D2.3

Reference Freight System Architecture

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1 Executive Summary

Rail freight transport faces significant challenges like asset utilization, poor data quality or complex processes. To cope with these challenges, changes are required. Automatization and digitalization play a crucial role in enhancing the competitiveness of rail freight. The vision of future freight transport involves an intelligent system that interconnects various stakeholders, processes, and technologies. However, due to the close interdependence in European rail freight transport and since the full digital freight train (FDFT) and its ecosystem is not compatible with today's systems, only a harmonized approach on European level will be successful.

To tackle these challenges, the project Flagship Project FP5 - TRANS4M-R was initiated. TRANS4M-R is a consortium project that is part of Europe's Rail Joint Undertaking (ERJU) and is funded within Flagship Area 5 with a duration from 2022 to 2026. The project aims to boost innovation for the European rail freight sector, concretely by developing, validating, and demonstrating TRANS4M-R technical enablers.

This document constitutes Deliverable 2.3 Reference Freight System Architecture of ERJU Flagship Area 5 project FP5 TRANS4M-R and is aimed at providing an overall functional reference freight system architecture by combining different subsystems into one. For FP5 – TRANS4M-R, these subsystems comprise the FDFT, yard automation systems, innovative freight assets as well as seamless operation. The developed architecture describes the target of full automation of the freight sector, as well as a subset based on the agreed technical enablers in TRANS4M-R.

The reference freight system architecture is compiled by the different partners of this task 2.3. Complementary to the work packages involved, this work focuses on the interfaces of the different subsystems, their interaction, and the resulting impacts on the overall systems. Accordingly, the level of detail presented within this document is on an aggregated level. For details on the subsystem architectures please refer to the deliverables of the respective work packages (WP3, WP4, WP5, WP6-WP12, WP25, WP26-WP31). The alignment process of WP2 on the reference freight system architecture is described in the methodology section of this document.

According to its delivery date early in the project, the aim of this report is to describe and define an overall architecture that is highly modular to leave enough space for future developments within the course of TRANS4M-R. The interfaces between the different subsystems are defined accordingly and the overall architecture is described at a high level. The architecture needs to be detailed out in upcoming deliverables of the different subsystems. This report therefore does not describe a fully detailed overall architecture.

The developed architecture provides an important basis for further collaboration on the development of an automatized and digitalized freight rail operation, especially within FP5 TRANS4M-R. In the further course of FP5 TRANS4M-R, the reference architecture will be applied enabling its further refinement in FP5 TRANS4M-R. Lead by the interoperability and modularity principles, further adjustments, and enhancements at later stages of the migration, i.e., roll-out scenarios, will be possible. The functional reference freight system architectures will serve as foundation for authorisation of FDFTO, Seamless Freight vision and yard automation technologies and procedures. In addition to this deliverable, the architecture will be provided as a separate model for better usability.

Keywords: System Architecture; Reference Architecture; Target Operational Procedures; Full Automation

2 Abbreviations & Acronyms

Abbreviation / Acronym	Description
ABT	Automated Brake Test
ASO	Automated Shunting Operations
ATO	Automatic Train Operation
ATP	Automated Train Protection
CCS	Control-Command and Signalling
CCU	Central Control Unit
CSM	Common Safety Method, see (EU) 402/2013
COTS	Commercial off-the-shelf
DAC	Digital Automatic Coupling
DAC4	DAC level 4
DEMO	Demonstrator
EDDP	European DAC Delivery Programme
EDIGES	Electronical Datainterchange Intermodal Global European Standard
EP brake	Electro-pneumatic brake
ER JU	Europe's Rail Joint Undertaking
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FDFTO	Full Digital Freight Train Operations
FDFT	Full Digital Freight Train
FP	Flagship Project
FPSE	Flagship Project System Engineers
FRMCS	Future Railway Mobile Communication System
GoA	Grade of Automation
HAZOP	Hazard and Operability
Herd	Harmonized European Railway Diagnostics
HMI	Human Machine Interface
IC	Interoperability Constituent
IVG	Intelligent Video Gates
NoBo	Notified Body
OCC	Operations Control Center
Polarion	Software environment used in TRANS4M-R
RAMS	Reliability, Availability, Maintainability and Safety
RSC	Remote Supervision Control
SIL	Safety Integrity Level
SPE	Single-Pair Ethernet
SPW	Self Propelled Wagon
SRAC	Safety Related Application Condition

Abbreviation / Acronym	Description
SRS	System Requirements Specifications
SSRS	Subsystem Requirements Specifications
TAF TSI	Telematics Applications for Freight Technical Specification for Interoperability
TE	Technical Enabler
TFFR	Tolerable Functional Failure Rate
THR	Tolerable Hazard Rate
TRL	Technology Readiness Level
TSI	Technical Specifications for Interoperability
TSI OPE	Operation and Traffic Management TSI
TU	Traction Unit
UIC	International Union of Railways
URS	User Requirements Specifications
WP	Working package
YAMS	Yard Automation and Management System
YCS	Yard Communication Server

Table 1: Abbreviation & Acronyms

3 Background

The present document constitutes the Deliverable D2.3 "Reference Freight System Architecture" in the framework of the Flagship Project FP5- TRANS4M-R.

The aim of FP5- TRANS4M-R is to transform the European rail freight sector into a digitalized and automated high-performance transport system. To this aim, different technical enablers are developed, validated, and demonstrated within the project scope. These technical enablers need to reach high levels of TRL, a highly complex task to be reached. The project structure, dividing the work into several work packages that are highly dependent on each other, supports this aim. The corresponding work package structure is shown in Figure 1 below.

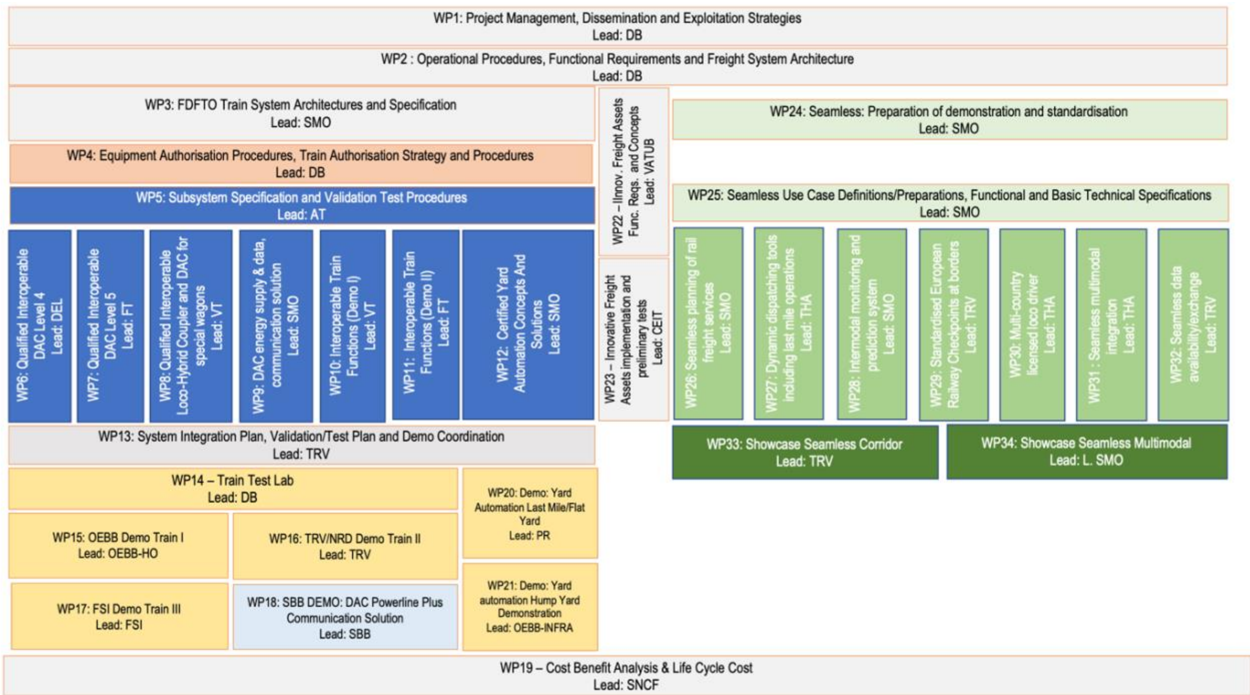

Figure 1: WP-structure in TRANS4M-R

Within this context, WP2 covers the different levels of the project by integrating the different work streams. One important aspect for future developments within FP5-TRANS4M-R is the definition of a common working basis. Accordingly, as part of WP2, this deliverable 2.3 comprises the definition of the functional "Reference Freight System Architecture". This reference architecture is a combination of the architectures developed in the different innovation workstreams of FDFTO, yard automation, innovative freight assets and seamless.

Complementary to the work packages involved, this work focuses on the interfaces of the different subsystems, their interaction, and the resulting impacts on the overall systems.

The aforementioned systems are developed within other work packages and the details of the systems are or will be described in separate deliverables. The following table summarizes the relevant inputs of other work packages and their deliverables to this document. Some of these deliverables will be delivered after this deliverable. For the according points to be handled in detail in future deliverables, a design indication will be given within this document. However, a detailed definition will be discussed in the respective work packages and presented in their deliverables but needs to be left open here. Altogether, also due to the early delivery date within the project FP5-TRANS4M-R, this document does not describe a fully detailed-out overall freight system architecture.

WP	Delivery Name	Due	Relevance to D2.3
WP3	D3.1: System Requirement Specification FDFT	M14	The functional to WP3 is defined based on the operational procedures (D2.1, [1]), which are considered and complemented by functional system requirements as described in deliverable D3.1.
	D3.2: Physical reference system architecture FDFT and D3.3: Digital/Data reference system architecture FDFT	M22	D3.2 and D3.3 focus on the physical system architecture and the digital / data architecture of the FDFT. The FDFT architecture is a service provider of functionality.
WP4	D4.2: Risk assessment and harmonized safety architecture	M13	Based on the result of task 4.1 the beneficiaries will do the risk assessment referred to Commission Implementing Regulation (EU) No 402/2013 to derive and assign the requirements to be verified for evidence for the component DAC and for safe integration into the vehicle and safe operation of DAC equipped vehicles.
WP5	D5.5: Requirements Specification Yard Automation	M17	In this document the focus is on the requirements of how to make best use of the DAC and its enabler functions in the yard area. Although called “train functions”, most of them are vital for automated shunting and the use-cases under which this is carried out. Automated Shunting Operation is summarized under the acronym of ASO, in this paper focusing on automated shunting movements. The aim of this Deliverable is to specify the requirements for the provision of competitive digital rail freight services

WP	Delivery Name	Due	Relevance to D2.3
			through yard automation supporting Full Digital Freight Train Operation. Fully Automated Decoupling and Automated Shunting Movements have been identified as the key enablers for automation in yards. A modular approach was chosen to later allow a stepwise introduction of the described technical enablers, which should finally help supporting the DAC migration. An architectural overview is also a vital part of the deliverable content.
WP12	D12.1: Hazard Analysis and Risk Assessment for Hump Yard and Flat Yard / Last Mile	M21	In D12.1, the hazard analysis and risk assessment for the yard demonstrators will derive and assign requirements for the demonstration of safe automatic shunting operations.
WP22	D22.3: Use cases and conceptual system specification for Self-Propelled Wagon	M24	D22.3 provides a common understanding of the state of the art of the self propelled wagon concept in freight railways. On its delivery it will expose the different visions of the topic, from the user needs to the state of the art (commercial references, projects, scientific literature). It will also include preliminary concepts, system specification and validation strategies for this concept. Based on a vision where a future freight train is able to run between different end-costumers with wagons that disconnect and connect autonomously at yards, D22.3 needs to be aligned with D2.3 on how to cope and complement the current operational procedures for the freight railway stakeholders.
WP25	D25.1: Report on the basic functional and technical specifications for the realisation of the technical enablers of Seamless Freight	M18	D25.1 provides general specifications with list of processes for seamless freight and seamless freight requirements. Further, task-based specifications are outlined for the technical enablers in WP26-32 (seamless planning, dynamic dispatching, intermodal prediction, European checkpoints, multimodal integration, seamless data exchange).

Table 2: Involved work packages and their relevant deliverables

Besides the description of the overall functional freight system architecture, the aim of this work package is to foster alignment between the different work packages. Accordingly, requirements on the design of the architecture of the subsystems arose which are considered within the different architectures but are not represented here. Within this context, D2.1 [1] plays an important role as common foundation of the architecture designs.

4 Objective/Aim

The objective of this document is to provide a functional reference freight system architecture concept integrating the functions of all technical enablers out of the WP6-WP12 & WP26-WP32. It will be based on the interoperability and modularity principles enabling adjustments and enhancements at the later stages of the migration, i.e., roll-out scenarios. The functional reference freight system architecture will serve as foundation for authorisation of FDFTO, Seamless Freight vision and yard automation technologies and procedures. For this reason, a strong collaboration with WP4 on the authorisation procedures is important as well as an alignment with WP3 & WP25.

4.1. Task description

Task 2.3 started in month three and the outputs of these tasks are included in this document. The following table gives the direct match of the task definition from the proposal with the output and a link to the section where more details can be found.

	Task definition from proposal (Task 2.3)	Output of WP2
Task 2.3	A functional reference freight system architecture concept integrating the functions of all technical enablers out of the WP6-WP12 & WP26-WP32 will be designed.	▪ Chapter 8 Reference Freight System Architecture ▪ Chapter 5 Technical enablers
Task 2.3	It will be based on the interoperability and modularity principles enabling adjustments and enhancements at the later stages of the migration, i.e., roll-out scenarios.	▪ Chapter 7.3 Interoperability and Modularity Principles
Task 2.3	The functional reference freight system architectures will serve as foundation for authorisation of FDFTO, Seamless Freight vision and yard automation technologies and procedures. For this reason, a strong collaboration with WP4 on the authorisation procedures is foreseen as well as an alignment with WP3 & WP25.	▪ Chapter 6 System of Interest ▪ Chapter 8 Reference Freight System Architecture
Task 2.3	A first draft release of the functional reference freight system architectures will be injected early enough to enable WP3 and WP25.	▪ Chapter 8.1 Draft Release

	Task definition from proposal (Task 2.3)	Output of WP2
Task 2.3	The main document will be released with D2.3. This task also coordinates the collaboration and regular interactions with the System Pillar experts.	▪ Chapter 7.4 Interaction with System Pillar

Table 3: Task description matched with output in deliverable

4.2. Outline of deliverable 2.3

The outline of this deliverable is the following:

Section 1-4: Summary, Abbreviations, Background & Objective

Section 5: Technical enablers

Section 6: System of Interest

Section 7: Methodology

Section 8: Reference Freight System Architecture

The process of alignment and input gathering is described in the Methodology section. At the core of this document is the functional reference freight system architecture, presented in chapter 8. The delimitation towards the input giving work packages and their content is given in the "System of Interest" section 6. The developed architecture describes the target of full automation of the freight sector.

5 Technical enablers

The technical enablers describe to be developed technologies within the TRANS4M-R project. These enable more efficient operations and provide other benefits which boost rail freight. Each of the enablers has a technology readiness level (TRL), which describes how mature a given technology is planned to be at the end of the project.

5.1 Technology Readiness Level

The TRL describes the maturity level of a particular technology, in this case a maturity level which must be reached within the development cycle of TRANS4M-R. This system was developed by NASA for flight tests and has been widely adopted for development projects and adapted into the ISO 16290:2013 norm. It specifies the maturity levels for space systems but can be adopted to fit into any development project. The TRLs reach from one to nine, with one being basic technology research and nine being a qualified system with inworld operations proven (see the following table).

TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in a lab
TRL 5	Technology validated in a relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6	Technology demonstrated in a relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7	System prototype demonstration in an operational environment
TRL 8	System complete and qualified
TRL 9	Actual system proven in an operational environment (competitive manufacturing in the case of key enabling technologies, or in space)

Table 4: Technical Readiness Levels (TRL) acc. to BRIDGE2HE[1]

[1] https://horizoneuropencpportal.eu/sites/default/files/2022-12/trl-assessment-tool-guide-final.pdf

5.2 Technical enablers

The Grant Agreement lists technical enablers (TE), that shall be developed within TRANS4M-R. Many of those enablers are not relevant for this document because of their focus of operations, and not on the architecture. The irrelevant enablers will not be mentioned here any further. The subsystems for which the different technical enablers are relevant, are listed below the according technical enabler.

List of relevant technical enablers:

- **EU-harmonized interoperable DAC Type 4 upgradable to interoperable DAC Type 5 and Hybrid Coupler for Loco/Wagon**
    - FDFT
    - Yard (especially for stationary devices)

- **Train functions for train Composition detection/management system, automated/automatic brake test**
    - FDFT
    - Yard
    - Seamless
- **Train functions enabling, Automated parking brake systems, Digital Wagon Inspection, DAC-based telematics applications, Distributed power system, electro-pneumatic brake**[2]
    - FDFT
    - Yard

- **DAC for T3000 Wagons**
    - FDFT

[2] This Technical Enabler is shown for the sake of completeness. However, these functions will not be (all) developed within FP5-TRANS4M-R.

6 System of Interest

In this chapter, the scope of the functional freight reference architecture is given. First, the relation to the involved work package and their according architectures is given – in the following described as “subsystems”. Second, the relation of the different subsystems to the reference architecture is described for every subsystem.

For the reference freight architecture, functionalities of the backend are relevant. However, the development and specification of the backend is not part of the development activities within FP5-TRANS4M-R. Consequently, the functional relations to the backend are described indicatively from today´s knowledge.

For FP5 – TRANS4M-R, the functional reference architecture comprises the following systems:

- Full Digital Freight Train (FDFT),
- Yard automation systems,
- innovative freight assets as well as
- seamless operation.

In addition, requirements for safe integration are considered.

The following figure summarizes this scope and illustrates the input flow from the different work packages into this document.

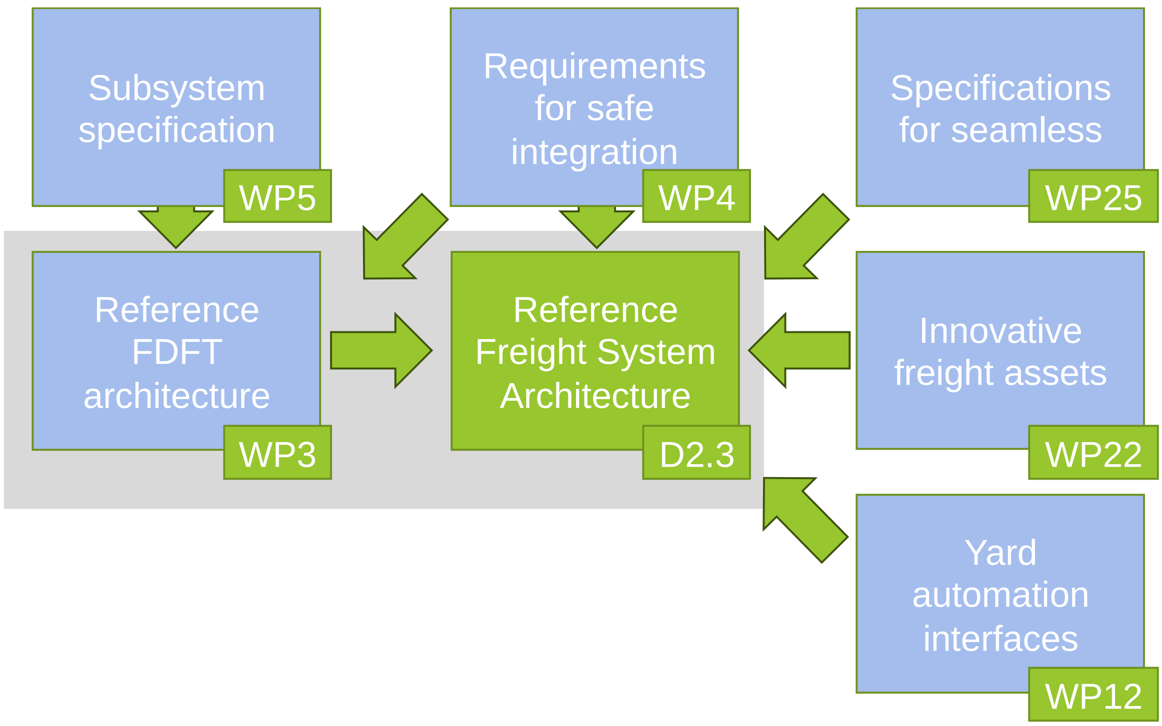

Figure 2: Overview of input flow from the different WP into D2.3.

6.1 Delimitation of the work in the individual work packages

The delimitation of the scope of this Deliverable against the single contributing work packages is explained shortly using WP3 as example.

The architecture for the FDFT including internal modules and interfaces will be defined in WP3. Within this document, it will be treated as black box. Here, the focus lies on the interfaces between the different building blocks. Within the different WPs, the outgoing interfaces were defined and combined within T2.3 into one architecture. Accordingly, modules or components that are not relevant for the interfaces of the different subsystems may not appear within the architecture presented in Figure 19, regardless of how important they are for the individual subsystems. For the work split between the different work packages, please refer to Figure 18.

6.2 FDFT

The functional interface between WP2 D2.3 and WP3 is defined through the operational procedures as described in D2.1 [1], which are considered and complemented by functional system requirements as described in deliverable D3.1. The deliverable D3.1 has been provided in August 2023 and has been reviewed and accepted. It has been published in January 2024 to the public.

In WP3, D3.2 and D3.3 the focus is on the physical system architecture and the digital / data architecture of the FDFT. The FDFT architecture is a service provider of functionality supporting the requirements from the upper layer (landside FDFT backends) to be supported by the FDFT system architecture (train side FDFT equipment), while enabling access to the train functions being described in WP5.

The communication connection within the FDFT is performed by a wired approach using single pair Ethernet (10BASE-T1L). This communication is used for most of the train functions, including safety related functions, such as train composition detection, train length calculation, train integrity monitoring and remote un-coupling.

The communication between FDFT (train side) and the landside FDFT backends is performed via a wireless link using foremost a public mobile communication network, readily available in almost all locations in Europe. To support wireless communication with the landside systems, where no mobile network is available, a local wireless communication using WLAN shall be supported. All wireless communication shall use protocol layers, with the specifications currently being under discussion within WP3.

The link between the two work packages is done by deriving system requirements out of the user requirements as described in this document (D2.3).

The deliverable D3.2 (physical system architecture FDFT) is currently written and is planned to be finalized in April 2024.

The data that needs to be exchanged, shall use a message structure, with the specifications currently being under discussion within WP3. The topics and the related detailed description of the contents shall be agreed between the users of the FDFT-functions. The users of these functions are connected to the FDFT-Backend, FDFT Yard System and mobile HMI.

The deliverables D3.3 is currently being written and is planned to be available in April 2024.

Both, the physical & digital interfaces that are derived from requirements as described in WP2 D2.3 will be defined in WP3 D3.2 and D3.3.

The overall target is to define a railway system that allows to integrate the FDFT (train side) into the overall system to support the visionary operational target procedures [1] by an implementation of the required functionality in a concise manner. Although the real implementation will be performed by the different suppliers, the standards, approaches, and hints for implementation will be described in WP3 D3.2 and D3.3.

6.3 Yard

In WP5 the focus is on the requirements of how to make best use of the DAC and its enabler functions in the yard area. Although called "train functions", most of them are vital for automated shunting and the use-cases under which this is carried out. Automated Shunting Operation is summarized under the acronym of ASO, in WP5 task 6 focusing on automated shunting movements. ASO is only applicable in FDFTO shunting mode, uses FDFTO train functions, but does not support train runs itself.

There are two core general use-cases named "hump shunting" and "flat shunting". While shunting in a hump yard is basically a one-directional workflow, it needs a different operational approach and has a higher goal of automation than shunting in a flat yard, with a never-ending variety of possible scenarios in the yard and its connected last mile.

Fully Automated Coupling, Decoupling and Automated Shunting Movements have been identified as the key enablers for automation in yards, stationary brake test installments being supportive devices until operational target processes can be reached through full implementation of all related FDFTO-train functions in all European freight wagon fleets. A modular approach was chosen to later allow a stepwise introduction of the described technical enablers, which should finally help supporting the DAC migration and make DAC implementation a full success in sustainability and economy.

Remote Supervision & Control

Driving operation will ideally be relying on ATO. However, while this will apply on nominal train operation, there must be a fallback-option in degraded mode. [2] But remote driving is also a necessary approach for wagon processing in Yards. In ATO Remote Supervision and Control (RSC) is meant as a fallback option where a remote driver can remotely control the train to manage the situation. In this position, a person remains the highest decision-making authority of the railway system. [2]

The RSC will be a new work environment with a new role for the RSC manager, in the Yard the YAMS is the work environment where the YAMS manager must supervise and manage wagon processing and all other situations. Accordingly, the driver´s job description needs to be adapted as well as the organizational structure within the railway undertaking [2]. In FDFTO the functions of RSC can be found in the YAMS architecture.

A basic specification of a remote driving system is currently developed within the scope of European research (Shift2Rail, IP2 X2Rail4 and IPX TAURO). FP5 subproject Yard is focused on shunting movements, whereas in FP2 ATO target functionality shall resolve malfunctions for GoA2 - 4 with an unoccupied locomotive under remote control. As such, remote control is an essential function of the ATO system, ASO making use of it for the specific requirements of shunting in Automated Yards.

High-Level Architecture

The high-level architecture of ASO is described in Deliverable D5.5 Requirements Specification Yard Automation [5]. A short summary is given in the following, for details, especially on requirements and the yard architecture for hump, flat yards and last mile, please refer to [5].

The ASO architecture is shown in Figure 3. The ASO architecture consists of trackside components and onboard components on the traction units. The scope of the suggested solutions for yard automation are limited to trains completely equipped with the DAC type 5 and decoupling in movement in the hump area [5].

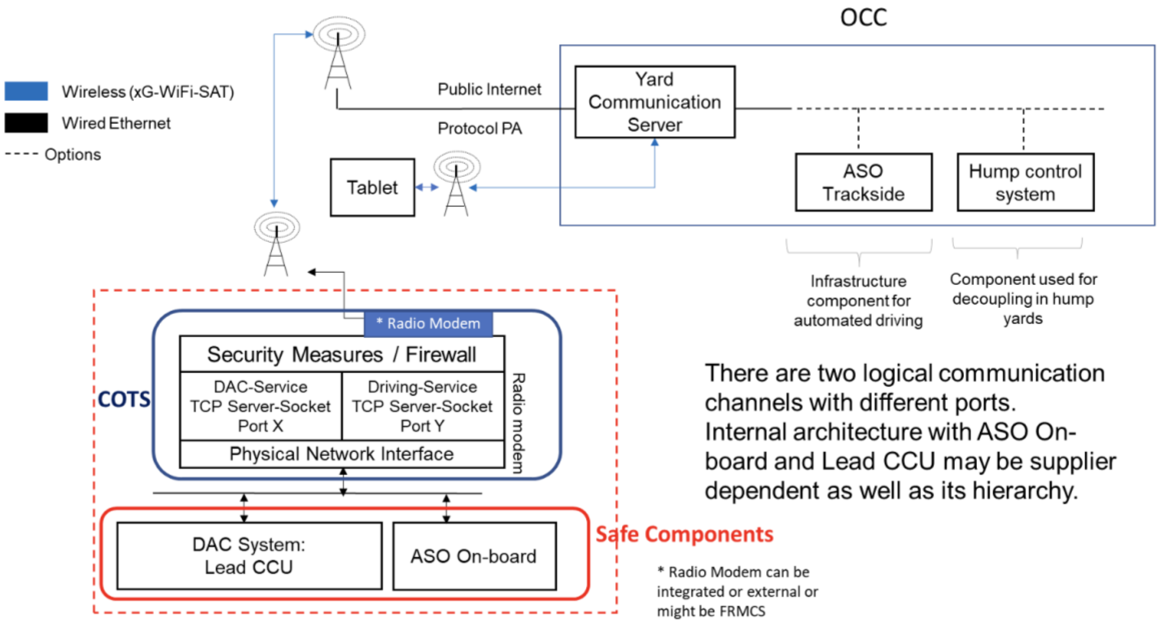

Figure 3: ASO architecture [5]

The Lead CCU has an interface to applications of yard automation, allowing remote control of train functions in yards. Since ASO contains components of remote control it is a safety critical system. ASO comprises, among others, the following capabilities [5]:

- The system localises the shunting composition to determine when the split point has reached its split position.
- During ASO operation the location of all TU and wagons must be supervised in the Yard. During ASO operation, it shall be possible to input the mission from the YAMS to start the mission.
- During ASO operation, it shall be possible to remotely operate the TU using a portable control device or from a remote supervision control.
- Depending on the GoA of the ASO on-board it shall be capable of interfacing with on-board sensors for obstacle detection.
- Onboard positioning instruments like d-GPS supported by odometry (or equivalent technological solutions) shall reach an exactness of +/-5cm at standstill and need to be available on the traction unit as a leading consist.

In the next figures it is shown how the application of several modules (all aligned with the high-level architecture presented before) concurs to evolve from GoA0 to GoA4.

GoA 0 – Full manual

In this architecture, the Yard Manager is based in the operations control center (OCC) to operate the freight yard. Arrivals and departures are scheduled manually and there is huge human presence on the track side:

- Shunter worker to operate point machine and Level Crossings
- Coupler worker to execute shunting
- Driver on the Loco.

Communication among the personnel via radio.

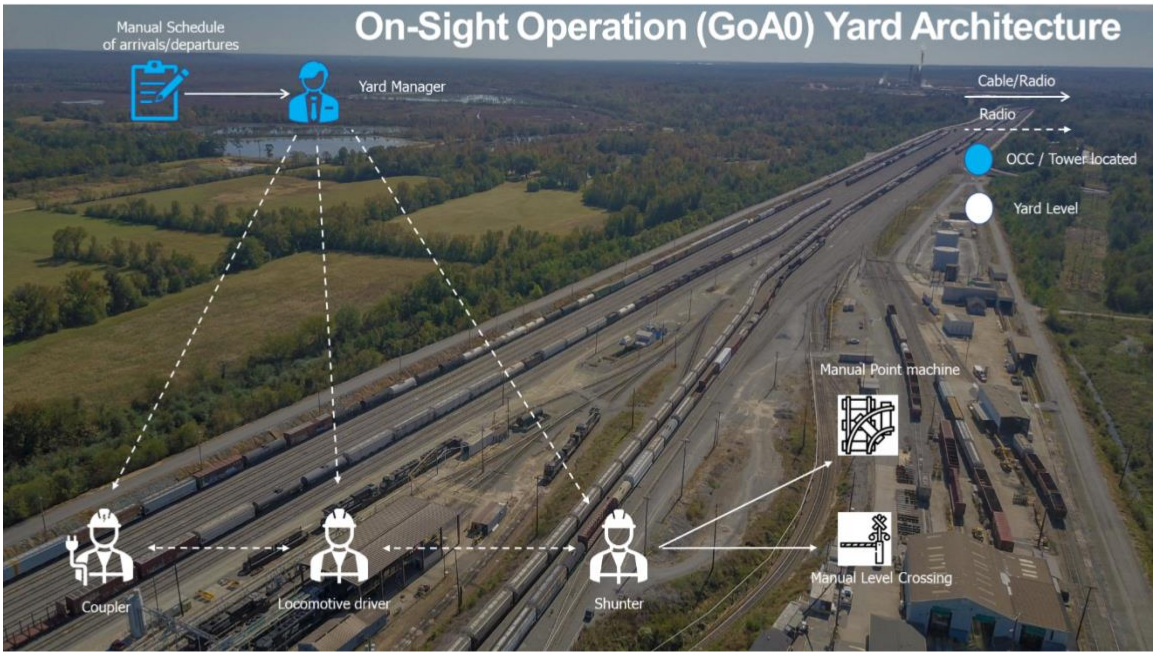

Figure 4: Yard: GoA0 architecture [5]

GoA 1 – Initial Automation

Also, in this configuration the Yard Manager is based in the OCC to operate the freight yard.

The interlocking (with the object controller) is now responsible to set routes, i.e., moving/locking switches and commanding level crossings.

Arrivals and departures are scheduled manually and there still is significant human presence on the trackside:

- Coupler worker to execute shunting.
- Driver on the Loco.

Communication among the personnel via radio.

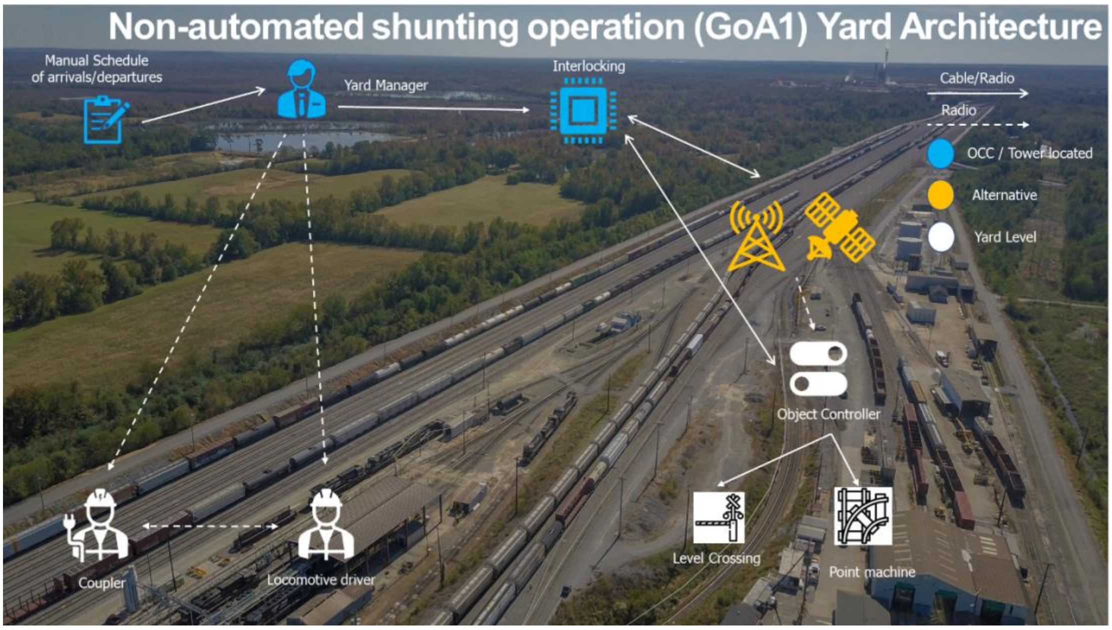

Figure 5: Yard: GoA1 architecture [5]

GoA 2 – Enhanced Automation

In this configuration, the Yard Manager is based in the OCC to operate the freight yard in conjunction with the Operator Control Unit who is responsible to manage the ASO remotely, to operate point machines and level crossings, and to send shunting commands.
The interlocking (with the object controller) remains responsible to set routes, i.e., moving/locking switches and commanding level crossings.

Arrivals and departures are still scheduled manually but there is no human presence on the track side. DAC 4 or DAC 4.5 is now available to execute shunting operations in an automated way.

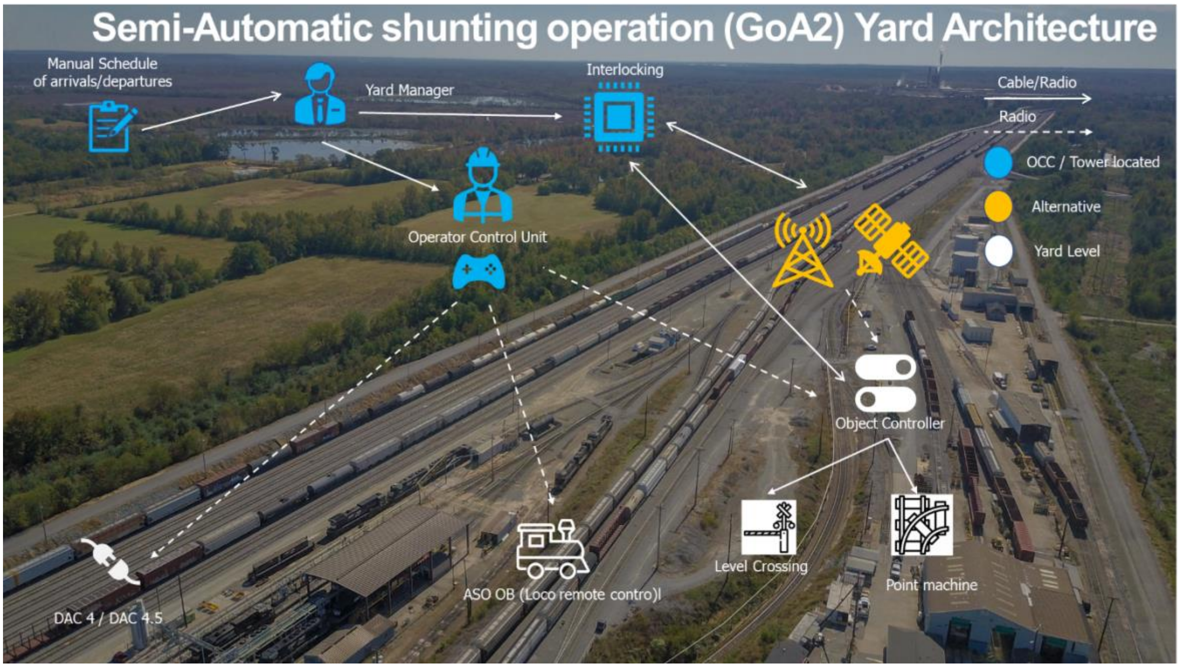

Figure 6: Yard: GoA2 architecture [5]

GoA 3 – Advanced Automation

In GoA3 architecture, the Yard Manager is based in the OCC to operate the freight yard in conjunction with the Operator Control Unit. The latter is responsible to manage the ASO remotely, operate point machines and level crossings and to send shunting commands. The interlocking (with the object controller) remains responsible to set routes, i.e., moving/locking switches and commanding level crossings.

Arrivals and departures are now scheduled and optimized by Yard Planner, reducing the human effort.
DAC 4, DAC 4.5 or DAC 5 supports automated shunting operations.

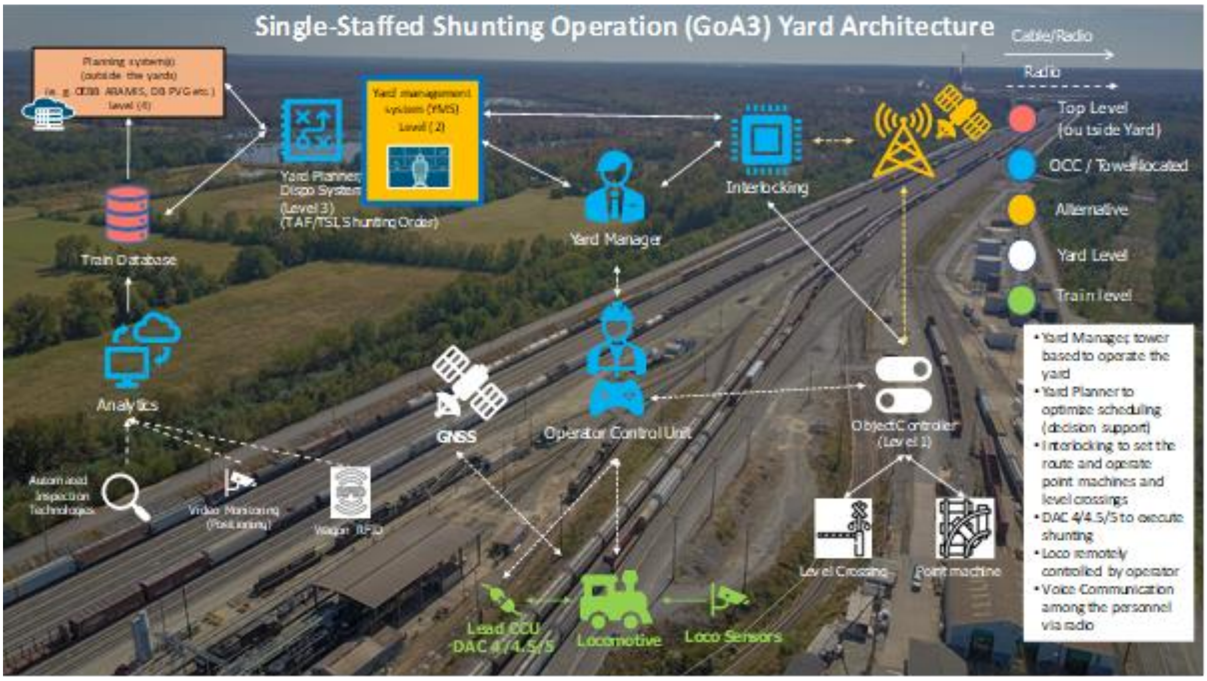

Figure 7: Yard: GoA3 architecture [5]

GoA 4 – Full Automation

In this configuration there is no human involvement for management of the freight yard as it is fully automated.
Analytics tools (video inspection, RFID, etc) will be responsible to reconciliate the expected data (planned once) versus the observed (actual data).
ASO trackside centralized intelligence will manage the freight yard autonomously by controlling the ASO on board, point machines, level crossings and DAC 5 for shunting operations.
The interlocking (with the object controller) remains responsible to set routes, i.e., moving/locking switches and commanding level crossings.

Like to previous architecture arrivals and departures are scheduled and optimized by Yard Planner. The real operation is carried out by the use of the YAMS.

Figure 8: Yard: GoA4 architecture [5]

While FP 2 has drawn an architecture called freight specific (e.g. FP2 D5.5 Documentation of Freight specific user requirements for automation process [2]), this is considered only for mainline operation (autonomous train operation ATO). Neither does FA2 cover requirements specific for FDFTO shunting (mode), nor does its ATO oriented architecture. The proposed architecture is presented for visualization purposes.

From FP5 Subproject Yard perspective FDFTO overall architecture would be envisaged as shown in the following Figure 9. The shown architecture is not an agreed upon view beyond the yard automation group. Accordingly, it is presented here as a discussion input of the yard automation group and not within the results chapter of this deliverable.

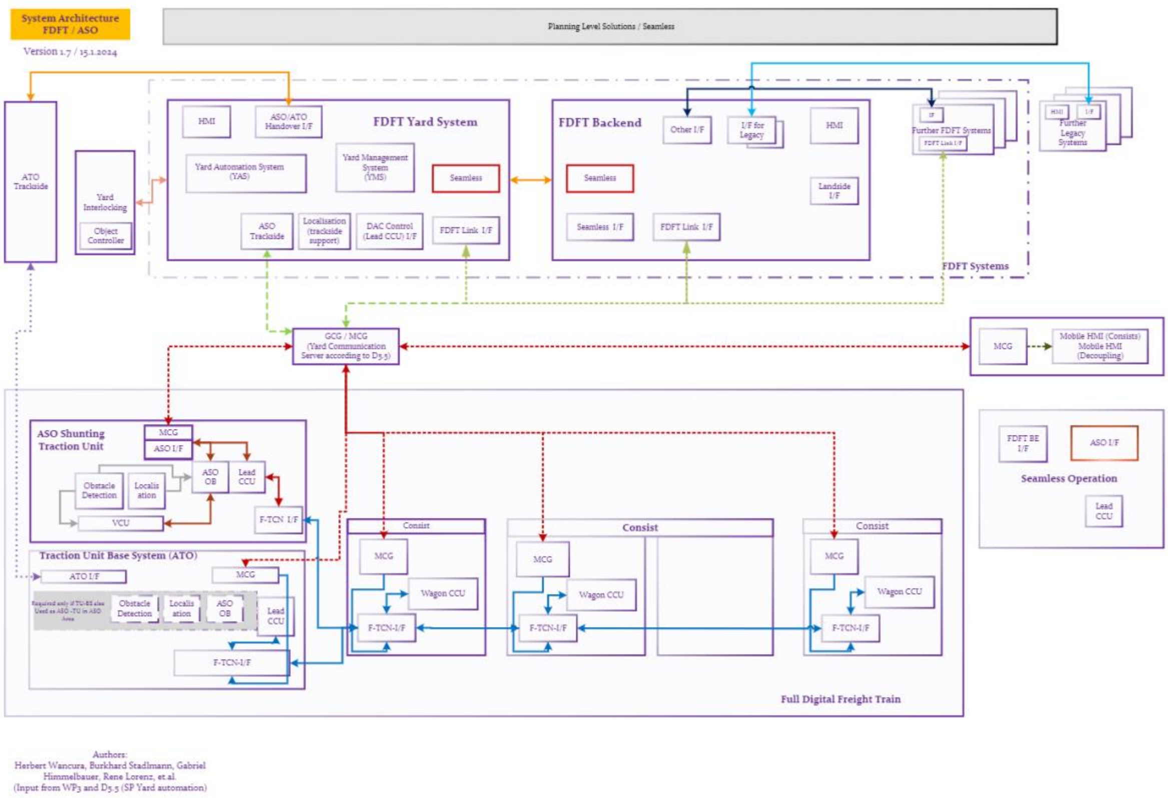

Figure 9: FDFTO Overall Architecture from SP Yard perspective, based on WP3 and D5.5

Since the ASO on-board is an advanced remote-control system, we foresee that in the future, ERTMS/ATO might be able to integrate within its architecture also all the functions to cover Freight Yard Automation and have a single on-board system in the Mainline Locomotives.

The advantage of the proposed approach is allowing a faster introduction of improved automation levels together with DAC and FDFTO-functions in freight yards, but at the same time not jeopardizing existing high level automation systems in yards.

Datamodel for shunting orders - based on TAF-TSI train & wagon data - requires standardized interfaces & protocols towards FDFTO – ASO. Split points and dynamic split positions (in hump yard) must be calculated based on these datasets by YAMS (YMS for points, YAS for positions), therefore ASO requirements (D5.5) have to be considered in FDFTO overall architecture.

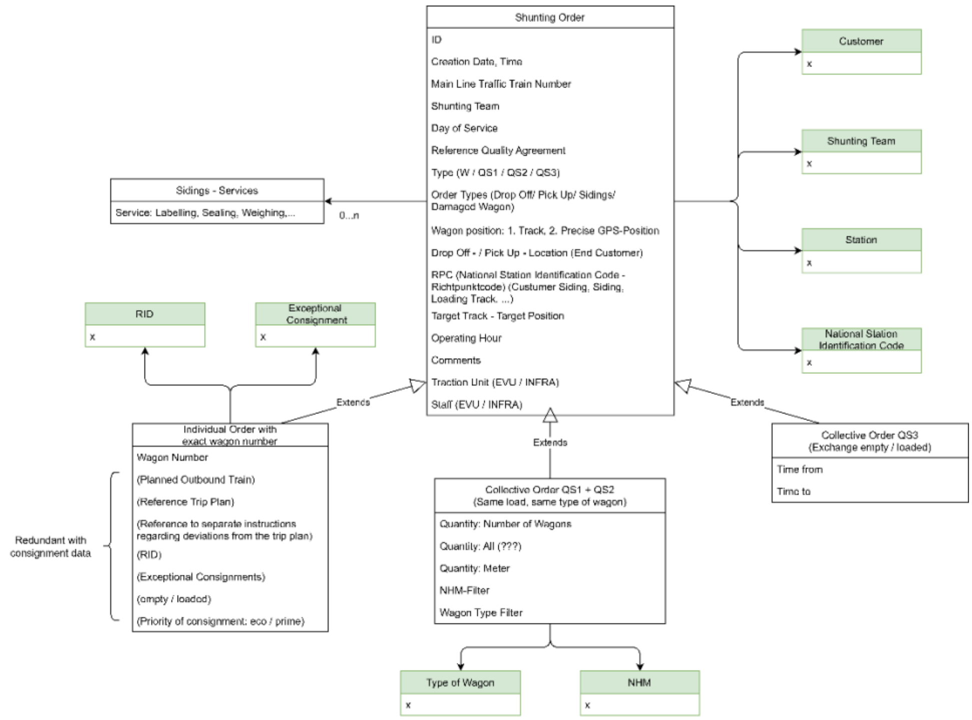

Figure 10: TAF-TSI based data model for Yard Management System (YAMS) sourced from FP2 D5.5

For further alignment, discussions are taking place between FDFTO WP 5 (Task 5.6), the Automatic Yards Operations subproject and WP 25 (Task 25.1) to discuss content and interfaces. According to the current timeline, the interfaces will be defined by WP 25 in the course of 2024 to be implemented in the demonstrators in 2025 [5].

6.4 Seamless

The Seamless Freight cluster aims to deliver an essential contribution towards the modernization, digitalization and harmonization of multimodal rail freight. By addressing various technical enablers Seamless Freight bridges the gaps between actors, countries, systems, processes and transport modes.

True seamless planning must result in perfectly consistent planning and allowing for smooth transition and continuity for all actors involved along the entire transport chain as well as all assets required for operating the railway system. Seamless planning therefore encompasses all planning horizons (e.g. long- and short-term as well as real-time), all planning environments (e.g. yards, terminals and all connecting infrastructure) and involves a variety of complex planning systems and processes. All these aspects feed the derivation of requirements for planning systems and their interfaces, with additional consideration of the interconnection to dispatching and keeping the information on line and network capacity updated for all actors, in order to achieve true seamless planning.

Dynamic Dispatching is the combination of two major elements. On the one hand it is the operational know-how about how to optimize tasks and actions in Yards and Terminals, thanks to digitalization to visualize it and there for to support effective decisions. The second and most important part about it, is the integration of dynamic information. Dynamic updates about estimated time of arrivals to minimize unproductive actions and to maximize the use of existing infrastructure.

Intermodal Prediction Systems, forecasting both the ETA and the ETD using advanced machine-learning models, enhance the transparency and reliability of rail freight. The systems use various TAF TSI and EDIGES message types as basis input. Its quality is evaluated using pre-defined TAF TSI KPIs. Main applications for the prediction values are the optimization of terminal and yard processes as well as the assignment and planning of rolling stock utilization (Asset Warehouse).

The concept of Standardised European Railway Checkpoints is a further development of the previous work carried out in Shift2Rail and the concept of "Intelligent Video Gates" (IVG). The main objective was thus a further development of the previous work. Moreover, in FP3 Checkpoints are also developed but at main lines for both freight and passenger trains. Hence, one main aim was to give a clear and thorough background description, including existing similar systems that the IMs in T25.4 currently possess. Process descriptions were carried out for three types of operational stops for freight trains: intermodal terminals, marshalling yards and borders. Opportunities for improving these processes though the use of Checkpoints as well as a vast set of use cases were identified. Functional and non-requirements were developed. Based on the process analysis and the defined requirements, technical specifications were outlined for detection technologies and for data sharing. Albeit technical standardization has been addressed, further work is needed to be carried jointly between the System Pillar sub-project Harmonized European Railway Diagnostics (Herd), FP5 T25.4/WP29 and FP3 WP7. Thus, the specifications outlined in this report will be the basis for a standardized development and installation of Checkpoints within WP29.

Multimodal Integration has the primary objective to further ease the access of freight to rail. Simplifying processes for the search and booking of existing intermodal services. Enabling a simplified booking for various services of different service providers and finally to enable a digitally supported establishment of new services on rail, where today either capacity is at its limits or no adequate service is existing.

6.5 Innovative Freight Assets

WP22 and WP23 are structured around 3 main topics of interest: multimodular container for hydrogen transport, self-propelled wagon concepts and aerodynamics and energy efficiency considerations for freights convoys. This will enable the analysis and preliminary work on the technical enablers developing concepts on these three levels.

WP22's goal is to define the preliminary functional requirements of the enablers while iterating on concepts that at the end shall lead to technical specifications, validation plans and preliminary designs feeding into WP23. WP22 is the only one potentially contributing the freight system architecture, as the latter is meant for preliminary validation of a specific use case.

From the three main topics considered in this subproject, the self-propelled wagon is the one that is connected to the freight system architecture presented in that document.

One of the challenges for more agile freight operation is to make freight trains more truck-like, i.e. replace long loco-hauled trains by smaller units with a high degree of modularity and flexibility, due to automatic coupling and decoupling, digitalization, and automation as main drivers. These shorter units can be realized in different ways: Short conventional loco-hauled freight trains or self propelled freight wagons, operating alone.

For the first one, CargoSprinter consisting of multiple platforms, the end ones of each group are powered by a small motor. The intermediate platforms are unpowered. Several of these trains can be linked together and run in multiple unit configuration.

Whereas, for the second one, Individual self propelled freight cars would run independently. For that, each wagon needs to be powered and usually requires driverless operation among other subsystems needed for the deployment of the function on the mainline and/or the yards. For instance, the following subsystem are desirable for a full autonomous operation: traction, brake and their control on each wagon, energy supply, autonomous navigation, automatic avoidance of conflict with other vehicles and new shunting methods.

The innovative freight assets subproject of this project refers to self-propelled freight cars since they are the most radical realization of the concept of modular and flexible freight trains. Self-propelled freight cars have a propulsion unit on-board. Several use cases are foreseen by the first tasks of WP22 deriving from the user needs and use cases under development.

The interfaces to be defined in this document are referring to the link of the self propelled wagon with the yard systems, as the first validation of the concept needs to be in a control environment and is not linked with the self-driving aspect, which is not in the scope of the FP5 innovative freight asset subproject.

In general, the roadmap to attain the objectives of a detached wagon able to operate alone in a yard, differs depending on the reference, but there will be several classes or steps, such as in this figure extracted from the reference presented below from the reference found also below the figure, which need to grow from 1 to 5.

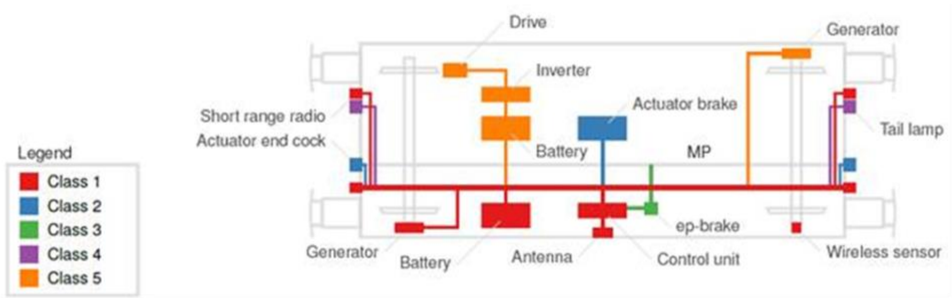

Figure 11: Potential development stages/classes of a self propelled wagon [3]

Further detail on the internal architecture on wagon level and on system requirements can be found in D22.3.

In this deliverable, the interfaces of the self propelled wagon to the FDFT system infrastructure and the environment, e.g. the FDFT backend, are described in a level of detail to understand the relations and requirements of the reference freight system architecture on system level.

The next figures present the interfaces that are defined on the higher level and with more detail to/from the block for this subproject and the rest of the subsystems on the yard environment, as presented in the subsection dedicated on WP3 and WP5.

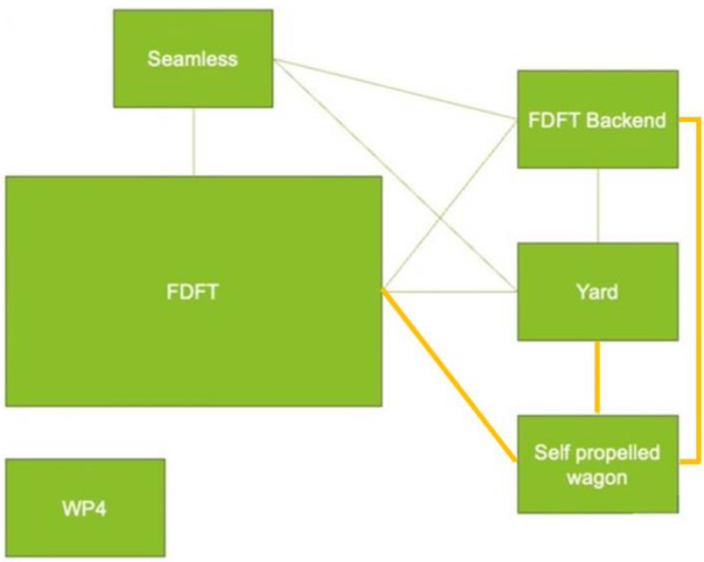

Figure 12: Interfaces of the self propelled wagon to the other subsystems

The links in bold are representing the relationships with the FDFT function on-board and with the Yard automation management system. Two blocks are mentioned for the latter and further details could be found in the figure below.

There are two ways from the Yard Automation Management System down to the operation on propulsion and brakes. The first and priority is by the on-board ASO element, which will be the link with the any GoA level yards where the wagon would be operated from the YMS. As a secondary option, in a non-operative yard automated area for validation or tests purposes, the control could be taken remotely by an operator. This is why a remote controller element is proposed to be added, at this stage, prior to the confirmation of these technologies by the operators and infrastructure managers.

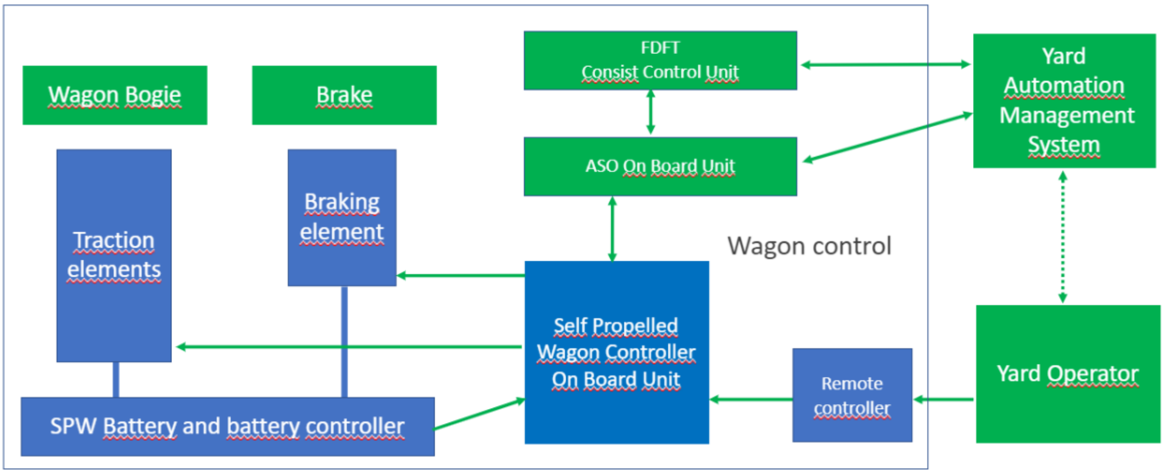

Figure 13: Interfaces of the self propelled wagon to the Yard subsystem

The black rectangle depicts which elements are on-board the wagon. Whereas the next table proposes the main data, functions and orders that are shared from/to the self propelled wagon controller on-board unit. So, only the interfaces from and to the SPW controller are described.

ORIGIN	DESTINATION	Function / data description
ASO	SPW	Destination and route for this wagon Predicted energy required for shunting & last mile operations at destination Train composition and weight estimated Mode of operation (priority) Assisted power demand for demanding traction scenarios
YARD	SPW	Mode of operation Remote control of the wagon (Acceleration and braking)
SPW	ASO	Battery and energy status
SPW	YARD	Position of the wagon Perception data during remote control mode (distance to nearest wagon or element, when uncoupled) Data on SPW control status (battery, etc.)

Table 5: External interfaces of the self propelled wagon

Some of the data and functions proposed in this table are not considered so far by the elements that need to receive or to generate them, but as a futuristic subproject, the innovative freight assets WPs try to anticipate the links and present them here.

For example, the so called "Predicted energy required for shunting & last mile operation at destination" is not a function that exists. The proposal of this subproject is to gather data to set the path to generate algorithms that could predict it, in future calls. And that could be done in the FDFT Backend, for example.

6.6 Safety

The WP 4, Deliverable 4.2 provides the safety requirements for the DAC, its related functions, its safe integration into the vehicle and the safe operation of DAC equipped vehicles. The safety requirements are described on the train level. The risk assessment was carried out as an iterative process according to the CSM-Directive. As shown in Figure 14, it consists of the steps

- System definition
- Risk analysis
- Risk evaluation.

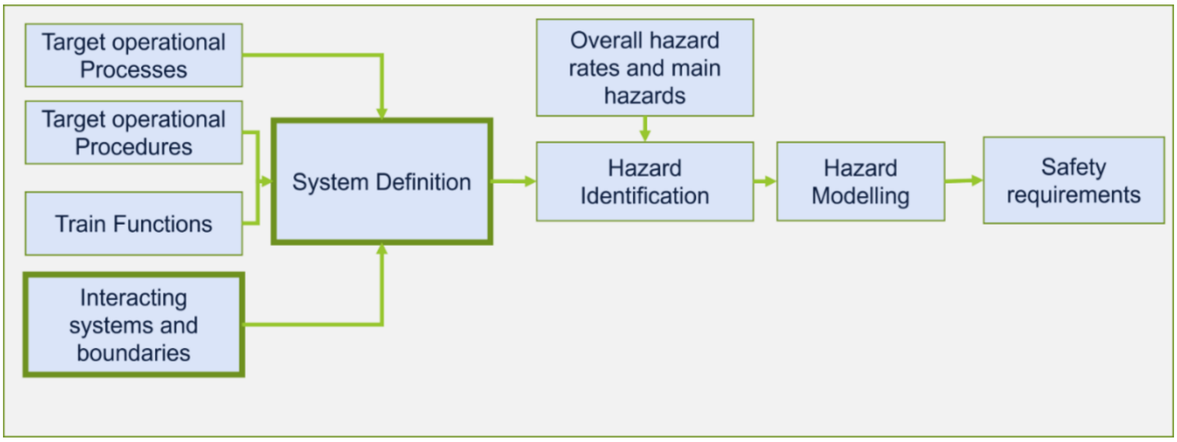

Figure 14: Approach of risk assessment

Interoperable train functions are defined in the project WP 5, Task 4. The risk is assigned to the operational procedures and then apportioning to the train, the user and other railway systems (like CCS). DAC Use Cases for the „Full Digital Freight Train Operation" (FDFTO) are part of this assessment, including the interface definition of the function. In the definition of the interoperable train functions, leading, intermediate and last consists of a train are distinguished.

The risk assessment is carried out as an iterative process. It is closely related to the WP 5 Train functions and WP 2.1 Operational Procedures. It also is in line with the Safety Plan of WP 4.1. An overview is shown in Figure 15 from WP 2.1.

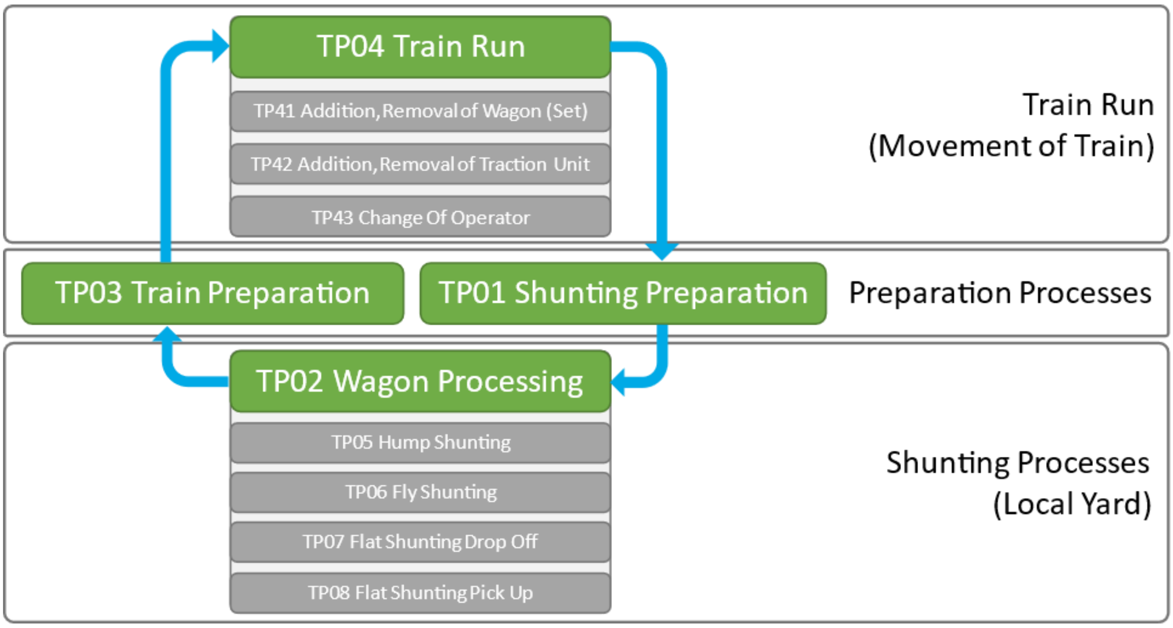

Figure 15: Process Overview with Four Main Processes [1]

For each activity it was analysed whether it was directly related to the component DAC or its functions. For each function, an HAZOP (Hazard and Operability) table is elaborated systematically and progressively. The functions in the system definition were assessed using generic failure modes, also depending on the state of the activity and the process in which it was called. The potential consequences of the different failure modes were identified for every assessed function. So, it was made sure that each relevant activity could be linked to a hazard and vice versa.

As a component, „Full DAC" (DAC 5 / DAC 4) is considered. Intermediate states will have to be considered as changes to the Full DAC state. „DAC ready" will also be considered separately as it only describes a small change to the current equipment. It only affects the wagons, not the locos.

The component DAC is considered as a single IC-Component. The exchange of sub-components and related authorizations (if any) during the life cycle will be in the responsibility of the ECM. Full safety for the IC-Components, the loco safety, and software themselves is not covered in the deliverable 4.2. All hazards and related safety requirements that cannot be controlled by one actor alone shall be communicated to another relevant actor in order to jointly find an adequate solution.

Considering the requirements from the train length determination, they are regarded as they are today. The maximum train length is handled by the staff, as it is described in the ERJU Process. As of today, the train integrity is handled by the braking system. Within the migration phase, DAC is not yet used on pure ETCS Level 2 lines without trackside line clear detection. This is to enable a cost-effective introduction of the DAC but does not exclude a future migration to enable this development.

In terms of remote control of the functions, e.g. uncoupling, only closed systems are considered in the assessment. That means, the train is considered as a closed system, as well as remote control or local remote wayside control. Far remote control, e.g. calling functions such as uncoupling from systems connected via the internet, is not considered in the risk assessment. Transmission of data for train functions with high safety requirements (e.g. SIL 4) will only be considered through an unsafe network (using a protocol with long enough check sums / … to validate the information by the receivers, i.e. Black or Grey Channel).

On the train level, catastrophic hazards have been identified which led to safety requirements with a TFFR $<10^{-9}$. These requirements have to be allocated to the sub-systems according to the system architecture. For the ongoing project it will be one of the major tasks to reduce the safety impact of single functions. It is the goal to avoid the risk of single points of failure leading to catastrophic events.

Safety integrity requirements that apply at the system level to each hazard as THR are expressed with a specific combination of functions. These are selected by the system architecture and determined, linked, and thus translated into TFFR for the functions (see EN 50126-2). See table 11 for relation between TFFR and SIL.

TFFR [h-1]	SIL reference	SIL related qualitative measures
$10^{-9} \le TFFR < 10^{-8}$	4	Defined in the specific norms
$10^{-8} \le TFFR < 10^{-7}$	3	
$10^{-8} \le TFFR < 10^{-7}$	2	
$10^{-6} \le TFFR < 10^{-5}$	1	

Table 6: SIL related quantitative and qualitative measures

The complete risk analysis with assigned risk acceptance criteria can be seen in the Deliverable 4.2 and its Appendix: Hazard identification and Assignment of safety requirements. In connection with the DAC, these are the most severe hazards were identified:

- Unwanted decoupling without braking
- Undetected decoupling (i.e. failure of the train integrity supervision in case of a train separation)
- Malfunctions affecting braking capability
- Wrong data for ATP affecting brake distance and speed supervision.

It is assumed, that the hazards can lead to catastrophic accidents only during “train run”. In yards, where shunting is allowed, infrastructure measures shall act as barriers to reduce the severity of the hazard to critical.

Derived from these hazards, in line with CSM, safety requirements with the TFFR < 10^{-9} were derived:

- Brake pipe must be continuous during the train- run.
- Unintended decoupling / train separation during the train run without opening the brake pipe must be prevented. If a local decoupling mechanism is introduced, the same safety requirement as for the central decoupling function applies. Unauthorized access must be prevented.
- Speed and brake distance related data must be provided correctly to ATP.
- Untimely inhibition of the pneumatic brake must be avoided.
- Without trackside line occupied monitoring, decoupling / train separation without information to the ATP must be avoided.
- Without trackside line occupied monitoring, train length determination must be provided correctly.

Summarising, the goal to derive safety requirements has been achieved on the train level. With further definition of the system architecture, these requirements can be reviewed, broken down and allocated to the components and sub-systems. Especially the integration into particular vehicles has to be assessed in further detail.

Not in the focus of the Deliverable 4.2 are systems that are not directly linked to coupling. The possibility to directly communicate with the locomotive gives the opportunity to further improve the railway operation, e.g.: Hot axle box detection, fire detection, derailment indication, or an ep-brake function with the possibility to reduce the braking distance. Another example for further improvement is the introduction of ETCS without trackside line occupied monitoring.

7 Methodology

This document provides the overall functional reference freight architecture by combining different architectures of subsystems. In this chapter, the methodology to align the different views into one is described.

WP2 and Task 2.3 are led by DB Cargo AG. Within task 2.3, experts with different backgrounds and from several companies are involved. The formal project work took place in regular work sequences and workshops and consisted of theoretical and practical parts.

The focus of the work was on providing the high-level overview of the functional freight reference architecture. To this aim, the overall system is described by defining the interfaces of the different subsystems: full digital freight train (FDFT), yard automation systems, innovative freight assets as well as seamless operation. For the development, the perspective of colleagues on safety and RAMS from WP4 “Equipment Authorisation Procedures, Train Authorisation Strategy and Procedures” was also an essential part.

In the regular task discussions, experts from the following work packages of FP5-TRANS4M-R were involved:

- WP3 for FDFT
- WP4 for Safety
- WP5, Yard, for Yard Automation
- WP22 for Innovative Freight Assets
- WP25 for Seamless Operation

Due to the involvement of the WP in the regular discussions on task level, a high alignment between the relevant experts was achieved. Additionally, discussions triggered by Task 2.3 and WP2 influenced design aspects within the subsystems, where further alignment took place. On project-level, these discussions and their impacts were handled within its official organs, if suitable, as e.g. within the steering committee.

The process for finalizing the Deliverable is based on best practice for creating OCORA High Level Methodology [6] and is shown in Figure 16.

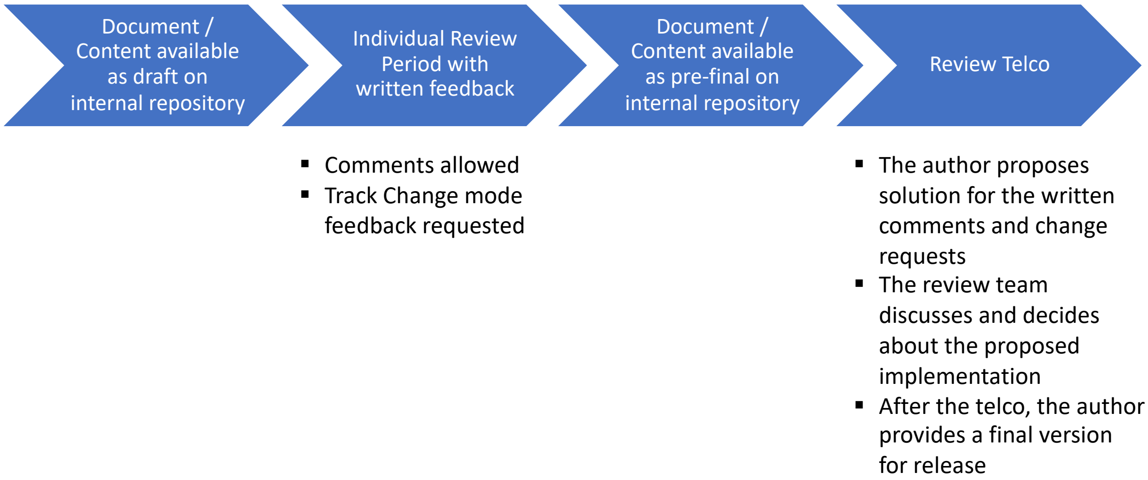

Figure 16: Best practice document review [6]

Documents submitted for final review must be provided to the review team at least 2 weeks prior to the final review Workshop. Review comments are due at least 1 week prior to the workshop for final review. This allows sufficient time for the author to incorporate all comments and forward a revised version to the review team. Review team members must be in possession of the revised document no later than 2 days prior to the final review.

A final review cycle is very costly, especially in terms of the time required. At least 2 weeks are required. Therefore, the workstream leader must ensure that the documents submitted for final review are in good order, and the workstream members must ensure that their organization's ideas are consistent with the documents submitted. [OCORA] With this procedure, task 2.3 follows the official requirements of the review process as requested by the project FP5-TRANS4M-R.

7.1 V-Model

According to EN 50126, development needs to follow the V-cycle. Within the project, it was agreed very early in the project to introduce feedback loops to every step of the V-cycle instead of a classical waterfall approach to enable for an intensive exchange between the project-partners and a determined development.

The overall project is in the design phase according to the V-Model, see Figure 17 below. Accordingly, verification on component level or the safe integration into vehicles as well as system validation will be carried out in a later stage and are not part of this deliverable.

With this accelerated approach a common high-level functional reference freight system architecture has been developed. The Freight System Architecture contains not only the FDFT-Architecture, but also the other project-parts yard-automation, seamless and innovative freight assets. As stated above, the overall process starts with use cases which were derived out of the Operational Procedures in D2.1. Features and functions as well as requirements. With the logical elements, the System of Interest is defined and contains all assets developed in TRANS4M-R.

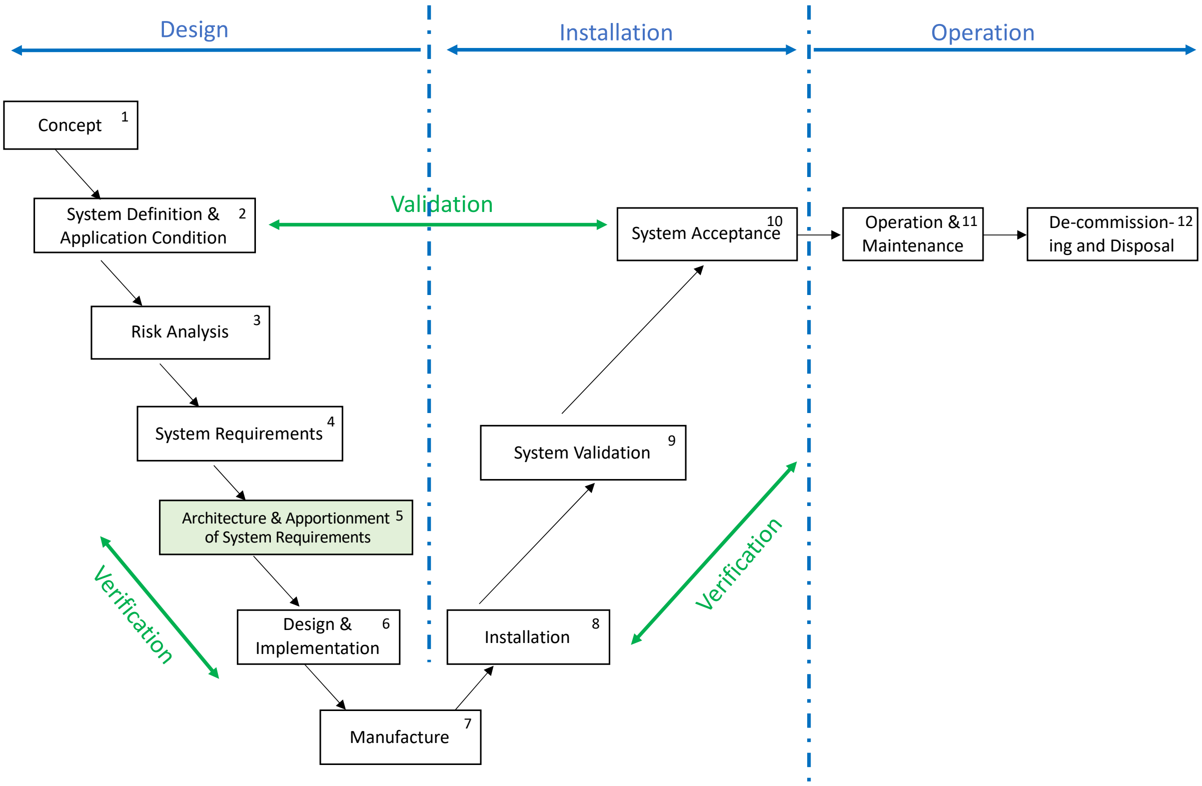

Figure 17: V-Model of the Development Process and the current phase of the project

7.2 Work Split FDFT

Although this document describes the functional reference freight system architecture on an aggregated level, it is based on work performed on a more detailed level within other work packages. For the full digital freight train, or FDFT, Figure 18 gives an overview on the level of detail and the related components considered, for the different WP. Generally, WP5 is on the deepest level of detail, elaborating on Subsystem Requirements Specifications (SSRS), with WP3 operating on System Requirement specifications (SRS). According to its focus, WP2 and accordingly this deliverable, are on the highest level, comprising User Requirement Specifications (URS).

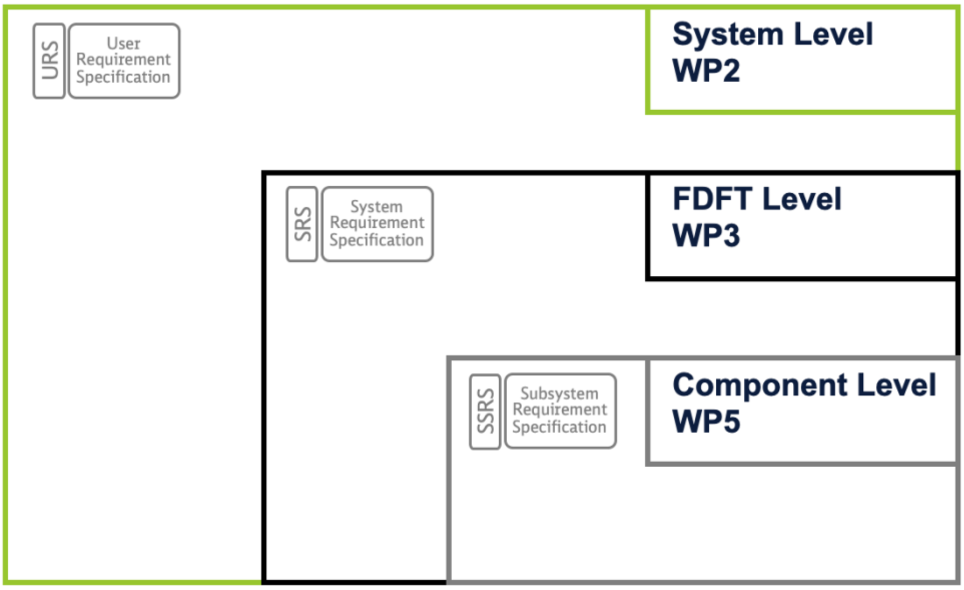

Figure 18: Work split within the project, distinguished by level of detail

7.3 Interoperability and Modularity Principles

Due to the very heterogeneous fleet of wagons – wagons vary regarding their function, their construction and thus their installation space for the new components, their owner, and their operational use – it is important for the wagon operation to reduce further complexity by following interoperable and modular principles for the development of new components. E.g., an interoperable and modular architecture allows to reduce maintenance and operational efforts. In addition, a modular approach allows for the integration of future components of functions that cannot be developed today or are even currently unknown.

For a future-proof and expandable result, in the project FP5-TRANS4M-R put high efforts into aligning on these principles and to realize modularity whenever possible. An example for such an alignment is the discussion in the interface between the DAC Coupler-Head and the spring unit, the so-called Interface A. With such an interface, the final goal is to realize interchangeability of the different parts.

Within this document, we follow the same approach. Every interface of a system to another is defined in a way to allow for the highest degree of modularity possible. At this early point in time of the project, this is realized by a high-level architecture that is lean in a way that it aims at reducing the number of the interfaces to allow for all required functionalities which are qualitatively described in this document.

7.4 Interaction with System Pillar

Based on the work done in FP5-TRANS4M-R, the freight system architecture, will be also reviewed again within the System Pillar Task4, to be later integrated into the System of Systems approach followed in System Pillar.

The most crucial interfaces have been already identified and were discussed with the various Tasks within System Pillar, especially with Task2 and System Pillar Core to guarantee a later seamless integration.

Further work and constant alignment are organised via the Flagship Project System Experts of TRANS4M-R, so that upcoming changes coming from System Pillar, or within TRANS4M-R will find its way into the architecture as well as to the requirements.

7.5 SysML

SysML (Systems Modelling Language) is a graphical standardized modelling language based on and extending UML (Unified Modelling Language) used for systems engineering applications.

Within the scope of this deliverable, SysML was used as the modelling language for the architecture models and the models depicting the different views in chapter 8. Furthermore, the use case structure is based on UML and SysML.

7.6 Link to Requirements Management

The development of the Full Digital Freight Train (FDFT) involves several levels. The operational procedures the system is to be designed for, are a fundamental base of the development process. On this basis, the functions and use cases of the system are derived to describe the required functionalities of the FDFT. Accordingly, both the functional requirements and the reference freight system architecture are developed. Therefore, as a part of the development process, the functional requirements are directly linked.

7.7 Tooling

7.7.1 Polarion

Polarion is a software platform specialized in product lifecycle management. This tool enables the product lifecycle to be managed in all stages, from the development of products and applications through to implementation and maintenance. Polarion offers a wide range of functions for developing, improving, verifying, and validating requirements, particularly during the design and development phase.

Advantages such as transparent and collaborative working, detailed version control and numerous customization options for the project environment and workflow within large teams are crucial for the development of highly complex products such as the FDFT. Polarion is used within the ERJU FP5 TRANS4M-R in requirements management, as the industry expressly requested it as a tool due to its wide range of functionalities. In addition, it is already being used successfully in the ERJU System Pillar.

For the use of Polarion in FP5, individual types of so-called work items were defined and customized for requirements, features as well as use cases and operational procedures to be able to precisely describe, categorize and link them in relation to each other. Each item gets a unique and unchangeable identifier. Content adjustments throughout the entire process in Polarion are traceable and transparent for all Polarion users involved in the project.

Within the scope of this deliverable, Polarion is used to link the requirements developed, clearly assignable via unique identifier, with elements of the system architecture. Moreover, the use cases derived from the operational procedures are defined and uploaded to Polarion.

7.7.2 Enterprise Architect

Enterprise Architect is a graphical tool used for modelling IT architecture. It allows the use of SysML (see chapter 7.5) and other standards in regard to modelling and designing IT systems. The created models can be exported in various file formats, e.g. HTML and XMI.

For this deliverable, Enterprise Architect is used for the architecture models in chapter 8 and the use case overview graphics in chapter 8.4.

8 Reference Freight System Architecture

8.1 Draft Release

A first approach to the Full Digital Freight Train system architecture was initiated in January 2023 with a joint effort of Siemens Mobility and DB Cargo resulting in a report detailing a base architecture with different architectural and structural views of the system. Specifically, the report provides models of the context view, the requirements view, the functional view, the logical view, and the technical view.

As the FDFT aims to improve not just single components of a freight train but aims to improve rail freight in Europe in terms of efficiency and capacity, the infrastructure and backend systems are represented in the provided system architecture as well.

The FDFT reference architecture presented in the report was created with Enterprise Architect as the modelling tool and uses SysML as a modelling language.

8.2 Model Overview

The overall functional reference freight architecture is shown in Figure 19. It constitutes the main result of this document. The elements of the figure are as follows:

- The different systems are shown as grey boxes.
- The background is described in chapter 6 for every FDFT relevant system
- Systems that are part of the overall system, but are not part of the FDFT development are not further described and shown only for sake of completeness in dark grey
- External interfaces are shown within the system (boxes)
- Each interface in one system has a counterpart in another
- Where available, details on the interface are given
- Internal interfaces of the different systems are not shown

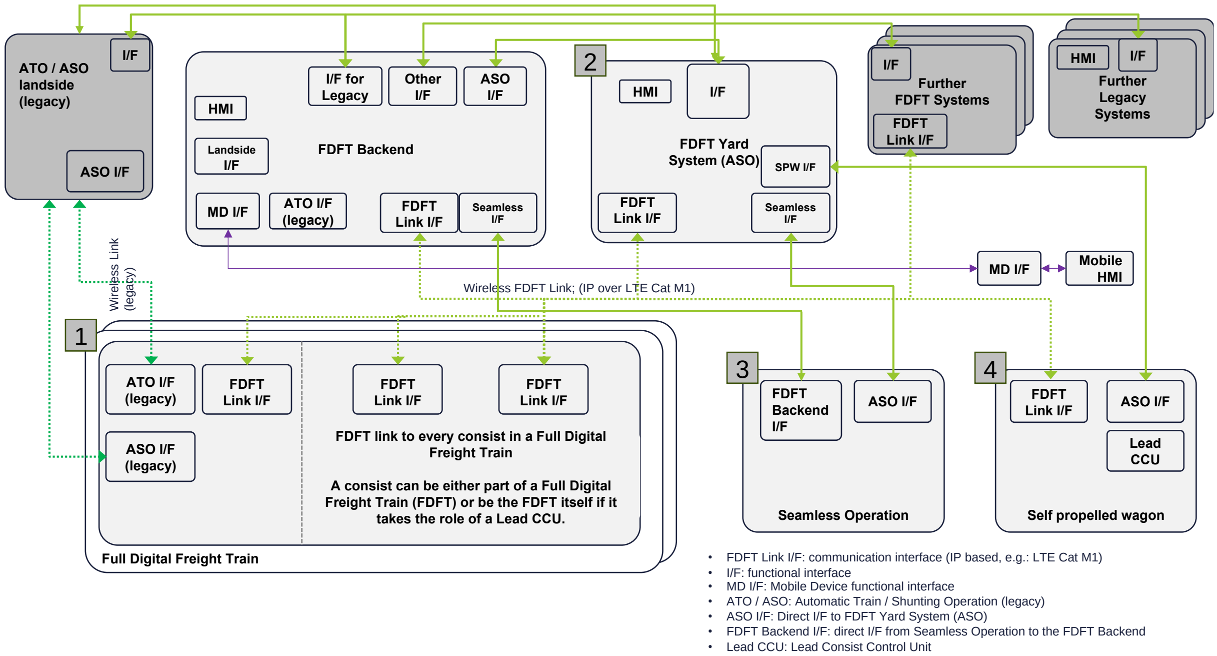

Figure 19 Reference freight system architecture[3]

1 Full Digital Freight Train (FDFT)

The FDFT architecture is a service provider of functionality, while enabling access to the train functions.

- Communication with landside FDFT backends via a wireless link
  - using foremost a public mobile communication network
  - a local wireless communication using WLAN shall be supported where no mobile network is available
- Exchanged data that shall use message structure
  - The topics and the detailed content description shall be agreed between the users of the FDFT-functions

2 Yard / Automatic shunting operations (ASO)

The ASO architecture consists of trackside components and onboard components on the traction units with the following interfaces.

- The yard system is connected to the train via the FDFT link
- An additional ASO legacy interface (as well as an ATO legacy interface) is foreseen. However, this is beyond the scope of the FDFT architecture definition.

[3] For a higher resolution figure please refer to Annex C (chapter 11.3) at the end of this document.

- A clear delimitation of the functionality of these interfaces is necessary to avoid contradictory commands.
- Accordingly, the decoupling command will be executed exclusively by the FDFT link
- Other yard specific functions, such as the localization of the shunting composition to determine when the split point has reached its split position, may be provided by the ASO legacy interface

3 Seamless Operation

The architecture for the seamless operations does not need to have direct communication with the FDFT link at train level but communicates with the FDFT Backend and FDFT Yard system. This could be exemplified as follows:

- WP26 Seamless Planning requires data from FDFT relevant for Train composition, Train preparation and Train running
- WP27 Dynamic dispatching will exchange data relevant for train arrival plan and status, train identity, yard and terminal operations
- WP28 Intermodal prediction will exchange data on planned (ETA) and actual train arrival and departure
- WP29 Checkpoint can provide data on actual train status to FDFT Backend and check towards expected status.
- WP31 Multimodal integration will connect to the other seamless systems.

4 Self-Propelled Wagon

The intended interfaces of the self propelled wagon are described with the yard systems, as the first validation of the concept will be done within a control environment and with the self-driving aspect being out of scope.

- Data sent from ASO to SPW include e.g., wagon destination and route, predicted energy, mode of operation.
- Data sent from yard to SPW comprises mode of operation and remote control of the wagon.
- Data sent from SPW to ASO comprises battery and energy status
- Data sent from SPW to yard comprises SPW status, position of the wagon and perception data during remote control

Due to the low TRL of the SPW, the interface definitions may be subject to change.

8.3 Stakeholder/actors

In the following table, the relevant actors involved in future rail freight operation are shown.

Actor	Description
Consist	A consist is the smallest railway rolling stock entity for operation, containing one DAC consist controller unit representing one node on DAC network. It can be a locomotive, a single wagon as well as a fixed set of single vehicles (segments) which are not disconnected while operation. A consist owns a unique vehicle identification number. A consist can be either part of a Full Digital Freight Train (FDFT) or be the FDFT itself if it takes the role of a Lead CCU.
FDFT Backend	Collection of new FDFT functions on land side. Receives, supplies, and stores Consist Data (e.g. Wagon Target Track Data, Traction Unit Status Data, Wagon Set Data and Additional Wagon Data). FDFT Backend provides and receives data to and from other systems (FDFT Yard, Traction Unit, etc.) FDFT Backend initiates different functions, e.g. coupling and uncoupling processes, in Target State.
FDFT Wagon Base System	FDFT Wagon Base System is a system on each wagon, which controls wagon components (e.g., DAC coupler heads, wagon wide power control system, battery management system, brake system). It can communicate via FDFT Link (network) e.g. with the Traction Unit, FDFT Backend (if available), landside systems, with personnel by using a Mobile HMI
FDFT Yard	FDFT Yard is infrastructure based and controls all infrastructure elements in its area. FDFT Yard provides current state of infrastructure to FDFT Backend if available. The interfaces between FDFT Backend and FDFT Yard will be defined in a later step.
Mobile HMI (HM)	(Locally) (remote) device for personnel to interact with FDFT Systems. For example, personnel can connect to a wagon in a wagon set and retrieve Wagon Status Data and Wagon Set Data of the entire Wagon Set.

Actor	Description
Stationary Device	Infrastructure-sided device that provides air for (automated) brake test and measurement data (e.g. air pressure). For target processes: Power and data are also supplied and connected. Over this device, a connection between Wagons to FDFT Backend or Legacy Systems is possible. Relevant especially within Yards.
Traction Unit	• A Traction Unit with DAC coupler heads that supplies traction power and moves itself and coupled vehicles. This also includes multiple traction units moving together. • The DAC coupler heads can also be hybrid couplers. • A Traction Unit can also have Distributed Power System functionalities. • ATO and ASO systems can be applied. • A Traction Unit can be equipped with FDFT functionalities, e.g, allows retrieving Wagon Status Data or Wagon Set Data and can initiate FDFT Wagon Base System's functions, like secure against rolling away, bleeding, etc. • An unpowered Traction Unit is considered and behaves like a wagon with FDFT Wagon Base System. • Traction Units can be main line locomotives, shunting locomotives, shunting devices, two-way vehicles, etc. • User Interface is available Related to FDFT.
Wagon	Single physical freight Wagon equipped with DAC coupler head at each end. Wagons permanently coupled (just one UIC Number) together should behave like a single wagon and cannot be uncoupled. Related to FDFT.
Wagon Set	Wagons coupled together by DAC coupler heads.
Yard Legacy System (YAMS)	Today's technical systems used in yard operations.
Yard Manager	Personnel responsible for operation of shunting yards.
Yard Personnel	On site personnel needed for manual shunting operations, e.g. for uncoupling / coupling rolling stock, for securing rolling stock and any other activities that require human intervention in shunting operation.

Table 7: Overview of actors/stakeholders

8.4 Use Case View

A use case describes how an actor interacts with the system to achieve a particular goal. It helps determine what a system will be used for, what conditions need to be met for the interaction to happen and what steps are involved in the interaction. The use cases in this chapter are derived from the ERJU processes introduced in deliverable 2.1 Preliminary Operational Procedures [1] and describe in more detail how the actors will interact with the system in these processes. For this purpose, a template for the use case structure was made based on discussions at a workshop involving WP2, WP3 and WP5 in Zurich, Switzerland in April 2023 and the SysML standard for use cases.

The development of the template took the workshop in Zurich (see also chapter 8.1) and literature regarding use cases in SysML into consideration and the template is based on these contents. The template was discussed with a member of the industry. Moreover, industry partners divided the ERJU processes of D2.1 into use cases and sent this division to the WP2 Core Team. This division was transferred to a list with which the Core Team developed the use cases in the span of several meetings. Some of the use cases were deemed Legacy processes by the Core Team and therefore not developed further, as the DAC will not change how such a process is handled (e.g. adjust rear end signal). The finished use cases were imported to Polarion and linked with each other there.

Use case title & ID	Unique identifier and version
Use case group	Direct “parents”
Main actor	Systems, organizations, or humans that participate in the use case, initiator
Other actors	Systems, organizations, or humans that are relevant in the use case, can give input
Pre-conditions	Expected state at the start of the use case / starting condition
Primary flow	Most frequent scenario of the use case
Alternate flow / exception flow	Less frequent scenarios
Post-conditions (success and failure)	Outcome of the use case / ending condition
Remark	Notes, hints, remarks

Table 8: Use Case Template

To get a better understanding what the expectation of the industry regarding such use cases might be, several meetings were held with some members of the industry. As a result, these industry members divided the ERJU processes described in deliverable 2.1 into use cases that were then further processed and developed in the WP2 core team. The use cases were divided into three categories:

- use case that has to be described
- legacy process that does not need to be described as a use case, as the development of the DAC will not change how such a process is handled (e.g. adjust rear end signal)
- use case that is already part of an earlier process and does not need to be described twice.

Some of the use cases that needed to be described were further divided into two use cases, as a different use case is created based on the actor (e.g. it makes a difference if an Operator Traction Unit checks the technical wagon inspection at the Traction Unit cab or Yard Personnel checks it via Mobile HMI). All the use cases were then developed in the span of several meetings and the finished use cases were imported to Polarion as work items, where the use cases were linked to their respective parents.

Furthermore, to showcase the linking of the use cases and their relation, hierarchical tree structures depicting the four main processes and all their use cases were created. The diagrams show the main processes as the root node and the corresponding use cases as the child nodes. As it is standard with use case diagrams, the tree diagrams do not depict the sequence of the use cases linked to the same parent node, but simply show the linking of the use cases to their parents – the arrangement of the sibling nodes does not define the sequence of events of the parent use case.

In the Appendix B, chapter 11.2, the use cases are shown for the different main processes. They are shown hierarchically to display their parent/child connection as well as sequentially. The ID used in Polarion is displayed for every use case. For a detailed view please refer to Polarion.

8.5 Feature View

The features to realize the defined use cases have been analyzed and grouped by the main purpose:

- Braking
- Cargo
- Train run
- Train status
- Shunting
- Performance
- Communication
- Power

A detailed list of the features is visible in Figure 20 Feature view and in the model.

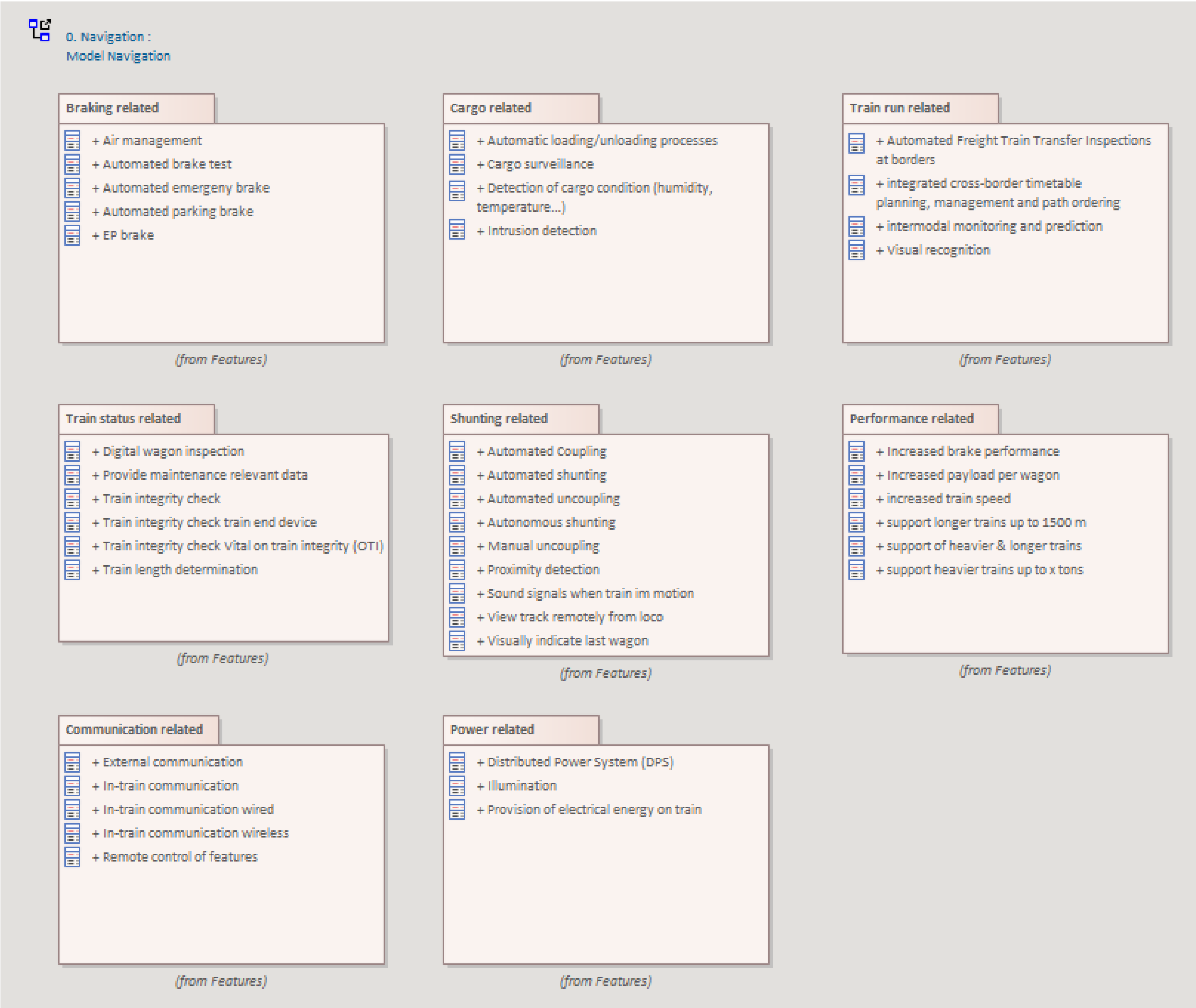

Figure 20 Feature view

8.6 Functional View

The functions to realize the defined features have been analyzed and grouped by packages:

- Braking
- Cargo
- Train run
- Train status
- Shunting
- Power

A detailed list of the features is visible in Figure 21 Functional view and in the model.

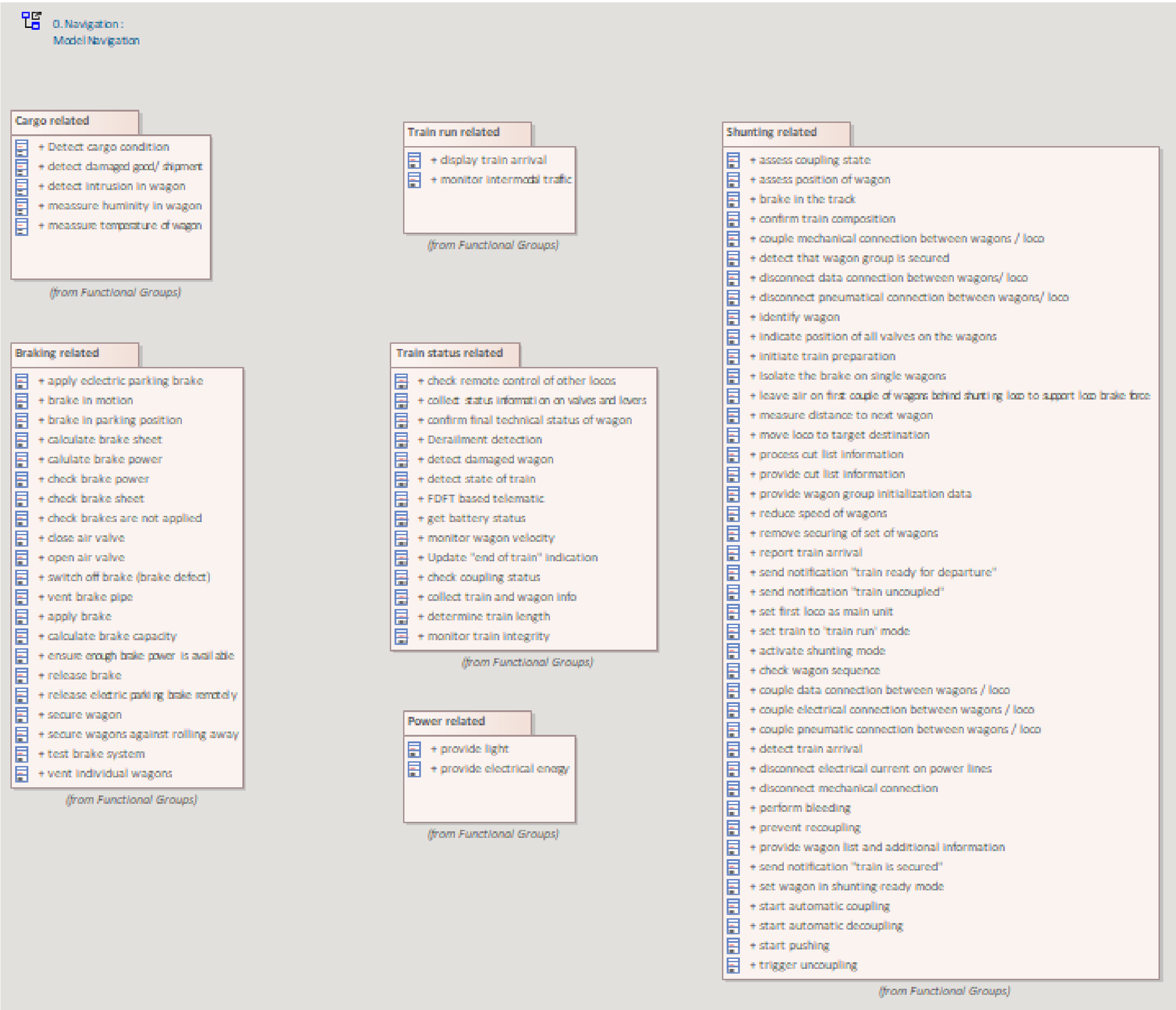

Figure 21 Functional view

8.7 Logical View

The different functions are related to "Logical elements", on top level either "Train side" or "Land side". On second level "Train side" splits into "FDFT Loco" and "FDFT Wagon" and "Land side" splits into "FDFT Backend" and "FDFT Wayside".

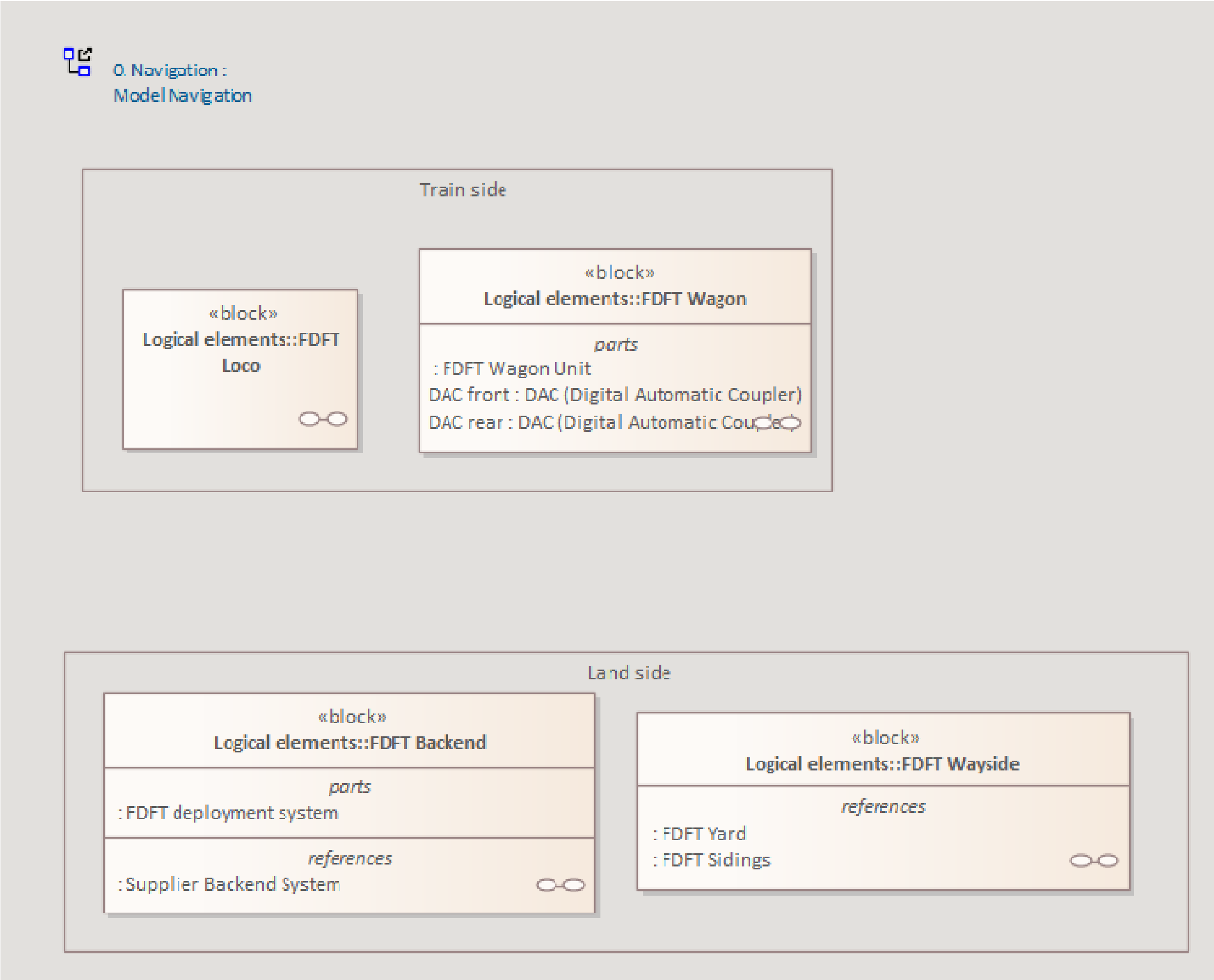

Figure 22 Logical view

More details are visible in Figure 22 Logical view and in a logical view "FDFT Logical View detailed" with all logical elements.

8.8 Technical View

According to the deliverable's focus on the high-level modular overview of the architecture, discussing and creating the technical views has been shifted to a later phase.

9 Conclusions

This document constitutes Deliverable 2.3 Reference Freight System Architecture of ER JU Flagship Area 5 project FP5-TRANS4M-R and introduces the overall functional reference freight architecture of the innovation project TRANS4M-R. The project FP5 TRANS4M-R aims at innovations transforming the rail freight sector by developing technical enablers that allow for its digitalization and automation.

By combining the views of different systems – the full digital freight train, or FDFT, Yard Management, Seamless operation, innovative freight assets in form of a single propelled wagon as well as the safety and RAMS perspective – this deliverable contributes to the project with a single architectural overview that combines all these systems. Hereby, the architectural design is driven by the modularity principle to aim for maintaining the highest degrees of freedom in designing the single architectures and at the same time to give a clear guidance on how interfaces to the other subsystem need to be designed. Through the continuous involvement of the necessary experts from various fields and work packages, the high degree of alignment was assured.

The early point in time within the project, at which this deliverable is due, makes it necessary to focus the work on a high-level overview of the functional reference freight architecture without detailing out the different subsystems. Accordingly, the aim of this deliverable is not a fully detailed overall architecture. The work of detailing the different system architectures will be performed during the further course of the project. The resulting architectures will be presented in different deliverables, that are mentioned throughout this report. Most importantly, for the FDFT architecture please refer to the deliverables of WP3. For Yard Management, including Automatic Shunting operations, and safety and security aspects of the Yard Demonstrator, please refer to deliverables of Yard related deliverables within work package 5. Details of the single-propelled wagon are described in work package 22, while seamless operation is described in work package 25.

During the work on this document as well as through general learning from the work within the project, open points were identified that are not yet covered by the deliverables linked in this document and mentioned before. These open points comprise the need for defining non-functional requirements, the analysis of backend functionality as well as harmonizing similar functionalities within different (sub-) systems, to just name the most important aspects.

The work on this deliverable underlined the high value, but also the necessity of an early alignment between the different system experts for building a congruent overall system with defined interfaces. Altogether, the developed architecture provides an important basis for further collaboration on the development of an automatized and digitalized freight rail operation, especially within FP5 TRANS4M-R.

10 References

[1] FP5-TRANS4M-R, Deliverable D2.1 Operational Procedures.

[2] FP2-R2DATO, Deliverable D5.5, Documentation of Freight specific user requirements for automation process. Draft version.

[3] R. Pfaff & B.D. Schmidt & D. Wilbring & M. Enning, J. Franzen, Wagon4.0 – the smart wagon for improved integration into Industry 4.0 plants, Aachen University of applied sciences, Aachen, Germany. And Ruhr Universität Bochum, Bochum, Germany

[4] EN, "EN 50126 Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Generic RAMS Process" 2015

[5] FP5-TRANS4M-R, Deliverable D5.5, Requirements Specification Yard Automation.

[6] OCORA Open CCS On-board Reference Architecture, 2020. High Level Methodology, Gamma Release. Document ID: OCORA-30-006-Gamma. Version: 1.10. Document ID: OCORA-30-006-Gamma.

11 Appendix

11.1 Appendix A: Enterprise Architect Model of the FP5 reference freight system architecture

Link to Model on projectplace:
https://service.projectplace.com/#direct/document/1287767962

Link to HTML export on projectplace:
https://service.projectplace.com/#direct/document/660721050

11.2 Appendix B: Use cases for the main processes

Use cases are an important basis for the development of both user requirements as well as the definition of user requirements. Accordingly, the use cases presented in the following, are directly related to D2.2 FDFTO User Requirements Specification. The methodology for the definition of the use cases as starting point for the architecture description is described in chapter 7.6. All use cases listed below represent a work in progress that will be adapted in future developments.

11.2.1 Use Cases within EP01 Shunting Preparation

IPTRANS-1827 EP01 – Shunting Preparation

IPTRANS-1829 Confirm Wagon Set

IPTRANS-1830 Initiate Collection, collect and provide consist status data at Traction Unit cab

IPTRANS-1831 Initiate Collection, collect and provide consist status data via Mobile HMI

IPTRANS-1832 Secure Wagon (Set) Against Rolling Away

IPTRANS-1834 Apply Parking Brake

IPTRANS-1836 Initiate Apply Parking Brake(s) at Traction Unit cab
IPTRANS-1838 Initiate Apply Parking Brake(s) via Mobile HMI
IPTRANS-1839 Initiate Actuation of Parking Brake(s)
IPTRANS-1840 Actuate Parking Brake(s)
IPTRANS-1841 Provide Parking Brake(s) Status
IPTRANS-1843 Check if Parking Brake(s) was applied at Traction Unit cab
IPTRANS-1845 Check if Parking Brake(s) was applied via Mobile HMI

IPTRANS-1847 Switch wagon(s) of set to FDFT mode Shunting

IPTRANS-1849 Initiate switch to FDFT mode Shunting at Traction Unit cab
IPTRANS-1850 Initiate switch to FDFT mode Shunting via Mobile HMI
IPTRANS-1851 Deactivate 400V power supply
IPTRANS-1852 Activate FDFT mode Shunting
IPTRANS-1853 Switch to FDFT mode Shunting
IPTRANS-1855 Stop monitor train run and provide integrity status to CCU
IPTRANS-1856 Provide status report FDFT mode Shunting
IPTRANS-1858 Check FDFT mode Shunting at Traction Unit cab

IPTRANS-1860 Check FDFT mode Shunting via Mobile HMI

IPTRANS-1861 Ensure Rolling Capability at Traction Unit cab
IPTRANS-1863 Ensure Rolling Capability via Mobile HMI
IPTRANS-1864 Uncouple

IPTRANS-1866 Initiate uncoupling at uncoupling point and deactivation 400V power supply at Traction Unit cab
IPTRANS-1869 Ensure 400V power supply is off
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1870 Initiate uncoupling at uncoupling point and FDFT function Prevent-coupling directly at the consists without an actuator
IPTRANS-1871 Initiate uncoupling at uncoupling point and FDFT function Prevent coupling directly at the consists with an actuator
IPTRANS-1868 - Activate uncoupling and FDFT function Prevent Coupling at Traction Unit cab
IPTRANS-1872 Activate uncoupling and FDFT function Prevent Coupling directly at the consists
IPTRANS-5277 Uncouple Traction Unit
IPTRANS-5278 Uncouple via Mobile HMI
IPTRANS-5279 Uncouple manually
IPTRANS-5280 Uncouple via push-button
IPTRANS-1873 Enable prevent coupling
IPTRANS-1874 Composition detection
IPTRANS-1876 Deactivate prevent coupling by coupler itself
IPTRANS-1877 Deactivate prevent coupling by infrastructure

11.2.2 Use Cases within EP02 Wagon Processing

IPTRANS-1880 EP02 – Wagon Processing
IPTRANS-1882 Couple

IPTRANS-1884 Do not fill break pipe with air
IPTRANS-1885 Check if FDFT function prevent coupling is deactivated at Traction Unit cab
IPTRANS-1887 Check if FDFT function prevent coupling is deactivated via Mobile HMI
IPTRANS-1888 Initiate deactivation of 400V power supply
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1892 DAC coupler head couples
IPTRANS-1874 Composition detection

IPTRANS-1832 Secure Wagon (Set) Against Rolling Away

IPTRANS-1834 Apply Parking Brake

IPTRANS-1836 Initiate apply parking brake(s) at Traction Unit cab
IPTRANS-1838 Initiate apply parking brake(s) via Mobile HMI
IPTRANS-1839 Initiate actuation of parking brake(s)
IPTRANS-1840 Actuate parking brake(s)
IPTRANS-1841 Provide brake(s) status
IPTRANS-1843 Check if parking brake(s) was applied at Traction Unit cab
IPTRANS-1845 Check if parking brake(s) was applied via Mobile HMI

IPTRANS-1864 Uncouple

IPTRANS-1866 Initiate uncoupling at uncoupling point and deactivation 400V power supply at Traction Unit cab
IPTRANS-1869 Ensure 400V power supply is off
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1870 Initiate uncoupling at uncoupling point and FDFT function Prevent-coupling directly at the consists without an actuator
IPTRANS-1871 Initiate uncoupling at uncoupling point and FDFT function Prevent coupling directly at the consists with an actuator
IPTRANS-1868 - Activate uncoupling and FDFT function Prevent Coupling at Traction Unit cab
IPTRANS-1872 Activate uncoupling and FDFT function Prevent Coupling directly at the consists
IPTRANS 1876 - Deactivate prevent coupling by coupler itself
IPTRANS-5277 Uncouple Traction Unit
IPTRANS-5278 Uncouple via Mobile HMI
IPTRANS-5279 Uncouple manually
IPTRANS-5280 Uncouple via push-button
IPTRANS-1873 Enable prevent coupling
IPTRANS-1874 Composition detection
IPTRANS-1876 Deactivate prevent coupling by coupler itself
IPTRANS-1877 Deactivate prevent coupling by infrastructure

IPTRANS-1829 Confirm wagon set

IPTRANS-1830 Initiate collection, collect and provide consist status data at Traction Unit cab

IPTRANS-1831 Initiate collection, collect and provide consist status data via Mobile HMI

IPTRANS-1893 Remove, Release Braking Means

IPTRANS-1895 Release parking brake

IPTRANS-1896 Initiate Release parking brake(s) at Traction Unit cab
IPTRANS-1898 Initiate Release parking brake(s) via Mobile HMI
IPTRANS-1899 Initiate actuation of parking brake(s)
IPTRANS-1900 Actuate parking brake(s) to be released
IPTRANS-1901 Provide parking brake(s) status
IPTRANS-1903 Check parking brake(s) at Traction Unit cab
IPTRANS-1905 Check parking brake(s) via Mobile HMI

IPTRANS-1916 Hump Shunting

IPTRANS-1864 Uncouple

IPTRANS-1866 Initiate uncoupling at uncoupling point and deactivation 400V power supply at Traction Unit cab
IPTRANS-1869 Ensure 400V power supply is off
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1870 Initiate uncoupling at uncoupling point and FDFT function Prevent Coupling directly at the consists without an actuator
IPTRANS-1871 Initiate uncoupling at uncoupling point and FDFT function Prevent coupling directly at the consists with an actuator
IPTRANS-1868 Activate uncoupling and FDFT function Prevent Coupling at Traction Unit cab
IPTRANS-1872 Activate uncoupling and FDFT function Prevent Coupling directly at the consists
IPTRANS-1876 Deactivate prevent coupling by coupler itself
IPTRANS-5277 Uncouple Traction Unit
IPTRANS-5278 Uncouple via Mobile HMI
IPTRANS-5279 Uncouple manually
IPTRANS-5280 Uncouple via push-button
IPTRANS-1873 Enable prevent coupling
IPTRANS-1874 Composition detection
IPTRANS-1876 Deactivate prevent coupling by coupler itself
IPTRANS-1877 Deactivate prevent coupling by infrastructure

IPTRANS-1882 Couple

- IPTRANS-1884 Do not fill break pipe with air
- IPTRANS-1885 Check if FDFT function prevent coupling is deactivated at Traction Unit cab
- IPTRANS-1887 Check if FDFT function prevent coupling is deactivated via Mobile HMI
- IPTRANS-1888 Initiate deactivation of 400V power supply
- IPTRANS-1890 Deactivate 400V power supply
- IPTRANS-1892 DAC coupler head couples
- IPTRANS-1874 Composition detection

IPTRANS-1832 Secure Wagon (Set) Against Rolling Away

IPTRANS-1834 Apply Parking Brake

- IPTRANS-1836 Initiate Apply Parking Brake(s) at Traction Unit cab
- IPTRANS-1838 Initiate Apply Parking Brake(s) via Mobile HMI
- IPTRANS-1839 Initiate Actuation of Parking Brake(s)
- IPTRANS-1840 Actuate Parking Brake(s)
- IPTRANS-1841 Provide Parking Brake(s) Status
- IPTRANS-1843 Check if Parking Brake(s) was applied at Traction Unit cab
- IPTRANS-1845_Check if Parking Brake(s) was applied via Mobile HMI

IPTRANS-1918 Fly Shunting

- IPTRANS-1920 Initiate acceleration
- IPTRANS-1922 Accelerate shunting composition
- IPTRANS-1864 Uncouple

- IPTRANS-1866 Initiate uncoupling at uncoupling point and deactivation 400V power supply at Traction Unit cab
- IPTRANS-1869 Ensure 400V power supply is off
- IPTRANS-1890 Deactivate 400V power supply
- IPTRANS-1870 Initiate uncoupling at uncoupling point and FDFT function Prevent-coupling directly at the consists without an actuator
- IPTRANS-1871 Initiate uncoupling at uncoupling point and FDFT function Prevent coupling directly at the consists with an actuator
- IPTRANS-1868 - Activate uncoupling and FDFT function Prevent Coupling at Traction Unit cab

IPTRANS-1872 Activate uncoupling and FDFT function Prevent Coupling directly at the consists
IPTRANS 1876 - Deactivate prevent coupling by coupler itself
IPTRANS-5277 Uncouple Traction Unit
IPTRANS-5278 Uncouple via Mobile HMI
IPTRANS-5279 Uncouple manually
IPTRANS-5280 Uncouple via push-button
IPTRANS-1873 Enable prevent coupling
IPTRANS-1874 Composition detection
IPTRANS-1876 Deactivate prevent coupling by coupler itself
IPTRANS-1877 Deactivate prevent coupling by infrastructure

IPTRANS-1923 Initiate deceleration
IPTRANS-1925 Traction Unit decelerates shunting composition
IPTRANS-1882 Couple

IPTRANS-1884 Do not fill break pipe with air
IPTRANS-1885 Check if FDFT function prevent coupling is deactivated at Traction Unit cab
IPTRANS-1887 Check if FDFT function prevent coupling is deactivated via Mobile HMI
IPTRANS-1888 Initiate deactivation of 400V power supply
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1892 DAC coupler head couples
IPTRANS-1874 Composition detection

IPTRANS-1832 Secure Wagon (Set) Against Rolling Away

IPTRANS-1834 Apply Parking Brake

IPTRANS-1836 Initiate Apply Parking Brake(s) at Traction Unit cab
IPTRANS-1838 Initiate Apply Parking Brake(s) via Mobile HMI
IPTRANS-1839 Initiate Actuation of Parking Brake(s)
IPTRANS-1840 Actuate Parking Brake(s)
IPTRANS-1841 Provide Parking Brake(s) Status
IPTRANS-1843 Check if Parking Brake(s) was applied at Traction Unit cab
IPTRANS-1845_Check if Parking Brake(s) was applied via Mobile HMI

IPTRANS-1927 Flat Shunting Drop Off

IPTRANS-1832 Secure Wagon (Set) Against Rolling Away

IPTRANS-1834 Apply Parking Brake

IPTRANS-1836 Initiate Apply Parking Brake(s) at Traction Unit cab
IPTRANS-1838 Initiate Apply Parking Brake(s) via Mobile HMI
IPTRANS-1839 Initiate Actuation of Parking Brake(s)
IPTRANS-1840 Actuate Parking Brake(s)
IPTRANS-1841 Provide Parking Brake(s) Status
IPTRANS-1843 Check if Parking Brake(s) was applied at Traction Unit cab
IPTRANS-1845 Check if Parking Brake(s) was applied via Mobile HMI

IPTRANS-1864 Uncouple

IPTRANS-1866 Initiate uncoupling at uncoupling point and deactivation 400V power supply at Traction Unit cab
IPTRANS-1869 Ensure 400V power supply is off
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1870 Initiate uncoupling at uncoupling point and FDFT function Prevent-coupling directly at the consists without an actuator
IPTRANS-1871 Initiate uncoupling at uncoupling point and FDFT function Prevent coupling directly at the consists with an actuator
IPTRANS-1868 - Activate uncoupling and FDFT function Prevent Coupling at Traction Unit cab
IPTRANS-1872 Activate uncoupling and FDFT function Prevent Coupling directly at the consists
IPTRANS 1876 - Deactivate prevent coupling by coupler itself
IPTRANS-5277 Uncouple Traction Unit
IPTRANS-5278 Uncouple via Mobile HMI
IPTRANS-5279 Uncouple manually
IPTRANS-5280 Uncouple via push-button
IPTRANS-1873 Enable prevent coupling
IPTRANS-1874 Composition detection
IPTRANS-1876 Deactivate prevent coupling by coupler itself
IPTRANS-1877 Deactivate prevent coupling by infrastructure

IPTRANS-1929 Flat Shunting Pick Up

IPTRANS-1882 Couple

IPTRANS-1884 Do not fill break pipe with air

IPTRANS-1885 Check if FDFT function prevent coupling is deactivated at Traction Unit cab
IPTRANS-1887 Check if FDFT function prevent coupling is deactivated via Mobile HMI
IPTRANS-1888 Initiate deactivation of 400V power supply
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1892 DAC coupler head couples
IPTRANS-1874 Composition detection

IPTRANS-1893 Remove, Release Braking Means

IPTRANS-1895 Release parking brake

IPTRANS-1896 Initiate Release parking brake(s) at Traction Unit cab
IPTRANS-1898 Initiate Release parking brake(s) via Mobile HMI
IPTRANS-1899 Initiate actuation of parking brake(s)
IPTRANS-1900 Actuate parking brake(s) to be released
IPTRANS-1901 Provide parking brake(s) status
IPTRANS-1903 Check parking brake(s) at Traction Unit cab
IPTRANS-1905 Check parking brake(s) via Mobile HMI

IPTRANS-1832 Secure Wagon (Set) Against Rolling Away

IPTRANS-1834 Apply Parking Brake

IPTRANS-1836 Initiate Apply Parking Brake(s) at Traction Unit cab
IPTRANS-1838 Initiate Apply Parking Brake(s) via Mobile HMI
IPTRANS-1839 Initiate Actuation of Parking Brake(s)
IPTRANS-1840 Actuate Parking Brake(s)
IPTRANS-1841 Provide Parking Brake(s) Status
IPTRANS-1843 Check if Parking Brake(s) was applied at Traction Unit cab
IPTRANS-1845_Check if Parking Brake(s) was applied via Mobile HMI

IPTRANS-1864 Uncouple

IPTRANS-1866 Initiate uncoupling at uncoupling point and deactivation 400V power supply at Traction Unit cab
IPTRANS-1869 Ensure 400V power supply is off
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1870 Initiate uncoupling at uncoupling point and FDFT function Prevent-coupling directly at the consists without an actuator

IPTRANS-1871 Initiate uncoupling at uncoupling point and FDFT function Prevent coupling directly at the consists with an actuator
IPTRANS-1868 Activate uncoupling and FDFT function Prevent Coupling at Traction Unit cab
IPTRANS-1872 Activate uncoupling and FDFT function Prevent Coupling directly at the consists
IPTRANS 1876 Deactivate prevent coupling by coupler itself
IPTRANS-5277 Uncouple Traction Unit
IPTRANS-5278 Uncouple via Mobile HMI
IPTRANS-5279 Uncouple manually
IPTRANS-5280 Uncouple via push-button
IPTRANS-1873 Enable prevent coupling
IPTRANS-1874 Composition detection
IPTRANS-1876 Deactivate prevent coupling by coupler itself
IPTRANS-1877 Deactivate prevent coupling by infrastructure

11.2.3 Use Cases within EP03 Train Preparation

IPTRANS-1931 EP03 – Train Preparation

IPTRANS-1882 Couple

IPTRANS-1884 Do not fill break pipe with air
IPTRANS-1885 Check if FDFT function prevent coupling is deactivated at Traction Unit cab
IPTRANS-1887 Check if FDFT function prevent coupling is deactivated via Mobile HMI
IPTRANS-1888 Initiate deactivation of 400V power supply
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1892 DAC coupler head couples
IPTRANS-1874 Composition detection

IPTRANS-1829 Confirm wagon set

IPTRANS-1830 Initiate collection, collect and provide consist status data at Traction Unit cab
IPTRANS-1831 Initiate collection, collect and provide consist status data via Mobile HMI

IPTRANS-1893 Remove, Release Braking Means

IPTRANS-1895 Release parking brake

IPTRANS-1896 Initiate Release parking brake(s) at Traction Unit cab
IPTRANS-1898 Initiate Release parking brake(s) via Mobile HMI
IPTRANS-1899 Initiate actuation of parking brake(s)
IPTRANS-1900 Actuate parking brake(s) to be released
IPTRANS-1901 Provide parking brake(s) status
IPTRANS-1903 Check parking brake(s) at Traction Unit cab
IPTRANS-1905 Check parking brake(s) via Mobile HMI

IPTRANS-1937 Automated brake test

IPTRANS-1941 Collect data and initiate brake test at Traction Unit cab
IPTRANS-1943 Receive brake test relevant data
IPTRANS-1945 Check if the test unit is ready for use
IPTRANS-1947 Bring and/or hold the pressure to standard operating pressure with Traction Unit
IPTRANS-1949 Execute leak test and check wagon set pressure data at Traction Unit cab
IPTRANS-1951 Execute leak test and check wagon set pressure data via Mobile HMI
IPTRANS-1952 Compensate pressure losses
IPTRANS-1954 Check G/P and brake lever position at Traction Unit cab
IPTRANS-1956 Check G/P and brake lever position via Mobile HMI
IPTRANS-1947 Bring and/or hold the pressure to standard operating pressure with Traction Unit
IPTRANS-1957 Adjust parking brake at Traction Unit cab
IPTRANS-1958 Adjust parking brake via Mobile HMI
IPTRANS-1960 Confirm and save final results at Traction Unit cab
IPTRANS-1962 Confirm and save final results via Mobile HMI

IPTRANS-1963 Technical Wagon Inspection
IPTRANS-1968 Brake calculation at Traction Unit cab
IPTRANS-1969 Brake calculation via Mobile HMI
IPTRANS-1971 Check technical wagon inspection and brake power at Traction Unit cab
IPTRANS-1972 Check technical wagon inspection and brake power via Mobile HMI
IPTRANS-1864 Uncouple

IPTRANS-1866 Initiate uncoupling at uncoupling point and deactivation 400V power supply at Traction Unit cab
IPTRANS-1869 Ensure 400V power supply is off
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1870 Initiate uncoupling at uncoupling point and FDFT function Prevent-coupling directly at the consists without an actuator
IPTRANS-1871 Initiate uncoupling at uncoupling point and FDFT function Prevent coupling directly at the consists with an actuator
IPTRANS-1868 - Activate uncoupling and FDFT function Prevent Coupling at Traction Unit cab
IPTRANS-1872 Activate uncoupling and FDFT function Prevent Coupling directly at the consists
IPTRANS 1876 - Deactivate prevent coupling by coupler itself
IPTRANS-5277 Uncouple Traction Unit
IPTRANS-5278 Uncouple via Mobile HMI
IPTRANS-5279 Uncouple manually
IPTRANS-5280 Uncouple via push-button
IPTRANS-1873 Enable prevent coupling
IPTRANS-1874 Composition detection
IPTRANS-1876 Deactivate prevent coupling by coupler itself
IPTRANS-1877 Deactivate prevent coupling by infrastructure

IPTRANS-1882 Couple

IPTRANS-1884 Do not fill break pipe with air
IPTRANS-1885 Check if FDFT function prevent coupling is deactivated at Traction Unit cab
IPTRANS-1887 Check if FDFT function prevent coupling is deactivated via Mobile HMI
IPTRANS-1888 Initiate deactivation of 400V power supply
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1892 DAC coupler head couples
IPTRANS-1874 Composition detection

IPTRANS-1829 Confirm wagon set

IPTRANS-1830 Initiate collection, collect and provide consist status data at Traction Unit cab
IPTRANS-1831 Initiate collection, collect and provide consist status data via Mobile HMI

IPTRANS-1893 Remove, Release Braking Means

IPTRANS-1895 Release parking brake

IPTRANS-1896 Initiate Release parking brake(s) at Traction Unit cab
IPTRANS-1898 Initiate Release parking brake(s) via Mobile HMI
IPTRANS-1899 Initiate actuation of parking brake(s)
IPTRANS-1900 Actuate parking brake(s) to be released
IPTRANS-1901 Provide parking brake(s) status
IPTRANS-1903 Check parking brake(s) at Traction Unit cab
IPTRANS-1905 Check parking brake(s) via Mobile HMI

IPTRANS-1937 Automated brake test

IPTRANS-1941 Collect data and initiate brake test at Traction Unit cab
IPTRANS-1943 Receive brake test relevant data
IPTRANS-1945 Check if the test unit is ready for use
IPTRANS-1947 Bring and/or hold the pressure to standard operating pressure with Traction Unit
IPTRANS-1949 Execute leak test and check wagon set pressure data at Traction Unit cab
IPTRANS-1951 Execute leak test and check wagon set pressure data via Mobile HMI
IPTRANS-1952 Compensate pressure losses
IPTRANS-1954 Check G/P and brake lever position at Traction Unit cab
IPTRANS-1956 Check G/P and brake lever position via Mobile HMI
IPTRANS-1947 Bring and/or hold the pressure to standard operating pressure with Traction Unit
IPTRANS-1957 Adjust parking brake at Traction Unit cab
IPTRANS-1958 Adjust parking brake via Mobile HMI
IPTRANS-1960 Confirm and save final results at Traction Unit cab
IPTRANS-1962 Confirm and save final results via Mobile HMI

IPTRANS-1975 Compile, check and send necessary train data to Yard Legacy System and FDFT Yard
IPTRANS-1978 Switch to FDFT mode Train Run

IPTRANS-1979 Initiate switch to FDFT mode Train Run for all wagons in set and Traction Unit
IPTRANS-1981 Activate FDFT mode Train Run
IPTRANS-1982 Switch to FDFT mode Train Run

IPTRANS-1983 Provide status report FDFT mode Train Run
IPTRANS-1985 Check if all wagons in set and Traction Unit are in FDFT mode Train Run
IPTRANS-1987 Start monitor train run and provide status to CCU / start monitor train integrity and provide status to CCU
IPTRANS-1988 Activate 400V power supply

11.2.4 Use Cases within EP04 Train Run

IPTRANS-1989 EP04 – Train Run

IPTRANS-1991 Initiate start train run
IPTRANS-1993 Start train run
IPTRANS-1996 Train stops in target track
IPTRANS-1847 Switch wagon(s) of set to FDFT mode Shunting

IPTRANS-1849 Initiate switch to FDFT mode Shunting at Traction Unit cab
IPTRANS-1850 Initiate switch to FDFT mode Shunting via Mobile HMI
IPTRANS-1851 Deactivate 400V power supply
IPTRANS-1852 Activate FDFT mode Shunting
IPTRANS-1853 Switch to FDFT mode Shunting
IPTRANS-1855 Stop monitor train run and provide integrity status to CCU
IPTRANS-1856 Provide status report FDFT mode Shunting
IPTRANS-1858 Check FDFT mode Shunting at Traction Unit cab
IPTRANS-1860 Check FDFT mode Shunting via Mobile HMI

IPTRANS-1997 Removal of Wagon (set)

IPTRANS-1832 Secure Wagon (Set) Against Rolling Away

IPTRANS-1834 Apply Parking Brake

IPTRANS-1836 Initiate Apply Parking Brake(s) at Traction Unit cab
IPTRANS-1838 Initiate Apply Parking Brake(s) via Mobile HMI
IPTRANS-1839 Initiate Actuation of Parking Brake(s)
IPTRANS-1840 Actuate Parking Brake(s)
IPTRANS-1841 Provide Parking Brake(s) Status
IPTRANS-1843 Check if Parking Brake(s) was applied at Traction Unit cab
IPTRANS-1845 Check if Parking Brake(s) was applied via Mobile HMI

IPTRANS-1864 Uncouple

IPTRANS-1866 Initiate uncoupling at uncoupling point and deactivation 400V power supply at Traction Unit cab
IPTRANS-1869 Ensure 400V power supply is off
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1870 Initiate uncoupling at uncoupling point and FDFT function Prevent-coupling directly at the consists without an actuator
IPTRANS-1871 Initiate uncoupling at uncoupling point and FDFT function Prevent coupling directly at the consists with an actuator
IPTRANS-1868 - Activate uncoupling and FDFT function Prevent Coupling at Traction Unit cab
IPTRANS-1872 Activate uncoupling and FDFT function Prevent Coupling directly at the consists
IPTRANS 1876 - Deactivate prevent coupling by coupler itself
IPTRANS-5277 Uncouple Traction Unit
IPTRANS-5278 Uncouple via Mobile HMI
IPTRANS-5279 Uncouple manually
IPTRANS-5280 Uncouple via push-button
IPTRANS-1873 Enable prevent coupling
IPTRANS-1874 Composition detection
IPTRANS-1876 Deactivate prevent coupling by coupler itself
IPTRANS-1877 Deactivate prevent coupling by infrastructure

IPTRANS-1882 Couple

IPTRANS-1884 Do not fill break pipe with air
IPTRANS-1885 Check if FDFT function prevent coupling is deactivated at Traction Unit cab
IPTRANS-1887 Check if FDFT function prevent coupling is deactivated via Mobile HMI
IPTRANS-1888 Initiate deactivation of 400V power supply
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1892 DAC coupler head couples
IPTRANS-1874 Composition detection

IPTRANS-1829 Confirm wagon set

IPTRANS-1830 Initiate collection, collect and provide consist status data at Traction Unit cab

IPTRANS-1831 Initiate collection, collect and provide consist status data via Mobile HMI

IPTRANS-1893 Remove, Release Braking Means

IPTRANS-1895 Release parking brake

IPTRANS-1896 Initiate Release parking brake(s) at Traction Unit cab
IPTRANS-1898 Initiate Release parking brake(s) via Mobile HMI
IPTRANS-1899 Initiate actuation of parking brake(s)
IPTRANS-1900 Actuate parking brake(s) to be released
IPTRANS-1901 Provide parking brake(s) status
IPTRANS-1903 Check parking brake(s) at Traction Unit cab
IPTRANS-1905 Check parking brake(s) via Mobile HMI

IPTRANS-1937 Automated brake test

IPTRANS-1941 Collect data and initiate brake test at Traction Unit cab
IPTRANS-1943 Receive brake test relevant data
IPTRANS-1945 Check if the test unit is ready for use
IPTRANS-1947 Bring and/or hold the pressure to standard operating pressure with Traction Unit
IPTRANS-1949 Execute leak test and check wagon set pressure data at Traction Unit cab
IPTRANS-1951 Execute leak test and check wagon set pressure data via Mobile HMI
IPTRANS-1952 Compensate pressure losses
IPTRANS-1954 Check G/P and brake lever position at Traction Unit cab
IPTRANS-1956 Check G/P and brake lever position via Mobile HMI
IPTRANS-1957 Adjust parking brake at Traction Unit cab
IPTRANS-1958 Adjust parking brake via Mobile HMI
IPTRANS-1960 Confirm and save final results at Traction Unit cab
IPTRANS-1962 Confirm and save final results via Mobile HMI

IPTRANS-1968 Brake calculation at Traction Unit cab
IPTRANS-1969 Brake calculation via Mobile HMI
IPTRANS-1971 Check technical wagon inspection and brake power at Traction Unit cab
IPTRANS-2001 Addition of Wagon (set)

IPTRANS-1882 Couple

IPTRANS-1884 Do not fill break pipe with air
IPTRANS-1885 Check if FDFT function prevent coupling is deactivated at Traction Unit cab
IPTRANS-1887 Check if FDFT function prevent coupling is deactivated via Mobile HMI
IPTRANS-1888 Initiate deactivation of 400V power supply
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1892 DAC coupler head couples
IPTRANS-1874 Composition detection

IPTRANS-1829 Confirm wagon set

IPTRANS-1830 Initiate collection, collect and provide consist status data at Traction Unit cab
IPTRANS-1831 Initiate collection, collect and provide consist status data via Mobile HMI

IPTRANS-1893 Remove, Release Braking Means

IPTRANS-1895 Release parking brake

IPTRANS-1896 Initiate Release parking brake(s) at Traction Unit cab
IPTRANS-1898 Initiate Release parking brake(s) via Mobile HMI
IPTRANS-1899 Initiate actuation of parking brake(s)
IPTRANS-1900 Actuate parking brake(s) to be released
IPTRANS-1901 Provide parking brake(s) status
IPTRANS-1903 Check parking brake(s) at Traction Unit cab
IPTRANS-1905 Check parking brake(s) via Mobile HMI

IPTRANS-1937 Automated brake test

IPTRANS-1941 Collect data and initiate brake test at Traction Unit cab
IPTRANS-1943 Receive brake test relevant data
IPTRANS-1945 Check if the test unit is ready for use
IPTRANS-1947 Bring and/or hold the pressure to standard operating pressure with Traction Unit
IPTRANS-1949 Execute leak test and check wagon set pressure data at Traction Unit cab
IPTRANS-1951 Execute leak test and check wagon set pressure data via Mobile HMI

IPTRANS-1952 Compensate pressure losses
IPTRANS-1954 Check G/P and brake lever position at Traction Unit cab
IPTRANS-1956 Check G/P and brake lever position via Mobile HMI
IPTRANS-1957 Adjust parking brake at Traction Unit cab
IPTRANS-1958 Adjust parking brake via Mobile HMI
IPTRANS-1960 Confirm and save final results at Traction Unit cab
IPTRANS-1962 Confirm and save final results via Mobile HMI

IPTRANS-1968 Brake calculation at Traction Unit cab
IPTRANS-1969 Brake calculation via Mobile HMI
IPTRANS-2003 Check technical wagon inspection of added wagon(s) and brake power of consist composition

IPTRANS-2004 Removal of Traction Unit

IPTRANS-1832 Secure Wagon (Set) Against Rolling Away

IPTRANS-1834 Apply Parking Brake

IPTRANS-1836 Initiate Apply Parking Brake(s) at Traction Unit cab
IPTRANS-1838 Initiate Apply Parking Brake(s) via Mobile HMI
IPTRANS-1839 Initiate Actuation of Parking Brake(s)
IPTRANS-1840 Actuate Parking Brake(s)
IPTRANS-1841 Provide Parking Brake(s) Status
IPTRANS-1843 Check if Parking Brake(s) was applied at Traction Unit cab
IPTRANS-1845 Check if Parking Brake(s) was applied via Mobile HMI

IPTRANS-1864 Uncouple

IPTRANS-1866 Initiate uncoupling at uncoupling point and deactivation 400V power supply at Traction Unit cab
IPTRANS-1869 Ensure 400V power supply is off
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1870 Initiate uncoupling at uncoupling point and FDFT function Prevent Coupling directly at the consists without an actuator
IPTRANS-1871 Initiate uncoupling at uncoupling point and FDFT function Prevent coupling directly at the consists with an actuator
IPTRANS-1868 Activate uncoupling and FDFT function Prevent Coupling at Traction Unit cab
IPTRANS-1872 Activate uncoupling and FDFT function Prevent Coupling directly at the consists

IPTRANS-1876 Deactivate prevent coupling by coupler itself
IPTRANS-5277 Uncouple Traction Unit
IPTRANS-5278 Uncouple via Mobile HMI
IPTRANS-5279 Uncouple manually
IPTRANS-5280 Uncouple via push-button
IPTRANS-1873 Enable prevent coupling
IPTRANS-1874 Composition detection
IPTRANS-1876 Deactivate prevent coupling by coupler itself
IPTRANS-1877 Deactivate prevent coupling by infrastructure

IPTRANS-2006 Configure DPS/multiple traction units
IPTRANS-1829 Confirm wagon set

IPTRANS-1830 Initiate collection, collect and provide consist status data at Traction Unit cab
IPTRANS-1831 Initiate collection, collect and provide consist status data via Mobile HMI

IPTRANS-1893 Remove, Release Braking Means

IPTRANS-1895 Release parking brake

IPTRANS-1896 Initiate Release parking brake(s) at Traction Unit cab
IPTRANS-1898 Initiate Release parking brake(s) via Mobile HMI
IPTRANS-1899 Initiate actuation of parking brake(s)
IPTRANS-1900 Actuate parking brake(s) to be released
IPTRANS-1901 Provide parking brake(s) status
IPTRANS-1903 Check parking brake(s) at Traction Unit cab
IPTRANS-1905 Check parking brake(s) via Mobile HMI

IPTRANS-1937 Automated brake test

IPTRANS-1941 Collect data and initiate brake test at Traction Unit cab
IPTRANS-1943 Receive brake test relevant data
IPTRANS-1945 Check if the test unit is ready for use
IPTRANS-1947 Bring and/or hold the pressure to standard operating pressure with Traction Unit
IPTRANS-1949 Execute leak test and check wagon set pressure data at Traction Unit cab
IPTRANS-1951 Execute leak test and check wagon set pressure data via Mobile HMI

IPTRANS-1952 Compensate pressure losses
IPTRANS-1954 Check G/P and brake lever position at Traction Unit cab
IPTRANS-1956 Check G/P and brake lever position via Mobile HMI
IPTRANS-1957 Adjust parking brake at Traction Unit cab
IPTRANS-1958 Adjust parking brake via Mobile HMI
IPTRANS-1960 Confirm and save final results at Traction Unit cab
IPTRANS-1962 Confirm and save final results via Mobile HMI

IPTRANS-1971 Check technical wagon inspection and brake power at Traction Unit cab
IPTRANS-1972 Check technical wagon inspection and brake power via Mobile HMI
IPTRANS-2003 Check technical wagon inspection of added wagon(s) and brake power of consist composition

IPTRANS-2007 Addition of Traction Unit

IPTRANS-1882 Couple

IPTRANS-1884 Do not fill break pipe with air
IPTRANS-1885 Check if FDFT function prevent coupling is deactivated at Traction Unit cab
IPTRANS-1887 Check if FDFT function prevent coupling is deactivated via Mobile HMI
IPTRANS-1888 Initiate deactivation of 400V power supply
IPTRANS-1890 Deactivate 400V power supply
IPTRANS-1892 DAC coupler head couples
IPTRANS-1874 Composition detection

IPTRANS-2006 Configure DPS/multiple traction units
IPTRANS-1829 Confirm wagon set

IPTRANS-1830 Initiate collection, collect and provide consist status data at Traction Unit cab
IPTRANS-1831 Initiate collection, collect and provide consist status data via Mobile HMI

IPTRANS-1893 Remove, Release Braking Means

IPTRANS-1895 Release parking brake

IPTRANS-1896 Initiate Release parking brake(s) at Traction Unit cab
IPTRANS-1898 Initiate Release parking brake(s) via Mobile HMI
IPTRANS-1899 Initiate actuation of parking brake(s)
IPTRANS-1900 Actuate parking brake(s) to be released
IPTRANS-1901 Provide parking brake(s) status
IPTRANS-1903 Check parking brake(s) at Traction Unit cab
IPTRANS-1905 Check parking brake(s) via Mobile HMI

IPTRANS-1937 Automated brake test

IPTRANS-1941 Collect data and initiate brake test at Traction Unit cab
IPTRANS-1943 Receive brake test relevant data
IPTRANS-1945 Check if the test unit is ready for use
IPTRANS-1947 Bring and/or hold the pressure to standard operating pressure with Traction Unit
IPTRANS-1949 Execute leak test and check wagon set pressure data at Traction Unit cab
IPTRANS-1951 Execute leak test and check wagon set pressure data via Mobile HMI
IPTRANS-1952 Compensate pressure losses
IPTRANS-1954 Check G/P and brake lever position at Traction Unit cab
IPTRANS-1956 Check G/P and brake lever position via Mobile HMI
IPTRANS-1957 Adjust parking brake at Traction Unit cab
IPTRANS-1958 Adjust parking brake via Mobile HMI
IPTRANS-1960 Confirm and save final results at Traction Unit cab
IPTRANS-1962 Confirm and save final results via Mobile HMI

IPTRANS-1971 Check technical wagon inspection and brake power at Traction Unit cab
IPTRANS-2003 Check technical wagon inspection of added wagon(s) and brake power of consist composition

IPTRANS-2009 Change of Operator Traction Unit

IPTRANS-1832 Secure Wagon (Set) Against Rolling Away

IPTRANS-1834 Apply Parking Brake

IPTRANS-1836 Initiate Apply Parking Brake(s) at Traction Unit cab
IPTRANS-1838 Initiate Apply Parking Brake(s) via Mobile HMI
IPTRANS-1839 Initiate Actuation of Parking Brake(s)

IPTRANS-1840 Actuate Parking Brake(s)
IPTRANS-1841 Provide Parking Brake(s) Status
IPTRANS-1843 Check if Parking Brake(s) was applied at Traction Unit cab
IPTRANS-1845 Check if Parking Brake(s) was applied via Mobile HMI

IPTRANS-2013 Initiate composition detection
IPTRANS-1874 Composition detection
IPTRANS-1893 Remove, Release Braking Means

IPTRANS-2004 Release parking brake

IPTRANS-1896 Initiate Release parking brake(s) at Traction Unit cab
IPTRANS-1898 Initiate Release parking brake(s) via Mobile HMI
IPTRANS-1899 Initiate actuation of parking brake(s)
IPTRANS-1900 Actuate parking brake(s) to be released
IPTRANS-1901 Provide parking brake(s)
IPTRANS-1903 Check parking brake(s) at Traction Unit cab
IPTRANS-1905 Check parking brake(s) via Mobile HMI

IPTRANS-1937 Automated brake test

IPTRANS-1941 Collect data and initiate brake test at Traction Unit cab
IPTRANS-1943 Receive brake test relevant data
IPTRANS-1945 Check if the test unit is ready for use
IPTRANS-1947 Bring and/or hold the pressure to standard operating pressure with Traction Unit
IPTRANS-1949 Execute leak test and check wagon set pressure data at Traction Unit cab
IPTRANS-1951 Execute leak test and check wagon set pressure data via Mobile HMI
IPTRANS-1952 Compensate pressure losses
IPTRANS-1954 Check G/P and brake lever position at Traction Unit cab
IPTRANS-1956 Check G/P and brake lever position via Mobile HMI
IPTRANS-1957 Adjust parking brake at Traction Unit cab
IPTRANS-1958 Adjust parking brake via Mobile HMI
IPTRANS-1960 Confirm and save final results at Traction Unit cab
IPTRANS-1962 Confirm and save final results via Mobile HMI

IPTRANS-1978 Switch to FDFT mode Train Run

IPTRANS-1979 Initiate switch to FDFT mode Train Run for all wagons in set and Traction Unit
IPTRANS-1981 Activate FDFT mode Train Run
IPTRANS-1982 Switch to FDFT mode Train Run
IPTRANS-1983 Provide status report FDFT mode Train Run
IPTRANS-1985 Check if all wagons in set and Traction Unit are in FDFT mode Train Run
IPTRANS-1987 Start monitor train run and provide status to CCU / start monitor train integrity and provide status to CCU
IPTRANS-1988 Activate 400V power supply

IPTRANS-1996 Train stops in target track
IPTRANS-2015 Stop train run

11.3 Appendix C: Reference freight system architecture overview