D4.2 PART 1- INTERFACE SPECIFICATION TRACKSIDE-TRAIN

Executive Summary

This is part 1 of the Deliverable D4.2 and summarizes the work performed to establish an interface for direct trackside-to-train communication between a SWOC MMLX and a train. It is recommended for the reader to first read the Top document [D4.2] to understand the context and main conclusions of this part of the delivery.

The requirements in this specification are mainly targeting autonomous technical enablers where the regional lines have an innovation need to keep costs low without compromising the existing safety integrity level. However, the work done has also evaluated greenfield deployments with the CCS TSI including ETCS and EUlynx where additional requirements are provided by the track to track and track to field interfaces in D4.2.

In the case of brownfield deployments that are already integrated with the CCS and where existing equipment and infrastructure for communication are present, no changes have been proposed either, since the train to track communication is already standardized through the ETCS management system. In addition, the work done in the track to track and track to field interfaces in D4.2 cover the standard G1 and also G2 lines.

For existing brownfield deployments, typically Eurobalises are used for track-to-train communication for e.g., communicating positions or breaking curves. In case of axel counters, track circuits or similar the interlocking obtains safety relevant messages and communicates the moving authority via a radio block center (RBC) to the train in case of an ERTMS based railway solution.

Such an interface is expected to allow infrastructure managers to provide an increased safety level for existing deployments while still meeting cost targets allowing lines in risk of closure to remain open. However, the work undertaken indicates that, given requirements and the current state of the art, providing this interface has proven not to be possible within the scope of this project. It is therefore concluded that, even though future developments and research may still make it possible to design this interface, that work should be performed in other projects.

Based on these circumstances, the guiding principle of the work performed has been to leave brownfield deployments untouched to the largest extent possible to avoid the costs associated with upgrading them to use the same technologies as the main lines. Any proposed solution has also been evaluated by looking at the complete system, not only from the perspective of the infrastructure managers. This means that a solution that simply results in a transfer of costs from the infrastructure side to, for example, the train operators will not be considered as an improvement as it will not improve the economic viability of the regional line in question.

By utilising the same technology solutions as on main lines, regional lines run the risk of being deemed economically unsustainable and instead closed rather than upgraded. The options presented in this document aimed to tackle these challenges using novel approaches for direct track to train communication on suitable lines.

The arguments and research activities undertaken which indicate that the task can’t deliver a solution for the specific case of autonomous LX in G2 lines be carried out are described in detail in chapter 4.

The main obstacles for providing this interface are described in the sections detailing the various proposed solutions but can be summarised as:

- The lack of an interface for direct communication between trackside and train in the Control Command and Signalling Technical Specification for Interoperability (CCS TSI)
- The need of additional communication equipment to be installed on trains and the resulting cost for operators
- Large variations in available trackside sensors throughout Europe making it difficult to propose a solution suitable for a significant share of deployments
- Inability of certain solutions to fulfil railway safety regulations

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. This STIP request has been aligned with the system pillar. The research will be collectively continued and finalized within the EU-RAIL program.

Background

Many existing level crossings on regional lines have very minimal trackside equipment and may often be in remote areas. Due to this, the cost associated with integrating these level crossings with the CCS have proven to be very high.

Costs for upgrades are driven by factors such as the need for extensive deployment of cabling and other communication equipment as well as the, often time-consuming, integration with the main CCS.

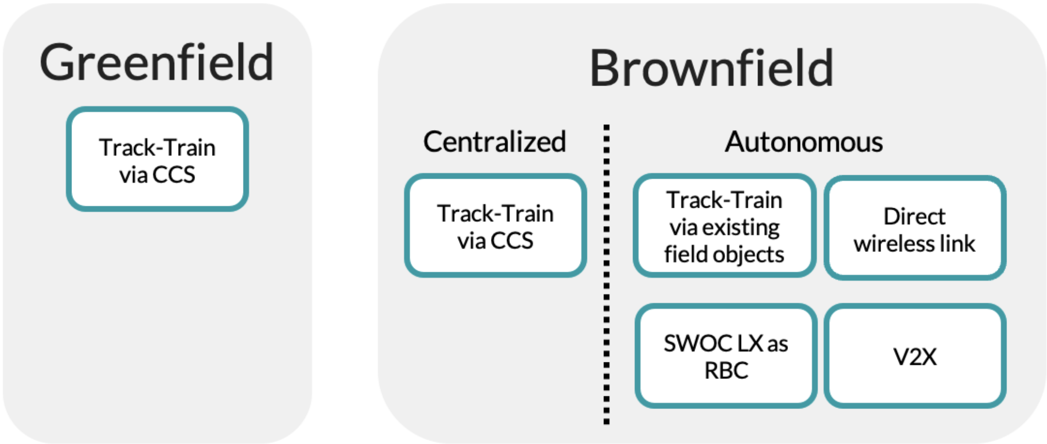

Figure 1: Deployment classifications and communication system options

Other costs and obstacles also apply, for example, national regulations may specify that any groundwork performed in vicinity of the track requires the rolling stock to operate at reduced speeds until a specific tonnage has passed that part of the track to ensure that the structure of the embankment is properly stabilised. For regional lines, which typically see less traffic compared to main lines, this can therefore lead to traffic disruptions due to longer travel times for extended periods. This further negatively impacting the economic viability of an upgrade.

Based on these circumstances, the guiding principle of the work performed has been to leave brownfield deployments untouched to the largest extent possible to avoid the costs associated with upgrading them to use the same technologies as the main lines. Any proposed solution has also been evaluated by looking at the complete system, not only from the perspective of the infrastructure managers. This means that a solution that simply results in a transfer of costs from the infrastructure side to, for example, the train operators will not be considered as an improvement as it will not improve the economic viability of the regional line in question.

By utilising the same technology solutions as on main lines, regional lines run the risk of being deemed economically unsustainable and instead closed rather than upgraded. The options presented in this text are aimed to tackle these challenges using novel approaches for direct track to train communication on suitable lines.

1. Working process and goals

The goal of the work has been to provide a solution for an autonomous MMLX capable of direct communication with the train without the involvement of the Control Command Signalling System (CCS). Originally this was envisioned using a public cloud solution (for cost reduction purposes) following the design illustrated in Figure 2 as an alternative to one based on existing field sensors available for strike-in and strike-out.

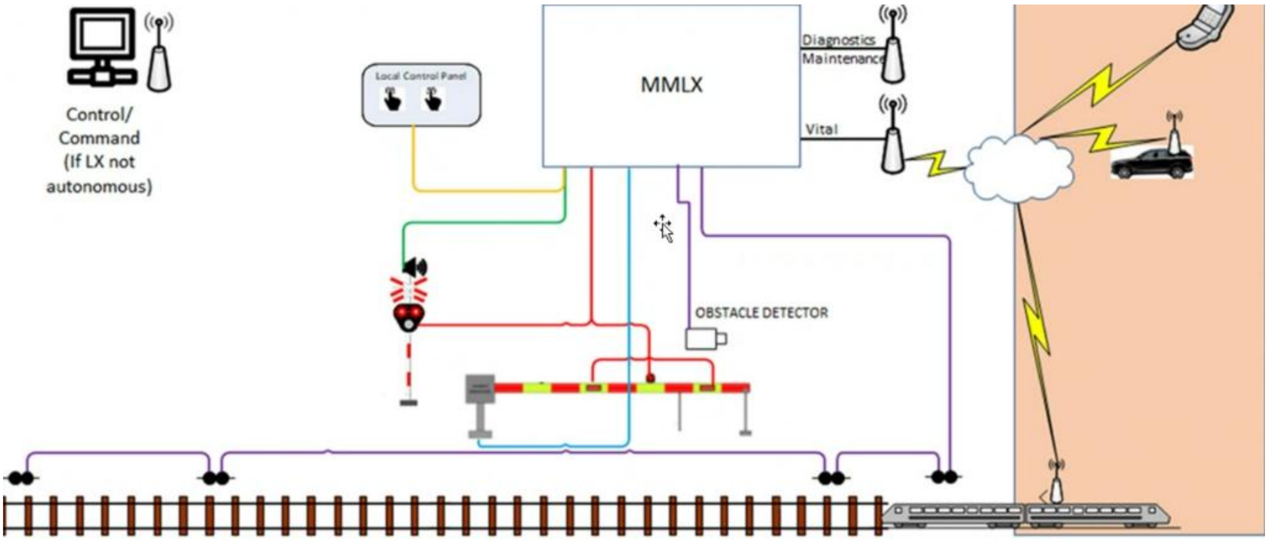

Figure 2: First draft of architecture

As it was deemed that such a solution, based on communication facilitated by a public cloud environment, cannot easily fulfil the railway RAMS requirements for vital communication the design was changed.

The updated version instead focused on providing an interface for direct communication between the trackside and train without a cloud-based intermediary. Based on the hypothesis that direct communication between train and MMLX would be possible, use cases and requirements for this interface were developed following the process used in defining the other interfaces (e.g. [D4.2 Track-Cloud] and others). As illustrated in Figure 3 below, establishing the requirements involved firstly the identification of functions and features resulting in Use Case definitions presented in the use cases document [D4.4 UC]. Based on the use cases, requirements were in turn defined, reviewed, and consolidated to finally be presented in the requirement specification [D4.4 RS].

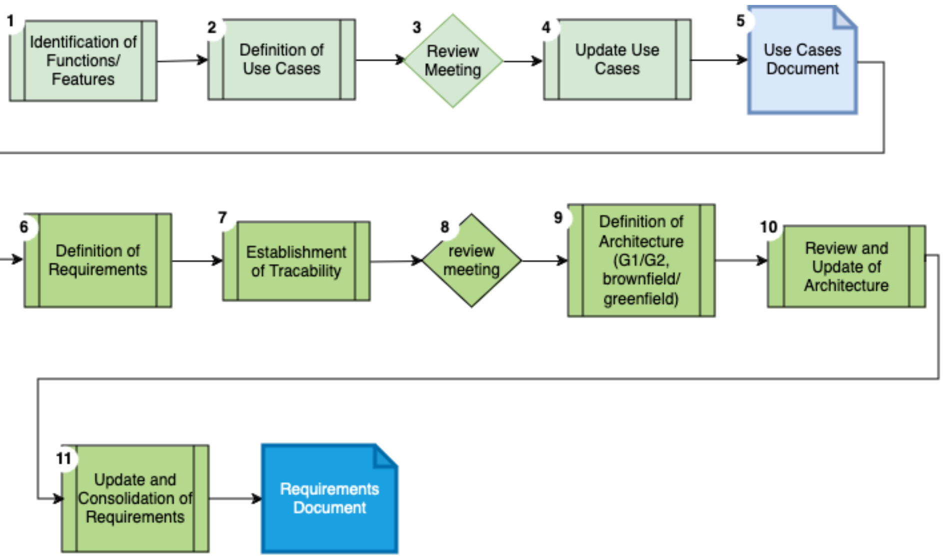

Figure 3: Requirements process

Formally, requirements (operational, functional, and non-functional) for the interface were derived in accordance with the requirement structure as illustrated in Figure 4T.

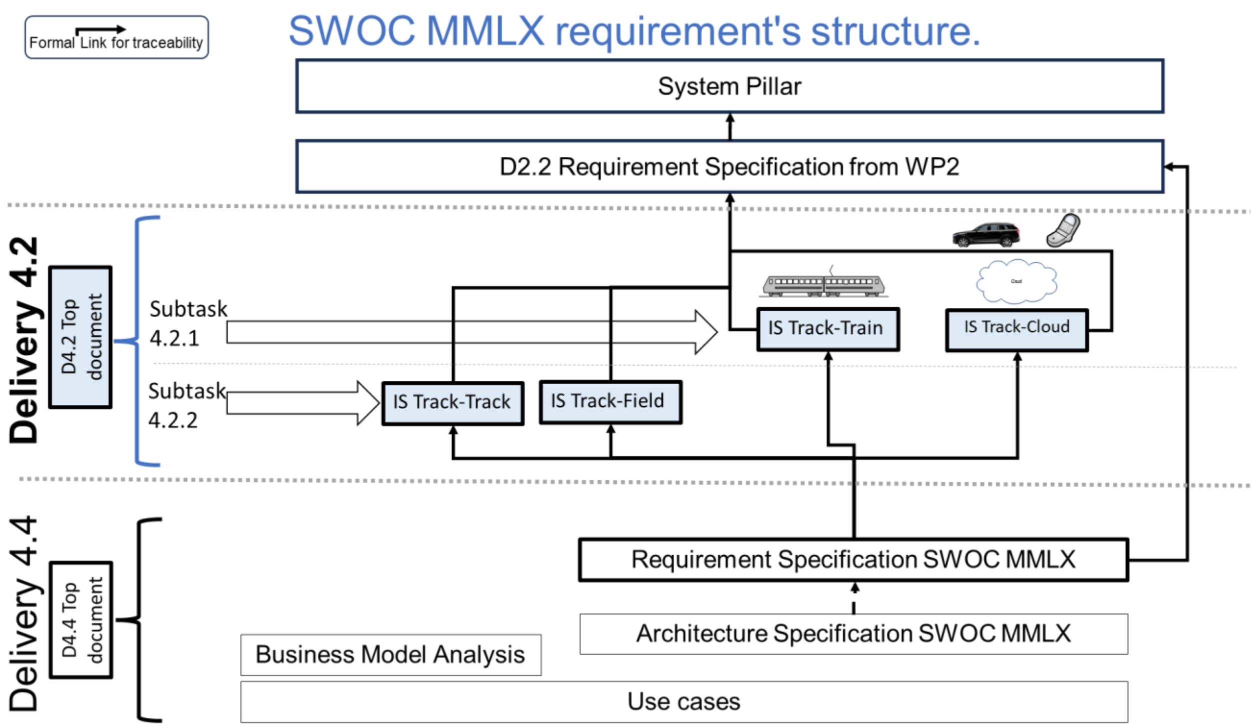

Figure 4: SWOC MMLX Requirements Structure

Each specific solution was put forward for discussion and evaluation to determine its feasibility and potential to fulfil requirements while still reaching the project KPIs. Following this process, it was determined that several project KPIs such as cost reduction, interoperability and standardization (see [D2.3]) would not be met by any of the proposed solutions. The main obstacles for the investigated approaches from a KPI fulfilment perspective is described in the following sections of Chapter 4 detailing the various alternatives, but can be summarised as:

- The lack of an interface for direct communication between trackside and train in the Control Command and Signalling Technical Specification for Interoperability (CCS TSI)
- The need of additional communication equipment to be installed on trains and the resulting cost for operators
- Large variations in available trackside sensors throughout Europe making it difficult to propose a solution suitable for a significant share of deployments.
- Inability of certain solutions to fulfil railway safety regulations

2. Shift2Rail results reuse

The MMLX concept gained ideas and momentum, besides other regional line operational experiences, from the input consisting in the concept of the Smart Wayside Object Controller (SWOC) as the result of S2R projects X2Rail-1 and X2Rail-4. See [X2R1.D7.2]. The architecture definitions and resulting specifications were studied and proved useful due to their comprehensive analysis of possible advantages of deploying wireless links for connection between spatially distributed trackside subsystems instead of laying optical or metallic cables.

The fact is that also in the architecture definition coming from the above mentioned S2R projects dealing with SWOC the link from trackside to train was proposed – see [X2R1.D7.2].

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3. Investigated solutions for communication

The different options for communication that have been put forward for investigation are described below. For greenfield deployments no changes have been proposed over existing available solutions for trackside to train communication. Greenfield deployments should be compliant with the CCS TSI. In the case of brownfield deployments that are already integrated with the CCS and where existing equipment and infrastructure for communication are present no changes have been proposed either.

For level crossings currently lacking CCS integration several options for direct trackside to train communication have been investigated and subsequently rejected. The following sections summarize each one and the reasons for why they have been deemed unsuitable.

4. Direct wireless link

In scenarios where there is no trackside or onboard equipment for CCS integration available, a direct wireless communication link has been investigated as an option.

Although this would, in theory, allow for creating a communication interface capable of fulfilling project requirements in a, from the infrastructure managers perspective, cost-efficient manner, it falls short of project targets in one major way.

As this manner of communication falls outside of the existing standard (i.e. CCS TSI) it would introduce the requirement for installing dedicated, non-standard, communication hardware for this link on trains operating the line regardless of the communication technology used. Adding such equipment is not only a matter of installing new hardware. Altering the on-board equipment has safety implications resulting in the need for additional, time consuming and costly work to be performed on behalf of operators.

Adopting this method without also amending the standards will simply introduce a transfer of costs from the infrastructure to the operator-side. In an environment where operators may already be working with slim profit-margins such an added burden is unlikely to be well received.

Thus, from an overall perspective, this solution is deemed unlikely to be cost-effective. It will therefore not be compatible with the cost-reduction KPIs established to guide the work in this project. In addition to this, creating an alternative solution not supported by the established standard fails to fulfil the interoperability requirement stipulated in the project KPIs.

Thus, further investigations on the details of creating such a link has been discontinued for the remainder of the project.

4.1. Using existing field objects

For deployments where current wired trackside infrastructure exists, one option is to make use of those existing field objects for communication. This would make an interface possible without introducing the need for, potentially costly, equipment on the train side.

While investigating this solution it became apparent that the availability of such equipment varies greatly between deployments across Europe. Basing the solution on a specific type of object or set of objects would therefore likely exclude many deployments from making use of the interface or introducing the need for infrastructure managers to deploy the required field objects which goes against the guiding principle of minimal changes to brownfield deployments.

As such, this approach does not provide a generic future solution to the problem applicable for all infrastructures and as such will not fulfil project KPI: s.

4.2. SWOC MMLX acting as RBC

A third solution that was investigated was to provide the SWOC LX with the capability to fulfil the role of RBC within the vicinity of the LX. This would provide a solution that is transparent from the perspective of the train and does not introduce the need for additional equipment on trains already capable of communication with the RBC.

Investigations revealed that this solution unfortunately has major safety implications related to the handover between the main RBC and the one implemented in the level crossing ultimately requiring it to be connected to the main RBC rendering the solution redundant.

4.3. V2X, railway to everything

Finally, the use of V2X technology for trackside to train communication has been brought forward as a possible candidate solution. This option, similarly, to one based on generic wireless communication, falls short of cost-reduction targets and interoperability. Also, outfitting trains with communication equipment not covered by the CCS TSI would be in breach of current regulations as such equipment needs to be certified for deployment.

In practice this solution is identical to the generic direct wireless link example from section 4 just using a different technology and will present the same issues.

5. References

DOC-ID	Title	Version
[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
[D4.2]	Requirement specifications for Communication Report	M22
[D4.2 Track-Cloud]	Interface Specification Track-Cloud non railway user	M22
[D4.4 AS]	D4.4 Architecture Specification SWOC MMLX	M22
[D4.4 RS]	D4.4 Requirement Specification SWOC MMLX	M22
[D4.4 UC]	D4.4 Use Cases T4.2 & T4.4	M22
[X2R1.D7.2]	X2R-T7.3-D-CFS-006-06_-_D7.2 Railway requirements and Standards application conditions	Rev. 1.0