Deliverable 4.4
High-Level functional requirements specification

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1 Executive Summary

Based on the multi-modal mobility systems definition results, the Deliverable D4.4 aims on providing the high-level functional requirements for the Pods System covering the transport units, the carriers and related operational system components. It represents a foundation for the Pods System concept and design specification of involved components or subsystems as to be prepared by work packages WP7-WP10. For the specification process conducted by the partners the outcome of the use case and cost evaluation performed in WP4 was considered (see D4.1 and D4.3 from the Pods4Rail project). In total, around 500 high-level functional requirements in 11 system areas were identified and specified, see Appendix A to this document.

2 Abbreviations and acronyms

CAPEX	Capital Expenditure
CBTC	Communication Based Train Control
CCTV	Closed Circuit Television
CEN	Comité Européen de Normalisation (European Standards Committee)
ERJU	Europe's Rail Joint Undertaking
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
FRS	Functional Requirement Specification
GA	Grant agreement
GoA	Grade of Automation
HS	Handling System
iCCTV	Intelligent Closed-Circuit Television
LCA	Life Cycle Assessment
MaaS	Mobility as a Service
MAWP	Multi Annual Working Plan
MMP	Mobility Management Platform
MMS	Mobility Management System
MPG	Main Product Group(s)
OPEX	Operational Expenditure
P4R	Pods4Rail project
PCS	Pod Coordination System
PIS	Passenger Information Systems
Pod	Decentralized, fully autonomous transport system
POF	Pathway of Future
R&D	Research and Development
RAMS	Reliability, Availability, Maintainability and Safety
RCU	Rail Carrier Unit
SPG	Subproduct Group(s)
SWOT	Strengths Weaknesses Opportunities Threats
TRL	Technology Readiness Level
TSI	Technical Specifications for Interoperability
TU	Transport Unit (s)
VDI	Verein Deutscher Ingenieure
VTOL	Vertical Take-off and Landing (for urban air mobility)
WP	Work Package

3 Background

The present document constitutes the Deliverable D4.4 “High-Level functional requirements specification” in the framework of the Flagship Area 7, project Pods4Rail as described in the EU-RAIL MAWP.

4 Objective/ Aim

The objective of this document is to provide the high-level Functional Requirements Specification (FRS), including the description of the scope and the boundaries for the Pods4Rail system through an initial general view.
In accordance with the general objectives of the Pods4Rail project and the aims for the WP4, the principal purpose of this task is to build a preliminary FRS for the system's components that will serve as input for the more detailed design specifications to be addressed on future Work Packages.
For this general objective, the following steps have been followed:

1. Definition of FRS structure
2. Definition of scope and system boundaries investigated in the FRS
3. Incorporation of the outcomes of the use case (D4.1) and cost evaluation (D4.3)
4. Integration of the safety recommendations derived in WP3 (Legislative and Normative Framework for Safety Requirements) into the FRS to ensure proper implementation in WP7 to WP14.

As a result, the FRS serves as input for the concept work in WP7-14.
For definition of the scope and system boundaries to be covered with the FRS (Chapter 6) the WP2 Deliverable D2.1 was used as an input regarding the general Pods definition consisting of the Pods carrier and transport unit(s). Furthermore, other documents created within the project provided valuable input e.g., D3.2 safety aspects, D4.1 Use Cases and D4.3 cost evaluation. Additionally, other resources as shown in Figure 1 were considered.

Figure 1: Presentation of sources used for the high-level requirements.

The document aims as input for the technical concept for the vessel system (WP7), design variants of the vessel (WP8), detailed concept of a sample vessel for one Use case (WP9), concept development for equipment of sample transport unit (WP10), concept development for traffic

coordination of Pods System (WP11), definition and concept development of the coupling system (WP12), concept for the handling, loading and unloading technologies (WP13), and development of a moving infrastructure carrier for rail, road and ropeway (WP14).

5 Introduction

In this document, the term *Pods System* refers to the system postulated in Europe's Rail Flagship Project 7 PODS4RAIL. In the underlying Grant Agreement no. 101121853, the term *Vessel* has been used originally. Meanwhile the PODS4RAIL consortium decided jointly to make use of the term *Transport Unit* instead which is seen as more appropriate since it provides more clarity about the scope which it refers to.

The basic approach in Work Package 4 foresees an initial baseline analysis performed in Task 4.1 providing input to Tasks 4.2 and Task 4.3 to cover a discussion and evolution of a solution at a pre-conceptual stage. The resulting outcomes of the SWOT and Economical analysis covered by these tasks are considered for the elaboration of a draft concept reflected in a high-level functional requirements specification for the Pods System as provided by this Deliverable, see also Figure 2 below.

Major challenges for this task have been identified and successfully tackled such as deciding an appropriate level of detail to enable an overall aligned specification covering several domains at the same time. Another challenge was to, where applicable, re-interpret technical specifications and related requirements for existing technical components or technologies for formulating them in the context of the new approach represented by the Pods System.

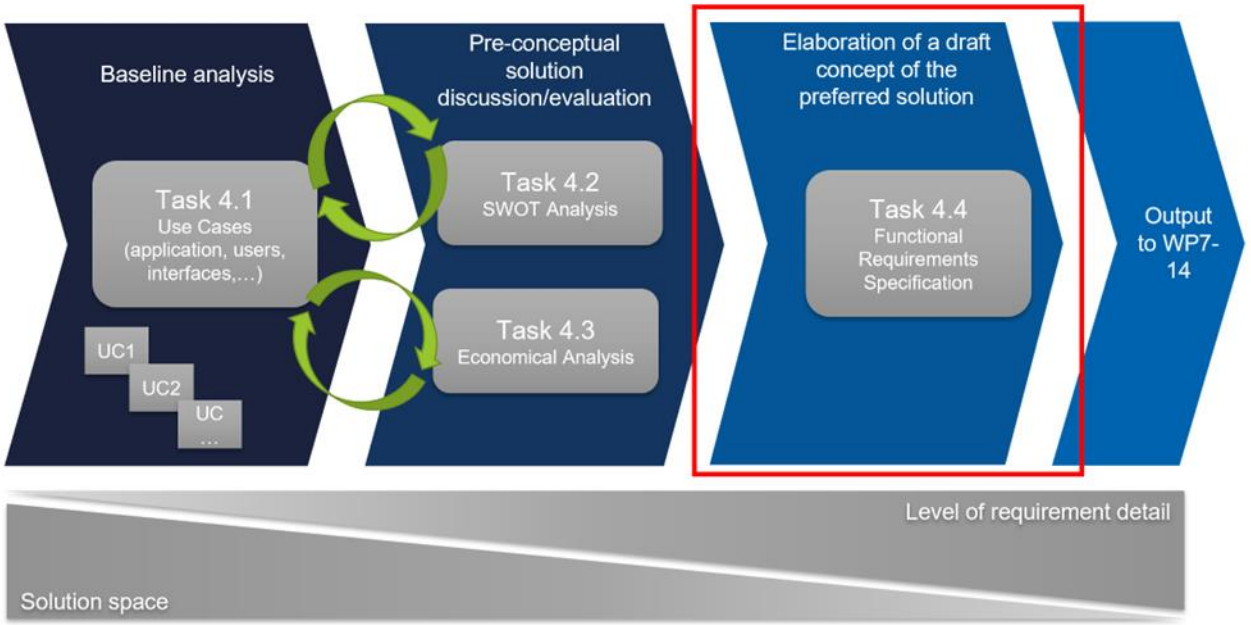

Figure 2: Structure of WP4 and Task 4.4

6 Scope and system boundaries

A functional requirement is a statement of what a product (system, subsystem, device, or software program) must do.

High-level requirements define key information that stakeholders use to outline and establish a project. Functional requirements are product features that developers must implement to enable the users to achieve their goals. They define the basic system behaviour under specific conditions.

The FRS describes how the system is going to function. It's a technical response to the needs and business objectives created during the planning phase of the project.

The main element of the FRS in the Pods4Rail project is the pod system with its transport unit (TU) and carrier. The transport unit will be shifted to different transport modes via the handling system (HS), which also must be analysed. For the safe and efficient movement of the Pods the Mobility Management Platform (MMP) will be introduced in detail. Figure 3 illustrates the scope of Pods4Rail and its sub systems.

In order to focus on the most important topics, the FRS will not include the railway infrastructure, because the existing infrastructure will be used. The definitions of station infrastructure like train stations, as well as urban air mobility (VTOL) and water ways (shipping etc.) are not part of the FRS.

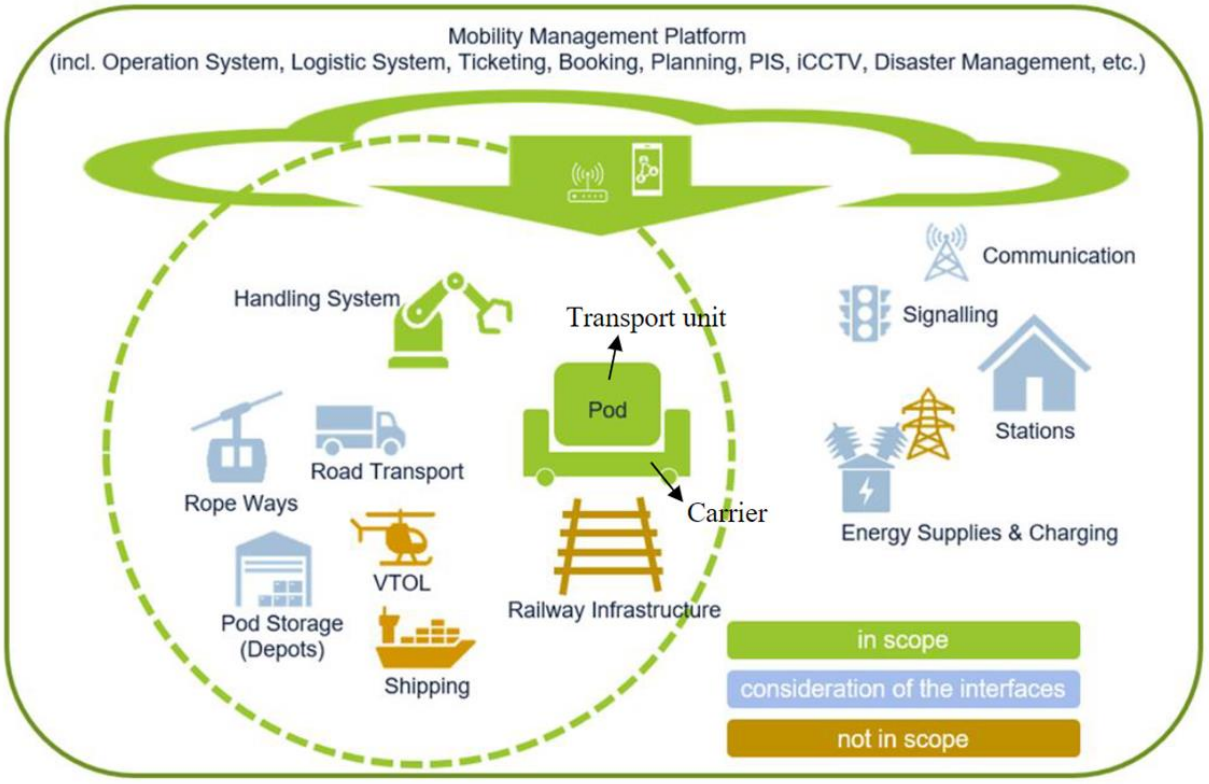

Figure 31: Illustration of the Pods4Rail System including the Mobility Management Platform (Source: Task D2.1, Figure 2)

To analyse the most important sub systems of the Pods System, the following areas are being

considered for the scope of the detailed FRS:

1. Planning and Operation System
Pods coordination and Mobility Management: To manage travel or transport demands and related availability of the vehicles and pods, a coordinating intelligence is required, knowing at any time the status of vehicles and pods including their current assignment to booked journeys. An overall Pod management system provides the basis for the required intelligence and includes the following components: Pod Coordination System (PCS), Disaster Management, Closed Circuit Television (CCTV) System, Communication systems, Pods trip planning and allocation system.

2. Logistics System and Pods Storage
Logistics System: Logistics is the process of planning and executing the efficient transportation and storage of goods from the point of origin to the point of consumption. The scope of the logistics system embraces the Mobility as a Service (MaaS) applications as well as dispatching of transport units and carrier units to the current demand (infrastructure capacity).
Storage system: The storage system stacks or stores the unused carrier and transport units. The system protects the devices from environmental influences and can also be used for service check-ups. The system is intended to ensure reliable transport of carrier and transport units to their place of use within a certain period without disrupting the operation of Pods.

3. Ticketing and Booking
The ticketing and booking system is a web-based service offering the planning and request of trips by end users with an integrated booking capability. The system includes the provision of digital tickets after a successful booking of a trip.

4. Passenger Information System (PIS)
The PIS includes different devices including platform and on-board screens or speakers as well as mobile phone apps for informing the passenger with relevant information about the current trip. In emergency situations, the PIS also acts as a medium for communication between passengers and the disaster management of the Operations System.

5. Incident Management
For the Pods System the Incident/ Disaster Management focuses on the transported people (health problems, fire, information problems, etc.), technical system (e.g. drive system failure, failure in air condition), the Mobility Management System (MMS) and the surrounding environment (e.g. obstacle on the route, route interrupted). It should solve problems e.g. for passengers, the freight forwarder, the system provider, the vehicle rental companies.4. TB4 states that the mobility management platform (MMP) can track the trips of travellers. Care should be taken not to infringe any GDPR regulations.

6. Handling System
The Handling System is required for the automated loading and unloading, ensuring, thus, the unhindered transfer of the transport units to the different carrier units, from storages, for loading and unloading of the transport units from one transportation mode (e.g. rail) to another (e.g. road). The handling system enables the multi-modality of the Pods System.

7. Transport unit
Note: this term is used synonymously for the term *Vessel* as appearing in the Grant Agreement.

'Transport Unit' refers to space for the transport of people or goods with a special design derived for this purpose and provided with the equipment necessary for the application, which can be loaded and coupled with carriers from different transport modes.

8. Rail carrier unit
Mobile drive unit for the railway domain without car body for transporting people or goods (TU), so that there is only a vehicle underframe construction (also called "carrier" or "moving infrastructure")

9. Coupling system
The system that ensures the safe mechanical coupling of transport unit and carrier, as well as, if necessary, the coupling of other systems, such as power supply and communication systems.

10. Road transport and road carrier (interfacing only)
Mobile drive unit for road transport without car body for transporting people or goods, so that there is only a vehicle underframe construction (also called "road carrier" or "moving infrastructure for road transport"). This topic also includes the interfaces and requirements for all road bound vehicles.

11. Rope Ways (not covered)
The area of integration of the Pods System and processes with Rope Ways systems have not been covered due to lack of expertise and contacts to industry for this specific transport mode. However, a future consideration of this transport mode should be considered in a consecutive project at a later stage.

7 Methodology

Introduction to high-level requirements:

This chapter will introduce the followed methodology for the definition of the high-level requirements needed for the aspects and components in the scope of this analysis that have been described in the previous section. As a result, the main identified characteristics and requisites will be presented as a complete list of requirements that can be found in the Appendix A.

For the better comprehension of these results, in this section, the FRS final table's structure will be explained as well including the used format and the main information (categories, sources, levels of generality) that have been considered. Furthermore, some special comments, highlights and challenges found during the functional requirements' identification have been explained as they are interesting matters that should be addressed on the continuation of this resulting FRS in future WPs.

Methodology of the creation of the FRS:

In addressing this task, a methodological approach was adopted, based primarily on the application standards in railway, tram and road transport. Additionally, insights from previous deliverables, such as the "System Definition", D2.1, "Use Case Definition", D4.1 and the "Safety Framework and Requirements," D3.2, were utilized. These inputs were complemented by guidelines for rolling stock specification like EuroSpec, to ensure the completeness and quality of the process, as well as by knowledge gathered from other

railway European projects.
Subsystems directly linked to the vehicle construction were structured according to the standard EN 15380-2 and its main product groups and subproduct groups, so that upcoming WPs can build upon it. For the subsystems with no related developed standards (e.g. coupling system between RCU and TU, ticketing and booking) the structure and categorization of requirements have been constructed, considered the experts' knowledge with the aim of focusing on the main aspects as safety and operation ease. In this sense, other similar projects and programmes (e.g. Shift2Rail, Europe's Rail, EuroSpec) have also been used as further references.
Moreover, the methodology considered the goals set out in the Grant Agreement, in order to maintain project alignment.

Description of the considered columns in the spreadsheet:

For the creation and definition of the FRS, a specific format has been used for a table's construction. This table includes 4 mandatory columns (Requirement ID, Category/Component, Description, Source) that provide all relevant information for the tracking and understanding of each requirement. For some components, additional columns are used containing other useful information. The headings for the optional columns are self-explanatory. This general table is as well divided in 10 different sheets corresponding to the previously mentioned components, i.e., Operation and Planning System (OPPL), Logistics and Storage (LS), Ticketing and Booking (TB), Passenger Information System (PIS), Incident Management (IM), Handling System (HM), Transport Unit (TU), Rail Carrier Unit (RCU), Coupling System (CS) and Road Transport (RT).

In the following, a further explanation of each column is given:

- Requirement-ID:
  This column represents and explains the hierarchy and logic behind the numeration/levels of generality of the requirements. For example, 'X3.7' would be used for a second level requirement in a subarea 3 of the component represented by its acronym X.
- Category/Component:
  This column is the main FRS element concerning the categorization and structure of the requirements. For the selection of these categories, different sources have been considered such as the EN 15380, experts' knowledge and other projects for reference. The aim of the categorization is to group the different requisites through their main aspects for an easier analysis of the final FRS.
- Description:
  This column contains the explanation of the requirements and their level of detail in accordance with the information also presented in the "Requirement ID" column. The formulation of each requirement uses the verb "shall" for the standardization of the future form of the characteristics.
- Source:
  This column gives an overview of the sources and references used for the definition of each requirement. This column may also include numerical references in accordance with the list of references present in this document.

8 Results

In the following, some of the most relevant specific subsystem related requirements for further WPs are highlighted.

Operation System and Planning:

The first component addressed in the FRS is the operation and planning system of the Pods System. It is assumed to make use of a centralized software system being installed and operated in a safeguarded technical environment which also includes the option for a cloud-based implementation with an adequate availability level. The required availability and other non-functional requirements should be assessed in further activities.

Handling System (HS):

For the system responsible of the seamless transition of the TU between transportation modes, 25 functional requirements were specified, addressing its operation, safety functions, communications, content loading/unloading, and its fixation and interaction with the TU. A closer look to HS6 (suspended handling) and HS7 (horizontal handling) will be necessary should any of these handling concepts (or both) be selected for the Pod system. The compatibility of the HS with different TUs shall be guaranteed, as indicated in HS7.4 and HS2.1.

Additionally, the safety of handling a passenger-TU shall draw special attention (HS3), considering that this process is an innovation of the Pod system.

Regarding the cargo loading and unloading into/from a TU, a set of requirements grouped under HS8 and based on the VDI 4420 [28] was specified.

Rail Carrier Unit:

The ninth subsystem addressed in the FRS-sheet is the rail carrier unit (RCU). A total of 90 functional requirements were specified and organized according to the structure of the main product groups (MPG) and subproduct groups (SPG) of the EN 15380-2 (Railway applications – designation systematic for railway vehicles) [27]. Additionally, the EuroSpec guideline (Common IDs [26] and Alt. traction energy supply [24]) for the specification of rolling stock was taken as an orientation for ensuring the quality of the RCU-requirements collection process.

It is worth noting that this list intends to encompass a RCU resembling tram applications and another RCU resembling a conventional railway vehicle. Consequently, the TSI is specified for the latter, while other requirements are tailored for the first use case. This adaptable approach ensures flexibility for future decisions regarding the design of the carrier unit (or units), as specified in RCU1.10 and RCU1.11.

Various requirements of the RCU show important links to other subsystems and, thus, to upcoming WPs, especially the requirements grouped under RCU1 (operation), RCU9 (monitoring and safety devices) and RCU16 (vehicle linkage devices). The design will strongly differ for a use case of long trips and for a basic design on regional and local networks. An individual compact Pod with one TU intended for long distances might encounter challenges in fulfilling RCU4.4 regarding sanitary facilities.

On the other hand, in order to avoid mechanical collisions and to enhance the safety of the Pod system, RCU2.2 “Underframe” underscores the importance of the compatibility of the designs of:

- Rail Carrier Unit

- Coupling system of RCU and TU
- Handling system, especially in the case of horizontal handling

Coupling System:

The functional requirements defined for the coupling system were conceived for the establishment of the principal and indispensable characteristics to ensure the correct connection between the transport unit and rail carrier unit. This connection shall guarantee the appropriate mechanical and electrical compatibility between components as well as the communications and data transmission.

For the address of this objectives, the functional requirements of this element have been divided in several subcategories as: General requirements, RAMS, material related, dimension related, communications/data transfer, energy transfer, operation, mechanical connection, electrical connection, manual coupling/uncoupling as redundant system, and interfaces with other subsystems. It should be noted that this categorization is not standardized due to the coupling between RCU and TU being a new component with no specific standards that cover it.

After the analysis of the coupling system, 37 first level requirements have been defined. These characteristics must be taken as inputs for the following work packages that will address a more detailed design for the coupling system as well as other principal components as Transport Unit and Rail Carrier Unit.

Next, as an introduction to the Coupling System's requirements in the appendix, some of its principal requisites will be shown in the following table. The election of this specific requisites was made by defining the features that are not available for discussion and must be addressed by the final design of the system to ensure its correct operation through regulations/safety conditions compliance.

RAMS:

Based on the proposed use of the Pods system and the underlying idea, several requirements are expected from different sectors like rail, road, rope way, software etc. Future RAMS studies should identify the component and Use Case specific RAMS requirements for defined operational Pods system environments based on the design for the system and its components as delivered in the current Pods4Rail project.

9 Conclusions

Based on the multi-modal mobility systems definition results, this deliverable reports the results of the activities of Task 4.4 in Work-package 4 with the aim of collecting high-level requirements for future ground-based intermodal and multimodal mobility systems.

The main outcome of this task is an FRS document that includes high-level requirements that define the key information in terms of product features that designers and developers must implement. It represents a foundation for the Pods System concept and design specification of involved components or subsystems. For the specification process conducted by the partners the outcome of the use case and cost evaluation performed in WP4 was considered.
For the definition of the scope and system boundaries to be covered by the FRS, the WP2 deliverable D2.1 was used as input regarding the general definition of pods, consisting of the pods carrier and the transport unit(s). In addition, other documents produced within the project provided valuable input e.g., D3.2 safety aspects, D4.1 Use Cases and D4.3 cost evaluation. A limitation of the FRS scope was given by exclusion of Rope Way systems from the assessments due to missing team expertise in this regard.

This deliverable provides a complete list of requirements of the FRS. It can be found in the appendix A.

Furthermore, some special comments, highlights and challenges founded during the functional requirements' identification have been explained as they are interesting matters that should be addressed on the continuation of this resulting FRS in future WP.

Finally, chapter 8 highlights the most relevant requirements for specific subsystems as results expected to be used for further WP, showing a brief summary of the main high-level functional requirements, implications and relations with other components of the FRS.

As a result of this deliverable, the FRS will serve as input for the technical concept for the vessel system (WP7), design variants of the vessel (WP8), detailed concept of a sample vessel for one Use case (WP9), concept development for equipment of sample transport unit (WP10), concept development for traffic coordination of Pods System (WP11), definition and concept development of the coupling system (WP12), concept for the handling, loading and unloading technologies (WP13), and development of a moving infrastructure carrier for rail, road and rope way (WP14).

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[43] EN 15227 Railway applications - Crashworthiness requirements for rail vehicles

[44] EN 45545-2 Railway applications - Fire protection on railway vehicles - Part 2: Requirements for fire behavior of materials and components

[45] EN 14752:2015 Railway applications - Bodyside entrance systems for rolling stock

[46] EN 45545 Railway Application – Fire protection on railway vehicles

[47] EN 50155:2021 Railway applications - Rolling stock – Electronic equipment

[48] IEC 60751 - Industrial platinum resistance thermometers and platinum temperature sensors

[49] StVZO - Straßenverkehrs-Zulassungs-Ordnung (German Road Traffic Licensing Act)

[50] ISO 22752 Railway applications — Bodyside windows for rolling stock

[51] ISO 3917:2016 Road vehicles — Safety glazing materials — Test methods for resistance to radiation, high temperature, humidity, fire and simulated weathering

[52] ISO 7892:1988, Vertical building elements — Impact resistance tests — Impact bodies and general test procedures

[53] EN 14750-1:2006 Railway applications - Air conditioning for urban and suburban rolling stock - Part 1: Comfort parameters

[54] EN 16584 Railway applications - Design for PRM use - General requirements

[55] EN 13272--2:2019-12-01 Railway applications – Electrical lighting for rolling stock in public transport systems – Part 2: Urban rail

[56] EN 62031:2008+A2:2015 LED modules for general lighting - Safety specifications (amendment)

[57] EN 16584-1:2017 Railway applications – Design for PRM use – General requirements – Part 1: Contrast; English version, English translation of DIN EN 16584-1:2017-03

[58] EN 50657:2017 Railways applications - Rolling stock applications - Software on Board Rolling Stock

[59] EN 16584-2:2017 Railway applications – Design for PRM use – General requirements – Part 1: Information

[60] EN 60268-16 - Sound system equipment — Part 16: Objective rating of speech intelligibility by speech transmission index (IEC 60286-16)

[61] EN 60297-3-100:2009 - Mechanical structures for electronic equipment - Dimensions of mechanical structures of the 482,6 mm (19 in) series - Part 3-100: Basic dimensions of front panels, subracks, chassis, racks and cabinets

[62] EN 60297-3-101:2004 - Mechanical structures for electronic equipment - Dimensions of mechanical structures of the 482,6 mm (19 in) series - Part 3-101: Subracks and associated plug-in units

[63] EN 60068-2-1:2007 Environmental testing - Part 2-1: Tests - Test A: Cold

[64] EN 60068-2-2:2007 Environmental testing - Part 2-2: Tests - Test B: Dry heat

[65] EN IEC 60068-2-11:2021 Environmental testing - Part 2-11: Tests - Test Ka: Salt mist

[66] EN 60068-2-30:2005 Environmental testing - Part 2-30: Tests - Test Db: Damp heat, cyclic (12 h + 12 h cycle)

[67] IEC 60297-3-101:2004 Mechanical structures for electronic equipment - Dimensions of mechanical structures of the 482,6 mm (19 in) series - Part 3-101: Subracks and associated plug-in units

[68] EN 50124-1:2017 Railway applications - Insulation coordination - Part 1: Basic requirements - Clearances and creepage distances for all electrical and electronic equipment

[69] EN 15663 Railway applications - Vehicle reference masses

[70] EN 15528 Railway applications - Line categories for managing the interface between load limits of vehicles and infrastructure

[71] EN 15380 Railway applications - Designation system for railway vehicles

[72] EN 12663-2 Railway applications - Structural requirements of railway vehicle bodies

[73] EN 15273 Railway applications - Gauges - Part 1: General - Common rules for infrastructure and rolling stock

[74] EN 15827 Railway applications - Requirements for bogies and running gears

[75] EN 13103 Railway applications - Wheelsets and bogies

[76] EN 15380-2 Railway applications - Designation system for railway vehicles - Part 2: Product groups

[77] EN 14198 Railway applications - Braking - Requirements for the brake system of trains hauled by locomotives

[78] EN 50343 Railway applications - Rolling stock - Rules for installation of cabling

[79] UIC code 571-4: Standard Wagons - Wagons For Combined Transport – Characteristics

[80] Commission Regulation (EU) No 678/2011 of 14 July 2011 replacing Annex II and amending Annexes IV, IX and XI to Directive 2007/46/EC of the European Parliament and of the Council establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles (Framework Directive) Text with EEA relevance

[81] Commission Regulation (EU) No 540/2014 of the European Parliament and of the Council of 16 April 2014 on the sound level of motor vehicles and of replacement silencing systems, and amending Directive 2007/46/EC and repealing Directive 70/157/EEC Text with EEA relevance

[82] Council Directive 96/53/EC of 25 July 1996 laying down for certain road vehicles circulating within the Community the maximum authorized dimensions in national and international traffic and the maximum authorized weights in international traffic

[83] Commission Regulation (EU) No 1300/2014 of 18 November 2014 on the technical specifications for interoperability relating to accessibility of the Union's rail system for persons with disabilities and persons with reduced mobility Text with EEA relevance

[84] Bauliche Standards für den barrierefreien Ausbau von Bushaltestellen im VGN - Ein Leitfaden für Baulastträger, Stand: 07. Juli 2020; Verkehrsplanung VGN

https://www.znas.de/downloads/leitfaden-bauliche-standards-barrierefreier-ausbau-bushaltestellen-im-vgn.pdf

[85] PBefG (Germany) - Personenbeförderungsgesetz in der Fassung der Bekanntmachung vom 8. August 1990 (BGBl. I S. 1690), das zuletzt durch Artikel 7 Absatz 4 des Gesetzes vom 11. April 2024 (BGBl. 2024 I Nr. 119) geändert worden ist

[86] Directive (EU) 2019/882 of the European Parliament and of the Council of 17 April 2019 on the accessibility requirements for products and services (Text with EEA relevance)

[87] Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure Text with EEA relevance

[88] Regulation (EU) 2019/2144 of the European Parliament and of the Council of 27 November 2019 on type-approval requirements for motor vehicles and their trailers, and systems, components and separate technical units intended for such vehicles, as regards their general safety and the protection of vehicle occupants and vulnerable road users, amending Regulation (EU) 2018/858 of the European Parliament and of the Council and repealing Regulations (EC) No 78/2009, (EC) No 79/2009 and (EC) No 661/2009 of the European Parliament and of the Council and Commission Regulations (EC) No 631/2009, (EU) No 406/2010, (EU) No 672/2010, (EU) No 1003/2010, (EU) No 1005/2010, (EU) No 1008/2010, (EU) No 1009/2010, (EU) No 19/2011, (EU) No 109/2011, (EU) No 458/2011, (EU) No 65/2012, (EU) No 130/2012, (EU) No 347/2012, (EU) No 351/2012, (EU) No 1230/2012 and (EU) 2015/166 (Text with EEA relevance)

[89] Regulation (EC) No 661/2009 of the European Parliament and of the Council of 13 July 2009 concerning type-approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor (Text with EEA relevance)

[90] Euro Conformity - Certification service, CERTIFICATE OF CONFORMITY COC; https://www.certificateofconformity-coc.com/

11 Appendices

Appendix A: High-level functional requirements specification for the Pods System

Operation and Planning System requirements:

Requirement ID	Category/Component	Description	Source (including PODS4Rail)	(P)lanning/ (O)perations
OPPL1		General requirements		
OPPL1.1	General requirements	The operating system shall be designed, being able to ensure the fully autonomous use of “moving infrastructure” carrier & vessel in the existing railway system	GA	P/O
OPPL1.2	General requirements	The system shall ensure smooth operations, including also considering safety-critical conditions.	GA T7.3	O
OPPL1.3	General requirements	The Pod system shall operate autonomously, shall be electrically powered and the approved transport units shall be designed for people and freight separated from a specific transport carrier.	Expert Knowledge - Pods4Rail	O
OPPL1.4	General requirements	The rail-bound Pod system shall be operated on passenger and freight routes in Europe (including branch lines) with a lifespan of 30 years.	Pods4Rail D2.1	O
OPPL1.5	General requirements	The Pod system's design shall separate the carrier (moving infrastructure) and the transport unit for people and/or goods with the possibility of fast switching from one transport system to another and thus a continuous transport chain shall be created.	Pods4Rail D2.1	O
OPPL1.6	General requirements	Pods shall be able to be used individually or in combination with each other for a wide variety of purposes.	Pods4Rail D2.1	O
OPPL1.7	General requirements	The Pod system shall be designed for, when changing transport modes, only the transport units are switched, while the transported goods or persons remain in the same transport receptacles (e.g. containers).	Pods4Rail D2.1	O
OPPL1.8	General requirements	The rail-bound Pod system shall contemplate its operation in various railway configurations such as branch lines, suburban lines and main lines for long-distance transport. These configurations shall be characterized by the standard track gauge of 1435 mm, and its loading gauge shall be in compliance with EN 15273. Similar requeriments for trams shall be followed.	Pods4Rail D2.1	O
OPPL1.9	General requirements	The system shall be designed for its operation in railway, tram, metro, funicular and road transport modes.	Pods4Rail D2.1	O
OPPL1.10	General requirements	The Pod system shall be designed for it to be virtually coupled to form train sets and eventual possibility of mechanical coupling (emergency coupling system based on hook coupling) between vehicles shall be contemplated.	Pods4Rail D2.1	O
OPPL1.11	General requirements	The Pod system shall integrate a handling system for the automated loading and unloading of the transport units for multiple purposes (e.g. changing transport modes) and it shall also integrate a storage system.	Pods4Rail D2.1	O
OPPL1.12	General requirements	The managing of travels, transport demands and vehicles' availability shall be in charge of a coordinating intelligence (Pods Coordination and Mobility Management). This intelligence shall include modules like a Pods Coordination System (PCS), Pods Mobility Management Platform (PMMP), disaster management system, CCTV system and a communications system.	Pods4Rail D2.1	O
OPPL1.12.1	General requirements	The Pods Coordination System (PCS) shall address the on-demand planning of trips, manage the routes to be followed, assign efficiently incoming travel requests for the available vehicles and manage the impact of incidents. For this purpose, the PCS shall receive the current vehicle's position and network's status, and it shall be communicated with the vehicles' on-board control units.	Pods4Rail D2.1	O
OPPL1.12.2	General requirements	The Pods Coordination System (PCS) shall be used as a source system for end-customer information about network, vehicle status, coordination decision taken and their effect on the impacted orders.	Pods4Rail D2.1	O
OPPL1.12.3	General requirements	The Pods Mobility Management Platform (PMMP) shall support end-customer applications acting in a similar way as classical MaaS platforms. It shall also include ticketing and booking options, and it shall provide adequate and updated information about the booked travels/transports and alternative options.	Pods4Rail D2.1	O
OPPL1.12.4	General requirements	The Disaster Management System shall organise and direct resources to cope with a disaster, coordinate responsibilities of responders and, overall, shall minimise the event's impact.	Pods4Rail D2.1	O
OPPL1.12.5	General requirements	The CCTV system shall be used to determine information on occupancy rates, passenger flow and safety-related incidents. It shall complement traditional monitoring with active evaluation of videos on-board and shall analyse them in real time using powerful algorithms.	Pods4Rail D2.1	O

OPPL1.12.6	General requirements	The Communication System shall facilitate real-time vehicle's tracking and secured data sharing (e.g. Internet of Things, telematics and cloud-based platforms).	Pods4Rail D2.1	O
OPPL1.13	General requirements	Pod system for passenger transport shall support the philosophy of autonomous rapid transport systems without any interference by humans. The Pod system shall operate with a minimum of human perception but shall be able to apply mobility on demand services in specific use cases.	Pods4Rail D2.1	O
OPPL1.14	General requirements	The Pod system shall use advanced communication systems and several sensor systems (e.g. Radar, Lidar) as support for the virtual coupling to synchronize the speed and braking of trains. The frequent communication network shall handle active and passive information about vehicle, network and the status of both.	Pods4Rail D2.1	O
OPPL2		Baseline Data		
OPPL2.1	Baseline data	Infrastructure/Topology model including track characteristics	Expert Knowledge - Pods4Rail	P/O
OPPL2.2	Baseline data	Signalling system model (ETCS Hybrid Train Detection (HTD))	Expert Knowledge - Pods4Rail	P/O
OPPL2.3	Baseline data	Pods characteristics and technical parameters	Expert Knowledge - Pods4Rail	P/O
OPPL2.4	Baseline data	The baseline data shall feature temporality (i.e. validity in terms of data being valid from ... to...)	Expert Knowledge - Pods4Rail	P/O
OPPL2.5	Baseline data	It shall be possible to maintain and validate the baseline data	Expert Knowledge - Pods4Rail	P/O
OPPL3		(on-demand) Scheduling and re-scheduling		
OPPL3.1	Pods planning	The system shall take energy consumption and requirements to fulfil the trips into consideration	Expert Knowledge - Pods4Rail	P/O
OPPL3.2	Pods planning	The system shall take the restriction between Pods caused by operational situations into account	Expert Knowledge - Pods4Rail	P/O
OPPL3.3	Pods planning	The system shall support the planning of assignment and de-assignment of Vessels to Moving Infrastructures of the Pods	Expert Knowledge - Pods4Rail	P/O
OPPL3.4	Network planning	The system shall be able to support planning in planning phases (long, short, dispatching)	Expert Knowledge - Pods4Rail	P
OPPL3.5	Network planning	The system shall support demand-based planning	Expert Knowledge - Pods4Rail	P
OPPL3.6	Network planning	The system shall be able to validate a plan at any time	Expert Knowledge - Pods4Rail	P
OPPL3.7	Network planning	The system shall be able to publish plans	Expert Knowledge - Pods4Rail	P
OPPL3.8	Network planning	The system shall be able to create new plans	Expert Knowledge - Pods4Rail	P
OPPL3.9	Network planning	The system shall be able to delete existing plans	Expert Knowledge - Pods4Rail	P
OPPL3.10	Network planning	The system shall allow modification of plans	Expert Knowledge - Pods4Rail	P
OPPL3.11	Network planning	The system shall enable creation of orders to generate new paths for Pods	Expert Knowledge - Pods4Rail	P/O
OPPL3.12	Network planning	The system shall enable modification of orders to generate new paths for Pods	Expert Knowledge - Pods4Rail	P/O
OPPL3.13	Network planning	The system shall enable cancellation of an existing Pods' path	Expert Knowledge - Pods4Rail	P/O
OPPL3.14	Network planning	The system shall enable to plan a re-routing under unpredicted incidents (restrictions)	Expert Knowledge - Pods4Rail	P/O
OPPL3.15	Network planning	The system shall enable resolution of planning conflicts	Expert Knowledge - Pods4Rail	P/O
OPPL3.16	Network planning	The system shall enable the planning and consideration of different types of temporary restrictions of the infrastructure impacting the Pods traffic	Expert Knowledge - Pods4Rail	P/O
OPPL3.17	Network planning	The system shall detect and resolve conflicts between Pods and temporary infrastructure restrictions	Expert Knowledge - Pods4Rail	P/O
OPPL3.18	Fleet planning and Management	The system shall allow to plan and manage the fleet of MIs and pools of Vessels	Expert Knowledge - Pods4Rail	P/O
OPPL3.19	Fleet planning and Management	The system shall allow to plan and manage the assignment of Vessels to MIs and MIs to available paths	Expert Knowledge - Pods4Rail	P/O
OPPL4		Operational data		
OPPL4.1	MI preparation	The system shall support information exchange in conjunction with automated technical preparation and registration of the Pods' MIs	Expert Knowledge - Pods4Rail	O
OPPL4.2	MI deregistration	The system shall support information exchange in conjunction with automated technical deregistration of the Pods' MIs	Expert Knowledge - Pods4Rail	O
OPPL4.3	MI status reports	The system shall continuously receive and use the updated positions of the Pods' Moving Infrastructures (MI)	Expert Knowledge - Pods4Rail	O
OPPL4.4	MI status reports	The system shall continuously receive and use the updated technical status information of the Pods' Moving Infrastructures (MI)	Expert Knowledge - Pods4Rail	O
OPPL4.5	Platooning	The system shall be able to manage and use data required for supporting Platooning of MIs	Expert Knowledge - Pods4Rail	O

OPPL4.6	Platooning	The system shall support the tracking of virtual coupling/de-coupling manoeuvres of the MIs	Expert Knowledge - Pods4Rail	O
OPPL4.7	Vessel status reports	The system shall continuously receive and use the updated positions of the Pods' Vessels	Expert Knowledge - Pods4Rail	O
OPPL4.8	Vessel status reports	The system shall continuously receive and use the updated technical status information of the Pods' Vessels	Expert Knowledge - Pods4Rail	O
OPPL4.9	Trackside status reports	The system shall receive and use the updated technical status information of the trackside infrastructure once it changed	Expert Knowledge - Pods4Rail	O
OPPL4.10	Operational restrictions	The system shall allow to handle and maintain required data for covering operational trackside restrictions	Expert Knowledge - Pods4Rail	O
OPPL4.11	Operational restrictions	The system shall allow to handle and maintain required data for covering operational Pods' MI or Vessel restrictions	Expert Knowledge - Pods4Rail	O
OPPL5		Traffic control		
OPPL5.1	Operational Plan	The system shall be able to initialize the Operational Plan (OP) based on the planning result	Expert Knowledge - Pods4Rail	O
OPPL5.2	Operational Plan	The system shall allow manual or automated updating of the OP following dispatcher's or automated decisions taken	Expert Knowledge - Pods4Rail	O
OPPL5.3	Operational Plan	The system shall at any time use the OP as the basis for traffic control	Expert Knowledge - Pods4Rail	O
OPPL5.4	Pods running prediction	Taking the OP into account, the system shall allow to predict the timing and routing of the Pods' MIs carrying their actually assigned Vessels or being empty	Expert Knowledge - Pods4Rail	O
OPPL5.5	Pods running prediction	The Pods running prediction shall consider the track's and Pods' characteristics and temporary restrictions of them (if applicable)	Expert Knowledge - Pods4Rail	O
OPPL5.6	Pods running prediction	The Pods running prediction shall be used to trigger conflict detection and manual or automated decision making resulting in an update of the OP.	Expert Knowledge - Pods4Rail	O
OPPL5.7	Pods running prediction	The Pods running prediction shall consider specific Pods running behaviour in relation to ATO GoA 4 and ETCS Hybrid Train Detection.	Expert Knowledge - Pods4Rail	O
OPPL5.8	Pods running prediction	The Pods running prediction and conflict detection shall consider Platooning and related virtual coupling/de-coupling manoeuvres	Expert Knowledge - Pods4Rail	O
OPPL5.9	Control decisions	The system shall be able to establish, manage and cancel MI control decisions	Expert Knowledge - Pods4Rail	O
OPPL5.10	Control decisions	The system shall be able to handle different types of MI control decisions, inter alia prioritization, waiting dependencies, hold back	Expert Knowledge - Pods4Rail	O
OPPL5.11	Alarm management	The system shall allow to manage Alarms and associated information	Expert Knowledge - Pods4Rail	O
OPPL5.12	Alarm management	The system shall support at any time the supervision of Pods and network operations	Expert Knowledge - Pods4Rail	O
OPPL6		Information management		
OPPL6.1	Information management	The system shall present updated incident and delay information	Expert Knowledge - Pods4Rail	O
OPPL6.2	Information management	The system shall indicate deviations from the Operational Plan	Expert Knowledge - Pods4Rail	O
OPPL6.3	Information management	The system shall support at any time the supervision of Pods and network operations	Expert Knowledge - Pods4Rail	O
OPPL7		Communication		
OPPL7.1	Communication	The system shall receive and react to requests related to empty pods/MI	Expert Knowledge - Pods4Rail	O
OPPL8		Monitoring		
OPPL8.1	Monitoring	Shall monitor planned vs. actual passenger boarding and unboarding	Expert Knowledge - Pods4Rail	O
OPPL8.2	Monitoring	Shall monitor planned vs. actual freight handling	Expert Knowledge - Pods4Rail	O
OPPL8.3	Monitoring	Shall monitor the energy consumption	Expert Knowledge - Pods4Rail	O
OPPL9		Compatibility		
OPPL9.1	Compatibility	The Operations and Planning system's network model shall consider and be compliant with the structure and characteristics of the existing railway infrastructure	Expert Knowledge - Pods4Rail	P/O

Logistics and Storage requirements:

Requirement ID	Category/Component	Description	Source (including PODS4Rail)
LS1	Storage and retrieval	The storage system must automate the storage and retrieval of unused carrier and transport units.	Expert Knowledge - Pods4Rail
LS2	Storage and retrieval	The storage system must provide environmental protection to protect the carrier and transport units against adverse weather conditions, dust, and other environmental influences.	Expert Knowledge - Pods4Rail
LS3	Storage and retrieval	The storage system design must facilitate easy access for service check-ups and maintenance activities.	Expert Knowledge - Pods4Rail
LS4	Storage and retrieval	The storage system must incorporate security features such as surveillance cameras, access controls, and alarms to prevent unauthorized access and ensure the safety of the units.	Expert Knowledge - Pods4Rail
LS5	Storage and retrieval	The storage system should include a real-time monitoring and reporting of the storage processes system to track the status and condition of carrier and transport units.	Expert Knowledge - Pods4Rail
LS6	Storage and retrieval	The storage system must be capable of quickly retrieving carrier and transport units when needed for pod operations.	Expert Knowledge - Pods4Rail
LS7	Storage and retrieval	The storage system must integrate seamlessly with the pod scheduling system to facilitate the coordinated deployment of carrier and transport units.	Expert Knowledge - Pods4Rail
LS8	Storage and retrieval	The storage system should be scalable to accommodate future expansion or changes in the fleet size and operational requirements (including required space)	Expert Knowledge - Pods4Rail
LS9	Storage and retrieval	The storage system must have protocols in place for emergency situations, including the swift retrieval of carrier and transport units to address unexpected disruptions (i.e. emergency response).	Expert Knowledge - Pods4Rail
LS10	Storage and retrieval	The storage system must comply with relevant regulatory standards and safety guidelines for the existing infrastructure.	Expert Knowledge - Pods4Rail

Ticketing and Booking requirements:

Requirement ID	Category/Component	Description	Source
TB1	Ticketing& Booking	PIS provides offers for ticketing options of the Mobility Management Platform of the Pods System	FP7-PODS4Rail D4.1 [32]
TB1.1	Ticketing& Booking	Travellers need to book Pods before their trips	FP7-PODS4Rail D4.1 [32]
TB1.2	Ticketing& Booking	Travellers are provided with a selection of products for booking	FP7-PODS4Rail D4.1 [32]
TB1.3	Ticketing& Booking	Travellers are provided with after-sales services to manage their bookings	FP7-PODS4Rail D4.1 [32]
TB1.4	Ticketing& Booking	Pods can be booked for freight shipments via the Mobility Management Platform of the Pods System	FP7-PODS4Rail D4.1 [32]
TB2	Ticketing& Booking	Mobility Management Platform automatically detects and charges the best ticket for the trip the Traveller has taken	Expert Knowledge - Pods4Rail
TB3	Ticketing& Booking	Travellers may activate XiXo functionality	Expert Knowledge - Pods4Rail
TB4	Ticketing& Booking	Mobility Management Platform can track the trip of the Traveller, GDPR regulations have to be considered.	Expert Knowledge - Pods4Rail
TB5	Ticketing& Booking	Mobility Management Platform can calculate the best offers for the tracked trip	Expert Knowledge - Pods4Rail
TB6	Ticketing& Booking	Mobility Management Platform can provide a valid ticket for the tracked trip even though the Traveller has not issued a ticket, yet.	Expert Knowledge - Pods4Rail
TB7	Ticketing& Booking	Mobility Management Platform analyses trips in a time frame (i.e., a day) of the Traveller to determine the best ticket for the tracked trips within that time frame.	Expert Knowledge - Pods4Rail
TB8	Ticketing& Booking	Mobility Management Platform can automatically charge the traveller for the determined best ticket	Expert Knowledge - Pods4Rail

Passenger Information System requirements:

Requirement ID	Category/ Component	Description	Source
PIS1	PIS	Pods are integrated in Public Transport as a form of Demand Responsive Transport (DRT)	FP7-PODS4Rail D4.1 [32], FP6-FutuRe D6.2 [34]
PIS1.1	PIS	Mobility Management Platform of the Pods System needs to provide an interface to request individual offers to the PIS	FP6-FutuRe D6.2 [34]
PIS1.2	PIS	Mobility Management Platform of the Pods System needs to provide base service information to the PIS	FP6-FutuRe D6.2 [34]
PIS2	PIS	PIS integrates Pods as a means for first or last mile services or for the complete trip	FP7-PODS4Rail D4.1 [32], FP6-FutuRe D6.2 [34]
PIS2.1	PIS	Mobility Management Platform of the Pods System provides offers that meet the individual request from the PIS	FP6-FutuRe D6.2 [34]
PIS2.2	PIS	Mobility Management Platform of the Pods System provides trip details in the offer, including durations and distances of the legs	FP6-FutuRe D6.2 [34]
PIS3	PIS	Interface of the Mobility Management Platform of the Pods System provides information in the offers to indicate special needs of Persons with Reduced Mobility	FP7-PODS4Rail D4.1 [32], FP6-FutuRe D6.2 [34]
PIS4	PIS	Interface of the Mobility Management Platform of the Pods System supports requests taking special needs of Person with reduced Mobility into account	FP7-PODS4Rail D4.1 [32], FP6-FutuRe D6.2 [34]
PIS5	PIS	Interface of the Pod Managing System supports requests to ship freight	FP7-PODS4Rail D4.1 [32], FP6-FutuRe D6.2 [34]
PIS6	PIS	PIS offers Pod services only if they are in line with the rules of competition for both public transport and DRT services	FP6-FutuRe D6.2 [34]
PIS7	PIS	PIS supports different classes of the Pod services	FP7-PODS4Rail D4.1 [32], FP6-FutuRe D6.2 [34]
PIS8	PIS	Platform and Onboard Screens (trip information, status information) and required software	Expert Knowledge - Pods4Rail
PIS9	PIS	Platform and Onboard speakers for notifications including emergency notifications and required software	Expert Knowledge - Pods4Rail
PIS10	PIS	PIS for autonomous driven Pod systems shall include Emergency and Disaster Management for unmanned vehicle and different transport modes. The PIS shall manage and classify independently a critical incident onboard and shall ensure the communication between passengers and the communication control centre during operation.	FP7-PODS4Rail D2.1 [29]

Incident Management requirements:

Requirement ID	Category/ Component	Description	Source (including PODS4Rail)
IM1		Incident Information Management	
IM1	Incident Information Management	Mobility Management Platform of the Pods System provides the Passenger Information Services (PIS) with real-time information	Expert Knowledge - Pods4Rail
IM1.1	Incident Information Management	Mobility Management Platform of the Pods System provides changes to the trips of the booked offers to the PIS	Expert Knowledge - Pods4Rail
IM1.2	Incident Information Management	Mobility Management Platform of the Pods System provides changes to the booked offer of the PIS	Expert Knowledge - Pods4Rail
IM1.3	Incident Information Management	Mobility Management Platform of the Pods System provides information about the external situation at the final destination.	PODS4Rail T4.4
IM2		Incident Detection and Diagnosis	
IM2.1	Incident Detection	The Carrier shall have the necessary sensors	PODS4Rail T4.4
IM2.2	Incident Detection	The Pods shall have the necessary sensors outside the pod	PODS4Rail T4.4
IM2.3	Incident Detection	The Pods shall have the necessary sensors inside the pod	PODS4Rail T4.4
IM2.4	Incident Detection	Software (potentially AI) shall exist and be able to detect deviations from normal state inside the pod based on the sensor data.	PODS4Rail T4.4
IM2.5	Incident Detection	Software (potentially AI) shall exist and be able to detect deviations from normal behaviour of the carrier based on the sensor data.	PODS4Rail T4.4
IM2.6	Incident Detection	Software shall classify the incident according to its nature and severity.	PODS4Rail T4.4
IM3		Cybersecurity	
IM3.1	Incident Detection	There shall be the option to detect unauthorized access, hacking and other cyber threads.	PODS4Rail T4.4
IM3.2	Incident Detection	If such a threat is detected an emergency protocol shall be followed.	PODS4Rail T4.4
IM4		Incident Prevention and Mitigation	
IM4.1	Prevention and risk mitigation	The Pods infrastructure and MIs/Vessels shall be maintained in regular intervals.	Expert Knowledge - Pods4Rail
IM4.2	Prevention and risk mitigation	The Pods infrastructure and MIs/Vessels shall issue warnings to the centralized incident management system	Expert Knowledge - Pods4Rail
IM4.3	Prevention and risk mitigation	Emergency procedures shall be developed, documented and updated regularly.	Expert Knowledge - Pods4Rail

IM4.4	Prevention and risk mitigation	Emergency procedures for cyber-attacks shall be developed, documented and updated regularly.	PODS4Rail T4.4
IM4.5	Prevention and risk mitigation	Responsibilities for all phases of emergency response and recovery shall be defined	Expert Knowledge - Pods4Rail
IM4.6	Prevention and risk mitigation	Emergency response training shall be performed regularly	Expert Knowledge - Pods4Rail
IM4.7	Prevention and risk mitigation	The Operation and Planning system shall deliver reliable plans	Expert Knowledge - Pods4Rail
IM4.8	Prevention and risk mitigation	A regular process for updating the mitigation strategy shall be performed	Expert Knowledge - Pods4Rail
IM4.9	Prevention and risk mitigation	There shall be the option for passengers to contact someone if they feel unwell or unsafe.	PODS4Rail T4.4
IM4.10	Prevention and risk mitigation	An emergency brake shall exist, and emergency evacuation of the pod shall be possible.	PODS4Rail T4.4
IM4.11	Prevention and risk mitigation	There shall be the option for vulnerable road users (VRUs) to interact with the autonomous pod.	PODS4Rail T4.4
IM4.12	Prevention and risk mitigation	There shall be procedures in place to react to dangerous environmental conditions.	PODS4Rail T4.4
IM4.13	Prevention and risk mitigation	Incidents that have their source in insufficient maintenance shall be prevented by applying predictive maintenance techniques (e.g. using AI)	PODS4Rail T4.4
IM5		Response to incidents	
IM5.1	Response to incidents	Emergency services and actions shall be activated or performed following pre-defined emergency procedures	Expert Knowledge - Pods4Rail
IM5.2	Response to incidents	Emergency incident reports shall follow local, national, and international regulations.	PODS4Rail T4.4
IM5.3	Response to incidents	Minimization of end-user impact shall be established by suitable re-planning and other measures	Expert Knowledge - Pods4Rail
IM5.4	Response to incidents	A replanning of Pods paths and related fleet assignments shall be established for addressing incidents	Expert Knowledge - Pods4Rail
IM5.5	Response to incidents	Intermodal traffic options shall be considered for deciding on public advices	Expert Knowledge - Pods4Rail
IM5.6	Response to incidents	It shall be possible to inform Pods system actors via defined channels about the incident and required behaviour	Expert Knowledge - Pods4Rail
IM5.7	Response to incidents	The Incident management system shall be integrated with external emergency response systems, especially if those are autonomous as well.	PODS4Rail T4.4
IM5.8	Response to incidents	The system shall be put in a safe state (e.g. stand still) if a serious incident was registered.	PODS4Rail T4.4
IM5.9	Response to incidents	There shall be a post-incident analysis to understand the root cause and prevent it in the future	PODS4Rail T4.4
IM5.10	Response to incidents	Incidents shall be reported to regulatory bodies and stakeholders accurately and timely	PODS4Rail T4.4

IM6		Recovery measures	
IM6.1	Incident Management	There shall be a fire extinguisher inside the pod	PODS4Rail T4.4
IM6.1	Incident Management	There shall be a tracking device inside the pod, so that rescuers can quickly and easily find the pod.	PODS4Rail T4.4
IM7		Ethical and legal	
IM7.1	Ethical and legal	Framework for decisions in dilemmas (when harm is unavoidable) shall exist.	PODS4Rail T4.4
IM7.2	Ethical and legal	Legal implications of incidents, including liability and insurance shall be defined.	PODS4Rail T4.4

Handling System requirements:

Requirement ID	Category/ Component	Description	Source
HS1		Baseline Data	
HS1.1	Baseline Data	The handling system must facilitate seamless transitions between different transportation modes, including transfers between rail and road or between two railway lines.	Pods4Rail GA [33]
HS1.2	Baseline Data	The handling system should support automated loading and unloading processes for both passengers and freight.	Pods4Rail GA [33]
HS1.3	Baseline Data	The handling system shall be able to operate without loss or reduction of functions in temperature range T1 (-25 °C to +40 °C)	EuroSpec (EN-50125-1) [35]
HS2		Operation	
HS2.1	Operation	The handling system should allow for easy transfer and compatibility between various types of TUs (Scalability for small/big TU´s and light/heavy TU´s)	Pods4Rail GA [33]
HS2.2	Operation	The handling system should prioritize passenger comfort during loading and unloading, incorporating features such as smooth acceleration and deceleration, and stable platforms.	Expert Knowledge - Pods4Rail
HS2.3	Operation	The handling system shall be capable of adapting transition speeds based on the type of TU, passenger or freight load, and operational requirements.	Expert Knowledge - Pods4Rail
HS2.4	Operation	The handling system should allow swift loading and unloading operations for intermediate stations.	Expert Knowledge - Pods4Rail
HS2.5	Operation	The handling system should support the efficient loading and unloading of freight en-route, minimizing disruptions to the overall transportation process.	Expert Knowledge - Pods4Rail
HS2.6	Operation	Operation range: The HS should be able to overcome the distance between the domains of separate carriers, e.g. on rail and road, at a terminal or station	Expert Knowledge - Pods4Rail
HS3		Automation Safety Functions	
HS3.1	Automation Safety Functions	The handling system shall ensure safety and security of passenger and freight	Expert Knowledge - Pods4Rail
HS3.2	Automation Safety Functions	The handling system shall provide emergency solutions for passengers (e.g. emergency exits for passengers during the transfer process, if applicable)	Pods4Rail, D3.2 [36]
HS3.3	Automation Safety Functions	The handling system must have action cards in place for emergency situations, including responses to unexpected events during loading, unloading, or transitions.	Pods4Rail, D3.2 [36]
HS3.4	Automation Safety Functions	The handling system shall follow a defined process description for safe loading and unloading.	Pods4Rail, D3.2 [36]
HS3.5	Automation Safety Functions	The handling system shall always communicate (provide and receive) specific feedback data about the process status according to the defined process description for safe loading and unloading.	Pods4Rail, D3.2 [36]

HS3.6	Automation Safety Functions	The handling system shall provide relevant automation functions, e.g. automatic movements, detection of Carrier and TU, detection of obstacles etc.	Expert Knowledge - Pods4Rail
HS4		Communications	
HS4.1	Communications	The handling system should integrate seamlessly with the overall control and scheduling systems of the pods coordination system to ensure coordinated operations	Expert Knowledge - Pods4Rail
HS4.2	Communications	The handling system must be designed to interface seamlessly with different carrier units.	Expert Knowledge - Pods4Rail
HS4.3	Communications	The handling system should provide clear instructions to passengers and operators/service staff during loading and unloading via the TU	Pods4Rail, D3.2 [36]
HS4.4	Communications	The handling system shall be equipped with all necessary communication infrastructure for seamless connectivity to the operation system.	Pods4Rail GA [33]
HS5		Power supply	
HS5.1	Power supply	If necessary, the Handling System should be able to transmit energy to the TU during transshipment	Expert Knowledge - Pods4Rail
HS5.2	Power supply	The Handling system should be seamlessly powered, including a protection or safety plan for loss of electricity	Expert Knowledge - Pods4Rail
HS6		Suspended handling: Interaction with TU and fixing	
HS6.1	Suspended handling	EN 15056+A1 Cranes - Requirements for suspension frames for container handling	Expert Knowledge - Pods4Rail
HS6.2	Suspended handling	ISO 3874:1999 (26 9345) Series 1 containers - Handling and fixing	Expert Knowledge - Pods4Rail
HS7		Horizontal handling: Interaction with TU and fixing	
HS7.1	Horizontal handling	If a horizontal handling is implemented, the following requirements shall be considered	Expert Knowledge - Pods4Rail
HS7.2	Horizontal handling	The materials for cargo handling systems should be in accordance with recognized standards for the design temperature. The design temperature for the materials should be calculated for the design condition accepted by the Administration	MSC.1/Circular.1363 [37]
HS7.3	Horizontal handling	At least one set of emergency shutdown systems should be provided for the cargo handling systems. Activation of the shutdown systems should be controlled at a continuously manned station during cargo handling. An established shutdown procedure should be followed automatically or by remote control, following activation of the shutdown system. Cargo handling should be stopped automatically in case of activation of the emergency shutdown systems	MSC.1/Circular.1363 [37]
HS7.4	Horizontal handling	All moving parts of cargo handling systems should be adequately secured to the carrier unit during voyage to prevent damage to the ship. Securing devices should be provided in accordance with the established securing plan for the cargo handling systems	MSC.1/Circular.1363 [37]

HS7.5	Horizontal handling	The coupling system shall be compatible with the handling system, especially in the case of horizontal handling, in order to avoid mechanical collisions. The electrical and digital connections shall also be compatible with the HS in this case. Additionally, the coupling system and the handling system (both horizontal or suspended) shall be able to communicate, in order to coordinate both processes.	Expert Knowledge - Pods4Rail
HS8		Content loading / unloading (cargo)	
HS8.1	Content loading / unloading (cargo)	Loading/unloading of non-autonomous cargo from inside TU without unloading whole TU according to VDI 4420 or similar. Chapter 2.2 for load floor conveyor system and chapter 2.3 without load floor conveyor system. Different systems also for rear or side loading.	VDI 4420 [38]
HS8.2	Content loading / unloading (cargo)	If fitted with load floor conveyor system, an external docking device prepared for the maximum load of the TU content is necessary	VDI 4420 [38]
HS8.3	Content loading / unloading (cargo)	If fitted with load floor conveyor system, transfer time of e.g. 30 Euro-pallets of maximum 5 min plus docking time of maximum 8 minutes	VDI 4420 [38]
HS8.4	Content loading / unloading (cargo)	The TU should be able to be loaded/unloaded manually or with standard equipment's as well (alternative operation types, e.g. in case of loss of electricity)	VDI 4420 [38]

Transport Unit requirements:

Requirement ID	EN 15380 MPG (Main Product Group)	Category/ Component SPG (Sub Product Group)	Description	Applied Use-Cases (Passenger, Cargo, Combined, others, all)	Rail/ road/ both domains	Source
TU_A	A		Baseline Data			
TU_A1		Weight Limits	Maximum empty weight shall be as low as possible	all	both	Pods4Rail GA [33]
TU_A2		Weight Limits	Maximum gross weight (including load and carrier weight) shall not exceed the limitations of each transport mode	all	both	Pods4Rail D4.4 [39]; Moving Blocks rail/road carrier
TU_A3		Dimensions	The TU shall be scalable to different sizes	all	both	Pods4Rail D4.1 [32]
TU_A4		Dimensions	TU Size 1 shall be similar to 1 EPAL Europallette	all	both	Pods4Rail D4.1 [32]
TU_A5		Dimensions	TU Size 2 shall be similar to several EPAL Europallette	all	both	Pods4Rail D4.1 [32]
TU_A6		Dimensions	TU Size 3 shall be similar to Type A (Iso-Container 10')	all	both	Pods4Rail D4.1 [32]
TU_A7		Dimensions	TU Size 4 shall be similar to Type B (Iso-Container 20')	all	both	Pods4Rail D4.1 [32]
TU_A8		Dimensions	TU Size 5 shall be similar to Type C (Iso-Container 40')	all	both	Pods4Rail D4.1 [32]
TU_A9		Dimensions	All Transport Units shall aim to maximise efficiency (inner dimensions as big as possible; outer dimensions as small as possible)	all	both	Expert Knowledge - Pods4Rail
TU_A10		Dimensions	Dimension of all units shall follow the maximal allowed dimensions of on the track-related components. (RAILWAY TRANSPORT STOCK - ROLLING STOCK CONSTRUCTION GAUGE)	all	rail	UIC 505-1 [40]
TU_A11		Dimensions	Dimension of all units shall follow the maximal allowed dimensions of on the track-related components for road.	all	road	Pods4Rail D4.4 [39]; Moving Block Road Carrier
TU_B	B		Transport Unit body			
TU_B1		General	Sufficient strength of unit with respect mechanical properties	all	both	ISO 1496
TU_B2		General	All Transport Units shall use fire-resistant materials	all	both	EN 45545-2 [44], EN 17064, EU 2020/ECE118:2020-02-21
TU_B3		General	Transport Units for passenger transport shall have doors at two opposite sides	passenger	both	

TU_B4		B Underframe	tbd			ISO 1496
TU_B5		C Side walls	tbd			ISO 1496
TU_B6		D Roof	tbd			ISO 1496
TU_B7		E Head of vehicle	tbd			ISO 1496
TU_B8		F End walls	tbd			ISO 1496
TU_B9		G Weld-on/add-on parts	tbd / not relevant			
TU_B10		H Intermediate floor	tbd / not relevant			
TU_B11		J Partitions	tbd / not relevant			
TU_C	C		Vehicle fitting out			DIN EN 50155 [47] / IEC 60751 [48]
TU_C1		B Window	All windows shall be made of safe materials to not harm passengers (e.g. safety glass)	all	both	StVZO [49] §40 (German)
TU_C2		B Window	Windows shall be provided for passenger TU´s	passenger	both	Pods4Rail GA [33]
TU_C3		B Window	All windows shall follow design criteria for approval	all	both	ISO 22752 [50]; ISO 3917:2016 [51]; ISO 7892:1988 [52]
TU_C4		B Window	Front windows (if relevant for a driver) shall be equipped with wipers, heaters and similar tools to keep a clear vision for driver	all	both	StVZO [49] §40 (German)
TU_C5		C Floor	100% Low floor shall be available for PRM relevant TU´s (specific PRM-TU or all passenger-TU´s)	all	both	EN 45545 [46]
TU_C6		D Interior panelling	tbd / not relevant			
TU_C7		E Partitions	tbd / not relevant			
TU_C8		F External additions	tbd / not relevant			

TU_C9		G Vehicle paintwork	Foiling	all	both	
TU_C10		H Insulation	Shall be according EN 14750-1 - Winter Climate Zone II, Summer Climate Zone I, Kategorie A (< 4 Person per sqrm)	all	both	EN 14750-1 [53]
TU_D	D		Interior appointment			
TU_D1		General Equipment	Screens for PIS shall be provided for passengers	Passenger, combined	both	Expert Knowledge - Pods4Rail
TU_D2		General Equipment	Speakers for PIS shall be provided for passenger information or entertainment	Passenger, combined	both	Expert Knowledge - Pods4Rail
TU_D3		General Equipment	Microphone, Calling-Device or similar shall be provided for passenger-Communication	Passenger, combined	both	Expert Knowledge - Pods4Rail
TU_D4		General Equipment	Air-conditioning / Heaters (HVAC) shall be provided for passengers	Passenger, combined	both	Expert Knowledge - Pods4Rail
TU_D5		General	The design shall prioritize passenger safety, including secure seating arrangements, safety belts, and emergency exits.	Passenger, combined	both	StVZO [49] §35a, §35i (German)
TU_D6		General	The interior of the transport unit shall be designed to accommodate varying configurations, allowing for flexibility in seating arrangements and freight storage.	Combined Transport	both	Expert Knowledge - Pods4Rail
TU_D7		B Rails, handles (inside)	The TU shall provide stable rails and handles			EN 16584 [54]
TU_D8		C Seats, sleeping berths, tables	Sleeping berths, tables shall be provided according to UC	Passenger, combined	both	Expert Knowledge - Pods4Rail
TU_D9		Seats	Wide space Seats shall be provided according to UC (e.g. premium passenger transport UC)	Passenger, combined	both	StVZO [49] §35a, §35i, Appendix X (German)
TU_D10		Seats	Standard Seats shall be provided according to UC (e.g. public transport UC)	Passenger, combined	both	StVZO [49] §35a, §35i, Appendix X (German)
TU_D11		Seats	Standing Seats shall be provided according to UC (e.g. mass transport UC)	Passenger, combined	both	Expert Knowledge - Pods4Rail
TU_D12		Seats	Foldable Seats shall be provided according to UC (e.g. mass transport UC)	Passenger, combined	both	StVZO [49] §35a, §35i, Appendix X (German)
TU_D13		Seats	All seats shall be arranged to provide a minimal aile dimension	Passenger, combined	both	StVZO [49] §35i, Appendix X (German)
TU_D14		Seats	All seats shall provide minimal seat dimensions	Passenger, combined	both	StVZO [49] §35i, Appendix X (German)

TU_D15		Seats	Wheelchair areas shall be provided for wheelchair accessible TU´s	Passenger, combined	both	StVZO [49] §35a (German)
TU_D16		D Sanitary facilities	Sanitary facilities shall be provided depending on UC.	Passenger	rail	Expert Knowledge - Pods4Rail
TU_D17		E Luggage racks	Luggage racks shall be provided for passengers' personal luggage	Passenger, combined	both	Expert Knowledge - Pods4Rail
TU_D18		E Luggage racks	Luggage racks shall be provided for bigger luggage or freight	Combined Transport	both	Expert Knowledge - Pods4Rail
TU_D19		E Luggage racks	Adequate and secure storage areas shall be provided for the transportation of freight, ensuring it doesn't pose a safety risk to passengers.	Combined Transport	both	Expert Knowledge - Pods4Rail
TU_D20		E Luggage racks	The transport unit shall have designated and secure attachment points for securing freight during transit.	Combined Transport	both	Expert Knowledge - Pods4Rail
TU_D21		E Luggage racks	The design shall be compatible with standardised containers for freight transport	Combined Transport	both	Expert Knowledge - Pods4Rail
TU_D22		F Additional devices	tbd / not relevant			
TU_F	F		Power system			
TU_F1		General	The TU shall have access to energy for on board systems (e.g. from Carrier/ infrastructure/ TU)	all	both	Pods4Rail GA [33]
TU_F2		General	The TU shall provide storage for own battery if necessary, without a carrier/infrastructure	all	both	Pods4Rail GA [33]
TU_F3		General	The TU shall provide energy via battery technologies	all	both	Pods4Rail GA [33]
TU_F4		General	The TU shall provide energy harvesting or charging technologies	all	both	Pods4Rail GA [33]
TU_J	J		Monitoring and safety equipment			
TU_J1		Emergency stops	Users shall be able to: emergency stop TU from inside	Passenger	both	Pods4Rail D3.2 [36]
TU_J2		Emergency stops	Users shall be able to: emergency stop TU from outside	all	both	Pods4Rail D3.2 [36]
TU_K	K		Lighting			
TU_K1		B Exterior lighting	Lightings shall comply with rail standards	all	rail	EN 13272-2:2019-12-01 [55]
TU_K2		B Exterior lighting	Lightings shall comply with road standards	all	road	StVZO [49] §49a-§54 (german)
TU_K3		C Interior lighting equipment	Lightings shall comply with rail standards	all	rail	Expert Knowledge - Pods4Rail
TU_K4		C Interior lighting equipment	Lightings shall comply with road standards	all	road	StVZO [49] §54a (german)

TU_L	L		Air conditioning (according EN 14750-1 - Winter Climate Zone II, Summer Climate Zone I, Kategorie A (< 4 Person per sqrm))			
TU_L1		B Intake/evacuation of air	The TU shall provide air flow between fresh and used air	Passenger	both	Expert Knowledge - Pods4Rail
TU_L2		C Treatment	The TU HVAC shall provide air treatment	Passenger	rail	EN 50155:2021 [47]
TU_L3		D Distribution	Central HVAC Unit roof mounted - airducts in roof	Passenger	both	Expert Knowledge - Pods4Rail
TU_L4		E Regulation	GWP < 20, air-based cycle	Passenger	rail	EN 50155:2021 [47]
TU_N	N		Doors, entrances			
TU_N1		General	The TU should provide doors with minimal space impact to the exterior and interior area	all	both	Expert Knowledge - Pods4Rail
TU_N2		General	The TU should provide maximum door sizes for comfortable entry/exit	all	both	Expert Knowledge - Pods4Rail
TU_N3		General	The door location shall be on two opposite sides of the TU and easy to reach (front, rear, left or right); location and size are depending on different Use Cases.	all	both	Expert Knowledge - Pods4Rail
TU_N4		General	The TU shall provide at least one door for entry and exit	all	both	Expert Knowledge - Pods4Rail
TU_N5		General	The entries should provide low floor ability (levelling, lifting or by ramp)	all	both	Expert Knowledge - Pods4Rail
TU_N6		General	Low floor entering, if possible	all	both	Expert Knowledge - Pods4Rail
TU_N7		General	Users shall be able to: open doors from outside (normally + manual fallback)	all	both	Expert Knowledge - Pods4Rail
TU_N8		General	Users shall be able to: open doors from inside (normally + manual fallback)	all	both	Expert Knowledge - Pods4Rail
TU_N9		Emergency Exits	The TU shall provide at least a minimal number of emergency exits (the more, the better)	Passenger	both	StVZO [49] Appendix X 5)
TU_N10		Emergency Exits	The TU shall provide at least minimal dimensions of emergency exits (the bigger, the better)	Passenger	both	StVZO [49] Appendix X 5)
TU_N11		B External doors	yes, see train configuration	Passenger	both	EN 14752:2015 [45]; EN 62031:2008+A2:2015 [56]
TU_N12		C Internal doors	yes, for special applications	Passenger	both	Expert Knowledge - Pods4Rail

TU_N13		D Entrances, steps (not inside)	tbd, for 100% Low floor --> yes	Passenger	both	EN 165841:2017 [57]
TU_N14		E Entrances for the disabled	yes	Passenger	both	Expert Knowledge - Pods4Rail
TU_P	P		Information facilities			EN 50657:2017 [58]
TU_P1		General	Users shall be able to: receive information from PIS from inside (trip destination, current stop, ...)	Passenger	both	Expert Knowledge - Pods4Rail
TU_P2		General	Users shall be able to: receive information from PIS from outside (trip destination, current stop, ...)	all	both	Expert Knowledge - Pods4Rail
TU_P3		General	Users shall be able to: communicate with service centre	Passenger	both	Expert Knowledge - Pods4Rail
TU_P4		General	Users shall be able to: communicate with emergency services	Passenger	both	Expert Knowledge - Pods4Rail
TU_P5		B Visual information facilities	yes	Passenger	both	EN 50155:2021 [47]
TU_P6		C Visual information elements	yes	Passenger	both	DIN EN 16584-2:2017 [59]
TU_P7		D Entertainment	yes	Passenger	both	EN 50657:2017 [58]
TU_P8		E Advertising	yes	Passenger	both	EN 50657:2017 [58]
TU_P9		F Audible information facilities	yes	Passenger	both	EN 60268-16 [60]
TU_S	S		Vehicle linkage devices			
TU_S1		General	All Transport Units shall have same contact points for placing on/in carrier or ground	all	both	Pods4Rail GA [33]
TU_S2		General	All Transport Units shall have same interfaces to coupling systems	all	both	Pods4Rail GA [33]
TU_S3		General	All Transport Units shall have possibility for mechanical coupling, if needed	all	both	Pods4Rail GA [33]
TU_S4		General	All Transport Units shall have possibility for electrical coupling, if needed	all	both	Pods4Rail GA [33]
TU_S5		General	All Transport Units shall have possibility for signal coupling, if needed	all	both	Pods4Rail GA [33]
TU_S6		General	All Transport Units shall have possibility for medium coupling, if needed (e.g. water, air)	all	both	Pods4Rail GA [33]
TU_S7		General	All Transport Units shall have interface to rail, road, ropeway	all	both	Pods4Rail GA [33]

			carriers and to the handling system			
TU_S8		F Gangways/gangway facilities	tbd - train configuration	all	both	Pods4Rail GA [33]
TU_T	T		Carrier systems, enclosures			EN 60297-3-100:2009 [61]; EN 60297-3-101:2004 [62]
TU_T1		B Cabinets, boxes, containers	CE standard	all	both	EN 60068-2-1:2007 [63]; EN 60068-2-2:2007 [64]; EN IEC 60068-2-11:2021 [65]; EN 60068-2-30:2005 [66]
TU_T2		C Frames, boards	CE standard	all	both	Expert Knowledge - Pods4Rail
TU_T3		D Control and display units	CE standard	all	both	IEC 60297-3-101:2004 [67]
TU_T4		E Electronic rack systems	CE standard	all	both	EN 50155:2021 [47]
TU_U	U		Electrical wiring			
TU_U1		B Cables, conductors and bars	see standard CE	all	both	EN 50124-1:2017 [68]
TU_U2		C Marking and connection material	see standard CE	all	both	Expert Knowledge - Pods4Rail
TU_U3		D Connecting material	see standard CE	all	both	Expert Knowledge - Pods4Rail
TU_U4		E Bushings	see standard CE	all	both	Expert Knowledge - Pods4Rail
TU_U5		F Cable ducts, pipes and flexible tubes	see standard CE	all	both	Expert Knowledge - Pods4Rail

Rail Carrier Unit requirements:

Requirement ID	Category/ Component	Description	Source
RCU1	Baseline Data		
RCU1.1	Baseline Data	The distribution of the components between the TU and the carriers shall achieve an optimum e.g., regarding effort, costs, complementarity.	Pods4Rail GA [33] Work Package 10
RCU1.2	Operation	The carrier shall contain all functionalities that are necessary for transport on existing rail networks (running gear, energy supply, drive units and braking)	Pods4Rail GA [33]
RCU1.3	Operation	The carrier shall contain all functionalities that are necessary for global and local transport coordination.	Pods4Rail GA [33]
RCU1.4	Operation	The carrier shall be able to communicate with the latest railway safety systems	Pods4Rail GA [33]
RCU1.5	Operation	The carrier shall contain all functionalities that are necessary for autonomous driving (sensor technology, communication technology, vehicle control, etc.).	Pods4Rail GA [33]
RCU1.6	Operation	In normal operation, the vehicle operates driverless in accordance with GoA 4	Pods4Rail GA [33]
RCU1.7	Operation	The carrier shall be able to operate in both driving directions without restrictions.	EN 15380 [71]
RCU1.8	Operation	The carrier shall be able to operate virtually coupled with other Pods of the same model.	EN 15380 [71]
RCU1.9	Operation	The carrier shall be able to allow mixed operation if necessary	Pods4Rail GA [33]
RCU1.10	Operation	The carrier shall follow the current Technical Specifications of Interoperability (Locomotives and Passengers, Freight Wagons, Infrastructure, Energy, Control-Command and Signalling, etc) to guarantee its compatibility with the existent infrastructure and the smooth operation shared with conventional railways. For trams and other transport modes, similar standards shall be followed.	Expert Knowledge - Pods4Rail
RCU1.11	Operation	The carrier shall be able to operate on the following network and on the lines described in the Use-Cases of D4.1: regional lines, ancillary lines. When possible main lines and tram networks.	Pods4Rail D4.1 [32]
RCU1.12	Operation	When passing another train in and outside a tunnel, the carrier shall be able to operate at its maximum operational speed	EuroSpec
RCU1.13	Physical limits	The manufacturer shall calculate all masses in the different load cases of the Pod according to EN 15663 "Railway applications - Vehicle reference masses"	EN 15663 [69]
RCU1.14	Physical limits	The manufacturer shall define the weight tolerances such that the specified weight is not exceeded in any load case.	EN 15663 [69]
RCU1.15	Physical limits	The vehicle shall have route availability according to EN 15528 "Railway applications - Line categories for managing the interface between load limits of vehicles and infrastructure" or a route availability corresponding to a lower weight.	EN 15528 [70]
RCU1.16	Environmental condition	Critical systems (e.g. warning horns [including heating them and preventing snow ingress]; couplers and head, tail and marker lights) shall be protected from the effects of the build-up of snow and ice.	EN 15380 [71]

RCU1.17	Environmental condition	The vehicle shall be able to operate without loss or reduction of functions in severe snow, ice and hail conditions according to LOC&PAS TSI 1302/2014/EU clause 4.2.6.1.2.	EN 15380 [71]
RCU1.18	Environmental condition	The carrier shall be designed with low noise-emission and shall operate with an admissible level of vibrations.	Pods4Rail GA [33]
RCU1.19	Environmental condition	Noise measurements shall be carried out in accordance with EN ISO 3381 "Acoustics - Railway applications - Measurement of noise inside rail-bound vehicles".	EN 15380 [71]
RCU1.20	Reliability, Availability, Maintainability (RAM)	All components that are subject to regular maintenance or inspection intervals should be accessible and replaceable without an increased level of effort.	Expert Knowledge - Pods4Rail
RCU1.21	Reliability, Availability, Maintainability (RAM)	The rail carrier unit shall have a life expectancy of at least 15 years	Expert Knowledge - Pods4Rail
RCU2	Vehicle Body		
RCU2.1	Vehicle Body	Crashworthiness and structural requirements: A distinction must be made in the vehicle design as to whether the vehicle is approved for island operation or mixed operation. - For a vehicle approved for island operation, the following must be observed DIN EN 15227 category C III scenarios 1, 3 and 4 as well as DIN EN 12663 category P-IV. - In the case of a vehicle with approval for mixed operation DIN EN 15227 category C III in its entirety and DIN EN 12663 category P-III. The introduction of a new category for a Pod system in DIN EN 12663 might be considered. Should the use case foreseen in RCU17.2 be addressed, RCU2.1 shall be revised accordingly.	EN 15227 [43] and EN 12663 [72]
RCU2.2	Underframe	The carrier, the coupling system and the handling system shall be compatible, especially in the case of horizontal handling, in order to avoid mechanical collisions. The electrical and digital connections shall also be compatible with the HS in this case. Additionally, the carrier, the coupling system and the handling system (both horizontal or suspended) shall be able to communicate, in order to coordinate both processes.	Expert Knowledge - Pods4Rail
RCU3	Vehicle fitting out		
RCU3.1	Vehicle fitting out	The external dimensions of the vehicle must be compatible with EBO clearance gauge G1 (structure gauge). The vehicle's loading gauge shall follow the EN 15273 for track gauge of 1435 mm (contemplated for the Pod system's operation).	Expert Knowledge - Pods4Rail
RCU3.2	Vehicle fitting out	In normal operation, the vehicle must be able to travel on tracks with a minimum track curve radius of 80 m in normal operation	Expert Knowledge - Pods4Rail
RCU3.3	Vehicle fitting out	The vehicle must be able to drive on tracks with a minimum track curve radius of be able to travel on tracks with a minimum track curve radius of 50 m	Expert Knowledge - Pods4Rail
RCU4	Interior appointments		
RCU4.1	Interior appointments	NA	
RCU4.2	Rails, handles (inside)	NA	
RCU4.3	Seats, sleeping berths, tables	NA	

RCU4.4	Sanitary facilities	When a use case for long distance passenger transport is selected, the vehicle shall include sanitary facilities in at least one of the TUs mounted on the carrier. Should the passengers be able to transfer between TUs during operation through the TUs, the carrier and the TUs at corresponding front/rear doors shall offer a comfortable and safe link between the TUs.	Expert Knowledge - Pods4Rail
RCU4.5	Luggage racks	When a use case for long distance passenger transport is selected, the vehicle shall include luggage racks for the situations where the passengers need to carry bags and other similar items.	Expert Knowledge - Pods4Rail
RCU4.6	Additional devices	NA	
RCU5	Running gear		
RCU5.2	Running gear	The carrier shall be compliant to track gauge 1435 mm according to EN 15273-2 "Railway applications - Gauges. Rolling stock gauge"	EN 15273 [73]; Pods4Rail GA [33]
RCU5.4	Supporting structures	Boogie strength and dimensions in accordance with the standard (rail application)	EN 15827 [74]
RCU5.5	Wheelsets	The strength and dimensions of the Railway-wheelset must be in accordance with the standard	EN 13103 [75]
RCU6	Power system, drive unit		
RCU6.1	Power system, drive unit	The carrier shall be battery-powered	Pods4Rail GA [33]
RCU6.2	Power system, drive unit	The carrier in its basic version shall reach an operation speed of 80 km/h, as stated in the majority of the Use Cases	Pods4Rail D4.1 [32]
RCU6.3	Power system, drive unit	The design speed shall be 10% higher than the maximum operation speed	Expert Knowledge - Pods4Rail
RCU6.4	Power supply	The carrier shall be designed for operation on non-electrified tracks	Pods4Rail GA [33]
RCU6.6	Power supply	The vehicle shall be able to charge the (Energy Storage System) ESS from the propulsion and braking system.	EuroSpec
RCU6.7	Power supply	Where the ESS is specified to obtain electrical energy via plug, the vehicle shall have at least one charging socket on each vehicle side.	EuroSpec
RCU6.8	Power generation	tbd	
RCU6.9	Power conversion	tbd	
RCU6.10	Power dissipation	For service braking in regular operation, regenerative braking should be used as far as possible and fed back into the energy storage system	Pods4Rail GA [33]
RCU6.11	Power storage	The energy storage system must be dimensioned in such a way that sufficient energy for traction, auxiliary and comfort operations for the intended route and a reserve is available	Expert Knowledge - Pods4Rail
RCU6.12	Power storage	A battery management system (BMS) shall protect the battery from harmful conditions, e.g.: - overcharge, - overdischarge, - abnormal operating temperature, - excess cell unbalance.	EuroSpec
RCU6.13	Power storage	The energy storage system shall have a modular design	Expert Knowledge - Pods4Rail

RCU7	Control apparatus for train operations		
RCU7.1	Control apparatus for train operations	The rail carrier unit shall integrate different type of sensing devices to locate the carrier and to predict the trajectory. Compatible sensing devices for standard railways shall be contemplated.	Pods4Rail GA [33] Work Package 10
RCU7.2	Control apparatus for train operations	The rail carrier unit's ATC shall rely on high-precision localization, digital topology information and on on-board radio communication networks.	Pods4Rail GA [33]
RCU7.3	Control apparatus for train operations	The rail carrier unit shall be designed in compliance with the TSI Control, Command and Signalling for it to reach an adequate level of interoperability through the operation of the current ERTMS levels. The equivalent systems for trams shall be contemplated.	Expert Knowledge - Pods4Rail
RCU7.4	Control apparatus for train operations	The rail carrier unit shall be designed for it to be prepared towards a future operation with moving blocks and virtual coupling.	Expert Knowledge - Pods4Rail
RCU7.5	Control apparatus for train operations	The control system shall be designed for it to give a highly automated, unattended and smooth operation, and shall contemplate scenarios where these new technologies can be mixed with conventional railway operations.	Pods4Rail GA [33] Work Package 6
RCU7.6	Control apparatus for train operations	The vehicle's automatic functions and perception systems shall enable autonomous driving and shall reduce the effort for conventional signalling systems, especially on branch lines, to a minimum.	Pods4Rail GA [33]
RCU7.7	Control apparatus for train operations	The functions for autonomous driving and for virtual coupling shall increase the active safety and shall reduce the factors for the passive safety of the vehicle so that the construction of the carrier and the transport unit can be made lighter and simpler and thus the energy consumption is reduced.	Pods4Rail GA [33]
RCU7.8	Control apparatus for train operations	The rail carrier unit's localization systems shall enable positioning in GNSS degraded/denied environments such as indoor or underground hubs for different “moving infrastructure” carriers.	Pods4Rail GA [33] Work Package 10
RCU8	Auxiliary operating equipment		
RCU8.1	Auxiliary operating equipment	External electrical connectors (plugs and sockets including jumper plugs and cables) shall be designed to operate reliably for the life of the rolling stock.	EuroSpec
RCU9	Monitoring and safety device		
RCU9.1	Monitoring and safety device	The carrier shall integrate communications (5G, Ultra-Wide-Band) and cybersecurity technologies	Pods4Rail GA [33] Work Package 10
RCU9.2	Measuring and protective devices	If a failure in the propulsion systems occurs, the diagnostics system shall report this change of status to the Control Centre.	EuroSpec
RCU9.3	Indicating, recording, display devices	tbd	
RCU9.4	Safety equipment	The train shall not be able to move, relative to the platform, once it has come to a stop and doors are enabled and shall only be able to move again once door interlock is achieved	EN 15380 [71]
RCU9.5	Safety equipment	If the fire detection system detects a fire, the carrier shall send a message to a landside contact defined by the purchaser.	EuroSpec

RCU9.6	Safety equipment	The rail carrier unit shall integrate alarm devices for passengers for the notification of emergency situations inside the unit. The system shall allow the person receiving the communication (e.g. driver) to cancel this communication link at his initiative.	Expert Knowledge - Pods4Rail
RCU9.7	Safety equipment	The rail carrier unit shall integrate active safety equipment and components in compliance with the current standards for railways (e.g. WSP - Wheel Slide Protection).	Expert Knowledge - Pods4Rail
RCU9.8	Safety equipment	The rail carrier unit shall integrate passive safety equipment and components in compliance with the current standards for railways that shall be present for some use cases (e.g. energy absorption components towards collisions in a mechanically coupled pods scenario).	Expert Knowledge - Pods4Rail
RCU9.9	Data transmission devices	tbd	
RCU9.10	Communication equipment	The carrier unit shall be compatible with GSM-R communication system for its interoperability. A future compatibility with FRMCS shall be contemplated.	Expert Knowledge - Pods4Rail
RCU9.11	Communication equipment	The rail carrier unit shall contemplate the operation with beyond 5G short range communication. Furthermore, beyond 5G short range communication shall enable redundant relative localization.	Pods4Rail GA [33] Work Package 10
RCU9.12	Miscellaneous equipment	tbd	
RCU10	Lighting		
RCU10.1	Lighting	See RCU10.2	
RCU10.2	Exterior lighting equipment	Head lights, marker lights and taillights shall use lamps in light emitting diode (LED) technology.	EN 15380-2 [76]
RCU10.3	Interior lighting equipment	tbd	
RCU10.4	Interior lighting equipment	To provide protection and safety on-board, in the event of emergency, the rail carrier unit shall be equipped with an emergency lighting system. This system shall provide a suitable lighting level in the passenger and in the service areas.	Expert Knowledge - Pods4Rail
RCU11	Air conditioning		
RCU11.1	Air conditioning	tbd	
RCU12	Ancillary operating equipment		
RCU12.1	Ancillary operating equipment	tbd	
RCU13	Doors, entrances		
RCU13.1	Doors, entrances	Passenger entrances shall be situated on two opposite sides of the vehicle. The carrier shall be "low entry" on both laterals.	EN 15380 [71]
RCU13.2	External doors	The unit's external doors shall follow the specified requirements determined by the TSI LocandPas, TSI Freight Wagons and TSI PRM.	Expert Knowledge - Pods4Rail
RCU13.3	Internal doors	The unit's internal doors shall follow the specified requirements determined by the TSI LocandPas, TSI Freight Wagons and TSI PRM.	Expert Knowledge - Pods4Rail
RCU13.4	Entrances, steps (not inside)	Platform heights must be accessible without barriers respecting the national standards.	Expert Knowledge - Pods4Rail
RCU13.5	Entrances, steps (not inside)	The gap between the vehicle floor and the platform must be kept as small as possible.	Expert Knowledge - Pods4Rail
RCU13.6	Entrances, steps (not inside)	Passenger entrances shall be situated on two opposite sides of the carrier.	EN 15380 [71]

RCU13.7	Entrances for the disabled	The vehicle shall be at least "low entry", the carrier shall be compatible with the platform heights on the route	Expert Knowledge - Pods4Rail
RCU14	Information facilities		
RCU14.1	Information facilities	Exterior visual information required for passenger transport.	Expert Knowledge - Pods4Rail
RCU14.2	Information facilities	The rail carrier unit shall integrate a Juridical Recording Unit (JRU) in compliance with the TSI Operation and TSI Locomotives and Passengers.	Expert Knowledge - Pods4Rail
RCU14.3	Visual information facilities	A visual information system containing line number and destination shall be included at the front and the rear of the carrier, for operation in passenger transport use cases.	Expert Knowledge - Pods4Rail
RCU14.4	Visual information elements	The information should be visible from all four sides of the vehicle. Communication between carrier and TU required for this purpose	EuroSpec
RCU14.5	Entertainment	NA	
RCU14.6	Advertising	NA	
RCU14.7	Audible information facilities	A signal horn shall be installed at the front and at the rear of the carrier unit and be connected to the TCMS.	Expert Knowledge - Pods4Rail
RCU15	Pneumatic/hydraulic equipment		
RCU15.1	Pneumatic/hydraulic equipment	Pneumatic system shall be dimensioned for the braking system required, depending on the aimed use cases	Expert Knowledge - Pods4Rail
RCU16	Brake		
RCU16.1	Brake	Braking system shall ensure braking with all types of loads and all types of pods. Braking system for railroad application is described in standards	EN 14198 [77]
RCU16.2	Brake	The Pod brake system shall be fully electric. Mechanical brakes shall be contemplated in an emergency case.	Pods4Rail D2.1 [29]
RCU16.3	Brake components	The braking system shall contemplate components related to the active safety of the vehicle (e.g. Wheel Slide Protection).	Expert Knowledge - Pods4Rail
RCU16.4	Mechanical brake force transmission	tbd	
RCU17	Vehicle linkage devices		
RCU17.1	Vehicle linkage devices	The carrier shall be able to operate virtually coupled with other Pods of the same model.	EN 15380 [71]
RCU17.2	Automatic coupling devices	The carrier shall include an emergency coupler between carriers (mandatory in case of failure of the autonomous driving or the electrical power supply) that shall be available for its particular functioning in specific use cases (e.g. long-distance trips, mechanically coupled pods scenarios).	EuroSpec - Automatic Coupler
RCU17.3	Manual coupling devices	The carrier shall include a manual coupling device between carriers as redundant system in case of failure of the automatic coupling device between carriers that shall be available for its particular functioning in specific use cases (e.g. long-distance trips, mechanically coupled pods scenarios).	EuroSpec - Automatic Coupler
RCU17.4	Automatic coupling devices Manual coupling devices	The coupling system between carriers shall follow the standards for conventional railways (for the rail carrier unit to be able to be carried by a conventional railway in a extraordinary situation in specific use cases).	EuroSpec - Automatic Coupler

RCU17.5	Buffing gear	The rail carrier unit shall integrate crash energy absorption elements as part of the passive safety of the vehicle towards accidents and collisions in specific use cases (e.g. long-distance trips, mechanically coupled pods scenarios).	Expert Knowledge - Pods4Rail
RCU17.6	Towing gear (emergency couplings)	See RCU17.4	
RCU17.7	Gangways/gangway facilities	NA	
RCU17.8	Vehicle-vehicle interface for media, signals, power	NA	
RCU18	Carrier systems, enclosures		
RCU18.1	Carrier systems, enclosures	It should be possible to connect shore supplies from both platform and track level.	EuroSpec
RCU19	Electrical wiring		
RCU19.1	Electrical wiring	Cabling shall be in accordance with EN 50343 "Railway applications - Rolling stock - Rules for installation of cabling".	EN 50343 [78]
RCU19.2	Cables, conductors and bars	See RCU19.1	
RCU19.3	Marking and connection material	Electrical wiring identification labels (idents) shall withstand normal wear and tear without significant physical degradation to remain legible for the life of the rolling stock.	EuroSpec
RCU19.4	Connecting material	See RCU19.1	
RCU19.5	Bushings	See RCU19.1	
RCU19.6	Cable ducts, pipes and flexible tubes	See RCU19.1	

Coupling System requirements:

Requirement ID	Category/ Component	Description	Source
CS1		General Requirements (GEN)	
CS1.1	General Requirement	The coupling shall ensure the safe coupling of transport unit and carrier including the safe mechanical and electrical connections.	Pods4Rail D2.1 [29]
CS1.2	General Requirement	Coupling/uncoupling shall be adapted for it to be fully automatic, semi-automatic or manual depending on its type or the conditions of the route.	Pods4Rail D4.1 [32]
CS1.3	General Requirement	The coupling shall achieve an easy, quick, and safe loading and unloading of the transport units from the carriers.	Pods4Rail GA [33]
CS1.4	General Requirement	The coupling shall enable the fast switching between one transport mode to another so it shall take a prudent time for its operation.	Pods4Rail D2.1 [29]
CS1.5	General Requirement	The coupling assembly shall be as simple as possible, but robust, and it shall be strong enough to maintain the transport unit in its position inside the carrier unit during an accident event (e.g. derailment).	Expert Knowledge - Pods4Rail
CS1.6	General Requirement	The coupling system shall be standardised, and it shall be designed considering automatisation principles and digitisation.	Pods4Rail GA [33]
CS1.7	General Requirement	The coupling system shall be designed for it to work with low levels of noise and vibrations, and it shall work in a range of temperatures defined by the corresponding standards.	Pods4Rail D4.1 [32]
CS1.8	General Requirement	The coupling system shall control the coupling for the security check, after coupling.	Pods4Rail GA [33]
CS1.9	General Requirement	The coupling system shall be designed and tested for it to be adequate for all the use cases (compatible with all the contemplated different sizes of transport units).	Pods4Rail D4.1 [32]
CS1.10	General Requirement	The coupling system shall work unrestricted, correctly and reliably under all environmental conditions (rain, snow, ice, hot summers, cold winters, etc). These conditions shall not have any influence on the function of the coupling system or in its mechanical and electrical connections.	Expert Knowledge - Pods4Rail
CS1.11	General Requirement	The coupling system shall be equipped with a heating system which defrosts it if environmental or operating conditions (including the preparation for service) demand this.	EuroSpec - Automatic Coupler [25]
CS1.12	General Requirement	The coupling/uncoupling processes shall follow regulations about prevention of occupational hazards (entrapment e.g.)	Expert Knowledge - Pods4Rail
CS1.13	General Requirement	The automatic coupling shall be equipped with a system (e.g. sensors) that detects when the system has been damaged or is no longer able to fulfil its function.	EuroSpec - Automatic Coupler [25]
CS1.14	General Requirement	The coupling system shall allow the visualization of its state through a visual display indicator (digital) and this visualization shall be available in different weather and environmental conditions. In that line, both mechanical and electrical connection shall be detected by sensors/switches/physical visualization.	Expert Knowledge - Pods4Rail

CS1.15	General Requirement	If the coupling system has been exposed to unacceptable load that may have caused a damage to the system, this damage shall be obviously visible.	EuroSpec - Automatic Coupler [25]
CS1.16	General Requirement	The coupling system and its electrical and digital connections shall be compatible with the handling system, especially in the case of horizontal handling, in order to avoid mechanical collisions. Additionally, the coupling system and the handling system (both horizontal or suspended) shall be able to communicate, in order to coordinate both processes.	Expert Knowledge - Pods4Rail
CS3		Material (MAT)	
CS3.1	Material	The coupling's materials shall be wear resistant, corrosion resistant and have good welding performance, etc.	Expert Knowledge - Pods4Rail
CS3.2	Material	The selection of the coupling's materials shall consider their fire behaviour properties, such as flammability, smoke opacity and toxicity.	TSI Locomotives and Passengers [19] 4.2.10.2.1.
CS4		Dimension (DIM)	
CS4.1	Dimension	The coupling should follow the UIC code 571-4: Standard Wagons - Wagons For Combined Transport - Characteristics.	UIC code 571-4 [79]
CS4.2	Dimension	The dimensions of the coupling system shall be designed as they allow normalization between different manufacturers and for it to have adequate tolerances to facilitate the coupling between the carrier and transport unit.	Expert Knowledge - Pods4Rail
CS5		Communications/Data Transfer (CAD)	
CS5.1	Communications/Data Transfer	The coupling shall enable communication/data transfer between carrier unit and transport unit.	Pods4Rail D2.1 [29]
CS6		Energy Transfer (ENG)	
CS6.1	Energy Transfer	The coupling shall enable power supply between carrier unit and transport unit.	Pods4Rail D2.1 [29]
CS7		Coupling's Operation (OP)	
CS7.1	Coupling's Operation	The coupling/uncoupling action shall occur when the vehicle is stopped and when it's in operation/movement.	Expert Knowledge - Pods4Rail
CS7.2	Coupling's Operation	The coupling system shall be designed so that staff is not exposed to undue risk during coupling and uncoupling, or rescue operations.	TSI Locomotives and Passengers [19] 4.2.2.2.5.
CS8		Mechanical Connection (MEC)	
CS8.1	Mechanical Connection	The coupling shall allow force transmission between carrier and transport unit without reaching the values of limit stress determined by the safety factors, and fulfil a fatigue loading test, both of them inside the maximum stablished ranges determined by the corresponding standards.	Expert Knowledge - Pods4Rail
CS9		Electrical Connection (ELEC)	
CS9.1	Electrical Connection	The electrical connection/disconnection of the automatic coupling shall be done automatically after or simultaneously to the mechanical connection/disconnection.	EuroSpec - Automatic Coupler [25]
CS9.2	Electrical Connection	The electrical connections shall have the adequate characteristics and protections determined by the corresponding standards (e.g. EN 60529, EN 50124).	EuroSpec - Automatic Coupler [25]

CS9.3	Electrical Connection	Single contacts of the electrical connection shall not be damaged during normal operation, and they shall be replaceable without removing the complete connection.	EuroSpec - Automatic Coupler [25]
CS9.4	Electrical Connection	The electrical connection shall have a "isolation switch" (mechanical/electrical) and its position shall be visible to the involved personal.	EuroSpec - Automatic Coupler [25]
CS9.5	Electrical Connection	The electrical connection system shall follow the current standards for electro-magnetic compatibility in a railway environment.	Expert Knowledge - Pods4Rail
CS10		Manual Coupling/Uncoupling - Redundant System (MAN)	
CS10.1	Manual Coupling/Uncoupling - Redundant System	Manual coupling/uncoupling shall be available as a redundant system (emergencies and other situations where it will be required). This system shall be easy, accessible, possible to be done by one person, shall work without malfunction or destruction of any parts (except for wearing parts) and include a protection against unauthorized handling.	Expert Knowledge - Pods4Rail
CS11		Interfaces with Other Subsystems (INT)	
CS11.1	Interfaces with Other Subsystems	The coupling shall produce a noise generated by the mechanical interaction of components or artificially made to inform when the coupling process has been successfully done (in a similar way for the uncoupling process).	Pods4Rail D2.2 [30]
CS11.2	Interfaces with Other Subsystems	In the case that there is a disconnection of the coupling (in electrical, mechanical, communication or data transmission terms, etc) this event shall be detected leading to and emergency braking of the pod (group of pods when they are virtually coupled). Failures in the coupling system shall lead to an emergency braking.	Expert Knowledge - Pods4Rail

Road Transport requirements:

Requirement ID	Category/ Component	Description	Source (including PODS4Rail)
RT1	DImensions		
RT1.1	Dimensions	The maximum length of the whole vehicle shall not exceed 12,00 m for a 2-axle vehicle (non-trailer)	§ 32 Abs. 1 StVZO [49]
RT1.2	Dimensions	The maximum width of the whole vehicle shall not exceed 2,55 m	§ 32 Abs. 2 StVZO [49]
RT1.3	Dimensions	The maximum height of the whole vehicle shall not exceed 4,00 m	§ 32 Abs. 2 StVZO [49]
RT1.4	Dimensions	Minimum ground clearance for safe crossing of obstacles in road traffic.	EU 678/2011 [80]
RT1.5	Dimensions	Minimum slope angle: driving on a ramp angle of 20° shall be guaranteed	EU 678/2011 [80]
RT1.6	Dimensions	Dimensions shall be according to fit all types of TU	Pods4Rail GA [33]
RT2	Operation		
RT2.1	Operation	The road carrier shall be drivable in both directions (bidirectional driving)	Pods4Rail D4.1 [32]
RT2.2	Operation	The road carrier shall be operable in SAE Lvl. 4/5	Pods4Rail GA [33] Work Package 4, Task 1
RT2.3	Operation	The road carrier shall be operable in urban, suburban and rural environments	Pods4Rail D4.1 [32]
RT2.4	Operation	The road carrier shall be operable via tele- or on-site remote control	Expert Knowledge - Pods4Rail
RT2.5	Operation	The road carrier shall be designed for speeds up to 80 km/h	Pods4Rail D4.1 [32]
RT2.6	Operation	The road carrier shall be operable under normal climatic conditions	Expert Knowledge - Pods4Rail
RT2.7	Operation	The road carrier shall be operable with minimal sound/noise emission.	EU 540/2024 [81]; Pods4Rail GA [33](26/44)
RT2.8	Operation	The road carrier shall be fully operable without a TU (e.g. communication system, lightings, etc.)	Pods4Rail GA [33]
RT2.9	Operation	The road carrier shall be operable in platooning mode (virtual coupling).	Expert Knowledge - Pods4Rail
RT3	Chassis		
RT3.1	Chassis	The road carrier shall have 2 axles (more axles are possible for special configurations, UC specific)	Pods4Rail D4.1 [32]
RT3.2	Chassis	Maximum vehicle mass (in fully loaded condition) for 2-axle-vehicle: 18t	Directive 96/53/EC [82]
RT3.3	Chassis	Maximum axle load for 2-axle-vehicle: steering axle = 11,5t	§ 34 Abs. 1b StVZO [49]
RT3.4	Chassis	Maximum axle load for 2-axle-vehicle: fix axle = 10t	§ 34 Abs. 1a StVZO [49]
RT3.5	Chassis	The turning circle shall be <25m	§ 32 Abs. d StVZO [49]
RT3.6	Entrance	The chassis shall allow for a sideway entrance for the people TU to access from the bus platforms	FGSV (GER) [84]
RT4	Power Train		
RT4.1	Power train	The carrier shall be equipped with a battery electric powertrain	Pods4Rail GA [33]

RT4.2	Power train	The power train shall be designed to deliver sufficient power for all transport tasks	Pods4Rail GA [33]
RT5	Loading, Unloading of TU		
RT5.1	Loading, Unloading of TU	Low-Entry accessibility according to regulations (for passengers, PRM and cargo)	(EU)1300/2014 [83] (for Railvehicles); PBefG (in Germany) [85]; (EU) 2019/882 [86]; Pods4Rail Work Package 4, Task 1 (Use-Case Matrix)
RT5.2	Loading, Unloading of TU	The Loading / Unloading of the TU shall be manageable with assistance through external devices / facilities	Pods4Rail Work Package 4, Task 1
RT5.3	Loading, Unloading of TU	The road carrier shall be driving to special areas for loading / Unloading of the TU (based on RT5.3)	Pods4Rail Work Package 4, Task 1
RT6	Interface		
RT6.1	User-Interfaces	Interface exterior: shall show relevant information to identify the road carrier (specific ID, licence plate)	Expert Knowledge - Pods4Rail
RT6.2	Technical Interfaces	Mechanical and electrical coupling points for all pod-types	Expert Knowledge - Pods4Rail
RT6.3	Technical Interfaces	Control interface for communication and data exchange also with external devices (VCIM / DLC / OBDII)	Expert Knowledge - Pods4Rail
RT6.4	Technical Interfaces	The road carrier shall have a uniform, suitable interface to connect and transport the TU	Pods4Rail GA [33]
RT7	Energy Supply		
RT7.1	Energy Supply	The road carrier shall supply use case specific energy capacity	Pods4Rail D4.1 [32]
RT7.2	Energy Supply	The energy source shall provide sufficient energy for all driving functions in the chosen scenario	Pods4Rail D4.1 [32]
RT7.3	Charging strategy	The charging system shall have compatibility with road standards (e.g. Type 2-Socket, ...)	DIRECTIVE 2014/94/EU (22 October 2014) on the deployment of alternative fuels infrastructure [87]
RT7.4	Charging strategy	The charging shall be performed by an automatic system (i.e. inductive charging) or through a responsible service person	Expert Knowledge - Pods4Rail
RT8	Safety		
RT8.3	Safety	Active and passive crash safety of the carrier unit shall be given according to NCAP (?)	NCAP / EU 2019/2144 [88]
RT8.4	Safety	Pedestrian safety standards shall be fulfilled	NCAP / EU 2019/2144 [88]
RT8.5	Safety	The road carrier shall have an exterior design according to safety standards to lower the risk of injuries (i.e. through protruding edges)	EU 661/2009 [89]
RT9	Serviceability		
RT8.1	Service-ability	Exchangeability of components shall be given	Expert Knowledge - Pods4Rail
RT8.2	Service-ability	An easy reachability of main components shall be given	Expert Knowledge - Pods4Rail
RT8.5	Service-ability	Exterior Components that are exposed to environmental influences shall be easy to replace	Expert Knowledge - Pods4Rail

RT8.6	Service-ability	During operation, parts shall be reusable / replaceable.	Expert Knowledge - Pods4Rail
RT10	Base structure / modularity		
RT9.1	Structure	Structural integrity must be guaranteed in every transport situation	Pods4Rail GA [33]
RT9.2	Structure	Structural modularity shall be given (i.e., variable carrier lengths)	Pods4Rail D4.1 [32]
RT9.3	Structure	The road carrier shall be able to transport all given TUs (in different sizes and loads)	Pods4Rail D4.1 [32], Pods4Rail GA [33]
RT11	Various component groups		
RT11.1	Packaging	The Road Carrier shall fulfil all existing EU road vehicle standards (Certificate of Conformity) for class M and N vehicles, if applicable	CoC
RT11.2	Vehicle chassis	The road carrier suspension shall be equipped with a "kneeling" function to guarantee easy access for passengers, if necessary	Expert Knowledge - Pods4Rail
RT11.3	Lighting	The road carrier shall be equipped with suitable lighting to fulfil EU road vehicle standards without carrying a TU	EU 661/2009 [89]
RT12	Autonomous driving		
RT11.1	Sensor Set	A sufficient object detection shall be given in every driving situation	
RT11.2	Sensor Set	Pedestrians and obstacles shall be recognised by the road carrier	EU 2019/2144 [88]
RT11.3	environmental conditions for autonomous driving	Automated driving in all / non optimal weather conditions (i.e. rain, snow, fog) shall be possible or safe states shall be defined.	Pods4Rail GA [33]
RT11.4	environmental conditions for autonomous driving	The road carrier shall be able to drive in day- and nighttime	Pods4Rail GA [33] (26/44)
RT11.5	environmental conditions for autonomous driving	The road carrier shall be able to drive in all relevant European climatic zones	Pods4Rail GA [33]
RT11.6	environmental conditions for autonomous driving	Depending on the conditions, the road carrier shall be autonomously drivable under permanent observation at low speed (<25km/h) in dedicated areas. High speed operation (26 to 80 km/h) shall be possible on certain roads with protected environments depending on normal weather conditions.	Pods4Rail GA [33] (11/44)
RT11.7	environmental conditions for autonomous driving	Infrastructure connectivity to sensors and traffic signals shall be adopted / readable for autonomous vehicles	Pods4Rail GA [33]
RT11.8	environmental conditions for autonomous driving	The road surface quality and road markings shall be suitable and in good condition for safe autonomous driving	Expert Knowledge - Pods4Rail
RT11.9	environmental conditions for autonomous driving	The road carrier shall be operable on all common road surface types	Expert Knowledge - Pods4Rail

RT11.10	environmental conditions for autonomous driving	No sidewalks next to the road for speeds above 25km/h	Expert Knowledge - Pods4Rail
RT13	Sustainability		
RT13.1	Sustainability	The production of the road carrier shall be CO_2 neutral	European Commission
RT13.2	Sustainability	The use of the road carrier shall allow emission free use	European Commission
RT13.3	Sustainability	The life span of the road carrier shall be maximized	Expert Knowledge - Pods4Rail
RT13.4	Sustainability	Systems and components shall be able to be exchanged or updated	Expert Knowledge - Pods4Rail
RT13.5	Sustainability	The road carrier shall be fully recyclable after its lifetime.	Expert Knowledge - Pods4Rail