Deliverable D 3.2
Proposition for an evolution of the existing safety framework and preliminary safety requirements

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Responsible/Author:	Simon Collart-dutilleul, Uni Eiffel
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Report contributors		
Name	Beneficiary Short Name	Details of Contribution
Simon Collart-Dutilleul	Uni Eiffel	Organisation of inputs, input to all parts of the Deliverable
Philippe Bon	Uni Eiffel	Review
Seddik Reguieg	Uni Eiffel	Review and redaction of ontology sections
Manuel Osebek	DLR	Review and input chapter 6
Nicolai Schmauder	DLR	Use case discussions and input chapter 6
Abhimanyu Tonk	RLN	Use case discussions
Abderraouf Boussif	RLN	Use case discussions
Walter Struckl	SMO-AT	Conclusion and Review
Michael Wild	DLR	Input chapter 6

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1. Executive Summary

The Deliverable 3.2 aims to provide a synthesis of the European and national standards, laws, and legal framework that are related to or can be involved in the development of the future Pod systems considering the system definition given by the deliverable 2.1: "Definition of multi-modal mobility systems". The focus of the overview is the safety and security aspects, as well as the system digitalisation and automation. The study includes the standardisation and legislative frameworks related to the different existing modes of transportation (railways, urban guided systems, buses, trucks, automotive, ropeways, etc.) in the objective to provide a multimodal service proposed by a Pod system as specified in the D2.1 deliverable of the Pods4rail project. The work consists of firstly identifying in the list proposed by the deliverable D3.1 the existing standards, EU and national laws, and then synthesising those which may be applied or involved in the development of the pod systems. Additionally, the work points out the standardisation gaps, and/or possible further evolution to take into consideration particular features or the different boundary conditions due to the inter-modality of the Pod systems.

In specific, the work of Task 3.2 provides the following contributions:

- Identify and review of the existing safety and security standards and regulations (from the different mode of transportation) which may be involved in the development of the Pod systems, and then discuss the relevance, practical applicability of such documents, as well as the challenging relation to the safety assurance of the Pod systems. More precisely, the study analyses multimodality EU directives. These high-level documents contain goals and objectives rather than clear requirements and specifications. Nevertheless, the walking episodes connecting the various infrastructures of transport are not well described in the reference documents and correcting this lack of consideration is an explicit recommendation of the current study. As a matter of fact, "passenger falling from the platform down to the track" is at least a railway hazard that can not be neglected. The corresponding risk is suppressed by the use of Pods because the pedestrian transit on platform is supressed.
- Discuss the technical specification challenges related to the design and development of the Pod systems. Starting from a real use case, the potential inter-modal implementation of a Pod system-based service is analysed from a legislative and normative point of view. As non-specific document exists concerning TUs used by several mode of transport, the union of mode specific requirements is considered. Some coherency issues were highlighted, related to legislative non-compatibilities and possible heavy over costs.

Because of compatibility issues, the document asks for a specific evaluation methodology of multimodal vehicles and proposes the use of well-known global criteria such as GAME ("Globalement Au Moins Équivalent") for driving risk assessment discussions.

2. Abbreviations and acronyms

Abbreviation / Acronym	Description
ADS	Automated Driving System
ALARP	At Least As Reasonably Possible
ATO	Automatic Train Operation
AUGT	Automated urban guided transport
CSM-RA	Common Safety Method for Risk Assessment
D	Deliverable
EU	European Union
ETCS	European Train Control System
EGNOS	European Geostationary Navigation Overlay Service
EU-RAIL MAWP	Europe's Rail Joint Undertaking Multi-Annual Work Programme
ERTMS	European Rail Traffic Management System
FM/LM	First mile/Last mile
GAME	Globalement Au Moins Équivalent (Globally at least equivalent)
GNSS	Global Navigation Satellite Systems
GoA	Grade of Automation
HL	Hazard Level
ISO	International Organization for Standardization
ITS	Intelligent Transportation Systems
KE	Knowledge Engineering
ODD	Operational Design Domain
TEN-T	Trans-European Transport Network
TSI	Technical specification of Interoperability
TSI CC	TSI Control Command and Signalling
WP	Work package

Hereafters are some definitions regarding the legislation and standardization framework[1].

Regulation: a "regulation" is a legal act that apply automatically and uniformly to all EU countries as soon as they enter into force, without needing to be transposed into national law. It is binding in their entirety on all EU countries.

Directive: a "directive" is a legislative act that sets out a goal that EU countries must achieve. However, it is up to the individual countries to devise their own laws on how to reach these goals. EU countries must adopt measures to incorporate them into national law (transpose) in order to achieve the objectives, set by the directive. National authorities must communicate these measures to the European Commission.

Decision: a "decision" is binding on those to whom it is addressed (e.g., an EU country or an

[1] Source : https://european-union.europa.eu/institutions-law-budget/law/types-legislation_en

individual company) and is directly applicable. The decision related to the country only.

Recommendations: A "recommendation" is not binding. When the Commission issued a recommendation that EU countries' media service providers improve their ownership transparency and safeguard their editorial independence, this did not have any legal consequences. A recommendation allows the institutions to make their views known and to suggest a line of action without imposing any legal obligation on those to whom it is addressed.

Opinions: An "opinion" is an instrument that allows the institutions to make a statement in a non-binding fashion, in other words without imposing any legal obligation on those to whom it is addressed. An opinion is not binding. It can be issued by the main EU institutions (Commission, Council, Parliament), the Committee of the Regions and the European Economic and Social Committee.

Standard: A "standard" is a document, established by a consensus of subject matter experts and approved by a recognized body that provides guidance on the design, use or performance of materials, products, processes, services, systems or persons[2].

[2] Source : https://www.iso.org/sites/ConsumersStandards/1_standards.html

3. Background

The present document constitutes the D3.2 “Proposition of an evolution for the safety framework and preliminary safety requirements” in the framework of the Flagship Project 7 Pods4Rail as described in the EU-RAIL MAWP and contributes to the Flagship Area 6 FutuRE, as well. It is one part of the requirement definition for future Pod systems together with other tasks within this project (e.g., Task 4.1 Description of use cases; Task 4.4 High level functional requirements specification).

4. Objective/Aim

This document aims at providing a high-level analysis considering various design options correlated to potential risks and various combination of transport modes that may compose a multi-modal transport service considered as a whole. Considering inputs from D3.1, and more precisely the review of regulations and standards fitting with the design and potential operations, a set of requirements can be identified. All reviewed legislative documents are considered in their dedicated context: they belong to a given transport mode, and a specific operating context (urban or inter-urban, different level of speed, various duration of travel, etc..).

The second stage is to consider the multi-modal travel as a whole. In this framework, the commutation phase from a transport mode to another is integrated in the global evaluation, which includes a safety evaluation. For this reason, specific safety requirements may be identified. As an example, the walking travel and the standing episodes to get to a transport means to another can be subject to specific safety requirements.

Let us assume that the same TU is used for several transport episodes belonging to different transport modes. This assumption is naturally impacting the industrial consensus leading to the redaction of a given norm. Roughly speaking, as motivations are not the same, the proposed implementation will probably differ. These scenarios are investigated through the study of several multi-modal options. This leads to formulate motivations to potential normative evolutions. To study the opportunities of normative evolutions, a specific set of safety requirements will be provided.

5. System analysis

The main aim of the project Pods4Rail is to provide *fully automated* inter-modal mobility system for passengers and goods which are sustainable, collaborative, interconnected, digital, on-demand, standardised, scalable and suitable for various transport modes. According to D2.1[3], the Pod system can be described as a decentralised, autonomous inter-modal transport system that utilises and enhances the advantages of rail transport. The system is intended to help enable continuous door-to-door transport that has the potential to offer on-demand services to people and goods, operation using a Mobility Management Platform, enabling constant availability of the system's transport components as well as all necessary services for the system and its users.

5.1. The Pods framework

The specific and innovative design of the Pod separates the autonomous driven transport vehicle (moving infrastructure) and the transport unit for people and/or goods with the possibility of fast switching from one transport system (e.g., railway) to another (e.g., road or cable car/funicular) and thus, a continuous transport chain from door-to-door without changing from one transport system to another (e.g., from a train to a metro, tram, taxi, car or bus) or reloading of the goods could be created.

Figure 1. depicts the global overview of a Pod system building blocks and interfaces.

Three main subsystems are composing the Pod system:

1) Carrier (or mobile drive unit): Mobile drive unit without car body for transporting people or goods, so that there is only a vehicle underframe construction (also called "carrier" or "moving infrastructure"). The Carrier should consist of an underframe construction, the energy storage, the propulsion, the auxiliaries and the wheel-axle system, the system for autonomous driving (incl. control units, sensor equipment, etc.). The individual carriers for the railway, road or ropeway network serve as a basis to enable intermodal transport with the transport unit.
2) Transport unit: 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. The transport unit can be loaded onto and coupled with the carrier.
3) 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). Thus, the handling system provides the possibility to fast switching from one means of transportation to another.

[3] Pods4Rail project, Deliverable D2.1, code: Pods4Rail-WP02-D-SMO-001-01, title: System definition

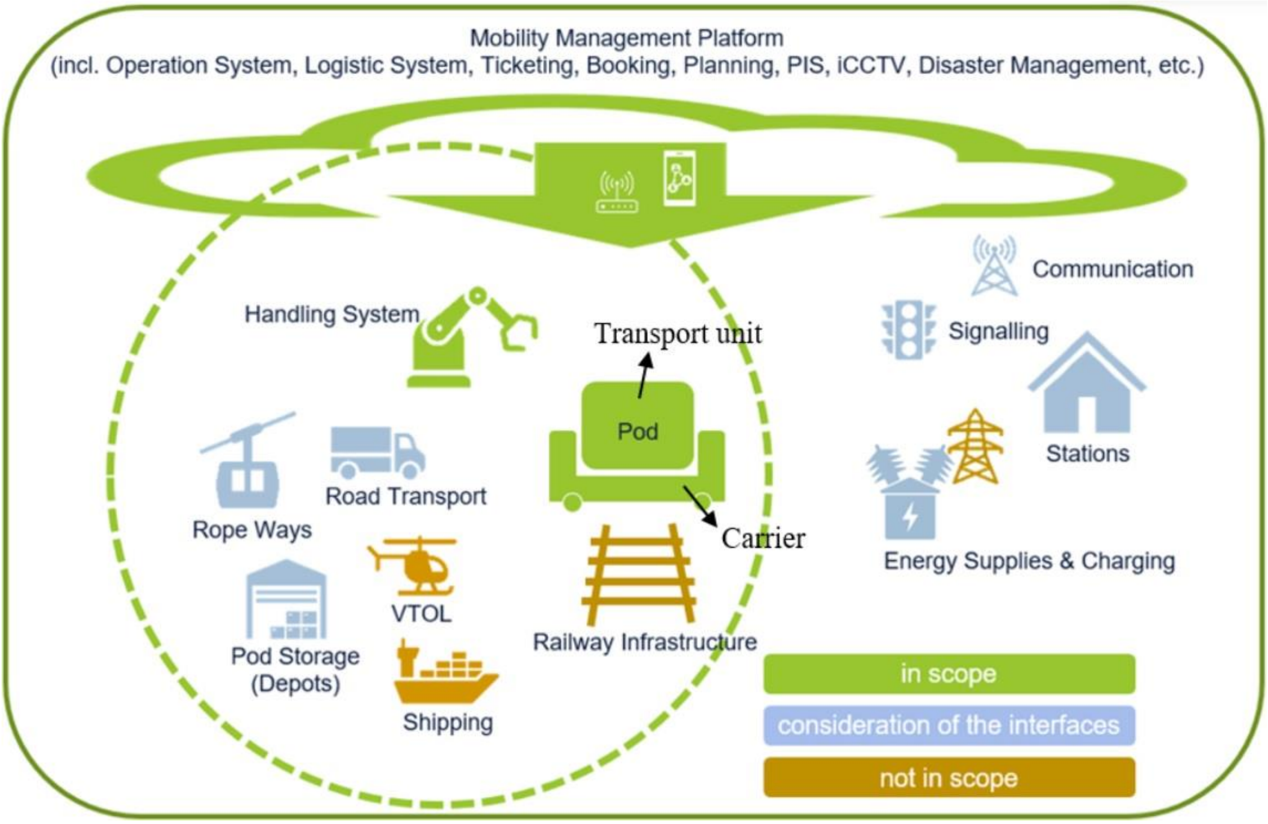

Figure 1. Scope of a Pod system and its core subsystem (from D2.1).

Figure 2. presents an example (*which will be used as an illustrative example in this deliverable*) illustrating the main operations of a Pod system transitioning from one means of transport to another. In this example, the considered transportation modes are automotive and railway.

Figure 2. An operating scenario of a Pod system.

A first analysis can be found in the D3.1 of the project on paragraph 5.3.2:

- Since the carrier constitutes the mobile component of the system, there will be multiple types, each designed for a specific mode of transportation (e.g., railway carrier, road carrier, etc.). Thus, each carrier has to be compliant with the standards of the related transportation mode.
- Contrarily to the carrier, the Transport Unit (TU) is the "intermodal component" which transits from one specific- domain carrier to another one. Thus, the Pod is hypothetically required to comply with all the applied transportation mode's standards (i.e., a cross-domain compliance).
- The handling system is the component that assuring the transition of the TUs from one carrier to another one. It cannot be considered intrinsically as a part of any transportation

mode, but it can rather be considered as an industrial machine, a manipulating robot, or a cable-based system. Concretely, the classification of the handling system (and thus the applied standards) depends strongly on the used technology for performing its functions. Notice that according to D2.2, a transporter similar to airport cargo transport could be considered as an option for the handling system.

5.2. The multi-modal vision

Considering the "Co-Active H2020 project" (CO-modal journey re-ACcommodation on associated Travel serVices, see https://cordis.europa.eu/project/id/730846/reporting), in the "Periodic Reporting for period 4, the following introductory motivations can be found:

> *"Currently, a large number of different ticketing, payment & validation systems exist across operators & transport modes. For the traveller, this means having to switch between multiple websites in order to book & pay for each episode of the planned journey."*

Achieving interoperability is presented as a critical target for providing an integrated multi-modal service of transport that can be presented as Mobility As A Service (MAAS). If switching between several websites is presented as an obstacle towards multi-modality, it is clear evidence that physical transfers of passengers between various transport resources used in the context of a given journey, are much more dissuasive.

However, from a system analysis point of view, it is a drastic simplification to resume the multi-modal travel requirements by performing the union of its elementary sub-travel components requirements.
It is not a theoretic question. To take an example, you can find in (UE) No 181/2011 , article 16:

> *"(..)In particular, when acquiring new rolling stock or making a major upgrade to existing rolling stock, they should provide an adequate number of places for bicycles unless the acquisition or upgrade concerns restaurant cars, sleeping cars or couchette cars (..)".*

Is this requirement relevant for a small Pod starting from the parking of a building in an urban area and designed to perform the last kilometres?
It would not be surprising, considering that even in the railway context the article 7 of the same document explains:

> *"Urban, suburban and regional rail passenger services are different in character from long-distance rail passenger services. Member States should therefore be allowed to exempt such services from certain provisions of this Regulation on passengers' rights. (...)"*

But it develops later:

> *"As regards regional rail passenger services, exemptions to the provisions of this Regulation that facilitate the use of rail services by persons with disabilities or persons with reduced mobility should be completely phased out, and exemptions should not apply as regards provisions of this Regulation promoting the use of bicycles"*

The parallel with the case of person with limited mobility is interesting in its implementation and it leads to requirements specifying that the service should be available. The service is not necessarily available for all entities, but possibly only on dedicated ones.

5.2.1. Safety framework for the analysis

The present study considers the journey as a whole and integrates various transition phases between transport modes which are used. It only focuses on legislative aspects and safety related requirements, but it also considers influences of economy and sociology as an input.
The analysis is composed of several steps, but before explaining them, the global strategy is presented.
"The Globalement au Moins Équivalent" (GAME) rule used railways states that "all new guided transport systems must offer a level of risk globally at least as good as the one of any of the existing one". To give an example, the Channel Tunnel Safety Authority imposed a requirement that the safety performance of the tunnel should not be worse than that of a surface railway of similar length. As an evidence, this criterion requires an existing system to be used as a reference."
"Globally at least as good" means that on a given risk criteria, the evaluated system may be allowed to not reach the target level if it is clearly better than the reference system on another criteria.
The current paragraph develops a more formal context which is provided in the deliverable D3.2 of the Pod4Rail project. The methodology to safety demonstration through driving scenarios appears to complement the safety demonstration developed using the GAME principal which seeks schematically to:

(i) identify the causes of contingencies based on the consequences in terms of events that have occurred, mainly in the form of malfunctions;
(ii) allocate overall safety objectives at the system level to the various functions of that system. In the GAME approach, the analysis of malfunctions is conducted from the system to the components and vice versa, and this analysis is not independent of the design or technologies used.

Notice the GAME principal, widely used in the railway domain for the risk assessment and the safety demonstration has been adapted to cope with the safety demonstration of the autonomous vehicles:

- Implementation guide (2021) Automated Road transport systems – GAME principle Globally at least equivalent

The Pod systems are new multi-modal systems owning some safety quality: they suppress two phases:

- the one when people are walking from a transport mean to another. It is a critical phase for limited mobility people, and it can be safety critical
- the one when people are standing on a platform, waiting for the vehicle that will take them for a new episode. In the railway domain, this phase is the place of a well-known hazard: "people falling from the platform down to the track". Moreover, overcrowding in a bus station may produce a similar effect.

The following section will explain that for Pod systems, there is a criterion where they are safer than existing systems. Then, naturally the system analysis should consider this criterion. For this reason, an upgrade of knowledge models of the state of the art is proposed.

The following step is to consider real use cases of multi modal use of the same TU on various transport mode specific carriers. Referring to the existing legislative document, the same TU may fulfil requirements from several transport modes. From a general case, there is no evidence that these requirements are compatible between each other. Moreover, as they are produced in different functioning context, it may lead to functional non-coherence.
Keeping in mind that we own a safety argument, the current section aims at demonstrating that reasonable compromising on given safety criteria may allow demonstrating that Pod system can "offer at least globally equivalent level of safety".
The current section is not a rigorous safety demonstration, but an illustration. Anyone may understand that from a safety point of view, it is better to avoid "falling on track" rather than providing a storage place for bicycle, even if using bicycles is healthy. In the case study, the requirements which are discussed are probably not the most relevant from a safety point of view. They have been chosen for pedagogic aims.

5.2.2. Passenger flows management and safety

A door-to-door integrated transport service involves the collaboration of the various available transport modes. There is a consensus on a door-to-door analysis where a travel is presented as an integrated service to passengers, like in the IMHOTEP project[4]. In the co-Active results justification, the first claim is the following:

> *"Fulfilling Traveller's needs & Achieving Trust are the most important issues. Travelers need to trust not only the transport provider(s), but also the ecosystem itself. They need to feel confident & protected."*

On the other hand, it has been demonstrated that a close orchestration of the different modes of transport introduces new potential critical coupling from a safety/security point of view, as demonstrated by Collart-Dutilleul et All in 2022. Among the couplings introduced, there are particularly critical passenger flows when integrating civil engineering infrastructures, as presented by Urban et All in 2016. As an example, considering a multimodal transport HUB as a whole for safety and security analysing becomes a mandatory need, presented by Collart-Dutilleul et All in 2020.

5.2.3. Multi-modal transport ontology

Before delving into the description of the multi-modal transport ontology, it is essential to introduce Knowledge Engineering and ontologies. In each system, the process of conceptualization of a problem is an essential task for its development, it introduces an abstracted and structured representation of the reality, which includes a set of objects and entities along with the relationships between them that are necessary to achieve a specific goal as explained by T. R. Gruber in 1993. In fact, the collaboration of multiple stakeholders possessing diverse knowledge across different domains aims to achieve a shared goal, such as the creation of an efficient system that fulfils specific requirements. Stakeholders often develop a conceptual model of the solution, even when it may not fully meet the criteria of adequacy, appropriateness, or optimality.
The task of aligning this conceptual model with the specified system requirements and smoothly incorporating it into the system architecture requires establishing and consistently maintaining

[4] IMHOTEP Project : https://www.sesarju.eu/projects/imhotep

a semantic bridge throughout the entire life cycle of the system. The representation of knowledge relies on ontologies and belongs to the discipline of Knowledge Engineering (KE), which we delve into in the following section. It is helpful to formally represent the domain's knowledge by a set of concepts and the relationships between those concepts. indeed, an ontology provides a vocabulary that is shared among the involved stakeholders which can be used as a model. Using a shared model is a basic need to understand the formal definitions of concepts and their relationship.

5.2.3.1. An existing ontology

The current document aims to present a subset of the Shift2Rail-IP4 reference ontology that is relevant for travel shopping functions. An ontology (See Figure 3Figure 3) is used to capture knowledge about some domain of interest. The domain of interest of S2R-IP4 is focused on a multi-modal travel combining several modes of transport, several operators in several countries: the project leader was Thales, and participants were Amadeus, Indra, Hacon and Network-rail (the semantic of the ontology is documented in the ANNEX 1 of the current documents). It is important to recall that working with a subset of the Shift2Rail-IP4 reference ontology, ensure a semantic coherence with the CEN "European reference Data Model for public Transport information" (see: https://transmodel-cen.eu/).

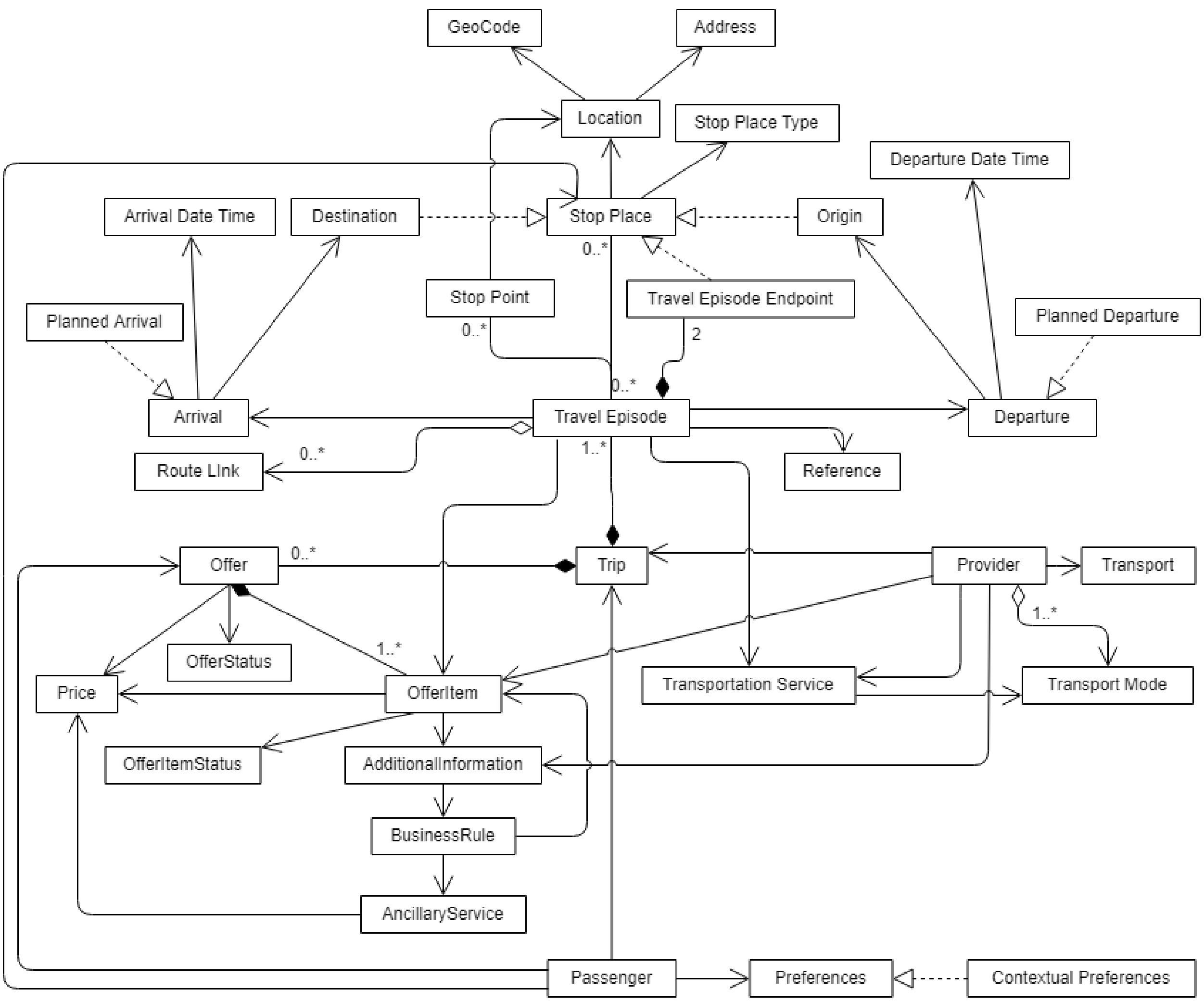

Figure 3. The FREL ontology from the project “Co-Active” (EU) 2017/1926

5.2.3.2. Enriching the ontology with intermediary commutations of mode of transport

5.2.3.2.1. Main question: why pedestrian does not exist?

Integrating the walking travels, and the correlated information is clearly recommended by European directives, for several reasons:

1. The first mile/last mile (FM/LM) problem in public transport refers to the spatial accessibility of public transport and is the most important factor determining whether an individual will choose public transport as presented by Kåresdotte et All in 2022.
2. Walking and riding bicycles is considered as a positive factor contributing to healthiness.
3. Queuing effects and overcrowding of pedestrian can produce safety and security related phenomenon.
4. Walking travels between two transport means may not be achievable by people with limited mobility or by people having any kind of disease: the accessibility quality of the walking path is crucial information to ensure access to the entire transport service.

The Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide multimodal travel information services. In the point (8) of the preliminary claims:
“*Walking as a travel option to fulfil parts of the first and last mile of the journey is very relevant for multimodal travel information*”

We must consider that the option of walking is very relevant in any part of the journey and it must be added as a requirement for the global management system:

– because any kind of walking sub-travel down the same quality for healthiness and energy saving.
– because walking uses to be the only solution to shift from a transport mean to another for short distances.
– because, considering the transport service as a whole, passenger fall under the same multi-modal legislative framework. In the right of the rail passenger, there is “information related access for limited mobility people”. Regulation 2021/782 on rail passengers’ rights and obligations can be consulted and concerning bus and coach passenger rights”, it is mentioned:

“Throughout your journey, the bus or coach operator has to provide clear and correct information about the service and your passenger rights. This information should also be made available in a format accessible for people with disabilities” (available on the web site: https://europa.eu/youreurope/citizens/travel/passenger-rights/ , but the legislative document is EU181/2011)

5.2.3.2.2. Proposition to add a concept of pedestrian travel

It is proposed to enrich the Co-ActiveWP1 D1.4 TravelShopping FREL Ontology[5] which was shortly presented in the previous section, with a concept corresponding to a walking travel between two means of public transport. It is the PedestrianCommutation concept in the following Figure 4Figure 4. The idea is that between two TravelEpisode, that are a specialization of a transportation service, there is a stop place that may own a component named PedestrianCommutation. let us note that this TransportationService Concept is composed at least by one, but potentially several TransportMode.

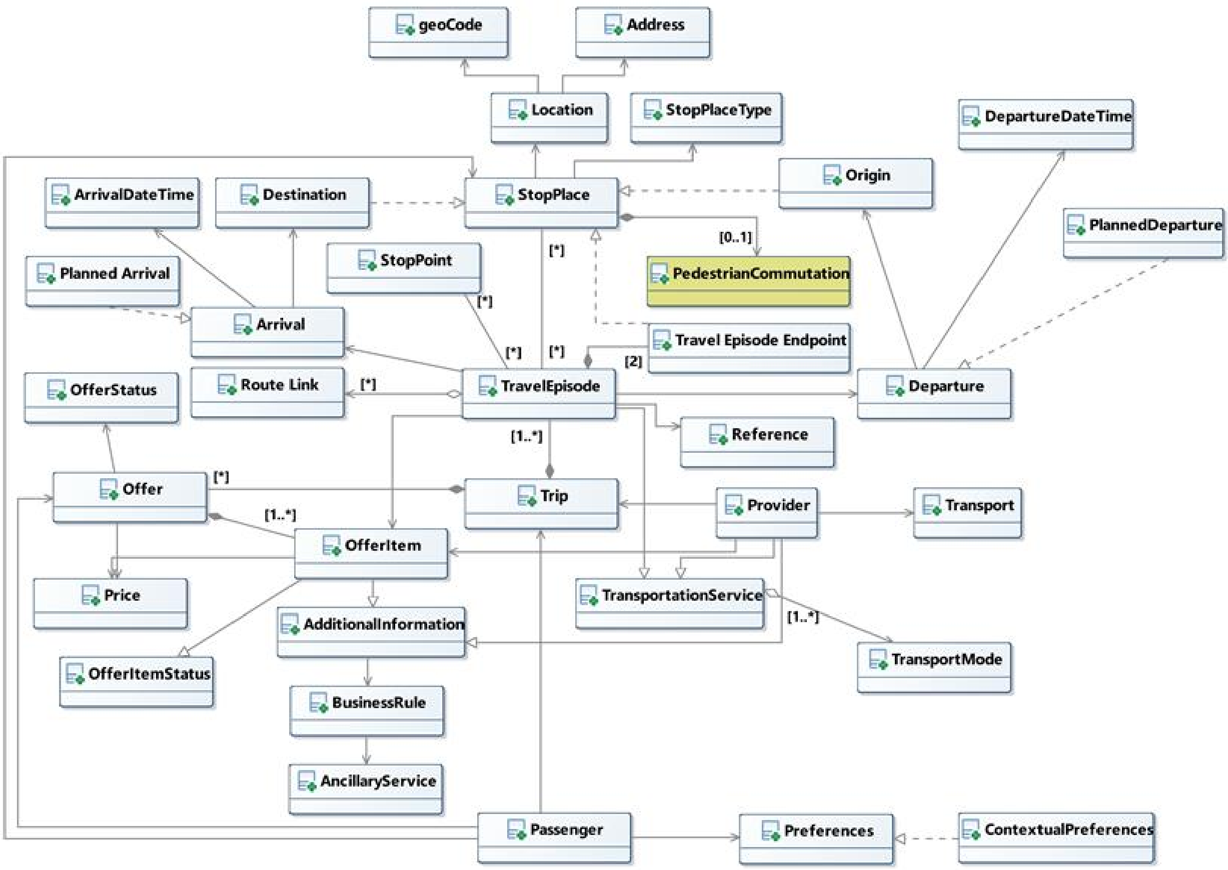

Figure 4. Updated FREL ontology

PedestrianCommutation should own data relative to accessibility for limited person, but not only. From a knowledge engineering point of view, implementing the requirement that a multimodal trip pedestrian should be considered as a passenger, it is just adding a link specifying that PedestrianCommutation is a "kind of" TransportationService. It means that PedestrianCommutation will inherits of all constraints and attributes of the TransportationService. It corresponds to the implementation of heh "door to door" vision, where all travel episodes are

[5] Co-ActiveWP1 D1.4 Travel Shopping FREL Ontology: https://projects.shift2rail.org/s2r_ip4_n.aspx?p=CO-ACTIVE

considered in the safety evaluation, without considering if it is a service given by a provider or a passenger self-provided mode, like bicycle riding or walking.

5.2.4. Discussion on case studies

The added value of a case study is to provide concrete object for discussions and lead the designer to focus on one of the needed scenarios, mentally eliminating all other elements and constraints of the considered system. The following use cases are not the result from a Requirements Engineering process nor from an economical study as described by Ross in 1977. It is a real case, being expected to contain a part of the main scenarios. The main motivation is to study legislative requirement impacts on real representative scenarios occurring on a real system. One of the contributions of this section is to illustrate the impact of various design options and the potential influence of the existing safety framework.

In France, in 2007, 90% of employees living in the peri-urban areas of towns with less than 50,000 inhabitants and those living in rural areas work outside their municipality of residence. Based on this observation and based on a composite public transport offer, we propose to roughly identify a transport service compatible with these needs as explain Baccaïni et All in 2007.

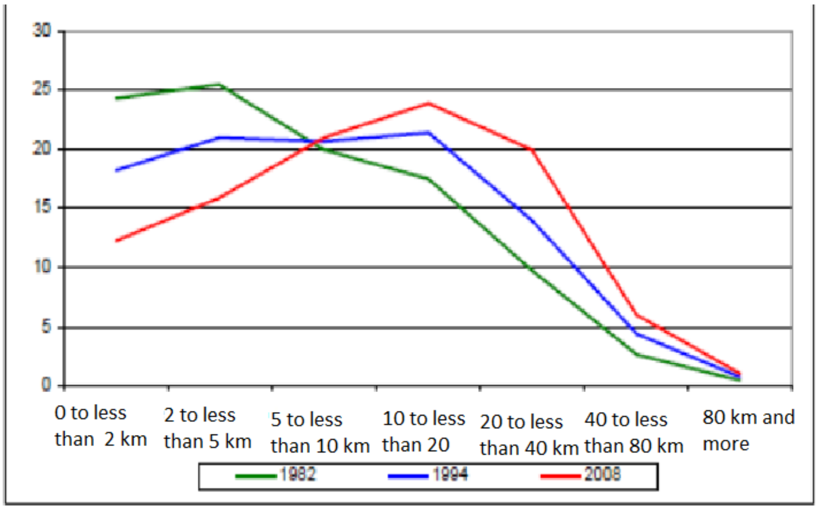

Figure 5 Distribution of assets according to travel distance to work (in %) (Conti, 2016)

The distance increasing from the workplace pushes us to consider means of transport offering appropriate commercial speeds.

5.2.5. Legislative framework

A low-tonnage guided transport will naturally be considered as a tram by the safety authority which issues commissioning authorizations. This is particularly the case of the "Ferromobile project"[6] in which a Peugeot E-expert weighing approximately 2 tons is considered as a tram. Considering a worker travelling 70km from home, this assumption from the legislator is very limiting. As a matter of fact, running a tram higher than 200 km/h is not possible. Nevertheless, assembling several "transport unit" on a wagon and assembling these wagons to form a train, from a weight point of view, it becomes a train. It remains to validate compliance with the passenger

6 https://ferromobile.fr/

TSI (Commission Regulation in 2014) and/or the CENELEC15380-4 standard.
Building a conventional train using an assembly of Pods introduces a synchronization constraint between Pods for which the assembly has a functional meaning at the transport level: they must include a part of common journey. Assuming a part of on-demand transport, this does not exempt us from the fact that it is wise to anticipate this assembly process, which requires a non-secure localization service linked to the overall management of the transport service. It is necessary to ensure that the benefit of the speed of the rail mode of transport is not annihilated by the waiting times induced by the synchronization process.

5.2.6. Synthesis

Considering a societal need related to the railway speed, the use of Pods will introduce an assembly process which will lead to the formation of trains. We could then associate Pod carriers with the management of signalling (CBTC in urban areas for capacity, ETCS2 in main lines for speed). An alternative would be a regulatory change authorizing railway speed for low-tonnage vehicles. This poses a challenge: how can we guarantee the safety of passengers in a "car" that hits a cow at 200km/h?
Completely closing the infrastructure, as it is done for automatic metros, would protect against this scenario. Capacity requirements would also lead to combining unit Pods with virtual coupling technologies, or at the very least we would be led to use "moving blocks". Out of the Shift2rail project, in the IP2- X2Rail1, it can be found:

> "Moving Block (TD 2.3) aims to improve line capacity by decoupling the signalling from the physical infrastructure, and removing the constraints imposed by track side train detection, thereby allowing more trains on a given main line, especially for high-density passenger services. The system is to be compatible with existing ERTMS system specifications, and will enable progression towards CBTC functionalities for urban applications."

All of these technologies have varying degrees of maturity which should be discussed with regard to various study cases such as:

- Intercity journey of more than 60KM
- Intra-urban journey of less than 12km (lower than the average distance value for a daily work travel).

5.2.7. Legislative and normative analysis

The first requirement is the need of a common management system as mentioned in DIRECTIVE 2010/40/EU, 2010:

> *"Article 3*
> *Priority actions*
> *(a) the provision of EU-wide multimodal travel information services;*
> *(b) the provision of EU-wide real-time traffic information services;*
>
> *Article 4*
> *Definitions*
> *(2) 'interoperability' means the capacity of systems and the underlying business processes to exchange data and to share information and knowledge"*

It is presented in a more general way in the following document (EU) 2017/1926, and we already underline the opinion expressing the presence of "walking as travel option". The need of an impact of this opinion in the proposed information and management system is developed in section 5.2.3.2. The second requirement is related to the passenger rights, in Regulation (EU) 2021/782, to provide updated information concerning delay, availability of various services and access to these services for limited mobility persons.

Concerning the vehicle composed by a transport unit and a carrier (according to the deliverable D2.1), some technical requirements are clearly mentioned in DIRECTIVE 2010/40/EU, 2010:

> *"16) For ITS applications and services for which accurate and guaranteed timing and positioning services are required, satellite-based infrastructures or any technology providing an equivalent level of precisions should be used, such as those provided for in Council Regulation (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations (1) and Regulation (EC) No 683/2008 of the European Parliament and of the Council of 9 July 2008 on the further implementation of the European satellite navigation programmes (EGNOS and Galileo) (2).*
>
> *(17) Innovative technologies such as Radio Frequency Identification Devices (RFID) or EGNOS/Galileo should be used for the realisation of ITS applications, notably for the tracking and tracing of freight along its journey and across modes of transport."*

The use of Egnos/Galileo for positioning is explicit, like the potential added value of RFID technologies. This technical requirement concerns, at least the carrier, but not only. Assuming that a TU full of passenger can wait for a carrier, then the "right of passenger" applies. Moreover, in case of emergency, passenger should be able to call, with or without a carrier, in REGULATION (EU) 2015/758:

> *"In order to further improve road safety, the Commission Communication of 21 August 2009 entitled 'eCall: Time for Deployment' proposed new measures to deploy an in-vehicle emergency call service in the Union. One of the suggested measures was to make mandatory the fitting of 112-based eCall in-vehicle systems in all new types of vehicles starting with vehicles of categories M1 and N1 as defined in Annex II to Directive 2007/46/EC"*

It means that TU should hold their personal connexion to the network, at least a dedicated network devoted to emergency management. Actually, there is no reason, not to provide update information concerning delays or other events as demanded in the "passenger rights" document

5.2.7.1. Intra-Urban Journey of less than 12 km

In this scenario, the majority of the daily travel from home to business and back can be found. A JCR Report untitled "Measuring congestion in European city start its introduction section with the following sentence written by Christodoulou, A. and Christidis, P. in 2020, says:

> *"Congestion is a major issue for cities and often a determining factor of connectivity within urban areas and for intra-city interactions. It is an externality directly related to the nature of cities as it represents the negative aspect of agglomeration, a major driving force of cites growth. Congestion is a consequence of the massive adoption*

of cars as the main transport mode, while the vast majority of measures against it aim to discourage the use of private vehicles within cities"

The capacity of the transports means becomes a critical parameter in this context, Ortúzar, J. and L. Willumsen in 1994 said:

"Congestion arises when demand levels approach the capacity of a facility and a time required to use it (travel through it) increases well above the average under low demand conditions."

In the considered case-study, solution like the iconic double decker London buses have been applied in order to face the capacity challenges. In the same context, typical metro lines l board more than five hundred passenger every 3 minutes. Like for urban buses, an important part of the passenger is standing and are not sitting. In urban buses and metro, there are no toilets (only long-distance buses own a toilet). In urban buses, there are no place dedicated to bicycle storage. In the framework of the Pods4rail project, all list of typical use case was presented in the context of Task4.1. The use case corresponding to the current scenario is the UC4 presented in appendix of the D4.1 Pod4rail project deliverable. The considered Pod-Bus belong to class I referring to (2001/85/CE).

Referring to *(UE) No 181/2011*, a train should own a storage area for bicycles. Consequently, should we conclude that urban Pod-Buses should own a storage area because they will be inside urban trains?

Let us consider two options and evaluate them.

1. Bicycle Storage in urban Pod-buses: In this case, the Urban Pod-Bus is a technical solution facing a concurrent technical solution which does not own a storage area for bicycle: the classical urban bus which can provide more capacity. If you consider that capacity is the more critical parameter, urban-Pod-buses have no chance.
2. No bicycle Storage in urban Pod-buses: Urban Pod-buses in this case, have to manage with specific technical constraints of their TU ensuing from their multi modal abilities.

It may have a cost, but from the main criteria they are competitive, and it can be argued that TUs are safer and more inclusive. Moreover, the global management of the multimodal system will provide better performances, because of its specific global understanding of the entire system.

Let us focus on peak hours, when all the Pods are full. Let us put the TU from a Pod-bus carrier. There may be no place to put a bicycle, but let us ask a stupid question: "where does this bicycle comes from?"

There cannot be a bicycle in the TU because it was on a bus. Is it reasonable, in the sense of the ALARP (At Least As Reasonably Possible) criterium (the document: "*HSE Principles for Cost Benefit Analysis (CBA) in Support of ALARP Decisions"* can be consulted for more explanation), to add this constraint?

Now let us consider the case where the TU is not full. In this case, it may be a technical solution, using removable seats allowing to create the bicycle storage area when needed. May be more expensive, but still preserving capacity during the peak hours.

The aim of this discussion is not to conclude on a technical solution, it is only to demonstrate that a further analysis is needed. In order to guide this analysis, EU should provide/update directive mentioning a criteria multi-modal analysis. There are many parameters, but if the system is at least globally equivalent (in the sense of the GAME criterium), it must not be eliminated. To give a chance to a multi modal design, which obviously will provide better global performances, a new directive, or an updated version of an existing one should declare that a multi-modal analysis should be considered.

Actually, it is important to allow assessing multi-modal materials on the basis of the global transport service, rather than simply cumulate the mode specific constraints on the TU.

5.2.7.2. Inter-city Journey of more than 60 km

This second scenario corresponds to the Pods UC1 case of the use case list presented by the Pods4rail project within the framework of WP4: it can be consulted in the appendix of the D4.1 deliverable. The transport unit contains 50 people, and when it is in a bus legal framework, there are no requirements for toilet nor bicycle storage. The considered Pod-Bus belong to class III referring to 2001/85/CE. In this document, the number of emergency exits is presented in a table of the section 7.6.1.4. For 50 passengers, the value is 6. The minimal dimensions of exits is stated in the section 7.6.3.1. of the same legislative document. The legal context aiming at increasing the use of bicycles is not developed again in the current section, because it is already presented in the previous section.

In the Cenelec 15380-4, toilet access is one of the needed functions corresponding to a main line rolling-stock. On the other hand, only tourist long distance buses own a toilet. The reasoning considering, that there is no need for bicycle storage in a train when the content of a Pod comes from a bus which does not contain bicycles cannot be applied for discussing the requirement corresponding to a toilet access as suggested by the norm CENELEC 15380-4. If the travel is long, you need a toilet access, and if there were no toilets in the previous transport mode of your journey, it makes it more important in the next travel episode. Considering toilets, if they are not required by buses but by inter-city trains, one may consider to put this requirement on the carrier dedicated to trains, with adding a requirement to the multi-modal TU that lateral doors should provide access to the toilet area and other wagons.

The aim of this section is not to conclude on a technical specification, but rather to highlight that a European legislative framework may allow building tailored solutions.

About the management of people with limited mobility, let us consider (UE) no. 181/2011, the passenger rights of the bus users:

> *"Article 9*
> *Right to transport*
> *1. Carriers, travel agents and tour operators shall not refuse to accept a reservation from, to issue or otherwise provide a ticket to, or to take on board, a person on the grounds of disability or of reduced mobility.*
> *2. Reservations and tickets shall be offered to disabled persons and persons with reduced mobility at no additional cost"*

When there is a train connection, the existence of a walking travel between the bus station and the railway station should be mentioned, if it is not the case, the consumer is buying a good that cannot be used, because of a lack of information. The requirement for mentioning the walking travel episode and their corresponding difficulty of access is discussed in the section 5.2.3.1. The current use case is an illustrative application providing an idea of difficulties that may face limited mobility people to go to work.

5.2.7.3. The transfer handling systems

Let us express the non-functional requirement allowing to send a metro each 3 minutes during an urban bus to metro transfer. Knowing that a classical metro capacity is more than 500 passengers. The corresponding quantity needs at least 5 urban Pods according to UC4 (In UC4 it is defined, that the passenger number is 30-100 passengers). 5 Pods transfer during 3 minutes, this is the non-limiting requirement. Under the previous functioning assumptions, if this rate is not reached, the transfer handling system will limit the performance of the global system. When the transport capacity is the critical parameter, this limitation is not acceptable. Depending on the business case, a TU can be added to a train that is already partially loaded by conventional passenger wagon, or by other TU that were put on the train during previous travel episodes. In this last case, not the whole quantity of 5 or 6 TU must be considered, but another quantity, decreasing a lot the non-functional requirement of the transfer handling system.

The inter-city scenario leads to a similar number of TUs: 5 Pods of 50 passengers corresponds to a classic capacity in main line. Nevertheless, in this case, there are not train departures every 3 minutes, and the transfer time can be longer. The global transfer handling system is not very advanced, but for connection with a railway system, capacity has to be considered. A classical way of expressing this reality is saying that "Gare du Nord" in Paris, with 770000 daily passengers, was the 24th railway station in the world in 2010 considering the number of passengers, but it was more than the biggest airport in the world: the airport of Atlanta. Tailored solution should be considered depending on the various cases, but the capacity of passenger is something to be studied in all cases.

5.2.7.4. Autonomous transport systems and Pods

Pod specific Carrier systems will probably differ a lot from each other and it may be relevant to assign a transport mode specific brain to each carrier. Focusing on metro lines, driverless metro exists for many years and it is difficult to explain why it should be better to add technical devices that are needed for other modes. Moreover, failure of these new sensors may decrease the reliability of an industrial system which have proved to be reliable for 30 years. Concerning main lines, the subset 125 may be considered, but a driver is still needed to deal with the hazards. Concerning road traffic, the relative legislative framework should be considered.

5.2.7.5. Requirements for an update or new directive

1. A new directive or a directive update may recommend a dedicated methodology to be included into the safety framework for the Pod system assessment.

2. The global methodology should consider disturbance management and crisis management in the door to door analysis. Implementing Ecall is just a step forward, but a global strategy should be considered.
3. This methodology should propose a strategy of allocation of global requirements to the various components of the Pod system. In the D2.1 deliverable, the Pod system is not a vehicle or a rolling stock but an aggregate of three components: carrier, transport unit, system of transfer. Moreover, in the D4.4 the number of entities is bigger, as the specification of the system is going deeper. Some criteria should be provided.
4. The need of a centralized information system is already documented, but the requirement asking for the documentation of walking episodes, including the specific information related to people with reduced mobility, should be added.
5. The real time information system for passengers should be included during the global service of transport: passenger information is a part of the "railway passenger right", but all transport episodes should be considered.

6. Comparison of normative frameworks

6.1. Discussion of the system and the most relevant safety requirements

Within the safety regulation assessment of the Pods4Rail project the Pod system is split into the carriers and the transport units (TU). The following comparison is therefore following these assumptions:

- The TU´s have to fulfill the standards from all different domains (road, rails, etc.), since they travel in those different domains.
- The carriers only need to fulfill the standards of their respective domain.

Our focus is on passive safety functions, i.e. the features that are relevant in terms of the construction and equipment of the Pod system. Active safety systems are out of scope of this comparison. A TU, independent of any specifics, like its size etc. will be used to transport people or goods and will be transported on rails and roads. Crashes and fires can happen in either domain and they are also relevant for every use case. Because of that the focus lies on both of them. We will also mention, but not go into detail of a third source of harm to the passengers, which is other passengers. This can, at least in part, be addressed by emergency buttons and video surveillance.

6.2. Relevant standards in the railway domain

In this section, the most relevant standards of the railway domain are listed. The railway domain both includes trains as well as light rail vehicles (e.g. trams).

6.2.1. Structural safety and crash safety of trains

Goal of the crash safety standard EN 15227 is the minimization of the consequences of a collision after all preventative measures have failed. Its primary means of accomplishing these aims are:

a) Preservation of the vehicle's structural integrity and thus the passengers' survival space
b) Prevention of derailments resulting from collisions with objects
c) Prevention of climbing and

d) Limitation of accelerations experienced by passengers.

As the trains which are subject to this standard are, in general, taken to be operating on separated infrastructure and primarily interacting with other vehicles which are also subject to the same requirements, the standard explicitly states that it is not concerned with the safety of people outside of the vehicle in question. The standard is also not concerned with the design of doors, windows or other system components or interior equipment except to the extent to which they are relevant to the preservation of the survival space inside the vehicle.
In addition, it is also noted that not all dangers and not all crash scenarios can be realistically dealt with or prevented, thus the standard is focused on the mitigation of the most common types of collisions in normal European train operations.

If a scenario can be ruled out due to the operational concept of a given vehicle (for instance, a collision with a road vehicle on a level crossing needn't be expected by a train operating on a completely separated grade with no level crossings), then provisions for that scenario are not necessary in that vehicle. Even positive train control systems which can separate traffic operating within a given network can be taken as fulfilling this condition. Conversely, if collision scenarios in a given operating system are predictable but not covered in standard scenarios, then these scenarios should be taken into account in the design of a vehicle.

In order to align the crash safety requirements with the operating concept of the vehicle, different categories of vehicle and operating regime are defined in EN 15227 (Table 1).

Category	Definition	Examples
C-I	Vehicles, with the exception of urban vehicles and trams, designed for operation on international, national and regional routes	Locomotives, passenger coaches and trains
C-II	Urban vehicles designed exclusively for a closed railway network without level crossings and without interfaces with road traffic	Metros
C-III	Vehicles designed for urban and/or regional networks with shared track utilisation of mainline railway lines and with interfaces to road traffic	Tram-trains, long-distance trams
C-IV	Trams	

Table 1 Overview of rail vehicle categories defined in EN 15227

If a Pod system is to represent a fully-fledged transportation solution, it must cover as many operational regimes as possible, thus fulfilling its goal of reducing the number of transfers a passenger must make. It would therefore appear logical for carriers on rails to be designed for at least the two categories C-I and C-III, thus covering both the long-distance regime and the rapid, high-capacity urban regime. In all likelihood this would be best accomplished with two different rail carriers. This is of course primarily because of the widely divergent mechanical and functional requirements posed by both regimes, but also allows each vehicle to be designed for the relevant scenarios, thus avoiding unnecessary over-dimensioning. The collision scenarios which the two carriers would be subjected to, according to EN 15227, are described in Table 2.

	Scenario				
	1	**2**		**3**	**4**
Category	Frontal collision between identical vehicles	Frontal collision with 80t freight wagon	Frontal collision with 129t regional train	Collision with road vehicle (15t deformable barrier)	Collision with low obstacle
C-I	36 km/h	36 km/h	N/A	Up to 110 km/h	Is carried out by the required obstacle deflector*
C-III	25 km/h	25 km/h	10 km/h	25 km/h	Is carried out by the required obstacle deflector*

Table 2 Selected collision scenarios for rail vehicles as defined in EN 15227

*Is carried out by the necessary obstacle deflectors of the leading vehicles. The exact design requirements are explained in EN 15227 chapters 6.5 and 6.6. Due to the very specific case, only reference is made to this here and the design measures are not discussed further.

The collision partners are defined in the norm as simple geometric bodies with fixed stiffnesses an/or energy absorption capacities in the relevant areas (in the case of the freight wagon, for instance the stiffness of the buffers). The deformable barrier representing the road vehicle is the most complex of the geometries defined, with the shape being given below (Figure 6) and the force imparted by it being defined by the resistance encountered by a rigid 3m diameter sphere being pressed into it.

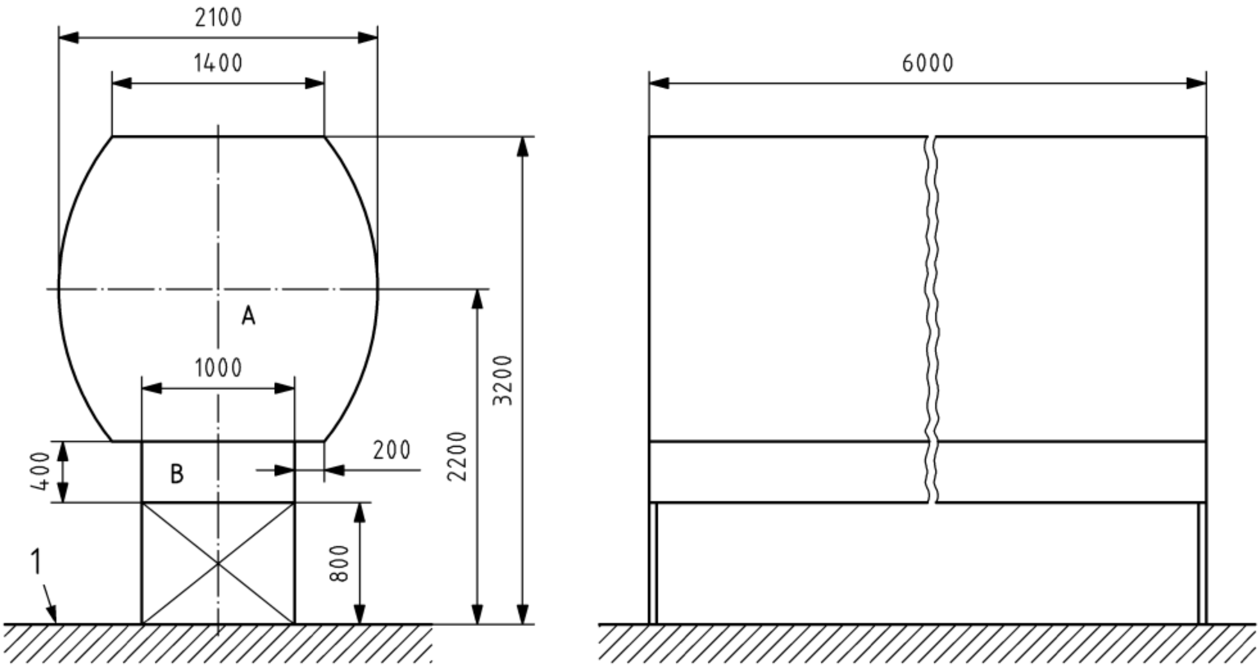

Figure 6 Road vehicle barrier as defined for Scenario 3 in EN 15227. The barrier consists of a 15 t deformable barrier, representing an obstacle such as a truck across a level crossing

Beyond the simple structural integrity of the vehicle which is necessary to preserve the survival space for passengers and staff, a number of other requirements are laid out in the norm which seek to ensure acceptable behaviour of the vehicle during the collision and the safety of its occupants after the event. These are listed below in Table 3.

Subject	Legal Framework	Concrete requirements for trains
Anti-climber	EN 15227 Chapter 6.2	Climbing between two trains must be prevented in the carrier design. Starting height offset of 40 mm in collision scenario 1
Survival space	EN 15227 Chapter 6.3	Vehicle structure must withstand the maximum loads during the entire deformation process of the energy absorbing elements Seating area for passenger must not be reduced by more than 50 mm per 5 m length. The last 5 metres must not decrease by more than 100 mm The compression zones/temporarily occupied passenger compartments may be reduced 30% in longitudinal direction. Driver's seat position: must be maintained (with restrictions)
Emergency exit	EN 15227 Chapter 6.3	An escape route must be maintained
Permissible acceleration/ collision impulse	EN 15227 Chapter 6.4	For the duration of collisions in scenarios 1 and 2: Average acceleration over any period of 30 ms may not exceed 10 g Average acceleration over any period of 120 ms may not exceed 5 g

Table 3 Most relevant requirements as defined in EN 15227

A key feature of the crash safety requirements for rail vehicles is that, as applied to a hypothetical Pod/carrier system, the demands of EN15227 can likely be met through a properly considered design of the carrier vehicle(s), thus opening up potential for easier compatibility with crash standards for road vehicles, for instance. Given a sufficiently dimensioned carrier which can sustain and survive the impacts listed in the above, the primary requirement for the Pods themselves (at least as far as EN15227 is concerned) would appear to be the ability to survive the resulting accelerations with minimal plastic deformation of the passenger cell. In order for the carrier vehicle to survive a collision according to the scenarios laid out above, it would appear advantageous for it to exhibit the following characteristics:

a) A structure with sufficient longitudinal strength to survive the forces resulting from a fully-loaded vehicle colliding in all relevant scenarios
b) Energy absorption structures which can limit the accelerations to the limits listed in Table 3
c) Structures at the ends of the vehicle which extend at least to the full height of the road vehicle barrier and are capable of sustaining the impact with it without impinging on the space designed for TUs
d) Anti-climbing devices compatible with other vehicles likely to be encountered
e) Obstacle deflectors capable of clearing obstacles from the rails and thus preventing derailments

While the TSIs primarily address interoperability and safety requirements for the EU's mainline rail system, for light rail and trams, standards such as those developed by the European Committee for Standardization (CEN) and the International Organization for Standardization (ISO) may be applicable. These standards cover various aspects of light rail vehicle design, safety, accessibility, and performance. They can differ for each country / region, specified by national or local regulatory bodies or standardization organizations. In Germany, for example, this is the BOStrab (tram construction and operating regulations). In other European countries, there are no explicit regulations for small and light rail vehicles. However, there are various regulations that must be considered when building trams. In France, for example, this is the *Code de l'urbanisme* and in Italy the legislative package for rail transport *Pacchetto normativo sui trasporti su rotaia*. However, these do not have any explicit requirements or requirements that go beyond the previous standards on crash requirements.

Some dedicated requirements were provided for European regional lines in (FP6 FutureD2.2 Regional Lines Operational and Functional Requirements FP6-WP020D-MER-001-01, 21.07.2023). Two classes of regional lines are identified:

1. Group 1 Regional Lines – those that are functionally/operationally connected with the mainline railway network
2. Group 2 Regional Lines – those that are not functionally/operationally connected with the mainline railway network

The TSI LOC and PAS refers to the standard EN15227 (crashworthiness) respective EN12663 (car body strength) and here to the vehicle category C-I respective the categories PI and PII which address the mainline vehicles. However, these categories do not fulfill exactly the specific requirements of the secondary lines, which were addressed in the FutuRe project. The loads are partial to high and the collision scenarios do not completely fit and overfulfill the necessary requirements. Further categories, which are considered in the standards but not in the TSI, have less loads, which corresponds more the specific frame conditions and requirements for the respective categories and use case.
For the Group 1regional rolling stocks, the collision with a standard main line rolling stocks is a hazard to be integrated in the safety study.
For the Group 2 rolling stock, as there are no possibilities of collision with the main line rolling stocks, proposition of lighter (to be explicit: lighter than EN15227 Chapter 6.3 and 6.4) trains are considered. Thus a state-of-the-art report concerning small, lightweight and cost-efficient regional rolling stocks for the Group 1 and Group 2 lines (FP6 Future project, D5.1 STATE-OF-THE-ART REPORT FOR REGIONAL LINES ROLLING STOCK) is providing proposition for a legislative evolution, for example concerning TSI LOC and PASS., CCS OPE. It is proposed to consider the vehicle category C-III of the EN15227 in the TSI LOC and PAS for the vehicle of the capillary Group 2 lines with a separate infrastructure. It has to be surveyed if some scenarios could be additional excluded, e.g. the collision with a 129t heavy commuter train for the rolling stocks of Group 2 lines. For the strength requirements, defined in EN12663, it is proposed to consider the vehicle category P-III for the Group 2 lines additionally in the TSI LOC and PAS.
The corresponding document is currently under ERJU approval.. At least, it must be mentioned that the provided safety argument should be considered when discussing the safety of Pods, that may connect G1 class to G2 class by the mean of dedicated handling systems. In this last case respective carrier should fulfil the respective normative framework, but TU should fulfil the most restrictive regulatory framework as they travel on both G1 and G2 lines.

6.2.2. Fire safety of trains

The main standard for railway vehicles with regard to fire protection is EN 45545 Railway application - fire protection on railway vehicles (7 parts). This applies to locomotives/traction heads, passenger coaches, light rail vehicles, underground railway vehicles, trams, luggage and mail coaches (within a passenger coach), but not to freight wagons in general. Nevertheless, the same principle of preventing fires and minimising the consequences in the event of a fire applies to freight wagons in accordance with TSI "rolling stock – freight wagon". This standard also applies to track-guided buses, trolleybuses (with regard to electrical equipment) and magnetic levitation vehicles. The primary aim is to protect passengers and staff in the event of a fire. This standard does not provide specific requirements for the preservation of the vehicle in the event of fire. In the event of a fire, it must be possible to rescue people and evacuate them effectively. Depending on the different operating conditions, sizes of the passenger area and possible ignition sources, it must be possible for passengers and accompanying personnel to leave areas affected by fire without additional help from outside. The construction and the used materials should limit the spread of fire.

In order to achieve this protection objective, the potential for fire must be minimised through design and organisational measures. In the event of a fire, the materials used in the rail vehicle must reduce the spread of fire and smoke in terms of their properties and minimise the effects on persons in the rail vehicle (e.g. through toxic fumes). In a few cases, EN 45545 refers to other standards, for example EN 1021 - Flammability of upholstered furniture due to various ignition sources. To ensure these points, various fire scenarios are defined depending on the operating and design class. If a vehicle fulfils several operating categories (OC), all requirements must be met, not just the most critical one. In addition to the operating classes, the vehicles are also differentiated according to their design, which in turn has an impact on the dwell times:

- A: Vehicles for automatic operation without trained board personnel
- D: Double-decker vehicles
- S: Sleeping cars / couchette cars
- N: all other vehicles

For Pods4Rail the design is assumed as "A". Derived from the operating class - and the associated evacuation options (see Table 5) - rail vehicles are categorised into different hazard levels (HL) depending on their use (Table 4). These result in further requirements for the materials used within the railway vehicles.

	Type class			
OC	N	A	D	S
1	HL1	HL2	HL2	HL2
2	HL2	HL4	HL3	N/A
3	HL3	HL4	HL4	HL4
4	HL4	HL4	HL4	HL4

Table 4: Hazard Level of the operating categories depending on the type class

Subject	Legal framework	Concrete requirements for trains
No/few tunnels, underground or elevated sections	EN 45545-1 OC-1	Stop immediately and clear the vehicle

Tunnels, underground or elevated sections with lateral paths	EN 45545-1 OC-2	Continue to the next station / stop, if this is not possible: lateral evacuation
Tunnels, underground or elevated sections with lateral paths	EN 45545-1 OC-3	Continue to a suitable stopping point, if this is not possible: lateral evacuation
Tunnels, underground or elevated sections without lateral paths	EN 45545-1 OC-4	Evacuation is extremely difficult, high safety standards necessary.
Load bearing Capacity of Materials	EN 45545-2 Chapter 5	List of materials that may be used. General subdivision into materials that fulfil the requirements and specified for each sub-area/assembly in the vehicle. Assignment of a set of requirements (R1 to R26) to the materials / components depending on the application. Within this, the necessary fire-technological properties and test methods are defined, which must be verified as proof of the usability of a material (similar UNIFE FCIL)
Fire resistance in case of vandalism	EN 45545-2 Chapter 6	Even in Case of a previous vandalism, Materials for e.g. seats should be fire resistant
Fire protection closures	EN 45545-3 Chapter 6.1 TSI rolling stock – freight wagon	must fulfil various requirements for stability in the event of fire, room-sealing effect and thermal insulation. Fire resistance duration 15 or 30 minutes (additions possible for special operating conditions), depending on the local situation in the vehicle (to be found in detail in the appendix A in EN 45545-3). Covering of the complete section between roof, floor and sidewalls. Partition walls that can withstand a fire for at least 15 minutes are required between the potential source of fire and the cargo being transported.
Partition walls	EN 45545-3 Chapter 6.2	No fire resistance test necessary
Luggage racks	EN 45545-4 Chapter 5.1	Luggage must be visible
General constructive measures	EN 45545-4 Chapter 5.1	No niches, no/small gaps, Avoid accumulations through constructive measures (dirt/oils/...)
Surface temperature	EN 45545-4 Chapter 5.1	Under normal condition not higher than 60 °C (except the cooking place)
Seats	EN 45545-4 Chapter 5.4	No cavities or heels, easy cleaning possibilities, protection of the underside of the seats against arson and thermal impact of train equipment

Special systems	EN 45545-4 Chapter 5.11.3	Special systems (Ventilation, fuel and gas supply, drive for automatic doors) have to be working even in a case of fire
Door arrangement	EN 45545-4 Chapter 5.12.1 EN 45545-6 Chapter 8.3	Doors shall be located on both sides of the vehicle, except where the operation requires doors on one side of the vehicle only. The escape route to the nearest external door or emergency exit (e.g. Window) shall not exceed 15 metres. Vehicles with ends without doors must have external doors or emergency exits that are less than 6 metres from this end It should be possible to open and close the doors manually If the distance between top of rail and lowest point in the train for passengers is higher than 1.2 m aids for exit is necessary Fire doors must close automatically in the event of fire
Window as emergency exit	EN 45545-4 Chapter 5.12.6	Depends highly on the wagon configuration. Details see in EN 45545-4 Chapter 5.12.6
Automatic fire alarm	TSI Loc&Pas, 4.2.10.3.2. EN45545-6 Chapter 5.2	The equipment and areas in vehicles where there is a fundamental risk of fire must be equipped with a system that recognises fires at an early stage. Signal must be loud enough to inform all the (sleeping) passengers. And clearly visible. For trains in category A, the operational control centre (OCC) has to be informed
Manually triggered fire alarms for passengers	EN 45545-6 Chapter 6	One of them is mandatory, all are possible: alarm to personal/OCC, voice contact to personal/OCC and braking systems. They have to be red, clearly visible, clearly labelled with "ALARM" and the distance should not exceed 20 m between them
Fire-fighting equipment	EN 45545-6 Chapter 6	Fire extinguisher must be easily accessible, and the position must be clearly recognisable. They have to be reached within 15 m, from the end of a train the distance should not exceed 6 m. Further detailed information to the fire extinguisher see in EN 45545-6 Chapter 6.3
Separation of systems	EN 45545-7	Equipment that can generate oil mist, vapours or gases have to be separated, if possible, from ignition sources
Fuelling systems	EN45545-7 Chapter 6	Not in the passenger compartment Protected from gravel flight and other mechanical equipment

Table 5 legal requirements regarding fire safety of trains

6.3. Relevant standards in the road vehicle domain

6.3.1. Structural safety and crash safety of buses:

Note: The requirements will be different for different vehicle categories. Very likely the category will be different for different use cases (mass transport vs premium passenger transport).

Overview of light vehicle categories (either for low passenger amounts or low freight tonnage) and heavier road vehicles (for high passenger amounts or high freight tonnage) according to ECE/TRANS/WP.29/78/Rev.6 Consolidated Resolution on the Construction of Vehicles (R.E.3):

- "M1: Vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat.
- M2: Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tonnes.
- M3: Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tonnes.
- N1: Vehicles used for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes.
- N2: Vehicles used for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes.
- N3: Vehicles used for the carriage of goods and having a maximum mass exceeding 12 tonnes."

Specifically, for vehicles of categories M2 and M3 are further subdivisions.

- Vehicles with more than 22 passengers (excluding the driver):
    - Class I: vehicles with areas for standing passengers (allowing frequent passenger changes)
    - Class II: mainly for the transport of seated passengers, standing passengers in the aisle and/or in a small restricted area
    - Class III: vehicles intended exclusively for the carriage of seated passengers.
- For vehicles with no more than 22 passengers (excluding driver):
    - Class A: Vehicles designed for the carriage of standing passengers; has seats and standing areas.
    - Class B: Vehicles not designed to carry standing passengers; no standing areas.

Table 6: Overview of crash safety requirements for vehicle categories M1 / N1

Name of Regulation	**Scope**	**Brief Description**	**Concrete Requirements**
ECE Regulation No. 94 (R94)	This Regulation applies to vehicles of category M1 of a total permissible mass not exceeding 3,500 kg and to vehicles of category N1 of a total permissible mass not exceeding 2,500 kg; other vehicles may be approved at the request of the manufacturer.	"Frontal Collision Protection": Specifies requirements for the protection of occupants in the event of a frontal collision.	Vehicle must withstand a frontal impact test against a deformable barrier at 56 km/h, with specific criteria for deceleration and cabin intrusion.
ECE Regulation No. 95 (R95)	This Regulation applies to the lateral collision behaviour of the structure of the passenger compartment of M1 and N1 categories of vehicles where the R point of the lowest seat is not more than 700 mm from ground level when the vehicle is in the condition corresponding to the reference mass defined in paragraph 2.10 of this Regulation.	"Lateral Collision Protection": Establishes requirements for the protection of occupants in the case of a lateral collision.	Vehicle must pass a side impact test with a mobile deformable barrier at 50 km/h, including limits on door intrusion and protection of the thorax, abdomen, and pelvis.
ECE Regulation No. 16 (R16)	This Regulation applies to safety-belts and restraint systems which are designed for installation in vehicles and are intended for separate use, i.e. as individual fittings, by persons of adult build occupying forward or rearward-facing seats. It also applies to child restraint systems and ISOFIX child restraint systems designated for installation in vehicles of category M1 and N1.	"Safety Belts and Restraint Systems": Covers specifications for safety belts and restraint systems.	Requirements for the design, resistance, anchorage, and durability of safety belts, including force limits for belt and buckle, and retractors' performance.
ECE Regulation No. 44 (R44)	This Regulation applies to child restraint systems which are suitable for installation in power-driven vehicles having three or more wheels, and which are not intended for use with	"Child Restraint Systems": Sets out specifications for child restraint systems.	Specifies classes based on weight of children, installation requirements, construction and design standards, and performance in frontal and rear impact

Name of Regulation	Scope	Brief Description	Concrete Requirements
	folding (tip-up) or with side-facing seats.		tests.
ECE Regulation No. 129 (R129)	This Regulation applies (in its Phase 1) to Integral Universal ISOFIX Child Restraint Systems (i-Size) and Integral "Specific vehicle ISOFIX" Child Restraint Systems for child occupants of power-driven vehicles.	"Enhanced Child Restraint Systems" (i-Size): Introduces more stringent requirements for child seats.	Introduces ISOFIX attachment requirements, improved side impact protection, and mandatory rear-facing seating for children up to 15 months old. Also includes Q-dummy usage for more realistic testing.
ECE Regulation No. 127 (R127)	This Regulation applies to motor vehicles of categories M1 and N1.1 However, vehicles of category N1 where the driver's position "R-point" is either forward of the front axle or longitudinally rearwards of the front axle transverse centreline by a maximum of 1,100 mm, are exempted from the requirements of this Regulation. This Regulation does not apply to vehicles of category M1 above 2,500 kg maximum mass and which are derived from N1 category vehicles, and where the driver's position "R-point" is either forward of the front axle or longitudinally rearwards of the front axle transverse centreline by a maximum of 1,100 mm; for these vehicle categories Contracting Parties may continue to apply the requirements already in force for that purpose at the time of acceding to this Regulation.	"Pedestrian Protection": Aims to reduce the risk of injury to pedestrians and cyclists.	Specifies performance criteria for vehicle fronts to mitigate injury in impacts, including head impact zones on bonnets and bonnet edges, and leg and pelvis impact areas.
ECE Regulation No. 135 (R135)	This Regulation applies to: (a) Category M 1 vehicles with a gross vehicle mass of up to 3 500 kg; and (b) Category N 1 vehicles where the acute angle alpha (α), measured between a horizontal plane passing through the centre of the front axle and an angular transverse plane passing through the centre of the front axle and the R-point of the driver's seat, as illustrated below, is less than 22,0 degrees; or the	"Pole Side Impact Occupant Protection": Specifies occupant protection in side impacts against poles.	Includes requirements for a side pole impact test at 32 km/h, criteria for head, chest, and abdomen injury measurements, and vehicle structural integrity.

Name of Regulation	Scope	Brief Description	Concrete Requirements
	ratio between the distance from the driver's R-point to the centre of the rear axle (L101-L114) and the centre of the front axle and the driver's R-point (L114) is less than 1,30. (2) Other Category M and Category N vehicles with a gross vehicle mass of up to 4 500 kg may also be approved if requested by the manufacturer.		

Table 7: Overview of crash safety requirements for vehicle categories M2, M3, N2 and N3

Name of Regulation	**Scope**	**Brief Description**	**Concrete Requirements**
ECE Regulation No. 66 (R66)	This Regulation applies to single-deck rigid or articulated vehicles belonging to categories M2 or M3, Classes II or III or class B having more than 16 passengers. At the request of the manufacturer, this Regulation may also apply to any other M2 or M3 vehicle that is not included above.	Specifies requirements for the strength of the bus superstructure to protect occupants in the event of a rollover.	Requires buses to undergo a rollover test ensuring the superstructure prevents excessive deformation of the passenger compartment.
ECE Regulation No. 80 (R80)	This Regulation applies to: (a) Passenger seats for forward-facing installation in vehicles of categories M2 and M3, of Classes II, III and B; (b) Vehicles of categories M2 and M3 of Classes II, III and B in respect of their passenger seat anchorages and seat installation. (c) It does not apply to rearward-facing seats or to any head restraint fitted to these seats.	Specifies the requirements for the strength and integrity of Seats, their Anchorages, and any Head Restraints.	Includes tests for seat strength, anchorage robustness, and head restraint effectiveness under static and dynamic conditions.
ECE Regulation No. 17 (R17) *Complements others, like R80*	This Regulation applies to (a) Vehicles of categories M1 and N (1) with regard to the strength of seats and their anchorages and with regard to their head restraints; (b) Vehicles of categories M2 and M3 with regard to seats not covered by Regulation No 80, in respect of the strength of seats and their anchorages, and in respect of their head restraints; (c) Vehicles of category M1 with regard to the design of the rear parts of seat backs and the design of devices intended to protect the occupants from the danger resulting from the displacement of luggage in a frontal impact. It does not apply to vehicles with regard to side-	Ensures the strength and integrity of vehicle seats and their anchorages to protect occupants.	Specifies testing criteria for seat strength and anchorage robustness, including requirements for withstanding forces applied in forward and rearward directions.

Name of Regulation	Scope	Brief Description	Concrete Requirements
	facing or rearward-facing seats, or to any head restraint fitted to these seats.		
ECE Regulation No. 107 (R107)	This Regulation applies to every single-deck, double-deck, rigid or articulated vehicle of category M2 or M3. However, the requirements of this Regulation do not apply to the following vehicles: Vehicles designed for the secure transport of persons, for example prisoners; Vehicles specially designed for the carriage of injured or sick persons (ambulances); Off-road vehicles. Vehicles specially designed for the carriage of school children. The requirements of this Regulation apply to the following vehicles only to the extent that they are compatible with their intended use and function: Vehicles designed for use by police, security and armed forces; Vehicles which contain seating intended solely for use when the vehicle is stationary, but which are not designed to carry more than 8 persons (excluding the driver) when in motion. Examples of these include mobile libraries, mobile churches and mobile hospitality units. The seats in such vehicles which are designated for use when the vehicle is in motion shall be clearly identified to users. Pending the addition of appropriate provisions, nothing in this Regulation shall prevent a Contracting Party from specifying requirements for vehicles to be registered in its territory for the fitting and technical requirements for audible and/or visual route and/or destination display equipment, whether fitted internally or externally.	Covers various safety aspects of buses including construction, equipment, and operation.	Mandates requirements for emergency exits, fire safety, passenger and driver protection including seat belts, and vehicle construction standards.
ECE Regulation	This Regulation applies to single-deck rigid or articulated	Focuses on specific	Specifies criteria for emergency

Name of Regulation	Scope	Brief Description	Concrete Requirements
No. 36 (R36)	vehicles designed and constructed for the carriage of persons and having a capacity in excess of 22 passengers, whether seated or standing, in addition to the driver, and having an overall width exceeding 2.30 metres. At the request of the manufacturer, approvals may be granted to vehicles having an overall width of 2.30 metres or less if such vehicles comply with the provisions of this Regulation. Technical provisions for the carriage of passengers with reduced mobility are outside of the scope of this Regulation. Until harmonized provisions for accessibility are finalized and included in an annex to this Regulation, Contracting Parties may apply additional requirements to ensure access to vehicles and the safety of such passengers.	construction and design requirements for the approval of large passenger vehicles.	exits, seat strength, vehicle dimensions, and other safety-related aspects.
ECE Regulation No. 100 (R100)	Part I: Safety requirements with respect to the electric power train of road vehicles of categories M and N, with a maximum design speed exceeding 25 km/h, equipped with electric power train, excluding vehicles permanently connected to the grid. Part I of this regulation does not cover; (a) Post-crash safety requirements of road vehicles. (b) High voltage components and systems which are not galvanically connected to the high voltage bus of the electric power train. Part II: Safety requirements with respect to the Rechargeable Electrical Energy Storage System (REESS), of road vehicles of categories M and N equipped with electric power train, **excluding vehicles permanently connected to the grid**.	Applies to buses that are electrically powered, specifying safety requirements for electric power trains.	Covers protection against electric shock, functional safety of the electric power train, and battery protection requirements.

Name of Regulation	Scope	Brief Description	Concrete Requirements
	Part II of this Regulation does not apply to a battery whose primary use is to supply power for starting the engine and/or lighting and/or other vehicle auxiliaries' systems.		

Fire safety of buses

The most important regulation for the fire safety of road buses is UN-ECE No. 118: Fire safety of materials used in city and travel buses. It applies to the categories M3 Class II and Class III from ECE/TRANS/WP.29/78/Rev.6, as explained above. Additional to that, there are EU-Regulations like UN ECE R36 that define the location and protection of critical components like the fuel tanks or engine compartments. International regulations are adapted by national regulations, mainly in the way of concretising limitations to specific vehicle categories and test scenarios. The following table shows the overview of relevant regulations and specifications regarding fire safety and passenger protection.

Table 8 Legal requirements regarding fire safety of buses (category M3)

Subject	Legal framework for buses	Specific requirements
General: Labelling of the approval	UN-ECE No. 118 [2015/622] (4.4.)	Labelling sign of the approval must be applied at the vehicle
General: Approval for material usage	UN-ECE No. 118 [2015/622] (5.2.3. / 4.5.3.1.)	Installation of materials only after approval for specific usage (e.g. Mounting position vertically, horizontally)
Definition of sensitive areas	UN-ECE No. 118 [2015/622] (5.2.1.); 2001/85/EG	Definition of sensitive areas: Passenger compartment, engine compartment and separate heating areas
Burning speed of material	UN-ECE No. 118 [2015/622] (6.2.1. / 6.2.3.)	Burning speed maximum 100 mm/minute (or fast extinguishing) for horizontal (test scenario according to appendix 6) and vertical mounted parts (test scenario according to appendix 8)
Flammability of material	UN-ECE No. 118 [2015/622] (6.2.2.)	No (flammable) dripping that ignites the absorbent cotton (applies to materials inside roof, above seats, and engine isolation parts) (test scenario according to appendix 7)
Resistance to flame spread of power cables	UN-ECE No. 118 [2015/622] (6.2.6.) Test: Paragraph 12 of ISO 6722:2006	flame of burning insulation material must extinguish within 70 seconds and at least 50 mm of insulation material in the upper area of the sample remains unburned.
Seating parts, that don't have to be tested like above	UN-ECE No. 118 [2015/622] (6.2.7.)	Parts made of metal or glass. Parts with a low mass or density or low amount of non-metallic material
Property of materials to repel fuel or lubricants	UN-ECE No. 118 [2015/622] (6.2.5.)	Maximum 1 g of fuel absorption of insulation Materials used in engine compartment and in heating areas (test scenario according to appendix 9)
Fire extinguishing systems for engine compartment	UN-ECE R107, Annex 3, Annex 13	For new long-distance buses, double-deckers and city buses, permanently installed extinguishing systems in the engine compartment are mandatory. Fire alarm

		system and fire suppression system shall be activated automatically through fire detection system. The fire extinguishing systems have to undergo specific tests.
Definition of Emergency exits trough doors or windows	UN-ECE R107	Doors and windows may be used as emergency exits. Minimal dimensions are to be considered (given portal dimensions with Width x Height): - (Regular) single doors: 550 x 1,800 mm - (Regular) double doors: 1,100 x 1,800 mm - Emergency-only doors: 600 x 1,450 mm - Side windows: min. 500 mm x 700 mm - Rear windows: 600 mm x 700 mm - Non-electric opening mechanism located max. 500 mm away and 1,000 - 1,500 mm high (reachable from inside and outside) - Doors may only be opened with max. 5 km/h
Separation of critical components	UN-ECE R107, Annex 3; German StVZO §45 and §46; UN ECE R36 (5.5.3)	The battery compartment shall be separated from the passenger compartment and driver's compartment and ventilated to outside air. Additionally, it must be located in an area which is protected against post-crash intrusions. The housing should protect the batter and cables (for combustion engines the fuel tank and fuel pipes must be protected and separated). Additionally, the critical components must be easy to reach and replace.
Fire extinguishers and first-aid equipment for passengers	UN-ECE R107, Annex 3; German StVZO §35g	Fire extinguishers and first aid kits shall be provided in passenger compartment (the locations of these items are clearly marked and they must be able to extract them easily in an emergency). The fire extinguisher needs at least 6 kg type ABC filling.
Flammability of interior materials and test procedures	Regulation 95/28/EG, Annex IV (EU); DIN 75200 (Germany); Regulation 70/156/EWG (EU)	Limitation of horizontal and vertical velocity of fire spread and the dripping behaviour under thermal load are similar to UN-ECE No. 118 (as stated above) for vehicles with more than 22 passenger seats and Regulation 70/156/EWG for less than 22 passengers.
Thermal limits of air and surfaces	Regulation 2001/56/EG, appendix V	Limitations of surface temperatures and hot air from engine compartment are not applicable for battery electric Pod system. Potentially relevant for electric components (e.g. battery or heater): – 70°C for metallic components – 80°C for other materials – 150°C for hot air
Fuel tank opening/	UN ECE R36 (5.5.2)	Fuel tanks (respective battery charger adapters) have to

Charging equipment		be reached and secured from outside. It must be protected against passenger contacts.
Emergency button for driver	UN ECE R36 (5.5.5)	The driver must be able to use an emergency button to shut down the critical vehicle functions (e.g fuel flow, battery etc.). Additionally, an automatic shutdown can be considered by the system in case of emergency. For the Pod system there is no driver. It is recommended to adopt this function for the passengers instead, also combined with an E-Call feature and/or other communication system for passengers.

6.4. Discussion of safety requirements

Discussion of rail crash safety

Crash safety in rail vehicles is primarily ensured by protecting the entire vehicle or the leading vehicle. There is no special protection for passengers (such as seat belts or special devices for children) in the standards. This is mainly due to the fact that rail vehicles have much more robust energy absorption elements on the traction head than road vehicles. Furthermore, due to the circumstances, no lateral impacts need to be considered for rail vehicles. In order to ensure the safety of passengers in the event of a crash within a transport unit, it is recommended on the basis of the standards research that the standards for road vehicles be considered for an intermodal system for passengers both inside and for non-frontal crash scenarios. At the same time, the carriers of the various transport systems must be designed to meet the respective standards, particularly in the area of crash safety. Merging these standards specifically for intermodal systems does not add any value due to the great differences in requirements and crash scenarios. The focus here in future standards development should be on the transport unit itself, so that it guarantees passenger safety in both cases - or the other possible transport modes. The requirements for an intact driver's seat are no longer needed in this way with an autonomous Pod system. This must be considered in future developments of the EN 15227 standard. In place of the driver, it must be assumed that there are passengers in an autonomous driving mode. In this last case, existing protective driver procedures must be learned and then applied by passengers sitting at the front of the train, otherwise another safety measure could be proposed

Discussion of rail fire safety

An essential point in the design of the fire protection of the Pod system or the Pod itself is the definition of the OC. The routes on which the Pod travels (tunnels, existing lateral ways next to the rail, ...) must be defined for the system. The fire protection requirements vary depending on this. If the system runs in narrow underground tunnels, OC-4 must be used, but if it mainly runs on overground branch lines and can stop immediately in the event of a fire, OC-1 can be used. Accordingly, only Hazard Level (HL) 2 must be considered instead of HL4. Furthermore, materials for the vehicle are predefined and precisely specified. Deviations in a material that are not on the list for the highest safety requirements in the standard must be verified for their fire behaviour in a complex process (this includes technical components through to armrests). A key criterion for fire protection in trains is the fire resistance of the materials or the system. In the event of a fire, the fire must always remain within an enclosed area for at least 15 minutes. Depending on the position in the railway vehicle, this is increased to 30+t minutes in accordance with EN 45545. t depends on the individual order requirements of the operator. This means that materials,

construction methods and structural approaches must be designed to minimise flammability and the spread of fire. For example, the passenger compartment must be separated from critical components (engines, heaters, etc.) through non-combustible barriers.
Furthermore, the fire and smoke must not spread over a length of more than 30 m within the passenger or crew areas of a unit during this time, which is a significant difference to the fire protection concept for buses. While buses concentrate on protecting the vehicle areas, the primary aim of train applications is to ensure that people have sufficient time to evacuate. For evacuation in the event of a fire, the number of emergencies exits on trains is therefore length-dependent. It must still be possible to open these manually. Devices for signalling a fire alarm must be available in every passenger compartment. In the case of an autonomous vehicle, a connection to an external control centre must be possible.
Another fundamental aspect of fire protection for trains is the materials that can be used. Here, care must be taken to ensure that they fulfil the high requirements of EN 45545-2. Within this standard, reference is made to other standards such as EN5510 (Preventive fire protection in railway vehicles).

Discussion of road crash safety

In the domain of vehicular regulations, a diverse array of standards is tailored to accommodate the distinctive characteristics of various vehicle classes. While the M1 standards may suffice for certain applications, particularly those involving smaller vehicles, the M2/M3 standards become imperative for use cases necessitating larger Pods or heavier vehicles. This stratification ensures that regulatory requirements align closely with the specific functionalities and safety needs of different vehicle types.
A pivotal factor influencing regulatory considerations is the mode of power supply for the vehicle, distinguishing between those connected to the grid and those reliant on battery power. This dichotomy holds significant implications for safety standards, as exemplified by ECE Regulation No. 100 (R100), which outlines detailed criteria for crash safety assessments, particularly concerning buses. Notably, the distinction between grid-connected and battery-operated vehicles underscores the nuanced approach required to address safety concerns associated with different power sources.
Within the ambit of these regulatory frameworks, there exists a discernible emphasis on passenger safety and well-being. This emphasis is manifest in the stringent specifications outlined for various safety features, with a particular focus on passenger protection mechanisms. For instance, regulations such as R44 or R129 meticulously delineate requirements for child restraint systems, underscoring the paramount importance accorded to passenger safety considerations within the broader regulatory landscape. This unwavering focus on enhancing passenger safety underscores the proactive approach adopted by regulatory bodies to mitigate potential risks and ensure the highest standards of safety across diverse vehicular contexts.

Discussion of road fire safety

Regarding bus fire safety, the seats are one of the main fire loads in bus interiors, which is why the burning behaviour of their materials is regulated the most. The most important regulation for the burning behaviour of materials in the passenger compartment is UN-ECE-R118, which is more and more tightened by the vehicle manufacturers themselves with company specific regulations (Dekra, 2020; Egelhaaf et. al, 2004). Another important regulation is UN-ECE-R107 for “Uniform provisions concerning the approval of category M2 or M3 vehicles with regard to their general construction”. It is figured out, that testing the original component offers more safety than individual component tests (e.g. DIN EN ISO 3582), which often do not adequately reflect the real

behavior of a bus seat (König 2024). The regulations for the materials are mainly trying to limit the spread of fires, that already started. Compared to trains, the requirements for the selection of materials in buses are less specific regulated by standards. Here it is important to ensure that the materials in the TU fulfil the requirements for the rail vehicle sector.
Also it is figured out that critical components must be separated from the passenger compartment to keep possible fires away from the passenger compartment and from emergency exits, to allow the passengers to escape. This is also an important goal on rail vehicle fire safety, even though the regulation itself has different methods and specifications.
There is a huge responsibility of the so-called secondary fire safety given to the operators of road buses. The operating company is responsible to keep their buses up to date and all installed systems running properly, e.g. doing regular check-ups. That also includes the responsibility to follow safety measures in an organizational way and to hold appropriate trainings for the staff (minimal requirement e.g. in StVZO §35g §3) (König, 2024). Because of that, it is needed to provide a clear safety protocol and safety concept by the Pod operation system as well as providing emergency plans for each use case.
Another finding is, that critical components must be protected from damage due to crashes or misuse. Also, systems designed to prevent accidents are an important factor to reduce post-crash fires. Therefore, especially driver assistance systems are recommended for all public transport vehicles. Also, an improved and standardized usage of passenger information (similar to an Airline service for flight passengers) and full training of the operating personnel are recommended steps to increase safety of public transport operations (Dekra, 2020). A combination of crash-reducing systems as well as a sufficient emergency process plan would make a great impact on the Pod system safety and are therefore recommended for the further developments.

6. Conclusions

The Pods4Rail project has a mission to imagine and design the future transportation systems. Hence, it intends to substantiate the concept for digitalised, decentralised mobility service with inter-modal interfaces (in terms of Pod systems) to different transportation modes in order to carry out a concept for a door-to-door transport system based on rail.

In this context, the aim of Task3.2 is to provide a study of multi-modal services motivating the specification of Pods systems. The list of selected legislative documents provided by the D3.1 have been consulted in order to identify the main elements of a legislative framework.

Considering that a global multi-modal management system is required, the lack of requirement related to pedestrian transfer is highlighted. It leads to propose a new concept to be added in the FREL Ontology proposed by the Co-Active European project. It is easy to understand why in the objective of providing ticketing, the walking travel episode are not described. Nevertheless, in order to inform fairly consumers, this information should be integrated. Moreover, in order to manage the whole system, this pedestrian transfer must be considered too.

So clear requirement, like GNSS positioning (using Galileo and EGNOS) or use of Ecall were identified, but from a general point of view, a directive may provide a more precise tool to defend specific designs ensuing from multi-modal activities, and more precisely Pod systems. Two different use cases built from the real environment of Paris (France) neighbourhood are used for illustrating that specifying a multi-modal transport unit will lead to non-consistency problems producing over cost and loss of capacity of transfer.

As a result of task 3.2, it was analysed that rail and road transport differ in terms of legal requirements and the approval process. The carrier unit and the transport unit must be analysed separately, as the carrier unit is not used in a different area of application. (one specific carrier unit for road and another for rail have to be developed). The requirements will follow the specific rules of the relevant field of application.
With regard to the transport unit, it is recommended to find a design concept that meets harmonized requirements (see Fig 7 of all modes of transport (with an initial focus on rail and road - other modes will follow in a later phase).

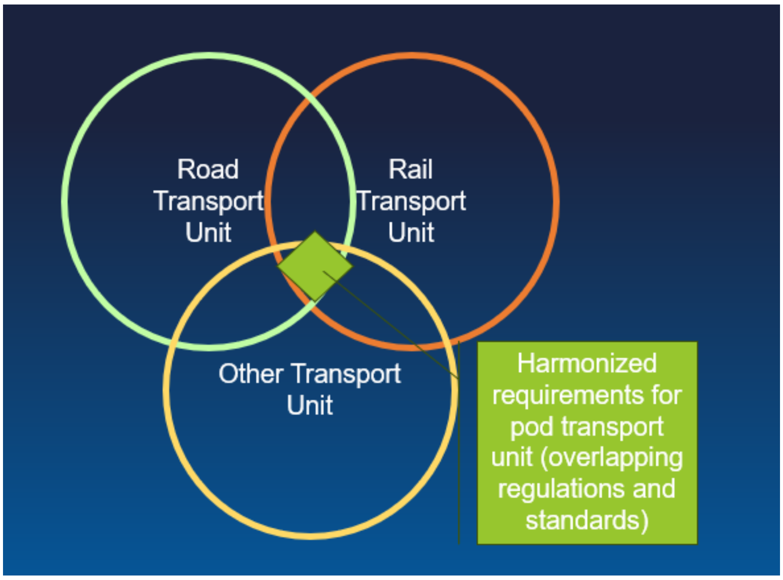

Figure 7. SEQ Figure * ArabiCommon requirements for the Pod transport unit need to be aligned with all kind of transport modes (overlapping). "Other transport unit" will be defined in a later work package.

If possible, the requirements should also be discussed with the aim of reducing the burden of over-engineering. However, safety requirements must be the leading format. Therefore, it should be possible to use active safety measures instead of passive ones, i.e. Advanced Driver Assistance Systems (ADAS) can reduce the level of passive crash requirements on the Pod where appropriate. The conceptual idea is to lower the frequency of an accident in order to balance the potential gravity increasing of the same accident.

This is the main conclusion of this report. A multi-modal directive may express the opinion that a global evaluation should be considered, for example considering GAME criteria or ALARP criteria, in order to allow a tailored solution to this new kind of transport to demonstrate their value.

7. List of Figures

8. List of Tables

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ANNEX 1: Semantic definition of the FREL ontology.

Based on the concept explained in the introduction of the document, this section describes the terms used within the scheme. The table is structured as follows:

- Term: the name of the concept that is to be described and which is used in the schema.
- Description: the meaning of the term in the context of the Travel Shopping domain. It contains the definition from the S2R glossary.
- Relations: list of other terms of the S2R-IP4 ontology which also links this part of the ontology to the other ontology parts in S2R-IP4.
- Terms described in S2R and its relation with other ontologies: this column explains the origin of the term.
- Representation in TRIAS: The name of the element, group or structure in the TRIAS specification which is used to represent the term within Travel Shopping.

Term	Description	Relations	Terms described in S2R and its relation with other ontologies	Representation in TRIAS
Additional Info	Entity related to OfferItem with auxiliary data such as sales conditions, the provider that provides this route (Travel Shopper) and other relevant information provided by the Provider.	OfferItem Provider	This term has been included in S2R-IP4 ontology in order to set all the supplementary information regarding its related entity OfferItem provided by the Provider	OfferItemContext FaresAuthorityCode
Address	Location identifies with its street, number and country	Location StopPlace	This term has been included in S2R-IP4 ontology but it was used in IT2Rail for data exchange.	AddressStructure
Ancillary Services	Ancillary Services are side Products which are bound to transportation Products in an Offer.	Price TravelEpisode	This term has been included in S2R as an entity because it already existed as a concept in IT2Rail.	TicketStructure
Arrival	An Arrival is a Transport Event, occurring, or planned to occur at a specific Arrival Date Time and Stop Place.	Travel Episode Destination Arrival Date Time Planned Arrival	This term is inherited from IT2Rail	LegAlight LegEnd StopPlace Call
Arrival Date Time	The date and time values associated with the Arrival that marks the actual and/or planned end of a Travel Episode.	Arrival	This term is inherited from IT2Rail	ServiceTime AimedArrivalTime ExpectedArrivalTime TimetabledTime
Business Rule	A business rule describes an agreement/contract between at least two stakeholders and has an (in)direct impact to a traveller.	Business Rule Engine	This term is inherited from IT2Rail	
Business Rule Engine	Part of the TSA which interprets BR in order to reflect the impact to Itineraries and Offers.	Business Rule Travel Shopping Aggregator (TSA)	This term is inherited from IT2Rail	
Contextual Preferences (C)	These preferences depend on the context of the travel; therefore, they are tailored to each situation or a certain type of travel (e.g.: leisure vs. working trip, airplane vs. train, temporary impairment or others). Some of these preferences are	Passenger Preference	This term has been included in S2R-IP4 glossary and, regarding exchange of data, it is a set of preferences related to a specific passenger when the passenger has activated a specific profile or when a profile has been used for a specific travel.	Preferences UserExtension

	connected to travels and travel habits and can be accounted for by the Travel Companion whenever a given context is active.			
Contractual Management Market Place	This component manages business rules, which govern the business relationship between the transportation partners (TSPs). The authorized users to configure providers and agreements. The system gives access to formal contracts generated from agreements. The business rules will be used to build an offer and Clearing and Settlements process.	Business Rules Travel Service Provider Offer	This term is inherited from IT2Rail	
Critical Product	It is a product that is absolutely required to achieve an itinerary. Without a critical product, the travel cannot be purchased	Trip	This term has been inserted in S2R-IP4 ontology but only as a constant not depending on the passenger for the moment. It must be changed in the next steps of the project	TicketStructure
Customer	Role of a Person who makes the payment for an offer and is a party (a person or an organization) to a contractual agreement concluded with a Transport Service Provider. The Customer performs a mobility request, selects one or several segments to create their trip and pays for their booking(s).	Offer	This conceptual term has been inherited from IT2Rail	UserExtension
Departure	A Departure is a Transport Event, occurring, or planned to occur at a specific Departure Date Time and Stop Place.	Travel Episode Departure Date Time Panned Departure Origin	This term is inherited from IT2Rail	LegStart LegBoard StopPlace Call
Departure Date Time	The date and time values associated with the Departure which marks the actual and/or planned start of a Travel Episode	Departure	This term is inherited from IT2Rail	ServiceTime AimedDepartureTime ExpectedDepartureTime TimetabledTime
Destination	A Destination is a Location marking the logical end of the Itinerary.	Arrival Stop Place	This term is inherited from IT2Rail	LegAlight LegEnd

Effective Time	Is the duration of segment	TravelEpisode	This term has been inherited from IT2Rail. Regarding exchange of data, it is described into the field duration inside the related entity TravelEpisode	Duration
Fare Policy	Is the set of items describing the price paid by the customer. It includes among other things: taxes, fees and other debited or credited amounts. It is a set of rules, regulations and principles for Fare Products.	Fare Product	This term is inherited from IT2Rail	Ticket-Price
Fare Product	Is a set of FareRule(s) and parameter(s) which are applied together. Allows the use of a TransportService. Is instantiated in a Token when issued	Product FareRule Token TransportService	This term is inherited from IT2Rail	TripFaresResultStruct ure
Fare Type	Category of product dedicated to transportation.	Fare Product	This term is inherited from IT2Rail	OfferItemType
Fare Rule	Is a description of how to compute the Price, validity and consumption of a FareProduct offered on a TravelEpisode	Price FareProduct TravelEpisode BusinessRule	This term is inherited from IT2Rail	BusinessRule AppliedBusinessRule
Fee	An amount of money paid for a particular right or service.	Tax Price TravelEpisode Offer OfferItem	This term has been included in S2R-IP4 ontology. Regarding exchanges of data, it is described with an entity Tax	Ticket-Price
GeoCode	The GeoCode represents the geographical position of a location with the values for altitude, latitude, and longitude.	Stop Place Stop Point	This term is inherited from IT2Rail (GeoCoordinates). But in S2R-IP4 ontology, it has been changed into a new entity for exchanges	GeoPosition
Global Quotation	Total quotation of an Offer.	Price Tax Offer Quotation AncillaryService	This term has been inherited from IT2Rail conceptually but in S2R-IP4 ontology and regarding exchange of data, it is described in the fields Price and Tax inside the related entity Offer.	Prices
Guaranteed	Is an Offer where all booked Offer	Provider	This term has been inherited from IT2Rail but in	

Price Offer	Item(s)'s Price(s) are guaranteed by the provider(s).	Price Offer OfferItem Tax AdditionalInfo	S2R-IP4 and regarding exchange of data, it is described into a field inside the related AdditionalInfo entity.	
Identification	Recognition of a Customer or a Passenger in order to provide him with a personalized process.	Passenger	This term has been inherited from IT2Rail. Regarding exchange of data, it is described with fields inside the related entity Passenger as for each provider (code) as a unique user in the environment (docId + docType).	UserId
Itinerary	An itinerary defines the Departure and Arrival places and associated Departure and Arrival times used for the realization of a travel. An itinerary is a set of nonoverlapping journeys	Offer Departure Departure Date Time Arrival Arrival Date Time	This term has been inherited from IT2Rail	
Journey	A Journey is a collection of consecutive Travel Episode(s)	TravelEpisode	This term has been inherited from IT2Rail.	Trip
Journey Planner	A Service that, given a mobility request, returns an itinerary or a part of it.	Travel Service Provider Mobility Request Itinerary	This term has been inherited from IT2Rail but only conceptually	
Key Performance Indicator (KPI)	Indicator measuring the performance of an organization on a specific task		This term has been inherited from IT2Rail but only conceptually.	
Location	A specific position or point in physical space. Location has geographical coordinates. It could be a Stop Point, a Stop Place, a Point of Interest or an Address	StopPlace Address Departure Destination Arrival	This term has been inherited from IT2Rail.	Location
MetaJourney	Is the couple Origin and Destination requested by the end-user, realized by Meta-Route Network.	Meta-Route— Network	This term has been inherited from IT2Rail.	
Meta-Route-Network	Network representing Stop Places and route links joining these Stop Places. The meta-route network is defined for a given zone (Europe, Berlin's agglomeration, ...) and based on schedule data which is	Stop Place Zone Schedule Travel Service Provider	This term has been inherited from IT2Rail.	

	provided by each TSP			
Mileage	Is the number of miles covered.	TravelEpisode	This term has been included in S2R-IP4 ontology but regarding exchange of data, it was used in IT2Rail.	distance
Mobility request	The Traveller's query for travel information. It consists at least of an origin and a destination and a date and time (for arrival or departure)	Traveller Preferences Travel	This term has been inherited from IT2Rail.	TripRequestStructure
Offer	An Offer is a collection of OfferItems associated with a specific itinerary chosen by the traveller	Passenger OfferItem. StopPlace	In IT2Rail exists various concepts related to it, e.g. bookedOffer. Those concepts have been kept from the glossary of S2RIP4. In S2R-IP4 ontology, regarding exchange of data, it has been simplified in this unique entity where the stage of the process is described into the status field instead of describing it by different terms	TripFaresResultStruct ure
OfferItem	An OfferItem is the smallest bookable part of an Offer bound with a specific Travel Service Provider. The collection of OfferItem composes an Offer for an itinerary.	Additional Information Provider Entitlement Travel Episode Offer	In IT2Rail exists various concepts related to it, e.g. ItineraryOfferItem. Those concepts have been kept from the glossary of S2RIP4. In S2R-IP4 ontology, regarding exchange of data, it has been simplified in this unique entity where the stage of the process is described into the status field instead of describing it by different terms.	TicketStructure OfferItemTicketExten sion
Origin	An Origin is a Location marking the logical start of the Itinerary or of a travel segment	Stop Place Departure	This term is inherited from IT2Rail.	LegBoard LegStart
Passenger	Using the Personal Application on the internet enabled device or physical tokens access to the transport network; they go from a point A to a point B through one or more Transport Service Providers vehicles. In Trip Tracking, the Passenger uses the PA to activate or deactivate the tracking of the passenger's trips or sets the tracking related preferences.	Preference Trip Notification	This term is inherited from IT2Rail and partially updated in order to adapt it to the new concepts in the S2R ontology	FaresPassenger
Planned	Refers to arrival information, which is	Arrival	This term is inherited from IT2Rail conceptually but	LegAligth LegEnd

Arrival	planned before travelling, such as: date, time, Stop Place.		in S2R-IP4 ontology regarding exchanges of data it is described in the related fields into the properly entity (Offer or Travel Episode)	ServiceTime AimedArrivalTime TimetabledTime
Planned Departure	Refers to departure information, which is planned before travelling, such as: date, time, Stop Place.	Departure	This term is inherited from IT2Rail conceptually but in S2R-IP4 ontology regarding exchanges of data it is described in the related fields into the properly entity (Offer or Travel Episode).	LegBoard LegStart ServiceTime AimedDepartureTime TimetabledTime
Point of Interest (POI)	POI is a Location that holds relevant information for a travel or which may be of Interest for a traveller during his journey.	StopPlace Location	This conceptual term has been inherited from IT2Rail	PointOfInterestStruct ure
Preference	The Traveller-related information that represents the travel-related needs	Passenger Contextual Preferences	This term is inherited from IT2Rail ontology but it was not used in its (IT2Rail) environment exchanges.	Preferences TripParamStructure
Price	Is the monetary value for a Product	Price Tax TravelEpisode OfferItem AncillaryService Offer Product Passenger Provider	This term has been inherited from IT2Rail	Price
Product	Is a travel-related, purchasable Service or Good supplied by a service provider.	TravelEpisode OfferItem Offer Provider Passenger	This term has been inherited from IT2Rail but only conceptually.	
Product Owner	A Product Owner creates Fare Products, fixes the Fare Rules (terms and conditions) attached to them used in the computation of the Fare Price. It can be a Transport Service Provider or Travel Service Provider (Tour Operator)	Product FareProduct FareRule Price Transport Service Provider Travel Service Provider	This term has been inherited from IT2Rail but only conceptually	
Product Provider	Is contractually responsible for providing a Product to the Traveller	Product Service Provider Traveller	This term has been inherited from IT2Rail but only conceptually.	OperatorCodeType TravelExpertId
Profile Connected Preferences	This is a list of personal characteristics of a user among which we can include some “stable” preferences, which are tailored by the permanent features of the customer, in the sense that they can be modified, but at a low rate (Years) (e.g.	Preferences Traveller	This term has been inherited from IT2Rail	Preferences

	Vegetarian food, Diabetic diet, ...). There preferences are permanently connected to the user (e.g. if he/she is on a wheel chair he/she prefers an elevator vs. an escalator).			
Provider	A Travel Service Provider (TSP) is a company providing travel services. TSP includes the transportation (on-board vehicles) and possibly services that are not transport but connected to it – either at the beginning or during the travel, like the access to a lounge or trip tracking – or at the end of the trip, like the access to after sales services.	Trip Transport Mode Transportation Service Transport	In IT2Rail exists various concepts related to it (e.g. Booking Provider). Those concepts have been kept from the glossary of S2R-IP4. In S2R-IP4 ontology, regarding exchange of data, they have been simplified in this unique entity where main differences are described in its related entity called additional Info.	OperatorCodeType TravelExpertId
Quotation	Pricing of the offer	Offer Price Tax Passenger	This term has been inherited from IT2Rail.	Prices
Reference	Data linked or related to other one.	TravelEpisode	This term has been inserted in S2R-IP4 ontology in order to use it for including needed additional information that has not been managed yet. In IT2Rail, it was used into exchanges of data	TravelEpisodeValidity TravelEpisodeId
Retailer	A retailer is an organization selling the Products of Travel Service Provider(s) using the services of Distributors. A retailer may have a direct relationship with a TSP whereby it acts as an appointed agent and/or it may have an indirect relationship with a TSP whereby it uses the services of a Commercial Distributor. A TSP can play the role of a retailer.	Product Travel Service Provider	This term has been inherited from IT2Rail	OperatorCodeType TravelExpertId
Route Link	An element of a Route that connects a pair of contiguous Stop Place(s) of the Route that will be performed with a vehicle.	Travel Episode	This term is inherited from IT2Rail.	TripLeg LegExtension
Sales Condition	Is a subset of terms and conditions specifying the conditions to be allowed to	OfferItem AdditionalInfo Provider	This term has been included conceptually in S2R-IP4 ontology but, regarding exchange of data, it is	

	book an OfferItem		inherited from IT2Rail	
Schedule	Transportation schedules, such as airline timetables, train schedules, bus schedules, and various public transport timetables are published to allow commuters to plan their travels. A schedule lists the times at which certain events, such as arrivals and departures at a transportation station, are planned to take place.	Transport Transport Mode Travel Arrival Departure	This term has been inherited from IT2Rail	StopEventResultStruc ture
Search Options	Among the Contextual Preferences there are still some possible choices left, which can be selected by the Traveller on a per-travel instance (e.g.: "hand_luggage_only", ...). These preferences can be selected by the user from a drop-down menu, where only a few residual possibilities are displayed, when planning or booking the travel (e.g.: "hand_luggage_only" can be meaningful only if the context is "airplane").	Preferences Traveller Travel	This term has been inherited from IT2Rail	TripParamStructure
Service Provider	Role of an Organization offering Service(s), especially but not exclusively on transportation.	Provider Travel Service Provider Transport Service Provider	This term has been inherited from IT2Rail	OperatorCodeType TravelExpertId
Stop Place	Is an element of the Infrastructure where Vehicle(s) may stop and where Traveler(s) may board or leave Vehicle(s). In most of the cases, a stop place has means to control the access to the transportation system.	Destination Origin Travel Episode Stop Place Type GeoCode Travel Episode End Point	This term is inherited from IT2Rail	StopPlace
Stop Place Type	Indicates the type of transport that starts and arrives in a stop place	Stop Place	In IT2Rail it was defined as a concept for each stop place (e.g. Airport). In S2R-IP4 glossary is kept these IT2Rail concepts. In S2R-IP4 ontology (exchange of data), it has been simplified in the same concept with a list of possible values (type within stop place).	Mode

Stop Point	The physical point at which passengers board or alight from Vehicle(s).	Travel Episode GeoCode	This conceptual term has been included in S2R-IP4 ontology.	StopPoint
Tax	Part of the Price of a Travel related to charges and duties.	Offer OfferItem TravelEpisode Price Quotation	This term has been included conceptually in S2R-IP4 but regarding exchanges of data, it is inherited from IT2Rail.	VatRate
Terms and Conditions	Terms and Conditions refer to the rules and provisions that can be applied to any type of product.	Offer OfferItem AncillaryService AfterSales SalesConditions TravelEpisode Provider Passenger	This term has been inherited from IT2Rail	InfoURL
Ticket	An artefact covering entitlement, embodiment and token	Embodiment Entitlement Token Payload	This conceptual term has been inherited from IT2Rail.	TicketStructure OfferItemTicketExten sion OfferItemContext
Ticket Time Limit	Time limit by which entitlement generation must occur before that inventory synchronization is undone, and the requested capacity/availability lost.	Entitlement Token Embodiment Ticket Payload	This term has been inherited from IT2Rail. Regarding exchange of data, this term has been included in specific field into the related entity Entitlement	ValidityDuration
Topology	The way in which constituent parts are interrelated or arranged		This conceptual term is inherited from IT2Rail.	
Transport	A category of travel which refers to on-board vehicle travel	Transport Mode Transportation Service	This conceptual term is inherited from IT2Rail.	
Transport Intelligence	All the KPIs provided to transport operators. A transport intelligence KPI could also be a travel intelligence KPI and vice versa. The two types of KPIs are not mutually exclusive	Transportation Service	This conceptual term is inherited from IT2Rail	
Transport Mode	Identifies the type of transportation for a specific segment offered by the travel service provider	Provider Transportation Service	In IT2Rail it was defined as a concept for each transport mode (e.g. Air transport mode). In S2R-IP4 glossary is kept these IT2Rail concepts. In S2R-IP4 ontology (exchange of data), it has been simplified in the same concept with a list of possible values (type within Provider related to Offer Item).	Mode
Transport Networks	A transport network refers to a group of lines of one or more transport modes,	Transportation Service Transport Mode	This conceptual term is inherited from IT2Rail.	

	within a geographical territory, provided by one or more companies and depending upon a local transport authority.			
Transport Service Provider (TSP)	Organization providing both services and means for journeys using one or more modes of transports: aircrafts, trains, metros, coaches, buses; or possible other services connected to the journeys (e.g. trip tracking). A Transport Service Provider can also be seen as a specific case of Travel Service Provider (see below) which is only responsible to the journeys. A Travel Service Provider is a company providing travel services. Travel includes "transport" (onboard vehicles) and possibly services which are not transport but connected to it – either at the beginning or during the travel, like the access to a lounge or trip tracking – or at the end of the trip, like the access to a sky resort. The Travel Service Provider offers the customers its Products (including Fare Products) for purchase (through Travel Shopping and Ticketing). It is also responsible for the travel service corresponding to the purchased offer.	Provider		OperatorCodeType TravelExpertId
Transportation Service	Service (Flight, Rail ...) that provides transportation on a Travel Episode	Transport Mode Provider Travel Episode	This conceptual term has been inserted in S2R-IP4 ontology. Regarding exchange of data, it is inherited from IT2Rail and inserted in a specific field into the related entities Provider and Travel Episode.	ServiceSectionStruct ure
Travel	Generic term without any technical assumptions, referring to the combination of services provided to a customer between a physical origin and a physical destination. Travel includes transport (on-	Trip Journey Itinerary	This conceptual term is inherited from IT2Rail.	

	board vehicles), as well as possible transfer between modes, possibly services which are offered during the trip out of vehicles, and possibly non-transport services which are proposed at either end of the trip from A to B.			
Travel Data	Generically, any information related to travels.	Travel	This conceptual term has been inherited from IT2Rail	
Travel Episode	Part of itinerary, characterized by Departure and Arrival, consisting of an ordered sequence of Route Links operated with the same vehicle.	Departure Arrival Stop Place Stop Point Route Link Trip Transportation Service Travel Episode End Point Mileage Duration	This term is inherited from IT2Rail but it has been modified in order to summarize the whole information itself instead of using other entities.	TripLeg LegExtension
Travel Episode Endpoint	A Travel Episode Endpoint is a Stop Place at which a Travel Episode starts or ends	Stop Place Travel Episode	This term has been inherited at conceptual level from IT2Rail but regarding exchange of data, it has been deleted and linked directly to the Stop Place in order to simplify the ontology in S2RIP4.	LegEnd LegAlight
Travel Expert	Technical entity that renders services to allow building an offer. This entity may be deployed by a TSP or distributor thus relying on a TSPs fare products and prices services	Provider Travel Solution Traveller	This conceptual term has been inherited from IT2Rail.	OperatorCodeType TravelExpertId
Travel Intelligence	All the KPIs provided to travellers. A travel intelligence KPI could also be a transport intelligence KPI and vice versa. The two types of KPIs are not mutually exclusive.	Transport Travel Passenger KPI		
Travel Solution	Solution provided to the customer answering its travel need.	Passenger Offer Travel Itinerary	This conceptual term has been inherited from IT2Rail	TripResultStructure
Travel Solution Aggregator (TSA)	Is a module for the calculation of itineraries and offers which interact with the IF – Broker to interface with TSPs. The TSA splits the mobility request of the traveller into parts per TSP and combines the responses in order to fulfil the mobility request.	Travel Mobility Request Traveller Travel Solution	This conceptual term has been inherited from IT2Rail	

Traveller	The Traveller (see also "Passenger" when on-board a vehicle) is the person making a travel in accordance with the terms and conditions of the entitlement(s)	Passenger Offer	This conceptual term has been inherited from IT2Rail.	UserExtension
Traveller Preferences	All information related to a customer or a traveller, which can be used by the travel solutions (fidelity program, PRM, preferred carrier, preferred Transport Mode, preferred payment means, needed facilities, etc.).	Preferences Passenger Travel		Preferences
Trip	A set of linked segments of an offer. However, for tracking a trip, the offer is not necessary.	Travel Episode Provider Partial Trip Tracker Passenger Subscription Impact Tracking Orchestrator	This conceptual term has been inherited from IT2Rail.	Trip
UniqueID	This identifies unambiguously a person in the whole Shift2Rail ecosystem.	Passenger	This term has been inherited from IT2Rail but regarding exchange of data, it is described in two fields (docType and docId) inside the passenger entity.	UserId
Unlimited Supply Product	A Product whose supply is not constrained by the Product Provider and is assumed to have unlimited Availability	Product Provider Ticket Time Limit Offer OfferItem TravelEpisode	This conceptual term has been inherited from IT2Rail	
User Interface	What the user is able to see and interact with		This term has been inherited from IT2Rail	
User Preferences	A set of characteristics representing the user needs and choices for traveling	Preferences Traveller Travel	This term has been inherited from IT2Rail	Preferences
UserID	A unique string of characters identifying a specific user. This unique identification is helpful to identify a user for different kinds of operations and on each of his devices	Passenger	This term has been inserted conceptually in S2R-IP4 ontology but it has been inherited from IT2Rail regarding exchange of data	UserId
UUID	Universally Unique Identifier: see UserID.			
Vehicle	Is a machine that transports Passenger(s) during a TravelEpisode	Passenger TravelEpisode		VehicleCodeType
Versioned	Set of parameters used by a TSP to build	Preferences Provider Fare	This term has been inherited from IT2Rail.	

Operational Parameter	its Offer Item, referring to Fare Product and Fare Rules and Topology.	Product Fare Rules		
Wallet	Technical component that will store customer / traveller preferences, itineraries and entitlements.	Offer Entitlement Passenger TripPreferences	This term has been inherited from IT2Rail	
WishedArrivalDate	ArrivalDateTime desired by the Customer.	ArrivalDateTime	This term has been inherited from IT2Rail.	DepArrTime
WishedDepartureDate	DepartureDateTime desired by the Customer.	DepartureDateTi me	This term has been inherited from IT2Rail.	DepArrTime
Zone	A set of stop places sharing a common set of business rules.	StopPlace Location	This conceptual term has been inherited from IT2Rail.	FareZoneStructure

Table 9.Definition and description of FREL Ontology entities (from the project “Co-Active” (EU) 2017/1926)