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

DELIVERABLE D4.2
REQUIREMENT SPECIFICATIONS FOR COMMUNICATION REPORT (TOP DOCUMENT)

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:	30-11-2024
Actual submission date:	30-11-2024
Coordinator:	Alessandro Mascis, Wabtec
Lead Beneficiary:	Alstom
Version:	5.5
Type:	Report
Sensitivity or Dissemination level[1]:	PU[1]
Taxonomy/keywords:	D4.2 Top document

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.

[1] PU: Public; SEN: Sensitive, only for members of the consortium (including Commission Services)

Document history

Version	Date	Name	Affiliation	Position/Project Role	Action/ Short Description
1.0	07/06/2024	Javier García Castaño	Alstom	Task leader	Draft
1.1	26/06/2024	Javier García Castaño	Alstom	Task leader	Released for M18 delivery
1.2	16/08/2024	Javier García Castaño	Alstom	Task leader	Update of title and minor changes with suggestions for report documents naming.
1.3	3/09/2024	Javier García Castaño	Alstom	Task leader	Report documents naming back to originals. Formatting according to agreement in task weekly meeting held on 2/09/2024
1.4	20/09/2024	Markus Hofer	ÖBB Infra	Author	Added V model process
1.5	30/09/2024	Javier García Castaño	Alstom	Task leader	Updated intro according to ÖBB Thomas Z. review
1.6	30/09/2024	Oskar Skoglund	Trafikverket	Author	Updated parts structure figure
5.0	22/10/2024	Javier García Castaño	Alstom	Task leader	Cleaned for Internal review M24. Update of version to 5.x to share the same version through all documents.
5.1	05/11/2024	Javier García Castaño	Alstom	Task leader	Update of version to 5.1 according to review comments from internal review. Cleaned for External review M24.
5.2	19/11/2024	Javier García Castaño	Alstom	Task leader	Updated after external review and released as v5.2 for delivery M24.
5.3	20/08/2025	Javier	Alstom	Task leader	Updated after JU

		García Castaño			review in 24/06/2025and released as v5.3 for delivery M24. Added link between T4.2.1 and T4.4 in executive summary. Added link to S2R reuse in executive summary. Added explanation of TCO analysis in conclusions.
5.4	21/10/2025	Markus Hofer	ÖBB Infra	Author	Updated after ERJU Review Added reviewed introduction, conclusion and economic analysis from part 3 and part 4.
5.5	23/10/2025	Tomé Ferreira	Trafikverket	Author	Updated after ERJU Review. Added reviewed introduction, conclusion and economic analysis from part 1 and part 2.

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Executive Summary

Deliverable D4.2 has been developed by Task 4.2 with title "Requirement specifications for Communication" within the technical Work Package 4 with title "Regional Rail Assets Requirements & Specifications" as a technical work package part of the FP6 "FutuRe – Future of Regional Lines".

It is highly recommended to read this delivery in conjunction with D4.4. Both deliveries are deeply interconnected and they complement each other. The formal links between D4.2 and D4.4 are presented later in this document in the requirements and documents structure. Specifically, High Level Requirements for Communication interfaces are defined to fit D4.4 context.

Reuse of S2R results in D4.2 is achieved in conjunction with S2R SWOC architecture and requirements present D4.4.

The deliverable D4.2 is formed by a set of documents referred as parts from now on. The present document is an executive summary of the deliverable D4.2 with the title "Requirement specifications for Communication Report". This document does not include all D4.2 parts of the deliverable but refers to them. The division of the report in different parts follows common industry practice working with Interface Specifications, increasing readability and usability of the parts/documents. This division provides isolation of communication entities in one document. Moreover, the different parts support a clear requirement management structure later presented in this document. Ultimately the different parts have differentiated uses in upcoming FP6 FutuRe work-packages, updates of specific documents will be tailored to specific tasks, avoiding updates of non-required parts.

The primary objective of D4.2 is to outline a set of requirements and architectures that reflect the operational and functional behaviour of:

1- The external wireless interfaces of D4.4 Smart Wayside Object Controller (SWOC) Multi Modal Level Crossing (MMLX). This scope clarification for the SWOC MMLX interfaces has been approved by the FP6 steering group.

2- The trackside-trackside and trackside-field devices wireless communications in general.

In addition to specifying requirements, D4.2 parts (documents) also include analysis and investigations of new direct wireless communication trackside to train in the context of SWOC MMLX.

This document also provides sections describing the process used to derive (a) the architecture from the requirements, (b) the requirements from the Use Cases and (c) it also describes how the requirements are managed.

The linked parts (documents) discuss the social-economic benefits targeted by the requirements and architecture specifications. FP6 FutuRe project has accepted the lack of cost baselines from infrastructure managers, thus D4.2 cost reduction proposals may need to be verified in the future.

List of abbreviations, acronyms and definitions

Table 1: List of abbreviations

Abbreviation / Acronym	Definition
3GPP	3rd Generation Partnership Project
5G	fifth generation
API	Application Programming Interface
AS	Architecture Specification
CCS	Control Command Signaling System
C-ITS	Cooperative Intelligent Transport Systems
COTS	common off the shelf
CTC	centralized traffic control
D	Deliverable
DOC= R	Document Report
ERTMS	European rail traffic management system
ETCS	European train control system
EU	European Union
FA	Flagship Area
FRMCS	future railway mobile communication system
FP	Flagship Project
G1	Group 1 Lines
G2	Group 2 Lines
GA	Grant Agreement
ID	Identifier
IM	Infrastructure manager
IP	internet protocol
IS	interface specification
ISM	Industrial, scientific and medical
IXL	interlocking
JU	Joint Undertaking
LX	Level Crossing
M	Month
MDC	management and diagnostics centre
MMLX	Multi Modal Level Crossing
MNO	Mobile Network Operator
MQTT	MQTT, the standard for IOT-messaging
NR	new radio
OSI	Open Systems Interconnection.
RAMS	Reliability, Availability, Maintainability & Safety
RBC	Radio Block Centre
Req	Requirement
RS	Requirement Specification
SEO	Social Economic Objective

SIL	Safety Integrity Level
SP	System Pilar
SWOC	Smart wayside object controller
TCP	transmission communication protocol
TFR	tolerable failure rate
THR	tolerable hazard rate
TMS	traffic management system
TSI	Technical Specification for Interoperability
UC	Use Case
V2X	Vehicle-to-everything
WP	Work Package

In the respective parts, the 3GPP modal verbs are used and have meanings shown in Table 2.

Table 2: 3GPP Modal verbs

Verb	**Meaning**
shall	indicates a mandatory requirement to do something
shall not	indicates an interdiction (prohibition) to do something
should	indicates a recommendation to do something
should not	indicates a recommendation not to do something
may	indicates permission to do something
need not	indicates permission not to do something
can	indicates that something is possible
cannot	indicates that something is impossible

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1. Document scope

This document represents the top document for Deliverable of Task 4.2 known as D4.2 entitled "Requirement specifications for Communication Report".

Task 4.2 is organisationally divided into two different Subtasks, which are assigned according to the communication interfaces to be addressed. The individual Subtasks therefore deal with the respective Requirement/Interface Specifications and architectures of the assigned communication interfaces.

Table 3: Task 4.2 consists of subtask 4.2.1 and 4.2.2

Task 4.2: Requirement specifications for Communication.	
Subtask 4.2.1	**High Level Requirements for Communication.** Purpose: Definition of high-level requirements for communications for trackside-to-train, trackside-to-car, trackside-to-pedestrian, and trackside-to-cloud for SWOC MMLX.
Subtask 4.2.2	**Requirement specifications for wireless connection between trackside/trackside and trackside/field devices.** Purpose: Definition of the requirement specifications for wireless connections for trackside-to-trackside and trackside-to-field devices, not limited to SWOC MMLX.

1.1. D4.2 Report structure

The deliverable D4.2 "Requirement specifications for Communication Report" consists of a main document with four interconnected parts, as visualized in Figure 1:

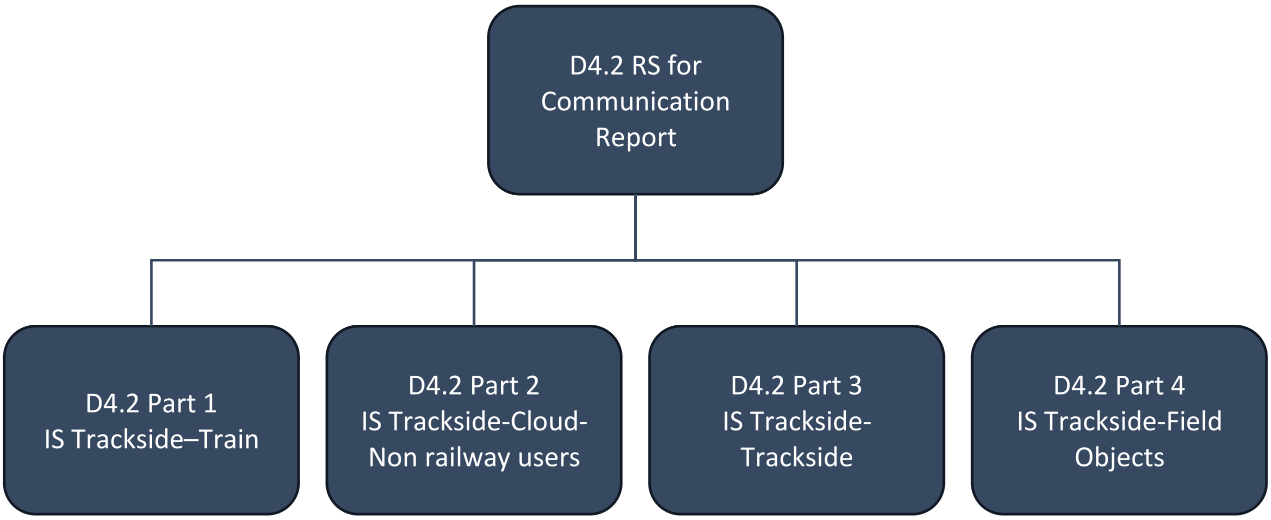

Figure 1: D4.2 Documents/Parts Structure

Each part (1 to 4) of Deliverable D4.2 is a document targeting specific content from each Subtask as shown in Table 3.

Table 4: D4.2 parts

Type	Deliverable name	Contents	From Subtask	Readiness M24
Word Document	D4.2 RS for Communication Report v5.1 (this document).	Top document providing deliverable overview and executive summary, including links to subtask specific deliverable documents and their relationships. It also provides the generic process followed.		Completed at the end of this task.
Word Document	D4.2 Part 1 IS Trackside–Train v5.1.	Investigations on direct communication Trackside-Train for autonomous SWOC MMLX with no RBC connection.	ST 4.2.1	Proposal to be continued in future projects.
Word Document	D4.2 Part 2 IS Trackside-Cloud-Non railway users v5.1.	Requirements for communication between SWOC MMLX and non-railway actors based on use cases.	ST 4.2.1	To be finalized in Task 9.11
Word Document	D4.2 Part 3 IS Trackside-Trackside v5.1.	Requirements for wireless communication trackside-trackside communication, interface specification for different use cases.	ST 4.2.2	To be finalized in Task 9.6
Word Document	D4.2 Part 4 IS Trackside-field devices v5.1.	Requirements for wireless communication trackside-field devices communication, interface specification for different use cases.	ST 4.2.2	To be finalized in Task 9.6

Contents common to all parts in Table 3:

- Use input from existing S2Rail deliveries, and SP through Deliverable 2.1 [D2.1] and Deliverable 2.2 [D2.2].
- Focus on covering both remote control (connection to CCS) and autonomous solutions for SWOC MMLX.
- Focus on covering both G1 and G2 lines.
- Focus on covering both brown and green field installations.
- Focus on covering both distributed communication links and centralized cloud-based solutions.
- Target highest SIL at each interface, depending on counterparts.
- High priority: Vital communications, minimizing number of different wireless communications and ranges.
- Low priority and possibly targeted in WP9: Energy handling, diagnostics, and other non-vital information. Definition of fundamentally new use cases. Redefinition of railway communication architecture aligned with [D4.1].

1.2. Introduction

Part 1 of the document focuses on the trackside to train interface and considers a communication link between two parts: the Smart Wayside Object Controller Multi-Modal Level Crossing (SWOC MMLX) and the train. The actual device for SWOC MMLX is the modular and scalable wireless object controller connected to field objects. This interface is not part of the SWOC generic architecture, but an add-on, which could be run on the same hardware platform or by an external dedicated hardware device connected to the SWOC.

In general, this interface can be implemented with long range communication being compatible with the work done in FP6 WP4 Task 4.3 (long range trackside to train communication) or by short range communication (the focus of Part 1) with direct links between the trackside and the train. The different combinations for topologies and paths for the information are presented in [D2.1] and [D4.4 AS].

For communication, only the exchange of vital information is considered in Part 1. Non-vital communication, primarily between the MMLX and non-railway users, is covered by [D4.2 Track-Cloud].

Part 1 makes use of the terms greenfield and brownfield to describe deployments. A greenfield deployment is a new installation without any existing infrastructure, or an installation intended to fully replace all current equipment. A brownfield deployment is a trackside with already existing installations such as axle counters, Eurobalises, and track circuits. Brownfield deployments can in turn be further separated into two main categories: integrated deployments where devices are mostly connected by wired solutions, e.g., copper or fibre optic cables to an interlocking (IXL) and autonomous deployments where no connection to the Control Command Signalling System (CCS) is present.

Using the above classification an interface for direct trackside to train communication using short-range communication technologies would be relevant for the latter of the described deployment scenarios: brownfield deployments not connected to the CCS. They have thus been the focus of the work undertaken. The former case, where a connection to the CCS is assumed, is covered by already existing solutions that are compliant with the CCS TSI.

Figure 1 in Part 1 provides an overview of the different deployment scenarios together with the communication system options that exist today as well as those that have been put forward for investigation within the scope of the work described.

Part 2 of the document focuses on the interface between two parts, the Smart Wayside Object Controller (SWOC) Multi Modal Level Crossing (MMLX) and the cloud as method for providing information regarding the state of connected level crossings to non-railway users, targeting multi-modality including communication with pedestrians and vehicles.

The initial work on this interface was targeted at designing a novel safety layer for a direct communication interface between trackside and non-railway users. The proposed safety layer was envisioned to enable safe communication over non-railway networks between the trackside and non-railway users such as (but not strictly limited to) cars, pedestrians and cyclists.

As the creation of this interface was deemed to require participation of parties from both the railway sector and non-railway actors, such as the automotive industry, the project reached out to several organizations in a request for cooperation on the design. However, the result of this led to the conclusion that interest in participation on this design effort among non-railway actors is limited. Of those parties that expressed interest none were willing or able to commit to compliance or adoption of such an interface.

Because of these findings the project participants decided to, rather than designing an interface that were deemed unlikely to see adoption, to instead provide a means for making information from level crossings available to non-railway users through a cloud environment. Consequently, this shift of focus leads to the abandonment of the requirements on providing a protocol implementing safety specific features. Instead, the underlying assumption of the design presented here is that even though the trackside provides information on, for example, the current state of a level crossing, the safety responsibility on how to act on this data lies solely on the consumer of the information. As such the solution is not intended to fulfil a safety purpose. The solution proposed in Part 2 cannot fulfil safety integrity requirements according to railway standards but may decrease safety risks for non-railway users of a level crossing. The providers of such information, making use of this cloud-based solution, are obliged to warn end-users that the level crossing status is only of an informative character and any protective signalling/waring statuses coming from the level crossing itself override those informative statuses.

Part 3 and Part 4 of the document present requirements and interface specifications for track-to-track and track-to-field communication.

The documents focus on backbone trackside command, control and signalling (CCS) equipment (including ETCS and legacy CCS systems) which are located at wayside technical buildings, and whose main responsibility is to control field-devices, also installed along the trackside.

As trackside elements, we consider the following as a minimum:

- interlockings (IXL),
- object controllers (OC) and smart wayside object controllers (SWOC),
- radio block centre (RBC)

As field devices the following elements are taken into account:

- switches and the corresponding point machines
- level crossings (LX)
- signals (e.g. lights, loudspeaker)
- axle counters
- track circuits.

These backbone trackside elements forming part of the CCS system, and distributed along the railway line, require the establishment of a communication channel between them for the exchange of operational information.

Traditionally, this type of communication has been supported by wired solutions based on electrical or fibre optic (FO) cables, being the deployment of these cable networks an important part of the overall cost at CCS system deployments.

So, aiming to search up new solutions that help to mitigate these costs, the scope of this document is to define the requirements for a wireless solution, publicly or railway owned, for connecting trackside and field CCS elements with each other whenever be appropriated.

In general, this alternative solution can be especially interesting for low-traffic railway lines, where the high costs of the private fibre optic deployment can represent a very high percentage of the total cost of the system.

Wireless solutions could also provide a more efficient and cost-effective way of modernizing regional lines which currently do not have an electronic signalling system deployed, and even nowadays still use a phone communication only (i.e. without any line block equipment) for controlling the rail line, i.e. based solely on the human factor.

Additionally, to the interfaces considered in this document, a track-to-cloud interface can be considered for future data flow / data management optimization of the railway network (maintenance, timetable, and route optimisation, etc). Here the reader is referred to [D4.2 Track-Cloud].

In Part 3 and Part 4, *brownfield* and *greenfield* deployments are considered.

- *Brownfield* deployments are deployments built upon existing installations (for instance installations already including IXL, RBC and SWOC, axel counters, level crossing, switches, etc.). Devices in this deployment type are mostly connected by wired solutions e.g., by metal or fibre optic cables.

- In case of a *greenfield* deployment, no existing installation is present. In this case, newly commissioned regional lines might directly use wirelessly enabled components.

In the case of the brownfield deployments, it is not the intention of this document to propose the replacement of already existing wired trackside elements with wireless ones, but to propose options helping to reduce cost in different migration options. For instance, wireless solutions can offer the possibility of cost-effective replacement of damaged wired components and a cost-effective roll-out for newly commissioned regional lines.

Considering the regional line classification made in the FP6-FutuRe project (see [D2.1]), G1 and G2 line are considered in this document.

- G1 lines are lines where trains can enter from a main line to a regional line and vice versa., i.e. must be interoperable, TSI CCS compliant
- G2 lines are lines that are functionally/operationally *not* connected to the main line.

The definition of G1 and G2 lines and their considered architecture are shown in D2.1 in its latest version [D2.1]. Currently the architecture of G2 lines and the associated specification is further developed in [D5.2].

Wireless communication networks should meet specific requirements for data rate, latency, and reliability based on the type of service being delivered. Additionally, they should ensure interoperability, if applicable (G1 solutions), and comply with the interface specifications described in this document.

The requirements on wireless communication in the track-to-track and track-to-field part of the document are derived mainly from the use cases listed below [D4.4UC]:

- UC_WP4_4.2.2_003 - IXL to IXL communication.
- UC_WP4_4.2.2_004 - Interlocking to object controller communication.
- UC_WP4_4.2.2_005 - RBC to RBC Communication.
- UC_WP4_4.2.2_001 - Point machine is set to a defined position
- UC_WP4_4.2.2_002 - Signal is set to a defined state.
- UC_WP4_4.2.2_006 - Level crossing is set to a defined state.
- UC_WP4_4.4_004 - Controlling of nearby LX objects.

Read [D4.4UC] for more specifics of the use cases.

2. Process and timeline

In general, D4.2 process illustrated in Figure 2 is influenced by the CENELEC EN 50126-1 [CEN-50126] V Model process, up to the design phase. However, CENELEC standards are not strictly used, but shall be seen as a concept. For the specific process followed in each part/document of the deliverable please consult each of the parts/documents provided in Figure 1.

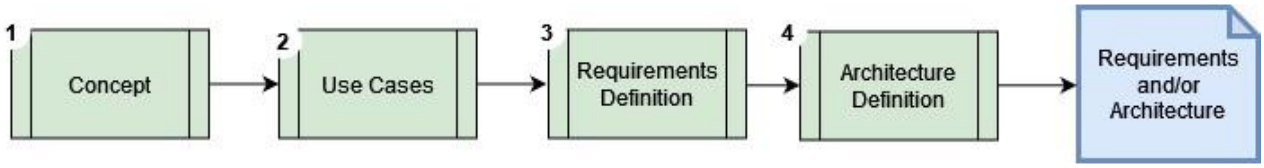

Figure 2: D4.2 process and timeline.

Before defining the requirements, a series of reference Use Cases were proposed to:

- Provide a foundation for the development and derivation of requirements.
- Serve as a reference for activities planned later in the project in context of demonstrator development (in future WP9).

The reference Use Cases can be found in the document of [D4.4UC].

2.1. Requirements handling

The traceability of the requirements and the relationship between different deliverable parts is shown in Figure 3. This has been done influenced by the CENELEC standards to ensure proper process management.

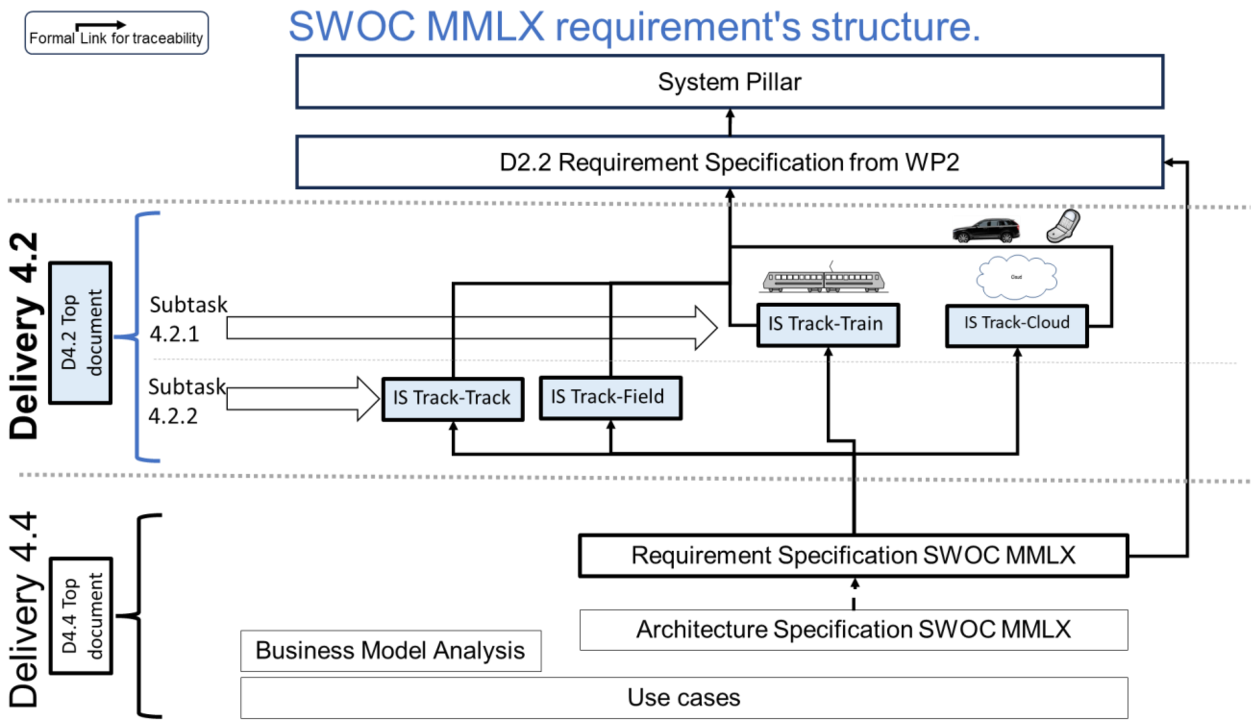

Figure 3: Deliverable D4.2 report documents (blue shaded) and requirement structure relationships with other deliveries and WPs.

The Word Document parts contain the Requirement Specifications of D4.2 for each Subtask in a detailed listing format. The requirements format includes specific attributes essential for the documentation and traceability of each requirement, providing a clear structure for managing and monitoring the requirements both within D4.2 and across Work Package 4.

3. Economic Analysis

A quantitative evaluation of the economical applicable *KPIs achievement will be performed after the demonstrator tasks in WP9 have been concluded.*

The KPIs assessment of track-to-track and track-to-field enablers will be based on the methodology, parameters (e.g. reduction of cabling length) provided in D2.3 and compared with D2.3/D2.6 baselines. It is important to remind the reader that WP4 tasks without corresponding demonstrators in WP9 will need future developments beyond FP6 wave 1 in order to evaluate KPIs for technical enablers.

The use of wireless communication solutions as a communication network for railway signalling systems aims to effectively reduce cost for the infrastructure managers of regional railway lines.

This is the case both during the deployment phase, reducing infrastructure costs, and during the operational phase of the railway line.

Furthermore, the results of two S2R projects X2Rail-1 and X2Rail-4 prove useful due to their analysis of possible advantages of deploying wireless links for connection between spatially distributed trackside subsystems instead of laying optical or metallic cables. The possible cost savings, primarily for CAPEX, are described in [X2R1D7.1].

In comparison with the communication systems supported over wired solutions used in current railway line deployments, the wireless-based communication system solution can provide the following advantages in terms of economic analysis:

- **Cost saving in communication cables deployment.** Making a preliminary analysis of new deployment projects or the renewal of signalling systems in railway lines, it has been verified that the deployment cost of the cables, together with the cost of the associated civil works, can be a major part in the project budget. This aspect, especially in low-traffic lines, in which projects typically have smaller budgets, can make the implementation of the signalling system economically unfeasible. At this point, the use of wireless communication, such as public mobile networks already deployed by mobile network operators (MNOs), can help to achieve a significant reduction in deployment costs (CAPEX reduction).

- **Ease of deployment.** Being the MNO network already deployed, the implementation of a signalling system at a rail line becomes an easier and faster task if wireless connections are used, reducing therefore the cost of project design and the cost of project execution (CAPEX reduction).

- **Simplification of maintenance actions.** (OPEX reduction). Depending on the deployment and the requirement of using wireless communications for newly installed railway infrastructure and assets it is expected that the cost of maintenance, and hence the operational cost decrease, since less maintenance on fibre optical and copper cables is required. Furthermore, it is expected that the failure resolution time is reduced. Furthermore, maintenance could be automated which leads to a reduction of person hours.

- **Reduction of possible points of failure.** (OPEX reduction). By using wireless communications for newly installed railway infrastructure a reduction in the trackside asset failures is expected. Failures in fibre optic and copper cables (and their thefts) are a major maintenance cost point of CCS systems, so a reduction in the length of wires of the system will reduce the possible points of failure. If there is a point of failure the failsafe states need to be applied.

These preliminary qualitative costs analysis, are valid for both G1 and G2 regional lines, and also, for greenfield and brownfield deployments. The actual achieved cost reduction depends on the specific scenario. Specifically greenfield deployments and deployments with wirelessly enabled self-sufficient autonomous level crossing have a high potential for cost reduction, since in those case the amount of groundwork is considerably reduced.
In the context of FutuRe, an analysis was conducted to assess how wireless connectivity between trackside systems and their various interfaces—including trains, cloud platforms, other trackside systems, and field devices—contributes to achieving the socio-economic objectives (SEO). This analysis considered FP6 Task 2.3 “KPI Achievement Monitoring” (see [D2.3]) as input.

Based on the findings, the deployment of wireless connectivity across the specified interfaces is expected to ensure compliance with the following SEO/KPI targets.

SEO5: Overall reduction of OPEX and CAPEX.

According to deliverable D2.3 “KPI Achievement Monitoring” ([D2.3]), SEO5 is defined as the overall reduction of both operational expenditure (OPEX) and capital expenditure (CAPEX). The corresponding KPI is stated as follows:

- **SEO5 KPI** - The overall reduction of OPEX and CAPEX is targeting 15%.

The implementation of wireless communication solutions within railway signaling networks is designed to reduce costs for regional railway infrastructure managers during both the deployment and operational phases of the railway line. In the deployment phase, wireless technologies help lower infrastructure costs (CAPEX), while in the operational phase, they contribute to reducing maintenance-related expenses (OPEX).

The use of public mobile networks, already deployed by the Mobile Network Operators (MNOs), will avoid the deployment of an important part of the fibre optical telecommunication network, contributing significantly to reduce CAPEX and OPEX at the railway line Command, Control, and Signalling (CCS) systems. It is therefore advantageous for railway operators to coordinate base station deployment with MNOs to ensure cost-effective coverage of trackside devices.

CAPEX savings are primarily achieved by minimizing the costs associated with laying trunk communication cables and the civil works required for their installation. OPEX savings result from reduced maintenance needs, as wireless systems require less upkeep compared to fiber optic and copper cabling. It is worth noting that failures in fiber and copper networks account for a considerable proportion of service disruptions in CCS systems.

As a result, the interfaces for *Track-to-Track, Track-to-Cloud and Non-Railway Users*, and *Track-to-Field Devices* meet the requirements of KPI SEO5, due to the adoption of wireless and cloud-based technologies that offer substantial cost advantages over traditional wired systems. In contrast, *Track-to-Train* interface, which already operate using wireless communications, would not benefit further from cost savings associated with replacing wired connections, as they are already optimized in this regard.

SEO8: OPEX costs/km for trackside railway assets.
According to deliverable D2.3 “KPI Achievement Monitoring” ([D2.3]), SEO8 is defined as the reduction of operational expenditure (OPEX) per kilometer for trackside railway assets. The

associated KPI is specified as follows:

- **SEO8 KPI** – Decrease of the OPEX by targeting 30%.

The adoption of wireless communication solutions as part of the railway signaling network is intended to significantly reduce operational costs for regional railway infrastructure managers during the operational phase of the railway line.
This cost reduction is primarily achieved by minimizing maintenance activities, as wireless systems eliminate the need for extensive upkeep of fiber optic and copper cabling. It is important to note that failures and incidents in fiber and copper networks represent a substantial portion of service disruptions in Command, Control, and Signalling (CCS) systems.

Given the direct correlation between the length of the railway line and the extent of the required cable-based telecommunications infrastructure, replacing wired systems with wireless alternatives has a proportional impact on reducing OPEX per kilometer.

Therefore, it can be concluded that the interfaces for *Track-to-Track*, *Track-to-Cloud and Non-Railway Users*, and *Track-to-Field Devices* align with the objectives of KPI SEO8, due to the integration of wireless and cloud-based technologies that offer considerable cost savings compared to traditional wired systems. Conversely, the *Track-to-Train* interface, which already utilizes wireless communication, would not experience further cost reductions from transitioning away from wired systems, as it is already optimized in this regard.

4. Conclusion

For *Track-to-Train*, the investigations undertaken have concluded that none of the options considered are currently deemed to fulfil the requirements while remaining cost-effective enough to fulfil project KPIs. Considering this result the decision has been made not to continue the work of specifying this interface in future work packages but instead leaving further research into this area to upcoming projects as is it still the opinion of the authors that such an interface would be useful. The major hurdle, apart from costs, facing any solution for direct communication between trackside and train is that there is no direct communication between LX and train in the CCS TSI. As such, establishing an interface would need further work leading to possible amendments to the CCS TSI. An estimated timeline for amendments to the CCS TSI is expected to be released during 2026 and 2028.

For *Track-to-Cloud* and Non-Railway Users, an overview on requirements of track-to-cloud and non-railway user communication for the SWOC MMLX is presents. The proposed solution allows infrastructure managers to collect data in the form of events from cloud connected SWOC MMLX deployments using standard Internet protocols enabling the deployment of cloud services targeted at both railway and non-railway users. These services allow users to subscribe to events from level crossings within, for example, a specified geographical area to receive updates regarding the current state of the level crossings. Users can also query API:s provided by the cloud environment for information such as the current state of connected level crossings. The requirements are expected to be updated in the following phase of the project (T9.11), with input taken from, among other things, the planned simulations as well as further refinement of the use cases.

The goal of the *Trackside-to-Trackside* and *Trackside-to-Field* parts of the deliverable was to provide requirement specifications for trackside-to-trackside and trackside-to-field communication, that can be used as a guideline to allow for CAPEX and OPEX reduction for regional lines.

The developed use cases have been used to derive system descriptions for *brownfield* and *greenfield* deployments as well as for G1 and G2 lines. From the system descriptions, requirements have been derived. The requirements are mapped to the different layers of the OSI 7-layer model.

The requirements of this document are input to demonstrators to WP9, specifically the finalization of requirements of trackside-to-trackside and trackside-to-field communication will be input to the finalization of Task 9.6 where the requirements will be further refined and the Task 9.7,

The work carried out in this task has a direct continuation in WP9 deliverables:

- D9.11 for MMLX where the contents will be updated for the IS Trackside-Cloud.
- D9.6 for Trackside-Trackside and Trackside-Field devices.

A cost reductions conclusion will be summarized in D2.3 by WP9 completion, where quantitative assessment of TCO reduction will be performed after the demonstration campaign.

5. References

Table 5: References

DOC-ID	Title	Version
[802.11]	IEEE Standard for Information Technology--Telecommunication and Information Exchange between Systems - Local and Metropolitan Area Networks--Specific Requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications	
[CCSTSI]	CCS TSI Appendix A – Mandatory specifications (ETCS B4 R1, RMR: GSM-R B1 MR1 + FRMCS B0, ATO B1 R1)	4.0.0
[CEN-50126]	EN 50126-1:2017(Main) Railway 2017 Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS)	
[D2.1]	Regional_Line_Architecture_02_00	M14
[D2.2]	Regional lines operational and functional requirements_02_00	M14
[D2.3]	First release of KPI achievement	M14
[D4.1]	Requirement specifications for Wayside Assets Report	M24

[D4.2]	Requirement specifications for Communication Report	M22
[D4.2 Track-Cloud]	Interface Specification Track-Cloud non railway user	M22
[D4.4]	D4.4 SWOC LX Solution for Multimodality Report	M24
[D4.4 AS]	D4.4 Architecture Specification SWOC MMLX	M22
[D4.4 RS]	D4.4 Requirement Specification SWOC MMLX	M22
[D4.4UC]	D4.4 Part 4 - Use_Cases_T4.2&T4.4	M24
[D5.2]	Specifications CCS for Group 2	M24
[ETSI TS 102 894]	Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary; Release 2	V2.2.1 (2023-10)
[MQTT311]	MQTT Version 3.1.1, OASIS Standard. Available at http://docs.oasis-open.org/mqtt/mqtt/v3.1.1/os/mqtt-v3.1.1-os.html	3.1.1
[X2R1.D7.1]	X2R-WP07-D-TTS-001-02_-_D7.1_-_Analysis_of_existing_lines_and_economic_models	DB-001-02-R2
[X2R1-D7.2]	Railway requirements and Standards application conditions Available at https://projects.shift2rail.org/s2r_ip2_n.aspx?p=X2RAIL-1	1.0, May 2018