X2Rail-1

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Deliverable D5.4
Moving Block Application Report

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Change History

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1.0	28/06/2019	First Release	First Release for review by TMT
2.0	30/07/2019	Second Release	Release after TMT Review
3.0	17/09/2019	Third Release	Release after TMT Review
4.0	15/01/2020	Forth Release	Release after JU Expert Review

Executive Summary

This Moving Block Application Report is one of a group of documents produced by WP5 Moving Block in the Shift2Rail project X2Rail-1, in accordance with the X2Rail-1 Grant Agreement:

- **D5.1 Moving Block System Specification** which defines the System Requirements for ETCS Level 3 Moving Block (refer to sections 2.3 ETCS Reference and 2.4 Architecture Assumptions for ETCS background).
- **D5.2 Moving Block Operational and Engineering Rules** which defines additional Operational and Engineering Rules required for an ETCS Level 3 Moving Block system.
- **D5.3 Moving Block Preliminary Safety Analysis** which describes hazards identified as a result of operating ETCS Level 3, and also describes the mitigation of those hazards.
- **D5.4 Moving Block Application Analysis** (this document) which describes the application of Moving Block systems to different railway types.

These documents are Deliverables from X2Rail-1, with further work intended in both X2Rail-3 and X2Rail-5.

This document has analysed the different railway types identified within the X2Rail-1 Grant Agreement (Urban/Suburban Railways, Overlay Systems, High Speed Lines, and Low Traffic and Freight Lines). More specifically, this analysis has focused on:

- How the Moving Block System Types identified within X2Rail-1 (refer to section 4 ETCS Level 3 Moving Block System Types for more detail) may be applied to each railway type, with the purpose of a desirable trade-off between costs and benefits.
- How the system requirements and rules defined in the Deliverables D5.1 and D5.2 provide a complete coverage of the functional and operational needs of each railway type. Where this analysis has shown that some extra requirements and/or rules are needed, these have been included within the affected sections.
- If new system functions need to be defined for the railway types analysed.

This document contains a report on the results achieved by the prototyping activities carried out within the following X2Rail-1 Moving Block tasks [section 7 Prototyping activities: result achieved]:

- Tasks 5.7 - Urban/Suburban Prototype Definition;
- Task 5.8 - Overlay Prototype Definition;
- Task 5.9 - High Speed Lines Prototype Definition;
- Task 5.10 - Low Traffic and Freight Prototype Definition.

This document is intended to be used:

1) as a basis for further requirements and rules analysis within X2Rail-3;

2) as a basis for further railway types and related Moving Block systems analysis within X2Rail-3;
3) as a report of the prototyping activity within X2Rail-1 (description/results/ lessons learnt)

The group of documents assume ETCS Level 2 [BL3 R2] as a baseline. The work has aimed to minimise the changes required beyond ETCS Level 2. Anything which is unchanged from ETCS Level 2 is not described, except where some description is required to provide context.

This group of documents covers different Moving Block system types. A high-level description of these different system types can be found in section 4 ETCS Level 3 Moving Block System Types.

Some subsystems of the Moving Block System are being addressed by other Technical Demonstrators within Shift2Rail and will be integrated in later phases. Section 3 Scope defines the scope of the WP5 deliverables and provides some assumptions about other system components.

As originally planned, the work is not finished in X2Rail-1. Further work is proposed to be carried out within the follow-on project X2Rail-3, and later X2Rail-5.

Table of Contents

Table of Figures

1 Objective

This deliverable is related to the X2Rail-1 WP5 Task 5.6 – Moving Block Application Analysis, whose objective is:

1) to study the application of Moving Block Signalling to the following application areas:
   - Urban/Suburban Railways
   - Overlay Systems
   - High Speed Lines
   - Low Traffic and Freight Lines
2) to define extra Operational and Engineering Rules, and extra system functions, required for each application area
3) to create a final report summarising the results of the prototyping tasks, which are:
   - Tasks 5.7 - Urban/Suburban Prototype Definition;
   - Task 5.8 - Overlay Prototype Definition;
   - Task 5.9 - High Speed Lines Prototype Definition;
   - Task 5.10 - Low Traffic and Freight Prototype Definition.

2 Background

2.1 Shift2Rail Background

This document has been produced within Shift2Rail IP2 “Advanced Traffic Management and Control Systems”. The work is part of the work on Technical Demonstrator TD2.3 Moving Block.

The document has been produced within the Shift2Rail project X2Rail-1 Work Package 5: Moving Block.

Besides the above reference (common to all the deliverables within X2Rail-1 WP5), this document references D5.1 and D5.2 as well. It should be noted that this work has been carried out in parallel with D5.1 and D5.2.

2.2 NGTC Background

The work in X2Rail-1 WP5 Moving Block has taken notice of the results of the “Next Generation of Train Control systems” (NGTC) project. The approach using analysis of scenarios follows from the work in the NGTC project [NGTCD51]. The principal difference is that the work in X2Rail-1 WP5 Moving Block has explicitly addressed the implementation of Moving Block using ETCS Level 3.

2.3 ETCS Reference

The work in X2Rail-1 WP5 Moving Block addresses the implementation of Moving Block signalling using ETCS Level 3. The term “ETCS Level 3 Moving Block” is used to mean a signalling system where Moving Block is implemented using ETCS Level 3.

The work in X2Rail-1 WP5 Moving Block has taken notice of the following specific objective from the introduction to the Description of Work in Annex 1 of the X2Rail-1 Grant Agreement:

‘To ensure the backward compatibility of ERTMS/ETCS technologies, notwithstanding of the required functional enrichment of the future signalling and control systems.’

Since direct inputs for this document have been D5.1 and D5.2, the ETCS reference is the same, (see D5.1 and D5.2 – section 2 Background for more detail).

2.4 Architecture Assumptions

In accordance with minimising the impact on Baseline 3 Release 2 [BL3 R2], the work in X2Rail-1 WP5 has assumed the system architecture for ETCS implementations remains unchanged. This architecture is summarised in Figure 1.

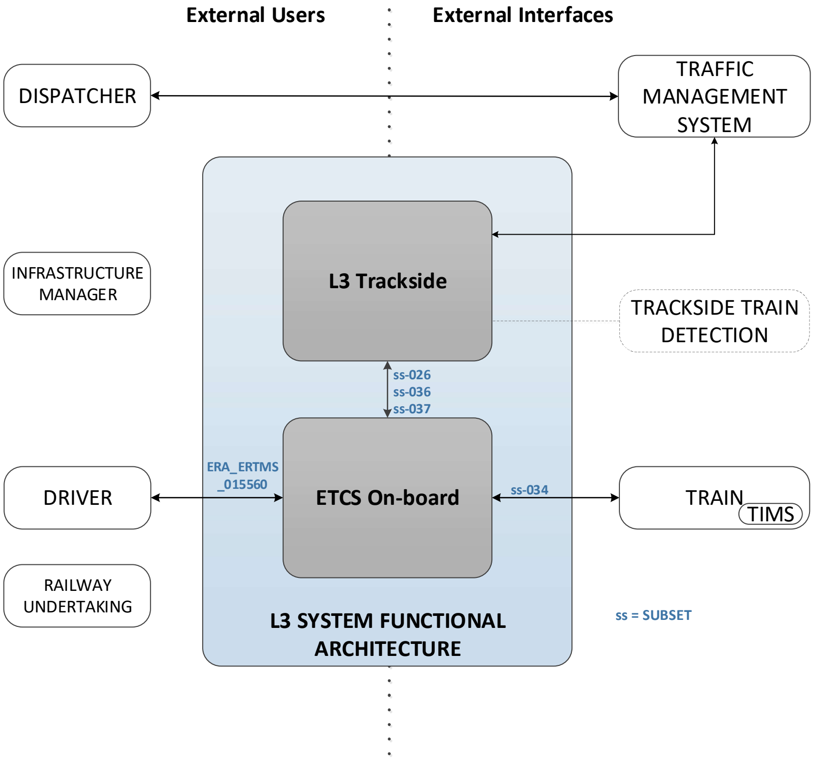

Figure 1 – Generic ETCS Level 3 Moving Block System Functional Architecture

From Figure 1, the key external actors in this system are:

- Dispatcher – the operator of the Traffic Management System
- Infrastructure Manager – the body responsible for the operation of the Railway and maintenance of infrastructure
- Driver – the operator of the train
- Railway Undertaking – Operator passenger/freight train service

In this document, the L3 Trackside includes functionality traditionally considered part of the interlocking as well as the RBC functionality. The System Architecture in the CCS TSI [BL3 R2] does not consider the interlocking as part of the ETCS system. In an ETCS Level 2 system, although there is no defined interface between RBC and Interlocking, the separation of functions is clearer. In an ETCS Level 3 Moving Block system, Track Status is derived primarily from Train Position Reports, not from Trackside Train Detection, and therefore the Track Status function is required to be in scope. This is shown in Figure 2 below. Throughout this document, the term "L3 Trackside" is used, which encompasses the Track Status Management function.

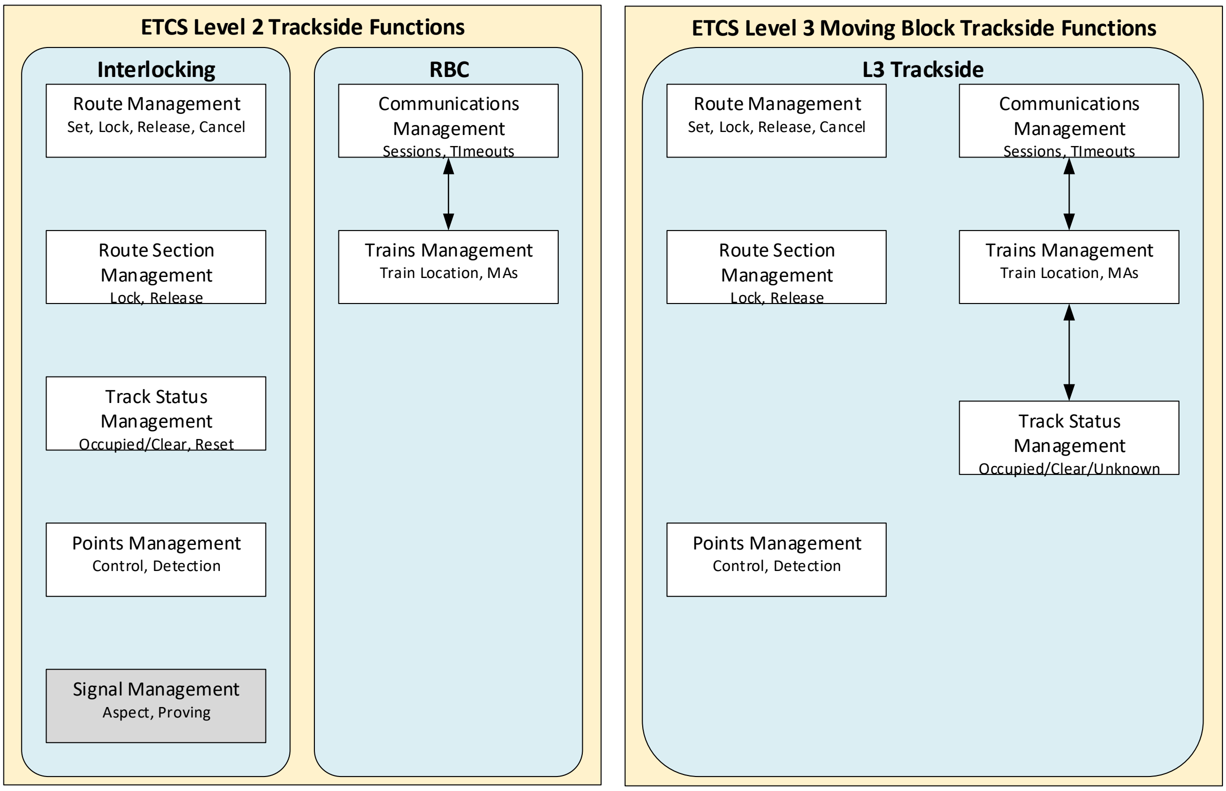

Figure 2 – Comparison of Functional Architectures for ETCS Level 2 and ETCS Level 3 Moving Block

The Traffic Management System shown in Figure 1 can be implemented in different ways, up to an automated Traffic Management System (TMS). The requirements for the interface between the L3 Trackside and TMS are summarised in D5.1 - section 6.27 Traffic Management System interface.

The Traffic Management System shown in Figure 1 can be anything from a simple route setting control system, through to an automated Traffic Management System (TMS).

Note that this architecture is aligned with that developed by X2Rail-1 WP2: Technical coordination and System Coherence [D2.1].

3 Scope

3.1 Document Scope

There are companion documents for other aspects of ETCS Level 3 Moving Block Systems. The following table summarises the set of documents produced within WP5:

X2Rail-1 Deliverable	Title	Notes
D5.1	Moving Block System Specification	Defines System Requirements for an ETCS Level 3 Moving Block System, where those requirements are beyond what is required for an ETCS Level 2 system.
D5.2	Moving Block Operational and Engineering Rules	Defines Operational and Engineering Rules for an ETCS Level 3 Moving Block System, where those rules are beyond what is required for an ETCS Level 2 system.
D5.3	Moving Block Preliminary Safety Analysis	Contains hazard analysis of an ETCS Level 3 Moving Block System. This is a proposed input to the update of subset-91 [SS091].
D5.4	Moving Block Application Report	Analysis of applying the ETCS Level 3 Moving Block system to different railway types (Urban/Suburban, High Speed, Overlay and Low Traffic/Freight).

D5.4 (this document) requires D5.1 and D5.2 as inputs, since the analysis carried out assumes the validity of the requirements and the rules defined within D5.1 and D5.2, respectively. On the contrary, D5.1 and D5.2 do not require D5.4 as input within X2Rail-1.

3.2 Application Scope

3.2.1 Railway Types

In accordance with the objective, the aim of this document has been to analyse the following railway types identified within the X2Rail-1 Grant Agreement:

- Urban/Suburban Railways;
- Overlay Systems;
- High Speed Lines;
- Low Traffic and Freight Lines.

This analysis has been carried out under the Shift2rail perspective of improving railways capacity and reducing infrastructure costs where possible, whilst satisfying the functional and operational needs of each railway type. Three main aspects have been studied:

1) How the four ETCS Level 3 Moving Block System Types defined within the X2Rail-1 Grant Agreement (refer to section 4 ETCS Level 3 Moving Block System Types for more detail) can be applied to each railway type;
2) How the System Requirements and the Operational and Engineering Rules respectively defined in D5.1 and in D5.2 can be applied across those railway types. This has led to the definition of some extra System Requirements and extra Rules not included within D5.1 and D5.2 and proposed as a future integration of the content of the X2Rail-1 Deliverable D5.1 and D5.2. This integration will be further analysed within the project X2Rail-3.
3) If new system functions need to be defined for the railway types analysed. As a result of this study, no new system functions have been identified.

It has also been within the scope of this deliverable to have a section describing the state of the art of the prototyping activities within "Tasks 5.7 - Urban/Suburban Prototype Definition", "Task 5.8 - Overlay Prototype Definition", "Task 5.9 - High Speed Lines Prototype Definition", and "Task 5.10 - Low Traffic and Freight Prototype Definition". It is worth underlining that this prototyping activity has been carried out in parallel with the above analysis, therefore is independent from the latter.

With reference to the document structure, three main sections have been defined:

- Section 5 Application Definitions (overview of each railway type: main characteristics and needs, ETCS Level 3 Moving Block System type applied);
- Section 6 Application Analysis (analysis of each railway type: assumptions on the ETCS level 3 Moving Block System type selected, scenarios);
- Section 7 Prototyping activities: result achieved (report on the prototyping activities)

3.2.2 Grade of Automation

Refer to D5.1 - section 3.2.2 Grade of Automation.

3.3 System Scope, Assumptions & Constraints

The four Moving Block System Types defined within the X2Rail-1 Grant Agreement represent possible implementations of the ETCS Level 3 Moving Block system, that is part of a larger railway control system.

The following are within the scope of this document:

- L3 Trackside
- ETCS On-board

The main assumptions about topics which are covered elsewhere within the X2Rail projects are those described in D5.1 (refer to D5.1 sections 3.3.1, 3.3.2, 3.3.3, 3.3.4, 3.3.5 and 3.3.6).

The co-ordination between the different work packages is being addressed by WP2, which is or will be present in all X2Rail projects.

4 ETCS Level 3 Moving Block System Types

Refer to D5.1 - section 5 ETCS Level 3 Moving Block System Types.

5 Application Definitions

The sections below present an overview of the different types of railway systems.

Please note that this information has been provided only to guide the comprehension of Moving Block Application Analysis carried out in the following section, which is the purpose of the document.

Railway applications may have a combination of types of railway traffic (i.e. a main line with high speed trains may run freight trains in off-peak hours), this section tries to evaluate what are the characteristics of the different railway types and which Moving Block system type is required for each of them to achieve improved capacity and reduced infrastructure costs, where possible.

5.1 "Urban/Suburban Railways" application

5.1.1 Definition

The Urban/Suburban railways application is primarily a passenger rail transport service that operates between a city centre and middle to outer suburbs (e.g. beyond 15 km). The system serves commuter towns or other locations that draw large numbers of commuters—people who travel on a daily basis for work.

5.1.2 Characteristics

Urban/Suburban railways run within cities, so speeds are normally reduced, and services operated closer together to enable higher capacity. The headway at peak times is therefore low, with a train separation of typically 2 – 5 minutes, in some instances less than 2 minutes. Furthermore, at peak commuter hours longer train sets (made up of multiple units) are operated. Services operate with a number of stations along the route, sometimes with a range of stopping patterns. The impact of failures results in very costly, significant performance and delay perturbation. Furthermore, trains on these lines are often crowded, and so, in the event of delays, there can be an impact on passenger welfare. The need to recover normal operation quickly is therefore also a safety related issue. Overall, the priorities for urban/suburban lines are managing capacity and fast recovery.

ETCS Level 3 Full Moving Block could provide extra capacity, depending on the base case. However, Fixed Virtual Block with blocks customised to the railways need (taking into account the length of trainsets in use) could provide similar results in terms of capacity.

The lack of TTD would be the most cost-effective solution as long as there are other ways to provide a fast recovery. However, TTD would be the easiest way to manage degraded operation (such as loss of communication) as a fall-back and to improve performance around complex switches and crossings. Therefore, it could be possible to install them only at strategic locations such as at points and crossings.

5.2 "Overlay System" application

5.2.1 Definition

An Overlay system application is a combination of an ERTMS/ETCS system and a conventional signalling system, i.e. ERTMS/ETCS is an overlay to an existing system. In a L3 application, the ERTMS/ETCS system is responsible for authorisations to the ETCS equipped trains it is communicating with, while the other trains are authorised by the conventional signalling system.

5.2.2 Characteristics

An ETCS Level 3 Overlay system can be implemented with ETCS Level 3 Full Moving Block or Fixed Virtual Blocks and for any type of railway; high speed, urban or freight lines.

As the Level 3 Overlay system is a mix of ERTMS and a conventional signalling system, it is expected that there is Trackside Train Detection, TTD, for the conventional part. The information from the TTD is then available also for the ERTMS system. The overlay scheme can be a simple replication of the fixed blocks used by the lineside signals, allow additional virtual blocks to sub-divide the lineside signal sections or allow ETCS Level 3 Full Moving Block for ETCS trains following trains reporting integrity confirmed.

The Level 3 Overlay system application can be installed for migration to ERTMS while equipping vehicles with ETCS On-board systems. It could also be used to increase the performance for a line by optimising the traffic flow, e.g. by only allowing trains operating in ETCS Level 3 during peak hours.

However, the overall benefit of an ETCS Level 3 Overlay system depends on the number of trains equipped with ETCS On-board systems and being able to confirm train integrity when operating in Level 3. The feasibility of having Level 3 as an Overlay system also depends on the possibility to interface the conventional interlocking system and the possible need for a specific signal aspect for allowing an ETCS train to proceed into an occupied route when already given a Movement Authority.

With an Overlay system, the conventional system may act as a fall-back system in case of degraded situations.

5.3 "High Speed Lines" application

5.3.1 Definition

High Speed Lines are complex systems, as defined by the UIC: "…involving various technical aspects such as infrastructure, rolling stock and operations and cross-sector issues such as financial, commercial aspects…" [UIC_def]. The worldwide implementations differ in for example the maximum and average speeds, number of stops, ways to operate conventional passenger trains and freight traffic etc. This makes it difficult to derive one single standard definition of High Speed Lines.

In the Technical Specification for Interoperability (TSI), High-Speed lines are considered in three types (Annex I, Directive (EU) 2016/797 [EU_Direct]):

(a) specially built high-speed lines equipped for speeds generally equal to or greater than 250 km/h;

(b) specially upgraded high-speed lines equipped for speeds of the order of 200 km/h;

(c) specially upgraded high-speed lines which have special features as a result of topographical, relief or town planning constraints, to which the speed must be adapted in each case.

Compared to other system types referred in this document HSLs tend to be simpler in terms of layout (e.g. points) and operational flexibility (e.g. terminal stations, splitting/joining, shunting).

5.3.2 Characteristics

Focusing on Category I the following attributes characterize a High Speed Line (HSL) and as such constitute a reference for the application analysis to be found in chapter 6.3. This is a pre-requisite for a systematic application analysis which would otherwise not be possible given the various implementations of HSL in Europe. Some of the attributes are not unique to HSL and are shared with other railway types.

- Vmax ≥ 250 km/h
- Interurban line (i.e. few intermediate stops)
- Tunnels and bridges with wind protection
- No level crossings
- ETCS Level 3 Passenger traffic
- Line length is between 50 and 250 km
- Speed limits due to external factors such as environment and noise protection
- Capacity of 16-20 trains per hour [Emery]
- No shunting movements

- SoM and Joining, Splitting less frequent (e.g. at terminal stations)
- HSLs can operate in any of the system types defined in deliverable D5.1.

5.4 “Low Traffic and Freight Lines” application

5.4.1 Definition

A Low Traffic line typically runs outside cities and may be isolated (low traffic railway service operated by a single train shuttling between the ends) or interconnected with another type of railway (for example High Speed or Freight lines). Freight Lines applications may be isolated (i.e. no interconnections between ports and mines) or interconnected with other types of railway as well. Freight trains are typically longer trains than passenger trains.

In principle, Low Traffic lines may be quite different to many Freight lines and have different operational needs and safety issues. This document treats them together, since this is possible in accordance with the definition of “Low Traffic Line” given within the X2Rail-1 Grant Agreement. Specifically, the Low Traffic Lines defined within the Grant Agreement are “low density” lines, therefore Freight and Low Traffic lines may be considered compatible from the perspective of their characteristics and needs, such as expanded upon in the following section.

5.4.2 Characteristics

Under the assumption that the “Low Traffic” lines here analysed are basically “low density lines”, Low Traffic and Freight lines show some similarities when it comes to the following aspects:

1) The Average Performance needs:

   Though not limited in speed, the Low traffic lines analysed have high headway and therefore limited needs for an increased capacity. On the other hand, Freight lines could achieve higher capacity, but they are often limited in speed. Speed limitations have a practical impact on the effective performances of most Freight lines, therefore it is possible to conclude that these two railway types may have similar performance needs.

2) The Moving block system type:

   From the perspective of the implementation solution, an ETCS Level 3 Fixed Virtual Block system type can be regarded as a solution for both lines. The virtual blocks of the line need to be engineered based on the specific performance needs of each specific type of application.

   A slight difference between these lines can be spotted when it comes to using TTDs: on the one hand, cost reduction is the main driver of Low Traffic lines, therefore the avoidance of trackside infrastructures and fixed communications equipment is recommendable. On the other hand, timeliness is strictly required in freight services, therefore it may be desirable to have some TTDs, at least where needed to speed up some operations (for example in loading areas).

As a consequence of what is said above, and provided that the Fixed Virtual Blocks are engineered according to the type of traffic requiring the highest performances, Low Traffic (assumed to be low density) and Freight services can be operated over the same line (mixed traffic), with possible restrictions in their timetable, depending on how their required performances can be similar. Three possible cases allowing for this mixed traffic may be identified:

a. Low (density) Traffic (with no high speed needs) is mixable with the average Freight Traffic (i.e. supposed limited in speed).
b. Freight Traffic designed for high performances (high capacity, track and train sets allowing for high speed): mixable with a Low (density) Traffic Line allowing for high speed.
c. Low (density) Traffic with high speed needs is not mixable with the average Freight traffic, and vice versa a high performance Freight traffic is not mixable with a low speed Low (density) Traffic line, but still these two types of traffic might run on the same line, at different hours.

6 Application Analysis

The previous section has provided an overview of the main characteristics of each railway type addressed by the X2Rail-1 Grant Agreement (Urban/Suburban Railways, Overlay Systems, High Speed Lines, Low Traffic and Freight Lines), by describing in particular:

1) How they are actually operated (i.e. headway and/or speed where relevant);
2) Which Moving Block system types, among those defined within X2Rail-1 (refer to section 4 ETCS Level 3 Moving Block System Types for more detail), would better provide potential benefits in accordance with their functional and operational needs.

Along this line, this section describes how each ETCS Level 3 Moving Block System type defined through the deliverables D5.1 and D5.2 may be suitable for the railway type to which the same has been associated. For this purpose, these railway types have been analysed through the sixteen main functionalities on which the X2Rail-1 Moving Block Scenarios have been based.

Furthermore, all the System Requirements, Engineering and Operational Rules resulted from the Deliverables D5.1 and D5.2 respectively, have been analysed for the purpose of investigating the need of extra requirements/rules matching specific exigencies of each railway type.

Where possible extra Requirements or Rules are identified, they will be considered for inclusion in the updated versions of D5.1, D5.2 which will be prepared as part of X2Rail-3.

To achieve this objective, each railway type has been analysed from its own perspective of what can be desirable, in terms of needed performance and affordable costs. Furthermore, it is worth noticing that these different analyses have been carried out by different suppliers, to get the most out of the comparison of their separate experiences as far as railway-specific needs are concerned. The table below provides a schematic overview of the philosophy standing behind the four analyses expanded in the following (it goes without saying that maintaining safety is the basis of each one):

Railway Type	Main Characteristics	Main drive of the analysis
Urban/Suburban Railways	Low headway (for details see section 5.1.2) Fixed Formation/Multiple Unit trains	Increasing capacity. Saving costs. Fast recovery from perturbations in service.

Overlay System	Variable headway (for details see section 5.2.2)	Increasing capacity (limited to peak hours). Progressive migration to an ETCS Level 3 Moving Block system without TTDs. Saving costs (by avoiding/postponing the trackside and on-board upgrades required for both ETCS and non-ETCS pre-existing applications to become an ETCS Level 3 Moving Block system without TTDs).
High Speed Lines	High Speed.(for details see section 5.3.2) Fixed Formation/Multiple Unit trains	Increasing capacity. Saving costs.
Low Traffic/Freight Lines	High Headway (Low Traffic), limited speed (Freight). (for details see section 5.4.2)	Saving Costs (Low Traffic and Freight). Increasing Capacity (Freight).

6.1 “Urban/Suburban Railways” application analysis

The general characteristics of Urban/Suburban railways are defined in 5.1 above. They can be summarised as:

- High capacity requirement
- High availability requirement / Fast recovery requirement
- Typically fixed consist trains, or multiples of fixed consist trains
- If there is mixed traffic with trains not fitted with ETCS, this is likely to be away from peak hours, when capacity is not such an issue. For mixed traffic, Trackside Train Detection (TTD) will be required.

6.1.1 Initialisation of Trackside

Urban/Suburban railways will seek to avoid initialisation of L3 Trackside as much as possible. This implies the use of high availability designs for equipment and communication infrastructure.

Where there is determined to be a significant risk that quick restarting of the system will be required, the L3 Trackside will need to store the state of the railway in a non-volatile manner, and be able to restart using the locations of trains within the area of control from the stored state of the railway.

If there is judged to be a significant risk that the L3 Trackside will need to perform a restart during operating hours, without access to the stored state of the railway then it may be required to provide TTD, to enable fast recovery. One reason for not using the stored state of the railway could be that the elapsed time since the data was stored is too long, meaning that trains may have moved.

TTD used for recovery could be longer TTD sections on plain track, thus reducing the equipment count. Such a design could be achieved with axle counters around points and crossings, then using the same axle counters to provide longer TTD sections for plain track sections. However, this might take a greater time to recover than shorter TTD sections, as there could be more than one train per TTD section for longer TTD sections.

Longer TTD sections would also reduce performance if there is mixed traffic operation, as unfitted trains will completely occupy the longer TTD sections.

Extra Requirements/ Rules or changes proposed

Extra Requirement:	Requirement for L3 Trackside to be configurable with a length of time for which it is valid to use stored data when performing initialisation.
Modified Requirement:	In order to provide a fully automated restart within the length of time for which it is valid to use stored data, it may be necessary to modify REQ-TrackInit-3, which requires a person to confirm that initialisation is completed.

6.1.2 Start of Train

If trains enter NP mode within the L3 Area of Control as part of the normal operation of a railway, trains could be fitted with Cold Movement Detectors to reduce the occurrences of trains performing Start of Mission with an unknown position. In order to reduce the risk of errors, or the risk of inconsistencies, it is expected that the Train Length for trains with a fixed consist, or a multiple of fixed consists, will be provided automatically by the train.

In order to enable an efficient Start of Mission in the case where a train has a known position, it is expected that the L3 Trackside will have stored information from when the train performed End of Mission. If the new train data is consistent with the stored data, then the L3 Trackside will be able to replace the “unknown” track status with “occupied” track status.

Extra Requirements/ Rules or changes proposed

None

6.1.3 Normal Train Movement

Urban/Suburban railways will include Normal Train Movement.

For systems without TTD, it will be necessary to define Release Points around points and diamond crossings, to release routes behind trains. The concept of Release Points is described in D5.1, section 5.6 Points Control. The placement of Release Points can influence performance, and so application of L3 without TTD will need to be engineered with this in mind.

Some railways may include the use of TTD around points and crossing areas, in which case these can be used to release routes behind trains.

Extra Requirements/ Rules or changes proposed

None

6.1.4 Transitions

Urban/Suburban railways are likely to include Transitions at the boundaries of L3 Areas of Control. The likely transitions are:

- ETCS Level 0 / NTC <-> ETCS Level 3
- ETCS Level 1 <-> ETCS Level 3
- ETCS Level 2 <-> ETCS Level 3

The key requirement is for trains to be able to transition in and out of ETCS Level 3 without a reduction in the headway between trains. This can be solved in the engineering of the transition, in the same way as for ETCS Level 2.

Extra Requirements/ Rules or changes proposed

None

6.1.5 Handover

Urban/Suburban railways may include Handover to adjacent L3 Areas of Control.

In order to achieve maximum capacity at the boundaries between Areas of Control, boundaries will need to be engineered to permit handover without reduction of the headway between trains. This could lead to a requirement for the L3 Trackside to be able to cater for the situation where there is more than one train in the handover area at any one time.

Use of TTDs at Handover boundaries could also assist with the faster clearing of track in the Handing Over L3 Trackside, or in degraded modes operations such as the handing over of a train without train integrity confirmed.

Extra Requirements/ Rules or changes proposed

Extra Requirement:	Consider if any extra Requirement is needed for L3 Trackside to be able to operate with more than one train in a handover area at any one time.

6.1.6 On Sight Movement

Urban/Suburban railways will include use of On Sight Movement.

On Sight movement may be used:

a) In degraded mode situations, e.g. after loss of communications or loss of integrity of a previous train;
b) In normal operation, e.g. for joining

Unscheduled use of On Sight movement will cause delays in the railway system. Therefore, it will be beneficial to:

a) Minimise the occasions where unscheduled use of On Sight mode is required
b) Minimise the extent of railway where unscheduled use of On Sight mode is required to be used.

To minimise the occasions where On Sight mode is required in degraded mode operations means minimising the occasions when a portion of track becomes “unknown”. For example, use of automated entry of train length data at Start of Mission should ensure that train lengths are always consistent, thus reducing the likelihood of inconsistent lengths resulting in unknown portions of track. This should be extended to include the splitting and joining of fixed consist trains.

TTD can also be used to minimise the portions of track which remain “unknown”, as a clear TTD section enables the track status to be set “clear”.

To minimise the extent where On Sight mode is required the L3 Trackside will be expected to provide On Sight Mode Profile only over the area where it is required.

The use of On Sight in normal operation, for example for joining, is less disruptive, as slow movements for joining is already built into the operational planning.

Extra Requirements/ Rules or changes proposed

None

6.1.7 End of Mission

Urban/Suburban railways will include the use of End of Mission.

In order to ensure minimum area of track with status “Unknown” after a train performs End of Mission, the train integrity confirmation reporting must be sufficiently frequent. This is to avoid the possibility of a Driver performing End of Mission when there is a larger area remaining “occupied” by the train, because there has been no recent confirmation of train integrity, leaving the Confirmed Rear End behind the physical end of the train. If Trackside Train detection (TTD) is deployed, the Unknown area created at End of Mission can be reduced in size by the clearance of TTDs.

At End of Mission, when the area occupied by the train will become “Unknown”, the L3 Trackside will store information about the train, so that when the train performs Start of Mission, perhaps in the opposite direction, the “Unknown” area will be removed automatically if the appropriate checks are satisfied.

Extra Requirements/ Rules or changes proposed

None

6.1.8 Reversing

Urban/Suburban railways are likely to avoid the use of Reversing Areas as much as possible, as these would have an impact on capacity.

Extra Requirements/ Rules or changes proposed

None

6.1.9 Splitting

Urban/Suburban railways are likely to use splitting and joining of multiples of fixed consist trains.

Urban/Suburban railways are likely to use automated entry of train length after splitting operations.

Extra Requirements/ Rules or changes proposed

None

6.1.10 Joining

Urban/Suburban railways are likely to use splitting and joining of multiples of fixed consist trains.

Urban/Suburban railways are likely to use automated entry of train length after joining operations.

Extra Requirements/ Rules or changes proposed

None

6.1.11 Shunting

Urban/Suburban railways are likely to avoid use of Shunting.

Extra Requirements/ Rules or changes proposed

None

6.1.12 Mixed Traffic

Urban/Suburban railways are likely to avoid the use of Mixed Traffic during peak hours, when capacity is important. This is because running trains without Train Integrity confirmed, or trains not fitted for ETCS, will reduce capacity.

However, it is possible that outside peak hours, other trains may be permitted. For these, it is likely to be acceptable to have reduced capacity. This may require the implementation of TTD. The TTD sections could be long on plain track sections.

Such long TTD sections would reduce performance, as unfitted trains will completely occupy the long TTD sections.

Lineside signals will be required if trains not fitted with ETCS will use the railway.

Extra Requirements/ Rules or changes proposed

None

6.1.13 Communication Failure

All railways, including Urban/Suburban railways, will want to avoid the impact on capacity caused by communications failure. This means engineering the radio system with high availability, and without areas with poor radio coverage.

Use of pre-defined Radio Holes would provide a mechanism for the continued operation of the railway in the event of a failure of a single cell of the communications system.

Communications failure could be very disruptive. This may mean that additional fall-back systems should be provided to enable railway operations to continue in the event of a communications failure, albeit in a degraded mode.

Extra Requirements/ Rules or changes proposed

None

6.1.14 Loss of Train Integrity

All railways, including Urban/Suburban railways, will want to avoid the impact on capacity caused by loss of train integrity.

The Train Integrity Management System (TIMS) should be designed so that there is a low probability of failure of the TIMS such that the L3 Trackside interprets train position reports to mean that the train has lost integrity.

Use of fixed consist trains should improve train integrity reporting and reduce the risk of loss of train integrity.

Use of multiples of fixed consist trains may create an extra challenge to the application of TIMS. In the short term, TIMS may not be available via the coupling of multiple fixed consist trains.

The system will be designed to react in a safe manner in the event of train integrity failure, whether this is a real failure of train integrity, or a failure of the Train Integrity Management System (TIMS).

In order to achieve maximum capacity, it could be that Infrastructure Managers of Urban/Suburban railways do not permit trains which do not have an operational Train Integrity Management System (TIMS) to enter the railway.

Extra Requirements/ Rules or changes proposed

Extra Operational Rule:	Consider if an extra Operational Rule is required to define whether or not a train without a functional Train Integrity Management System (TIMS) is permitted to enter the L3 Area of Control.

6.1.15 Recovery

All Railways, including Urban/Suburban railways, will want to achieve fast recovery in the event of failures such as communications failure or loss of train integrity.

There are already mechanisms defined for recovery of the Track Status if communications are regained after loss of communications, and if train integrity is regained after loss of train integrity, based on the use of information stored within the L3 Trackside.

If communications are not regained after loss of communications, or train integrity is not regained after loss of train integrity, then it will still be necessary to recover the railway to normal operation. For example, this could be by procedures to move non-communicating trains, or procedures to clear the track behind trains which have lost train integrity.

One mechanism to achieve faster recovery is to use TTD, which can be used to quickly determine which sections of track are occupied or clear.

For railways without TTD, or with long TTD sections which could contain multiple trains, then it may be necessary to sweep areas of Unknown track status using On Sight mode profile.

Extra Requirements/ Rules or changes proposed

None

6.1.16 Override

All Railways, including Urban/Suburban railways, will want to minimise the movement of trains in Staff Responsible (SR) mode , in order to reduce the risk of human error, and avoid the impact on capacity.

However, the system must still be designed to permit the movement of trains when normal operation is not possible, so Movement in SR mode must be included.

When engineering an ETCS Level 3 railway with no signals and Full Moving Block, there will potentially be minimal trackside infrastructure to act as a reference for the driver (e.g. Markerboards). This delivers the benefit of reducing the amount of equipment that requires maintenance and increasing system reliability. However, operating in SR mode requires a reference for the driver to drive to and stop in rear of. Minimal trackside reference assets would therefore result in trains operating in SR mode over a long distance. As such, Engineering rules will be required to define the minimum distance between reference assets. This would be defined at a project level, dependant on the specific track layout and operating procedures of that country.

Extra Requirements/ Rules or changes proposed

Extra Engineering Rule: Consider if an extra Engineering Rule is required to define the minimum distance between reference assets for use during movement of trains in SR mode.

6.2 "Overlay System" application analysis

The Overlay system assumes ETCS Level 3 in operation together with a conventional signalling system using some sort of Trackside Train Detection (TTD) and optical signals. Thus, it is foreseen that in an Overlay system, there will be mixed traffic in the sense that only part of the fleet of trains are equipped with an ETCS on-board system. The TTD system in use may be sub-divided in some routes or block section (see Figure 3), which can constitute a virtual sub-route in the Overlay system and used to authorise movements into an occupied route as soon as its TTD sub-sections are detected free, i.e. a TTD subsection is a virtual block. This is only an example and other configurations of the virtual blocks are possible depending on the length of the TTD subsections.

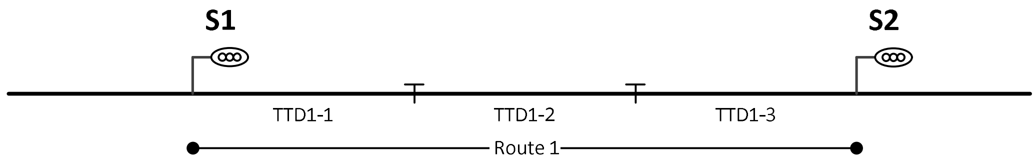

Figure 3 – Trackside Train Detection system with sub-sections in a route

The ETCS Level 3 Overlay system may operate with either Full Moving Block or Fixed Virtual Blocks; it may even use a combination of both. When an ETCS train is following another ETCS train able to confirm train integrity, then the Overlay system can operate with moving or fixed blocks. Even if the Overlay system has TTD, a correct Train Length is as important as for the other applications.

When an ETCS train is following a train unable to confirm train integrity, then the Overlay system may use Fixed Virtual Blocks to authorise the ETCS train into the same route as the other train when the first TTD subsection equal to a virtual block being part of that route is detected free. For this to be possible, when a train is authorised by the Overlay system to pass a signal that protects an occupied route, it is expected that either the train drivers are allowed (by rule for ETCS trains) to pass signals at stop or that the signal shows a specific aspect that allows the train driver to pass the signal.

6.2.1 Initialisation of Trackside

For a Level 3 Overlay system application, there is no need to initialise the L3 Trackside in the sense of clearing tracks with status Unknown as there is TTD.

Extra Requirements/Rules or changes proposed

None

6.2.2 Start of Train

In a Level 3 Overlay area, ETCS trains cannot be authorised in Full Supervision (FS mode) directly after Start of Mission unless there is some (project specific) way to guarantee that the track is free up to the start of the first route that the ETCS train is about to be authorised for, e.g. by using information stored when the train performed End of Mission. This is because the track section under the train is detected occupied and therefore the part up to the first TTD section detected free may need to be authorised with an On Sight (OS) mode profile, similar to an ETCS Level 2 Overlay system.

If trains regularly perform Start of Mission from No Power mode in the L3 Overlay area, they could be fitted with a Cold Movement Detector that may help starting with a known position.

In case the L3 Overlay system cannot provide a Movement Authority (MA), e.g. for a train with an unknown or ambiguous position after Start of Mission, it may instead give the train an SR Authorisation. If the system cannot provide any authorisation for a train, then drivers may use Override; see 6.2.16.

Extra Requirements/Rules or changes proposed

None

6.2.3 Normal Train Movement

When an ETCS train is following another ETCS train and the first reports train integrity confirmed, then the second train could be authorised into the same (non-virtual) route as the first train. The authorisation given by the ETCS Level 3 Overlay system will then end at either the Confirmed Safe Rear End (CSRE) of the first train (Full Moving Block operation) or at some predefined location in rear of the CSRE (Fixed Virtual Block operation).

If an ETCS train follows a train that cannot report train integrity, then the Level 3 Overlay system may authorise the ETCS train to enter the occupied route when the first TTD subsection equal to a virtual block section is detected free and continue to extend the authorisation as subsequent sections are detected free (Fixed Virtual Block operation); see figure in 6.2 for TTD subsections.

But, when an ETCS train is authorised by the Level 3 Overlay system to pass an optical signal that protects an occupied route, for the driver to move the ETCS train into this route either the train drivers are allowed to pass signals at stop, or the signal shows a specific aspect that allows the train driver to pass the signal.

Extra Requirements/Rules or changes proposed

None

6.2.4 Transitions

In general, there is nothing different compared to ETCS Level 2 Overlay systems.

Compared to an ETCS Level 3 (only) system there is TTD in the Level 3 Overlay system that will detect any passage at its level borders.

Extra Requirements/Rules or changes proposed

None

6.2.5 Handover

In general, there is nothing different compared to ETCS Level 2 Overlay systems.

Compared to an ETCS Level 3 (only) system there is TTD in the Level 3 Overlay system that will detect any passage at its RBC-RBC borders.

Extra Requirements/Rules or changes proposed

None

6.2.6 On Sight Movement

In general, there is nothing different compared to an ETCS Level 2 Overlay system where the Movement Authorities are given with an On Sight mode profile when the track is not detected free; either because there is an occupied track in the route or the TTD has failed.

Compared to an ETCS Level 3 (only) system there is TTD in the Level 3 Overlay system, so there is no need to use On Sight movements to ‘sweep’ a part of track with unknown occupancy. However, depending on the TTD system in use, a project may make use of a train passing a failed section with an On Sight authorisation to ‘recover’ or ‘reinitialise’ the TTD system for this section.

Extra Requirements/Rules or changes proposed

None

6.2.7 End of Mission

In general, there is nothing different compared to EoM in ETCS Level 2 Overlay systems.

Compared to an ETCS Level 3 (only) system there is TTD in the Level 3 Overlay system, so there is no absolute need to store any information about a train reporting End of Mission. However, stored information could be used to enable a train to start in Full Supervision after Start of Mission.

Extra Requirements/Rules or changes proposed

None

6.2.8 Reversing

In general, there is nothing different compared to ETCS Level 2 Overlay systems.

Compared to an ETCS Level 3 (only) system there is TTD in the Level 3 Overlay system, so it is possible to detect and trace backward movements depending on the resolution of the TTD system in use.

Extra Requirements/Rules or changes proposed

None

6.2.9 Splitting

In general, there is nothing different compared to splitting in ETCS Level 2 Overlay systems.

Compared to an ETCS Level 3 (only) system there is TTD in the Level 3 Overlay system, so there is no absolute need to keep track of occupations (train locations) when a train is split. However, doing that can make it possible for trains to depart in Full Supervision after splitting.

Extra Requirements/Rules or changes proposed

None

6.2.10 Joining

In general, there is nothing different compared to joining in ETCS Level 2 Overlay systems.

Compared to an ETCS Level 3 (only) system there is TTD in the Level 3 Overlay system, so there is no absolute need to keep track of occupations (train locations) when trains join. However, doing that can make it possible for trains to depart in Full Supervision after joining.

Extra Requirements/Rules or changes proposed

None

6.2.11 Shunting

In general, there is nothing different compared to shunting in ETCS Level 2 Overlay systems.

Compared to an ETCS Level 3 (only) system there is TTD in the Level 3 Overlay system, so there is no absolute need to store information about trains reporting Shunting mode.

Extra Requirements/Rules or changes proposed

None

6.2.12 Mixed Traffic

In general, there is nothing different compared to mixed traffic in ETCS Level 2 Overlay systems.

Compared to an ETCS Level 3 (only) system there is TTD in the Level 3 Overlay system, which helps to keep track of movements made by non-ETCS train.

Extra Requirements/Rules or changes proposed

None

6.2.13 Communication Failure

In general, there is nothing different compared to ETCS Level 2 Overlay systems. However, it should be noted that even if a communication failure could have impact on the operation in a Level 3 Overlay application, the coexistence of a conventional signalling system can limit the impact compared to signalling systems solely based on radio communication.

Extra Requirements/Rules or changes proposed

None

6.2.14 Loss of Train Integrity

Compared to an ETCS Level 3 (only) system there is TTD in the Level 3 Overlay system, which helps to keep track of occupations in case a train reports integrity lost. Thus, the use of information from the TTD system may limit the possible impact on other train movements in rear of a train which has reported loss of integrity. However, as in other systems, derailment of lost wagons might not be detected and lead to collisions on adjacent tracks.

Extra Requirements/Rules or changes proposed

None

6.2.15 Recovery

For a Level 3 Overlay system application, there is no need to (re-) initialise the trackside in the sense of clearing tracks with status Unknown as there is TTD.

Extra Requirements/Rules or changes proposed

None

6.2.16 Override

Compared to ETCS Level 2 Overlay systems, there could be several trains in the same route or block section that may need to use Override and this could require a specific procedure.

Compared to an ETCS Level 3 (only) system there is TTD in the Level 3 Overlay system, which helps to keep track of train movements after using Override.

Extra Requirements/Rules or changes proposed

Extra Operational Rule	Consider if a specific Operational Rule or procedure when several trains need to use Override in the same route or block section.

6.3 "High Speed Lines" application analysis

The following analysis is based on the general characteristics of High Speed Lines as defined in chapter 5.3.2. HSLs can operate in any of the system types defined in D5.1. However, in degraded or special operational situations system types with TTD could help to mitigate negative impact on the service.

6.3.1 Initialisation of Trackside

Initialisation is applicable to HSLs.

Initialisation of a HSL L3 Trackside system can occur due to a number of different reasons (first commissioning, planned restart, etc.). During the initialisation phase L3 Trackside establishes the status of the track (Unknown, Clear, Occupied).

A key requirement for all railways including HSLs is to avoid sweeping movements for areas with status Unknown as much as possible as these types of movements are conducted at low speed (e.g. 30 km/h) and this would reduce the capacity of a HSL in an unacceptable way.

System types with TTD represent an opportunity to reduce the need for sweeping movements, other options include retention of track occupancy and movement authority information in non-volatile memory or operator input to manage occupancy.

Extra Requirements/ Rules or changes proposed

None

6.3.2 Start of Train

Start of Train is applicable for HSLs.

However, considering the characteristics of a HSL this operational situation is rather rare due to the interurban nature of HSLs with few intermediate stations. Typically the Start of Mission procedure is executed in station sidings, passing loops, platform tracks or in dedicated areas e.g. depots or yards in order not to interfere with the High Speed traffic on the main tracks. In degraded situations Start of Mission could be necessary on the open line to recover a failed train (see also 6.3.15).

To allow efficient Start of Train movements in terminal stations additional measures such as Cold Movement Detectors and TTD should be considered to mitigate the impact of remaining Unknown Areas.

The different system types have less impact on this scenario.

Extra Requirements/ Rules or changes proposed

None

6.3.3 Normal Train Movement

Normal Train Movement is applicable for HSLs.

Typically, high speed trains have long braking curves (e.g. 7 km) with the consequence that movement authorities of sufficient length need to be granted to the train in order to utilise the line in a most efficient way. Therefore, non-stopping areas like tunnels or viaducts need to be specially considered during the timetable definition of a HSL as MAs are not allowed to end in such an area (EoA exclusion area).

System types with TTD where TTD are placed around points and crossing areas support the possibility to release routes behind trains more quickly.

Extra Requirements/ Rules or changes proposed

None

6.3.4 Transitions

Transitions are applicable to HSLs.

Transitions to and from L3 are very likely at the boundaries of HSLs. At these boundaries the hazard of non-communicating trains trying to enter the L3 area needs to be addressed.

System types with TTD at the border could provide the means to detect such trains.

Extra Requirements/ Rules or changes proposed

None

6.3.5 Handover

Handover is applicable to HSLs.

HSL will include a transition from a Handing Over to an Accepting L3 Trackside system. The distances between two Handing Over borders shall enable processing the handing over scenario in sequence.

The rationale is to avoid that the L3 Trackside is in the Handing over and Accepting role at the same time.

System types with TTD support clearing the track area at the border also in degraded situations.

Extra Requirements/ Rules or changes proposed

None

6.3.6 On Sight Movement

On Sight Movement is applicable to HSLs.

On HSLs On Sight movement is typically used for sweeping movements. As already indicated this kind of manoeuvre could have a negative impact on the capacity and therefore the installation of TTD or functions like allowing the dispatcher to clear a piece of track provide opportunities to mitigate the impact on line performance.

Extra Requirements/ Rules or changes proposed

None

6.3.7 End of Mission

End of Mission is applicable to HSLs.

However, considering the characteristics of a HSL this operational situation is rather rare due to the interurban nature of HSLs with few intermediate stations. Typically, the End of Mission procedure is executed in station sidings or in dedicated areas e.g. depots or yards in order not to interfere with the high speed traffic.

In areas where an End of Mission is executed the L3 Trackside system stores train related information in order to allow clearing the Unknown Area after Start of Train movement. In order to minimise the areas considered as Unknown after an End of Mission the CRE should be updated before the communication session is terminated (see D5.1 for details). System types with TTD could limit the extent of the track that becomes Unknown e.g. due to propagation of Unknown status.

Extra Requirements/ Rules or changes proposed

None

6.3.8 Reversing

Reversing is applicable to HSLs.

Regarding the characteristics of a HSL reversing may be used for evacuation of trains in tunnels in emergency situations e.g. fire in the tunnel.

System types with TTD enable detection and traceability of backward movements, therefore, supporting evacuation in an emergency situation.

Extra Requirements/ Rules or changes proposed

None

6.3.9 Splitting

Splitting is applicable to HSLs.

Splitting is used to separate trains before they start their operational mission. It is strongly recommended to execute this procedure only in a depot or in station sidings to not impact the capacity of the line.

The system types with TTD could mitigate the impact of remaining Unknown Areas after Splitting is completed.

Extra Requirements/ Rules or changes proposed

None

6.3.10 Joining

Joining is applicable to HSLs.

Joining is used to assemble trains before they start their operational mission. This procedure is typically executed in depots, in sidings or designated part of stations not impacting the capacity of the line.

The system types with TTD could mitigate the impact of remaining Unknown Areas after Joining is completed.

Extra Requirements/ Rules or changes proposed

None

6.3.11 Shunting

Shunting movements are not typical for a HSL and therefore not considered here.

Extra Requirements/ Rules or changes proposed

None

6.3.12 Mixed Traffic

Mixed traffic is applicable to HSLs.

Trains operating in L3 could be used to increase the capacity for an existing HSL for example at peak hours. During a migration phase it may be useful to allow for mixed traffic.

This scenario is applicable only to system types with TTD.

Extra Requirements/ Rules or changes proposed

None

6.3.13 Communication Failure

Communication failure is applicable to HSLs.

For most railways, including HSLs, a communication failure may cause major impact on the operation regarding the capacity of the line.

Redundant installation of communication devices may reduce the probability of such a failure but nevertheless it cannot be eliminated. In the application of mute and propagation timers (see D5.1) their dimensioning should, in particular, consider the impact on the train following at high speed.

System Types with TTD would help to follow the train movement, but the operational impact on the line could still be present due to the train travelling at a reduced speed.

Extra Requirements/ Rules or changes proposed

None

6.3.14 Loss of Train Integrity

Loss of Train Integrity is applicable to HSLs.

For most railways, including HSLs, Loss of Train Integrity during operation may cause major impact on the operation regarding the capacity of the line.

For high speed trains Loss of Train Integrity is less likely assuming that fixed train sets are used but cannot be completely ruled out. In the application of propagation timers (see D5.1) their dimensioning should, in particular, consider the likelihood that a train is physically broken and the impact on the train following at high speed.

System Types with TTD would mitigate the impact of a Loss of Train Integrity.

Extra Requirements/ Rules or changes proposed

None

6.3.15 Recovery

Recovery of failed trains is applicable to HSLs.

A fast recovery is essential for all railways, including HSLs, in order to resume normal operation without longer interruption of service. Therefore, sweeping should be avoided.

If recovering a failed communicating high speed train (train set) which is reporting integrity confirmed the integrity of the combined hauling and failed high speed train can be performed more easily compared to trains without reporting integrity confirmed. Therefore, this provides the ability to clear the track after the failed train has been hauled away without the need to sweep the area.

System Types with TTD would allow for faster recovery if the train integrity information is unavailable.

Extra Requirements/ Rules or changes proposed

None

6.3.16 Override

Override is applicable to HSLs.

All railways, including HSLs, will want to minimise the use of Override, in order to avoid the impact on capacity. If possible, the use of Override should be restricted to the station areas.

However, the system must still be designed to permit the movement of trains when normal operation is not possible, so Override must be included.

System types with TTD reduce the impact of performing Override procedure compared to not having TTD, due to the possibility of releasing portions of track behind a train moving in SR (see D5.1). Furthermore, it can help to keep track of train movements after using Override.

Extra Requirements/ Rules or changes proposed

None

6.4 "Low Traffic and Freight Lines" application analysis

Based on the preliminary description provided within section 5.4 "Low Traffic and Freight Lines" application, the ETCS Level 3 Moving Block System type engineering the L3 trackside of the "Low Traffic" and the "Freight Lines" railway types analysed in the following is a Fixed Virtual Blocks without TTDs system.

According to this choice, the use of TTDs in the line is excluded. Mixed traffic requiring TTDs in the line (ETCS and non ETCS trains, ETCS trains with TIMS and ETCS trains without) has been analysed within section 6.2 “Overlay System” application analysis. However, it is to be noted that some scenarios in the following address the possibility to install TTDs at some locations within the main line or within specific areas.

With TIMS, it is expected that the confirmation of train integrity is performed by means of external devices installed on-board. Despite this assumption, it is to be noted that a confirmation by driver could be regarded as a desirable alternative, for the following reasons:

- For Low Traffic applications not interfaced into higher traffic applications it may be envisaged to have a “low cost” Systems with no “high technology trains” (i.e. trains for Low Traffic applications are expected to have no TIMS (Train Integrity Monitoring System)).
- Freight trains typically have variable consist, which can make it difficult to manage TIMS installation. On the other hand, ETCS trains not equipped with TIMS are against any efficient use of the line, therefore it is strongly recommended that it is always investigated the best TIMS solution as possible according to the railway needs.

When it comes to Cold Movement Detection, the scenarios in the following take into account the possibility that no CMD are implemented, since this may be desirable for the purpose of having “low cost” trains without any specific optional functions.

6.4.1 Trackside Initialisation

As for this scenario, Low Traffic service needs are considered completely fulfilled by D5.1 and D5.2.

When it comes to Freight applications, special reference needs to be made to the management of those freight areas where specific procedures take place, such as loading and unloading operations at the yard. Such operations may be carried out in SH mode or by means of a Remote Control System, taking control of the train as soon as it performs EoM and the driver gets off the locomotive. Since such procedure involves cold movements, it could be desirable for these specific areas to be equipped with TTDs, where possible. As an alternative, these yards and their entrance areas may be configured within one or more Permanent Unknown/Shunting Areas. In both cases neither sweeping nor any specific operational procedure are required to complete their initialisation.

In case a new trackside initialisation should be required at the moment a train is inside such an area, it may be desirable that:

- According to non-harmonised operational rules preventing these yards to be entered by other trains, any ongoing loading/unloading operation in NP/SH mode is not stopped during the re-initialisation phase;
- in the absence of TTDs, the L3 Trackside maintains whatever train information stored before its disconnection (see also End of Mission [6.4.7]).

Extra Requirements/ Rules or changes proposed

Modified Rule:	OPE-TrackInit-4: it is proposed that the guidance of this rule references this scenario as well, especially regarding the possibility that the rule does not affect in-yard NP/SH freight operations.

6.4.2 Start of Train

As for this scenario, Low Traffic service needs are considered completely fulfilled by D5.1 and D5.2.

When it comes to Freight applications, cold movements may frequently occur during freight loading and unloading operations, such as described in section 6.4.1. A train can be moved in No Power mode through a remote controlled yard and then perform a SoM to exit this yard at such a location that the area it occupies does not intersect at all the Unknown Area that the L3 Trackside should have created to protect the same train at the time of its EoM. This event (SoM reported position not matching the EoM stored position) generally represents a degraded case to deal with, but it should be regarded differently in some specific cases such as the above described. Such as pointed out within section 6.4.1, TTDs may be required in these yards to detect cold movements.

In the absence of TTDs, the needed protection against these movements may be provided by configuring these yards and their entrance areas within one or more Permanent Unknown/Shunting Areas.

Furthermore, it is not unusual for freight loading/unloading yards to be configured in such a way that only one train at a time can be handled. The operator (person in charge of this areas) may be required to authorise the entrance of a train only if the entrance area can be regarded free of other parked trains.

For this purpose, and in the absence of TTDs, it may be desirable for the L3 Trackside to store some specific information (for example the NID Engine of leading and non-leading locomotives) of each entered train (see also End of Mission, [6.4.7]), until its subsequent SoM.

Extra Requirements/ Rules or changes proposed

Modified Requirement:	D5.1 - REQ-StartTrain-5, REQ-StartTrain-6, and REQ-StartTrain-7: these requirements are only based on a trackside comparison between the Unknown Area resulting from a previous EoM of the train and the occupied area due to the SoM performed after. Therefore, it should be specified (for example in their guidance) that the above scenario may not require any comparison between the SoM position and the previous EoM position. Instead, a simple update/deletion of some other information (trains parked in, entering, exiting the area) could be managed at each SoM (see also End of Mission, [6.4.7]).
Extra Requirement:	D5.1 - REQ-TrainLoc-9: it is stated that the L3 Trackside shall store the train information needed for recognising a train regaining communication or for cleaning up an Unknown Area. On one hand, cleaning up an Unknown Area is outside the scope of the above scenario, whereas the scope of displaying such information is not covered by this requirement. It is to be noted that the addressee of the information that may be required for allowing train entry/exit from unloading areas is an external operator (local or remote control operator different from the Dispatcher or other Trackside (i.e. RBC) Operator). As a consequence of the above considerations, the following new system requirement is proposed: Requirement: If required by the Infrastructure Manager, the L3 Trackside shall be able to provide the person in charge of a non-sweepable Unknown Area with the information needed to handle entry/exit permissions in a safe way. Guidance: this could be achieved by displaying some specific information identifying each train having entered the area, and by updating/deleting this information every time a train has released the entrance track (for example when it performs a new SoM in order to exit the area).

6.4.3 Normal Train Movement

The normal train movement scenario in general terms includes the operation of two trains running with Level 3 MA.

This scenario is not applicable to those Low Traffic application operated by one train (closed systems with just one train shuttling the line from end to end).

In Low Traffic applications operated by more trains - that typically involve headways of about 60 minutes, the end of an MA will probably not be the last Fixed Virtual Block detected free of the Confirmed Safe Rear End of the preceding train (that perhaps is so far), but path conditions as a route ahead that has to be set or a point not detected in any position.

In "Freight Lines" applications two trains could run on the same route and so the MA could be set at the last Fixed Virtual Block detected free of the Confirmed Safe Rear End of the preceding train.

Extra Requirements/ Rules or changes proposed

None

6.4.4 Transitions

Transitions normally take place both in Low Traffic and in Freight applications, unless considering isolated Freight lines or those Low Traffic services operated with just one train operating the line from end to end.

No specific needs are required regarding transitions. However, when it comes to freight trains that may be considerably long, installing TTDs across a transition area may speed up the clearing of those areas, especially in case of TIMS failure.

Extra Requirements/ Rules or changes proposed

None

6.4.5 Handover

Handover may take place both in Low Traffic and in Freight railway types, unless considering some isolated Freight lines or those Low Traffic services operated with just one train shuttling the line from end to end. However, these applications may be quite different when it comes to their typical line extension and complexity. In fact, it often happens that a single RBC could be sufficient in order to control the whole Low Traffic area and the adjacent area as well, therefore a handover between two RBCs controlling the Low Traffic area or adjacent areas may be not required. Freight lines are often more complex and extended, therefore handover is more usual.

No specific needs are to be pointed out regarding transitions, assuming that trains are expected to be equipped with two mobile terminals, especially freight trains that may be very long. However, when it comes to freight trains, installing TTDs across a handover border may speed up the cleaning of this area.

Extra Requirements/ Rules or changes proposed

None

6.4.6 On Sight Movement

According to the system requirements defined within the deliverable D5.1, it is expected that an MA with an On Sight mode profile is issued to let a train move towards/through an Unknown Area.

As for this scenario, Low Traffic service needs are considered completely fulfilled by D5.1 and D5.2.

When it comes to Freight applications, a possible On Sight scenario may be given by configuring one or more "Permanent Unknown Areas" over loading/unloading freight yards, such as mentioned in the Trackside Initialisation section ([6.4.1]). In particular, where the boundaries of freight yards are not equipped with TTDs it may be desirable for these permanent areas to be extended over each entrance route to the yard. This is for the purpose of:

- Preventing the RBC from issuing an entry/exit MA to/from yards automatically (i.e. without any authorisation from the person in charge of loading/unloading operations).
- Providing the trains with adequate protection during loading/ unloading operations.

On the other hand, in case a freight yard for loading/unloading operations should be protected by means of a permanent Unknown Area including an entry/exit area, it may be desirable for a train to minimise the time to exit such area, which would imply the possibility to upgrade the exit MA given by deleting the On Sight Profile covering the path within the Unknown Area. Installing TTDs at the boundaries of freight yards could be an alternative solution for the L3 trackside to manage the computation of an On Sight speed profile that should be included within an exit MA. In this case, the On Sight profile might be assigned or not depending on the information provided by TTDs. However, as long as freight yards are under the responsibility of the Dispatcher or of local personnel, it is expected that entering/exiting these areas is not permitted without any appropriate command from them, regardless of the installation of TTDs.

Extra Requirements/ Rules or changes proposed

Extra Requirement:	D5.1 - REQ-TrackStatus-8 and REQ-TrackStatus-11: these system requirements are only focused on sweeping (the Unknown Area they refer is temporary, and is cleaned-up as the train passes or by means of a confirmation by driver or by dispatcher). On the other hand, the same document defines a non-sweepable area as an area created by the Dispatcher to provide protection from permanent

obstacles, therefore an On Sight profile is assumed to be always included within any MA over such areas.

The non-sweepable Unknown Area on which the above scenario is focused is permanent, and such areas are configured for application-specific scopes related to procedures rather than to obstructions. Though mentioning these areas, the deliverable D5.1 does not expand upon any way for permanent Unknown Area to be managed, at least from the point of view of the Movement Authority.

As a consequence of the above observations, the following system requirement is proposed for entry/exit Unknown Areas not equipped with TTDs:

Requirement: Where required by the Dispatcher according to non-harmonised operational rules, and as long as non-harmonised L3 Trackside checks and/or non-harmonised engineering rules allow for an MA within a permanent Unknown Area to be upgraded, it must be possible for the L3 trackside to send the on-board an upgraded MA without On Sight mode profile over this area.

Guidance: This could be achieved by means of an application-specific procedure (involving the Trackside and/or the Dispatcher and/or the Driver) aimed to ensure that the path between the train front and the end of the Unknown Area is clear of obstacles.

Extra Operational Rule

Consider if an Extra Operational Rule is needed to define at least the necessary conditions under which the Dispatcher could authorise an exit MA upgrade (deletion of the OS profile) within a permanent Unknown Area.

Guidance: As an example, necessary conditions might be the following ones:

- The Infrastructure Manger shall have required such feature;
- The Dispatcher shall be provided with safe and real-time information from the Trackside about the last known position of any communicating or non-communicating train within this area.

	− The Dispatcher has not authorised any other operation requiring OS mode within this area, at least as far as the path involved (e.g. the path included in the MA) is concerned. − The Dispatcher has neither activated nor set any (temporary) Unknown Area within this area, at least as far as the path involved (e.g. the path included in the MA) is concerned.
Extra Engineering Rule	Consider if an Extra Engineering Rule is needed to define at least the necessary conditions under which the L3 Trackside could authorise a request of exit MA upgrade from the dispatcher. Guidance: As an example, a necessary condition might be to configure an "exit area" within which this upgrade is applied.

6.4.7 End of Mission

As for this scenario, Low Traffic service needs are considered completely fulfilled by D5.1 and D5.2.

When it comes to freight trains that can be considerably long, it is worth underlying the importance of waiting for TIMS confirmation before performing EoM, according to what is stated in D5.1 - 6.4 "Request of train integrity update".

In Freight applications, it may occur that the train performs a new SoM after moving in SH (or being moved in NP depending on the operational needs) across significant distances within specific areas (e.g. marshalling yards, loading and unloading areas). In such cases, the SoM location of the train may be expected not to intersect the area occupied at the time of its previous EoM, therefore it may be not useful for the L3 Trackside to compare EoM and SoM locations to determine if any "anomalous" movement have occurred since the EoM. On the other hand, storing information such as the NID_ENGINE of both leading and non-leading cabs of each train performing EoM within the above mentioned areas can be useful for more control over these areas (see also Start of Mission, [6.4.2]).

Installing TTDs at the boundaries of freight yards could be an alternative solution for the L3 Trackside to manage cold movements and may help with cleaning up the Unknown Area that had automatically been computed by the L3 Trackside to protect a train performing EoM.

Extra Requirements/ Rules or changes proposed

See Start of Mission, [6.4.2]

6.4.8 Reversing

Reversing Scenario can occur both in "Low Traffic" and in "Freight Lines" applications, for example to manage a permission from the L3 Trackside to move the train backwards a certain distance starting from a defined area (e.g. to evacuate a train from a tunnel). No specific needs are to be pointed out as far as Low Traffic and Freight applications are concerned. However, installing TTDs within a reversing area may help the L3 Trackside detect backwards movements.

Extra Requirements/ Rules or changes proposed

None

6.4.9 Splitting

No specific needs are to be pointed out as far as Low Traffic and Freight applications are concerned. However, installing TTDs within the preconfigured areas where Splitting may be performed could mitigate the impact of remaining Unknown Areas after Splitting is completed.

The need for frequent changes of trainset makes Freight applications typically more involved in this procedure. Freight trains are usually split within yards and stations, mainly in order to shorten the number of wagons of a train, without obtaining two trains from the initial one. However, a fast splitting in the plain line cannot be excluded to allow a banker to be split from a loaded train after providing it with the traction power needed to allow that train to run through a certain area.

Extra Requirements/ Rules or changes proposed

None

6.4.10 Joining

No specific needs are to be pointed out as far as Low Traffic and Freight applications are concerned. However, installing TTDs within the preconfigured areas where Joining may be performed could mitigate the impact of remaining Unknown Areas after Joining is completed.

Analogous to what was described in the Splitting section ([6.4.9]), freight applications are typically more involved in this procedure. Freight joining may consist of either adding new wagons to a train or joining a banker in order to provide the train with more traction power where necessary. This latter case typically occurs when the train is loaded and has to run through a high slope track.

Extra Requirements/ Rules or changes proposed

None

6.4.11 Shunting

Shunting procedures can be performed in temporary or in fixed (permanent) Shunting areas.

As for this scenario, Low Traffic service needs are considered completely fulfilled by D5.1 and D5.2.

Independent of the railway type (Low Traffic or Freight lines), installing TTDs within the preconfigured areas where Shunting may be performed it is not expected to have significant impact on the L3 Trackside performance as long as, according to what is stated within D5.1, shunting Unknown Areas are not expected to be automatically set nor cleaned up by the L3 Trackside.

When it comes to Freight applications, Shunting Procedures are envisaged to be “usual” scenarios (such as loading and unloading operations or changing train composition) that can occur several times per day.

Extra Requirements/ Rules or changes proposed

Modified Requirement:	REQ-SH-1: It is suggested that the guidance of this requirement points out that a Permanent or Temporary Area with track status “unknown” may be used for movements in NP mode as well.

6.4.12 Mixed Traffic

Mixed Traffic scenarios occur in areas where some trains might not be equipped with Train Integrity Monitoring system (TIMS) or not even with ETCS. This could apply during a migration phase, pending TIMS installation, or - especially in Freight Line application - because not all the trains are expected to be equipped or managed by the same Stakeholder.

Whether considering Freight or Low Traffic applications, the above described Mixed Traffic scenario requires TTD and optical signals. Please refer to section 6.2 for a detailed analysis.

Extra Requirements/ Rules or changes proposed

refer to [6.2].

6.4.13 Communication Failure

Communication failure includes an ETCS On-board losing the communication for a short/long period of time and also the management of a radio hole located in a L3 line.

Low Traffic lines might be more often affected by communication failure, since these are often designed against a tight budget and without redundant communications systems. It is not critical for Low Traffic lines to have static radio holes since there is no need for high capacity.

When it comes to Freight trains, a high performance radio communication system should be required. However it may not be avoidable to have failures in communications, if considering that Freight lines may operate across mountainous or desert territories. Therefore, it is particularly recommended that radio holes are clearly identified throughout the line and configured as static radio holes, to be managed according to D5.1 and D5.2.

Static radio holes may be dealt with by installing TTDs so as to have a faster clearing of the line.

Extra Requirements/ Rules or changes proposed

None

6.4.14 Loss of Train Integrity

All railways, including Low Traffic and Freight railways, will want to avoid the impact on capacity caused by loss of train integrity.

Whether for Freight or Low Traffic Trains, the TIMS are expected to be designed so that there is a low probability of failure of the TIMS such that the L3 Trackside interprets train position reports to mean that the train has lost integrity.

Use of fixed consist trains (typical case of passenger train) should improve train integrity reporting, and reduce the risk of loss of train integrity, whereas use of variable consist trains (typical case of freight train) may create an extra challenge to the application of TIMS. TIMS may not be available via the coupling of variable consist trains.

The system will still be designed to react in a safe manner in the event of train integrity failure, whether this is a real failure of train integrity, or a failure of the TIMS.

Both for Low Traffic and Freight lines, a Loss of Train Integrity (whether real or due to TIMS failure) is a degraded scenario that needs to be covered with the requirements and rules addressed in D5.1 and D5.2. However, it is to be noticed that when affecting freight trains, a loss of integrity may imply a more significant unavailability of the path, therefore, installing TTD in some specific areas (for example transition/handover areas, and station entry/exit areas) could be required as a mitigation.

Extra Requirements/ Rules or changes proposed

None

6.4.15 Recovery

A fast recovery is essential for all railways, including Low Traffic and Freight lines, in order to resume normal operation without longer interruption of service.

Recovery is correlated with Communication failure and Loss of Train Integrity (refer to section 6.4.13, 6.4.14, respectively), and therefore what is described within those scenarios is applicable to this one as well.

System Types with TTDs would allow for faster recovery if the train integrity information is unavailable or a failure occurs on the radio communication system.

Extra Requirements/ Rules or changes proposed

None.

6.4.16 Override

Installing TTDs helps both the Dispatcher and the L3 Trackside to detect the presence and the movements of a non-communicating train or of a train with invalid/unknown position, and this also prevents the Dispatcher from making mistakes when managing SR movements, that are even more critical when involving other overlapping Unknown Areas.

In the absence of TTDs, all train movements in SR mode must be protected in compliance with what is stated in D5.1 and D5.2. When it comes to non-communicating trains or trains with an unknown or invalid position, this protection is provided by means of an Unknown Area. In compliance with what is stated in D5.1, this Unknown Area is normally set by the Dispatcher for the purpose, and has a length covering the SR distance to be assigned to the train.

When it comes to Freight applications, it could occur that a movement in SR mode is necessary to let a non-communicating train or a train with invalid/unknown position exit a loading/unloading yard that should have been configured as a permanent Unknown Area, according to what is proposed within scenarios 6.4.1, 6.4.2, 6.4.6 and 6.4.7. In this case, since there is no correlation between the permanent Unknown Area and the one necessary for protecting SR movements, the Dispatcher is expected to set this latter area over the permanent one. In principle, an analogous scenario may also occur for Low Traffic Lines and other types of railway, as long as they have some permanent Unknown Areas configured for whatever other scope. More generally, an Unknown Area to be set for an SR Movement could overlap another one of whatever type (permanent, temporary) that had been set for whatever scope, and this overlap should be allowed, as long as this does not cause unnecessary safe reactions to other vehicles. Therefore, it is worth making the following general considerations about the case of overlap between an Unknown Area to be set for an SR movement and a pre-existing one (for whatever purpose):

- Where the path to be included in the SR distance had already been assigned/reserved to another train, it is expected that the Dispatcher makes sure that the SR procedure has priority, and have stopped any other conflicting movement before setting the SR distance.
- On the other hand, the L3 Trackside might have application-specific means for evaluating if a Dispatcher request for an Unknown Area to be set for an SR movement can be accepted or not, in case this area includes a path that had already been "assigned" to another train within an Authority (path reserved) or by means of a pre-existent Unknown Area for whatever purpose.

The above considerations, originating from this scenario, lead to the general proposal in the following.

Extra Requirements/ Rules or changes proposed

D5.1 - REQ-TrackStatus-15: in compliance with this requirement, a safe reaction shall be applied where an Unknown Area is set that is in conflict with other train movements. However, it would be recommendable to prevent such situation from happening, where possible.

D5.2 - ENG-REC-1: in compliance with this engineering rule, the L3 Trackside may be engineered to require confirmation via the Traffic Management System before extending a Movement Authority into the path of an Unknown Area. However, it may be recommended that the case of Unknown Area to be set over the path of a pre-issued Authority or other Unknown Area is regulated as well.

Extra Requirement:	Consider if an extra requirement is needed for the L3 Trackside to be able to limit the Dispatcher in setting/activating overlapping areas having conflicting operational scope.
Extra Engineering Rule:	Consider if an extra engineering rule is needed for the L3 Trackside to require confirmation via the Traffic Management System before setting or extending an Unknown Area into the path of an Authority (MA, SR Authorisation) or into the path included in a pre-existing Unknown Area.

7 Prototyping activities: result achieved

This section provides a report on the results achieved by the prototyping activities in X2Rail-1 WP5 Tasks 5.7, 5.8, 5.9 and 5.10.

All the prototypes have been aimed to study how the ETCS Level 3 Moving Block Principles defined within X2Rail-1 WP5 could be applied to real railways. For this purpose, four real railway applications (one for each type of railway analysed within this document) have been selected for an ETCS Level 3 Moving Block prototype to be built upon each of them. It has to be specified that project timing has made it necessary that the prototyping activity were started before D5.1 and D5.2 became consolidated. Innotrans 2018 was a reference milestone for the prototypes to be prepared, and therefore the following reports reflect Innotrans constraints as well.

7.1 Task 5.7 – Urban/Suburban Prototype Definition: result achieved

7.1.1 Method

The Urban / Suburban Prototyping in Task 5.7 was performed by building a laboratory demonstration based on a mixture of existing and prototype equipment.

Different scenarios were then run, for example Normal Train Movement, Loss of Train Integrity, Loss of Communications, to see how the system performed.

7.1.2 System Types

The Urban / Suburban Prototyping in Task 5.7 was an implementation for the ETCS Level 3 system type:

- ✓ Full Moving Block, no Trackside Train Detection

The demonstrator was constructed using real data from an area of existing operational infrastructure in the UK: the Bournemouth Mainline between Clapham Junction and Esher station. The line is a busy commuter corridor into central London, with services operating in both stopping and non-stopping patterns. The area modelled is c. 20km in length with four tracks (Up & Down lines both with Fast & Slow). For the purposes of the simulation environment, all gradients were levelled to a value of 0%. Approximately 270 services operate in each direction, every day. The maximum frequency of service currently in operation is 17 trains per hour. The yellow highlight in Figure 4 below shows the area of railway used.

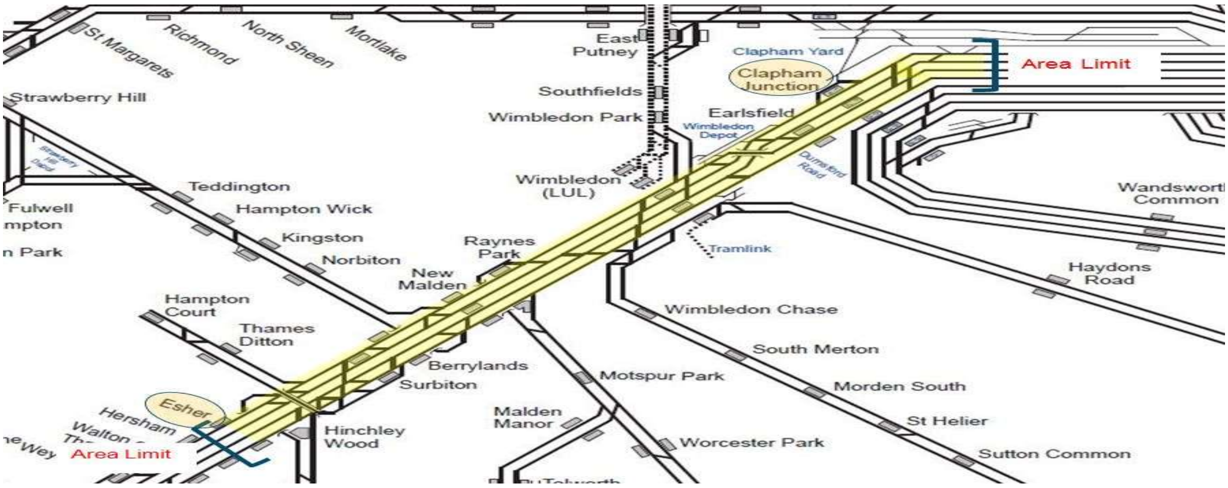

Figure 4 – Area of railway used for Urban/Suburban Prototype

7.1.3 System Architecture

Figure 5 below shows the architecture of the physical prototype equipment:

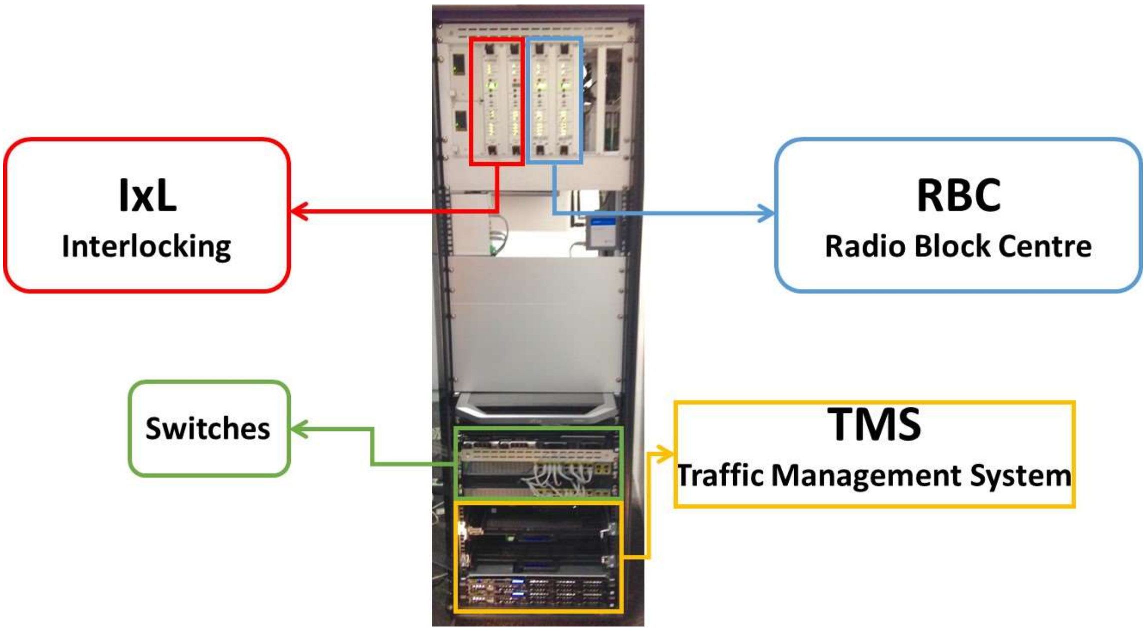

Figure 5 – Architecture of Urban/Suburban Prototype

The prototype system included a PC simulation of the trackside and trains, including the ETCS behaviour. The Interlocking and RBC were operated on target hardware platforms. The system had the functional architecture given in Figure 6.

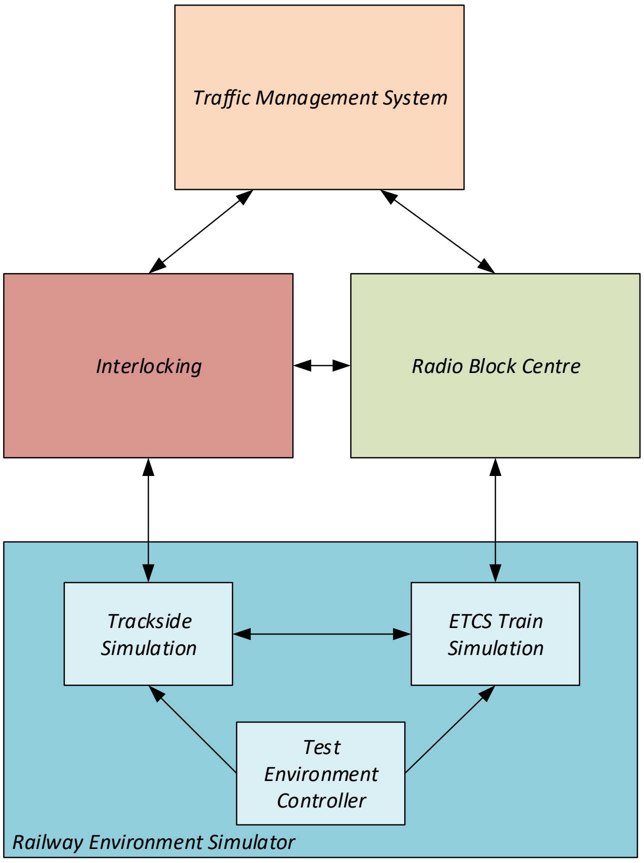

Figure 6 – Architecture for Simulator of Urban/Suburban Traffic Demonstrator

In the Railway Environment Simulator, the Trackside simulation provided the physical railway model (track and distance), along with Points, Balises and Markerboards. The ETCS Train Simulation included the SUBSET-26 behaviour as well as simulation of the TIMS function. The system supported the operation of multiple trains in the layout area.

7.1.4 Scenarios included

The Urban / Suburban Prototyping in Task 5.7 included demonstration of the following operational scenarios:

a) Start of Mission
b) Normal Train Movement, with a number of trains moving through the network
c) Rerouting of trains around a failed train
d) Simulation of loss of train integrity
e) Simulation of loss of communications (of a single train)
f) End of Mission

7.1.5 Summary of Results

The Urban / Suburban Prototyping in Task 5.7 showed:

a) Proof of concept of an ETCS Level 3 Moving Block system engineered for an Urban / Suburban railway, realising the benefits of increased capacity with significantly reduced trackside infrastructure
b) Simulation of some degraded mode scenarios (Loss of Integrity, Loss of Communications, Rerouting around a failed train)
c) Initial investigation of the engineering required to convert from conventional fixed block signalled railway to ETCS Level 3 Moving Block concept
d) Investigation of the potential increase in train capacity.
   The current railway has 17 trains per hour at morning peak time, in one direction.
   Tests using the prototype demonstrated that the number of trains per hour running through this section could be significantly increased. It should be noted though that the area of railway simulated was a section of plain 4 track. A thorough capacity assessment would need to take into account the wider network area, considering constraints such as terminus stations and major junctions.

7.2 Task 5.8 – Overlay Prototype Definition: result achieved

7.2.1 Method

The Level 3 Overlay Prototyping in Task 5.8 was mainly the design of a solution concept built on our experience from Level 2 Overlay systems and pure Level 3 systems. Some tests have been done in a development environment to verify the concept of ETCS Level 3 as overlay on a conventional signalling system. There have also been some initial tests in a virtual machine with product software and simulated hardware.

The overlay Prototyping in Task 5.8 included demonstration of the following:

a) Verify the RBC internal interface between Generic Product and Generic Application,
b) Data/information transfer over the interface between Interlocking and RBC,
c) A solution roleplay against selected WP5 scenarios to verify the solution.

7.2.2 System Types

The Overlay Prototyping in Task 5.8 was an implementation for the ETCS Level 3 system type:

- ✓ Fixed Virtual Block with Trackside Train Detection

This was implemented as an overlay on a conventional signalling system with optical signals.

However, depending on operational needs, an ETCS Level 3 Overlay system may also be implemented with Full Moving Block (with TTD) or a mix of both.

The initial tests were performed on the simple site outlined below showing the RBC perspective, i.e. the figure only intendeds to show the track layout and available routes. The marker boards indicate the location of optical signals and each route was split in two virtual sections even if there was only one TTD section.

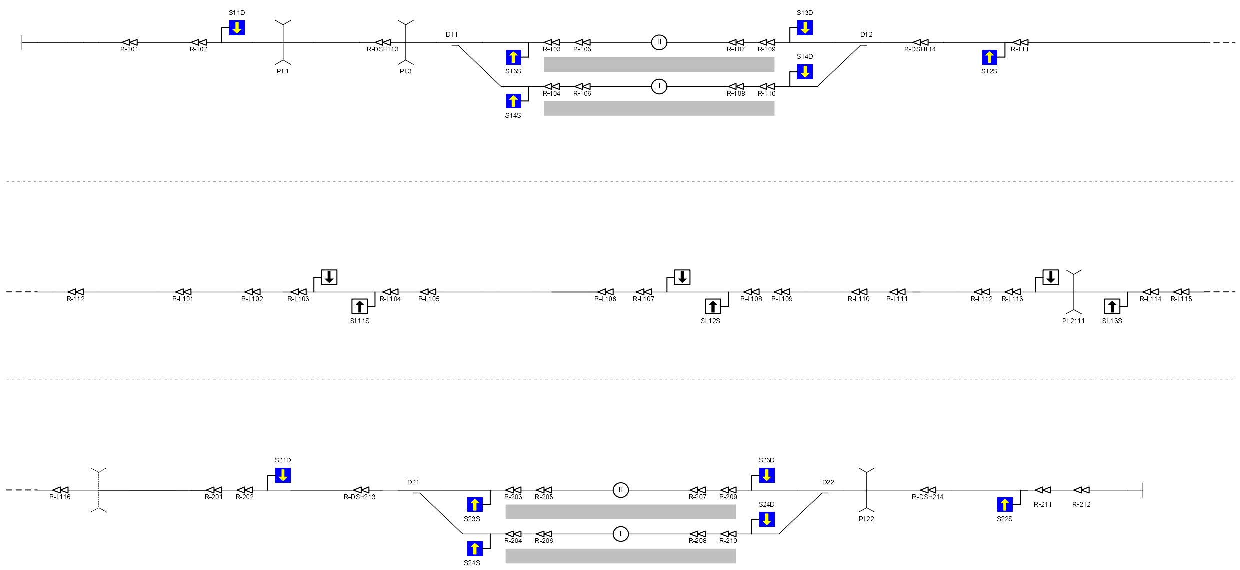

Figure 7 – Simple track layout for initial tests of an ETCS L3 Overlay system

7.2.3 System Architecture

The following figure shows the architecture of the prototype equipment foreseen for the lab tests:

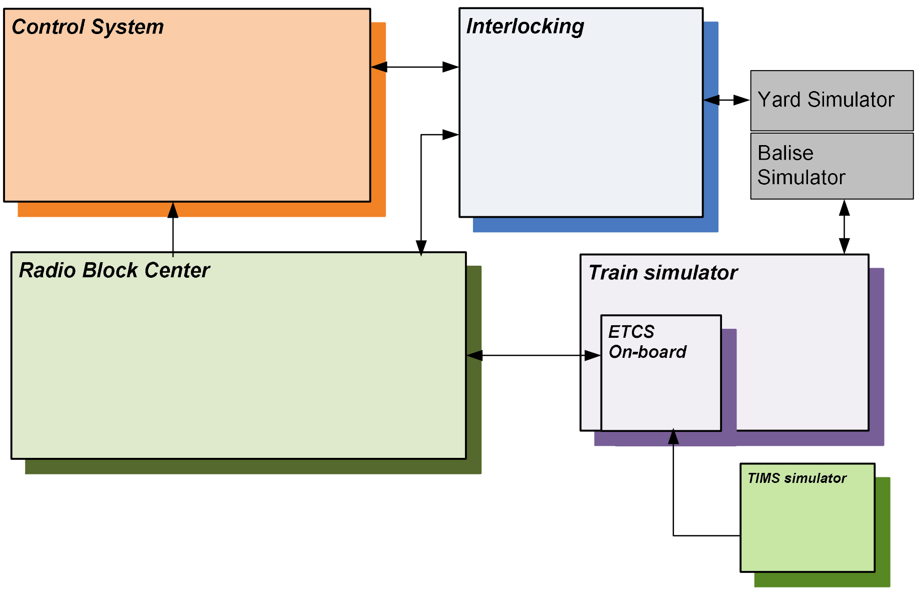

Figure 8 – Architecture of the prototype equipment for lab tests of an ETCS L3 Overlay system

The picture below shows the equipment hosting the virtual machine simulating this architecture.

The components used in the initial test environment are:

- a simplified Control System, configured with a Test Yard;
- an RBC emulator, configured with a Test Yard;
- an Interlocking emulator, configured with a Test Yard;
- a Yard simulator for the field elements in the Test Yard;
- a Balise simulator for the Balise telegrams;
- a Train simulator with an ETCS On-board emulator;
- a TIMS simulator for train integrity information.

The Control System is the interface towards the dispatcher displaying the current yard status and relevant information about trains. It also interacts with the emulated RBC and Interlocking.

The RBC emulator performs the foreseen ETCS Level 3 Overlay functions by interacting with the Train simulator, the emulated Interlocking and the Control System.

The Interlocking emulator performs the normal interlocking functions by interacting with the Yard simulator, the emulated RBC and the Control System.

The simulated environment consists of the Yard simulator, the Balise simulator, a Train simulator and a TIMS simulator. The Train simulator is used to simulate the ETCS trains, either with a real or an emulated ETCS On-board system. Non-ETCS trains are simulated via the Yard simulator by sequentially occupying TTD sections.

The data for the components in the test environment can by generated by a tool or manually.

The example data has been mostly from internal test sites. There have also been some tests in a test environment with simulated and emulated components for a simple real site having added fixed virtual block sections.

When executing the initial tests, the system components had been modified as follows:

RBC

Added functionality to handle fixed virtual blocks and safe train length; added a state machine to handle virtual sections; adaption of the interface to the Interlocking.

Interlocking

Added interface to RBC and modified the route release functionality, but no change to signal aspects.

Control System

Added new commands and indications but very limited visual changes.

TIMS

Continuous indication of train integrity confirmed.

Obviously, this is still far from the foreseen final ETCS Level 3 Overlay system.

7.2.4 Scenarios included

In a test environment the following scenarios have been tested:

a) Start of Mission – train registration with the RBC
b) Start of Mission request MA – first authorisation FS/OS/SR depending on position status
c) Normal Train Movement – verifying the behaviour of the state machine for virtual blocks
d) End of Mission – end of test sequence

7.2.5 Summary of Results

The Overlay Prototyping in Task 5.8 showed:

a) We have concluded that the conceptual design of an ETCS Level 3 Overlay system works and are prepared for the implementation of a complete lab system in the next phase.
b) We have concluded that the Interlocking used in an ETCS Level 3 Overlay System must be analysed regarding route setting and releasing.
c) We have concluded that with ETCS Level 3 as an overlay on a conventional system with optical signals, the project must decide if there is need for a specific signal aspect when the RBC authorises a train into an already occupied route.

7.3 Task 5.9 – High Speed Lines Prototype Definition: result achieved

7.3.1 Method

To prove the feasibility of an ETCS Level 3 Moving Block system with FVB and TTD a prototype based on existing Thales products was developed for a given HSL. This section starts with the description of the investigated key considerations/issues, continues with an overview of the selected HSL and system architecture. The section ends with a description of the executed scenarios.

The prototype development was driven by the following considerations/issues:

1) What is the impact of an ETCS Level 3 Moving Block system with FVB and TTD on an existing HSL system?
2) To analyse testing of ETCS Level 3 Moving Block systems on non-safety related HW.
3) To provide a system to investigate the possible performance improvements in terms of capacity.
4) To test relevant ETCS Level 3 Moving Block scenarios.

7.3.2 System Types

The HSL Paris – Strasbourg was selected for the prototype. This line is equipped with ETCS L2 (B2) and TVM and is used by passenger trains either 200 m or 400 m long. Non-passenger trains are used for maintenance reasons. The current timetable allows one train every 5 minutes each direction. There are no radio holes and no non-stopping areas.

The SNCF interest in L3 is to increase capacity in peak hours (every 3 minutes), with trains fitted with TIMS without installing additional TTD. In non-peak hours trains not fitted with TIMS (e.g. old TGV) could use the line.

In order to investigate the impact of ETCS Level 3 and possible gains in capacity as indicated above a sample area from the HSL was selected. This sample area starts from the station Champagne-Ardenne-TGV and covers 50 km of double track westwards including a transition from L-NTC to L3 and L3 to L-NTC at each end of the area. There are no optical signals except at the level borders.

Figure 9 – HSL prototype – sample area

Taking this sample schema as a starting the track layout was rearranged for the ETCS Level 3 Moving Block prototype in the following way:

- the TTD in the station, point areas and borders were retained,
- the open lines were reconfigured with only one TTD section,
- the main tracks in stations were also sub-divided in FVBs,
- each TTD section of the open line was sub-divided in FVB of 400m length.

In total 163 FVBs were engineered.

7.3.3 System Architecture

The following figure shows the architecture of the prototype.

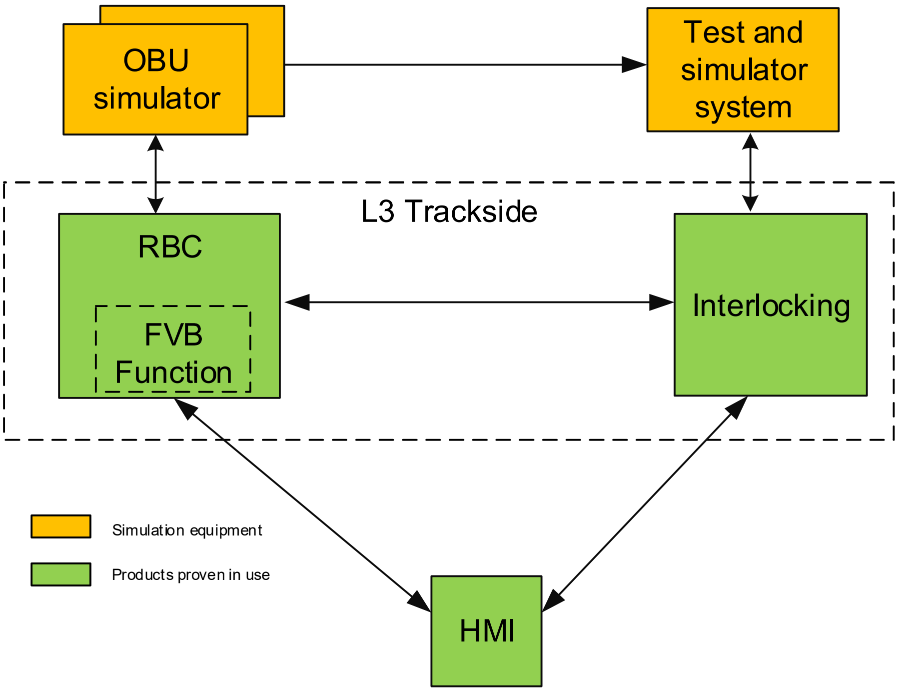

Figure 10 – HSL prototype – architecture

The prototype consists of an Interlocking, an RBC (including the FVB function), an HMI, and an OBU simulator and a test and simulation system.

The Interlocking handles the central interlocking functions like route setting, route checking, route protection, flank protection and route release.

The HMI maintains and displays the track layout, field equipment and train information. The functionality incudes safety and also non-safety related operations for the dispatcher like route setting, entering Temporary Speed Restrictions etc.

The RBC covers ETCS train control system functions and procedures like Start of Mission, End of Mission, Shunting, Override, On Sight, and Level Transition. The FVB function as part of the RBC manages the FVB and TTD track state transitions based on information received from the train and interlocking. RBC grants the MA to borders of the FVB considering their status

The simulation environment consists of the OBU simulator, trackside simulator and a platform to integrate the different products. The OBU simulator is an implementation of SUBSET-026 on-board functions which was extended to handle train integrity information. It allows to instantiate more than 10 OBUs if deemed necessary for the test runs and also includes an automatic mode to support capacity tests. The trackside simulator simulates field elements like points, TTDs and by interfacing with the OBU makes it possible for example to plot train movements. Not shown in the figure is the data preparation tool chain which was adapted to support engineering of FVB for the RBC and HMI.

In order to execute the ETCS Level 3 Moving Block test scenarios, the existing system was extended in the following way:

Interlocking system

- The RBC-Interlocking interface was augmented in order to allow Interlocking to send the TTD status to the RBC.
- At the HMI aspects of the virtual signals protecting a TTD are indicated to the dispatcher. In case more than one train enters a TTD section the protecting signal would indicate – if unchanged - a stop aspect. This is confusing to the dispatcher. Therefore, for the prototype it was decided to mask this signal, when a second train follows.
- The Interlocking was adapted to permit more than one L3 train to enter the TTD section.

HMI

For the HMI it was decided to display the FVB status in addition to the indication of the TTD status in order to better analyse the system behaviour. This increases the amount of information displayed to the dispatcher, so this decision needs to be revisited for the subsequent development. In total more than 163 FVBs were engineered which raised the issue how to visualise this amount of FVBs on the screen in such a way that there is enough space to indicate the train running number. For the prototype it was decided to restrict the length of the train running number. In order to allow the user to quickly identify a degraded situation like loss of train integrity or communication it was decided to let the train running number blink. More detailed information can be obtained by the dispatcher by clicking on the blinking train running number.

RBC and FVB

FVB function was encapsulated in a separate RBC component with the main function being to manage the FVB states (Unknown, Clear, Occupied) based on train position reports and TTD information received from the Interlocking system. Additionally, a function was implemented to automatically clear Unknown Areas by sweeping movements.

7.3.4 Scenarios included

To prove the L3 system behaviour, the scenarios Initialisation, Start of Mission, Normal train movement, Loss of train Integrity, Loss of communication and reestablishment, End of Mission and Sweeping were executed. In following the main steps of the executed scenarios are summarized.

Initialisation

For the Initialisation scenario the trackside system utilises the TTD information to clear the FVB status.

Start of Mission

When the train is created on a TTD by the simulation system the TTD becomes occupied which in turn provokes the transition to the state Unknown for the affected FVBs. After the train receives a SR authorisation it starts moving and receives an FS MA once the L3 Trackside can unambiguously locate the train. After the train has left the start-up area the FVB status can be cleared based on the TTD information.

Normal train Movement

For this scenario the Start of Train scenario was executed for two trains in the Champagne Station. The second train starts to follow the first train after 3 minutes to investigate if the desired capacity can be reached. Both trains were running at 300 km/h. The route allowing the second train to enter the block was set manually. First test runs showed that the second train could follow the first train at 300 km/h thus proving the required capacity improvement.

Loss of train Integrity

This scenario is very similar to the normal train movement with the exception that for the first train the train integrity confirmation was suppressed with the consequence that 1) the affected FVB could not be cleared because of the missing train integrity information and 2) the MA of the following train could not be extended. Once the train integrity information was available again the L3 Trackside could clear the FVB and the MA of the following train was extended.

Loss of communications

This scenario is very similar to the normal train movement with the exception that for the first train the safe connection was interrupted with the consequence that the state of the affected FVBs changes to Unknown after a period of time (mute timer). Once the communication was “switched” back the L3 Trackside could clear the FVB and the MA of the following train was extended.

End of Mission

A train performed an End of Mission with the result that the states of the affected FVBs changed to the state Unknown.

Sweeping

The scenario for loss of communication was repeated without switching back the communication thus resulting in the FVB being in the state Unknown. For the following train an OS MA is granted allowing sweeping movements thus clearing the FVB.

7.3.5 Summary of Results

The High Speed Lines Prototyping in Task 5.9 showed:

a) An ETCS Level 3 Moving Block system using proven products with FVB and TTD demonstrating normal operation and degraded mode scenarios based on the deliverables D5.1 and D5.2.
b) Execution of test scenarios indicates the feasibility of 3 minutes headway.
c) For an FVB with TTD system type the arrangement of information on the HMI represents a challenge which must be carefully analysed in order to avoid increasing the workload on the dispatcher compared to Level 2.

7.4 Task 5.10 – Low Traffic and Freight Prototype Definition: result achieved

The present section is a report about the state of the art of the Low Traffic and/or Freight prototype activity carried out within X2Rail-1.

7.4.1 Method

The Prototype developed consists of a software model realised with a proprietary tool. This choice is to be considered as the first step towards the realisation of a laboratory prototype. The model implemented emulates the behaviour of the specific L3-based trackside system type that has been considered the best one for freight/Low traffic applications, such as expanded upon in the following.

The prototype development was driven by the following considerations/issues:

1) How a Fixed Virtual Block system without TTDs can deal with the main issues affecting Low Traffic and Freight lines?
2) What is the benefit of a Fixed Virtual Block system without TTDs for a Low Traffic or Freight system
3) To provide a way to investigate the possible performance improvements in terms of capacity and cost reduction, by emulating some relevant ETCS Level 3 Moving Block scenarios.

7.4.2 System Types

The trackside system modelled is a Moving Block with Fixed Virtual Block system. The choice of this specific configuration is due to the following considerations:

- Both Low Traffic and Freight services may achieve the maximum capacity possible according to their characteristics without requiring Full Moving Block, since an ETCS Level 3 Moving Block with Fixed Virtual Block system can be properly engineered to provide the same capacity of a Full Moving Block system.
- Especially for freight railways, FVBs may also be associated with in-field markers, that may be necessary to define the boundaries of some specific areas.

Another characteristic of the MB-based system type established for the demonstrator concerns the use of TTDs. The system modelled has no TTDs, since they are considered unnecessary according to the following choices:

- The model implements an ETCS L3 only area (no overlay has been considered);

- The environment modelled is the main line between two adjacent stations, which makes it reasonable to assume that no in-yard manoeuvres involving cold movements are carried on. However, a single axle counter between these two stations has been foreseen.
- The environment modelled reflects a Low Traffic Line (as specified in the following), which makes it reasonable to assume that TTDs are undesirable in order to reduce infrastructure costs.

As for the specific trackside application modelled, the ERTMS L2-based Haparanda Line was selected for the prototype. The Haparanda Line (Swedish Haparandabanan) is a 165-kilometer long railway line between Boden and Haparanda in Sweden.

Figure 11 – Extension of Haparanda Line

Including a 42 km cut-off between Kalix and Haparanda opened in December 2012, the line from Boden has been electrified at 15 kV 16·7 Hz and resignalled with EU assistance to increase capacity for cross-border freight traffic. The portion of line from Kalix to Karlsborg is considered part of Haparanda Line as well, but is not electrified. This portion of line leads to the port of Karlsborg and is only operated by freight trains. For this purpose, this area is configured as a Permanent Shunting Area.

Main characteristics are:

- Single track
- 9 stations
- 9 level crossings
- Estimated about 16 trains/day
- Mixed traffic (passenger and freight)

The objective of this prototype has been to perform a preliminary study of how Moving Block Principles can be applied to a line with such characteristics. In particular, the following aspects have been investigated:

- how Fixed Virtual Blocks (FVBs) should be engineered to achieve increased capacity over this line
- how level crossings could be managed in the absence of TTDs.

For this purpose, the portion of line between the stations Boden and Niemisel has been selected.

This portion includes a level crossing. The corresponding part of TrafikVerket's Haparanda Scheme Plan has been redesigned by applying the following changes:

- Both open line and stations have been engineered with FVBs (typically more than one FVB over each former TTD section). As a first step, they have all been engineered with the same length except the one including the level crossing
- The ending marker of each FVB can be an End of Authority
- TTDs in the stations have been retained
- The open line has been reconfigured with only one TTD section (axle counter).

7.4.3 System Architecture

The software model implemented is based on a Hitachi Rail STS proprietary application running on a personal computer and based on scripts emulating the L3 trackside behaviour following configured dispatcher commands and configured messages from an ETCS on-board.

7.4.4 Scenarios included

To prove the L3 system behaviour, the scenarios Start of Mission, Normal train movement and End of Mission were executed.

In all scenarios, the portion of track that the L3 Trackside displays as Unknown or Occupied by the train includes the CRE of this latter. The length of this portion of track is a multiple of the length of an FVB. Both the physical length of the train and the related CRE are configurable. The CRE has been configured as 17% train length (this value indicates a train integrity refresh within 5 seconds, considering a train speed of 120 km/h).

In the following the main steps of the executed scenarios are summarized:

<u>Start of Mission</u>

a train performs SoM in the exit zone of Boden station. The state of the track is initially Clear, and transitions to Unknown as soon as the connection between the train and the L3 Trackside is established. The reported train position is valid, Train Data has been acknowledged by the L3 Trackside and integrity confirmed information is received from the train. The state of the track transitions to occupied. The L3 trackside receives a MA Request message and computes the MA available. Once computed, the path of the MA become Reserved. The whole path between Boden and Niemisel is detected as available, but, according to Haparanda specific requirements, the End of Authority is computed at the start location of a level crossing located between Boden and Niemisel. The train receives the MA message and starts moving towards the level crossing starting location.

Normal Train Movement

As soon as a few FVBs of the line become Clear in rear of the moving train (the FVBs corresponding to the train occupation change their status as the train moves), a second train performs SoM within Boden station and requests the L3 Trackside to issue an MA in the same direction as the first train. The L3 Trackside computes, reserves and sends this train an MA up to the end of the last clear FVB in rear of the FVB occupied by the CRE of the first train. The second train starts moving at the same speed of the first one. In the meanwhile, the L3 Trackside assigns an extended MA (up to Niemisel) to the first train and monitors its passage over the level crossing.

End of Mission

The first train arrives at Niemisel station and performs EoM. The L3 Trackside receives the End of Mission message The L3 Trackside requests the on-board to disconnect, and the track status of the FVBs on which the train is localised transitions from Occupied to Unknown.

7.4.5 Summary of Results

Each scenario has been emulated for each possible change of the preconditions affecting the length of the train and the length of the FVBs. In this way, it has been proved that:

a) The more the Movement Authority increments become frequent (due to shorter FVB or shorter Train Integrity refresh period and/or shorter train length) the more a fixed virtual block system allows to achieve a reduced headway. However, it is worth noticing that a real L3 trackside system shall prevent the train from being continuously issued with updated Movement Authorities.

Other computed exercises have been:

b) How to engineer the FVBs in the area of a level crossing. Application-specific requirements concerning the definition of distance parameters from the centre of the level crossing have led the level crossing to be included within one FVB having application-specific length.

c) How to manage opening of the level crossing after the train has passed it. If assuming that no degraded condition affects the path and/or train integrity information, it appears reasonable that the L3 trackside regards the area including the level crossing as clear as soon as the FVB including the level crossing transitions to clear (i.e. the train has passed it with its CRE). However, degraded cases such as loss of train integrity information may require a sweeping procedure. Installing TTDs at the boundaries of the FVB including a level crossing could be taken into account.

As mentioned in Method section [7.4.1], the software-modelling activity carried out at this stage is to be considered as the earlier step towards the laboratory realisation of a Low Traffic/Freight prototype. Therefore, the next step will be the implementation of the L3 trackside software based on the current model in the context of X2Rail-3.

8 Conclusions

According to the X2Rail-1 Grant Agreement, four types of railway have been analysed and a specific type of MB-based system has been associated with each one, based on the target of each application in terms of achievable performance.

With regard to the application analysis (refer to section 6 Application Analysis) carried out, the final association has been the following one:

Railway Type	Associated ETCS Level 3System Type
Urban/Suburban Railways	Full Moving Block without TTDs
Overlay Systems	Fixed Virtual Blocks with TTDs
High Speed Lines	Fixed Virtual Blocks with TTDs
Low Traffic/Freight lines	Fixed Virtual Blocks without TTDs

Figure 12 - Association between railway types and Moving Block System Types

From this initial analysis carried out, the Working Group have identified that the 4 railway types may not always be an accurate representation of real applications. As such, it is proposed that for X2RAIL-3 WP4 Low Traffic and Freight are considered separately and that a category of mixed (Freight and Passenger) traffic is to be analysed.

As far as extra requirements and rules are concerned, some have been identified, in particular within:

a) Urban/suburban applications
b) Overlay System applications
c) Low Traffic and Freight lines

Therefore, future work within X2Rail-3 is expected to take into account these accomplishments.

The following potential updates to D5.1/D5.2 will be addressed in X2RAIL-3:

Section	Additional requirements or rules
6.1.1	Possible need for a new requirement regarding the length of time for which it is valid to use stored data when performing initialisation.

Section	Additional requirements or rules
	Possible modification of REQ-TrackInit-3
6.1.5	Possible need for an extra handover requirement to manage more than one handing over train at any time.
6.1.14	Possible need for an extra operational rule to define how to deal with trains without a functional TIMS.
6.1.16	Possible need for an extra engineering rule to define a minimum distance between reference assets for when moving trains in Staff Responsible mode.
6.2.16	Possible need for an extra operational rule when several trains need to use Override in the same route or block section.
6.4.1	Possible modification of requirement OPE-TrackInit-4
6.4.2	Possible modification of requirements REQ-StartTrain-5, REQ-StartTrain-6, and REQ-StartTrain-7. Possible extra requirement to handle freight area entry/exit permission in a safe way and impacting Start of Mission.
6.4.6	Possible extra requirement to speed up exit from a freight area. Possible extra operational rule correlated to the extra requirement proposed. Possible extra engineering rule correlated to the requirement proposed.
6.4.7	Possible extra requirement to handle freight area entry/exit permission in a safe way and impacting End of Mission.
6.4.11	Possible modification of requirement REQ-SH-01
6.4.16	Possible extra requirement for the L3 Trackside to manage setting/activation of overlapping Unknown Areas in a safe way. Possible extra engineering rule for the L3 Trackside to be engineered to manage setting/activation of overlapping Unknown Areas in a safe way.

With regard to the prototypes described within section 7 Prototyping activities: result achieved, it is possible to draw the following conclusions on what has been learnt from their implementation at this stage:

Regardless of the method, the Moving Block System type and the specific application considered, it has been proved that the design of an ETCS Level 3 Moving Block system implementing the concepts defined within D5.1 and D5.2 works, which means that:

- It is feasible to convert an existing railway application from conventional fixed block signalled railway to Moving Block concept;
- Besides reducing costs, encouraging results have come out from investigating the potential increase in train capacity;
- Prototypes can be considered ready for further development steps within X2Rail-3.

Nevertheless, some aspects related to the use of FVBs and/or TTDs need to be explored deeper:

- A Moving Block system with FVBs may provide the same capacity of a Full Moving Block system, however it is worth pointing out that engineering and managing FVBs may be challenging, if considering that Scheme Plans and functional/operational needs of real railways may impose several constraints whether on their design and their release. TTDs, points and level crossings are a few examples of “constraints” from the Scheme Plan, and they are typically managed according to application-specific rules as well.
- The Interlocking used in a Level 3 Overlay System needs to be further analysed regarding route setting and releasing.
- The arrangement of information on the HMI represents a challenge which must be carefully analysed in order to avoid increasing the workload on the dispatcher compared to Level 2.

It is worth noticing that the above analysed challenging aspects has meant that some mitigations may need to be applied to the Moving Block System types defined within D5.1 and ideally associated with the four Railway types under analysis (Figure 12). As an example, Low Traffic and Freight prototype has considered to use some TTDs within stations, and an axle counter between each pair of adjacent stations.

This leads to the general conclusion that the four associations shown in Figure 12 represent guidance, but their application should not be considered rigid at least at this prototyping stage, for the following reasons:

1) They represent an achievable target, but their practical realisation may need one or more intermediate steps, depending on several factors such as complexity of the specific application or a migration strategy to be implemented.

2) They are based on some assumptions, such as Grant Agreement statements and/or average performance needs based on the average characteristics of each railway type. Where the target performance of a specific railway type does not match the average ones here pointed out, a different or even a “mixed” moving block system (for example, having some TTDs or in-field virtual signals only at some locations, or a Full Moving Block system having some Fixed Virtual Blocks just as a protection of some specific locations on the line) can be designed ad-hoc.

9 References

[BL3 R2] TSI Commission regulation (EU) 2016/919, of 27 May 2016, on the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union
Set of specifications # 3 (ETCS baseline 3 and GSM-R baseline 1)

This set of specifications is colloquially referred to as "Baseline 3 Release 2"

[CR940] Opinion ERA/OPI/2017-2 (https://www.era.europa.eu/sites/default/files/library/docs/opinion-advice/opinion_era-opi-2017-2_en.pdf)

This opinion contains Change Request 940, which covers the reporting of Train Integrity.

[CSM-RA] Commission implementing Regulation (EU) 2015/1136 of 13 July 2015 amending implementing Regulation (EU) No 402/2013 on the common safety method for risk evaluation and assessment

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This is the process for changing the documents which make up the ETCS Baselines.

[EU_Direct] DIRECTIVE (EU) 2016/797 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 May 2016 on the interoperability of the rail system within the European Union (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32016L0797)

[Emery] "Headways on High Speed Lines", D. Emery, École Polytechnique Fédérale de Lausanne, World Congress on Railway Research 2011 (http://www.railway-research.org/IMG/pdf/f2_emery_daniel.pdf).

[D2.1] X2Rail-1 Deliverable D2.1 "Reference Architecture"

This was developed by X2Rail-1 WP2.

[GLO] X2Rail-1 Integrated Glossary.

[D5.1] X2Rail-1 Deliverable D5.1 "Moving Block System Specifications".

[D5.2] X2Rail-1 Deliverable D5.2 “Moving Block Operational and Engineering Rules”.

[D5.3] X2Rail-1 Deliverable D5.3 “Moving Block Preliminary Safety Analysis”.

[D4.1] X2Rail-2 Deliverable D4.1 “Train Integrity Concept and Functional Requirements”.

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This is the principles document describing the behaviour and state machine of the Hybrid Level 3 concept.

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[15560] ETCS Driver Machine Interface ERA_ERTMS_015560, V3.6.0, 13/05/2016

[Article10-2017] ERA Technical Opinion ERA/OPI/2017-2