EU-RAIL FRMCS EUROPEAN DEPLOYMENT GROUP

Report on the FRMCS Migration Scenarios 2025

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1 Introduction

This document is the first report from working group 3 focusing on migration scenarios answering to the remit coming from ERJU high level deployment group.

This report is based on a system-based approach focusing initially on technical and legal layer. This report also proposes an approach that could address various technical topics including ETCS versions, DAC or ATO.

1.1 History of the scope

In 2024 the High-Level Deployment Group of EURAIL decided to create the FRMCS Deployment subgroup for considering the broader questions of deployment and implementation of FRMCS. The FRMCS deployment subgroup is working on 10 remits[1].

This document is corresponding to remit number 7 with the following content:

« Define possible migration scenarios, in order to define the conditions to deploy FRMCS as soon as possible, as part of the ERTMS system (i.e. ETCS, RMR (GSM-R + FRMCS) including voice communication and ATO). The migration scenarios should consider the number of vehicles on the different countries to be equipped and will consider also other technical topics such as DAC or ATO. Objective is to understand challenges and identify potential synergies. Also, identifying the funding and financing possible schemes for the deployment in the different migration scenarios. A minimum of a two-layer basis/approach (workstreams) should be considered: a. the technical layer and b. the legal, economical and political layer. The number of migration scenarios need to cover the relevant part of the potential solution. Different starting positions in different countries and with different technologies (e.g. interface to ETCS versions) has to be taken into account. «

1.2 Methodology

This report is based on the FRMCS working group 3 (WG3) activities and knowledge sharing between the FRMCS deployment subgroup members. In addition to that an FRMCS questionnaire was created to collect information widely from the sector. The

[1] 20250213_HL-DpG-FRMCS-subgroup-remits-Decision-2025-05.pdf

questionnaire was sent to railway sector stakeholders and a separate report[2] was generated by the FRMCS subgroup management team.

The FRMCS questionnaire is used as input to the technical layer of the migration scenarios. The information is also used as an input for creating the guideline on a choice of technologies and migration scenarios, together with input from working group 1 report[3] about FRMCS implementation plan based on National Implementation Plans (NIP).

The ERJU System Pillar Report[4] is also giving the guidelines of which FRMCS functionalities are expected to be used at the first phase of the FRMCS deployment.

The legal layer is described based on ERA legal framework[5] and standardization activities based on C(2024)2466 – Standardization request M/603 to European Telecommunications Standards Institute as regards the definition of system specification requirements for the Future Railway Mobile Communication System in support of Directive (EU) 2016/797.[6]

NOTE: The economical layer and political layer will be analyzed (during 2026) based on the expectations from the FRMCS questionnaire report as well as the cost analysis from working group 2 remit report.

NOTE: Conditions for FRMCS deployment will be described (during 2026) with the help of a value chain to avoid bottlenecks from the system's perspective.

[2] https://rail-research.europa.eu/wp-content/uploads/2025/10/20250909_FRMCS-Deployment-Questionnaire-2025-Report_V1.0.pdf
[3] https://rail-research.europa.eu/wp-content/uploads/2025/10/WG1-Status-Report-V-1.0.pdf
[4] https://rail-research.europa.eu/wp-content/uploads/2025/10/20251024-FRMCS-V2-report-clean.pdf
[5] Control Command and Signalling TSI | European Union Agency for Railways
[6] eNorm Platform

2 Key Principles and elements

For the introduction of FRMCS, the defined subsystems based on CCS TSI (EU) 2023/1695 are:

(1) Trackside control-command and signalling subsystem

(2) On-board control-command and signalling subsystem

For the introduction of FRMCS, the key elements as actors defined in ETSI TR 103 791 Terminology for FRMCS specifications[7] are:

*« **FRMCS operator** railway infrastructure manager, or an operator delegated by a railway infrastructure manager, who manages the FRMCS transport domain and/or FRMCS service domain for which FRMCS policies and FRMCS user subscriptions are applicable.*

NOTE: Term derived from UIC FRMCS SRS [i.1].

***FRMCS user** human or machine making use of communication services and/or complementary services.*

***IM application** an application that is either interoperable or non-interoperable and associated to an Infrastructure Manager (IM).*
NOTE: Infrastructure manager is defined in point 2 of Article 3 in Directive 2012/34/EU [i.5].

***RU application** an application that is either Interoperable or Non-interoperable and associated to a Railway Undertaking (RU).*
NOTE: Railway undertaking is defined in point 1 of Article 3 of [i.5]. «

7 https://www.etsi.org/deliver/etsi_tr/103700_103799/103791/01.01.01_60/tr_103791v010101p.pdf

The following diagram illustrates the previously identified key elements of FRMCS in a railway system context illustrating key elements together with other items in terms of maintenance as part of an ecosystem.

The purpose of the diagram is to identify common definitions when considering information and communication technology for FRMCS to:

a) Support IM implementers as FRMCS operator in risk assessment for FRMCS applications and communication services towards subscription policies and network verification.
b) Support RU implementers and lessors in risk assessment for railway applications towards decisions in relation to FRMCS on-board their vehicles.
c) Support enhancements to harmonisation of operational rules and their procedures with regards to definition and maintenance of such rules and procedures
d) Provide a generic and system based approach towards railway RAMS, performance analysis and the railway business process described in 2.1

NOTE: The diagram also considers Subset-150, issue 2.0.1[8] that, among other topics, indicates a potential restructuring of the interoperability constituent « ETCS on-board » towards the next version of CCS TSI.

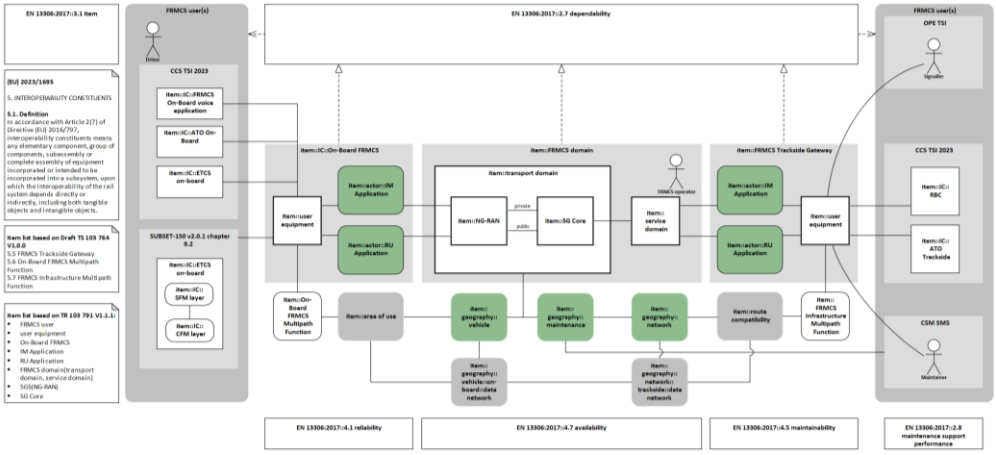


Figure 2-1 Railway system context for FRMCS applications without GSM-R

[8] https://www.ertms.net/wp-content/uploads/2025/11/SUBSET-150.pdf

2.1 Railway business process

The following diagram takes a systematic approach towards introduction of FRMCS. The diagram is inspired by (EU) 2012/34[9], CCS TSI 2023[10] and EN 50126-1[11]. The diagram outlines an iterative and stepwise approach towards the introduction of FRMCS as a class A radio system for ERTMS.

The purpose of the diagram and the railway business process it describes is to provide guidance for infrastructure managers and railway undertakings on preliminary planning steps that can be taken based on their respective expressed future operational needs in anticipation of the next CCS TSI (expected 2028).

NOTE: Apart from use in the context of FRMCS introduction for the next CCS TSI, this model may over time prove itself and evolve to be relevant and have a value as one item of a safety management system following (EU) 2018/762[12]. Any such use is subject to company policies which may involve national authorities.

The diagram is further described and explained in section 2.1.1.1

[9] Directive 2012/34/EU of the European Parliament and of the Council of 21 November 2012 establishing a single European railway area
[10] Control Command and Signaling TSI | European Union Agency for Railways
[11] Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Generic RAMS Process
[12] Commission Delegated Regulation (EU) 2018/762 of 8 March 2018 establishing common safety methods on safety management system requirements pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council

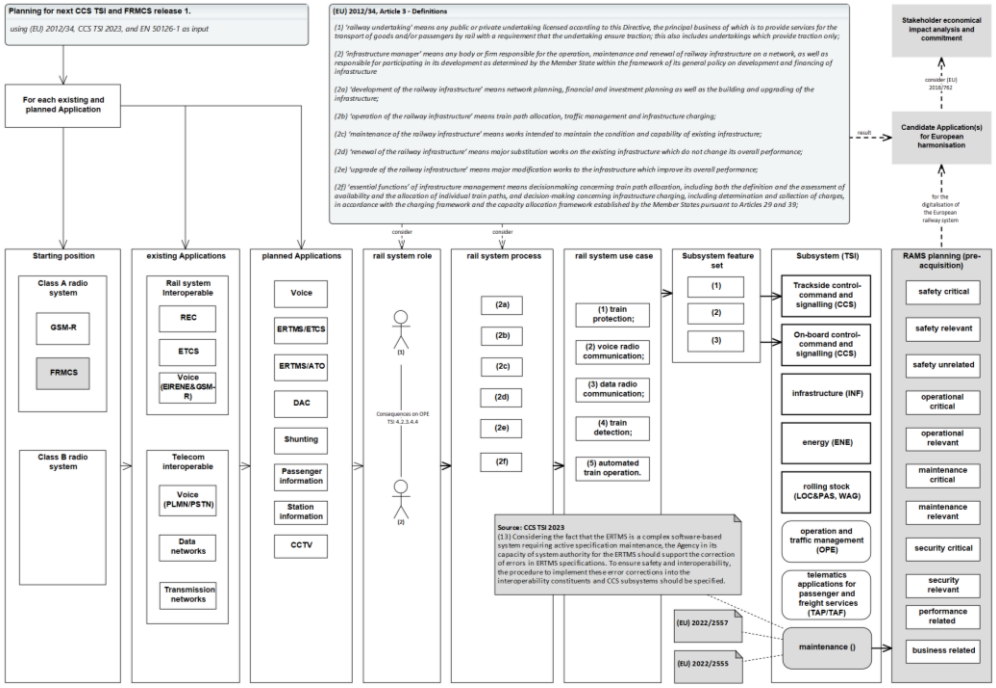


Figure 2-2 Business process for class A RMR system applications

2.1.1 Railway business process description

The overall purpose of this railway business process is to support or enable:

- Operational quality as required in clause 4.2.3.4.4 of OPE TSI[13]
- FRMCS application concept as defined and specified in chapter 5 of UIC FRMCS FRS
- FRMCS functional addressing as defined and specified in chapter 6 of UIC FRMCS FRS.
- Operations and Maintenance as defined and specified in chapter 7.7 of UIC On-Board FRMCS FRS

NOTE : Process with regards to application management will not be described in this document. There are dependencies with Subset-150 v2.0.1[14]

2.1.1.1 Description

[13] Operation and Traffic Management TSI | European Union Agency for Railways
[14] Concept for the evolution of the on-board CCS architecture

Each railway organisation, identified by their rail system role has a starting position that is based on their current infrastructure for radio systems and Applications. The starting position must be expressed as a list of:

- Existing Applications
- Planned Applications

The target of the process is to compile a list of existing Applications and planned Applications with associated parameters as a dictionary that provides a minimum set of relevant and necessary data points to enable RAMS planning. The compiled list is based on the starting position in terms of currently deployed radiosystems and Applications.

For each unique Application item in the compiled list, the path to RAMS planning goes through a set of intermediate steps, where some work within each step is needed prior to moving to the next step by following the arrows in the diagram.

As an exit criteria towards RAMS planning, a question regarding the subsystem ”maintenance”, (defined in (EU) 2016/797)[15] is reflected in point 13 of CCS TSI 2023 pointing out the need for a maintenance procedure for implementing error corrections related with ERTMS specifications. However (EU) 2022/2557[16] (CRA) in conjunction with (EU) 2022/2555[17] (NIS2) are additional sources of input to be consulted prior to exiting the maintenance step.

[15] Directive - 2016/797 - EN - EUR-Lex
[16] Directive - 2022/2557 - EN - CER - EUR-Lex
[17] Directive - 2022/2555 - EN - EUR-Lex

2.1.2 Railway business process steps

2.1.2.1 Starting position

The purpose of this initial step is to make sure that necessary input data is available to start the railway business process.

As a prerequisite, access to updated and quality assured configuration data on the railway network with respect to class A radio systems and class B radio systems is needed.

Using appropriate tools and means, compile a list with information of lines with class A radio systems in operation and with class B radio systems in operation. The list needs to contain one record for each railway line of the railway network being monitored and where each railway line is administratively under the responsibility of an infrastructure manager.

Area(s) or sub-areas as part(s) of a line need to be identified in a distinguishable way. By doing so it is also possible to identify directly and indirectly affected vehicles. Indirectly affected vehicles refers to vehicles that could operate in the area at a time when their usual area is unavailable.

NOTE: The geographical division and layout of lines into sections as areas needs to be performed in such a way as to support the purpose of this process and need also to implement policies that enables support for clause 4.2.3.4.4 of (EU) 2019/773[18] on operational quality.

The lines may be represented by a human understandable text or as an anonymous character string that for each line within the railway network is unique and can be translated to a shape that is understandable and can be represented as part of geography.

This step provides as output, a list object that contains the attributes Line, Area, Class A radio system, Class B radio system.

2.1.2.2 Existing Applications

The purpose of this step is to complement the started list object from previous step with data on existing Applications. Existing Applications refers to Applications that are administratively in an operational state.

Existing Applications need to be assigned a distinguished name and to be complemented with a data object that can describe their geographical deployment in a

[18] Technical specification for interoperability relating to the operation and traffic management subsystem

generic and quantifiable way. The distinguished name is a name that is agreed upon between the infrastructure manager and the railway undertakings.

NOTE: Some existing Applications may at some point in time get to be assigned a harmonised name as a complement to their distinguished name. The procedure for such assignment is currently unknown.

2.1.2.3 Planned Applications

The purpose of this step is to complement the started list object from previous step with data on planned Applications. Planned Applications refers to Applications that are administratively not in an operational state and for which there is an expressed need from one or more stakeholders. This expressed need can result in one or more of the following set of maintenance activities as a consequence of the expressed need:

a) New Application
b) Modified Application
c) Removed Application

Planned Applications need to be assigned a distinguished name and to be complemented with a data object that can describe their planned geographical deployment in a generic and quantifiable way. The distinguished name is a name that is agreed upon between the infrastructure manager and the railway undertakings.

NOTE: Some planned Applications may at some point in time get to be assigned a harmonised name as a complement to their distinguished name. The procedure for such assignment is currently unknown.

2.1.2.4 Rail system role

The purpose of this step is to complement the started list object from previous step with data on rail system role(s) that either has or will need to assume some responsibilities with regards to Applications and that results in being responsible and accountable for one or more part(s) of Applications. For each Application the result is a percentage assigned to infrastructure manager and railway undertaking.

NOTE: The usage of the percentage per Application is not in the scope of this document and may be business confidential between infrastructure managers and railway undertakings. The percentage can be of relevance in conjunction with §4.2.3.4.4 of OPE TSI[19]

[19] (EU) 2019/773

2.1.2.5 Rail system process

The purpose of this step is to complement the started list object from previous step with definition of characteristics on the change process and the expected outcome from that change process using a rail network level perspective.

2.1.2.6 Rail system use case

The purpose of this step is to complement the started list object from previous step with identification of the applicable use case where the use cases are limited to only one of the parts listed in chapter 2.2. Scope of CCS TSI 2023

2.1.2.7 Subsystem feature set

The purpose of this step is to complement the started list object from previous step with identification of one or more features affected by each Application. The features are defined in chapter 2.1. Introduction of CCS TSI 2023

2.1.2.8 Subsystem (TSI)

The purpose of this step is to complement the started list object from previous step using a ”top down” approach with respect to all rail system TSIs. For each Application, the task is to identify the best fit subsystem and its associated TSI. Control-Command and Signalling Subsystems are defined in chapter 2.1. Introduction of CCS TSI and other subsystems are defined in (EU) 2016/797 ANNEX II.

The exit point for this process step in the process diagram goes through the subsystem of ”maintenance”. In order to exit this step and for each Application in the list, (EU) 2022/2557 and (EU) 2022/2555 need to be considered in conjunction with point 13 of CCS TSI 2023.

The outcome of this process step is a set of characteristics that provides input as data for further work with respect to standardisation and may lead to an improved management of railway Applications in Europe over time in terms of quality and efficiency.

NOTE: One example of such management could be common determination criterias and decision on whether a railway Application either is a class A RMR system Application, is to become a class A RMR system Application or is not a class A RMR system Application.

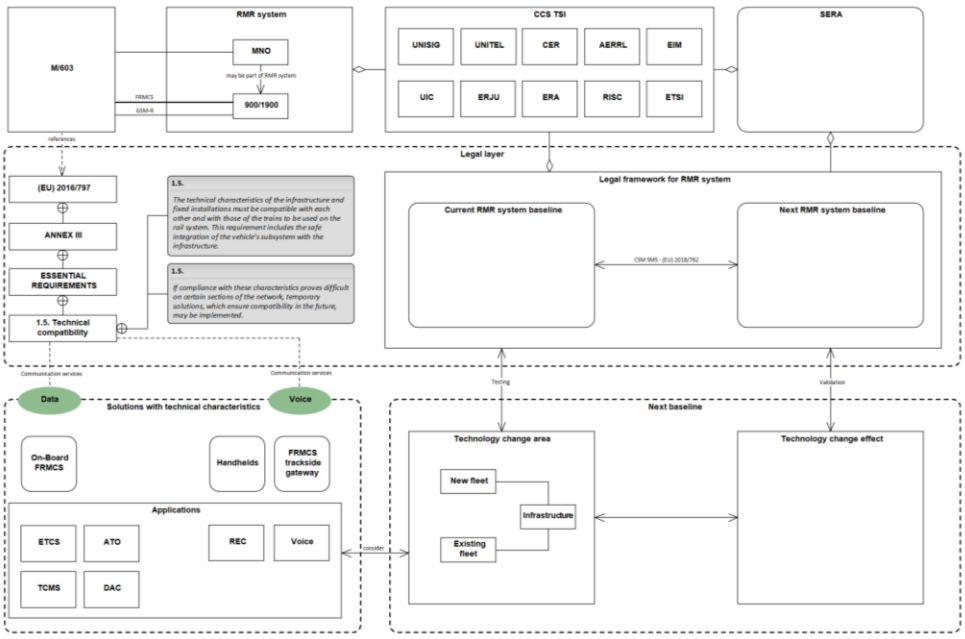
2.1.2.9 RAMS planning (pre-acquisition)

This step is based on Annex A (informative) – ”RAMS plan” in EN 50126-1:2017 as referenced by CCS TSI 2023 as part of Table A 3 – ”List of standards”

NOTE: This step is preliminary and in the process diagram only reflects the view of the author of this process. The sole purpose is to provide the reader of this process with some initial input that reflects the intention behind the last note in the previous step (Subsystem (TSI)) with regards to the subsystem ”maintenance”.

2.2 Legal Framework landscape

The following diagram illustrates a high-level view of the RMR system as defined in CCS TSI 2023 in which FRMCS represents a candidate class A radio system (alongside with the already established and widely deployed GSM-R system).



For the purpose of technological evolution and technical neutrality, FRMCS and GSM-R is only depicted as links to their corresponding spectrum parts. FRMCS is further described in the solution space in the lower part of the diagram where FRMCS and its currently defined major features are indicated for the next CCS baseline as per current CCS TSI 2023.

The CCS TSI block in the upper part of the diagram represents actors with various degree of impact on the RMR system which may lead closer to goals defined in Single European Railway Area.. SERA is defined in (EU) 2012/34[20].

The middle part of the diagram represents the total amount of underlying technical specifications with the total amount of technically oriented requirements that directly or indirectly for the RMR system serve as one of:

- technical enabler,
- technical constraint,
- technical obstacle;

[20] Directive 2012/34/EU of the European Parliament and of the Council of 21 November 2012 establishing a single European railway area

NOTE: The subsystem “maintenance” as defined in ANNEX II of (EU) 2016/797 in conjunction with point 13 of CCS TSI 2023 together with (EU) 2022/2557 and (EU)2022/2555 is not represented in the diagram and is further described in section 2.1 of this document.

2.3 Technological layer

An FRMCS operator is responsible for one or more FRMCS domain(s) which is considered to be a home FRMCS domain.

NOTE: A border between FRMCS domains does not need to follow a map in the sense of geography. A border between FRMCS domains is an administered and therefore configurable construct subject to national regulations by governmental authorities.

The purpose of an FRMCS operator is to provide communication services and complementary services to FRMCS user(s).

In order to function for a FRMCS user, communication services and complementary services need to be provisioned (i.e. configured) in one or more FRMCS user equipment(s) (i.e. devices) as well as in other trackside equipment. This is required to enable and maintain the capability of communication between FRMCS user(s) in an interoperable, reliable, available and maintainable way by means of policies that enables or prohibits communication based on type of application, safety/security requirements, interoperability requirements and RAM requirements.

NOTE: EN 13306:2017[21] can provide further input with regards to RAM requirements and necessary data associated with RAM requirements.

CCS TSI 2023 provides reference to the technical specifications applicable for ERTMS and FRMCS as a candidate class A radio system. Testing and validation activities are ongoing as FP2-MORANE-2 under ERJU management and is coordinated by UIC.[22]

[21] Maintenance – Maintenance terminology
[22] FP2-MORANE-2 - MObile radio for RAilway Networks in Europe 2 - Europe's Rail

2.3.1 RMR system components for class A radio systems

An inventory of installed base with respect to RMR system components described in this section is needed in order to plan for deployment on a European scale.

2.3.1.1 Trackside control-command and signalling subsystem

NOTE: Apart from system blocks in the table below, site acquisition, civil works, passive infrastructure and active components for transmission and data communication networks for interconnection(s) between system blocks for each member state and on a national and international scale is needed.

The following table shows system blocks in FRMCS and GSM-R as parts of the trackside control-command and signalling subsystem for functional equivalence:

FRMCS (IP)	**GSM-R (IP + ISDN)**	**RMR system feature**
NG-RAN	BSS	Mobile radio system features: coverage, access control, mobility and capacity
5GC MC System MC Data (IPCon) MC Voice (Ptt) MC Service(s) Functional Aliasing IMS (Optional)	NSS MSS/MGW GPRS GSM ASCI features (VGCS/VBS) GSM FollowMe (USSD/HLR or USSD/IN) PBX/SIP/VoIP/ISDN	Mobile core system features: communication services complementary services NOTE: additional network features are needed for: IT for data management, network synchronization, time synchronization, IP address management, IT/OT for SW maintenance, IT/OT for security management
Controller Equipment	Controller Equipment	voice radio communication
Trackside gateway	GGSN + IP Network(s)	Interfacing features to ERTMS/ETCS
MC Data SDS	SMSC	Messaging services

2.3.1.2 *On-board control-command and signalling subsystem*

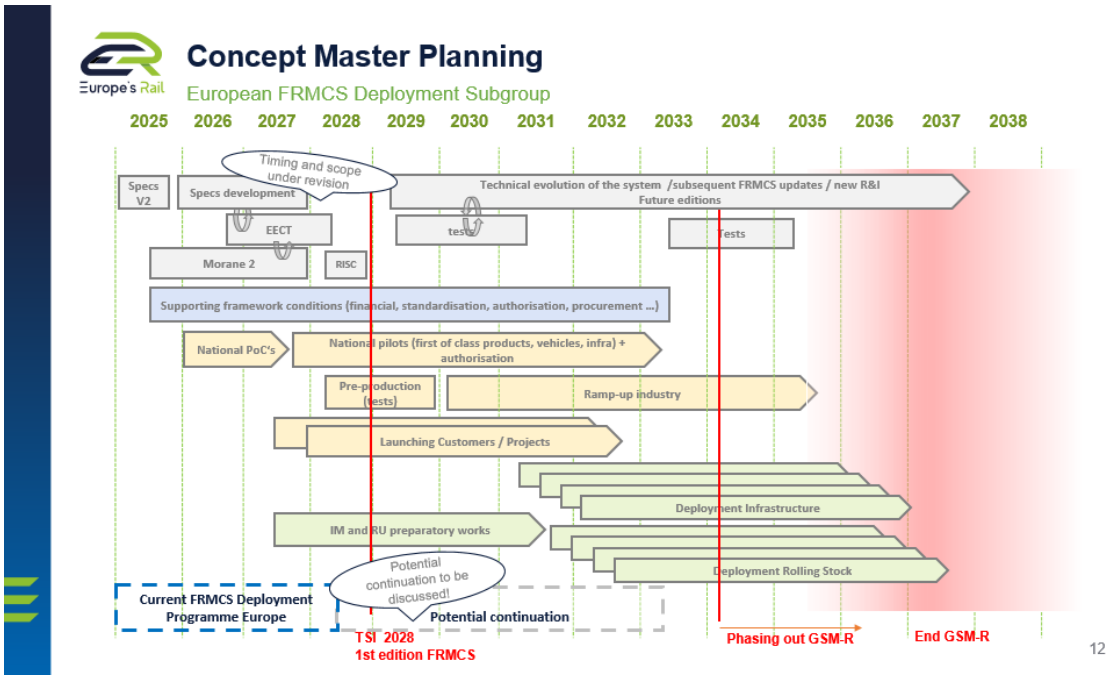
The following table shows system blocks in FRMCS and GSM-R as parts of the on-board control-command and signalling subsystem for functional equivalence:

FRMCS (IP)	**GSM-R (IP + ISDN)**	**RMR system feature**
FRMCS On-Board voice application (VAS) + On-Board FRMCS + FRMCS Profile	GSM-R voice cab radio + GSM-R SIM card	voice radio communication
ETCS on-board + On-Board FRMCS + FRMCS Profile	ETCS on-board + GSM-R data radio + GSM-R SIM card	train protection
Application + Agent + On-Board FRMCS + Application Profile	Unspecified (vendor specific)	data radio communication
ATO On-Board + On-Board FRMCS + FRMCS Profile	ATO On-Board + GSM-R data radio or MNO data radio	Automated train operation

3 Deployment of FRMCS

Global coordination is the key for a successful deployment of FRMCS in Europe, stakeholder alignment is necessary to achieve the targets set by the European Commission for deploying ERTMS in Europe.

Global deployment scheme is presented by the FRMCS deployment subgroup as per below:

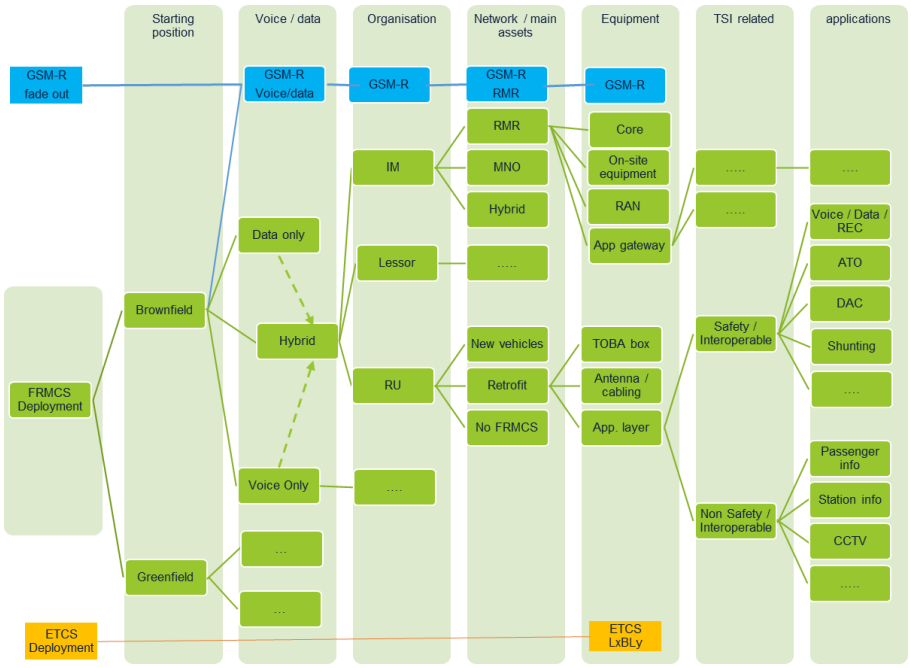


Throughout Europe railways face an enormous, complex transformation towards the usage of new telecommunication system. A wide variety already exists in the usage of current systems (like GSM-R), some countries have 100% coverage, some on only few corridors/area's and some countries haven't introduced railway mobile networks at all.

Next to the different starting positions of Infrastructure Managers and Railway Undertakings also technological, legal and financial reasons drive the upcoming programmes towards standardisation and modernisation. For example following questions may arise :

- Which applications shall be used in which order?
- What is the timeframe to fade-out GSM-R ?
- What are the legal possibilities and obligations ?
- In which way can the Public Mobile Networks be used ?
- Is there a need for retrofitting the vehicles considering their age ?
- What is the mean duration in time for vehicle authorisation or re-authorisation?
- What are the bottlenecks with respect to vehicle deployments?
- What are the main issues, duration variations and human resources needed with regards to authorisation/re-authorisation of vehicle and trackside respectively.

All parameters which are to be considered when choosing a deployment migration scenario. In picture below the complexity is shown, where also we have to consider the related programmes fading out GSM-R and introducing a new signalling system ETCS. In the next paragraphs we will consider the main foreseen deployment scenario's, also based on the first results of the FRMCS Questionnaire.



Starting position: Is GSM-R or other mobile telecommunication already available (brownfield) or is it a first introduction of mobile railway telecommunication (greenfield)

Voice/data: Migration towards the digitalised end situation in one step (hybrid) or via a 2-step approach by starting to transform voice communication first and then add data functionalities. Scenario's which can go in parallel with the fading out of GSM-R and migration period and geographical situation.

Organisation: Agreement and close cooperation between Infrastructure managers and RU's/lessors needed on tuned programmes on infrastructure and rolling stock.

Network/main assets: Will IM's use own networks, use MNO's or a hybrid situation. During migration the usage can differ over time. For RU's/Lessors, do they invest in retrofitting vehicles (coordinated with ETCS programmes), buy new vehicles or, considering the end-of-life situation decide not to invest in new on-board equipment at all (of course in close collaboration with IM)

Equipment: investment to be made in -future proof- trackside assets and on-board equipment. Including the usage of already available assets.

TSI related: FRMCS roll-out will start with 1:1 replacement of GSM-R functionalities - Voice/Data/REC (radio emergency call)- All safety and interoperability related topics, via TSI and standardisation regulations. -Future- functionalities don't need to be safety or interoperability related (e.g. train-station communication) and could possibly be handled in another situation (WG2). Also from a business perspective RU/IM/Lessors consider only 1:1 GSM-R replacement as a non-profitable investment. They have to consider and see new possibilities to make the business case positive for investments. For example by later reducing number of vehicle antennas, add new functionalities (energy diagnostics) by simple new applications or software updates, etc.

Applications: The approach towards FRMCS is application based (also voice, REC can be considered as app based functionalities). After publication of the 1st FRMCS edition new functionalities will be added to vehicle or processes. This can be done - similar to mobile phone- using apps. Authorisation for these new functionalities has to be considered, but can also lead to simpler processes.

3.1 Deployment scenarios

The most important question is to determine the ownership of and required level of control over data (at rest) and data protection management (capability to access and potentially read or update data). With data is to be understood as digitalized data concerning the CCS TSI features for train protection, voice radio communication and data radio communication.

To provide guidance on the aforementioned question, (EU) 2022/2557 and (EU) 2022/2555 should be consulted in conjunction with CCS TSI and therein referenced technical specifications for interoperability.

When a decision has been made, then the following scenarios can be considered in light of the decision that has been made.

It is also important that for a decision on trackside deployment, to also consider any necessary modifications towards RINF register to maintain railway safety and rail system performance with regards to route compatibility.

RMR system scenario	RMR system activity	Description
Greenfield	class A deployment	Deploy FRMCS applications and FRMCS user(s) Please refer to section 3.1.5
Brownfield to greenfield	class A migration	Deploy FRMCS applications and FRMCS user(s) and move GSM-R Applications to FRMCS Applications and FRMCS user(s) Please refer to 3.1.1
Brownfield to greenfield	class B migration to class A (FRMCS)	Deploy FRMCS applications and FRMCS user(s) and move class B Applications to FRMCS Applications and FRMCS user(s) Please refer to 3.1.5
Brownfield + Grey	class A deployment with class B migration to GSM-R	Deploy FRMCS applications and FRMCS user(s) and upgrade class B Applications to GSM-R Applications Please refer to 3.1.1
Brownfield + Grey	class B maintenance	Deploy FRMCS applications and FRMCS user(s) and maintain class B Applications Please refer to 3.1.5

Green+	class B decommision	Deploy FRMCS applications and FRMCS user(s) and decommision class B Applications Please refer to 3.1.5
Close green deal	GSM-R and class B decommisioning	Gradually decommision and take proper care of equipment

Please also refer to Annex 2 Matrix for Migration Scenarios.

3.1.1 Parallel operation with existing GSM-R and FRMCS dedicated networks

GSM-R is in operation and in parallel FRMCS dedicated network will be introduced.

Following aspects need to be considered for vehicles:

1) Inventory of the GSM-R installed base on the vehicles
2) Decide which applications will be used based on the railway business process description
3) Procurement of the FRMCS Train Onboard equipment
4) Install FRMCS onboard on the new vehicles, planning for dual-mode operation with GSM-R. If ETCS is used, coordination of the installation is needed to avoid non-productive time at the workshop
5) Decision to retrofit or to not retrofit the installed base in an older vehicle depending on the lifecycle of the vehicle

Technical conditions for the infrastructure:

1) Mobile radio system owned by the infrastructure manager
2) GSM-R is using 900Mhz spectrum, FRMCS needs to be implemented on 1900Mhz spectrum during the migration period due to risk for spectrum collision
3) Mobile Core System is owned by the infrastructure manager including subscriber management
4) ETCS baseline 4 needs to be installed by the infrastructure manager to be FRMCS compatible if ETCS is deployed or planned to be deployed within the country, with reference to CCS TSI mandatory specifications

5) Minimize interference from GSM-R and public network operators

NOTE: There is a proposal for a solution called “white space” studied by 5G-RACOM project[23] with following scope: *To allow a coexistence scheme between the 5G NR and the GSM-R within the 900 MHz RMR frequency band allocated to railways without impacting neither refarming the GSM-R deployed networks* « The white space option needs to studied further if it is aimed to be used in some countries

Operational conditions:

1) FRMCS operator is infrastructure manager (without delegation)
2) Build infrastructure line by line to verify interworking with GSM-R
    a. Pilot line
    b. specially built high-speed lines equipped for speeds generally equal to or greater than 250 km/h;
    c. specially upgraded high-speed lines equipped for speeds of the order of 200 km/h;
    d. 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. This category includes interconnecting lines between high-speed and conventional networks, lines through stations, accesses to terminals, depots, etc. travelled at conventional speed by ‘high-speed’ rolling stock;
    e. conventional lines intended for passenger services;
    f. conventional lines intended for mixed traffic (passengers and freight);
    g. conventional lines intended for freight services;
    h. passenger hubs;
    i. freight hubs, including intermodal terminals;
    j. lines connecting the abovementioned elements.
    k. International border crossing lines in co-operation with neighbouring countries

    NOTE: Categories from b to j in the above list are derived from (EU) 2016/797 ANNEX I.

3) Migrate applications from GSM-R to FRMCS by starting with voice and then data if ETCS is used within the network, ATO will be enabled after ETCS is activated
4) Consider and migrate class B applications

[23] 5G-RACOM WP1 Report

3.1.2 Parallel operation with existing GSM-R and FRMCS dedicated networks and Public Network operator (Hybrid)

GSM-R is in operation and in parallel FRMCS dedicated network will be introduced in co-operation with public Network operators.

Following aspects need to be considered for vehicles:

1) Inventory of the GSM-R installed base on the vehicles

2) Decide which applications will be used based on the railway business process description

3) Procurement of the FRMCS Train Onboard equipment supporting RMR spectrum as well as MNO spectrum

4) Install FRMCS onboard on the new vehicles, planning for dual-mode operation with GSM-R. If ETCS is used, coordination of the installation is needed to avoid non-productive time at the workshop

5) Decision to retrofit or to not retrofit the installed base in an older vehicle depending on the lifecycle of the vehicle

Technical conditions for the infrastructure:

1) Mobile radio system owned by the infrastructure manager

2) Integration to chosen public network operator

3) GSM-R is using 900Mhz spectrum, FRMCS needs to be implemented on 1900Mhz spectrum during the migration period due to risk for spectrum collision

4) Mobile Core System is owned by the infrastructure manager including subscriber management

5) ETCS baseline 4 needs to be installed by the infrastructure manager to be FRMCS compatible if ETCS is deployed or planned to be deployed within the country, with reference to CCS TSI mandatory specifications

6) Minimize interference from GSM-R and public network operators

NOTE: There is a proposal for a solution called “white space” studied by 5G-RACOM project[24] with following scope: *To allow a coexistence scheme between the 5G NR and the GSM-R within the 900 MHz RMR frequency band allocated to railways without*

[24] 5G-RACOM WP1 Report

impacting neither refarming the GSM-R deployed networks « The white space option needs to studied further if it is aimed to be used in some countries

Operational conditions:

1) FRMCS operator is infrastructure manager (without delegation)
2) Build infrastructure line by line to verify interworking with GSM-R
    a. Pilot line
    b. specially built high-speed lines equipped for speeds generally equal to or greater than 250 km/h;
    c. specially upgraded high-speed lines equipped for speeds of the order of 200 km/h;
    d. 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. This category includes interconnecting lines between high-speed and conventional networks, lines through stations, accesses to terminals, depots, etc. travelled at conventional speed by 'high-speed' rolling stock;
    e. conventional lines intended for passenger services;
    f. conventional lines intended for mixed traffic (passengers and freight);
    g. conventional lines intended for freight services;
    h. passenger hubs;
    i. freight hubs, including intermodal terminals;
    j. lines connecting the abovementioned elements.
    k. International border crossing lines in co-operation with neighbouring countries

    NOTE: Categories from b to j in the above list are derived from (EU) 2016/797 ANNEX I.

3) Migrate applications from GSM-R to FRMCS by starting with voice and then data if ETCS is used within the network, ATO will be enabled after ETCS is activated
4) Use Mobile Network Operators mobile radio system in the initial phase of the migration to avoid building infrastructure for FRMCS 1900Mhz
5) After migration from GSM-R to FRMCS is completed, start decommission the existing GSM-R sites with 900 Mhz and start deploying FRMCS on those sites with 900Mhz.
6) Keep MNO for redundancy and potentially for business and performance applications (high data requirements)

3.1.3 Parallel operation with shared FRMCS infrastructure

GSM-R is in operation and in parallel FRMCS will be introduced by sharing infrastructure with Mobile Network Operator(s) (MNO)

Following aspects need to be considered for vehicles:

1) Inventory of the GSM-R installed base on the vehicles

2) Decide which applications will be used based on the railway business process description

3) Procurement of the FRMCS Train Onboard equipment supporting the MNO spectrum

4) Install FRMCS onboard on the new vehicles, planning for dual-mode operation with GSM-R. If ETCS is used, coordination of the installation is needed to avoid non-productive time at the workshop

5) Decision to retrofit or to not retrofit the installed base in an older vehicle depending on the lifecycle of the vehicle

Technical conditions for the infrastructure:

1) Mobile radio system owned by the Mobile Network Operator

2) GSM-R is using 900Mhz spectrum, FRMCS needs to be implemented on spectrum used by the MNO

3) Mobile Core System is owned by the infrastructure manager including subscriber management

4) ETCS baseline 4 needs to be installed by the infrastructure manager to be FRMCS compatible if ETCS is deployed or planned to be deployed within the country, with reference to CCS TSI mandatory specifications

5) Minimize interference from GSM-R and public network operators

Operational conditions:

1) FRMCS operator is infrastructure manager (without delegation)

2) Deploy radio infrastructure line by line to verify interworking with GSM-R

   a. Pilot line
   b. specially built high-speed lines equipped for speeds generally equal to or greater than 250 km/h;
   c. specially upgraded high-speed lines equipped for speeds of the order of 200 km/h;
   d. 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. This category includes interconnecting lines between high-speed and conventional networks, lines through stations, accesses to terminals, depots, etc. travelled at conventional speed by 'high-speed' rolling stock;

e. conventional lines intended for passenger services;
f. conventional lines intended for mixed traffic (passengers and freight);
g. conventional lines intended for freight services;
h. passenger hubs;
i. freight hubs, including intermodal terminals;
j. lines connecting the abovementioned elements.
k. International border crossing lines in co-operation with neighbouring countries

NOTE: Categories from b to j in the above list are derived from (EU) 2016/797 ANNEX I.

3) Migrate applications from GSM-R to FRMCS by starting with voice and then data if ETCS is used within the network, ATO will be enabled after ETCS is activated

3.1.4 Existing GSM-R network migrated to FRMCS based on Public Mobile Network Operator(s)

GSM-R is in operation and in parallel FRMCS will be introduced by using Mobile Network Operators (MNO) as service providers

Following aspects need to be considered for vehicles:

1) Inventory of the GSM-R installed base on the vehicles

2) Decide which applications will be used based on the railway business process description

3) Procurement of the FRMCS Train Onboard equipment supporting the MNO spectrum

4) Install FRMCS onboard on the new vehicles, planning for dual-mode operation with GSM-R. If ETCS is used, coordination of the installation is needed to avoid non-productive time at the workshop

5) Decision to retrofit or to not retrofit the installed base in an older vehicle depending on the lifecycle of the vehicle

Technical conditions for the infrastructure:

1) Mobile radio system owned by the Mobile Network Operator

2) GSM-R is using 900Mhz spectrum, FRMCS needs to be implemented on spectrum used by the MNO

3) Mobile Core System is owned by the Mobile Network operator including subscriber management

4) ETCS baseline 4 needs to be installed by the infrastructure manager to be FRMCS compatible if ETCS is deployed or planned to be deployed within the country, with reference to CCS TSI mandatory specifications

5) Minimize interference from GSM-R and public network operators

Operational conditions:

1) FRMCS operator is Mobile network operator (delegated by infrastructure manager)
2) Deploy radio infrastructure line by line to verify interworking with GSM-R
    a. Pilot line
    b. specially built high-speed lines equipped for speeds generally equal to or greater than 250 km/h;
    c. specially upgraded high-speed lines equipped for speeds of the order of 200 km/h;
    d. 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. This category includes interconnecting lines between high-speed and conventional networks, lines through stations, accesses to terminals, depots, etc. travelled at conventional speed by 'high-speed' rolling stock;

e. conventional lines intended for passenger services;
f. conventional lines intended for mixed traffic (passengers and freight);
g. conventional lines intended for freight services;
h. passenger hubs;
i. freight hubs, including intermodal terminals;
j. lines connecting the abovementioned elements.
k. International border crossing lines in co-operation with neighbouring countries

NOTE: Categories from b to j in the above list are derived from (EU) 2016/797 ANNEX I.

3) Migrate applications from GSM-R to FRMCS by starting with voice and then data if ETCS is used within the network, ATO will be enabled after ETCS is activated

NOTE: This scenario is having the highest risk for accountability due to operational conditions not in control of the infrastructure manager for safety and security management system.

3.1.5 FRMCS greenfield deployment

First time installation of Class A radio system using FRMCS as a baseline

Following aspects need to be considered for vehicles:

1) Inventory of the Class B installed base on the vehicles

2) Decide which applications will be used with FRMCS based on the railway business process description

3) Procurement of the FRMCS Train Onboard equipment supporting the chosen business model of the infrastructure manager

4) Install FRMCS onboard on the new vehicles. If ETCS is planned to be used, coordination of the installation is needed to avoid non-productive time at the workshop

5) Decision to retrofit or to not retrofit the installed base in an older vehicle depending on the lifecycle of the vehicle

Technical conditions for the infrastructure:

1) Decision of the business model:

a) Dedicated network owned by the infrastructure manager

b) Shared network with Mobile Network Operator(s)

c) Mobile Network operator as a service provider

2) Apply for spectrum license

3) Establish organisation for operation and maintenance, subscriber management and asset management

4) ETCS baseline 4 needs to be installed by the infrastructure manager to be FRMCS compatible if ETCS is deployed or planned to be deployed within the country, with reference to CCS TSI mandatory specifications

5) Minimize interference from public network operators

Operational conditions:

1) FRMCS operator is according to chosen business model (with or without delegation)
2) Deploy radio infrastructure line by line to verify the FRMCS functionality:
    a. Pilot line
    b. specially built high-speed lines equipped for speeds generally equal to or greater than 250 km/h;
    c. specially upgraded high-speed lines equipped for speeds of the order of 200 km/h;

d. 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. This category includes interconnecting lines between high-speed and conventional networks, lines through stations, accesses to terminals, depots, etc. travelled at conventional speed by 'high-speed' rolling stock;
e. conventional lines intended for passenger services;
f. conventional lines intended for mixed traffic (passengers and freight);
g. conventional lines intended for freight services;
h. passenger hubs;
i. freight hubs, including intermodal terminals;
j. lines connecting the abovementioned elements.
k. International border crossing lines in co-operation with neighbouring countries

NOTE: Categories from b to j in the above list are derived from (EU) 2016/797 ANNEX I.

3) Deploy FRMCS by starting with voice and then data if ETCS is used within the network, ATO will be enabled after ETCS is activated.

3.2 Authorization

3.2.1 Stepwise approach

The stepwise approach will be further described in coordination between IMs, lessors and RUs as well as implementation of remote maintenance.

For ETCS compatibility with FRMCS, CTO council is the body that performs the analysis[25]

However, voice radio communication could be considered as the first application to be deployed and used with FRMCS. This could bring further insights on operational quality aspects that could also be used for other applications including ETCS.

NOTE: Authorization topics are currently dealt with by ERJU FRMCS Deployment group for legal and financial matters (WG2).

3.3 Handhelds migration scenarios

Today the GSM-R capable handhelds are used widely by infrastructure managers and constructions workers for safety purposes. The industry is targeting to launch GSM-R equivalent FRMCS as a starting point. Therefore, it is important to cover also the need of FRMCS capable handhelds for service continuity.

Following aspects needs to be considered by the sector stakeholders:

1) Inventory of existing and active GSM-R capable handhelds and applications
2) Standardization of FRMCS capable handheld, either as application based and/or a dedicated Hardware terminal, this task needs to be addressed and studied for example by ETSI Technical Committee for Rail Telecommunications
3) Boost innovations related to FRMCS capable handhelds, potentially a dual mode handheld supporting necessary GSM-R and FRMCS voice applications during transition
4) Product Development based on point 2 and 3
5) Procurement process
6) Replacement of the GSM-R handhelds

If the GSM-R is not used within the country, then step 5) applies for the FRMCS deployment.

[25] https://www.era.europa.eu/system/files/2024-11/%5Bref%202%5D%2020240426_etcs-frmcs_final%20results%20wg%20v2.pdf

3.4 Scenarios explored however not recommended

The following sections identify scenarios that are not generally recommended, however they are not excluded as such.

3.4.1 "Big bang" – complete transition of the entire network to FRMCS at one time

Not feasible due to the need to keep GSM-R in operation on lines with ETCS L2.

Not feasible in terms of available spectrum in the 900 MHz band.

Inability to verify the functionality of such a solution in real operation in a timely manner.

NOTE: This scenario is valid only in a Greenfield situation.

3.4.2 FRMCS only in the 900 MHz band (n8) with existing GSM-R infrastructure using 900MHz band

Spectral collision with GSM-R, impossibility of coexistence on one infrastructure.

Insufficient spectrum in an environment with dense traffic and ETCS.

Need for parallel existence of GSM-R and FRMCS in different bands (e.g. n101) and using potentially mobile network operators as an alternative during the transition period.

3.5 Points to be further explored

3.5.1 Operation of FRMCS exclusively through public mobile operators (MNO-only model)

There is a risk of loss of control over critical communication infrastructure.

Uncertainty of ensuring the required level of QoS and cybersecurity needs to be clarified.

Legal uncertainties in the area of responsibility for ETCS/ATO communication need to be clarified.

NOTE: This point is related to (EU) 2022/2557 and (EU) 2022/2555 and may need to involve national safety/security authorities on member state level.

3.5.2 Lifecycle management of FRMCS specifications during the active deployment period

When the FRMCS specifications and standards are updated during 2030, for example to cover evolving technologies (e.g., 6G) and are part of the legal framework, the target maintenance versions and main versions of FRMCS specifications needs to be investigated,planned and aligned between all implementers

3.5.3 Study on multimodal services during transition period

The following paragraph can be found in (EU) 2010/40 :

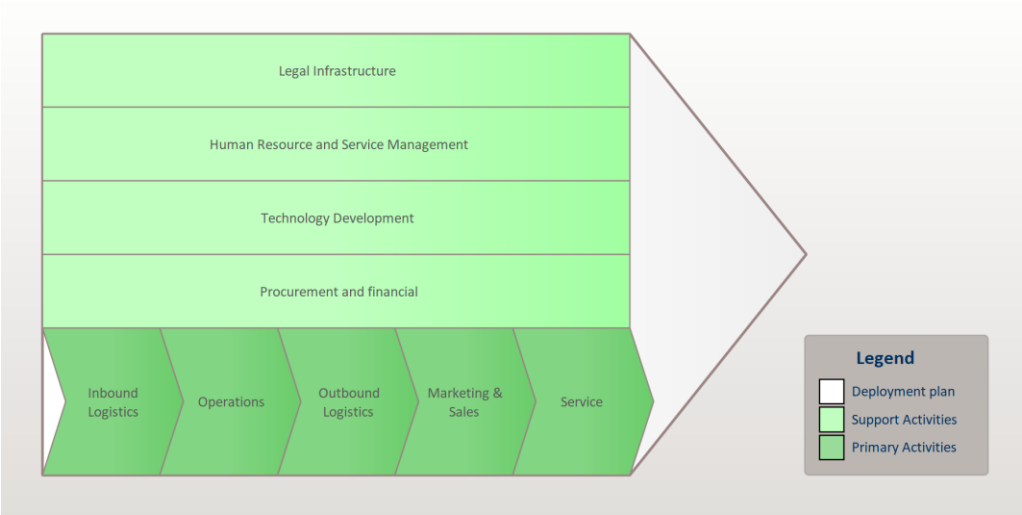
« 3. This Directive shall apply to ITS applications and services in the field of road transport **and to their interfaces with other modes of transport without prejudice to matters concerning national security or necessary in the interest of defence**. »

The following text can be found in (EU) 2023/1695 :
« Currently the CCS TSI does not specify any interoperability requirement for the interlockings, level crossings and certain other elements of the CCS. »

This leads to that this WG currently cannot go much further with analysis on multimodal services at this point in time. However such studies may become necessary during the time needed for transition to FRMCS.

3.5.4 Continue study on the value chain and business perspectives

The railway sector needs to describe the expected value chain from systems and business perspective also in relation to the FRMCS questionnaire results.



3.5.5 Assessment of public mobile operators' involvement in FRMCS deployment

The possible use of public mobile operators as an alternative or complementary model to a dedicated FRMCS network requires further investigation. Key aspects to be explored include current and planned network deployments in relevant areas, operators' interest in different infrastructure sharing or roamingmodels, potential collaboration frameworks, and the ability to meet railway-specific requirements in terms of coverage, throughput, availability, and SLAs.

3.5.6 Migration scenarios for the control rooms

How to secure a smooth transition for the operator/dispatcher control rooms with a minimum impact on the train operations as well as the network operations?

3.5.7 Additional benefits of FRMCS

In addition to the defined migrations scenarios, have other potential benefits and scenarios been identified to make full use of the FRMCS possibilities? If yes, what are those and what are their impact on the migration scenarios? (Drones, videos, surveillance)

4 Recommendations

4.1 Deployment planning

All planning starts with National Implementation Plan (NIP) based on TSI CCS Annex H. It should be noted that ERTMS/ETCS is only one specific application of the RMR system where FRMCS is a class A radio system. Therefore, it is recommended that the procedure in section 2.1 is applied as a complement to the ERTMS/ETCS deployment. The national implementation plans should be updated on yearly basis.

Infrastructure will be built first including the handheld capability.

Existing applications using existing class A radiosystem (GSM-R) need to be considered and migrated first. Other planned applications may be implemented after or in parallel with the introduction of FRMCS.

For an FRMCS operator, the following figure illustrates interface types to manage and their applicability as part of one FRMCS domain.

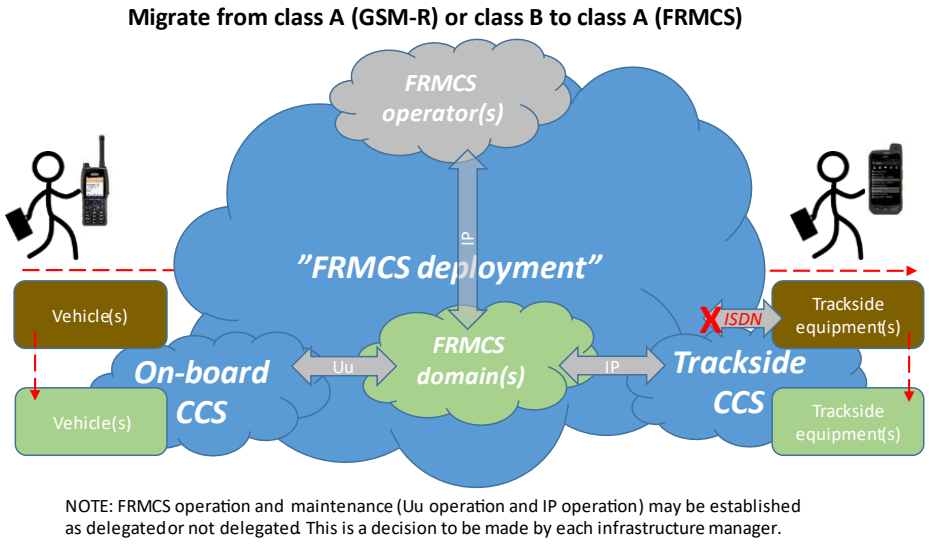


Figure 4-1 Becoming an FRMCS operator

Onboard deployment: first preparing the equipment considering the applications chosen from section 2.1 on the rolling stock and then activate it when tested, validated and authorized using the legal framework as a basis.

Compatibility among intermediate states of the ERTMS specifications is crucial for the deployment, allowing interim maintenance versions full compatibility between GSM-R and FRMCS functionalities. Simplification of ERTMS specifications needs to be implemented based on e.g., harmonized standard(s).

Coordination and alignment

The following figure illustrates a set of topics (non exhaustive) that all are important to the successful deployment of FRMCS on a European scale. However these topics are addressed by a set of non-interconnected groups having different approaches and methods which lead to a fragmented approach to migration rather than a systematic and coordinated approach.

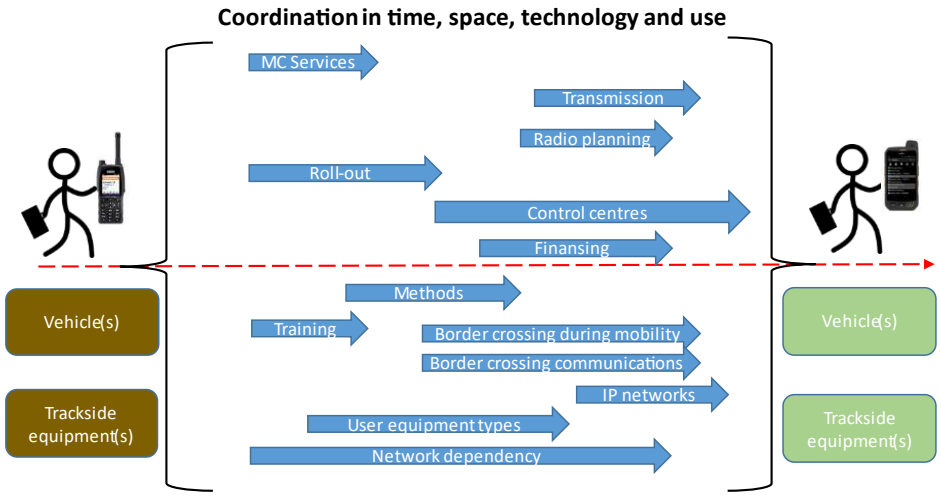


Figure 4-2 Coordination space challenges

The following figure illustrates a systematic and more synchronized approach where a more high level E2E perspective is in focus to enable tangible results. This would also require better incorporation of the railway vehicle industry and rail telecommunication industry as enablers of a sustainable supply chain.

The harmonization of operational aspects does not mean harmonization from the legal point of view. The aim is to create an alignment and expectation within the railway sector stakeholders about the common approach and transparency in the planning processes.

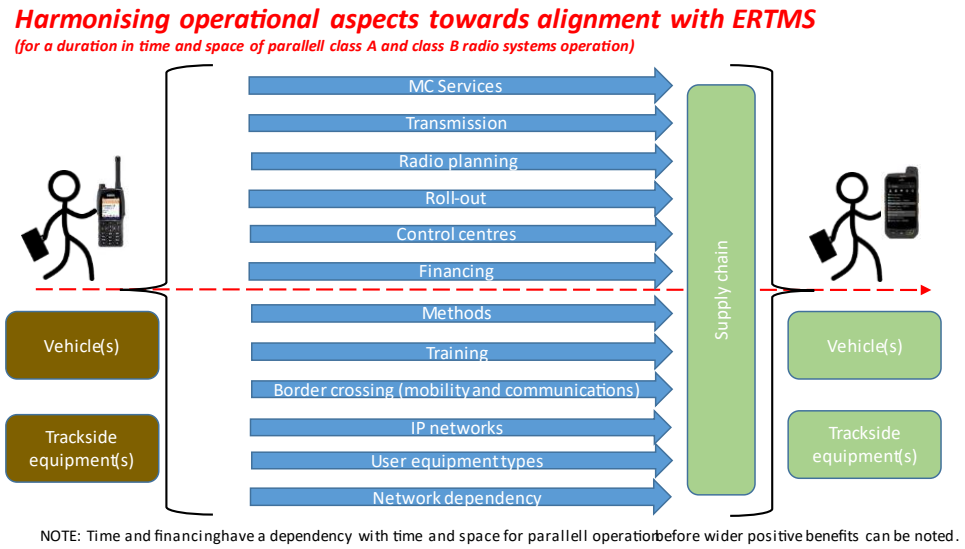


Figure 4-3 Obtaining synchronized planning for rail system operation

4.2 Financing & Funding

Financing and funding need to be handled per company and per country.

4.3 Human resources

There is a need to introduce a European Support Competence Center to enable and share knowledge about Deployment scenario's, Lessons learnt, new Procedures, Test / validation issues during the transition period with the purpose to maintain or increase the Operational quality as defined in chapter 4.2.3.4.4 of the (EU) 2019/773.

5 Summary

The Railway sector is on a critical path to transition from legacy networks to future proof networks enabling the key principle of FRMCS, namely enabling digitalization of the railways and increase the possibilities to use different types of applications and business models for the operators. With a joint effort and believing on the vision on the sector, the FRMCS deployment will be successful in Europe.

Annex 1 Matrix for Migration Scenarios for further studies

	Scenario 1: Parallel operation with existing GSM-R and FRMCS dedicated networks	Scenario 2: Parallel operation with existing GSM-R and FRMCS dedicated networks and Public Network operator (Hybrid)	Scenario 3: Parallel operation with shared FRMCS infrastructure	Scenario 4: Existing GSM-R network migrated to FRMCS based on Public Mobile Network Operator(s)	Scenario 5: FRMCS greenfield deployment
Complexity					
Risk					
Cost					
Time					
Challenges					
Synergies					