBSCRIPTION**: Asset provides data on a scheduled basis.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_Def_4015	**UNDER DEMAND**: Asset provides data when the Maintenance Terminal asks for it.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_Def_4016	**UPDATE**: The Maintenance Terminal send information to update any item to the asset.	Definition	NO	Definition included to ensure correct understanding of functional, architectural and configuration requirements.				New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_AD_4017	Switch shall implement remote maintenance facilities throughout the **wired or wireless** connection.	ArchDes	NO	External Communications.	None.		[FA6, WP2, D2.2] ORWA 5;	Inherited
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_AD_4018	The Ethernet based wired or wireless connections of the G1 Switch shall implement the EULYNX **SDI-P** diagnostics protocol, among others.	ArchDes	NO	External Communications. G2: the applicability of EULYNX protocol is optional, based on specific needs by each Infrastructure Manager	None.		[FA6, WP2, D2.2] ORWA 6; [FA6, WP2, D2.2] FRWA 5;	Inherited
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4019	The Switch maintenance module shall support **2 different purposes**:	Functional	NO	See sub-requirements.	See sub-requirements.			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4019_a	Diagnosis and,	Functional	NO	See UCs.	UC_WP4_4.1.2_301; UC_WP4_4.1.2_302; UC_WP4_4.1.2_303;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4019_b	Maintenance.	Functional	NO	See UCs.	UC_WP4_4.1.2_304; UC_WP4_4.1.2_305;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_C_4020	The Switch shall provide the capability to **configure** the type of data and the way in which that data is going to be provided.	Configuration	NO	See UCs.	UC_WP4_4.1.2_301; UC_WP4_4.1.2_302; UC_WP4_4.1.2_303; UC_WP4_4.1.2_304; UC_WP4_4.1.2_305;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4021	The Switch maintenance module shall have **non-remote maintenance as backup**.	Functional	NO	See UCs.	UC_WP4_4.1.2_301;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4022	(Diagnosis) The Switch maintenance module shall provide all the following data **under demand**:	Functional	NO	See sub-requirements.	See sub-requirements.			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4022_a	Memory.	Functional	NO	See UCs.	UC_WP4_4.1.2_302;			New

4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4022_b	Configuration.	Functional	NO	See UCs.	UC_WP4_4.1.2_302;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4022_c	On-time Events.	Functional	NO	See UCs.	UC_WP4_4.1.2_302;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4022_d	Historical Events.	Functional	NO	See UCs.	UC_WP4_4.1.2_302;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4023	(Diagnosis) The Switch maintenance module shall provide the following data **through dump transmission**: Note: a) and b) are optionally provided according to the asset configuration.	Functional	NO	See sub-requirements.	See sub-requirements.			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4023_a	Memory.	Functional	NO	See UCs.	UC_WP4_4.1.2_303;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4023_b	Configuration.	Functional	NO	See UCs.	UC_WP4_4.1.2_303;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4023_c	On-time Events.	Functional	NO	See UCs.	UC_WP4_4.1.2_303;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4024	(Diagnosis) The Switch maintenance module shall provide the following data **through subscription**: Note: b) is optionally provided according to the asset configuration.	Functional	NO	See sub-requirements.	See sub-requirements.			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4024_a	On-time Events.	Functional	NO	See UCs.	UC_WP4_4.1.2_304;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4024_b	Historical Events.	Functional	NO	See UCs.	UC_WP4_4.1.2_304;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4025	(Maintenance) The Switch maintenance module shall **update** the following items when ordered by maintenance terminal: Note: It must be proven that each item can be updated, either individually or concurrently.	Functional	NO	See sub-requirements.	See sub-requirements.			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4025_a	Software.	Functional	NO	See UCs.	UC_WP4_4.1.2_305;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4025_b	Software Data.	Functional	NO	See UCs.	UC_WP4_4.1.2_305;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4025_c	Operational Data.	Functional	NO	See UCs.	UC_WP4_4.1.2_305;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4026	(Maintenance) The Switch maintenance module shall provide optionally an **acknowledgement** indicating successful updated of some or all the following items: Note: This acknowledgement is optional.	Functional	NO	See sub-requirements.	See sub-requirements.			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4026_a	Software.	Functional	NO	See UCs.	UC_WP4_4.1.2_305;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4026_b	Software Data.	Functional	NO	See UCs.	UC_WP4_4.1.2_305;			New
4.1.2	Switch	Remote Maintenance	ENYSE	REQ_WP4_4.1.2_F_4026_c	Operational Data.	Functional	NO	See UCs.	UC_WP4_4.1.2_305;			New

4.1.3	**Obstacle Detector**		**MERMEC**									
4.1.3	Obstacle Detector	Operational Requirement	MERMEC	REQ_WP4_4.1.3_O_0001	The railway system equipped with LCOB shall recognize whether there are obstacles inside a level crossing area.	Operational	YES	An obstacle stuck at a level crossing has truly important safety consequences. It also has repercussions on regular circulation.				New
4.1.3	Obstacle Detector	Operational Requirement	MERMEC	REQ_WP4_4.1.3_O_0002	The railway system shall be able to evaluate the danger for railway traffic due to the obstacle in the level crossing area.	Operational	YES	To avoid being intrusive in railway traffic, it is necessary to discriminate which events have an impact on the safety of the train and those which can instead be overlooked.				Refined
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0003	The LCOB System shall automatically determine the obstacle clearance of Level Crossings by monitoring the LXA.	Functional	YES		UC_WP4 _4.1.3_001			New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0004	The LCOB System shall work for Level Crossings equipped with complete barriers.	Functional	YES		UC_WP4 _4.1.3_001		[FA6, WP2, D2.2] FRWA 12.	Refined
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0005	The LCOB System shall work for Level Crossing equipped with half barriers	Functional	YES		UC_WP4 _4.1.3_001		[FA6, WP2, D2.2] FRWA 12.	Refined
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0006	The LCOB System shall work for Level Crossing equipped without barriers	Functional	YES				[FA6, WP2, D2.2] FRWA 12.	Refined
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0007	The LCOB System shall work for Level Crossings equipped or not equipped with recovery areas.	Functional			UC_WP4 _4.1.3_001		[FA6, WP2, D2.2] FRWA 12.	Refined
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0008	The monitoring area of the LCOB System shall cover the whole LXA completely. The characteristics of the railway line (single track, double track, etc.) and the road intersection shall be considered for the LXA.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0009	The LCOB System shall be compatible with existing level crossings systems.	Functional	NO				[FA6, WP2, D2.2] FRWA 12.	Refined
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0010	The LCOB System shall be compatible with existing signalling system. The LCOB System shall not be intrusive with the existing signalling.	Functional	NO		UC_WP4 _4.1.3_001		[FA6, WP2, D2.2] FRWA 11.	New

4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0011	The LCOB System shall detect obstacles with a minimum sample size, defined as a rectangular cuboid with a sides equal to a configurable values (in meters) linked to national regulation	Functional	YES	With the defined minimum sample size, following obstacles will be detected: vehicles (cars, trucks, motorcycles, scooters, etc.) pedestrians (walkers, cyclists, wheelchair users, etc.) moveable objects (buggies, etc.) Following obstacle will not be detected: small to medium sized animals (cats, dogs, birds, etc.) small to medium sized movable objects (toys, etc.)	UC_WP4 _4.1.3_001			New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0012	The LCOB System shall detect obstacles in relation to time characteristics of line and signalling.	Functional	YES	To ensure, that the train can be warned in time to stop before the obstacle.	UC_WP4 _4.1.3_001		[FA6, WP2, D2.2] FRWA 13.	Refined
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0013	The LCOB System shall determine the operating status of the system at any time and provide the operating status on request within time limits according to the national regulations.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0014	The LCOB System at the power on shall boot/wake up and send its status to the LXC or signalling system.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0015	The LCOB System shall include a self-diagnostic function to verify the correct functionality of the system.	Functional	YES		UC_WP4 _4.1.3_001			New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0016	The self-diagnostic function of the LCOB System shall test minimum the following: Testing of electronic board and sensors Testing of correct data transmission Testing of correct management of interfaces Testing of functional interoperability between the components of the entire apparatus Testing of correct functioning of the detection sensors	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0017	The LCOB System shall transmit the result of the self-diagnostic system to the signalling system.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0018	If the self-diagnostic function does notice any errors/failures, the LCOB System shall enter to operating state “Fallback mode”.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0019	If the self-diagnostic function does not notice any errors/failures, the LCOB System shall wait for the start scanning command provided from the Level Crossing Control (LXC).	Functional	YES	The assumption is that the start scanning command is linked to the barriers closed.	UC_WP4 _4.1.3_001			New

4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0020	The LCOB System shall enter operating state “Scanning” after receiving the command start scanning provided by the Level Crossing Controller (LXC)	Functional	YES	It is done the assumption that the level crossing informs the signalling system about the barrier status, If the barriers aren’t close the signalling system avoid the train passage.	UC_WP4 _4.1.3_001			New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0021	The LCOB system when receiving the start scanning command shall start the scanning process of the level crossing area (LXA) for any obstacles.	Functional	YES	Often the start scanning command is linked to the barriers close condition.	UC_WP4 _4.1.3_001			New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0022	The scanning process of the LCOB System shall consist of scanning the LXA, identifying of any obstacle larger than the threshold size and providing the result.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0023	The total scanning process shall comply with time limits based on national regulations.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0024	If the result of the scanning process is “No Obstacle Detected”, the LCOB System shall provide the status of LXA to the signalling system or to the system connected to.	Functional	YES		UC_WP4 _4.1.3_001			New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0025	The status [Level Crossing Area Free] shall be safely guaranteed by the LCOB System and shall not be caused by external influences like advance weather and climatic conditions.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0026	If the result of the scanning process is “No Obstacle Detected”, the scanning process of the LCOB System shall be repeatable.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0027	If the scanning process of the LXA results in “Obstacle detected”, the LCOB System shall enter to operating state “Obstacle Detected”.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0028	The LCOB System should identify, whether this obstacle is resting/standstill or moving.	Functional	YES				[FA6, WP2, D2.2] FRWA 6.	Refined
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0029	The LCOB System shall identify the size of this obstacle	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0030	The LCOB System shall generate and transmit a vital alarm [“Obstacle detected”] to the signalling system/LXC.	Functional	YES	Assumption: Line is equipped with signalling system.	UC_WP4 _4.1.3_001		[FA6, WP2, D2.2] FRWA 9.	Refined
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0031	The LCOB System shall generate and transmit a vital alarm [“Obstacle detected”] to a pre-established receiver via dedicated interface.	Functional	YES	Assumption: Line is not equipped with signalling system. The radio link is regulated by national IM.			[FA6, WP2, D2.2] FRWA 10.	Refined
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0032	The LCOB System shall repeat the transmission of the vital alarm until an acknowledgement of the alarm has been received.	Functional	YES	To ensure, that the alarm as arrived safely				New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0033	The LCOB System shall be adaptable (at deployment) to the shape of the level crossing area.	Functional	YES					New

4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0034	The LCOB System shall provide real time information to a remote operator about the current situation at the LXA.	Functional	YES	Real time information may be live footage by using cameras as sensors, etc.				New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0035	The LCOB System shall enter in operating state Stand by after receiving the stop scanning command " from the LXC.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0036	The LCOB System shall shut down the system properly. (Shutdown)	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0037	The LCOB System shall enter in operating state "Fallback Mode" after noticing any errors/failures of the self-diagnostic function.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0038	The LCOB System shall identify the actual error/failure cause.	Functional	YES	The fault/error is determined by the tests performed by the LCOB. The more exhaustive the tests are, the greater the coverage and recognition of faults that may occur				New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0039	The LCOB System shall transmit the identified cause to the LXC.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0040	The LCOB System shall remain in the operating state "Fallback Mode" until the error/failure has been resolved.	Functional	YES					New
4.1.3	Obstacle Detector	Functional Requirements	MERMEC	REQ_WP4_4.1.3_F_0041	The LCOB System shall reboot after elimination of the error/failure cause.	Functional	YES					New
4.1.3	Obstacle Detector	Non-Functional Requirements regarding LCOB Sensors	MERMEC	REQ_WP4_4.1.3_NF_0042	The LCOB Sensors shall work with any light conditions and with any weather conditions (high/low temperatures, rain, fog, snow, ice, sand storms, …), vibrations	Non Functional		These values shall be the environment class specified in CENELEC rules			[FA6, WP2, D2.2] FRWA 15.	Inherited
4.1.3	Obstacle Detector	Non-Functional Requirements regarding LCOB Sensors	MERMEC	REQ_WP4_4.1.3_NF_0043	The LCOB Sensors shall use a technology that is safe for people around the LXA.	Non Functional		This includes the people passing the LXA and the people waiting at closed barriers			[FA6, WP2, D2.2] FRWA 14.	Inherited
4.1.3	Obstacle Detector	Non-Functional Requirements regarding LCOB Sensors	MERMEC	REQ_WP4_4.1.3_NF_0044	Timing for stat up	Non Functional		Less then SWOC/Object Controller one				New
4.1.3	Obstacle Detector	Non-Functional Requirements regarding LCOB Sensors	MERMEC	REQ_WP4_4.1.3_NF_0045	Requirements on reliability, maintainability, technical durability. These value shall fulfil the requirements for CENELEC rules.	Non Functional					[FA6, WP2, D2.2] FRWA 16.	Inherited

6 Social-economic Assessment

6.1 Regarding Level Crossings and Switches

The enhancements and innovation introduced in the design for Level Crossings and Switches within the scope of the FutuRe project are based on four key pillars:

1. Wireless-enabled functionality,
2. Remote maintenance capability,
3. Energy self-sufficiency,
4. (Level Crossing only) Controlled from different places (IXL, RBC, etc.)
5. (Switch only) Configurability for different track gauges

In the context of FutuRe, an analysis has been conducted to assess how these key features of Level Crossings and Switches contribute to the expected Socio-Economic Objectives (SEO) as defined by Task 2.3 “KPI Achievement Monitoring” [REF.22]. The relevant SEOs are:

- SEO8 Reduction of OPEX costs per kilometer for trackside railway assets by 30%
- SEO9 Increase in energy efficiency for trackside railway assets (as part of SEO8) by increasing the consumption of renewable energy by 30%
- SEO12 Improvement in the energy efficiency of railway assets

Regarding SEO8: The primary pillar impacting the reduction in OPEX is the implementation of remote maintenance (pillar 2). By enabling preventive maintenance to be reported to a central location (remote from the installation) and allowing corrective maintenance to be performed remotely (such as software updates, data management, or resetting components), there will be a significant reduction in the need for travel and the number of personnel required for maintenance tasks. Additionally, the time required to resolve issues will be shortened, thereby minimizing disruptions to operational traffic.

An explorative cost estimation carried out in T9.11 on smart multimodal level crossings showed that an OPEX reduction could be achieved by using SWOC based solutions at level crossings [Ref.24]. Some findings can be applied to wireless enabled energy self-sufficient level crossings and switches. According to the study wireless activation modules, a modular architecture and remote diagnostic solutions can foster the cost reduction. Especially the enabling of remote diagnostics can decrease the maintenance costs and therefore the operational expenditures [Ref.24].

Regarding SEO9: In terms of energy efficiency, the foundational pillar is energy self-sufficiency (pillar 3). While energy consumption cannot be reduced to zero since a certain amount of energy is always necessary for asset operation, the focus of FutuRe is on enhancing energy efficiency through better energy sourcing. The goal is to configure the energy supply for these assets in a hybrid model. Traditionally, assets rely solely on grid power, however, after FutuRe, the objective is to enable energy procurement from both the grid and renewable sources, such as solar panels. In such configurations, grid consumption will decrease as the utilization of renewable sources increases.

Regarding SEO 12: Like SEO9, the foundational pillar is energy self-sufficiency (pillar 3). The concept of “improving” energy efficiency in this context should be understood as making better use of available energy. The goal is to configure the energy sources for these assets in a hybrid model that includes battery usage, enabling intelligent energy management. For instance, on a sunny day, sufficient energy could be generated to operate the assets throughout the day while as charging batteries, which would then provide stored energy for nighttime operations.

6.2 Regarding Obstacle Detection System

In the context of FutuRe, an analysis has been conducted to assess how these critical features of the Obstacle Detection System contributes to the expected Social-Economic Objectives (SEO) as defined by Task 2.3 “KPI Achievement Monitoring [REF.22]. The relevant SEOs are:

- SEO5: Overall reduction of OPEX and (CAPEX) by 15%

Regarding SEO5: The primary objective of the Obstacle Detection system is to enhance the safety at Level Crossings and other trackside areas. By improving the safety, the Obstacle Detection system can reduce the likelihood of accidents, thereby lowering the associated costs. These cost savings include expenses related to track outages and closures, costs associated with repairing and replacing of damaged Level Crossing components, and minimized costs resulting from train damage, which can lead to operational interruptions and repairs.

7 Conclusion

This report, “Requirement Specification for Wayside Assets,” provides a comprehensive set of operational and functional requirements for Level Crossings, Switches, and Obstacle Detection Systems, with a particular focus on deployment of Regional Lines. These requirements are designed to enhance efficiency and safety by incorporating wireless communication, energy self-sufficiency, diagnosis data transmission and integrated remote maintenance functions for Level Crossings and Switches. Furthermore, dedicated requirements for Obstacle Detection System have been developed, complemented by extensive analyses and investigations. These includes the detailed benchmarking of sensor, an examination of safety considerations pertaining to the deployment of ML/AI components and the formulation of interface specification. Collectively, these advancements are intended to optimize the performance of Wayside Assets while achieving a significant reduction in associated lifecycle costs.

The identified use cases provided a valuable foundation for the development of the requirements and serve as an important reference for future implementations in subsequent project stages. By aligning closely with the identified use cases and presenting a well-structured framework, the requirements facilitate the development of demonstrators within the FutuRe project, ensuring alignment with targeted operational and socio-economic objectives. In the long term, the successful implementation of these requirements is expected to reduce both operational and capital costs, increase the use of renewable energy, and improve the attractiveness and safety of regional railways.

8 References

- **[Ref.1]**

Reference Work package:	[FP6 WP1]
Title:	EU-RAIL JU Call Proposal 2022-1
ID:	-
Version:	FINAL
Due date of deliverable:	-
Actual submission date:	-
Link.	Proposal-SEP-210868548.pdf

- **[Ref.2]**

Reference Work package/Task:	[FP6 WP4 T4.1]
Title:	Requirement of T4.1 (Excel Document)
ID:	101101962
Version:	2.0
Due date of deliverable:	31.12.2024
Actual submission date:	-
Link.	FutuRe WP4 T4.1 - Requirements_v2.0.xlsx

- **[Ref.3]**

Reference Work package/Task:	[FP6 WP2 T2.1]
Title:	Deliverable D2.1 Regional Lines Architecture
ID:	101101962
Version:	1.0
Due date of deliverable:	31/05/2023
Actual submission date:	13/07/2023
Link.	FutuRe - D2.1_RegionalLine Architecture_00_01 20220713 clean.pdf

- **[Ref.4]**

Reference Work package/Task:	[FP6 WP4 T4.2]
Title:	Deliverable D4.2 Interface Specification Track-Field
ID:	101101962
Version:	4.4 (Month 18)
Due date of deliverable:	31/12/2024
Actual submission date:	-
Link.	D4.2_Interface_Specification_Track-Field_v4.4.docx

- **[Ref.5]**

Reference Work package/Task: [FP6 WP4]
Title: Deliverable D4.4 “D4.4_Use_Cases_T4.2&T4.4”

- **[Ref.6]**

Reference Work package/Task: [FP6 WP2 T2.2]
Title: Deliverable D2.2 Regional Lines Operational and Functional Requirements
ID: 101101962
Version: 1.0
Due date of deliverable: 31/05/2023
Actual submission date: 21/07/2023
Link. FP6-WP02-D-MER-001-01 FutuRe - D2.2_Regional lines operational and functional requirements_00_01 + Annex1 UC.pdf

- **[Ref.7]**

Reference Work package/Task: [FP6 WP5 T5.2]
Title: Deliverable D5.2 – Specification CCS for Group 2
ID: -
Version: 0.2
Due date of deliverable: 31/12/2024
Actual submission date: 31/12/2024
Link. FP6-WP02-D-MER-001-01 FutuRe - D2.2_Regional lines operational and functional requirements_00_01 + Annex1 UC.pdf

- **[Ref.8]**

Rail Safety & Standards Board, 2006. Research into obstacle detection at level crossings – Final report
https://www.rssb.co.uk/en/research-catalogue/CatalogueItem/t522

- **[Ref.9]**

Yamada, Naoyuiki, Yuichi Tanaka, and Kunitoshi Nishikawa. "Radar cross section for pedestrian in 76GHz band." 2005 European Microwave Conference. Vol. 2. IEEE, 2005.

- **[Ref.10]**

EIT Urban Mobility, E-Micromobility Safety Assessment, 2020
https://www.eiturbanmobility.eu/projects/living-lab-e-micromobility/

- **[Ref.11]**

Li, You, and Javier Ibanez-Guzman. "Lidar for autonomous driving: The principles, challenges, and trends for automotive lidar and perception systems." IEEE Signal Processing Magazine 37.4 (2020): 50-61.
https://arxiv.org/pdf/2004.08467

- **[Ref.12]**

Roriz, Ricardo, Jorge Cabral, and Tiago Gomes. "Automotive LiDAR technology: A survey." IEEE Transactions on Intelligent Transportation Systems 23.7 (2021): 6282-6297.
https://ieeexplore.ieee.org/iel7/6979/9826234/09455394.pdf

- **[Ref.13]**

Iwata, K., Nakamura, K., Zhao, H., Shibasaki, R., & Takeuchi, H. (2006, March). Object detection with background occlusion modeling by using multiple laser range scanners. In Proceedings of the 6th International Conference on ASIA GIS.
https://a-a-r-s.org/proceeding/ACRS2005/Papers/NGS-1.pdf

- **[Ref.14]**

Guo, Yanming, et al. "Deep learning for visual understanding: A review." Neurocomputing 187 (2016): 27-48.
http://deeplearning.ir/wp-content/uploads/2016/07/Deep-learning-for-visual-understanding_-A-review.pdf

- **[Ref.15]**

Ekermo, A., and Norell V. "Reducing the need for manual cleaning maintenance of digital surveillance cameras-A conceptual study."ISRN LUTMDN/TMKT 13/5466 SE”, Lund University, 2013. https://lup.lub.lu.se/student-papers/record/3865414/file/3865415.pdf

- **[Ref.16]**

García, J. Jesús, et al. "Efficient multisensory barrier for obstacle detection on railways." *IEEE Transactions on intelligent transportation systems* 11.3 (2010): 702-713. https://www.academia.edu/download/60826130/IR_sensor_in_railway_track20191007-62004-1dwj2jd.pdf

- **[Ref.17]**

Hilleary, Thomas, Omar, Tarek, 2012. A Radar Vehicle Detection System for Four-quadrant Gate Warning Systems and Blocked Crossing Detection. Federal Railroad Administration, Washington, DC. DOR/FRA/ORD-12/24.
https://railroads.dot.gov/elibrary/radar-vehicle-detection-system-four-quadrant-gate-warning-systems-and-blocked-crossing

- **[Ref.18]**

David Bickell, Level crossing insight, RailEngineer, June 2017.
https://www.railengineer.co.uk/level-crossing-insight/

- **[Ref.19]**

“Rethinking the maturity of artificial intelligence in safety-critical settings.” AI Magazine 42.1 (2021): 6-15.

- **[Ref.20]**

Jan Gruteser, David Geleßus, Michael Leuschel, Jan Roßbach and Fabian Vu. A Formal Model of Train Control with AI-based Obstacle Detection. Proceedings RSSRail 2023. LNCS. Springer-Verlag.

- **[Ref.21]**

Jackson, Daniel, et al. “Certified control: An architecture for verifiable safety of autonomous vehicles.” arXiv preprint arXiv:2104.06178 (2021).

- **[Ref.22]**

Reference Work package/Task:	[FP6 WP2 T2.3]
Title:	Deliverable D2.3 First Release of KPI Achievement
ID:	101101962
Version:	2.0
Due date of deliverable:	31/01/2024
Actual submission date:	21/02/2024
Link.	D2.3 FP6 FutuRe - First release of KPI achievement.pdf

- **[Ref.23]**

EULYNX Partners. (2023). *Requirements specification for subsystem Level Crossing* (Version 2.2). Document number: Eu.Doc.108. Europe’s Rail Joint Undertaking. Baseline Set 4 Release 2 - Europe's Rail (europa.eu)

https://rail-research.europa.eu/wp-content/uploads/2023/06/20230628-Requirements-specification-for-subsystem-Level-Crossing-Eu.Doc.108-v2.2-0.A.pdf

- **[Ref.24]**

Reference Work package/Task:	[FP6 WP9 T9.11]
Title:	Cost Factor Analysis of a Smart Multimodal Level Crossing
Version:	7th draft
Link.	Kopia av EXJOBB 7th draft (1).pdf