

Rail to Digital & Automated up to Autonomous Train Operation

D3.4 - Architecture Baseline

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Disclaimer

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EXECUTIVE SUMMARY

The FP2-R2DATO project specifies, develops and demonstrates solutions contributing to the DATO system of systems.

This document presents the system baseline for DATO. It intends to **formalize and leverage the outcomes** of Systems Architecture workshops and discussions organised between January 2024 and end 2025 and led by Work Package 3 task 1. The objective is to provide a consolidated and coherent set of system descriptions from and for discussions related to Systems Architecture inside the FP2-R2DATO project and beyond.

Its purpose is **not** to provide **extensive** design files nor to become an extensive System engineering management plan, but rather to **stabilize and to clarify the current knowledge, vocabulary, hypothesis and working plan around Systems Architecture**, based on workshop outcomes, established and challenged by all its participants and FP2-R2DATO WP3 partners. The purpose is also to build foundations for the deliverable D3.1.

This document therefore presents the applicable **Systems Architecture methodology** (§3) as well as the applicable associated **Systems Architecture Practical Guidance** (§4.2) including a preliminary roadmap (§4.5). A more detailed description of the methodology and planning on how this vision was collaboratively built is presented in Appendices.

Activities performed on architecture have been organised in the frame of WP3 task 1 to deliver "architecture guidance" as defined in FP2-R2DATO grant agreement. The objective is primarily to find common understanding within FP2-R2DATO project on architecture needs and applicable descriptions. The architecture should therefore support a constructive dialogue with SP but also ownership within FP2-R2DATO, of sector decisions related to system evolutions.

Next step is mostly to start using these architecture views to guide the assessment of area of improvements in relation to DATO solutions. The architecture file also provides a solid basis that can be used in future collaborative projects in relation to DATO technical enablers: design communities can collect, interpret, use their input artefacts and share their feedback to continue improving the architecture and the collaboration mechanism.

GLOSSARY, ABBREVIATIONS AND ACRONYMS

AP	Automation Processes
APC	Automation Processes Cluster
ATO	Automatic Train Operation
ATP	Automatic Train Protection
Baseline	set of architectural artefacts (views, models, specifications, methodology) describing the DATO metasystem as developed in D3.4, used as a basis for integration assessments in D3.1.
CCB	Change Control Board
CCS	Control Command and Signalling
Cluster	logical grouping of Technology Enablers and activities within FP2-R2DATO, typically aligned with a specific functional or technological focus (e.g. Automation Processes Cluster).
CR	Change Request
Comms	Communications
DATO	Digital and automated up to autonomous train operation : system of systems characterised and specified within the FP2-R2DATO project.
DETC	Digital Enabling Technologies Cluster
DEMO	Demonstrator cluster
EDT	Enabling Digital Technologies
EGNOS	European Geostationary Navigation Overlay Service
ETCS	European Train Control System
FA	Flagship Area
FED	Fast and effective deployment Cluster
FFIS	Form Fit Function Interface Specification
FP2-R2DATO	Project related to DATO specification and demonstration.
GNSS	Global navigation satellite system
GoA	Grade of automation from manual driving (GoA 0) to fully unattended train operation (GoA 4).
HL3	Hybrid Level 3
HTD	Hybrid Train Detection
MB	Moving Block
Metasystem	System of autonomous & interoperable systems that can be governed, simulated & deployed
OB	On Board
OCORA	Open CCS Onboard Reference Architecture
OH	Optimized Headway
OHC	Optimized Headway Cluster
OTI	On-board Train Integrity
OTL	On-board Train Length
RCA	Reference CCS Architecture
RS	Rolling Stock
SP	System Pillar : The EU-Rail JU process that defines the sector-wide system vision, reference functional architecture and related specifications, that FP2-R2DATO must feed and align.
SOI	System of Interest
STIP	Standardisation and TSI Input Plan
SEMP	Systems Engineering Management Plan
TAURO	Technologies for the AUtonomous Rail Operation (former Shift2Rail project)
TBD	To Be Defined
TDD	Train Detection Device
TMS	Traffic Management System
TRL	Technological Readiness Level
V&V	Verification & Validation
WP	Work Package

RELATION BETWEEN FP2-R2DATO AND DATO

FP2-R2DATO

FP2-R2DATO refers to the Europe's Rail Flagship Project that executes the research, specification, prototyping and demonstration activities related to digital and automated train operation. FP2-R2DATO is a project with governance, work packages, deliverables, milestones and resources.

DATO (Digital and Automated up to Autonomous Train Operation)

DATO refers to the system-of-systems enabling Digital and Automated up to Autonomous Train Operation within the European railway system. DATO is the system of interest characterised by this architecture baseline, independently of the project executing the work. DATO is qualified by engineering artefacts as technical capabilities, use cases, functions, constituents, interfaces, and is realised by solutions.

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1 INTRODUCTION

The FP2-R2DATO project specifies, develops and demonstrates solutions contributing to the DATO system of systems.

The present document constitutes the Deliverable D3.4 “Architecture baseline” in the framework of the WP 3.1 of FP2-R2DATO project. The architecture work within the task consolidates the diverse developments across the project’s work packages (WPs). A strategic objective is to act as a bridge between the technical work of the WPs and the overarching System Pillar, ensuring coherence, integration, and shared understanding.

Following the first feedback loops, this document provides applicable information to support:

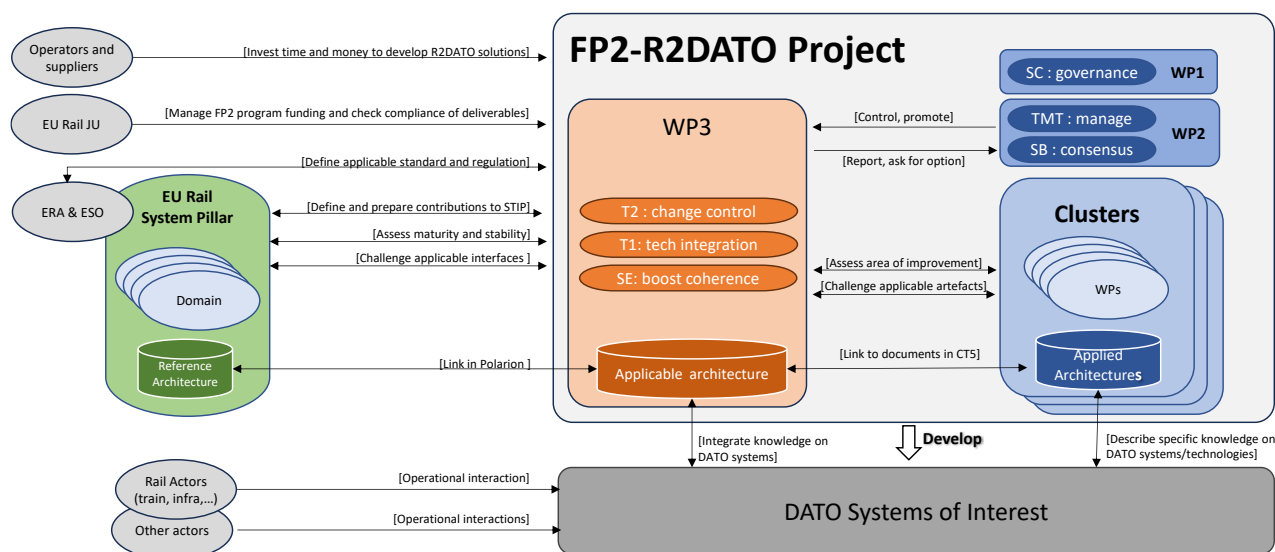
- **Technical Coordination and coherence:**
 - Consolidate the scope of demonstrators and facilitate alignment with the System Pillar.
 - Align system engineering vocabulary used in internal and external communication for FP2-R2DATO project.
 - Identify interactions, gaps, overlaps, and constraints across WPs beyond what is defined in the grant agreement.
- **Consensual Architectural Vision:**
 - Provide a holistic and coherent overview of DATO solutions, aiming to avoid contradictions and promote synergy among clusters.
 - Offer a simplified yet comprehensive description of the services, systems, and organizations involved.
 - Define generic blocks (artefacts) and their interactions.
- **Strategic Role:**
 - Consolidate applicable information to guide and simplify integration efforts.
 - Lay the foundation for an agile integration strategy for mature DATO solutions.
 - Provide foundations for collaborative modelling, by defining clear Systems of interest, preparing descriptions, and metamodels easy to use in Capella tool and relevant for current and future developments.
- **Monitoring and Innovation:**
 - Provide a structured list of engineering items, such as interfaces, functions or constituents, to support WPs iterations and support the identification of areas of improvement: coherence issues, uncertainties and unknowns.
 - Offer a framework to explore and qualify new ideas, balancing specificity for current implementations with flexibility for future innovation.
- The document is presented as an architecture file, covering system description and framework aspects. Chapter 2 reminds the organisational context and challenges in relation to a consolidated architecture for DATO systems. Chapter 3 describes the methodology used for developing the architecture. The chapter 4 proposes how the architecture can be used and governed. The chapter 5 presents the content architecture views and actual open points.

2 CONTEXT OF FP2-R2DATO WP3

2.1 ORGANISATION CONTEXT

The role of WP3 is to perform technical integration activities within the FP2-R2DATO project, in order to enable system coherence among the various engineering activities organised within the project.

Figure 1: Organisation context of DATO Architecture



WP3 is organised as a support process including the integration and evaluation of consistent and coherent baselines for DATO system-of-systems description.

To facilitate integration, the most pressing concern for WP3 is to provide architecture guidance.

While the System Pillar is developing its reference architecture and FP2-R2DATO WPs are applying specific design choices, there is an opportunity to define an “applicable architecture” to integrate existing system knowledge and identify system coherence risks/issues as early as possible in the design process.

System Architecture approaches from **System Pillar** should not create conflict with the steps engaged within R2DATO and, on the contrary, the parallel developments should be complementary regardless:

- They have different scopes and different levels of abstraction,
- They have different timelines and stakeholders,
- They have different concerns and objectives (system design targets, consolidation versus innovation, level of maturity, top-down vs bottom-up approach).

DATO Systems Architecture should be performed in order to support the decision making in relation to specific concerns for the design of systems. Therefore, before defining relevant views, it is key to precisely identify and understand what perspectives are required from an Engineering point of view and which problems they are intended to solve. The system architecture is to be used as both prescriptive and descriptive asset as well as a tool to raise the right Engineering questions and to help solve them. At this stage, WP3 has focused on consolidating existing knowledge, therefore the

ambition is to progress on system description. **When the description of architectures and their open points are aligned within FP2-R2DATO and with the SP, FP2-R2DATO TMT may prescribe the application of WP3 architecture guidance.**

It is clear that the complexity of DATO requires to tackle several concerns and that these concerns should be tackled at different granularity.

Some themes are transverse to the different concerns identified and can be discussed at all applicable granularity and are therefore presented here below:

- Building an architecture for DATO systems is the opportunity to build a systematic **traceability between the needs** (e.g. contribution of DATO towards EU Rail KPIs) **and the products** (and concrete prototypes) developed in FP2-R2DATO WPs,
- The system architectures should help to analyse the business (e.g. cost and benefit) and legal (e.g. TSI) **implications of a design choice** (e.g. accountability or competition in the railway sector),
- The system architectures should cover the nominal cases but also the degraded ones and the associated design elements for recovery. The architecture guides and relies on specific product development and system deployment to **limit variants** and decide on necessary redundancy.
- The system architectures should allow to **define and assess several design alternatives** to perform trade-off and globally optimize the design, at Railway System scale (exploration within multi company structure of the railway sector),
- The **system architecture prepared in WP3 shall be synthetic** (i.e. remain on a low level of detail in order to be understandable and to avoid the reader to be drowned by details) and traceable with engineering information developed in FP2-R2DATO WPs,
- The architecture shall be refined up to a level where the contribution of each cluster/WP is clear.

The following sections explain how the development of the architecture is addressed through:

- **Understanding the architecture context**, known as the *System of Interest*, in order to understand responsibilities, clarify expectations, and streamline communication throughout the project's lifecycle.
- **Creating a methodological framework** that addresses transversal themes and identified concerns.

Through this approach, the final outcome will be a coherent and consistent architecture that incorporates technical integration to consolidate different points of view, to ensure that engineering work drives clear benefit and is effectively usable within the defined context of the FP2-R2DATO project.

It should be noted that the complete resolution of these concerns may not be possible within this deliverable, but may be achieved through the iterative and recursive nature of systems engineering.

2.2 PURPOSE OF ARCHITECTURE DEVELOPED

Several Systems Engineering activities for the Control-Command Signalling (CCS), and Railway System in general, are currently in progress in FP2-R2DATO project and also beyond (especially in System Pillar). There are pending System Pillar outcomes and related sector decisions on what the CCS reference architecture should be. The different workstreams in FP2-R2DATO project address the architecture in a fragmented and isolated way, focusing on their local needs and constraints, and sometimes using different system architectures built in previous projects (X2RAIL-3,-4,-5, OCORA, RCA, Linx4Rail and TAURO). Furthermore, some design decisions become sensitive when development of products and demonstrators have already started.

A limited systemic coherence can lead to failures and delays in FP2-R2DATO project because of the following risks it generates:

- Technical inconsistency between systems developed (integration problems),
- Unmanaged interdependencies between DATO Technical Enablers (responsibility overlaps or gaps),
- Lack of common engineering framework and ontology, leading to slow communication and long or difficult discussions on architecture and interfaces within FP2-R2DATO project and with other FPs in Europe's Rail.

To mitigate these risks, it was therefore key to define how to consolidate and leverage system architecture assumptions that:

- Cover the whole technical scope of FP2-R2DATO project, at the right level of abstraction,
- Define common requirements and targets as well as answer concrete Engineering needs for FP2-R2DATO Work Packages,

while:

- Helping to find collaborative work between FP2-R2DATO project and System Pillar,
- Not replacing nor overlapping activities already done in System Pillar.

This document is capitalizing current knowledge on system engineering applied to DATO. It was developed in a gradual approach, using the consensual material elaborated during WP3 collaborative workshops. It provides a comprehensive proposal that addresses both the technical content of system architectures (including the description of technical artefacts, engineering frameworks and methods) and the associated organizational aspects (such as milestones, roles and responsibilities,...). The report contributes to stabilizing and clarifying the current knowledge, vocabulary, hypothesis and working plan around Systems Architecture inside FP2-R2DATO project and beyond. A specific benefit is also to facilitate collaboration and alignment with System Pillar teams.

This document shall now be used as a stepping-stone for FP2-R2DATO to:

- Build deliverable D3.1 (identification of FP2-R2DATO areas of improvement).
- Drive synergies between FP2-R2DATO and System Pillar, thanks to a clear position and vision on Systems Architecture from FP2-R2DATO project
- Support collaboration with other relevant FPs in Europe's Rail.

Finally, lessons learnt, and perspectives of development related to Systems Architecture in FP2-R2DATO project are identified.

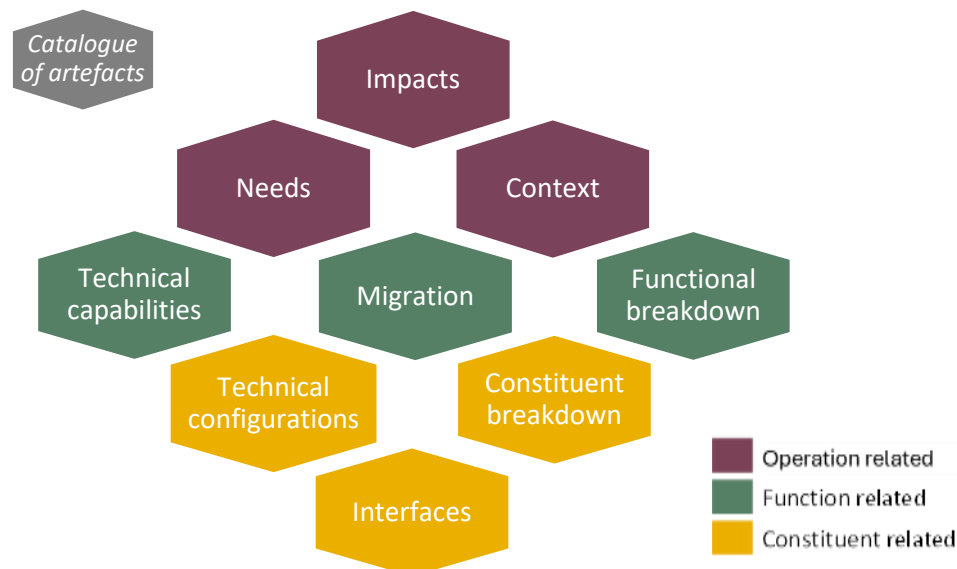
3 IMPLEMENTED ARCHITECTURE METHODOLOGY

This section's purpose is to present the methodology for WP3 architecture development with a pragmatic approach for its continuous refinement and evolution. To summarise, this methodology is built upon an **architecture framework** that models strictly defined, interdependent **artefacts** represented in **views**.

3.1 ARCHITECTURE FRAMEWORK : HOW MODELING IS ORGANISED

The Architecture framework defines **how the architecture is described**: what information is described, where it is described, for what purpose, and with which associated syntax, to ensure all project members and stakeholders have a common vocabulary and understanding when contributing to or using the architecture.

Figure 2: Architecture Framework simplified representation



First, the Framework describes DATO solutions from **3 different perspectives**, that we want to be able to analyse separately and relate together. Those perspectives are:

- **Operation:** how DATO solutions are used and operated, associated needs and constraints
- **Function:** how and how-well DATO solutions behaves, independently from its constituents,
- **Constituent:** how DATO solutions are built to implement the function perspective and satisfy the need perspective

To analyse those perspectives at a sufficient level for project collaboration, each perspective is made of **artefacts** represented in **views**:

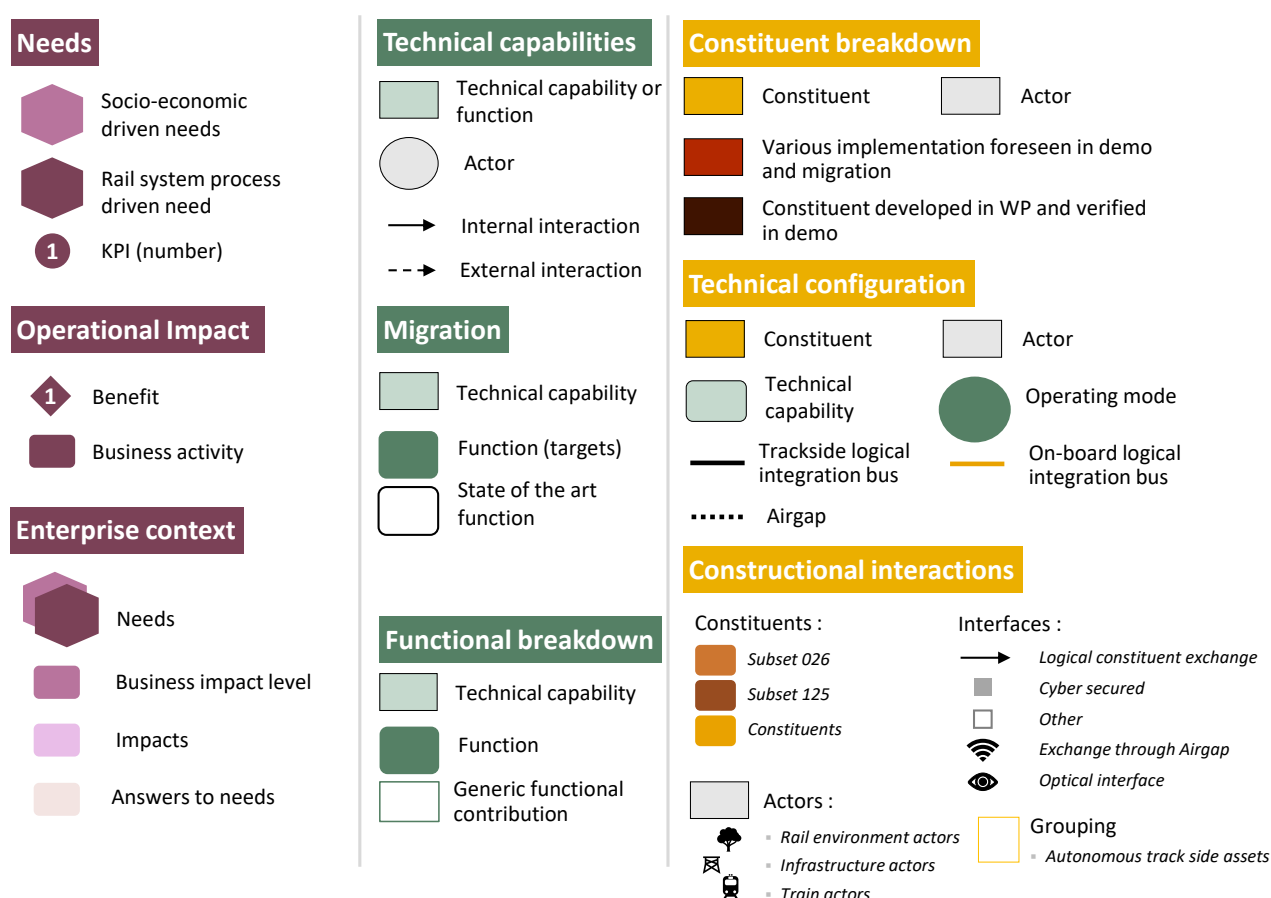
- **Artefacts:** Information with a precise engineering definition, that can be represented in multiple views. For instance, the *actor* artefacts appear in the technical capability view and in the constructional interaction view.
- **Views:** Visual representation of a meaningful set of artefacts. For instance, the *technical capabilities view* represents 4 artefacts: technical capabilities, actors, internal interactions and external interactions

Other methodological considerations such as Milestones, Roles and Responsibilities, Validation, Configuration management, change management and Tooling & Data as well as a more detailed description of the method is provided in the Appendices 7.1 & 7.2. The challenge is indeed not only to build an architecture but to find the process through which the architecture can gradually integrate new knowledge gained by FP2-R2DATO WPs and by the SP on CCS technology.

3.2 ARCHITECTURE CONTENT : WHAT IS MODELED

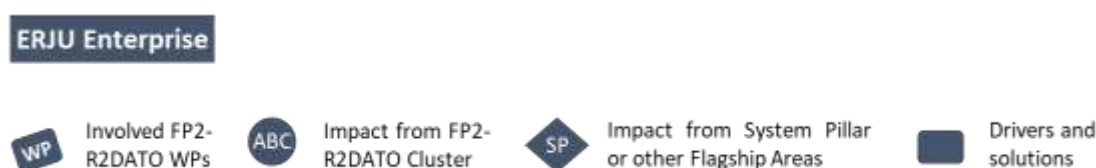
Once the structure of the Framework known, we can detail its content. The figure below defines what artefacts are described, with their official and stable syntax, and the views in which they appear:

Figure 3: Architecture semantics, showing the artefacts and views of the Architecture framework



To ease responsibility sharing for the ERJU Enterprise, the following tags are also introduced:

Figure 4: Special ERJU Enterprise tags on view content

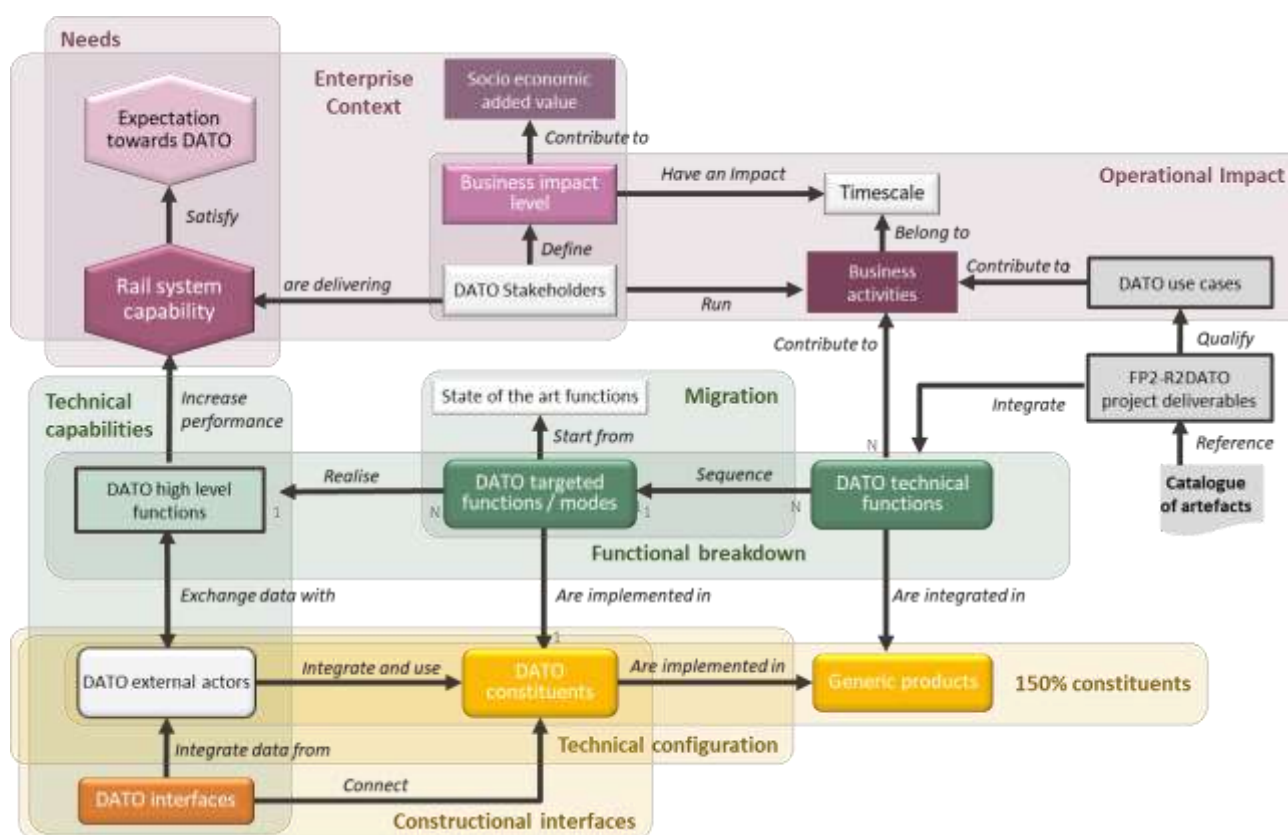


Important note: all these tags are a reflection of FP2-R2DATO. They will be updated according to any new collaborative activities in the frame of ERJU.

3.3 ARCHITECTURE METAMODEL : INTERDEPENDENCIES IN THE MODEL

To ensure need-to-solution consistency, the artefacts are related to each other through logical links that are described in the diagram below, called architecture metamodel.

Figure 5: Architecture metamodel, showing the logical relationships between artefacts



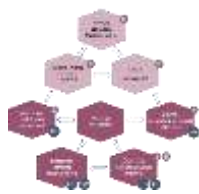
3.4 DEFINITION OF THE VIEWS

This section describes the **objective** of each view of the framework, i.e. the *intention* with which they were built : what do we want to learn from each view ? To ease the linking with the rest of the document, views are shown as a thumbnail.

- The full details of views are in chapter 5.
- The level of detail of each view, and the handover with WP & SPs is discussed in Chapter 4.

Operation perspective

Objective : Understand the operational use and business context of the DATO system of systems, in order to fully capture the related needs and constraints. It is about taking an external perspective on the system to secure its integration into its operational environment



Needs view

Identify the expectations placed on FP2-R2DATO project to enhance the performance of the EU railway system, from both socio-economic and process considerations, in order to determine where efforts should be focused for DATO solutions to generate a tangible impact on the railway system



Operational impacts and lifecycle views

Show how DATO solutions enhance rail system lifecycle activities - from long-term planning to real-time operations, by improving stakeholders' processes (suppliers, IMS, RUs) across timescales, with each improvement mapped to the relevant FP2-R2DATO cluster

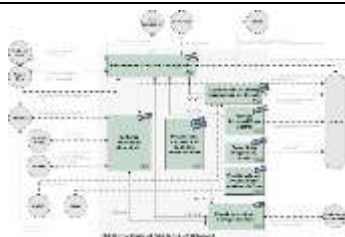


Enterprise context view

Illustrates how FP2-R2DATO project, through the use of its drivers and solutions, aims to address the key needs of the EU railway sector, across different business levels (strategic, tactical, and operational) to generate impacts on the activities of the main railway stakeholders (suppliers, IMS, and RUs).

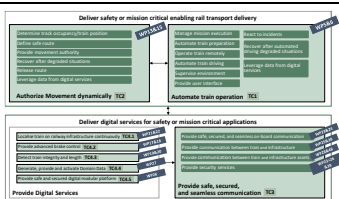
Function perspective

Objective: Understand the behaviour of the DATO system-of-systems to ensure it addresses needs and constraints, while defining functional perimeters, interfaces, and interdependencies of constituents to secure proper integration



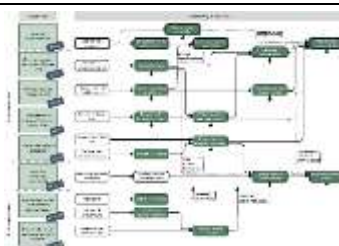
Technical capabilities view

Identify the high-level functions of the DATO system of systems and their external and internal dependencies, independently of technical solutions, to ensure all DATO stakeholders have a clear and common understanding of how the system high-level functions operate.



Functional breakdown view

Decompose the high-level functions of the DATO system-of-systems in functions that can be allocated to constituents and therefore to FP2-R2DATO Work Packages in order to trace WP constraints, assess technological impacts, while avoiding duplications, overlaps, or gaps in the architecture.

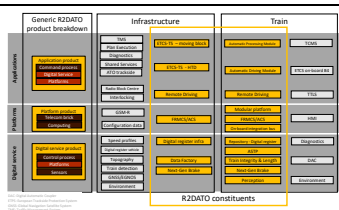


Migration view

Illustrate intermediate steps necessary to bring the railway system from what it is today to the DATO of tomorrow.

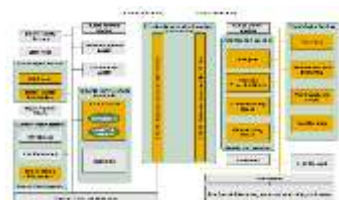
Constituent perspective

Objective : Understand the abstract (logical) and concrete (physical) implementation of constituents, and deployment into various DATO systems of systems, in order to fully capture interface needs and variability and secure their integration into their physical environment



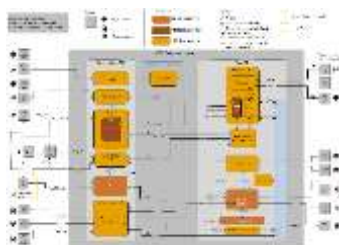
Constituents view

Identify all constituents, independently from their possible and variable physical implementations - software application, digital service, platform – to ensure all necessary functions, technical capabilities and needs are covered, while leaving degree of freedom for concrete definition by WPs.



Technical Configurations view

Highlight all the possible sets of DATO systems of systems, as a consistent set of external actors, needs to satisfy, system capabilities, functions allocated to logical constituents, implemented as integrated physical constituents, in order to identify all DATO system of systems variants and secure their communalities to optimise the overall effort.



Constructional Interfaces view

Identify all DATO constituents' internal and external interactions to approve point-to-point logical interfaces between FP2-R2DATO work packages owning the different constituents. Through 2 views: a high-level diagram with a just sufficient overview to trigger new ideas and input for improvements, associate to a table that provides the description of each interface.

3.5 DEFINITION OF ARTEFACTS

The artefacts (as described in section 3.2) are all collected in a unique location called the **DATO catalogue of artefacts**, with an engineering definition, with the aim to simplify ownership and consistent use by each FP2-R2DATO Work Package. Note that most concepts are included in the architecture framework, but some of them are not, mostly when WP3 is not in responsibility at all:

Railway related	
System	A system is a combination of interacting constituents organized to achieve one or more stated purposes, properties or behaviours.
System of interest	System of Interest (SOI) refers to the system whose architecture is under consideration. The system of interest of the present document is DATO
Rail environment	Any engineered system, natural system, organisation or human outside the rail system.
Rail System	Set of all constituents of the Rail system involved in a transport service, based on their geographical location (as opposed to based on who owns them).
Train	Any moving item within the rail system, including for maintenance.
Infrastructure (syn. Trackside)	Any fixed item (<i>synonym</i> : trackside asset) within the rail system.

Operation perspective	
Actor or Stakeholder (syn. external system)	Any engineered system, natural system, organisation or human that: - interact with the system, through use cases and needs, - influence the system, through constraints.
Benefit	A positive outcome expected as a result of satisfying a need.
Business activity	A set of processes or tasks in the different business impact levels of main railway stakeholders (suppliers, infrastructure managers, railway undertakers).
Need	A need relative to a System of interest is a stakeholder characteristic or constraint, which is unambiguous, clear, unique, consistent, and verifiable, and is deemed necessary for acceptability of the system by its environment.
Lifecycle phase	A lifecycle phase represents a period during which the environment of the system – i.e. the subset of stakeholders that are interacting with the system and the nature of their interactions - is invariant.
Operational scenario	An operational scenario is a dynamic specification of a use case. It describes the sequence of interactions between the system and its stakeholders from the beginning to the end of the considered use case.
Operational flow	An operational flow is the specification of the transfer of one or more items from the system and one of its stakeholders.

Function perspective	
Function	A function of a system models a transformation of a given set of inputs into a given set of outputs by the system.
Technical Capability	A high-level function that the system must deliver in order to satisfy its stakeholder needs and use cases.

Functional Mode	A functional mode represents a period of time during which the behaviour of the system – i.e. the available subset of functions and their levels of performance – is invariant.
Functional requirement	A functional requirement is a system functional characteristic, which is unambiguous, clear, unique, consistent, and verifiable, and is deemed necessary to cover needs.
Functional scenario	A functional scenario represents a sequence of interactions between the functions of the system and with its stakeholders, from the beginning to the end of a considered use case.
Functional flows	A Functional flow is the specification of the transfer of one or more items between 2 functions of the system or between a function and one of its stakeholders.

Constituent perspective	
Constituent	Any element that constitutes the system.
Technical configuration	Fixed definition of a given system that can be traced to specific requirements and performances.
Constructional requirement	A constructional requirement is a system structural property, which is unambiguous, clear, unique, consistent, and verifiable, and is deemed necessary to cover needs or functional requirements.
Constructional scenario	A constructional scenario represents a sequence of interactions between the constituents of the system and with its stakeholders, from the beginning to the end of a considered use case.
Constructional flows	A constructional flow is the specification of the transfer of one or more items between 2 constituents of the system or between a constituent and one of its stakeholders.

3.6 MATURITY OF THE METHODOLOGY

The methodology presented so far has been developed as a derivation of the CESAM framework, which is recognized for three main qualities:

- **Simplicity:** it uses only the minimum number of concepts required to fully describe a system.
- **Rigor:** it is grounded in formal mathematical logic, with precisely defined concepts that have been demonstrated and validated.
- **Practicality:** it has been widely applied across a broad range of industries, always with some tailoring but without any major structural gaps or inconsistencies.

In addition, the chosen methodology was developed to secure consistence with arcadia framework and the possibility to use the tool Capella.

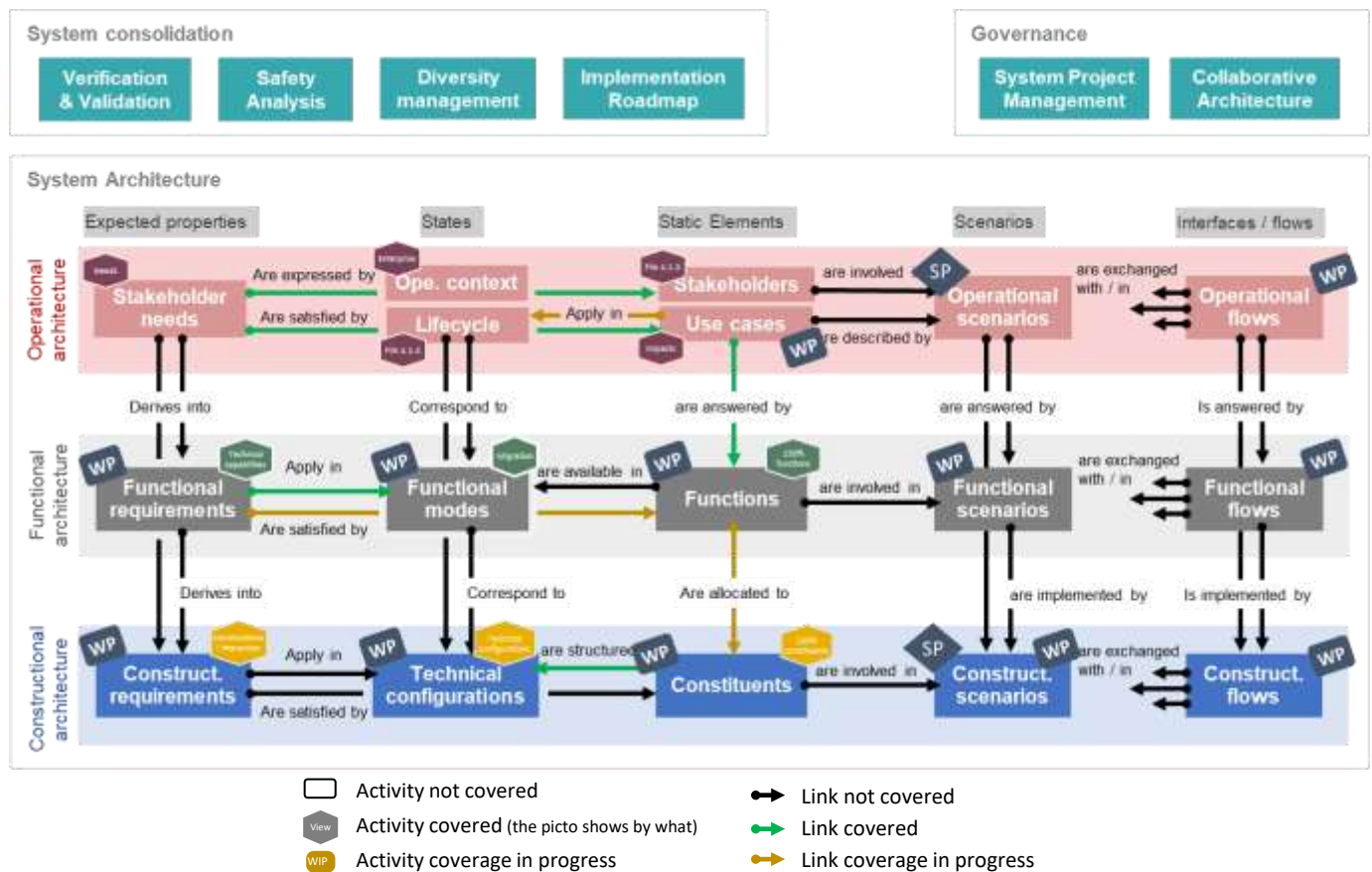
The framework has been adapted to the FP2-R2DATO context and to the specific missions of WP3, as well as WPs dealing with demo or TEs development and beyond the JU context with System Pillar engineering approach. The main adaptations are as follows:

- the number of architectural views – originally 15 – has been reduced to 9, while maintaining nearly the same artefact coverage,
- the vocabulary has been slightly adjusted to remain consistent with railway-sector terminology,

- the level of abstraction to be handled by each work package has been clarified to ensure a smooth handover and clear definition of their intersection points.

Finally, the CESAM framework will be used as a reference for assessing the maturity of the DATO Architecture framework, through a mapping exercise and a coverage statement explaining which artefacts are addressed — and, when not, why they are not required. The current maturity mapping is illustrated on the figure below that takes as a reference the CESAM framework description (more information in the [CESAM Framework internet page](#)):

Figure 6: Evaluation of methodology maturity, based on CESAM Framework



Upon this evaluation, the following methodological disclaimers can be mentioned:

#Levels of Performance: The needs and technical capabilities have been positioned as contributing to the expected properties aspect where the prevalent objective is to define levels of performance used to inform and guide design decisions. Currently, the technical capabilities view is focused on capturing the functionalities of DATO solutions without considering their levels of performance. As a matter of fact, the needs are not all traced to measurable properties of the system either. This is a notable consistency issue to build into the architecture in future iterations.

#Migration: The migration perspective is currently addressed with the perspective of States in a continuous deployment whereby:

- Lifecycle phases contribute to describing the operational contexts that create the need for intermediate steps in the migration.
- Functional modes contribute to describing the various behaviours that the system needs to adopt across the various steps of the migration process.
- The Technical configuration (deployment) view contributes by describing the various physical configurations of the system in its various migration steps.

Indeed, migration to DATO goes beyond the States aspect and implies artefacts from other aspects.

4 COLLECTIVELY OWNING AND REFINING THE ARCHITECTURE

4.1 ARCHITECTURE AT THE HEART OF COLLABORATION

While chapter 3 describes the methodology used to define the Architecture of DATO solutions, it is important to remember that this methodology is **not static**. It is a living framework that evolves through continuous collaboration between Work Packages and System Pillar – the main teams who ultimately build, use, and benefit from the architecture.

The quality and consistency of the architecture depends directly on how these teams interact, challenge, and refine the architecture together, through a collaboration process proposed in this chapter, and structured around a few shared fundamentals:

1. **Collaboration is iterative:** The architecture matures gradually through successive refinements. Each iteration consolidates understanding, aligns viewpoints, and integrates feedback.
2. **The architecture is never final:** Its evolution is a strength, not a weakness. Collaboration continuously challenges and improves it as knowledge grows and system constraints evolve.
3. **Transparency of maturity and decisions:** Everyone should understand the current level of maturity of the architecture and the rationale behind key decisions. This transparency builds trust and ensures that each team uses and challenges the architecture appropriately.
4. **A common language and shared understanding:** Collaboration relies on a shared vocabulary of concepts, models, and representations. A common language is what allows alignment between disciplines, tools, and viewpoints.
5. **Complementary responsibilities and balanced autonomy:** FP2-R2DATO and SP have their own scope and objectives, but consistency emerges at their intersections. Collaboration means balancing local autonomy with global alignment, - neither can exist without the other.
6. **Architecture as both outcome and enabler of collaboration:** Collaboration shapes the architecture, but the architecture also structures collaboration by clarifying interfaces, roles, and decision boundaries. It becomes both the result and the medium of collective work.

4.2 THE SYSTEMS OF INTEREST AROUND DATO

To effectively collaborate around the FP2-R2DATO project, it is essential to clearly distinguish between three interrelated but distinct systems of interest. These are often referred to interchangeably, which can lead to misunderstandings. Each has its own mission, lifecycle, and needs:

1. The DATO solutions

This is the integrated set of constituents that will evolve over time and provide services to all its end users - referred to as **DATO Actors** – within the European Railway System. It is the system being delivered. *We could think it as the **Product system**.*

2. The DATO Stakeholders

These are the teams who are responsible for operating DATO in a live context.
*We could think it as the **Owning system**.*

3. The ERJU enterprise

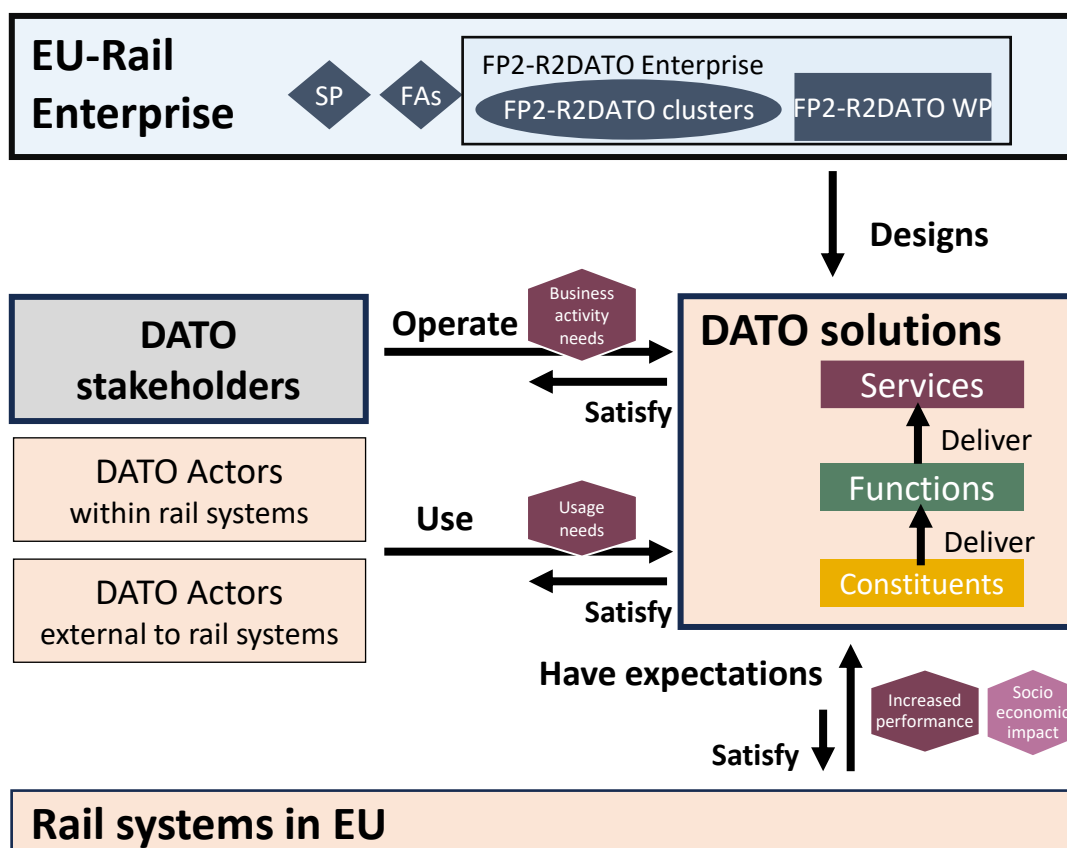
This refers to the teams and processes responsible for collecting needs from the DATO actors and DATO stakeholders, specifying and designing the DATO solutions.
*We could think it as the **Project system**.*

The DATO solutions are designed by the ERJU enterprise to achieve the best **compromise** between:

- **Integration in the Rail systems in EU**, for increased performance and socioeconomics impacts.
- **Usage by DATO actors**, to improve daily operation services.
- **Operation by the DATO stakeholders**, for improved operation-related business activities.

This articulation is summarized on Figure 7 :

Figure 7: The systems of interest (with thick black border) around FP2-R2DATO



4.3 COLLABORATION IN PRACTICE

The following process description builds on the experience gained over the 3 releases of DATO architecture. The process is building on System experts best practice but it was not practiced yet in a formalized and extensive way as FP2-R2DATO project did not start with an integrated architecture governance. The collaborative process presented in this section is a practical approach that could be implemented for future development in order to secure good alignment and synergies across all DATO solutions.

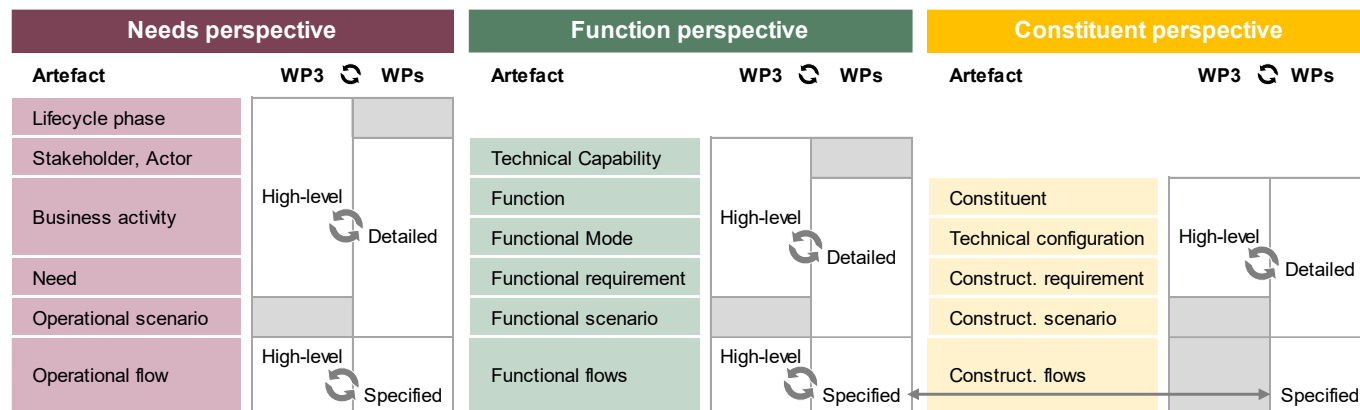
Where are the ‘intersections’ between WP3, WPs and SP?

The figure below illustrates the *distribution of information* between WP3 and the Work Packages, in other words, who is responsible for which artefact, and at what level of detail.

Three levels of detail for views and artefacts are introduced:

- **High-level:** mainly used to ensure an initial level of completeness and consistency. It provides a global understanding of the system but remains voluntarily generic not to interfere with design.
- **Detailed:** used to ensure the appropriate level of precision and specificity required for design. It is typically obtained through the breakdown and specialization of higher-level. Each detailed view must also remain consistent with all related artefacts, following the links defined in the metamodel.
- **Specified:** a detailed view complemented by explicit specifications, typically for defining interfaces.

Figure 8: Distribution of artefacts and handover between WP3 and WPs



For example, WP3 defines the high-level actors. Why at a high level? Because such a shared view is necessary for all work packages to align on a common understanding of the DATO solution boundaries.

WP3, however, cannot go into a detailed level of definition, as this level will emerge naturally from the constituent technologies, which will determine the specific actors and their interactions.

Explicit responsibilities aligned on the architecture

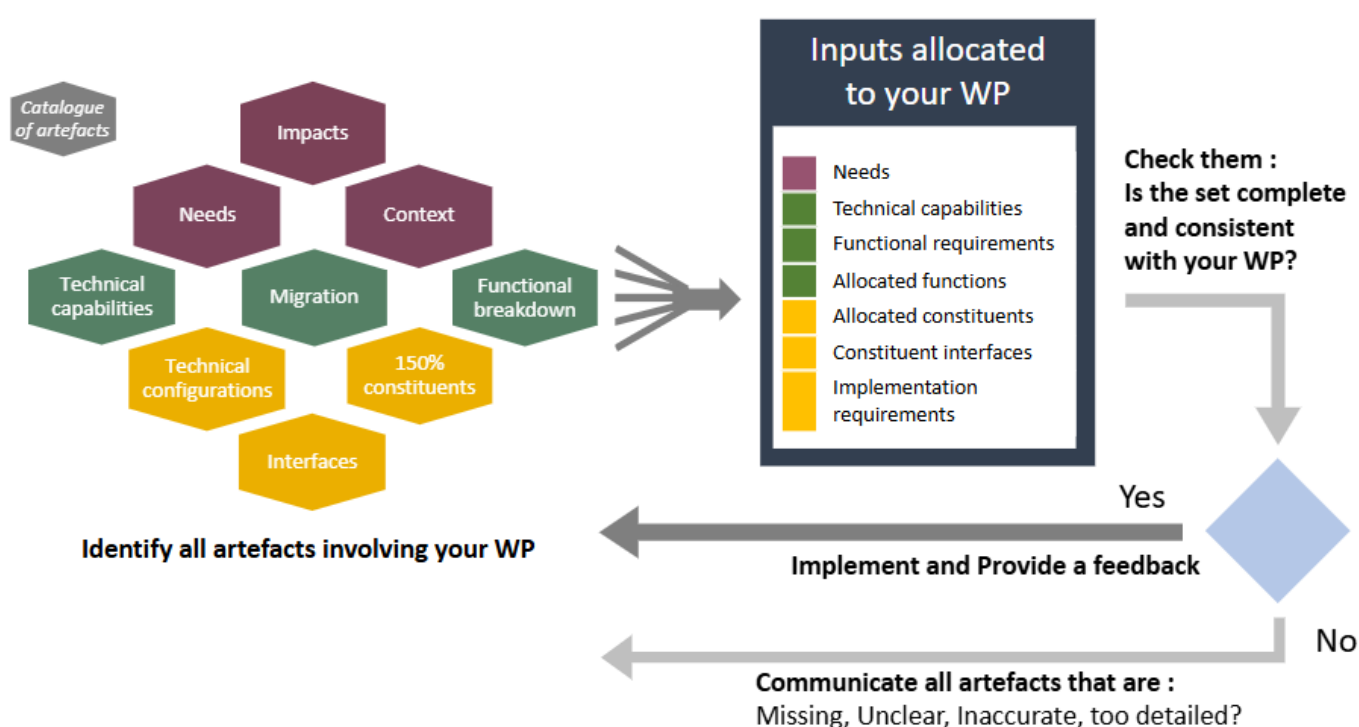
To ease the handover of artefacts to work packages, all artefacts are tagged with the work packages in charge of them or contributing to them, both on each view (where this is relevant) and in the catalogue of artefacts:

What is expected from WP teams

Helped by the tags, each Work package can:

- Collect the artefacts tagged with their WP (e.g. a constituent) together with the associated artefacts (e.g. the interfaces of that constituent)
- Check the consistency and completeness of these artefacts (rather high-level) against their own, understanding of their and objectives (rather detailed).
- Challenge or implement these artefacts and provide feedback to the architecture level, in order to manage cross-WP dependencies and ensure that specifications activities across FP2-R2DATO remains globally optimized and coherent.

Figure 9: Iterative and collaborative approach between architecture and WPs



4.4 MATURITY OF THE ARCHITECTURE

The following points are worth highlighting as “disclaimers” about the achieved maturity:

#Level of detail suitability: In the development of the views, a recurring question was about the level of detail that had to be developed. There is no systematic answer to the question, and in the context of DATO solutions development, the right level of detail is the one that enables useful discussions with the FP2-R2DATO WPs. Hence the aim for notably functional and constructional views is to develop enough detail to be able to allocate artefacts to FP2-R2DATO WPs.

#Consistency between views

Compared to the previous revision, all diagrams have now a consistent semantic and appearance, and some major cross-view links have been developed. As there are still some links not yet implemented (see §0), there may still be inconsistencies across the views. This consistency is intended to be addressed in every iteration and does not prevent at all to start using the views.

#Consolidation with WPs

The validation of the views will imply further review of the FP2-R2DATO WPs to challenge and improve the proposed views.

#Alignment with SP

As well as with the FP2-R2DATO WPs, the views may also be challenged by the reference architecture provided by SP. There will also be a necessary degree of alignment with SP to consolidate the views.

#Cybersecurity

Cybersecurity constraints have not yet been fully analysed and should be part of future iterations.

4.5 ROADMAP

The following figure shows in a synthetic way the development process up to the R3. As explained previously, this report's aims are gradually progressing towards the D3.1 deliverable, set as the endpoint of the roadmap.

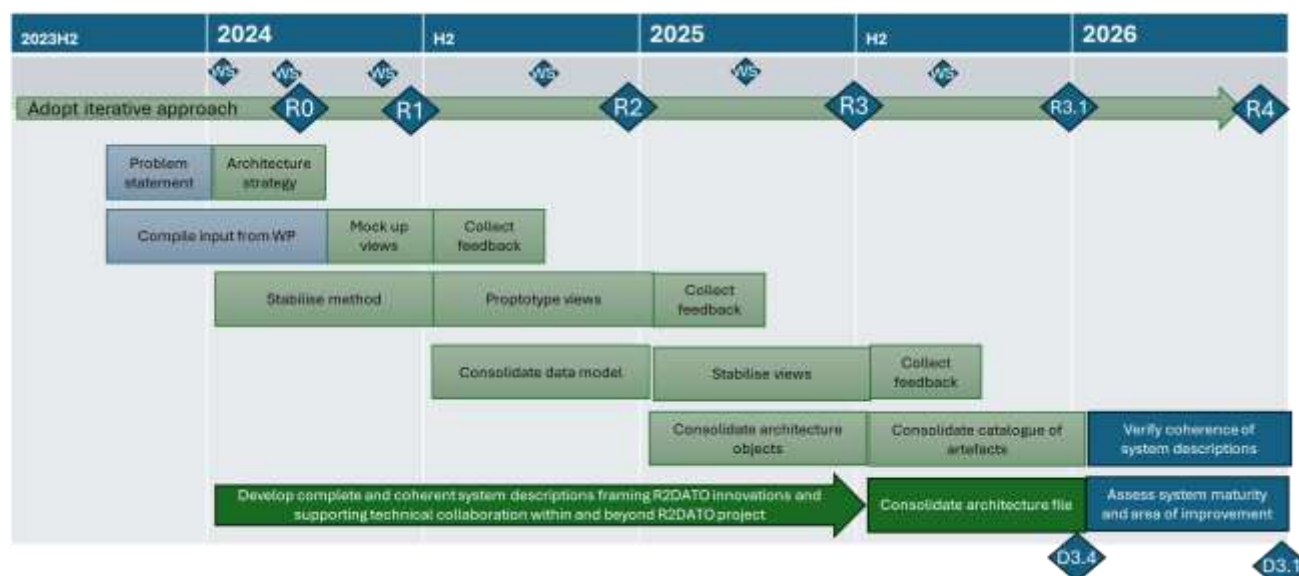


Figure 10: Development plan

Note: in this figure, “R2DATO” is to be understood as FP2-R2DATO project.

From the maturity review and listed open points in the views, the following list of considerations shall be addressed in the next steps:

- **Collaboration** (Consolidation with WPs and alignment with SP): One of the objectives of the views is to collect useful feedback on the system through peer review. It is one of the fundamental roles of the architect within a project structure and explains why all of the diagrams have sought to remain easily understandable by any contributor of the system. In the next steps, feedback is therefore sought notably from WP and SP as key stakeholders of the architecture.
- **Validation**: The collaboration should be the first step towards validating the proposed views. The views developed become useful only as soon as they are accepted and endorsed by the stakeholders.

- **Levels of performance:** Currently, this report does not include sufficient considerations on levels of performance relative to the system and this has been identified as a lack. Future development shall aim to address this issue notably through the needs and capabilities views.
- **Migration:** Today the migration considerations are diluted notably in the States views. In the future, the considerations for migration may be refactored into a vision of its own. This can however be considered as a project within the project and the outcome may depend on the resources at hand.
- **Diversity management:** consideration on implementation and technical heterogeneity are today missing. There is a diversity in operational requirements and in industrial approaches that does not always conflict with standardisation but can create complexity for product development and migration.

5 DETAILED DESCRIPTION OF THE VIEWS

This section is dedicated to the detailed description of each view in the framework.

5.1 OPERATIONAL VIEWS

5.1.1 Needs

Figure 11: Needs view

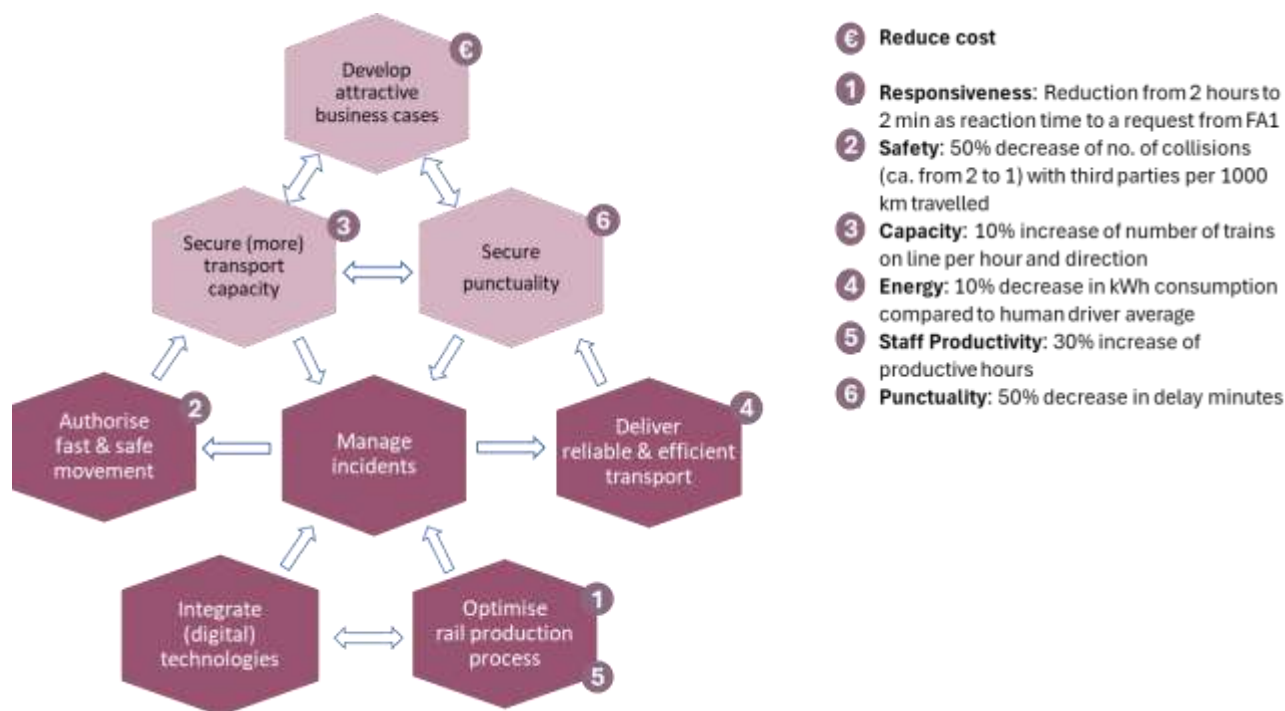


Figure 11: Needs view represents the *Needs View* that captures a set of key expectations of the railway system, understood as needs that must be met to improve the efficiency, reliability, and competitiveness of EU rail transport. These expectations reflect both the external demand from society and the market, as well as internal needs of the railway system.

The expectations are grouped into two main categories:

- Socio-economic expectations: These stem from high-level strategic objectives, such as increasing the competitiveness of rail transport, contributing to sustainable development, and improving the quality of service offered to users.
- Rail system process-driven expectations: These correspond to operational and technological processes that the railway system must optimise in order to respond effectively to external demands.

This structure highlights how operational improvements within the railway system must be aligned and connected with the sector's strategic objectives.

As shown in Figure 11: Needs view, the FP2-R2DATO project contributes to meeting these expectations through the coordinated work of its different functional clusters, each with a specific technical-operational focus. Each cluster contributes to the development of functionalities, processes, and technological solutions that address one or more of these expectations.

At the same time, the impact of the FP2-R2DATO project in terms of how well it meets the expectations will be assessed through KPIs, which provide an objective measure of the extent to which these expectations are being fulfilled. The alignment between needs, KPIs, and cluster activities is one of the fundamental tasks of FP2-R2DATO, ensuring that technical advancements are directly linked to the operational objectives of the European railway system.

Maturity & Open Points

#Technical scope: The current view focuses on some of the key expectations towards DATO and remind existing KPIs. Further considerations are need for new KPIs with qualified targets & measurement method.

#Needs as system requirements: Refine and agree on the definition of each need so that in the next iteration of the DATO architecture, all needs can be formulated as system requirements.

#Consolidate the railway system context: understand the interaction between the needs and map other key capabilities of the railway system related to DATO use cases.

#KPIs & State of the art: Investigate state-of-the-art and targeted performance parameters.

5.1.2 Lifecycle and Operational impact

Figure 12: Lifecycle view

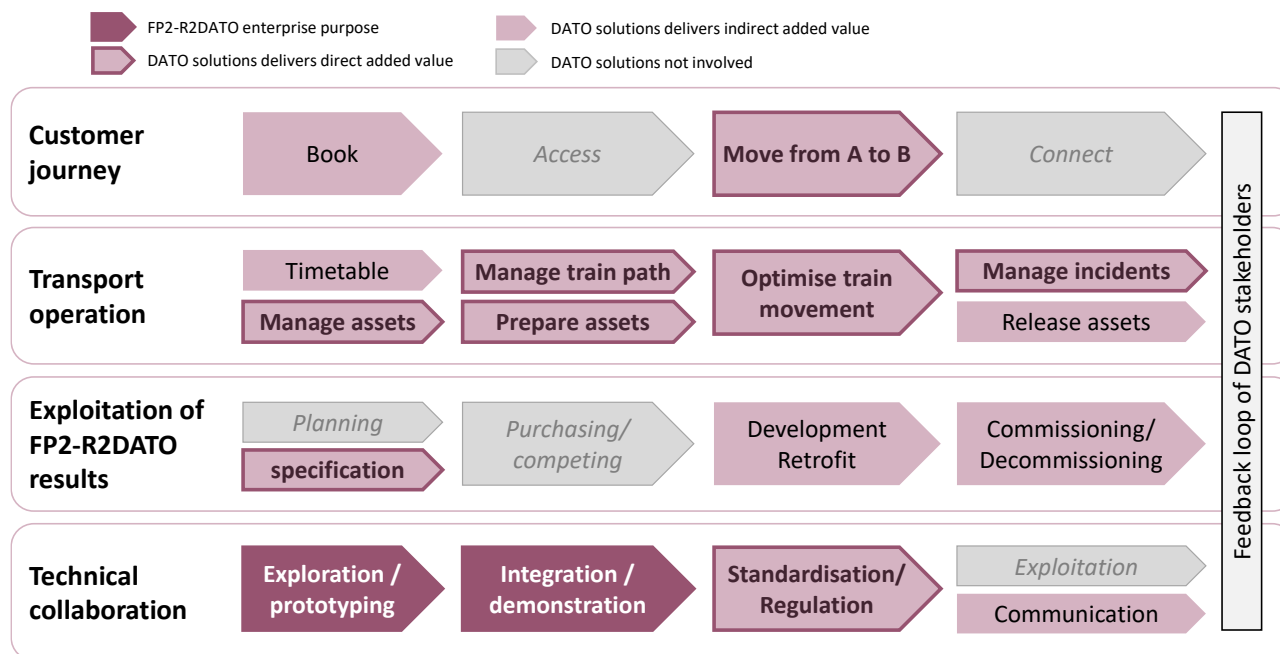


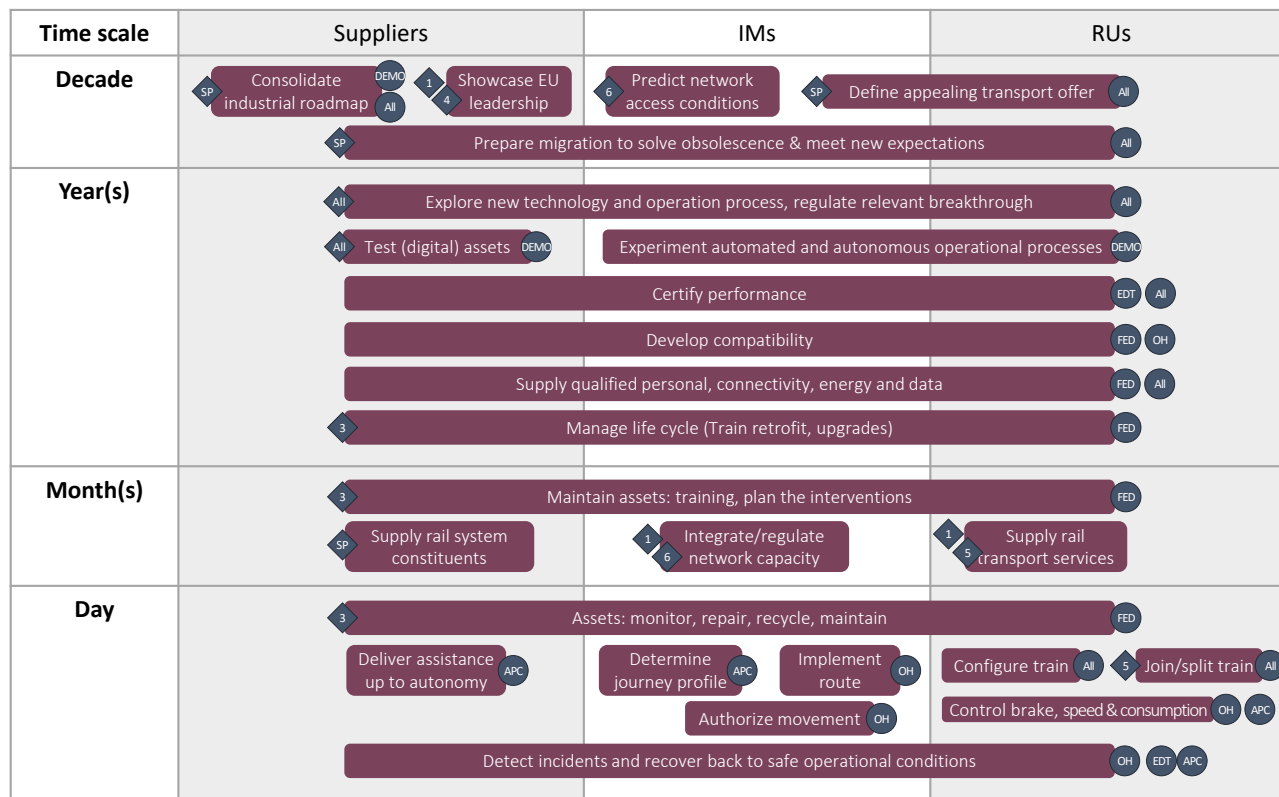
Figure 12: Lifecycle view is separated in four different lifecycles that are interdependent: Customer journey, Transport operation, Exploitation of FP2-R2DATO results, and technical collaboration. Each of these lifecycles is then refined in different phases where some can be performed in parallel.

The view gives with the colouring of arrows a preliminary identification of DATO expected contributions.

- **Customer journey lifecycle:** Looking outside the railway system, DATO can contribute to customer satisfaction. As a passenger and or charger, rail customer should have access to abundant offers (DATO contributes to more capacity). The customer should primarily benefit from a reliable transport service when using it to move from A to B (DATO can help traffic and operational robustness)
- **Transport operation lifecycle:** Looking within the rail system, DATO creates new solutions, assets, that optimise network capacity and train movement. With new roles for humans in the system, DATO is challenging incident management.
- **Exploitation of FP2-R2DATO results lifecycle:** FP2-R2DATO results can be exploited for industrialisation and migration purpose.
- **Technical collaboration lifecycle:** Last but not least, DATO is about a collaborative roadmap allowing, over different projects (in the past Shift2Rail, now together with the SP and in the future new wave of flagship projects). There are typical phases in each project and generic maturity targets for each iteration defined through TRL.

The lifecycle view provides the context for the following view – called operational impact view – which lists all the business activities that are performed by various EU-Rail stakeholders and that contribute to developing, maintaining, and more generally, using DATO. To ensure completeness and readability, these business activities are structured around 2 axis: the type of stakeholder performing them (suppliers, IMs and RUs) and the time scale of their duration, from decade to day.

Figure 13: Operational impact view



Representation guidelines:

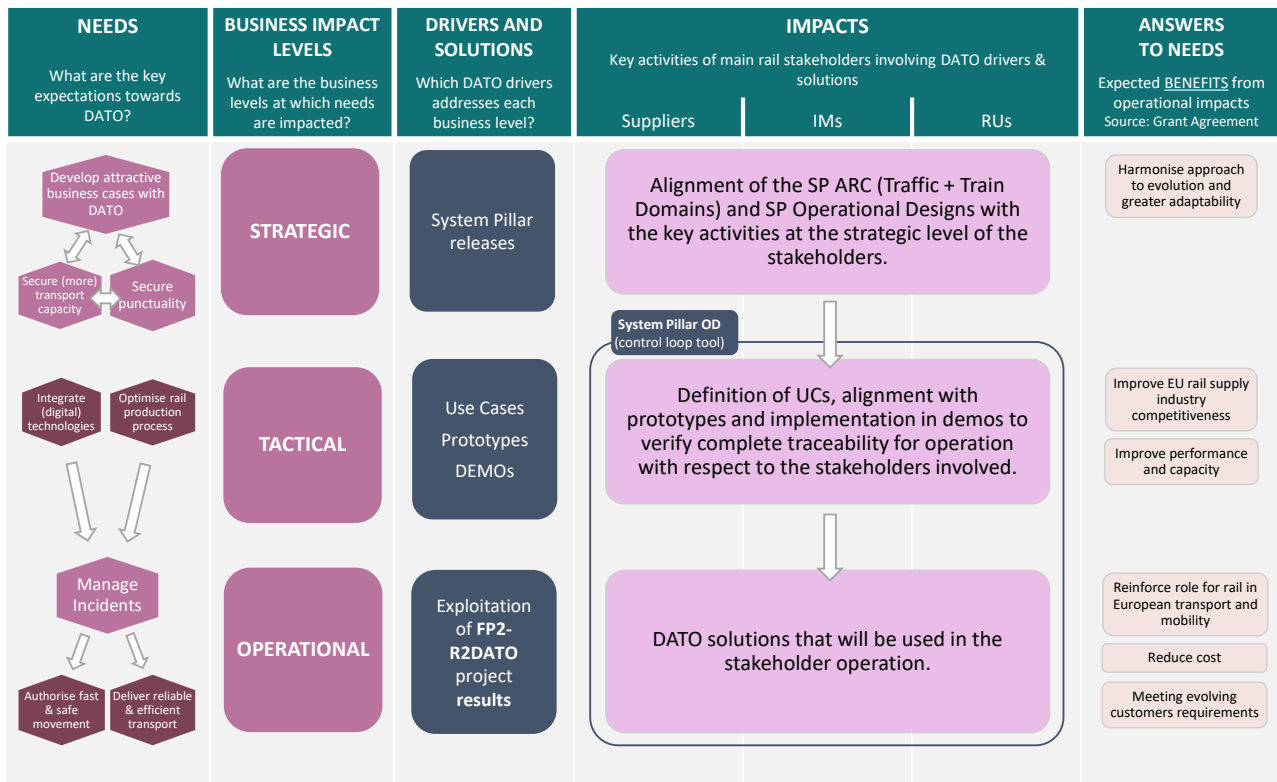
- Business activities
- Impact from FP2-R2DATO clusters
- Expected impacts from SP or other FAs

Maturity & Open Points

#Allocation: It should be clarified which work packages are working on which lifecycle phases and how lifecycles consideration allows to refine approaches, in particular to structure and simplify DATO Use cases.

5.1.3 Enterprise Context

Figure 14: Enterprise Context view



The enterprise context view illustrates how an EU rail sector stakeholder can use DATO to contribute to the lifecycle delivery process and, therefore, address the needs identified in DATO, generating socioeconomic added value (benefits).

To better understand this process in a simple way, we must see the final benefits as responses to the identified needs. These needs will require the use of drivers and solutions, which will be proportional. Through the operational impact they cause, these drivers and solutions will result in the attainment of benefits. This is reflected in the following circular flow diagram.

Figure 15: Enterprise Context flow diagram

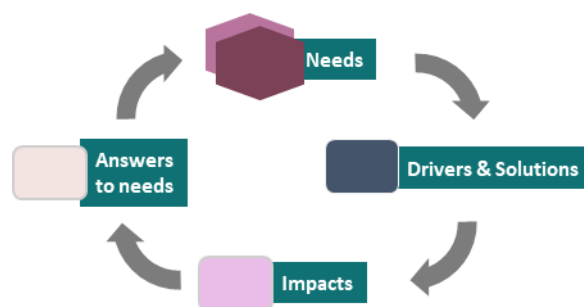
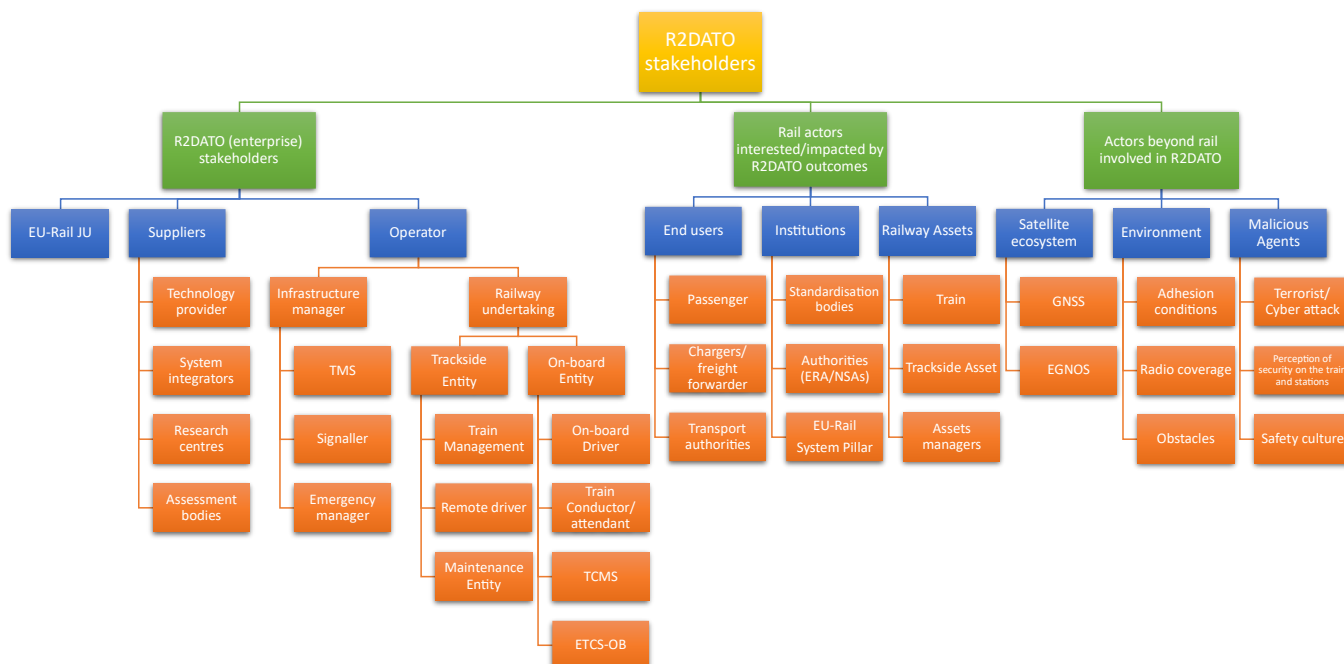


Figure 16: Breakdown of DATO stakeholders



Note: in this figure, “R2DATO” is to be understood as DATO system of systems.

Figure 16: Breakdown of DATO stakeholders captures all the stakeholders in interaction or influence with DATO and organises them into lower-level ones through breakdown links to precisely describe stakeholders from an abstract level down to the FP2-R2DATO WPs level.

FP2-R2DATO WPs should use this view as a reference to define the stakeholders in relation to their work package scope.

Disclaimer: the particularity of this Stakeholders’ hierarchy view is to include both technical systems and operational entities. Therefore, it should be considered as an hybrid view between a strict stakeholder’s hierarchy and a system technical breakdown. This choice is motivated by the aim of displaying all the DATO actors (technical and human) on a single view.

Maturity & Open Points

None other than those mentioned in the disclaimers.

A quick win in the collaboration with SP is to share common definition of the stakeholder breakdown.

5.2 FUNCTIONAL VIEWS

5.2.1 Technical Capabilities

Figure 17: Capabilities view

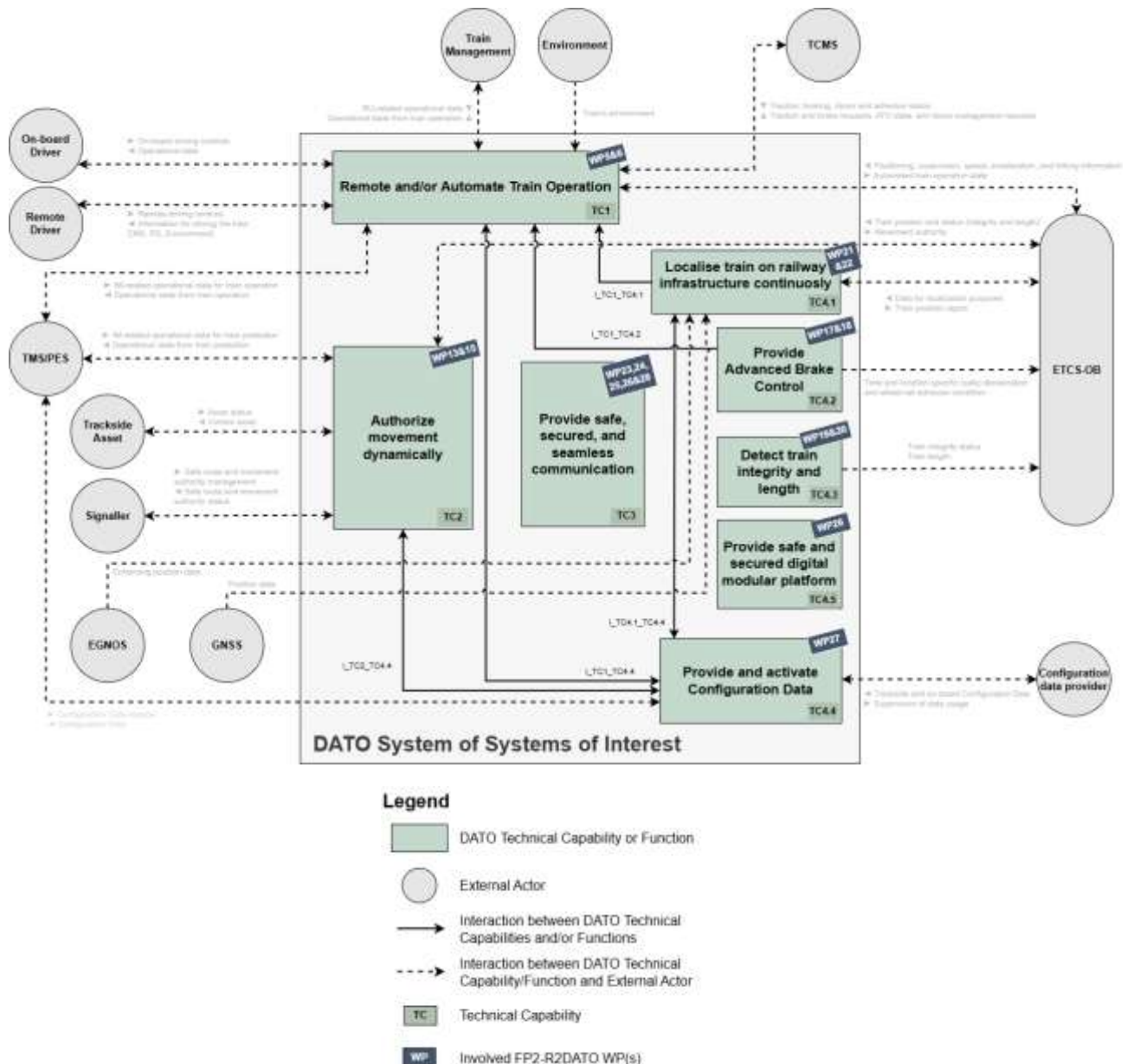


Figure 17: Capabilities view describes the overarching Technical Capabilities and the strategic interactions between them and (external) Actors, rather than diving into specific technical details or implementation methods. This level of abstraction is intentional and aligns with the objective of providing a clear and concise overview of high-level system functionalities and their relationships. It helps to understand the system's broad architecture without getting overwhelmed by complexity.

The assumption taken for defining this view is that a Technical Capability is a high-level function (at the level of stakeholders). A Technical capability is a service an actor requires from the system to fulfil its business goals. Technical capabilities are realised by exploiting one or multiple Functions (Ref.5.2.2 Functional breakdown).

Additionally, it connects with other views, such as the Constructional Interfaces and technical configurations views, as they share the same actors, and the Functional breakdown views as the Technical Capabilities are the starting point from which detailed functions are derived.

Technical Capabilities descriptions:

- **Authorize movement dynamically** is covered by the trackside to allow for real-time authorization of train operations based on current track conditions and traffic. It ensures safe distances between trains, optimizing track usage and reducing delays.
- **Generate, provide, and activate Domain Data** involves the automated dissemination and activation of critical infrastructure data for trackside and on-board systems. This ensures updates and activation of configuration data essential for managing and optimizing system performance.
- **Provide advanced brake control** enables adaptation of train speeds, braking curves based on the current wheel-rail adhesion conditions.
- **Remote and/or Automate train operation** involves using automating functions to control train operations, including driving, remote driving and enhanced on-board perception. This automation enhances efficiency and scheduling precision by reducing human error and optimizing train traffic management on the tracks.
- **Localise train on railway infrastructure continuously** enables the continuous localization of trains on the railway infrastructure, utilizing advanced sensors and communication technologies. It provides real-time positioning data, ensuring precise tracking of each train's location. This capability is crucial for enhancing operational efficiency and safety.
- **Detect train integrity and length** involves continuously monitoring the physical coherence of the train and measures the total length of the train, essential for safe operation and accurate track allocation within the railway network.
- **Provide safe, secured, and seamless communication** ensures the delivery of secure and uninterrupted communication channels. It incorporates robust encryption and continuous connectivity solutions to maintain data integrity and privacy. This functionality is crucial for preventing unauthorized access and ensuring reliable transmission of information across the network.
- **Provide safe and secured digital modular platform** focuses on delivering a digital modular platform that ensures robust security and safety for applications.

Maturity & Open Points

#Technical Scope: This view covers the main scope of the technical enablers of FP2-R2DATO. It covers mainly the work done in the specifications WPs.

The technical capability *Remote and/or automate train operation* could also explicitly consider, in future iterations, the assistance to external actors.

#Level of detail: The level of details is sufficient to cover the main and high-level DATO functions. It could be developed further to:

- Cover new capabilities and External Actors
- Cover additional dependencies between the capabilities and between the capabilities and Actors
- Apportion specific targets in relation to KPIs
- Refine terminology

- Adding layers to view different levels of detail or to highlight specific interactions or operational impacts could enhance understanding. However, the view as it is, covers the relevant interactions and exchanges (interfaces) that contribute to DATO needs.

#Interfaces: The view illustrates the main information exchange flows between the DATO Technical Capabilities and External Actors to convey the range of services a stakeholder requires from the system to fulfil its business goals. Interfaces are added between technical capabilities. The interface between *Provide advanced brake control* and *Remote and/or to automate train operation* is today still an open point: there is a logical link and information to exchange between the 2 functions but the physical architecture for the related constituents may be decoupled.

#Levels of performance: As per the disclaimer at the beginning of this section, the DATO Technical Capabilities view should eventually prescribe functional levels of performance on the system.

5.2.2 Functional breakdown

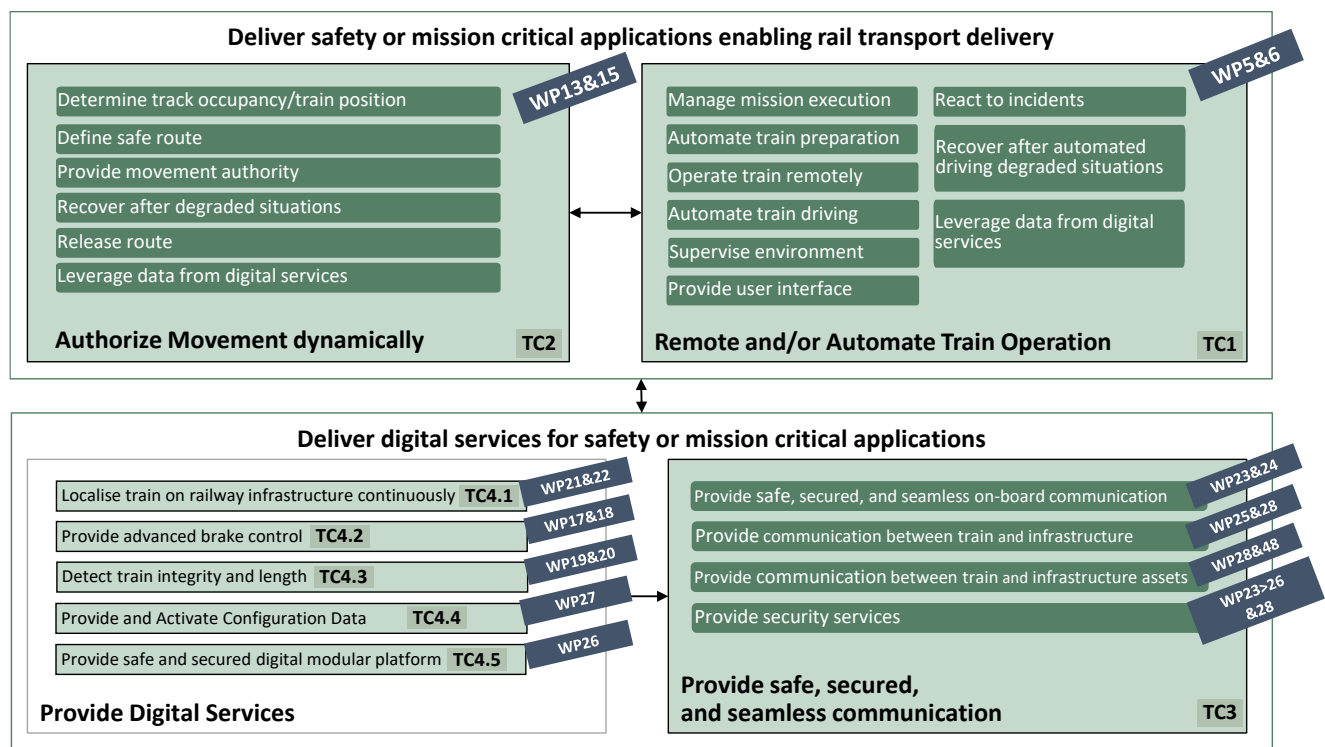


Figure 18: Functional breakdown view

The DATO Functional breakdown view comprises four basic functional groups:

- **Remote and/or Automate Train Operation**, which corresponds with the Technical Capability 1 (TC1) of the DATO Technical Capabilities view.
- **Authorize movement dynamically**, which corresponds with the Technical Capability 2 (TC2) of the DATO Technical Capabilities view.
- **Provide safe, secured, and seamless communication**, which corresponds with the Technical Capability 3 (TC3) of the DATO Technical Capabilities view.
- **Provide Digital Services**, defined as a cluster of other DATO Technical Capabilities.

Each functional group is decomposed into lower-level functions or Technical Capabilities that stem from FP2-R2DATO WPs. The Catalogue of Functions file further elaborates the view by listing the complete set of functions deemed as relevant to the architecture consolidation. Such file contains the Catalogue of Functions itself, where each function is characterized by:

- Constituent type, which defines whether the function is performed by an infrastructure-based or train-based asset.
- Responsibilities, which indicates the FP2-R2DATO work package the function is specified in.
- Technical Capabilities Relationships Matrix, which establishes the links between the Technical Capabilities acting as “father” functions. These links are likewise represented in the DATO Technical Capabilities view by means of the arrows.

Maturity and Open Points

The view and the Catalogue of Functions are functional representations of DATO and are coherent with the state-of-the-art outcomes of the specification developments, so the aim is not to cover all CCS related functionalities (e.g. ATO or ATP). Further refinement might include:

- Definition of new/overlooked functions
- Fine-tuning of the already-defined functions so that they adapt to FP2-R2DATO work packages' terminology
- Definition of the Catalogue of Functional Requirements to be mapped to the functions
- Contribution of the functions to FP2-R2DATO KPIs
- FP2-R2DATO WPs should confirm that all their constraints can be traced towards the identified functional blocks. If not, refinement to the view will be needed.
- The function “leverage data from digital services” may need further investigation to facilitate interoperability and migration.
- Innovative Operational Solutions (from FP2-R2DATO iOS cluster) are not yet specifically considered.

5.2.3 Functional Modes (with focus on Migration)

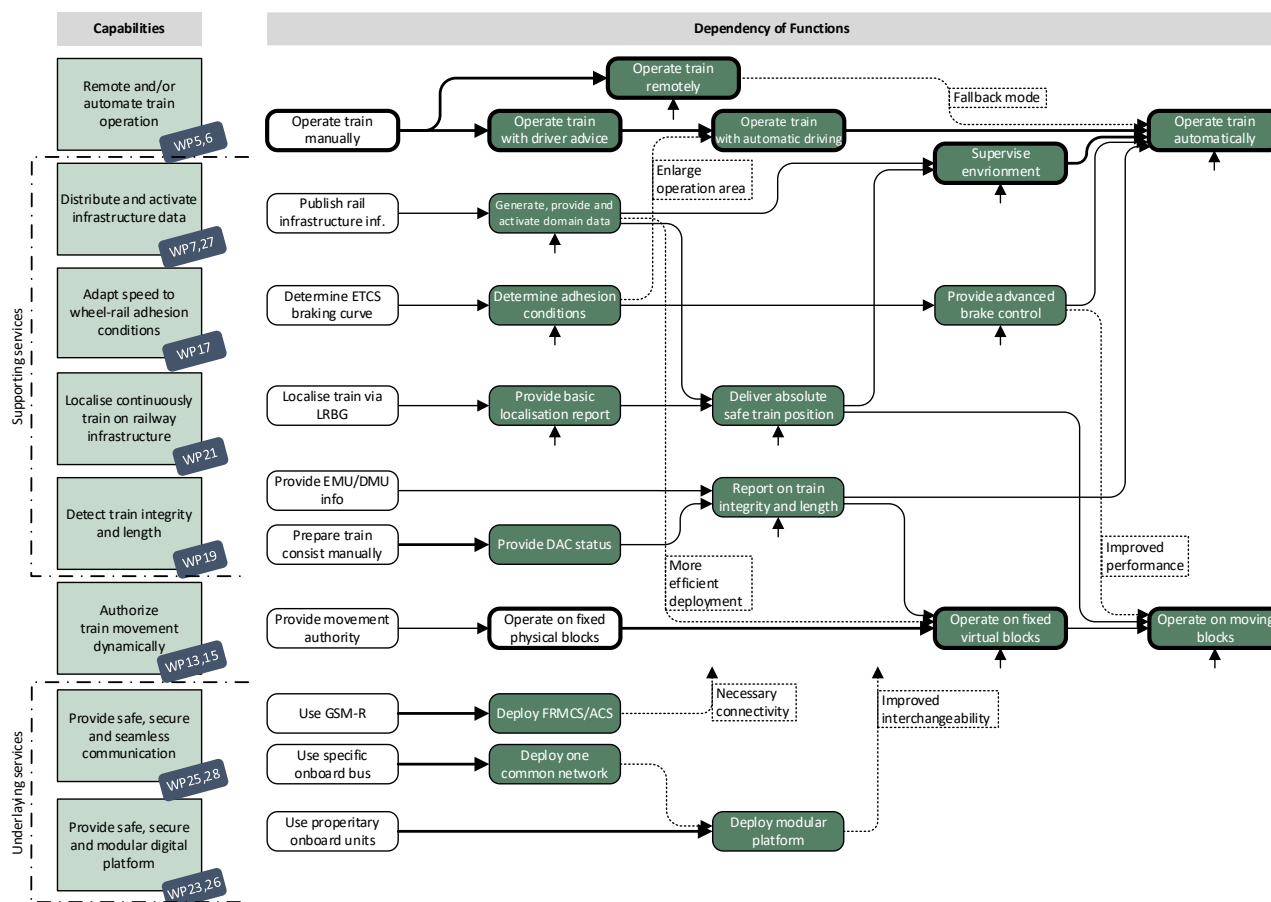


Figure 19: Functional modes (with focus on migration) view

Figure 19: Functional modes (with focus on migration) view shows the functional modes of the railway system following migration paths, which result from dependencies between the involved functions. The DATO capabilities R2DATO Capabilities listed on the left side determine the vertical structure of the view. The different functions R2DATO Functions State of the art contributing to a capability are aligned on the same vertical level. The capabilities 'Remote and/or to automate train operation' and 'Authorize movement dynamically' are the ones, which cover the functional modes Operate ... for operation of the railway. The other capabilities between them are related to supporting services, which cover functions helping to achieve or to improve a functional mode. The capabilities at the bottom are related to underlying services for communication and for the deployment on a modular platform.

The horizontal axis represents a kind of sequence scenario illustrating the dependencies between functions and functional modes but not an absolute timeline. Thus, precedence between the functions is defined along the horizontal axis: The functions more on the left side need to come before those on the right side.

The arrows between the functions indicate their relation. A thick arrow Transition to called 'Transition to' represents a transition from one function or functional mode to another. A thin arrow To be used by called 'To be used by' represents a dependency where a function is necessary for another one. A dashed arrow Improves called 'improves' indicates a relation, where a function can contribute to an improvement of another function. The nature of the improvement is named in the dashed banner Improvement attached to the arrow.

For an envisaged operation in a particular functional mode a suitable system configuration is derived just with collection of the functions following in opposite direction of the arrows.

For example, to 'Operate train automatically' (i.e. unattended train operation in GoA4) it is necessary to have 'Supervise environment' (i.e. onboard perception system for obstacle detection), which further on requires 'Generate, provide and activate domain data' (i.e. provision of track data along the train path) and 'Deliver absolute safe train position' (i.e. provision of precise train location).

For example, to 'Operate train remotely' (i.e. a driver controls the train from remote location) is an own functional mode, which may use all available resources like driver advisory system, automatic driving and/or even a perception system. Further on, it can but does not need to be used as a fall-back mode for 'Operate train automatically' as illustrated in this view.

Maturity

#Technical scope: For the time being, only specification Work Packages from APC, OHC and DETC are included. Prototyping Work Packages, Deployment Work Packages and Demonstration Clusters are not reflected.

#Technical unknown: Interoperability aspects resulting from the specific distribution of functions between trackside and onboard are not illustrated. However, backward compatibility is typically the means to cater for a smooth migration and to guarantee interoperability. For example, a track fitted for ATO up to GoA4 should be also compatible for trains fitted with no ATO or with an ATO up to GoA2 according to an older TSI version.

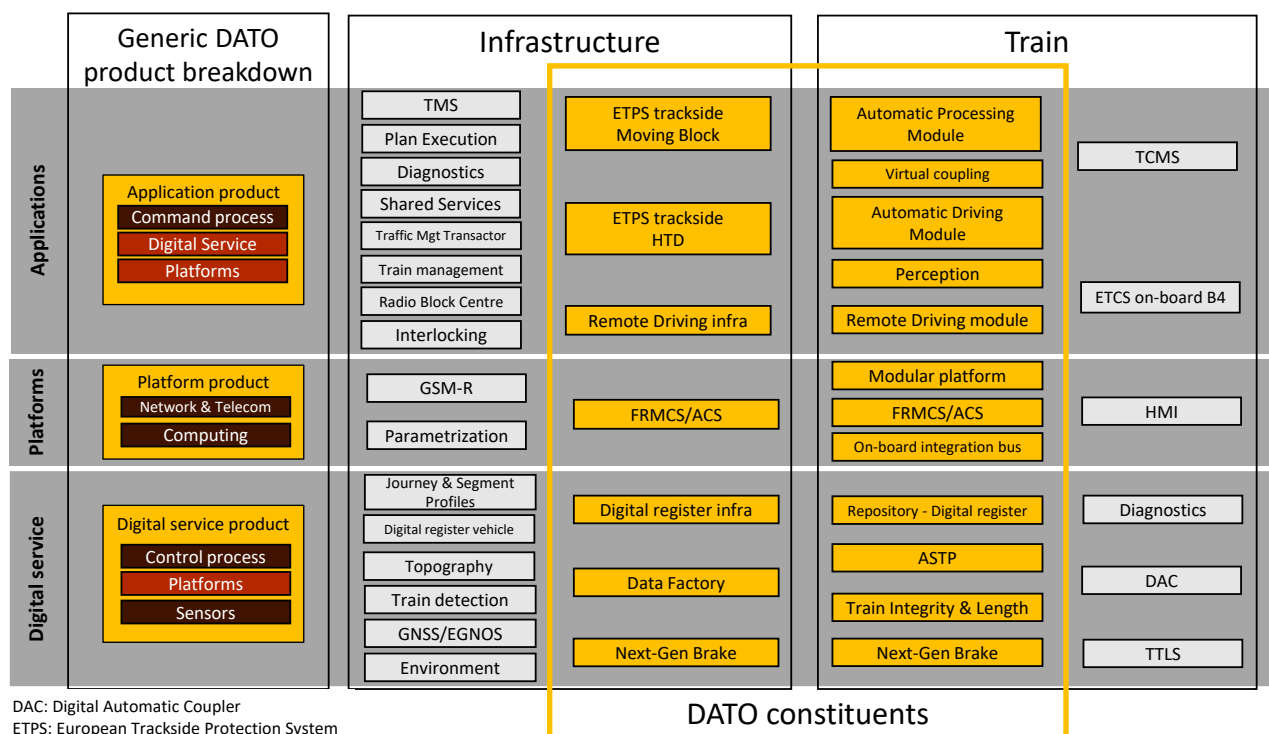
#Method: In order to fulfil the objectives given for this view, the information in the migration and dependencies views may need to be re-factored. Currently the view is very focused on the functional migration considerations. In order to fulfil the functional mode view objectives, a higher level of abstraction may be necessary to simply identify how many different functional behaviours (or modes) the system needs to master throughout its lifetime? In other words, there might even be no DATO system but various local instances of the DATO system of systems.

#Migration To fully describe the considerations of a migration view, a larger scope of artefacts may have to be taken into account. As mentioned, the current views focus on the functional vision, but potentially, the migration will bring changes at a physical or even operational level which is not currently captured. However, the view does introduce an AS-IS versus TO-BE paradigm at the functional level which provides a good premise to the development of this enlarged scope. Essentially, the view of the migration could be represented systematically as a sum of pairs, AS-IS and TO-BE, of all views affected by the migration.

5.3 CONSTITUENT VIEWS

5.3.1 Constituent breakdown

Figure 20: Constituent breakdown



DAC: Digital Automatic Coupler
ETPS: European Trackside Protection System
GNSS: Global Navigation Satellite System
TMS: Traffic Management System
TTLS: Train time location service

Representation guidelines

- DATO constituents
- External constituents (human or machine interfaced to DATO)
- Various implementation foreseen in demo and migration
- Constituent developed in WPs and verified in demo

The constituent breakdown view illustrates logical and physical constituents, some of them being developed by FP2-R2DATO (yellow), others not developed by FP2-R2DATO and external of the DATO system of systems of interest (grey).

The view makes a distinction between constituents deployed on the infrastructure, and constituents deployed on-board the train.

Logical constituents can be implemented into various physical constituents: software application, digital service, platform (red). These generic physical constituents are identified in this view in order to illustrate the physical implementation variability that is present in the FP2-R2DATO project via its different demonstrators (brown).

A major objective of the view is therefore to highlight that a logical constituent can be implemented into different physical constituents. This enables to discuss on:

- technical coherence and consistency of the constituents and, by extension, between activities performed by Work Packages,
- the technological impacts at physical level, and implementation compatibility between logical constituents and physical constituents,

Maturity & Open Points

#Technical Scope: The view is highlighting two different kinds of constituents: logical constituents and the nature of the hosting physical constituents (digital service, platform...). This view also displays external constituents known in the system of systems.

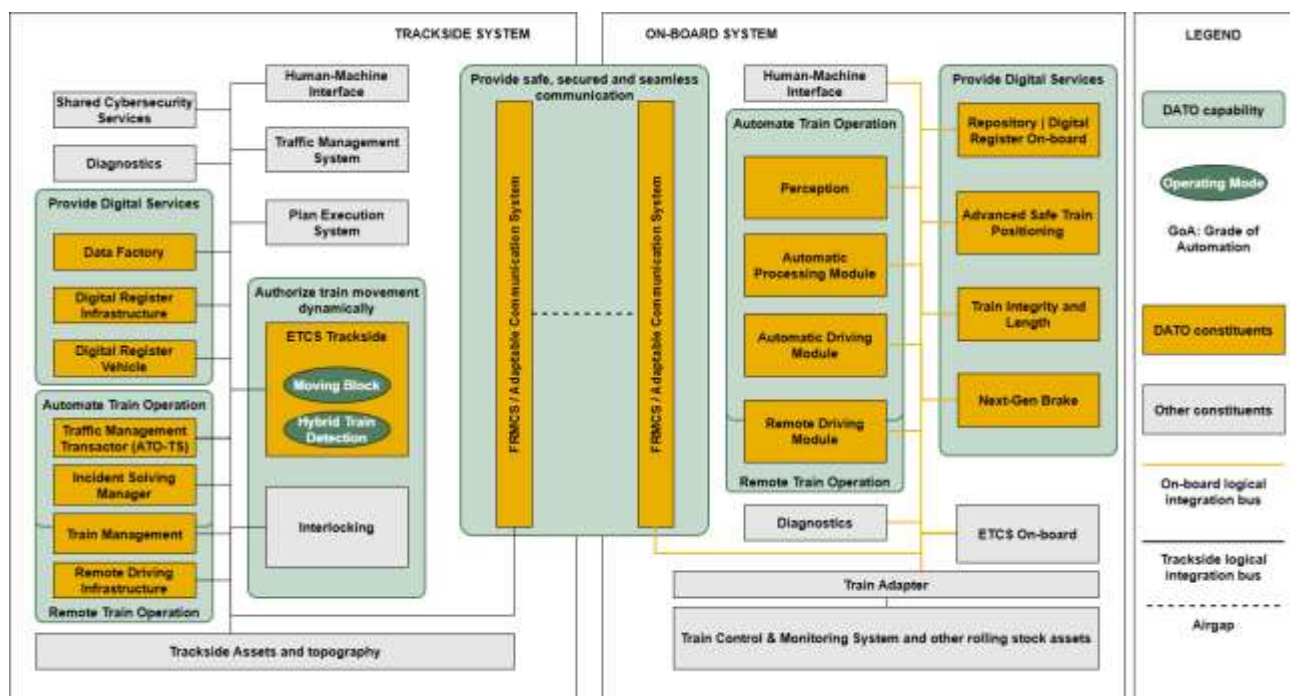
Virtual coupling solution studied in cluster IOS has been introduced in the view as a logical constituent even though it is still unsure how the solution will integrate and interface with other DATO systems.

#Method: Highlighting both logical constituents and hosting physical constituents studied within FP2-R2DATO enables the discussion on the different implementations of logical constituents into hosting physical constituents. This discussion can address the criteria for implementation, contexts for a particular implementation, requirements on both logical constituent and physical constituent for a given implementation.

While this constituent breakdown view focuses on the physical implementation variability of the logical constituents, the deployment variability of the logical and physical constituents of this constituent breakdown view is discussed in the Technical configuration view.

5.3.2 Technical configuration

Figure 21: Technical configuration view



The technical configuration view highlights how the DATO system of systems can be instantiated into a given technical configuration.

A technical configuration emerges when user needs (5.1.1) are answered by use cases in a given implementation context. Use cases are realised by technical capabilities (5.2.1), satisfied by a set of functions (5.2.2) allocated to constituents (5.3.1) that are integrated via constructional interfaces (5.3.3).

The Figure 21: Technical configuration view is only an example of one possible technical configuration calling for technical capabilities realised by constituents. It is crucial to highlight that the amount of technical configurations for DATO system of systems can be very high. The identification of the necessary and sufficient technical configurations of DATO will reveal the must have system targets, enabling a controlled variability on constituents.

In the view, some constituents are overlapping over two capabilities. One example is the Train Management constituent:

- For the *Remote Train Operation* capability, Train Management is there to enable the railway undertaking to operate some of the functions of the rolling stock remotely (e.g. remote driving),
- For the *Automate Train Operation*, especially for GoA3/4, Train Management is there to manage the Mission Profile (set of tasks to be performed by the automation system) and Train Data (exact composition and specification of the rolling stock needed for the automated data entry).

This is consistent with the capability naming *Remote and/or Automate Train Operation* adopted in the capabilities view.

With this example, the view reveals that the constituent Train Management can have 3 possible configurations:

1. Satisfying the *Remote Train Operation* capability, enabling the railway undertaking to operate remotely rolling stock,
2. Satisfying the *Automate Train Operation* capability enabling GoA3/4 operations.
3. Satisfying both *Remote Train Operation* and *Automate Train Operation* when remote driving is used as a fallback solution for GoA3/4 degraded situation.

This view enables to highlight and to discuss on:

- The different DATO configurations developed inside the project,
- Anticipate the need for a selection of relevant technical configuration to secure controlled variability and definition of DATO system targets.

Maturity & Open Points

#Technical Scope: The view is displaying a configuration of the DATO system-of-systems that may exist or not. The objective of this configuration is to showcase a maximum amount of constituents studied in FP2-R2DATO project, alongside external constituents (e.g. actors) that are needed in the DATO system of systems in order to fulfil needs. The consultation discussions with demonstrators WP in 2024 revealed that the view present a DATO system of systems that is highlighting logical constituents effectively involved in each demo but never as an entire integrated system.

#Method: By displaying a fictional configuration DATO system of systems, containing most of developed constituents, this view provides a sort of “menu” that can be used to determine what constituents to implement into an instance of the DATO system of systems, in order to satisfy specific needs. Having a defined set of logical constituents and interfaces will help in rationalising the configurations of the DATO system of systems.

5.3.3 Constructional interfaces

The figure 23 aim to describe on a “high level” a constituent breakdown, including some of the constituent interfaces. The figure reminds today’s reference documentation, such as TSI-CCS, involved in most of the systems developed in FP2-R2DATO. The overview aims to compromise coherence and completeness with an adequate level of simplicity. Obviously more detailed architecture sketches are developed within the FP2-R2DATO WPs as well as former Shift2Rail X2RAIL-4 and OCORA Capella models with their modelling of Capabilities and related Functions can be viewed as Input Models by the Capella Collaboration Manager: Capella Collaboration (europa.eu) covering the OB-system only.

Figure 22: Constructional interfaces view

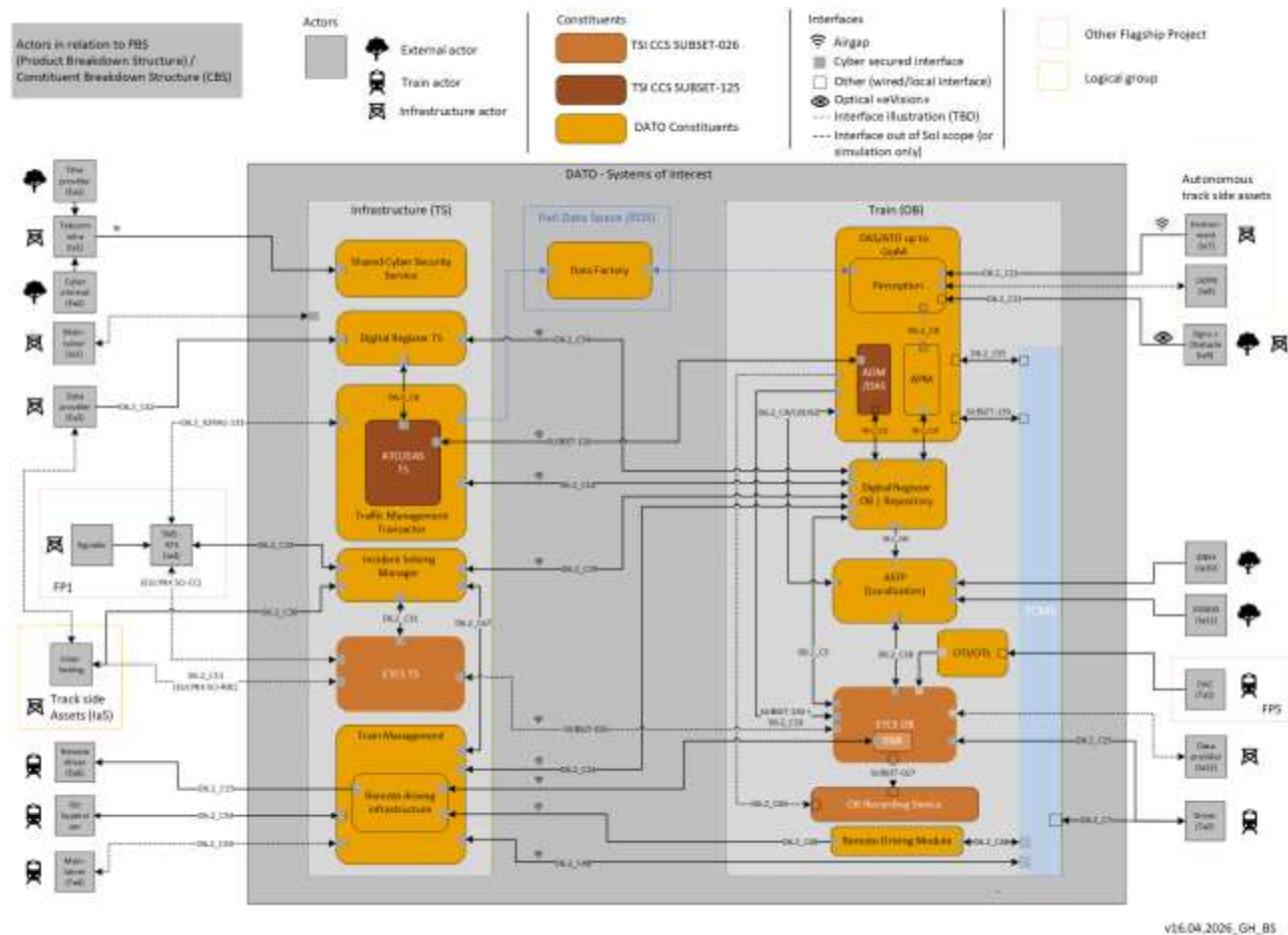


Figure 22: Constructional interfaces view is building on TSI-CCS, Subset-026, Subset 125, Functional breakdown as well as Technical configuration views, and includes the existing interfaces between ETCS, ATO (GoA2) and the train.

On the left side of the figure, the stakeholders interface with the sub-systems in infrastructure. On the right hand side they interface with the train. The DATO system of interest is represented as a grey box.

In the attempt to get an insight on the composition of the system, the contents of the grey-shaded box is included. The constituents are divided into two main groups, one for infrastructure, to be seen on the left side of the figure, and one for trains, illustrated on the right side in the system of interest.

Autonomous track side assets, like information from railway crossings, avalanche detection installations may be connected directly to ETCS trackside, or more “flexible” to the perception system of the train.

Constructional interfaces are numbered and most of the interfaces are reused from the logical architecture described in FP2-R2DATO D6.2 (*Report on System Architecture Specification and Interface Specification (preliminary FFFIS) for automating functions*). The reused interfaces are numbered D6.2_Cxx.

Maturity & Open Points

#Technical scope: This model does not illustrate the entire scope of work in FP2-R2DATO. This is deliberate in the search of a compromise between simplicity, coherence and completeness. Some interfaces are not yet mature for inclusion and need to be exploited further to include them into the sketch as well as the interface description. E.g., it does at this stage not include the connection to advanced solutions such as Brake NG or Virtual coupling. Further the sketch does not illustrate the Work Packages that create the basis for the content of the subsystems in the form of the detailed use cases, security analysis or streamlining of work processes, like Work Packages within the cluster fast and effective deployment.

#Interfaces: With various system configurations and level of digitalisation/automation, it is complex to find an adequate level of simplicity in the representation of key interfaces. It is also acknowledged that some design decisions are still open. In the aim to include interfaces to external actors interfaces out of DATO scope are illustrated with dotted lines.

The purpose of the dotted lines between Digital Register TS – Data Factory and Perception is to illustrate the required data collection from the perception sensors back to the Data Factory to include the opportunity for training of AI-models/improving development of machine learning. This process is likely to require data from the Digital Register for model improvement. The interfaces are not necessarily real-time connections and may be handled in various ways for data collection as well as for transferring improved or newly developed models from the Data Factory into the trains for perception operation.

5.4 CATALOGUE OF ARTEFACTS

Definition of content: How and Why?

The architecture is made of a lot of information calling a lot of information. The catalogue of artefacts aims at structuring and consolidating those information applicable for the design of DATO solutions.

In this version of the report, the aim of WP3 has been to take in, interpret and project the information from a catalogue into architectural views. The projection of the catalogue data into the framework gradually organises the artefacts so they inform the right space of the overall DATO architecture.

Once these views have been formalised, consolidated and validated, then the catalogue of artefacts / solutions was refined to return a more integrated and shared dictionary for each work package to develop in their solution perimeter.

By extension, one of the key aims of the Catalogue of artefacts / solutions is to be able to allocate the various WPs to different artefacts or views according to their scope. In FP2-R2DATO the various WPs have different goals, not all of them can be easily related to a traditional architecture.

The catalogue has achieved a first level of coherence and completeness but should be further refined. The catalogue or artefacts / solutions should continue to learn from practice, however, according to the current understanding, the following statements can be made:

- It will manage the following DATO artefacts:
 - Technical Capabilities and functions
 - External Actors and Constituents
 - Interfaces
 - Use cases
- It shall be easily interpretable and used by the various work packages.
- It shall not be intrusive on the design and development of the WPs perimeter but facilitate the management of interfaces and exported constraints.
- It shall help to inject consistency across the breadth of WPs in FP2-R2DATO.
- It shall support communication with architecture stakeholders.

Maturity & Open points

Properties to be described for each artefact are not fixed yet, but traceability in the artefact table should be further developed : to FP2-R2DATO deliverables, applicable standards, STIPs, Operational and Functional expected properties (Needs and Capabilities).

6 CONCLUSION

The current version of the report presents a total of 9 views of the DATO system of systems each, with specific open points. The views have been organised in a framework that will ensure that each view meets its designated objective in relation to the global system. The preparation of these views has followed several iterations and feedback loops. It secured the reuse of the information provided by the WPs step by step consolidated in the Catalogue of Artefacts / Solutions. Thus, the process has proven the viability of the working method to define the architecture file.

Regarding the initial objectives of the architecture, it can be stated that the current version of the architecture:

- ▶ Supports WP's work, in particular in relation with the specification WPs, for what regards the coherence and the consistency;
- ▶ Supports technical alignment and gap analysis with System Pillar;
- ▶ gives a description of the design context of DATO;
- ▶ Helps to identify interactions between WPs;

For what regards the development of demonstrators, the current state of the FP2-R2DATO project and of the interaction with the System Pillar does not allow to consider the depicted architecture applicable to all the demonstrators, because there may be implementation choices, in order to be compliant with the timeframe defined by the FP2-R2DATO Grant Agreement, not covered by the common architecture. This limitation is expected to be solved in the following waves of FP2, as the convergence on the architecture is achieved and the developments of the industrial products progress.

New steps with the architecture would imply enlarging the report's outreach in order to collect information through periodic peer review. The current version of the report has been developed by the WP3 Architecture team and further exchanges with all stakeholders would improve the maturity of the views and pave the way for an extensive use.

▪

7 APPENDICES

7.1 APPENDIX 1: ARCHITECTURE APPROACH

This section details the thought process from the architecture needs to the architectural framework. Indeed the framework that is developed in this report has been tailored to the needs expressed on the DATO architecture.

The process described in 5 steps is as follows:

1. The stakeholders of the architecture have been identified, described in Section 2.1 and figure 1
2. The lifecycle phases of the architecture relative to the DATO lifecycle are defined,
3. The use cases expressed by the stakeholders in each lifecycle are then defined,
4. This information is synthesized in a set of needs for the architecture,
5. A modelling metamodel and a framework are defined relative to these needs.

Moreover, this section also describes other systems engineering considerations to be taken into account in the development of the architecture:

- Milestones,
- Roles and responsibilities,
- Configuration management,
- Change Management,
- Tooling and data management.

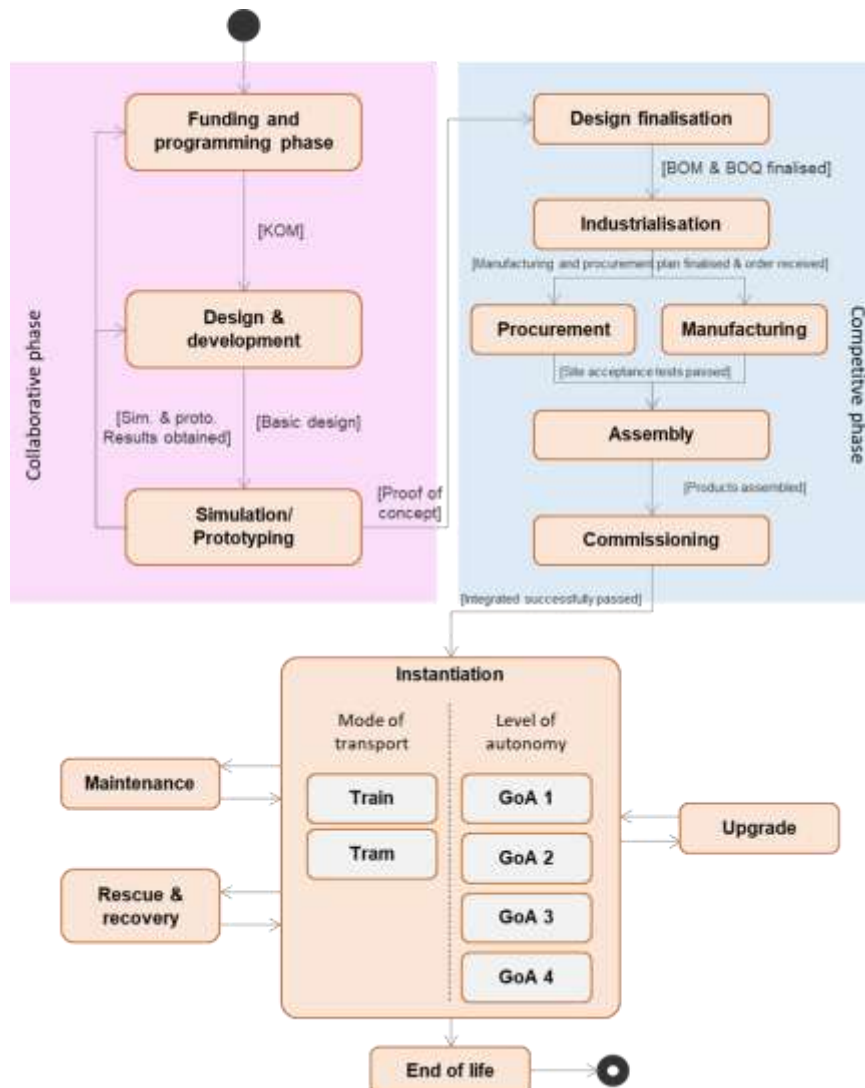
7.1.1 Architecture lifecycle

The objectives of this section are to:

- Contextualise the role of the architecture in each step of the DATO development cycle,
- Model the engineering cycle that enables EU Rail's ambitions,
- Categorise the strategies or nature of the stake (industrial, technological, etc.) of the outcomes of the architecture.

Figure 23: Architecture lifecycle presents a simplified DATO development cycle. The objective is to have a clear view of the DATO development cycle in order to clarify the role of the architecture at each step. **Please note that this view is an initial version and there will likely be improvement and additions on this view through ensuing collaboration.**

Figure 23: Architecture lifecycle

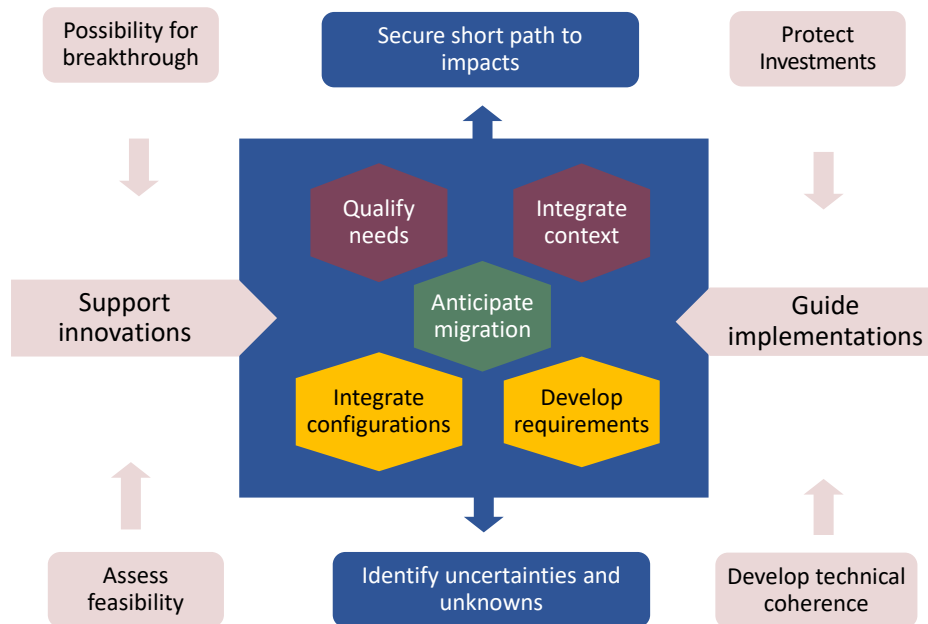


N.B. The iteration loops have not been exhaustively represented in this view for the sake of readability hence it can be considered a nominal development sequence.

This view highlights that the DATO system of systems has a high degree of variability as can be observed in the instantiation lifecycle phase. As a matter of fact, the definition of the variants are not exhaustively modelled. Instead, two known variability drivers which are the Mode of Transport and the Level of autonomy are given although there could possibly be more. The definition of the variability in the design is therefore also listed as a use case for the architecture. Moreover, the sequence of implementation of these variants has technical constraints since there are laws of precedence to abide by for a successful migration. These laws of precedence and potential migration are crucial to define as part of the WP3 architecture.

The next step is to identify the use cases for the DATO architecture in each of these steps, as represented in Figure 24: Architecture Use Cases.

Figure 24: Architecture Use Cases



The architecture contributes to the business outcomes - As can be seen in the scheme, the architecture has a prevalent role in the design & collaborative stages of the FP2-R2DATO project although its incidence may have impacts along the entire lifetime of the DATO system. This is consistent with the global objective of systems engineering to push as many considerations of the future implementation as possible in the design stages as design rectifications tend to become increasingly costly as the system grows in maturity. Therefore, all of the use cases somehow contribute to the business outcome of streamlining the design activities with regard to stakeholder needs. **Innovation always create diversity and often overlap, this is generally a good thing as long as it is consolidated at a later stage, the architecture shall be the frame for this reconciliation exercise.**

The architecture also contributes to the technical outcome – notably through clear formalisation of internal and external interfaces, supporting trade-off analysis and ensuring a comprehensive analysis of constraints. The analysis of interfaces allows the engineers to go into detail and collaborate on the specification of boundaries of the system and sub-systems. **Clarifying these boundaries reduces the risks for future integration: managing the overlap between technologies help to consolidate a solid system as a whole.** Trade-off analysis implies taking design decisions with the due considerations for the added value that it may bring to the stakeholders. An informed design decision therefore implies rigorous traceability between detailed technical artefacts at the granularity at which the decision is taken and high-level needs where the added value can be gauged. It is the system architecture's role to ensure this traceability. Finally, systems architecture pushes the engineers to multiply the perspectives they take of the system, increasing the chances of "leaving no stone unturned" and addressing as many constraints as possible in order to **secure that the system will behave as expected.**

The architecture also contributes to the facilitation and collaboration between entities – An often-overlooked aspect of system's architecture is to provide a common language and common views to the contributors in order to optimize collaboration. Indeed, as presented in previous sections, the architecture has a key role in defining the applicable architecture that requires close collaboration

with SP and the WPs. Providing **a common language based on standards and best practice** as well as providing validated global views of the system will help in ensuring the alignment between the entities.

The architecture also contributes to defining the variability in the design – As mentioned relative to the development lifecycle, the variability in the design brings significant added complexity in the development, operation and maintenance. Using the formal tools and representations of systems architecture shall enable a rigorous definition of variants and their associated specifications.

The architecture also contributes to the safe and secured integration of the design – the architectural views and artefacts are useful tools for the safety engineer to lead formal analysis of failure modes and degraded cases. It can also be a tool to protect the system from malicious attack. As for all analysis that require a more global outlook of the system, the architecture provides a common backbone for the disciplines to branch out from. This is also the case for the definition of the V&V plan and activities.

7.1.2 Milestones

The definition plan related to the system architectures can be found in the action plan (see chapter 3.2).

For the longer-term milestones, it is key that they fit as well as possible with the already defined milestones inside FP2-R2DATO (and more generally in DATO environment) in order for the system architectures to deliver their most value. The relevant milestones identified are the following ones:

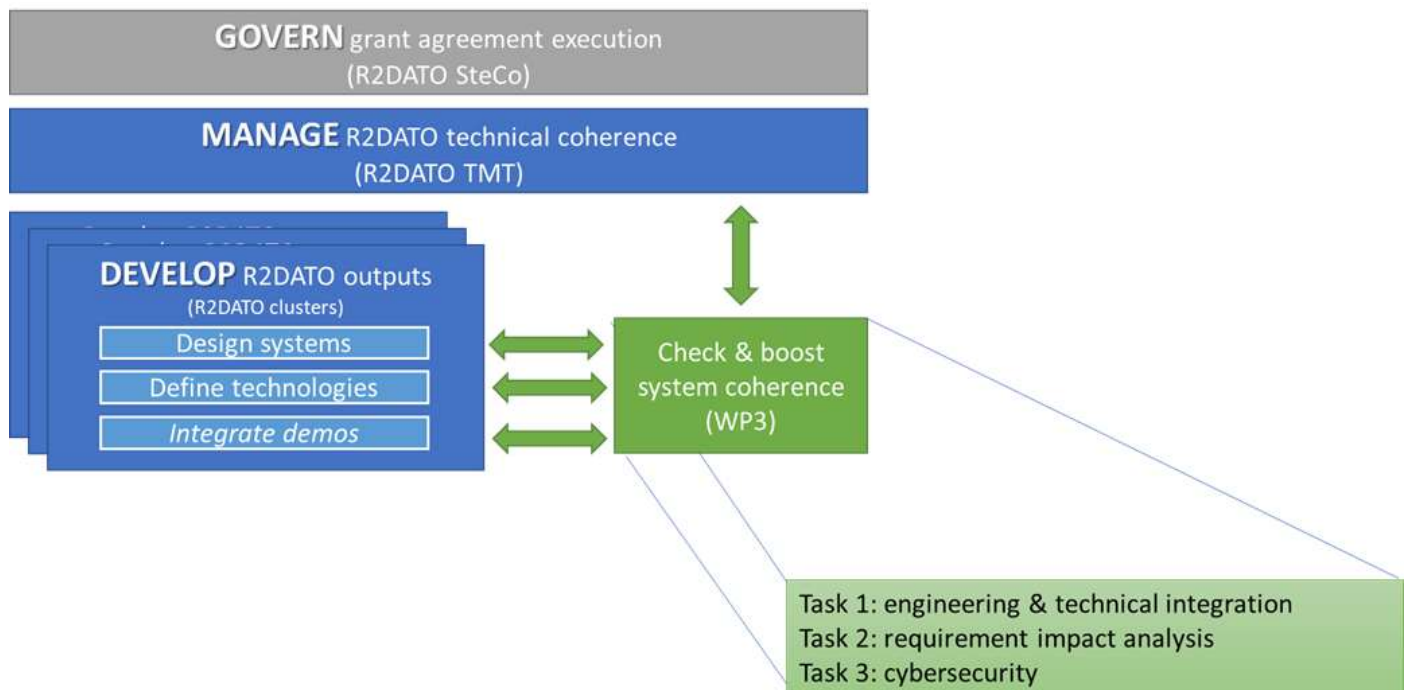
- FP2-R2DATO project milestones (in general) and maturity checkpoints in particular
- FP2-R2DATO Demonstrations milestones (specifically)
- System Pillar milestones, in particular in relation to STIP
- Europe's Rail milestones, in particular in relation to future projects.

7.1.3 Roles and responsibilities

7.1.3.1 Inside FP2-R2DATO

WP3 is a workbench for architecture integration and technical evaluation within the FP2-R2DATO project. Following the NATO architecture governance approach, the situation of WP3 in the overall project organisation can be illustrated in Figure 25: WP3 Role description below.

Figure 25: WP3 Role description



Note: in this figure, “R2DATO” is to be understood as FP2-R2DATO project.

While FP2-R2DATO WPs are developing and validating solutions, WP3 will allow to check and facilitate, therefore boost system coherence. WP3 outcomes are regulated by the TMT.

The overall development and collaboration process is an architecture governance issue and therefore must be challenged and accepted by R2DATO SteCo.

The architecture file prepared by WP3 is about living working material allowing to find common understanding on targets, constraints and open issues in relation to FP2-R2DATO outputs. There is therefore no foreseen formal approval step envisaged for the architecture itself.

7.1.3.2 Beyond FP2-R2DATO

Inside Innovation Pillar

The basic assumption is that System Pillar will anyhow consolidate needs across FAs, therefore, at this stage, no direct collaboration between FPs is needed between FP2-R2DATO and other FAs. Informal exchanges between FP2-R2DATO and other FAs will nevertheless always be beneficial.

With System Pillar

Systems Architecture approaches from System Pillar and Innovation Pillar should converge and related activities should complement each other. Synchronisations regarding this topic are therefore required between FP2-R2DATO and SP. How this should happen concretely has not yet been defined in detail but will anyhow be channelled during the regular SP/FP2-R2DATO coordination meetings.

○ Validation

System architecture validation is now understood as an activity that will allow to check if the architecture meet the expectations/design criteria of its stakeholder’s target group. This

understanding should be further challenged notably in relation to interfaces: validation of the architecture maturity may be more than checking that FIS and FFFIS descriptions are coherent and should include test in operation.

Design and validation activities should be clearly separated but may be repeated iteratively until the results meet the design criteria set for the system and its architecture.

Demonstrations are currently seen as the main validator of the system architectures, but one has to keep in mind that for most of them their concrete results will only be available quite late in the project and that the integration of a system of systems in a global demonstrator covering all TEs is not foreseen in the current project..

The architecture context is also a question that will need to be taken into account while further exploring validation means. Validation of a given architecture should apply in a specific context. In this respect, the concept of “architecture context” needs a clear definition and implementation up to the validation of a given architecture solution.

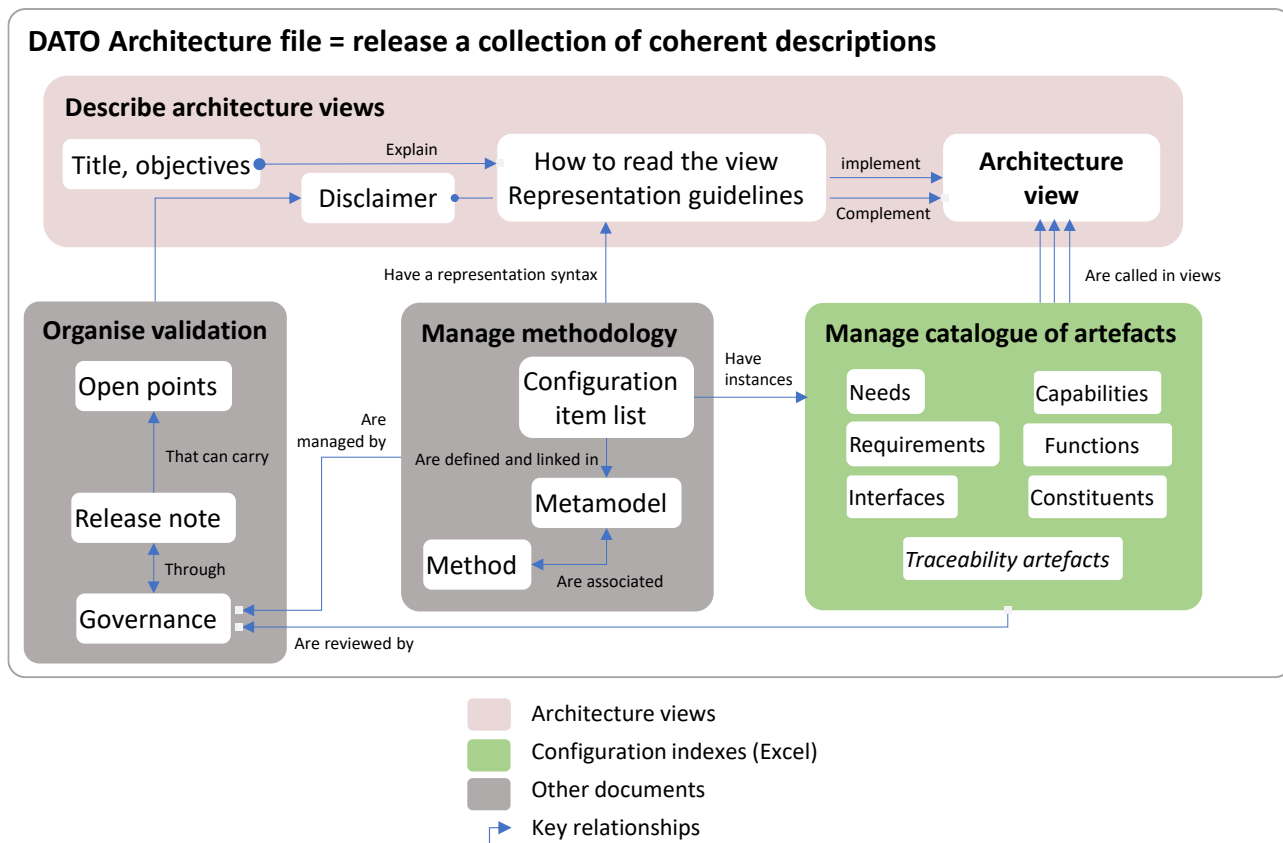
7.1.4 Configuration Management

The architecture Configuration Management process is recommended to have the following orthodox responsibilities:

- Identifying configuration items (at a yet to be defined level)
- Controlling configuration status
- Verifying and auditing configuration

It is quite clear that the level of maturity should be the number one criterion to trigger the freeze and release (baselining) of a given system architecture (note that any development activity can lead to gain maturity on studied topics). Indeed, the level of maturity is often a very good measure of the level of stability. In addition to being a criterion, the level of maturity shall be a compulsory information accompanying each release, so that stakeholders understand the potential gaps and limitations (e.g. risk of change) of what is delivered. Note that no comprehensive maturity scale has been defined yet beyond TRL definition.

Today no strict process or tool is decided to manage the evolution but the relation between all engineering information (views, open points...), methodological (metamodel) and governance aspects have been analysed and rationalised to secure that the architecture can be maintained. The following figure shows that architecture views in this report are the visible result of a structured engineering approach, strengthened by three key enablers: an artefact catalogue, a methodology, and a validation process



7.1.5 Change Management

We need to pay attention on organisational success conditions for a Change Control Board and to have necessary technical foundations to handle change management.

This CCB shall have the following orthodox responsibilities:

- Synchronising FP2-R2DATO system documentation with other architectural changes in its environment (mainly from SP and other FPs in IP)
- Assessing change requests impacts and associated risks
- Prepare necessary information for FP2-R2DATO Committees to approve or reject change requests (if only technical impact, through TMT, if impact on GA, up to the SteCo)
- Monitor implementation of changes

7.1.6 Tooling and data management

At this stage, neither specific modelling tool nor specific requirement management tool have been selected to support Systems Architecture inside FP2-R2DATO project. The currently existing system architectures have been built with non-dedicated tools (i.e. mainly using Microsoft Office suite), with no major limitation identified.

The need for more powerful tooling is therefore yet to be assessed, based on the defined Systems Architecture Strategy. If this assessment reveals that there is a real need towards tooling, a cost / benefit trade-off should be conducted to select the right toolchain supporting the right processes, with a strong emphasis on compatibility with the defined Systems Architecture Framework and Method.

A strong need for data accessibility has nevertheless been identified and should be investigated, with a focus on identifying quick-wins leveraging currently existing tools in FP2-R2DATO.

A need for harmonisation of the aspect of the diagrams has also been identified for which a common modelling tools would help.

7.2 APPENDIX 2 – DEVELOPMENT METHOD: WORKSHOPS & CONTRIBUTIONS

The end goal of architecture activities organised in WP3 is to develop common understanding & secure ownership on DATO integration challenges.

The development of an architecture for DATO system of systems cannot be done in one step but follow an iterative process.

The first workshop in January 2024 allowed to understand architecture needs. The first report proposed a strategy.

The first half of 2024 allowed to build a team of 9 architects, each bringing a point of view on DATO systems. A first architecture file wave consolidated and presented within FP2-R2DATO project and to the system pillar. Comments received were integrated in the next version of the architecture. End of 2024, the Release 2 of architecture views was finalised, allowing to build further coherence between views.

Beginning of 2025, the architecture approach (from needs to solutions) and content (migration) has been a successful story line for FP2-R2DATO midterm event.

The present report is the third time that the architecture methodology is used. The architecture views achieve a good level of maturity : inside each views and between the views.

The architecture provides now a framework that seems sufficiently stable to serve as foundation for building FP2-R2DATO Deliverable 3.1. The views and catalogues may be further refined after the publication of this report but already provides a coherent and complete definition of DATO system of systems.

The architecture material can today serve to assess the maturity of DATO specification, it is a sound foundation to further explore and decide on collaborative research and innovation activities.

7.3 APPENDIX 3 – CATALOGUE OF ARTEFACTS

7.3.1 Catalogue of stakeholders

The Catalogue of Stakeholders captures all the stakeholders in interaction or influence with DATO.

Disclaimer: It includes both technical systems and operational entities. Therefore, it should be considered as an hybrid view between a strict stakeholder's hierarchy and a system technical breakdown. This choice is motivated by the aim of displaying all the R2DATO actors (technical and human) on a single view.

ID	Stakeholder	Definition	Reference
1	R2DATO Stakeholder		
1.1	R2DATO (enterprise) stakeholders		
1.1.1	EU-Rail JU	Europe's Rail Joint Undertaking (EU-Rail) is the European partnership for rail research and innovation under the Horizon Europe programme (2020-2027) and the successor to the Shift2Rail Joint Undertaking.	LINK
1.1.2	Suppliers		
1.1.2.1	Technology providers	Entities that offer technology-related products and services	
1.1.2.2	System integrators	Entities that harmonize hardware, software, and networking components into a unified system	
1.1.2.3	Research centres	Entities that conduct scientific and technical research	
1.1.2.4	Assessment bodies	Entities that perform conformity assessments to ensure that products and services meet legal and technical standards	
1.1.3	Operator		
1.1.3.1	Infrastructure manager	The Infrastructure Manager (IM) provides the rail infrastructure, manages all relevant infrastructure data and maintains the infrastructure.	X2R4 D3.2 GoA3/4 Specification
1.1.3.1.1	TMS	System for monitoring and managing the traffic and the signalling system from the control centres	FP1-MOTIONAL D15.1
1.1.3.1.2	Signaller	The Signaller supervises and controls the operation of trains as defined in the TSI OPE	
1.1.3.1.3	Emergency Manager	The Emergency Manager carries-out non-automated emergency functions which require human actions.	X2R4 D3.2 GoA3/4 Specification
1.1.3.1.4	Maintenance Entity		
1.1.3.2	Railway Undertaking		
1.1.3.2.1	Trackside Entity		
1.1.3.2.1.1	Train Management		
1.1.3.2.1.2	Remote Driver	Sub-actor of Driver. In the frame of the remote driving capability, the Remote Driver has the same role as the Driver except that he is not located in the train but at the trackside level.	
1.1.3.2.1.3	Maintenance Entity	Entity in charge of maintenance	LINK
1.1.3.2.2	On-board Entity		
1.1.3.2.2.1	On-board Driver	A person capable and authorised to drive trains, including locomotives, shunting locomotives, work trains, maintenance railway vehicles or trains for the carriage of passengers or goods by rail in an autonomous, responsible and safe manner.	ERTMS/ATO GLOSSARY v2 EUG Reference: 13E154
1.1.3.2.2.2	Train Conductor/Attendant	In the context of Driverless Train Operation (GoA3), person in charge of some operational tasks, e.g. operating the train doors (although this can also be done automatically) and of assuming control in case of emergency or degraded situations	SUBSET-125 - 1.0.0
1.1.3.2.2.3	TOMS	The Train Control Management System represents the systems installed on a train with which an interaction is necessary in order to perform automatic railway operation (brakes, traction...).	
1.1.3.2.2.4	ETCS-OB	The ERTMS/ETCS on-board equipment is a computer-based system that supervises the movement of the train to which it belongs, on the basis of information exchanged with the trackside subsystem	SUBSET-026-2.4.0.0
1.2	Rail actors interested/impacted by R2DATO outcomes		
1.2.1	End users		
1.2.1.1	Passenger	Persons travelling on passenger trains and embarking or disembarking at stations	X2R4 D3.2 GoA3/4 Specification
1.2.1.2	Chargers / freight forwarder	Freight Forwarder: Party who ensures that internationally traded goods move from point of origin to point of destination to arrive at their place, at the right time, in good condition and at the most economical cost.	LINK
1.2.1.3	Transport authorities	Government agencies that regulate, manage, and administer transportation, with responsibilities including infrastructure, safety, and policy for modes like roads, rail, air, and maritime transport.	
1.2.2	Institutions		
1.2.2.1	Standardisation bodies	Standardisation bodies ensure coordination between the development of the technical specifications for interoperability and their standardisation activities. This cooperation mainly hinges on the following organisations: European Committee for Electrotechnical Standardisation (CENELEC); European Committee for Standards (CEN); and European Telecommunications Standards Institute.	LINK
1.2.2.2	Authorities (ERA/NSAs)	ERA: The European Union Agency for Railways is an agency of the European Union established by the Regulation (EU) 2016/796. Its purpose is to support the development of a Single European Railway Area, without frontiers, guaranteeing a high level of safety. NSAs: NSAs are national bodies entrusted with the tasks regarding railway safety in order to ensure a unified safety regime for specialised cross-border infrastructures.	LINK
1.2.2.3	EU-Rail System Pillar	The System Pillar is the "generic system integrator" for the Europe's Rail Joint Undertaking (EU-Rail), and the architect of the future EU's railway system. Under this role, the System Pillar provides governance, resource, and outputs to support a coherent and coordinated approach to the evolution of the rail system and the development of the system view, based on a formal functional system architecture approach to speed innovation and deployment	LINK
1.2.3	Railway Assets		
1.2.3.1	Train	Rolling stock composed of one or more vehicles	
1.2.3.2	Trackside Asset	Fixed infrastructure installation or equipment	
1.2.3.3	Assets managers	Entity in charge of owning, keeping, and maintaining an asset	
1.2.3.4	Configuration data provider		
1.3	Actors beyond rail involved in R2DATO		
1.3.1	Satellite ecosystem		
1.3.1.1	GNSS	Global Navigation Satellite System (GNSS) refers to any satellite constellation that provides global positioning, navigation, and timing services. Using signals from space, each of these systems transmits ranging and timing data to GNSS-enabled receivers, which then use this data to determine location.	LINK
1.3.1.2	EGNOS	EGNOS, which stands for the European Geostationary Navigation Overlay Service, is Europe's regional Satellite-based Augmentation System (SBAS). SBASs are used to augment the signals of Global Navigation Satellite Systems (GNSS) so that they can be used for Safety-of-Life applications such as Precision Approaches in Aviation.	LINK
1.3.2	Environment	Physical Environment (PE) represents the physical environment around infrastructure assets and Vehicles as well as inside Vehicles. It consists of any entities being part of the railway system or external to it that might have an influence on railway operation. The environment might physically interact with the R2DATO system for which a supervision is required.	X2R4 D3.2 GoA3/4 Specification
1.3.2.1	Adhesion conditions	Degree of friction between train wheels and the rail critical for train's traction and braking	
1.3.2.2	Radio coverage		
1.3.2.3	Obstacles	Any unexpected condition (e.g., object, train, animal, fire, flood) on the track being dangerous for the train movement	
1.3.3	Malicious Agents		
1.3.3.1	Terrorist/Cyber criminal	Actor who attempts attacks the rail system	
1.3.3.2	Perception of security in the train and stations		
1.3.3.3	Safety culture		

7.3.2 Catalogue of activities

OPERATIONAL IMPACTS VIEW			
Stakeholder Activity	Definition	Time scale (decade/year/month/day)	Stakeholder(s) concerned (supplier/IM/RU)
Consolidate industrial roadmap	Manage the products roadmaps (rationalisation, innovation, obsolescence, etc.)	decade	supplier
Showcase EU leadership	Develop the most innovative and performant solutions for the aim of the european railway network	decade	supplier
Predict network access conditions	Define the future traffic capacity and offer	decade	IM
Define appealing transport offer	Define the offers that will make the final customer choose the rail rather than any other transport mode	decade	RU, IM
Prepare migration to solve obsolescence and meet new expectations	Handle highly complicated obsolescence issue impacting the whole CCS system (eg. : GSM-R) or new expectations impacting the whole CCS system (eg. : GoA2-4)	decade	supplier, RU, IM
Explore new technology and operation process, regulate relevant breakthrough	Specify new solutions to integrate them in the existing design and in the existing regulation	year	supplier, RU, IM
Test (digital) assets	Achieve Proof of Concepts, demonstrators to validate new technologies on a technical point of view	year	supplier
Experiment automated and autonomous operational processes	Achieve Proof of Concepts, demonstrators to validate new technologies on train operation point of view	year	RU, IM
Certify performance	Define PRAMSS objectives and demonstrate their fulfilment	year	supplier, RU, IM
Develop compatibility	Harmonize operational rules and standardize product interfaces in order to fasten the deployment and to reduce the costs	year	supplier, RU, IM
Supply qualified personal, connectivity, energy and data	Achieve human and technical activities to make possible the development and the deployment of innovation	year	supplier, RU, IM
Manage life cycle (Train retrofit, upgrades)	Prepare and plan the upgrades of the already operated on-board and trackside CCS	year	supplier, RU, IM
Maintain assets: training, plan the interventions	Prepare and plan the systematic and corrective maintenance	month	supplier, RU, IM
Supply rail system constituents	Produce constituents according to the technical specifications	month	supplier
Integrate/regulate network capacity	Produce the track slots	month	IM
Supply rail transport services	Produce the timetables	month	RU
Assets: monitor, repair, recycle, maintain	Produce daily maintenance	day	supplier, RU, IM
Deliver assistance up to autonomy	Provide technical support to the railway operators	day	supplier
Determine journey profile	Elaborate the missions of the trains based on the timetables, also considering the status of the tracks and specific locations for train needs (parking area, depot, or washing facility)	day	IM
Implement route	Establish the route for a train according to its mission, including the end of mission and any changes on the route required based on input data.	day	IM
Authorize movement	Establish the Movement authority (or End of Authority) of a train	day	IM
Configure train	Build the train with the wagons and the locomotives to reach the desired. For the configuration train, it is included the autotests, OB initialization & comms and register the train for remote driving.	day	RU
Join/split train	Reconfigure the train during train operation	day	RU
Control brake, speed & consumption	Drive the train	day	RU
Detect incidents and recover back to safe operational conditions	Manage all the activities required to recover from an incident during train operation	day	supplier, RU, IM

7.3.3 Actual source of document on use cases

WP	Work Package name	Deliverable	Deliverable Name	State	Version	Link
WP 5	Automation Processes Use Cases and user requirements	5.1	Documentation of use cases for automating functions	Issued	Rev 06 (29/02/2024)	https://cooperationtool5.eu:443/documents/details/d4e48cdd-466a-4723-83fb-759739f69cb7
		5.2	Documentation of use cases for perception system	Issued	Rev 05 (19/12/2023)	https://cooperationtool5.eu:443/documents/details/d82e9801-a0e0-4ee1-8fb9-7cb73f6e3a1b
		5.4	Documentation of Use Cases for remote driving	Issued	Rev 06 (14/02/2024)	https://cooperationtool5.eu:443/documents/details/7ee35339-e7ae-4f9a-831c-5e57b22365fe
		5.6	Documentation of urban user cases and operational rules for automation process	Issued	Rev 02 (30/10/2023)	https://cooperationtool5.eu:443/documents/details/7d2b6feb-4ec2-4b0c-9971-a071e976f60f
WP 6	Automation Processes Specifications	6.6	Documentation of Use cases, requirements & Specification autonomous operations for tramways	Issued	Rev 05 (21/11/2024)	https://cooperationtool5.eu:443/documents/details/015c05f3-a14b-4b63-b642-55eaa6fd01e
WP 15	Hybrid Level 3 Specification	15.1	HL3 System Specification with identification of use cases and related engineering rules	Issued	Rev 01.01 (05/12/2024)	DELIVERABLES – eurail-fp2
WP 20	Development of Train Integrity & Train Length Determination Demonstrators	20.3	Use cases and scenarios for Train Integrity and Train Length over ETCS	No Access	-	
WP 21	Absolute Safe Train Positioning (ASTP)-operational needs	21.1	Operational Requirements and System Capabilities of ASTP System (Use Cases)	Issued	Rev 17 (11/06/2024)	ShP Link
WP 23	Onboard Communications – Communication foundations and basic functionality	23.1	List of use cases for the Onboard Communication Network	Issued	Rev 04 (05/04/2024)	DELIVERABLES – eurail-fp2
WP 27	Digital Register Specification, Development, and Implementation	D27.1	D27.1 - Set of requirements on the Digital Register in R2DATO	Issued	Rev 05 (27/08/2024)	DELIVERABLES – eurail-fp2
WP 29	RailIndustrial DevOps and Architecting4evolution	29.1	List of user stories and requirements	Issued	Rev 02 (19/12/2023)	DELIVERABLES – eurail-fp2
WP 40	Autonomous Tram Demonstrator	40.1	Operational use cases collection	Issued	Rev 02 (20/11/2023)	DELIVERABLES – eurail-fp2
WP 44	Moving Block ETCS L3 Demonstrator –Specification	44.2	List of use cases/test cases to be demonstrated	Draft	-	D44.2 (FP2-T44.2-D-0BB-034-01) Operational Scenarios & UCs https://cooperationtool5.eu:443/documents/details/5ede07f9-97bc-4ddb-abb3-804fbb886f4f D44.2 (FP2-T44.2-D-0BB-034-01)- Test Cases https://cooperationtool5.eu:443/documents/details/7d396ede-3194-4e09-bbd0-b9936007c5ed
WP 45	Moving Block ETCS L3 Demonstrator –Realisation	45.6	Simulation Tool for demonstrator & use cases Report	Issued	Rev 04 (02/12/2024)	https://cooperationtool5.eu:443/documents/details/4db9f743-95b1-442a-ae72-8922eac9d868

7.3.4 Catalogue of functions

The Catalogue of Functions comprises the complete set of functions presented as Functional Views in the Architecture. The following pieces of information are shown:

- Functions and Technical Capabilities
- Constituent type in charge of executing the function/Technical Capability: Infrastructure, train, or external entity.
- FP2-R2DATO Work Package involved in the Function/Technical Capability
- Functional Requirement: To be further elaborated
- Correspondence with FP2R2DATO KPIs: To be further elaborated
- Technical Capabilities Relationships Matrix, which expresses the relationships between Technical Capabilities illustrated in the Technical Capabilities View.

Level	Function			Constituent type			Responsibilities	Technical Capabilities Relationships Matrix							
LO	ID	Name	Technical	Infra	Train	Ext.	Involved WP	TC1	TC2	TC3	TC4.1	TC4.2	TC4.3	TC4.4	TC4.5
ATO	x	1	Remote and/or Automate train operation	x			WP5, WP6							I_TC1_TC4.4	
	x	1.1	Manage mission execution				WP5, WP6								
	x	1.1.1	Automate mission profile definition		x		WP5, WP6								
	x	1.1.2	Initialize mission profile execution		x	x	WP5, WP6								
	x	1.2	Automate train preparation				WP5, WP6								
	x	1.2.1	Automate system tests and configuration			x	WP5, WP6								
	x	1.3	Operate train remotely				WP5, WP6								
	x	1.3.1	Monitor and control rolling stock remotely		x		WP5, WP6								
	x	1.3.2	Drive the train remotely		x	x	WP5, WP6								
	x	1.4	Automate train driving				WP5, WP6								
	x	1.4.1	Drive the train automatically			x	WP5, WP6								
	x	1.4.2	Provide on-board with Journey and Segment Profiles		x		WP5, WP6								
	x	1.5	Supervise environment				WP5, WP6								
	x	1.5.1	Detect objects			x	WP5, WP6								
	x	1.5.2	Detect and interpret lineside signals			x	WP5, WP6								
	x	1.5.3	Monitor location			x	WP5, WP6								
	x	1.5.4	Detect anomalies and infrastructure defects			x	WP5, WP6								
	x	1.6	Provide user interface		x	x	WP5, WP6								
	x	1.7	React to incidents		x	x	WP5, WP6								
	x	1.8	Recover after automated driving degraded situations		x	x	WP5, WP6								
	x	1.9	Leverage data from digital services		x	x	WP5, WP6								
ATP	x	2	Authorize movement dynamically	x										I_TC2_TC4.4	
	x	2.1	Determine track occupancy/train position												
	x	2.1.1	Detect Trackside Train Detection system occupancy		x										
	x	2.1.2	Deliver train position report			x									
	x	2.2	Define safe route		x		WP13, WP15								
	x	2.3	Provide movement authority		x		WP13, WP15								
	x	2.4	Recover after degraded situations		x		WP13, WP15								
Comms	x	2.5	Release route		x		WP13, WP15								
	x	2.6	Leverage data from digital services		x		WP13, WP15								
	x	3	Provide safe, secured, and seamless communication	x											
	x	3.1	Provide safe, secured, and seamless on-board communication			x	WP23, WP24								
Comms	x	3.2	Provide safe, secured, and seamless communication between train and infrastructure		x	x	WP25, WP28								
	x	3.3	Provide safe, secured, and seamless communication between train and infrastructure assets		x	x	WP28, WP48								
	x	3.4	Provide security services		x	x	WP23, WP28, WP24, WP29 & WP26								
DS	x	4	Provide digital services												
	x	4.1	Localise train on railway infrastructure continuously	x			WP21, WP22	I_TC1_TC4.1						I_TC4.1_TC4.4	
	x	4.1.1	Acquire safety-related data for train localization			x	WP21, WP22								
	x	4.1.2	Provide safety-related train localization data			x	WP21, WP22								
	x	4.1.3	Provide non-safety related train localization data (e.g., beneficial for diagnostic purposes)			x	WP21, WP22								
	x	4.1.4	Perform security access tasks (authenticate and authorize users and technical systems, and access domain information)			x	WP21, WP22								
	x	4.1.5	Perform diagnostic and maintenance tasks			x	WP21, WP22								
	x	4.1.6	Consume and provide time information for synchronization purposes			x	WP21, WP22								
	x	4.2	Provide advanced brake control	x			WP17, WP18	I_TC1_TC4.2							
	x	4.2.1	Provide time and location specific wheel-rail adhesion condition			x	WP17, WP18								
	x	4.2.2	Provide time (safe) deceleration which can be assumed for a specific train at a specific time in a specific part of the track			x	WP17, WP18								
	x	4.2.3	Activate measure(s) to secure sufficient adhesion condition for the (safe) deceleration provided (brake force) according to maximum usage or specific wheel-rail adhesion condition		x	x	WP17, WP18								
	x	4.2.4			x	x	WP17, WP18								
	x	4.3	Detect train integrity and length	x			WP19, WP20								
	x	4.3.1	Monitor train integrity status			x	WP19, WP20								
	x	4.3.2	Determine train length			x	WP19, WP20								
	x	4.4	Generate, provide, and activate Domain Data	x			WP27	I_TC1_TC4.4	I_TC2_TC4.4		I_TC4.1_TC4.4				
	x	4.4.1	Import Engineering Input Data into a standardised data model format as Engineering Data		x	x	WP27								
	x	4.4.2	Aggregate and validate Engineering Data (including Parameter Data)		x	x	WP27								
	x	4.4.3	Compile validated Engineering Data into consuming system specific Domain Data		x	x	WP27								
	x	4.4.4	Distribute Domain Data (including Parameter Data) to the Consuming Systems		x	x	WP27								
	x	4.4.5	Ensure that all Consuming Systems use the right version of Domain Data as active version		x	x	WP27								
	x	4.5	Provide safe and secured digital modular platform	x		x	WP26								
	x	4.5.1	Support the implementation of on-board applications			x	WP26								
	x	4.5.2	Support the implementation of trackside applications		x		WP26								

7.3.5 Catalogue of constituents

The Catalogue of Constituents is made up of the logical and physical constituents identified in the Constituents Views presented in the R2DATO Architecture Report R3 and comprises the following pieces of information/categorization:

- Category: Platform, Digital Service, Application, Operator, or External Infra.
- Reference (Ref.#)
- Constituent definition
- Internal Constituent or Actor
- Constituent type in charge of executing the function/Technical Capability: Infrastructure, train, or external entity
- Involved Constituents / Actors, that is, the Constituent or actor with which a given Constituent interact
- Involved Communication link / Interface name between constituents and between Constituents and Actors (supplemented by the "Interface Definition" sheet)
- Involved WP
- RACI Matrix (To be developed)

7.3.5.1 Internal constituents (refinement in progress – to be realigned with views)

Category	Ref.#	Constituent	Constituent definition	Internal constituent or actor	Constituent type (Infrastructure, Train, External)	Involved Constituents / Actors (according to Ref.#)	Involved Communication link / Interface name	Involved WP	RACI MATRIX			
									R	A	C	I
Platforms	1	Cyber Security Mgt System	Cyber security Management System handles all internal safety related constraints in the infrastructure as well as vehicles using one or more of the constituent parts of the PBS. Time management is supplied for all constituents.	Internal	Infrastructure	Ia1, 2, 12	(Ia1) (1) External data exchange (Wireless/Wireless, e.g. Rail Data Space (RDS), Federated Data Space) (1) (a) linked by Wire (bus) or wireless to internal/external networks	WP3 WP5 WP8 FP1-Motional	WP3		WP25 WP28 all WPs in Set	WP30
Digital Service	2	Data Factory	Data Factory is an ecosystem that enables sensor data to be collected, simulated, processed and shared, as well as AI models to be generated, certified and implemented in automated rail operations. (from D7.1 Requirements and specifications for Data Factory - see Figure 1: Simplified target configuration of the Data Factory)	Internal	Infrastructure	Ea3, 7	(Ia3) (2) Static, Dynamic, AI-data (2) (7) C14, Wireless - Cloud use Rail Data Space (RDS) (Federated Data Space)	WP7 WP11	WP7		WP11	
Digital Service	3	Digital Register	Digital Register (DR) shall provide reliable (meaning complete, accurate, current, consistent, and validated), interoperable, and accessible static infrastructure information (i.e., track layout incl. geometry, track objects, track civil structures), with the aim of supporting a wide range of use cases for consuming systems like Automatic Train Operation Transactor, Traffic Management System (TMS), Plan Execution (PE), Moving Block System(MBS), Absolute Safe Train Positioning (ASTP), Perception On-Board (PER-OB), Automatic Processing Module On-Board (APM-OB), Automatic Driving Module (ADM).	Internal	Infrastructure	Ia4, 4, 8	(Ia4) (3) I-OR-TS-TMS (3) (4) X2Rail-131, Wired-Bus (3) (8) C15, Wireless (FRMCS, MNO, cloud)	WP27 WP10	WP27		WP10	WP6 WP22 FP1 (TMS)
Applications	4	ATO/DAS trackside	ATO/DAS enable vehicle movement up to GoA3/4 ensuring adaptation to optimal speed profile, exact start/stop positioning at station/departing/yards, information exchange with Digital Register and ETCS Trackside e.g. for movement modes, position information (from RBC).	Internal	Infrastructure	3,5,9	(Ia) (3) - see constituent (3) above (4) (6) C17, Wireless - Cloud use Rail Data Space (RDS) (Federated Data Space) (4) (6) Subnet 128, 128 App A, Wireless	WP10 WP27	WP10		WP27 TS-CCS for ETCS, S6130, 143 Trackside + Onboard (No current WP)	
Applications	5	ETCS trackside	Ensure safe movement of vehicles connected to RBC according to various modes. Communicate with ETCS Onboard.	Internal	Infrastructure	Ia5, 4, 11	(Ia5) (5) Trackside assets, e.g. - RX/Railway crossing status - Point/Point status - TTD/Occupation status - etc. (5) (4) - see constituent (4) above (5) (12) C10, wireless (GSM-R/FRMCS)	WP13 (MB spec) WP14 (MB Prot) WP15 (HTD spec) WP16 (MB Prot) WP19 WP20 WP22	WP13 (MB spec) WP14 (MB Prot) WP15 (HTD spec) WP16 (MB Prot)		WP15 (HTD spec) WP16 (HTD Prot) WP15 (MB spec) WP14 (MB Prot) WP10	WP20 WP22 FP1 (TMS)
Digital Service	6	Remote control (driving)	Remote driving give the opportunity to move vehicles from a remote terminal. It rely on information from the perception system, a remotely connected DM (from the ETCS onboard, and necessary control elements e.g. power, braking, pantograph, doors, horn, video surveillance in the train.	Internal	Infrastructure	Ia6, 7, + control-equipment in vehicle	(Ia6) (6) Remote driving, wireless (MNO/FRMCS) (6) (7) Camerage for remote control, wireless (MNO) (6) (8) Controls + Information for remote control e.g. DM, RS, door control, horn, etc.	WP12	WP12		WP11	
Digital Service	7	Perception OB	Perception handling based on external interfaces (e.g. cameras, sensors, input from autonomous trackside assets). Perception handling is based on models and simulations handled by Data Factory. The Perception system provide data to the Data Factory from the Perception Vehicle logger.	Internal	Train	Ia7, Ia8, Ia9, 2, 6, 8, 9, 10, 12 external actors (autonomous trackside assets, obstacle detection sensors***)	(Ia7) (7) Environment Data/Wireless, Wired-Bus (Ia8) (7) RailwayLevel Crossing Status, Wireless (MNO/FRMCS) (Ia9) (7) Obstacle detection, Wireless (7) (12) see constituent (2) above (7) (6) see constituent (8) above (7) (10) C19, Wired/Bus (7) (10) C19, to be detected, Wired/Bus (7) (12) C27, Wired/Bus	WP11	WP11		WP7 WP12 WP27	WP22
Digital Service	8	Digital Register OB	The digital Register publish reliable static infrastructure data to the consuming systems, e.g. Automatic Train Operation Transactor (ATO), Moving Block System(MBS), Safe Train Positioning (ASTP), Perception (PER)	Internal	Train	3,7,9,10	(8) (3) see constituent (3) above (8) (7) see constituent (7) above (8) (10) C20, Wired/Bus (8) (10) C23, Wired/Bus (Wireless, FRMCS)	WP27 WP10 WP11 WP22 FP1 (TMS)	WP27		WP10 WP11 WP22	FP1 (TMS)
Applications	9	ATO/DAS Onboard ADM (GoA2) + APM (GoA3/4)	ATO/DAS enable vehicle movement up to GoA3/4 ensuring adaptation to optimal speed profile, exact start/stop positioning at station/departing/yards, Control power, braking, pantograph, doors, horn.	Internal	Train	4,7,12,13 controls e.g. power, braking, pantograph, doors, horn	(9) (Train) Subnet 130, 143, Wired-Bus (9) (4) see constituent (4) above (9) (12) Subnet 130, 143, Wired-Bus (9) (13) Subnet 140, 143, Wired-Bus	WP10 WP27 WP11(TBD)	WP10		WP27 TS-CCS for ETCS, S6130, 143 Trackside + Onboard (No current WP)	
Digital Service	10	Safe Train Positioning	The ASTP shall provide ASTP localization information such as ASTP ID position along the track relative to a reference location, speed and acceleration of the vehicle where the ASTP is installed which complies with the current ERM/ETCS principle (distance and position qualifier from a LRB0 and a speed) and can also provide additional new localization information such as: - The ASTP track id. - The ASTP reference point absolute (3D) geographic positioning (Long, Lat, Alt). - The ASTP vector velocity within the 3D coordinate system based on the track axis. - The ASTP vector acceleration within the 3D coordinate system based on the track axis. - The attitude (roll, pitch, and yaw angles) and angular rates of the vehicle where ASTP sensors are installed. The location information in 3D is required by new needs as the perception, incident management functions.	Internal	Train	Ia10, Ia11, 7, 8, 12	(Ia10) (10) (11) (14) Satellite (10) (7) see constituent (7) above (10) (8) see constituent (8) above (10) (10) (Sensors) Required sensors for ASTP (10) (12) LRB0 to ASTP + Position return to ETCS (to be decided)	WP22 WP11 WP27	WP22		WP11(TBD) WP27 TS-CCS for ETCS, Onboard (No current WP - LRB07)	
Digital Service	11	OT/COTL	Optional function to receive information of Train length on Train integrity from the DAC system.	Internal	Train	Ta1, 12	(Ta1) (11) Couple status, Train Length, Wired/Bus (11) (12) C29, Wired/Bus	WP20 WP14 WP16	WP20		WP13 (MB spec) WP14 (MB Prot) WP15 (HTD spec) WP16 (HTD Prot)	
Applications	12	ETCS on-board	Receive Position information from ASTP to give the opportunity for ETCS to evaluate correlation with its own sensor correction. This to secure a double barrier solution when TTD no longer is in use for ETCS MB - The need for such a safety measure must be analysed carefully in a safety perspective.	Internal	Train	Ia12, 5,7,9,10,11,13	(Ia12) (12) Balise reader (Dataexchange through angula to balise, wireless/Wired-Bus (12) (5) see constituent (5) above (12) (7) see constituent (7) above (12) (9) see constituent (9) above (12) (10) see constituent (10) above (12) (11) see constituent (11) above (12) (13) C28, Wired/Bus	WP13 WP14 WP15 WP16 WP19 WP20 WP22	WP13 (MB spec) WP14 (MB Prot) WP15 (HTD spec) WP16 (HTD Prot)		WP10 WP11 WP20 WP22(T - LRB0)	
Platforms	13	Onboard Recording		Internal	Train	9	(Ia3) (9) see constituent (9) above		No current WP			

7.3.5.2 Actors (refinement in progress – to be realigned with views)

Category	Ref. #	Constituent	Constituent definition	Internal constituent of actor	Constituent type (Infrastructure, Train, External)	Involved Constituents / Actors (according to Ref. #)	Involved Communication link / Interface name	Involved WP	RACI MATRIX			
									R	A	C	I
Platforms	Ea3	Configuration data provider	Actor who feeds the CCS with configuration data	Actor	External		Wired, wireless (FRMCS, cloud)					
Operator	Ea2	Cyber criminal	Actor who attempts cyber attacks on the CCS	Actor	External		Wired and/or wireless on common and external networks					
Digital Service	Ta1	DAC	Digital Automatic Coupling (DAC) is an innovative component to automatically couple and decouple the rolling stock in a freight train both physically (the mechanical connection and the air line for braking) as well as digitally (electrical power and data connection). DAC is key to enable the needed increase in efficiency and transparency of rail freight. Source: https://rail-research.europa.eu/wp-content/uploads/2021/04/DAC-Factheet_EN.pdf	Actor	Train		Wired	FP5				
Operator	Ta2	Driver	A person capable and authorized to drive trains, including locomotives, shunting locomotives, work trains, maintenance railway vehicles or trains for the carriage of passengers or goods by rail in an autonomous, responsible and safe manner Source: EU Directive 2007/59/v90708	Actor	External		Wired, wireless (FRMCS, cloud)					
Digital Service	Ia11	EGNOS	The European Geostationary Navigation Overlay Service (EGNOS) is a satellite-based augmentation system (SBAS) developed by the European Space Agency and EUROCONTROL on behalf of the European Commission. Currently, it supplements GPS by reporting on the reliability and accuracy of their positioning data and sending out corrections. The system will supplement Galileo in the future version 3.0. Source: wikipedia	Actor	External		Wired and/or wireless on common and external networks					
Environment	0	Environment	Actor which might physically interact with the R2DATO system for which a supervision is required	Actor	External		eVision					
Applications	5	ETCS-OB	ETCS is the control command part of the ERTMS (Signalling and operation management system encompassing ETCS for the Control Command, ATO for the Automatic Train Operation and FRMCS and/or GSM-R for voice and data communication. FRMCS and/or GSM-R are used as radio bearers for ETCS and ATO). ETCS-OB is the on-board part of ETCS. Source: subset 023	Actor	Train		Wired, wireless (FRMCS, cloud)					
Applications	12	ETCS-TS	ETCS is the control command part of the ERTMS (Signalling and operation management system encompassing ETCS for the Control Command, ATO for the Automatic Train Operation and FRMCS and/or GSM-R for voice and data communication. FRMCS and/or GSM-R are used as radio bearers for ETCS and ATO). ETCS is the trackside part of ETCS. Source: subset 023	Actor	Infrastructure		Wired, wireless (FRMCS, cloud)					
Digital Service	Ia10	GNSS	A satellite navigation or satnav system is a system that uses satellites to provide autonomous geolocation. A satellite navigation system with global coverage is termed global navigation satellite system (GNSS). As of 2024, four global systems are operational: the United States's Global Positioning System (GPS), Russia's Global Navigation Satellite System (GLONASS), China's BeiDou Navigation Satellite System (BDS), and the European Union's Galileo.	Actor	External		Satellite					
Operator	Ea3	Maintainer	The Maintainer performs preventive and corrective maintenance on R2DATO system	Actor	External		Wired, wireless (FRMCS, cloud)	FP3				
Environment	Ia9	Obstacle	This actor is a subpart of the Environment actor and stands for any obstacle on the track	Actor	External		eVision					
External Infra	Ia5	Point	Assembly of rails, blades, and of auxiliaries, certain ones being movable, which effect the tangential branching of tracks and allows to run over either one track or another. Includes a Point machine and Point detector. Source: EULYNX Glossary Definitions v240605	Actor	Infrastructure		Wired					
Operator	Ea6	Remote driver	In the frame of the remote driving capability, the Remote Driver has the same role as the Driver except that he is not located in the train but at the trackside level.	Actor	External		Wired, wireless (FRMCS, cloud)					
External Infra	Ia5	RX	Level crossing: any level intersection between a road or passage and a railway, as recognised by the infrastructure manager and open to public or private users. Passages between platforms within stations are excluded, as well as passages over tracks for the sole use of employees. Source: EU Directive 2016/798 v201023	Actor	Infrastructure		Wired					
Operator	EaX	Signaller	The Signaller supervises and controls the operation of trains as defined in the TSI OPE	Actor	External		Wired, wireless (FRMCS, cloud)					
Digital Service	Ta3	TCMS	Train Control and Monitoring System of a Rolling Stock	Actor	Train		Wired, wireless (FRMCS, cloud)					
Platforms	Ia1	com infra, FRMCS/ACS(M	Telecommunication infrastructure used for the railway communications	Actor	Infrastructure		Wired and/or wireless on common and external networks					
Applications	Ea1	Time provider	Actor providing clock time that is used by all the components of the R2DATO systems	Actor	External		Wired and/or wireless on common and external networks					
Applications	Ia4	TMS	Traffic Management System supports planning activities including producing an operational plan, based upon the operational state and operational events	Actor	Infrastructure		Wired and/or wireless on common and external networks	FP1				
Platforms	Ia5	TTD	Trackside Train Detection. The proof of the presence or absence of trains on a defined section of line. Source: ERAU SP Definitions v241203	Actor	Infrastructure		Wired					
Platforms	TaX	Train	Various connections to the trains control elements like doors, horn, breaks, status information for monitoring	Actor	Train							
Platforms	Ia8	LX/RX	Level crossing status from autonomous level crossings railway crossing safety systems	Actor	Infrastructure		Wireless					
Digital Service	Ia12	Balise Data Provider	Information received from a balise via the ETCS balise reader	Actor	Train		Air/gap					
Platforms	IaX	Infrastructure	Various systems/devices used to monitor/maintain infrastructure	Actor	Infrastructure		Wired and/or wireless on common and external networks					
Operator	Ta4	Maintainer	The person to perform infrastructure maintenance activity	Actor	Infrastructure		NA					