Progress towards Federated Logistics through the Integration of TEN-T into A Global Trade Network

D4.4 PI-facilitating technology Roadmaps for EGTN

Document Summary Information

Grant Agreement No	860274	**Acronym**	PLANET
Full Title	Progress towards Federated Logistics through the Integration of TEN-T into A Global Trade Network		
Start Date	01/06/2020	**Duration**	36 months
Project URL	www.planetproject.eu		
Deliverable	D4.4 PI-facilitating technology Roadmaps for EGTN		
Work Package	WP4-Steering innovation & building capacity towards EGTN		
Contractual due date	31/05/2023	**Actual submission date**	26/05/2023
Nature	Report	**Dissemination Level**	Public
Lead Beneficiary	15-ZLC		
Responsible Author	ZLC		
Contributions from	EUR, NEWO, NGS, IBM		

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement No 860274.

Revision history (including peer reviewing & quality control)

Version	Issue Date	% Complete[1]	Changes	Contributor(s)
V0.1	15/02/2021	5%	Initial Deliverable Structure (ToC)	ZLC
V0.4	29/06/2022	40%	Update after the first workshop	EUR, ZLC
V0.6	30/01/2023	70%	ST4.4.4 Incorporation of PI-facilitating technologies into current roadmaps (ERRAC, WATERBONE)	NEWO
V0.7	28/02/2023	85%	Key legal and policy initiatives barriers and results from the Simulation-based analysis of T&L and ICT innovation technologies	UIRR, EUR, ZLC
V0.8	20/04/2023	90%	Technical partners validation	NGS, IBM
V0.9	1/05/2023	95%	Executive summary, Conclusions	ZLC
V1	26/05/2023	100%	Quality assurance and document finalization	EUR, IBM, EBOS, ZLC

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1 According to PLANET's Quality Assurance Process

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
AI	Artificial Intelligence
BC	Blockchain

DSS	Decision Support Systems
DT	Digital Twin
DTLF	Digital Transport and Logistics Forum
eFTI	EU Regulation on electronic freight transport information
EGNOS	European Geostationary Navigation Overlay Service
EGTN	Integrated Green EU-Global Transport & Logistics Network
ERP	Enterprise Resource Planning
ETP	European Technology Platform
ICT	Information and communications technology
iMLU	Intelligent modular and logistics units
IoT	Internet of things
KER	Key Exploitable Result
LL	Living Lab
LMD	Last mile delivery
LSP	Logistics service provider
ML	Machine learning
PI	Physical Internet
S2R	Shift to rail
SCM	Supply Chain Management
SRIA	Strategic Research and Innovation Agenda
T&L	Transport and Logistics
TMS	Transport Management System
TRL	Technology Readiness Level
UAV	Unmanned aerial vehicle
WP	Work package

1 Executive Summary

PLANET Work Package 4 provides guidance and builds capacity on geo-economic and technological awareness. This awareness is critical in the development of the EGTN concept. The present report has been developed in the framework of T4.4 PI-facilitating technology Roadmaps. Its main objective is to deliver PI-facilitating technology Roadmaps towards an Integrated Green EU-Global T&L Network. This deliverable has built upon the findings from the project Living Labs and Sines Use Case, the solutions developed in WP2 and Task1.4 (Simulation-based analysis of T&L and ICT innovations), and Task1.3 (Legislation and EU policy to impact EGTN). It also consolidates results from other relevant EU Projects and initiatives, as the ALICE roadmap towards PI, and strategic documents from WATERBORNE and ERRAC. The methodology followed has relied in the consolidation of results and desk research, individual exploitation paths of PLANET solutions (in WP5), workshops and consecutive validation round with experts. The present document presents the interdependencies and prioritisation of technological areas for the PI realization. In this sense, finalising the coverage of 5G network in the European geography (and beyond it) and increase the IoT implementation along the T&L network has been identified as key enablers of the other technologies considered. After 5G and IoT, AI also enables the full potential of blockchain, iMLU, UAVs and AVs. The disruptive fifth mode of transportation, the hyperloop is also considered. Chapter 7 contains individual roadmaps for each technology, and Chapter 8 looks into the EU legislation and policy that may impact the technological aspects of the EGTN.

Finally, Chapter 9 compares PLANET vision of the PI/EGTN concepts with the strategies of the rail and water ETPs (ERRAC and WATERBORNE). It also identifies those elements that could accelerate the PI uptake by those platforms.

2 Introduction

In the general framework of PLANET WP4- Steering innovation & building capacity towards EGTN, this report aims to develop of technology awareness to understand how technological innovations can be deployed in support of the network and the role of the different with stakeholders amongst which are innovation communities, logistics and transport communities, as well as policy makers. The technology roadmaps presented in Chapter 7 have built upon the results of the project (results from the simulations in WP1, Platform services in WP2, impacts in the LLs, commercialization strategies in WP5) and other related initiatives.

A synoptic analysis of the project results and the strategic documents of the ERRAC and WATERBORNE platforms has also been performed, to identify synergies that could accelerate PI uptake in the mentioned ETPs.

2.1 Mapping PLANET Outputs

Purpose of this section is to map PLANET's Grant Agreement commitments, both within the formal Deliverable and Task description, against the project's respective outputs and work performed.

Table 1: Adherence to PLANET's GA Deliverable & Tasks Descriptions

PLANET GA Component Title	PLANET GA Component Outline	Respective Document Chapter(s)	Justification
DELIVERABLE			
D4.4 : PI-facilitating technology Roadmaps for EGTN	*In this report, the identified PI related advances in models and services from WP2 and WP3 and the outputs from related projects will be described*	Chapter 7	Chapter 7 presents the different technology roadmaps, "current status" section details the advances done in PLANET
	while the interdependencies between technology areas and sequence innovations for the facilitation of the PI will be presented.	Chapter 6	Interdependencies and sequence of innovations are presented in chapter 6
	Finally, the incorporation of PI-facilitating technologies into current roadmaps will be assessed.	Chapter 9	Section 9 is devoted to the incorporation of PLANET results into ERRAC and WATERBONE roadmaps
TASKS			
ST4.4.1 Consolidation of results from previous road	*will identify PI related advances in models and services from WP2 and WP3 and provide consolidated report*	Chapter 3 and Chapter 7	Chapter 3 introduces the PI and related road mapping exercise under the ALICE umbrella. Chapter 7 presents the services in WP2 and findings from the tests in WP3.

mapping initiatives	*including outputs from related projects.*		
T4.4.2 Impact documentation of technological areas on the PI	*will document impact of each identified technology area to the future of the PI.*	Chapter 5 and Chapter 7	Impact on PI characteristics is presented in Chapter 5. It is later expanded in Chapter 7
ST4.4.3 Prioritisation of technological areas for the facilitation of the PI	*will identify interdependencies between technology areas and prioritize or sequence innovations for the facilitation of the PI*	Chapter 6	Interdependencies and sequence of innovations are presented in chapter 6
ST4.4.4 Incorporation of PI-facilitating technologies into current roadmaps	*will assess development needs of current roadmaps of rail and water modes for incorporating PI technologies and exploiting their potential for contributing to EGNT.*	Chapter 9	Chapter 9 addresses roadmaps of rail and water modes and PLANET derived recommendations towards them.
ST4.4.5 Workshops definition, execution and follow up	*1 Workshop in M24, gathering together the three Living Labs stakeholder's groups and Advisory Board, especially industry to validate the roadmaps.*	Chapter 4 Road mapping methodology	Chapter 4 explain the methodology followed to develop this document, including workshops

2.2 Deliverable Overview and Report Structure

In this section, a description of the Deliverable's Structure is provided, outlining the respective Chapters and their content.

- Chapter 1 presents an Executive Summary that highlights the major points of the report and describes its conclusions and recommendations.
- Chapter 2 maps the PLANET Outputs and outlines the report structure.
- Chapter 3 introduces the concept of Physical Internet and consolidates previous road mapping initiatives.
- Chapter 4 explains the methodology that has been followed to develop this document
- Chapter 5 presents the PI-facilitating technologies considered in this document and their impacts on the PI characteristics.
- Chapter 6 shows the different interdependencies and prioritizations of technologies found according to three different scenarios defined in the project. This will serve as basis for the individual technology roadmaps in the next chapter.
- Chapter 7 presents the PI facilitating technology roadmaps.
- Chapter 8 brings attention to the EU legislation and policies that may facilitate or hinder the technology layer of the EGTN. It is based on the analysis done in PLANET D1.7-Legislation and EU Policy to impact EGTN final version.
- Chapter 9 tackles the incorporation of PLANET outputs in the WATERBONE and ERRAC strategic roadmaps

- Chapter 10 summarizes the main conclusions and Chapter 11 lists the references used in the development of this report.

3 The Physical Internet concept and previous road mapping initiatives

The Physical Internet (PI) is a holistic Supply Chain Management (SCM) concept that merges many relevant areas of current SCM research, including sustainability, effectiveness and efficiency of global value chains, information flows, as well as horizontal and vertical collaboration (Treiblmaier et al 2020). The PI is probably the most ambitious concept towards efficiency and sustainability in transport and logistics. It stands for a far-reaching reorganisation of freight transport and logistics.

The motivation for this paradigm shift is based on the claim that, "the way physical objects are moved, handled, stored, realized, supplied and used throughout the world is not sustainable economically, environmentally and socially" (Montreuil, 2010).

The model for the new concept is the Internet. When data is exchanged via the Internet, neither the sender nor the recipient is concerned about the path data packets take. The fact is data finds a way - without human intervention. This is ensured by both, autonomous networks, which are interconnected, and technically standardised Internet protocols.

The Physical Internet transfers the principles of data exchange on the Internet to goods transport in the real world in terms of technical and operational standardised protocols and automatic transport control. The objective is to make optimum use of vehicles, assets and the existing infrastructure through open and shared logistics networks and flexible goods routing making freight transport more efficient overall for companies and for society by reducing energy use and emissions.

The concept of the Physical Internet aims at realising full interconnectivity (information, physical and financial flows) of freight transport and logistics services and make them ready to be seamlessly usable as part of one large heterogeneous logistics network involving seamlessly truly interconnected subnetworks. The seamless physical, digital and process connectivity of the logistic networks will include transport, storage and physical handling operations of load units like containers, swap-bodies, pallets, boxes, etc., as well as associated processes to ensure correct execution of contracts in end-to-end supply chains.

For the Physical Internet, (existing) transshipment- and distribution-centres, roads, railways, waterways, and airway services are digitally connected to each other and services are visible and accessible to all users. Companies register transports needs from A to B through their own network or to its logistics service provider who transfers these requirements into their network. Shipments are then automatically planned and executed through PI services taking the best route through the fully networked transport and services infrastructure and accessing seamlessly external resources available to fulfil the assignment.

In this new open logistics system, goods can be routed in a similar way as data on the Internet. Of course, data packets on the Internet are boxes, pallets or containers in the Physical Internet and, contrary to the digital Internet, the cost of losing packets is important and non-negligible. The movement of "packets" in the PI is much slower, which allows in-transit management and higher flexibility in terms of information and financial flows management.

The Physical Internet is a logical evolution of existing approaches for increased efficiency in goods transport. This transformational change does not require heavy investments in infrastructure or other types of capital investments, but it does require a change in how business operations are arranged.

In today's logistics world, most of the logistics companies still need to develop proprietary logistics solutions for their clients (e.g., manufacturers and retailers) that include dedicated distribution centres and transport routes that, in many cases, imply some inefficiencies (e.g., low load factors, empty trips, too many stops in a route delivering a small number of units per stop, idle capacity in warehouses and terminals, etc.). The Physical Internet's objective is to open the existing dedicated infrastructure, assets and services to make them more available and accessible for use in a fully integrated network of logistics networks. In this way, logistics service providers and freight forwarders could make use of owned or third-party resources to address the consolidated demand of their portfolio of customers, leveraging the full potential of not only their logistics networks, resources, and capabilities, but those of the entire integrated network.

The Physical Internet should be inclusive, open and for the benefit of all stakeholders including SMEs. However, without proper steering and guidance, this transformation may not lead to a desirable future. The Physical Internet could develop in a different way, for example, as a monopolistic, very-profitable business but not necessarily open, accessible, and supporting sustainable solutions[2].

The PI is an integrative concept, rather than a single technology, which spans the boundaries between companies and therefore also necessitates substantial changes within and between organizations (Treiblmaier, 2019).

The Physical Internet Concept was outlined by Prof. Benoit Montreuil in the Physical Internet Manifesto in 2009, elaborated in the OpenFret project[3]. The concept and its foundations have evolved since then. In 2014, ALICE, the Alliance for Logistics Innovation through Collaboration in Europe, developed its research and innovation roadmaps[4] aiming to achieve a 30% improvement in efficiency and sustainability of logistics by 2030. It was recognized that the roadmaps' realisation and implementation would lead to a paradigm aligned with the Physical Internet concept. Thus, ALICE has the PI concept in the center of its strategic vision to achieve the sustainability goals and articulates this through different European Projects.

In the last decade, there has been a growing interest on the Physical Internet by researchers and companies. In 2017, the first published literature review, based on publications from 2016 and earlier, found 46 articles (Sternberg and Norrman, 2017). In early 2020, ScienceDirect's scientific publications database found 300 published articles about the "Physical Internet", most of them in the last 5 years.

The purpose of the FP7-SETRIS project5 was to deliver a cohesive and coordinated approach to research and innovation strategies of air, road, rail and waterborne transport modes in Europe. SETRIS sought to identify synergies between the transport European Technology Platforms' (ETPs´) strategic research and innovation agendas (SRIAs) and between these and relevant national platforms.

In the framework of SETRIS project, ALICE launched in 2017 its Research and Innovation Roadmap on the Physical Internet, complementary to ALICE Research and Innovation roadmaps. This roadmap has as background the major innovation areas identified and outlines how advancing in them will contribute to a real Physical Internet in 2050 (later adjusted to 2040).

[2] Dans, E. (2019) *The Battle For The Physical Internet* https://www.forbes.com/sites/enriquedans/2019/05/17/the-battle-for-the-physical-internet/#68092e883baa

[3] E. Ballot, R. Glardon and B. Montrueil (2010) OPENFRET report, PREDIT, FRANCE.

[4] https://www.etp-logistics.eu/roadmaps

[5] https://cordis.europa.eu/project/id/653739/es

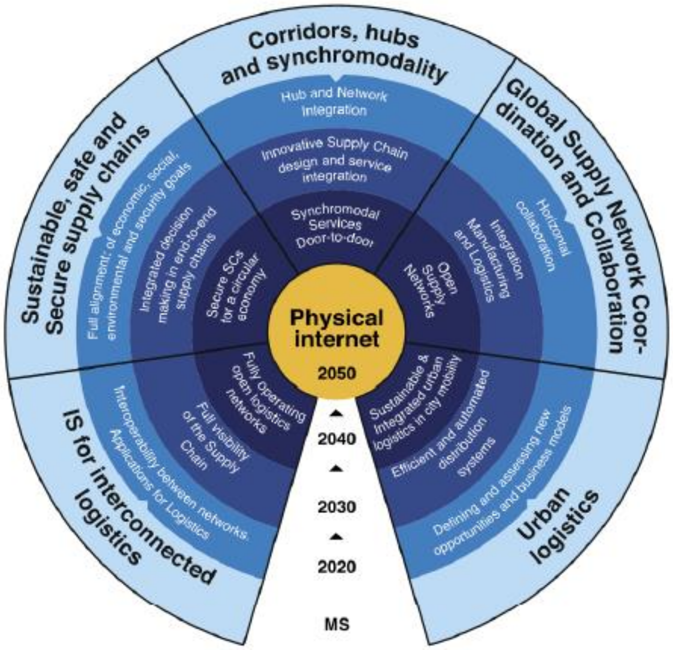

Figure 1 Milestones towards the Physical Internet (ALICE Research and Innovation Roadmap on the Physical Internet, SETRIS D3.1)

The roadmap addressed the components & technical developments (including standards) needed to achieve PI implementation. Those were grouped in the following topics (sorted regarding their importance):

1. Boxes, containers and physical handling
2. PI nodes and network operation
3. Data sharing (and data securing technologies)
4. Decision support
5. Work on standards
6. Business, governance and benefit models
7. Others (general IT-related issues also relevant for a realisation of the PI such as intuitive use of technology, combination of smart manufacturing and PI or usage of common IT-standards).

Expected impacts of the PI realization at different time-horizons regarding energy, costs, emissions and other (people, planet and profit) were also defined.

The H2020-SENSE[6] was a CSA aiming to accelerate the path towards the PI. It can be seen as a continuation of the work initiated in SETRIS. One of its outputs was the Roadmap to PI, a comprehensive roadmap sketching a path from 2020 now to 2040 showing important milestones, required technologies and first implementation opportunities for the PI.

[6] https://cordis.europa.eu/project/id/769967

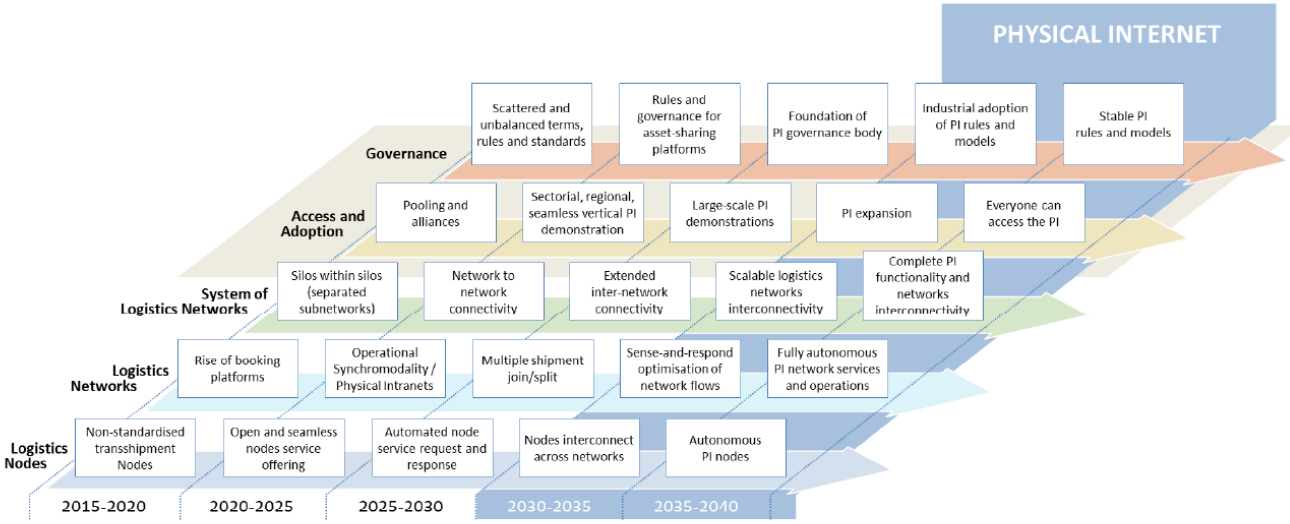

Figure 2 The Physical Internet Roadmap (SENSE D2.3)

Figure 2 summarizes the PI roadmap developed in SENSE project to explain the development of the PI over the next twenty years. The PI matrix shows the development path of five specific areas for the Physical Internet:

1. **From Logistics Nodes to PI Nodes** – In Logistics Nodes, goods are consumed, stored, transformed, or transshipped from one transport mode to another. Ports, airports, logistics hubs, terminals, distribution centres, warehouses, and depots are examples of Logistics Nodes. The Physical Internet envisions the development of Logistics Nodes into Physical Internet nodes in which operations are standardised and the usage of a family of standard and interoperable modular load units from maritime containers to smaller boxes is extensive. Services in PI nodes are visible and digitally accessible for planning, booking and execution of operations.

2. **From Logistics Networks to Physical Internet Networks** – Logistics networks include Logistics Nodes as well as the transportation services connecting the nodes and servicing the destination of shipments. Logistics networks are under the control of a single company (e.g., a shipper, a freight forwarder, a transportation company or a logistics service provider) covering their value chain (i.e., customers and suppliers). PI networks are expected to build seamless, flexible and resilient, door-to-door services consolidating and deconsolidating all shipments within the network in which all assets, capabilities and resources are visible, accessible and usable to make the most efficient use of them.

3. **Developing the System of Logistics Networks towards the Physical Internet** – A System of Logistics Networks includes several individual logistics networks. These networks are interconnected and, therefore, the assets, resources and services in the individual logistics networks can be accessed by the individual logistics network owners. The System of Logistics Networks forms the backbone of the Physical Internet and requires secure, efficient and extensible services for the flow of goods, information and finances across the networks.

4. **Access and Adoption –** Access and adoption describes the main requirements to access the Physical Internet through a logistics network. It also includes different steps and mind shifts required for organisations to adopt Physical Internet concepts.

5. **Governance** – Governance includes the developments needed to evolve the Logistics Nodes, logistics networks and the System of Logistics Networks into the Physical Internet, i.e., the rules defined by the stakeholders managing the various networks and nodes and users of their services as well as the trust building processes and mechanisms required to ensure that the PI operates to the advantage of all stakeholders.

In SENSE's PI roadmap, the role of technologies is envisioned as enablers and facilitators of the development paths.

There are emerging new, disruptive technologies linked to the Industry 4.0. As they increase in maturity they will act as enablers of facilitators of the PI concept and make it gain more capabilities. Those emerging technologies are, among others Blockchain, iMLUs, Hyperloop, ML, AVs, UAVs, 5G, EGNOS and 3D Printing, Sensors and IoT. Their impact on the logistics operational system and the potential development paths that lead to the optimal exploitation of their positive effect in form of the PI are the subject of this document.

4 PLANET Roadmapping methodology

The methodology followed in this task was based on desk research, technical expertise of the project partners and workshops execution.

Initially, a desk research effort was done in order to consolidate results from previous initiatives, such as ALICE-ETP, and other European projects working on the PI realization and/or the development of the technologies in the scope of this document in the T&L domain.

An online workshop with PLANET consortium was arranged by EUR and ZLC in June 2022 to identify the interdependencies between technologies and sequence the innovations for the facilitation of the PI.

The workshop was arranged in Teams and the on-line environment Miroboard was used. Based on some inputs provided by the leading partners, the participants in the workshop were requested to prioritize innovations in the roadmap toward PI. The following one-pagers were prepared to trigger the discussion and be validated by the participants:

1. Technologies (current TRL level) and their expected impact on EGTN;
2. Infrastructural aspects (current state of TEN-T network, regional developments, data infrastructure);
3. Regulations (current developments);
4. Stakeholders needs (one page per domain).

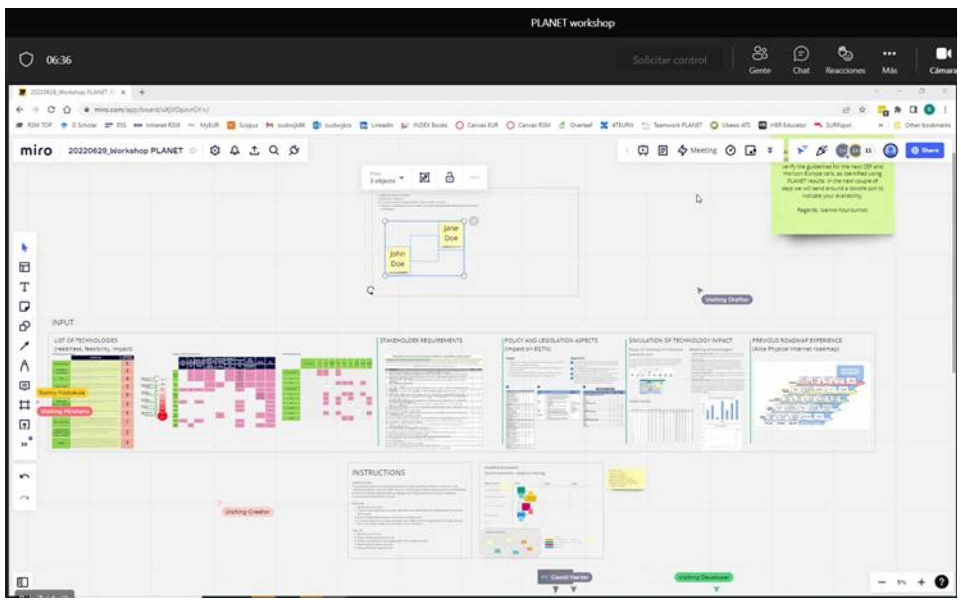

Figure 3 Workshop screenshot

The team working in the task defined three different scenarios, following the three use cases based on the project Living Labs defined in D1.9 Simulation-based analysis of T&L and ICT innovation technologies:

- Last mile delivery
- Maritime transport
- Inland transport

In the context of defining the three scenarios of last-mile delivery, maritime transportation, and inland transportation, another perspective is to consider how the scope of activities is categorized in door-to-door transportation. Door-to-door transportation involves various stages or legs, which can be broadly classified into two levels: international and regional. At the international level, the transportation process encompasses activities that occur across different countries or even continents. This includes the movement of goods from the originating location, such as a factory or warehouse, to the port or terminal for export and vice versa (i.e., import). Once the goods reach the port, they are typically loaded onto maritime vessels for transport across the sea. This maritime leg constitutes a significant part of international transportation, especially for long-distance shipments. After the maritime leg, the goods arrive at the destination port or terminal, marking the transition to the regional level of transportation. At this stage, the focus shifts to the movement of goods within a specific region or country (inland transportation). The last-mile leg comes into play, which involves the transportation of goods from the port to the final destination, often a customer's doorstep or a local distribution center. This leg is crucial for completing the entire transportation chain and ensuring that the goods reach the intended recipients efficiently and on time. By categorizing the scope of activities in this manner, the three scenarios of last-mile, maritime, and hinterland can be understood as distinct components of the door-to-door transportation process. It is crucial to recognize that the each of these scenarios involve distinct communities of stakeholders. Each scenario has its own set of players and dynamics, highlighting the importance of understanding their unique characteristics when assessing the impact of technology development on creating a PI (Physical Internet) based transportation network. Consequently, the formulation of technology roadmaps must be tailored to each scenario, recognizing their specific requirements and challenges. Considering these separate domains as use-cases becomes essential to effectively address the needs and opportunities within each scenario and ensure the successful implementation of technology-driven solutions within the broader transportation network.

In the workshop, the group of experts was split into three, each one working on one of the scenarios with the goal to identify the interdependencies between technologies and sequence innovations for the PI facilitation.

A follow-up session for enriching and validating the workshop results was carried out in the consortium meeting that was held in Poznan in October 2022, also using Miro board.

Those outputs together with PLANET developments in WP2 and WP3, and results from related projects were used to draft the individual Technologies Roadmaps that consider the current state of the technology regarding the PI, and the developments needed in the timeframes 2022-2030, 2030-2050, and beyond 2050 (when it applies). The roadmaps were later validated with the technical experts in the consortium.

Finally, in order to assess development needs of rail and water modes for incorporating PI technologies and exploiting their potential for contributing to EGNT, the subtask leaders NEWO, analyzed the main features of ETPs regarding Rail and Waterborne transportation – ERRAC and WATERBORNE - in the aspects mirroring PLANET scope and deliveries and how to incorporate PLANET results into their current roadmaps.

A final round of validation took place in the framework of T4.3, as the roadmaps were part of one of the e-learning courses piloted in the project (Innovation Technologies: Impact and Roadmap).

5 PI -facilitating technologies

The following technologies are considered in this document:

- **Blockchain** is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets (both, tangible and intangible) in a business network[7]. The biggest advantage that blockchain has brought along with it is the increased trust within and between organizations, without the need for a third party, by ensuring the accuracy and security of a record of data[8].
- **Artificial Intelligence/Machine Learning** Artificial intelligence (AI) can be defined as the science and engineering of intelligent machines with a special focus on intelligent computer programs. Machine learning (ML) is considered as an integral part of AI, which refers to the automated detection of meaningful patterns in datasets. ML tools aim to increase the efficiency of algorithms by ensuring the ability to learn and adapt based on big-data analytics[9]. This is a technology used to help mitigate risks and uncertainties through data analysis, processes optimization and forecasting (Supply Chain Planning; Inventory optimization, warehouse management/analysis; Demand Prediction; Logistics Route Optimization; Supplier Selection).
- **IoT** refers to a network of physical devices integrated with sensors, software, and other technologies for connecting and sharing data with other devices and systems through the internet. Internet of Things is normally set up with a three-layer technological stack. The device layer includes the hardware, sensors, and embedded software that run on the hardware devices. The connectivity layer in the middle consists of network communication protocols that allow devices to communicate. An IoT cloud layer at the top provides features like control of devices, analytics, and data management, as well as common IoT application software. These three layers together enable seamless communication between people, processes, and things[10].
- **Intelligent Modular Load Units** "iMLUs" or PI-containers are standardized, smart and modularized in terms of size and dimension, enabling herewith, on the one hand, secure protection of the encapsulated products and on the other hand an efficient utilization of automated process handling. iMLUs contribute to the network efficiency by reducing empty space and allowing smart routing of products across the logistics network. Also provide added value services such as monitoring product conditions, detecting security problems and providing information for loading and unloading systems.
- **5G** is the 5th generation mobile network. 5G wireless technology is meant to enable faster, stable and secure connectivity for high-speed data transfer, ultra-low latency, more reliability, massive network capacity, increased availability, and a more uniform user experience. Due to the increased bandwidth, 5G will make possible new applications in internet-of-things (IoT) and machine-to-machine areas where networks can serve billions of connected IoT devices with the right tradeoff between speed latency and cost.
- The European Geostationary Navigation Overlay Service (**EGNOS**) is Europe's regional satellite-based augmentation system (SBAS) that is used to improve the performance of global navigation satellite systems (GNSSs), such as GPS and Galileo. It has been deployed to provide safety of life navigation services to aviation, maritime and land-based users over most of Europe. Expected to accelerate transition towards PI.
- **Hyperloop** as a disruptive, sustainable and competitive alternative for air cargo (A hypothetical 10.000 km European hyperloop network would be able to take over 65% of the flights within the EU). Hyperloop addresses small and medium cargo units. Focus on time-sensitive, demand-sensitive and high-value products, such as fresh food, horticultural products, pharmaceuticals, e-commerce, fashion, electronics, and high technology equipment.

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[7] IBM. (2022). *What is Blockchain?* https://www.ibm.com/topics/what-is-blockchain

[8] Hayes, A. (2022). *What is a blockchain?* Investopedia. https://www.investopedia.com/terms/b/blockchain.asp

[9] Woschank, M.; Rauch, E.; Zsifkovits, H. A Review of Further Directions for Artificial Intelligence, Machine Learning, and Deep Learning in Smart Logistics. Sustainability 2020, 12, 3760. https://doi.org/10.3390/su12093760

[10] Oracle. (2022). *What is IoT?* https://www.oracle.com/internet-of-things/what-is-iot/

- **Unmanned aerial vehicles** (UAVs) are aircrafts that carry no human pilots or passengers. UAVs — sometimes called “drones” are more often controlled remotely by a human pilot. Autonomous vehicles, or driverless vehicles, are ones that can operate themselves and perform necessary functions without any human intervention, through ability to sense their surroundings. An autonomous vehicle utilizes a fully automated driving system to allow the vehicle to respond to external conditions that a human driver would manage. There are six different levels of automation and, as the levels increase, the extent of the driverless car’s independence regarding operation control increases.
- **Autonomous vehicles, “**Ground Drones” or EAVs have been typically used in intra-logistics operations. Nowadays, new applications of this technology can be observed in extra logistics, as car and truck producers strive to provide autonomous vehicles, and thus pave a path for EAVs commercial use in extra-logistics (Kunze, 2016) .

3D printing “additive manufacturing” enables companies to design and produce new products, easily individualizing them to meet the end-user’s growing needs for customization and personalization. This technology was not further investigated as it was not finally considered in any of the project activities.

Benoit Montreuil defined in 2011 (Montreuil 2011) which are the key characteristics of the PI. The following table indicates in which of those characteristics each of the considered technologies impact on. Individual technology roadmaps are presented in Chapter 7.

Table 2 Impact on PI characteristics

Technology	Impact on PI characteristics (Montreuil, Benoit 2011)									
	Smart encapsulation	IoT enabled Visibility	Digital and operational interconnectivity	Evolve network to distributed multi-segment intermodal	Materialize objects as locally as possible	Sharing information about performance and capability	Connected and autonomous SCs	Open network, Resources sharing/Collaboration	Network Resilience	BMs Innovation
Blockchain		x	x	x		x	when integration with algorithms, smart contracts	x	x	x
Machine Learning				x	x	x	synchromodal route optimization	x	x	x
IoT	x	x	x	x			x		x	x
Hyperloop	x (potentially)		x						x (as it provides an alternative transportation mode)	x
5G standard	x	x	x				x			x
Unmanned Aerial Vehicles "UAVs"							x			x
AVs							x			x
3D Printing					x			x	x	x
Intelligent Modular Load Units "iMLUs"	x	x	x				x			x
EGNOS		x					x		x	x

6 Interdependencies and Prioritisation of technological areas for the facilitation of the PI.

As explained in the methodology chapter (Chapter 4), to enable the identification of interdependencies between technologies and sequence innovations for the PI, the PLANET team working on this task defined three different scenarios, following the three use cases based on the project Living Labs defined in D1.9 Simulation-based analysis of T&L and ICT innovation technologies:

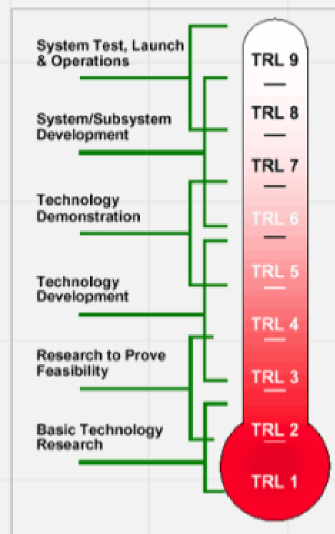
- Last mile delivery
- Maritime transport
- Inland transport

Additionally, maturity levels for each technology were identified and validated by the project consortium, in the form of Technology readiness level (TRL)[11]. TRL scale spans over nine levels and is defined as a type of measurement system used to assess the maturity level of a particular technology. The next table shows the results.

Table 3TRL values of the different technologies considered

Technology description

TECHNOLOGIES	DESCRIPTION	READINESS (TRL level)
Blockchain	Creates transparency, interconnectivity, and trust	6
Machine Learning	data analysis, optimize processess and forecasting (Supply Chain Planning; Inventory optimization, warehouse management/analysis; Demand Prediction; Logistics Route Optimization; Supplier Selection)	9
IoT	IoT potentially provides an end-to-end visibility of the PI objects, operations, and systems through ubiquitous information exchange.	9
Hyperloop	Alternative for air cargo. Addresses small and medium cargo units. Focus on time-sensitive, demand-sensitive and high-value products, such as fresh food, horticultural products, pharmaceuticals, e-commerce, fashion, electronics, and high technology equipment.	3
5G standard	5th generation of wireless data networks. Will transmit information at faster speeds, with lower latency (virtually real-time) and higher reliability than previous generations.	9
Unmanned Aerial Vehicle (UAV)	In city logistics can provide final and last segments of the Physical Internet-enabled hyperconnected logistics and transportation networks.	6
Autonomous Vehicles (AV)	Autonomous vehicles. ePIcenter sister project has an UC around this technology	6
3D printing	The term "3D printing" covers a range of printing technologies that apply different approaches. While these technologies differ significantly, they all pursue the same purpose: creating complex designs and effortlessly customizable products on an individual basis. This enables companies to design and produce new products, easily individualizing them to meet the end-user's growing needs for customization and personalization.	7
Intelligent modular load units (iMLU)	Standardized, smart and modularized in terms of size and dimension, enabling herewith, on the one hand, secure protection of the encapsulated products and on the other hand an efficient utilization of automated process handling	5
EGNOS	The European Geostationary Navigation Overlay Service (EGNOS) is Europe's regional satellite-based augmentation system (SBAS) that is used to improve the performance of global navigation satellite systems (GNSSs), such as GPS and Galileo. It has been deployed to provide safety of life navigation services to aviation, maritime and land-based users over most of Europe. Expected to accelerate transition towards PI. Sister project ePIcenter develops a use case on it (also on AVs)	9



The outputs of this activity fed the technology roadmaps presented in Chapter 7.

[11] https://euraxess.ec.europa.eu/career-development/researchers/manual-scientific-entrepreneurship/major-steps/trl

6.1 Interdependencies and prioritisation of technological areas for the facilitation of the PI in the LAST MILE

The last few years have seen and will continue to see an exponential growth in globalization and e-commerce. While the e-commerce market size was valued at $ 4.21 Trillion in 2020, it is projected to reach $ 17.53 Trillion by 2030, growing at a CAGR of 15.1% from 2021 to 2030 (Rake & Wadodkar, 2021). With the potential to capture an enormous market share, businesses are becoming increasingly competitive, demanding their Logistics Service Providers (LSPs) for faster, cheaper, and greener logistics services across the length and breadth of their supply chains. The requirements for businesses to shorten the delivery times of their products to their final customers across the globe while reducing not only their costs but also their carbon footprint has opened a plethora of opportunities for research and innovation involving different stakeholders.

Figure 4 highlights the roadmap developed for the prioritization of technological areas to facilitate the Physical internet concept in the last mile after discussions with participants from different WPs of the PLANET project.

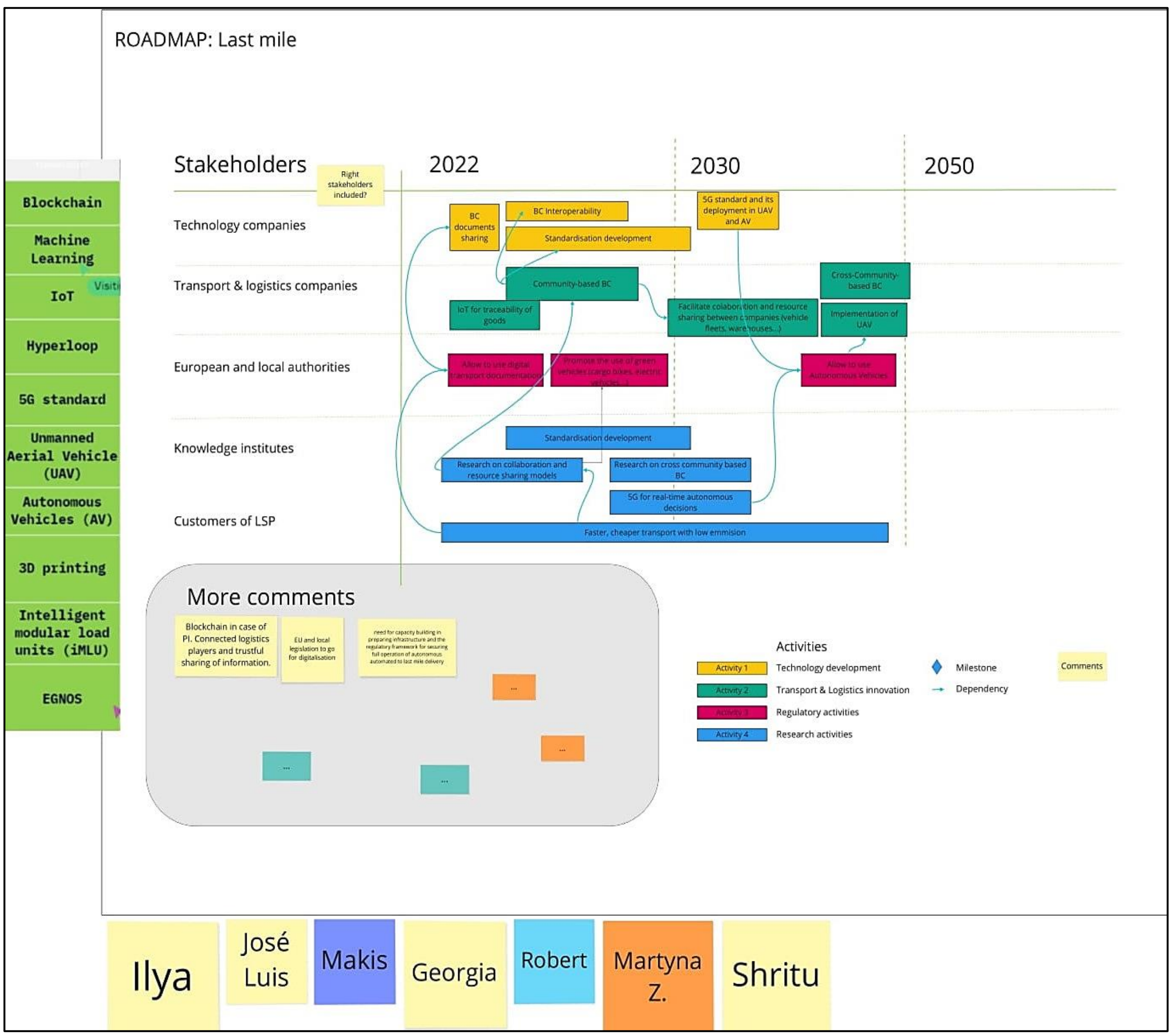


Figure 4 Roadmap for prioritization in the last mile (workshop)

As can be observed, the roadmap developed can be divided into two major stages, as delineated below:

I. **Stage 1 (2022-2030):**

Last mile delivery is increasingly becoming challenging where enterprises need to figure out how to get products to customers' doors more cost-effectively without compromising delivery. In the age of omni-channel operations, the current state of last mile logistics is highly fragmented with individual organizations operating independently and where warehouses and modes of transport are not shared. These independent and closed operations make last-mile delivery less effective, with low vehicle fill rates and empty back hauls that drive up costs and emissions. However, the concept of physical internet, which is based on the main principle of an open access and interconnected logistics network, promises to enhance the scalability, effectiveness, resilience, and sustainability of current last-mile operations. In the past few years, several technologies such as IoT, Blockchain, etc. have emerged and continue to evolve as solutions to handle the nuances of the last mile delivery operations and facilitate PI.

As required by the PI concept, digitizing all available information is the first step in building an open access, interconnected last mile logistics network. The period of 2022-2030 in the roadmap is associated with *digitization* of logistics processes, physical assets, services, and capabilities of various organizations operating in the last mile. In addition, this stage also focuses on the *development of standards and protocols* to enable seamless sharing of data and information among these organizations, which together form a system of logistics networks. As observed in Fig. 1, Knowledge institutes, European and local authorities, Transport and Logistics as well as technology companies are major stakeholders who would be involved in the research, development, and authorization phase of various technologies in the last mile.

II. <u>Stage 2 (2030-2050):</u>

While Stage 1 placed a lot of emphasis on researching, developing, and testing use cases of various technologies in the last mile delivery, this stage focuses on the widespread use of these technologies and the complete automation of logistics processes in the last mile. As observed in Fig. 1, Technology and Transport and Logistics companies are major stakeholders who would be involved in the implementation of different technologies to facilitate PI in the last mile.

6.2 Interdependencies and prioritisation of technological areas for the facilitation of the PI in the Port Hinterland

Figure 5 highlights the roadmap developed for the prioritization of technological areas to facilitate the Physical internet concept in Hinterland transportation after discussions with participants from different WPs of the PLANET project.

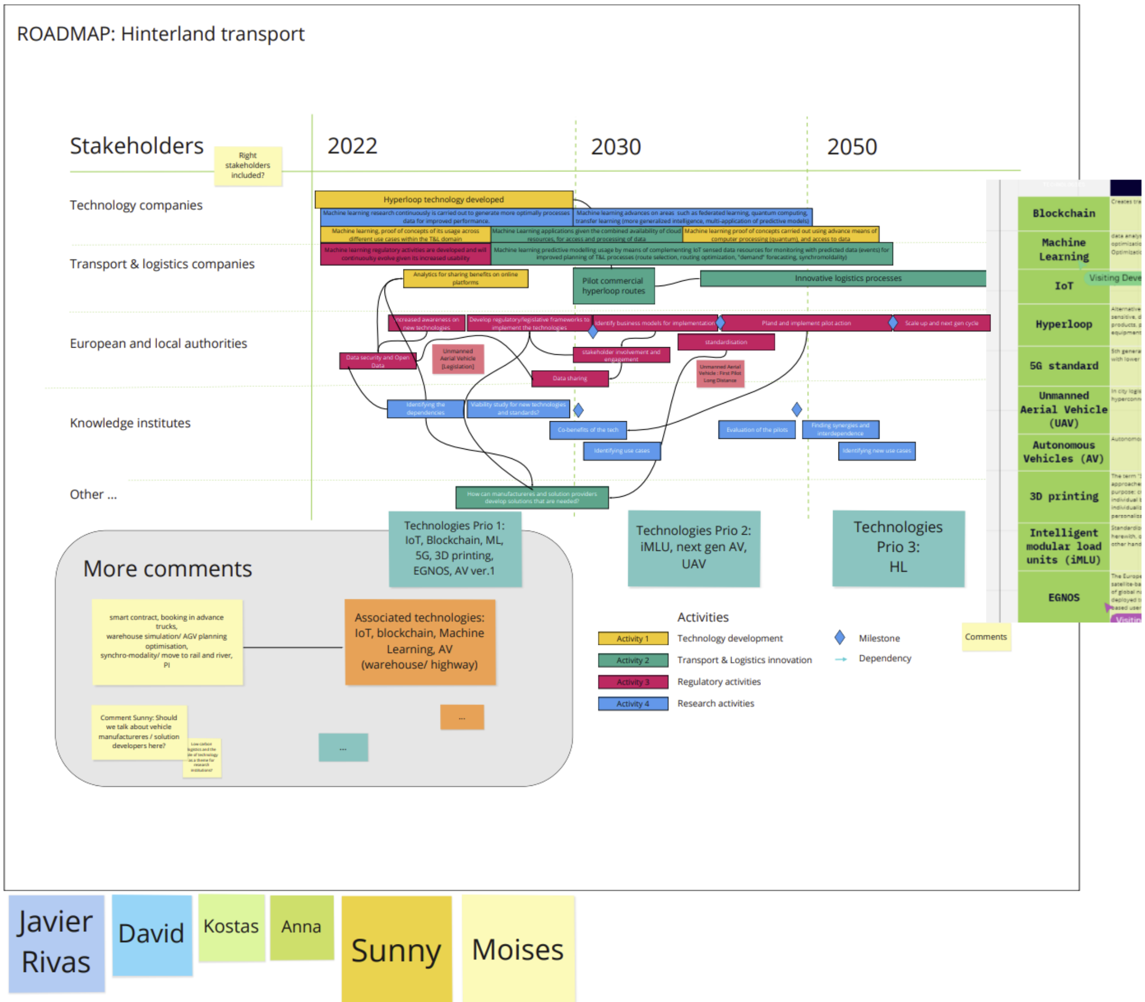


Figure 5 Roadmap for prioritization in the hinterland transport (workshop)

As can be observed, the roadmap developed can roughly be divided into two major stages, as delineated below:

I. <u>Stage 1 (2022-2030):</u>

Port hinterland transportation is both a well-established, perhaps even traditional domain, while at the same time confronted with major disruptive developments. Innovative concepts are developed to address the accompanying challenges. Main issues that hinterland transportation is confronted with are relatively high operational costs, lack of reliability, and negative externalities. Some of these are caused by congestion on road networks and at port facilities, the latter also for barge transportation. Policy makers aim to steer at modal shift in favor of modes alternative to road transport. There is also general understanding that in Europe, expansion of physical transport capacity is not feasible. Therefore, better utilization of existing infrastructures is favored. The improvement of decision logic in the planning and execution of transportation is an enabler.

This explains the interest workshop participants in machine learning as a tool to further improve transportation performance. One the one hand, in the coming years, machine learning as a tool needs to prove its worth in transport applications, while rules and regulations need to incorporate the possible side-effects of automated decision making, for instance. The solutions at hand need not be developed by incumbents in the logistics domain, but could well be (and are) developed by new entrants.

Decision logic may be applied to decision support tools such as planning systems in companies, but may play a specific role as part of information services provided through digital platforms. These platforms represent their own dynamics in the market, while striving for zero marginal costs or scalability of information services.

Part of the societal discussion around digital platforms are data security and open data, and such a discussion requires increased awareness of the new technologies that develop in combination with the rise of these platforms. Research needs to be conducted to properly address the aforementioned technological developments and their intended and unintended consequences. Some research objectives will pursue the development of smart decision logic for freight transportation, while other research objectives will inform policy measures and standards that help govern these technological developments in the logistics domain and in society at large.

Hyperloop, with its dedicated and costly infrastructure, could serve a specific market segment in the mobility of freight. Question is whether this particular technology has a role to play in the next few years.

Renewable energy sources are left out of scope in PLANET, but certainly play an important role. The current project MAGPIE[12] addresses this topic also for the port hinterland.

II. **Stage 2 (2030-2050):**

In this stage, some of the foreseen technologies have matured and need to be developed further. The participants in the workshop elaborated on such developments in the case of machine learning. Topics areas are federated learning, which allows multiple system to jointly deploy descriptive, predictive, or prescriptive capabilities, while using distributed data sources from IoT devices for instance. This should benefit the (collaborative) planning of transport and logistics in a dynamic fashion. Here synchromodality serves as an example toward Physical Internet.

At the same time, rules and regulations have been set to allow for the responsible adoption of the various technologies. Clear examples are machine learning and other AI technologies that challenge the verifiability and legal status of autonomous behavior by algorithms, and Unmanned Aerial Vehicle deployment that ask for regulations concerning the general use of aerospace, and data sharing among machines that do not necessarily represent legal entities. Development of such rules and regulation requires, amongst other things, identification and involvement of the relevant stakeholders.

Standardization of technologies at various levels and their uses in logistics needs a proper understanding of the relevant use cases in which they provide value to stakeholders. In particular, standardization initiatives need to have an open eye for competitive forces (“standard wars”) and a proper balance between the need for interoperability and room for innovation. These use cases will materialize in pilot studies in research projects that will help to conclude on such matters. This is a ongoing process in which findings from one generation of use cases are a source of inspiration for a new generation of use cases in follow-up projects.

The hyperloop concept should now develop into a viable option with operational pilot trajectories.

The discussion around the consecutive stages also led to a prioritization of technologies:

Priority 1: IoT, Blockchain, ML, 5G, 3D printing, EGNOS, AV

Priority 2: iMLU, next gen AV, UAV

Priority 3: Hyperloop

6.3 Interdependencies and prioritisation of technological areas for the facilitation of the PI in the Gateway to Hinterland

Figure 6 depicts the roadmap developed for the prioritization of technological areas to facilitate the Physical internet concept in maritime transportation and ports after discussions with participants from different WPs of the PLANET project.

[12] https://www.magpie-ports.eu/

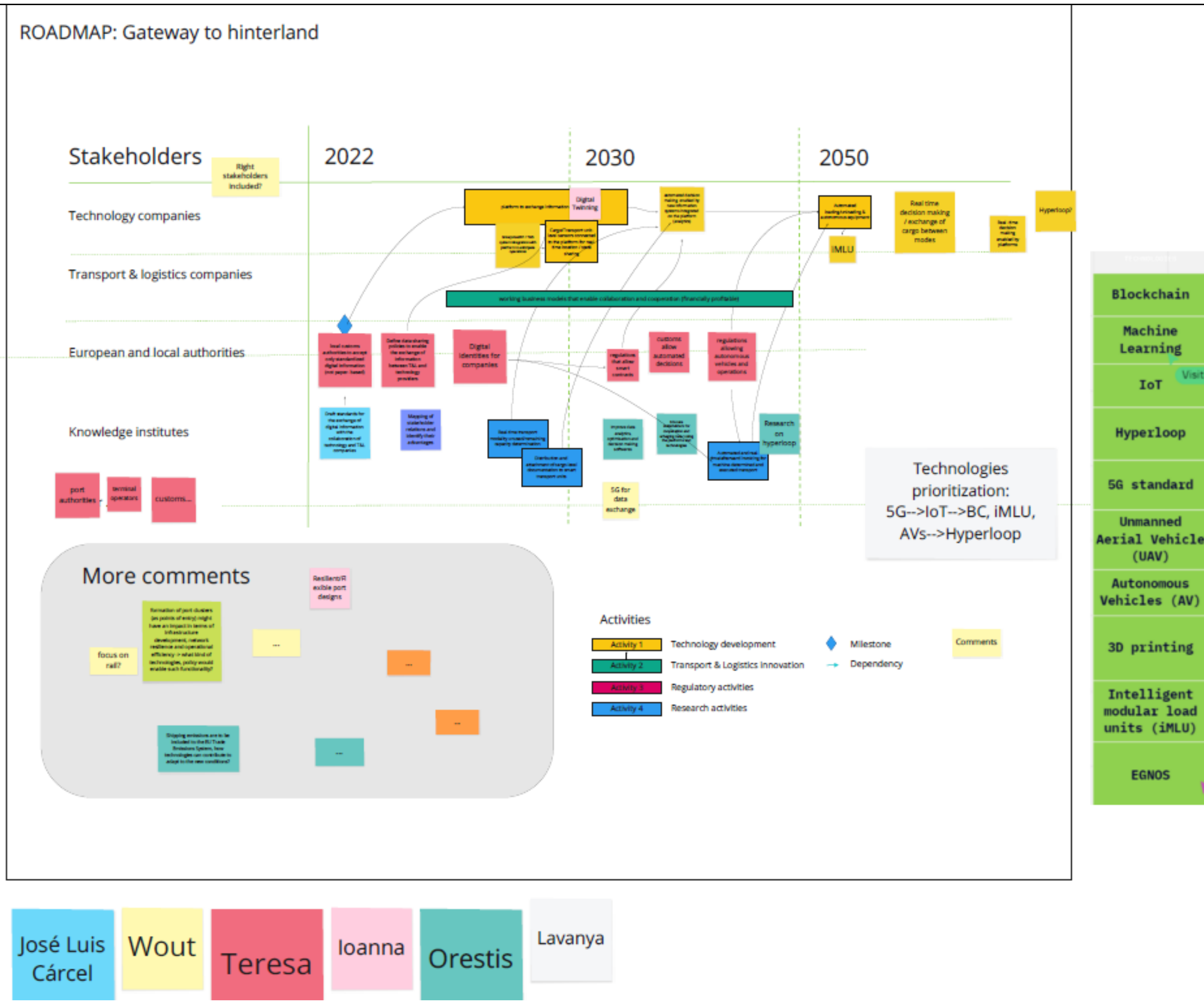


Figure 6 Roadmap for prioritization in the gateway to hinterland (workshop)

The roadmap developed can roughly be divided into three major stages:

I. **Stage 1 (2022-2030):**

Development of a digital twin of port operations- a platform to exchange information integrated with the enterprises' ERPs/TMSs. Cargo equipped with sensors connected to the platform. Automated decision making enabled by analytics integrated also in the platform.

This DT would completely support the role of ports as intelligent PI nodes, and requires of the following three elements:

- Development of business models enabling the cooperation.
- Regulations and policies enabling transition towards digital documents sharing and automated decision making
- Research and adherence to standards for digital information exchange

II. **Stage 2 (2030-2050):**

The project team identified automated and intelligent exchange of cargo between modes as the next logical step. Thus, iMLU and the appropriate handing equipment are required in this stage, supported by a more mature version of the DT.

III. **Stage 3 (2050 onwards):**

In the long run, the experts considered that Hyperloop development would take place in this third stage. This disruptive technology needs first to face some regulatory and infrastructure-related challenges. By 2050 it is expected that it is mature enough to start practical implementations to automate container movements, first between terminals and afterwards as part of the overall network.

The experts identified the following two strands of technology development: 5G, IoT, and BC and ML and iMLU, AVs and finally Hyperloop.

7 Technology roadmaps

PLANET team identified the following interdependencies in the general context of T&L between technology areas.

Table 4 PI facilitating technologies interdependencies

Interdependencies

TECHNOLOGIES	Blockchain	ML	IoT	Hyperloop	5G	UAV	AV	3D print.	iMLU	EGNOS
Blockchain	x	x	x		x					
ML		x								
IoT			x		x	x	x		x	
Hyperloop				x						
5G			x		x	x	x		x	
UAV			x		x	x	x			x
AV			x		x		x			x
3D print.								x		
iMLU			x		x				x	x
EGNOS						x	x			x

Based on the previous chapters and the exploitation paths drafted for PLANET KERs in WP5, the following roadmaps for the technologies enabling the PI realization have been developed.

7.1 Internet of Things

Based on the work done in previous chapters, the project team developed the following PI-facilitating technology Roadmap for IoT.

7.1.1 Current Status

IoT has continued to grow in popularity in recent years, with more and more devices being connected to the internet. In 2016, there were an estimated 8.4 billion connected devices, and this reached the number of 20.4 billion in 2020. It is estimated that there will be 75 billion devices connected to the internet by 2025. Despite its increasing significance in the recent years, the potential of IoT technology in the T&L domain is yet to be fully realized (Tanweer, 2018).

PLANET EGTN Platform is designed to meet the particular needs of the T&L industry by implementing a customised combination of technologies and models. The EGTN architecture imports data both in real time and in batch from various sources, such as IoT networks and devices.

Living Labs have served as testbeds for the solutions developed in the project. LL1 and LL3 carried out IoT deployment for worldwide tracking of containers and other load units and logistics assets rail and maritime Asia-Europe shipments and warehouses.

On the one hand, **Track & Trace monitoring** service deployed at the EGTN platform enables the visibility of the shipment by proving detailed information, such as position, temperature, luminance, humidity, acceleration. Supply chain visibility is a critical component of the PI, aiming to create a more transparent supply chain.

On the other hand, IoT data together with traffic and weather information can be fed into the platform and used for offering T&L actors **real-time automated decisions** as will be discussed later. In this sense, IoT is a pre-requisite for the deployment of other technologies with the ability to extract information and create rules for decision making (AI) through forecasting or navigation (UAVs and AVs).

IoT technology is also essential to provide information to the blockchain and for the development of iMLU.

To unleash the full potential of the IoT, a widespread implementation of **5G network** is required.

7.1.2 Roadmap for 2022-2030

Large scale implementation of IoT for tracking and tracing goods. The following example refers to the last mile scenario:

To facilitate PI by 2040, every mode of transport, logistics hub, and customer location will have to be recorded electronically. Thus, this stage needs to ensure large scale implementation of IoT in last mile which would help create greater visibility of the parcel's location, quality of the parcel (in case of sensitive products) and also ETA of the parcel at customer location. The IoT enabled PI would provide last mile logistics service providers a chance to become more user-friendly, resilient, effective, sustainable, and flexible by altering how physical objects move across the network. Additionally, IoT technology in the last mile can assist in gathering data on traffic congestion, use of hubs (e.g., warehouses) and bottleneck locations.

Large scale implementation of IoT will help in enabling the hyper connection of players and standardized information sharing which is necessary to integrate other modern technologies. The integrated technologies like Blockchain, ML and AI, can be fed with the data collected through IoT sensors which can then help plan and optimize last mile delivery routes.

7.1.3 Roadmap for 2030-2050

In this stage, IoT would support the implementation of other key technologies. Complete digitization of assets using IoT during Stage 1 is key to the success of implementing BC in Stages 1 and 2, as the data collected through IoT can be stored and shared via BC platforms with other enterprises in a system of logistic network to facilitate PI. Further, IoT will help in the deployment of UAV and AI. Integration of IoT with Blockchain helps in improving the security of data and also make the system cyber proof. The development of an IoT management hub that requests access control information from other technologies on behalf of IoT is required at this point before merging the other technologies. Not only management hub at this stage there is a need to interoperability regulation and consensus protocol for integrating other technologies with IoT network. Last, but not least, IoT provides the data so AI systems can develop their potential.

7.1.4 Role of stakeholders in advancement of IoT for PI

Table 5 presents the role of the T&L stakeholders in the roadmap of IoT for PI realization.

Table 5 Role of stakeholders in advancement of IoT for PI

Stage	Activity	Main Stakeholders

2022-2030	Implement IoT technology on large scale within organizations to establish physical intranets	Transport and Logistics Companies, warehouses, producers, and retailers
2030-2050	Collaborate and utilize IoT data across logistics networks to facilitate efficient resource sharing	Transport and Logistics Companies, warehouses, producers, and retailers

7.2 5G Standard

Based on the work done in previous chapters, the project team developed the following PI-facilitating technology Roadmap for 5G.

7.2.1 Current Status

5G deployments started in 2018 in the USA but got properly underway in 2019 with many EU countries offering a limited service in cities. The developed continued throughout 2020 and by the end of the year, there had been commercial 5G launches in almost all EU countries.

In 2016 the 5G Action Plan was launched by the EC to boost the deployment of 5G across the EU. By 2021, most of those objectives had been met and improving coverage became one of the European Commission's key targets.

5G deployment began in cities, and extending this nationwide is the next step. 5G is at an early stage in harnessing the full potential of services it can offer to vertical industries. Trials are underway but the level of commercial deployment is far behind that achieved in consumer services[13].

According the European 5G Observatory, the 72% population coverage has been achieved in EU27[14].

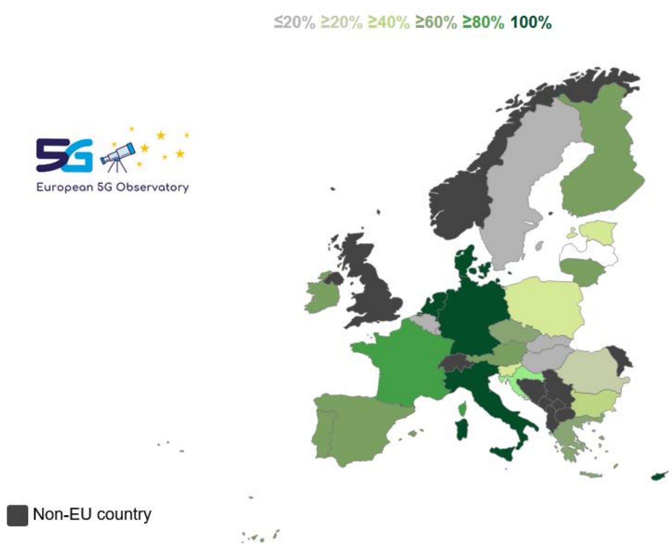


Figure 7 5G European Coverage

[13] https://5gobservatory.eu/about/what-is-5g/
[14] https://5gobservatory.eu/observatory-overview/interactive-5g-scoreboard/

However, the network coverage beyond European frontiers is poor as seen in Figure 8. This is a limitation when it comes to global T&L activities.

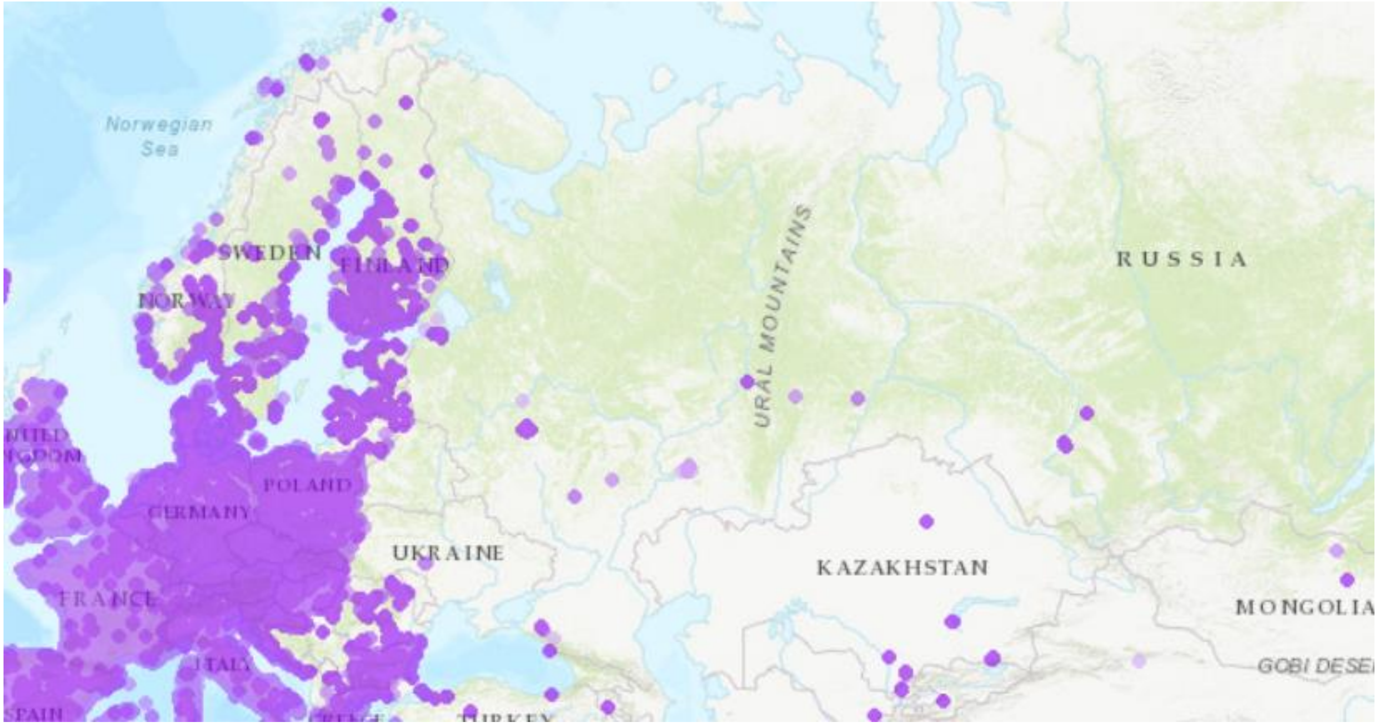


Figure 8 5G coverage map outside Europe (from https://www.nperf.com/en/map/5g)

Related to this issue, the New Silk Road tests carried out in PLANET LL3, showed that there were considerable problems with the GSM network along the container route. When passing through Kazakhstan, which has relatively low GSM network coverage, there were problems with international roaming transmissions. In this regard, active support in additional public policies and regulations to promote further digital homogeneity across EU Member States is recognised as essential to achieve the desired future outcome of the European Union becoming a reference in 5G.

The deployment of 5G functionality will be gradual. Initially, it will focus on increasing data transfer speeds and handling large volumes of traffic. Over time, a growing number of functionalities will become available, such as those necessary for ultra-low latency communications, connecting large numbers of devices, and enabling more open and distributed networking capabilities (European Investment Bank, 2021).

In terms of applications, continued deployment of the more cutting-edge 5G functionalities in telecommunications networks will enable the development of progressively more advanced 5G applications and disruptive innovations and business models as is represented in Figure 9.

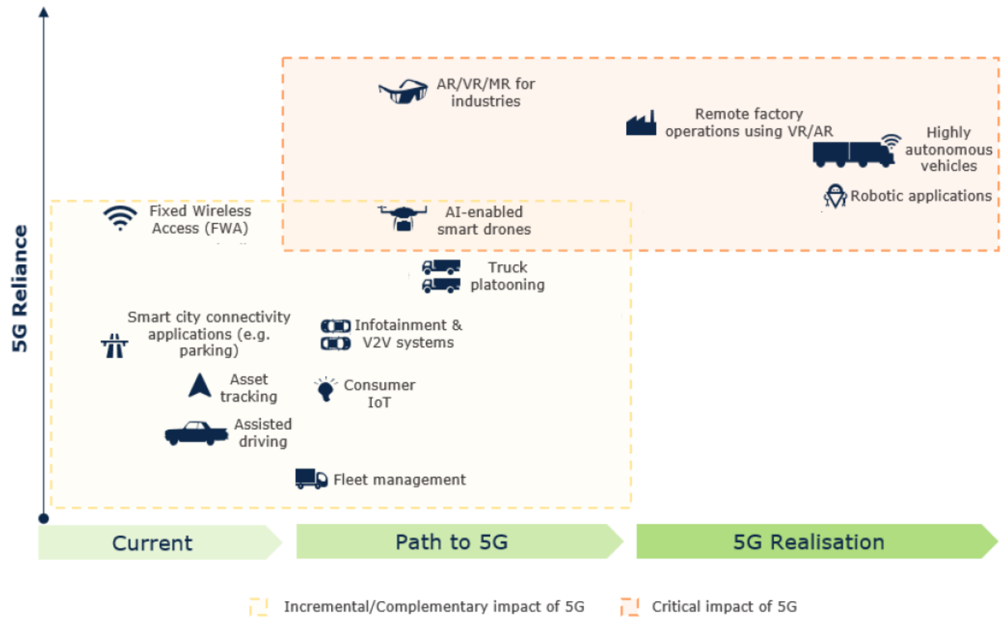


Figure 9 5G implementation timeline (adapted from European Investment Bank, 2021).

7.2.2 Roadmap for 2022-2030

The EC adopted a 5G action plan for Europe in 2016 to ensure the early deployment of 5G infrastructure across Europe[15]. The objective of the action plan was to start launching 5G services in all EU Member States by end 2020 at the latest. Following this, it suggests a rapid build-up to ensure uninterrupted 5G coverage in urban areas and along main transport paths by 2025.

In parallel to this deployment, it is envisioned a **Proof-of-concept/ Research and impact evaluation** of 5G network standard on performance of autonomous and unmanned aerial vehicles.

With the recent roll out of 5G network standard, this stage will undertake research and evaluate the performance of autonomous and unmanned aerial vehicles enabled with 5G, for example in delivering parcels to final customers in the last mile. Further, this stage will also evaluate the reliability and performance of various IoT devices connected via 5G, which upon receiving real-time updates (such as inventory in warehouse, parcel locations, traffic congestion etc.) would trigger a series of autonomous decisions (such as initiating inventory orders, intermodal transshipment decisions and vehicle rerouting in the event of traffic congestions and delays) in the last-mile operations in the PI context. However, prior to conducting these performance assessments, businesses must build their 5G distribution network and assess the physical layer's vulnerabilities as any weakness would provide hackers access to data and the ability to attack multiple devices connected to the 5G Service Based Architecture. For this purpose, the EU Toolbox for 5G security launched its set of measures to strengthen security requirements for mobile networks; assess the risks posed by suppliers; limit any dependency on a single vendor and stimulate the EU's own 5G capabilities[16].

7.2.3 Roadmap for 2030-2050

In this stage, **deployment and roll out** of 5G enabled autonomous and unmanned aerial vehicles will be undertaken. Organizations can use the features of 5G's low latency for monitoring unmanned air and land drone delivery with air traffic in a busy logistics hub for improving productivity. Deployment will allow companies to take advantages of diagnostic data in real time. Data can be captured, analyzed, and viewed no matter where the assets are located. All the trucks which are sensor-IoT enabled could form coordinated identically spaced convoys that can drive close together, thus reducing drag, fuel consumption and further help in reducing CO_2 emissions of vehicles by using 5G.

[15] https://digital-strategy.ec.europa.eu/en/policies/5g-action-plan
[16] https://5gobservatory.eu/category/5g-security-toolbox/

Additionally, beyond the abovementioned objective of deploying 5G coverage in urban areas and along main transport paths by 2025, it is in the EC's strategy to cover all populated areas with 5G by 2030. This will widen the implementation of the technology in the territory.

6G, the sixth-generation mobile system standard is the planned successor to 5G and will likely be significantly faster. This should enable new critical applications such as real-time automation or extended reality (“Internet of Senses”) sensing, collecting and providing the data for a digital twin of the physical world. The EC’s Smart Networks and Services Joint Undertaking set out 6G vision in 2022. Development of technology capacities for 6G systems as a basis for future digital services are expected in the 2030-2050 timeframe.

7.2.4 Role of stakeholders in advancement of 5G technology for PI

Table 6 presents the role of the T&L stakeholders in the roadmap of 5G for PI realization.

Table 6 Role of stakeholders in advancement of 5G for PI

Stage	Activity	Main Stakeholders
2022-2030	Research and performance evaluation of 5G enabled devices in real time autonomous decisions	Knowledge institutes, Transport and Logistics companies
	Reduce cross-border challenges by promoting homogeneity and standardisation	Policy makers (specially Body of European Regulators for Electronic Communications)
2030-2050	Deployment of 5G standards	Network operators and technology providers
	Pan-European multi-stakeholder trials	Knowledge institutes, Transport and Logistics companies
	Regulatory support to the technology	European and Local authorities

7.3 AI/ML

Based on the work done in previous chapters, the project team developed the following PI-facilitating technology Roadmap for AI/ML.

7.3.1 Current Status

In the context of Smart Logistics/transportation, the application of AI/ML technologies is still in an early stage of development. Most of the identified studies are concepts, laboratory experiments, or in a very early testing phase. More mature industrial applications are still required. Until today, AI applications in transportation are limited to specific ITS applications such as data analysis and predictions of future mobility (Abduljabbar et al., 2019). There is a general agreement that current TRL is 6. However, there are specific applications (ie Transport scheduling systems) where commercial products exist and TRL reaches level 9. These software components are in general specialised (or adapted) for performing in very particular scenarios, and there is no general-purpose tool.

PLANET EGTN platform includes the following **PI Predictive Analytics & DSS** solutions (D3.2):

• Routing optimisation service: Service used to address some of the most challenging aspects in delivering freight volume within the last mile delivery (urban area). A core aspect of the service is that it scales the optimisation within a big number of delivery nodes, in the order of thousands per day. It prioritizes the use of hybrid and electric vehicles to comply with carbon emission norms within the Madrid urban area.

• Predictive transport service: Service that makes use of simulation data and machine learning-based predictive models to predict changes in freight volume across corridors. Based on the data provided, the service can generate correlation graphs between the predicted changes in volume and historical information on relevant variables such as transportation cost and lead time.

• Demand forecast service: Service used to forecast the number of pallets/containers arriving in a warehouse or port, providing confidence intervals for the next 10 days. The Demand forecast service reduces hiring costs, as it enables the booking of vehicles in advance to avoid demand peaks and high prices.

• Booking Capacity DSS: Service used to determine the number of trucks that a warehouse needs to book in a time range of ten or three days ahead. It is based on time series predictions (from the Demand Forecast Service) and on a dynamic pricing strategy i.e., booking and cancellation fees. The service determines the trucking capacity that needs to be booked by the warehouse towards minimizing costs.

• Last mile parcel reshuffling: Service used to optimise parcel reshuffling for last mile delivery, involving collaborative opportunities between vans to expedite deliveries. It determines if a van operating in proximity can be of meaningful assistance to a van running late. If yes, it redistributes the parcels, sets a meeting point, and redesigns the vehicle route.

•Combinations of services following a specific data pipeline also offer meta-services with additional value for the T&L community such as the Warehouse Management based on AI and Smart Contracts service. It leverages the AI-enabled smart contracts meta-service and employing the Demand Forecast service for predicting incoming pallets in a warehouse as well as the Booking Capacity DSS for establishing a clear strategy for booking trucks and setting up a pricing policy for the agreements between different communities.

•Routing Optimization service is also available by consuming either real time or historical data, processing them and calculating better routes in terms of carbon emissions and/or other factors for last-mile logistics.

7.3.2 Roadmap for 2022-2030

During this stage it is expected to continue developing AI solutions for better forecasts and intelligent decisions based on machine learning algorithms such as the dynamic assessment of the impact of potential route changes developed in LL1. However, PLANET results (D1.9) show that implementation of only AI without implementing IoT to collect real-time data on parameters such as wagon and container locations, container temperature and humidity, condition of rolling stock components such as wheels, axle etc. does not lead to any significant improvement compared to the baseline situation. Also, implementing AI without implementing GS1 to standardize the data shared across the stakeholders in the corridors doesn’t result in remarkable improvements. It is combined with those technologies where AI finds the highest potential.

Based on the workshops results, in this stage it is envisioned the development of ports as intelligent PI nodes, using Digital Twin technology to improve port operations executing automated decision making enabled by analytics integrated in the port platform.

Moreover, during this period several task could take place. These activities might include the ones enlisted below:

- Validating decisions and views regarding the features of the solution with the stakeholders that are more relevant.
- Continue scheduling interviews and meetings with stakeholders for a broader understanding of their pain points within the transport and logistic domain. And for further agreements on the future data landscape required for further and continuous development of the service (update maintenance etc).
- Fine tune assumptions on business needs for AI as a computational solution.
- Continue further engagements with stakeholders to acquire feedback (from using and testing the service) and to fine tune the effects of technology on collaboration and acceptance of the service within T&L.

- Final prototype ready for further integration to transportation systems in real application settings.
- Tests and usage of service across different transport modalities such as rail, freight terminals, operations in dryland and waterway ports.

Within this time frame it is expected for the service to have generated tangible evidence with regards to its capability to enable stakeholders to achieve competitive advantage. The service and other analytics could inform and empower future T&L stakeholders for applications on strategic sourcing, supplier negotiation and supplier risk.

AI models such as the demand forecasts would be expected to provide near-instant insights supporting ecosystems and fluid work unit teams. Also, self-correcting, and self-learning operations should be feasible and cost-effective. Self-correctness and self-learning would enable higher level of automation and autonomy striving for self-directing capabilities within the transportation operations.

During this time the use of foundation models within frictionless multi-hybrid-cloud heterogenous environments will become the standard in AI development practices. Such a practice will allow to reduce costs (and operational time) not only for development but also for the deployment and maintenance (update and retraining) of the forecasting models used to enable the demand service. Reducing development time, such as the time spent labelling data and programming code to enable the models, will make it much easier for businesses to dive in in the technology, allowing more T&L and supply chain stakeholders to deploy AI in a wider range of mission-critical situations.

7.3.3 Roadmap for 2030-2050

Integrate AI across modes and systems towards fully autonomous PI network services and operations and autonomous PI nodes. During this phase minimal manual intervention will take place at scale across the manual T&L operational processes required. Within this time period the majority of the transporters and suppliers will not consider their own company boundaries only, but they should consider also beyond to increase partnership-based exchange. This includes exchanging data across the whole value chain. To achieve such a collaboration establishing business platforms encompassing people, processes and data will be critical components of the cognitive applied enterprises. The platforms will allow the exponential use of Ai, blockchain and IoT for automation and enable stakeholders to re-engineer workflows, leverage vast amounts of proprietary data and create platform-centric business models at scale.

7.3.4 Roadmap beyond 2050

During this time period several tasks are foreseen to continue, such tasks include:

- Continuously inform stakeholder of further research carried out.
- Updating future ideas to become part of operation scenarios and put them in front of stakeholders for continuous adaptation of technical solutions.
- Continuously document “final” experiences using the service by stakeholders.
- Future highly adapted prototypes integrated to stakeholders’ systems.

Future ideas and applications across AI based T&L applications will continue proliferating. These ideas and applications will include the use of quantum computing. Applications based on quantum computing will increase exponentially the computer power available improving the way to analyze the data generated across all the transportation phases, particularly for modelling purposes of the supply chain and optimal transportation operations.

Within this phase quantum computing will impact the transport and logistics also by simplifying the variability and planning, safely sharing protected data through a convoluted network of ecosystem partners and enabling the capturing all the value of digital twin simulations.

7.3.5 Role of stakeholders in advancement of AI/ML technology for PI

Table 7 presents the role of the T&L stakeholders in the roadmap of AI/ML for PI realization.

Table 7 Role of stakeholders in advancement of AI for PI

Stage	Activity	Main Stakeholders
2022-2030	Service agreements (maintenance, updating, re-training…)	Transport and Logistics companies, Technology companies
	Integration to transportation systems in real application settings	Transport and Logistics companies, Technology companies
2030-2050	Establishment business platforms encompassing people, processes and data	Transport and Logistics companies
Beyond 2050	New applications improving computing power (ie. Quantum computing)	Technology companies

7.4 BLOCKCHAIN

Based on the work done in previous chapters, the project team developed the following PI-facilitating technology Roadmap for Blockchain.

7.4.1 Current Status

While currently, popular use cases of BC include transparency and data integrity within healthcare systems (IBM), payments and settlements for crude oil (Shell), information traceability and tracking in food supply chains (Walmart), it has not been able to demonstrate its proposed impact, yet. Organizations, though appreciative of its transformational capability, are unclear about next steps. Thus, with a TRL of 6, many organizations are still testing out proof of concepts, which is why there haven't been colossal mainstream use cases of BC to date.

In the PI context, application of Blockchain technology in the T&L domain promises several benefits such as, increased visibility, digital and operational interconnectivity, increased data, information and resource sharing for collaborative logistics, network resilience, enhanced synchromodality etc. which are being demonstrated in simulated logistics network environments (WP1, WP3).

The impact of the blockchain technology on the PI realization is well documented in PLANET D2.18. The PI will be able to proliferate only if it is handled in a distributed and community-driven approach. Not only the entire blockchain technology premise is based on strictly decentralised solutions, but also overcome issues of information asymmetry. The benefits of the PI are enhanced through Blockchain technologies, as they offer better tracking of data across the entire T&L network, efficient, trustworthy, and objective contract execution through smart contracts and increased security protection through encryption. In this manner, the T&L process chain becomes more effective through increased information transparency and power balance.

A key enabler for the PI is digital interoperability as it enables separate T&L networks to conduct business with each other seamlessly. As the PI aims at interconnecting T&L networks, i.e., moving from collaboration to interconnection of the involved actors, in a similar manner, Blockchain solutions need to take a step towards the interconnection of the different Blockchain solutions that are currently employed by separate T&L stakeholders. Blockchain interoperability is a growing research topic; in PLANET it has been explored under the scope of T&L and it has been the focus of the work undertaken in Task 2.5. More specifically, it has been addressed by developing a Blockchain Interoperability solution for T&L and applying it to the project's Living Labs. LL1 and LL2 tested the design and implementation of interoperable blockchain platforms, connecting the blockchain platform in the Port of Rotterdam with the one in the Port of Valencia, and the latter with DHL blockchain network. It is crucial to address the management of multiple interactions and transactions with a large number of different stakeholders, public and private in different counties, including port and maritime authorities, customs and other inspection bodies, transport companies, port and rail terminals, freight forwarders, importers and exporters, etc.

Additionally, efficient contract negotiation in the DHL warehouse shall be achieved through the automated trigger of smart contracts based on AI outputs. AI-enabled smart contracts employing the Demand Forecast service for predicting incoming pallets in a warehouse as well as the Booking Capacity DSS for establishing a clear strategy for booking trucks and setting up a pricing policy for the agreements between different communities.

7.4.2 Roadmap for 2022-2030

1. **Development of standards** for data and information sharing on BC platforms between organizations operating in the T&L domain.
2. **Implement digitalization and sharing of transport documents using Blockchain** to significantly reduce time and costs involved in intermodal transportation.
3. **Development and research on impact of Block-chain interoperability** to facilitate information sharing across a system of logistics networks enabling collaborations and shared use of assets, equipment, services, and other resources.

7.4.3 Roadmap for 2030-2050

Implementation of Blockchain interoperability in a system to **facilitate collaboration and sharing of resources**: Having developed and extensively researched the benefits of the concept of interoperability in the previous stage, this stage focuses on the roll out and practice of advanced blockchain technology features such as interoperability to realize the concept of Physical internet.

7.4.4 Role of Stakeholders in advancement of Blockchain to facilitate PI

Table 8 presents the role of the T&L stakeholders in the roadmap of Blockchain for PI realization.

Table 8 Role of stakeholders in advancement of blockchain for PI

Stage	Activity	Main Stakeholders
2022-2030	Prioritizing adoption of BC technology in logistics/transportations operations	Customers of LSP

	Research on role of BC interoperability in improvement of performance of operations by enabling seamless data and resource sharing for collaborative logistics	Knowledge Institutes, Technology Companies, T&L companies
	Development of standards and protocols for data and information sharing on BC platforms between organizations operating in the T&L domain	Knowledge Institutes, Technology Companies
	Develop and regulate policies that enable sharing transport documentation electronically between organizations and authorities to facilitate faster and cheaper intermodal operations	European and Local authorities
2030-2050	Implementation of Blockchain interoperability across a system of logistics networks to facilitate collaboration and resource sharing	T&L companies

7.5 iMLU

Based on the work done in previous chapters, the project team developed the following PI-facilitating technology Roadmap for iMLU.

7.5.1 Current Status

In the innovative Physical Internet field, the design of efficient PI-containers constitutes a cornerstone. Projects such PI-NUTS (French National Research Agency)[17], Modulushca[18], CLUSTERS 2.0[19] or ICONET[20] have positioned the TRL in 5. PLANET has contributed to the state of art of this technology through its EGTN IoT infrastructure architecture. The Smart LU and the Smart Container/Transport Mean/Warehouse concepts can be implemented supporting an improved visibility on the whole legs of the supply chain (included first/last mile legs, not only cargo logistics).

7.5.2 Roadmap for 2022-2030

1.- In PLANET, hardware limitations related to battery duration are one of the main restrictions when thinking about scaling up the use of IoT tracking solutions in the supply chain ecosystem. Currently, IoT tracking solutions installed on shipping containers require non-lithium batteries for being shipped as regular containerized cargo. This aspect limits the duration of the battery, since non-lithium batteries typically offer lower duration than conventional lithium solutions. The solution provided in LL1 relies on a lithium battery, and as a consequence, this limitation needs to be addressed in the next stage.

2.- Also, it is required Edge computing enablement. The exploitation of edge computing devices will enable the distribution of intelligence along the network.

3.- The project team identifies the need to implement both technical and syntactic interoperability functionalities for the IoT and the remote communication networks, thus simplifying the integration of commercial-of-the-shelf sensors nodes and the integration with the PI platforms respectively.

[17] https://anr.fr/Project-ANR-14-CE27-0015
[18] https://cordis.europa.eu/project/id/314468/es
[19] http://www.clusters20.eu/
[20] https://www.iconetproject.eu/

7.5.3 Roadmap for 2030-2050

Develop physical assets and processes to automatically handle and build unit loads and integration with autonomous decision systems.

7.5.4 Role of stakeholders in advancement of iMLU technology for PI

Table 9 presents the role of the T&L stakeholders in the roadmap of iMLU for PI realization.

Table 9 Role of stakeholders in advancement of iMLU for PI

Stage	Activity	Main Stakeholders
2022-2030	Research on materials and batteries	Knowledge institutes, Technology companies
	Standards development and adoption	European Institutions, Technology companies, T&L companies
	Development of the edge computing	Technology companies
2030-2050	Handling material development and implementation	Knowledge institutes, Technology companies, T&L companies

7.6 UAVs and AVs

Based on the work done in previous chapters, the project team developed the following PI-facilitating technology Roadmap for UAVs and AVs.

7.6.1 Current Status

The PLANET consortium identified the scenario of the last mile delivery as the most prominent for the UAVs and AVs. IoT and AI are enablers of these technologies. According to a survey launched by Deloitte[21] , 80% of the sample companies are either currently investing in or planning to invest in technologies like autonomous trucks or delivery drones/droids.

7.6.2 Roadmap for 2022-2030

During this phase, companies need to identify the requirement for last mile capabilities that can be potentially fulfilled by UAVs and AVs. The primary focus during 2022–2030 would be on the development of platforms, sensors, and information processing technologies with their roles for UAVs and AVs. Surveys of different zones, infrastructure development, maintenance management for ground safety (self-diagnosis, fault tolerance, emergency landing, etc.), performance management for speed accuracy, endurance, payload, energy efficiency, and controllability of UAVs and AVs before actual deployment needs to be undertaken. Further, in this phase, the security system of UAVs and AVs can be improved to avoid collisions, reduce hijacking and jamming of communication. With UAVs and AVs companies need to integrate GPS and weather forecasting systems for scheduling of last mile delivery during bad weathers.

[21] https://www.deloitte.com/global/en/Industries/infrastructure/perspectives/driverless-delivery-and-last-mile-coverage.html

7.6.3 Roadmap for 2030-2050

In this phase, deployment of UAVs and AVs for the last mile will be undertaken. Here companies need to ensure the safety characteristics (reliability, redundancy, etc.), performance improvement of UAVs/ AVs (stability, resistance to weather fluctuations, etc.) and security of the system. Further after implementation, companies must focus on continuous environmental improvement by managing the air-traffic. In this phase the last mile delivery service can be extended for disasters, harsh environment and areas beyond line of sight with adequate safety and under government policies.

7.6.4 Role of stakeholders in advancement of UAVs and AV technology for PI

Table 10 presents the role of the T&L stakeholders in the roadmap of UAVs and AV for PI realization.

Table 10 Role of stakeholders in advancement of UAVs and AV for PI

Stage	Activity	Main Stakeholders
2022-2030	Research and development	Knowledge institutes, Transport and Logistics companies
2030-2050	Deployment UAV and AVs	Technology companies
	Regulate use of UAV and AVs in the last mile delivery operations	European and Local authorities

7.7 Hyperloop

Based on the work done in previous chapters, the project team developed the following PI-facilitating technology Roadmap for Hyperloop.

7.7.1 Current status

Hyperloop system is a combination of existing technologies from different industries into a new mobility concept. Overall, Hyperloop technology is considered to be currently at a TRL 3 (Experimental proof of concept). There are several companies working on this disruptive concept (Hardt, Zeleros, HyperloopTT, Virgin...). The following figure shows the envisaged shape of the continental hyperloop network in Europe as per the Hardt hyperloop company, partners of this project.

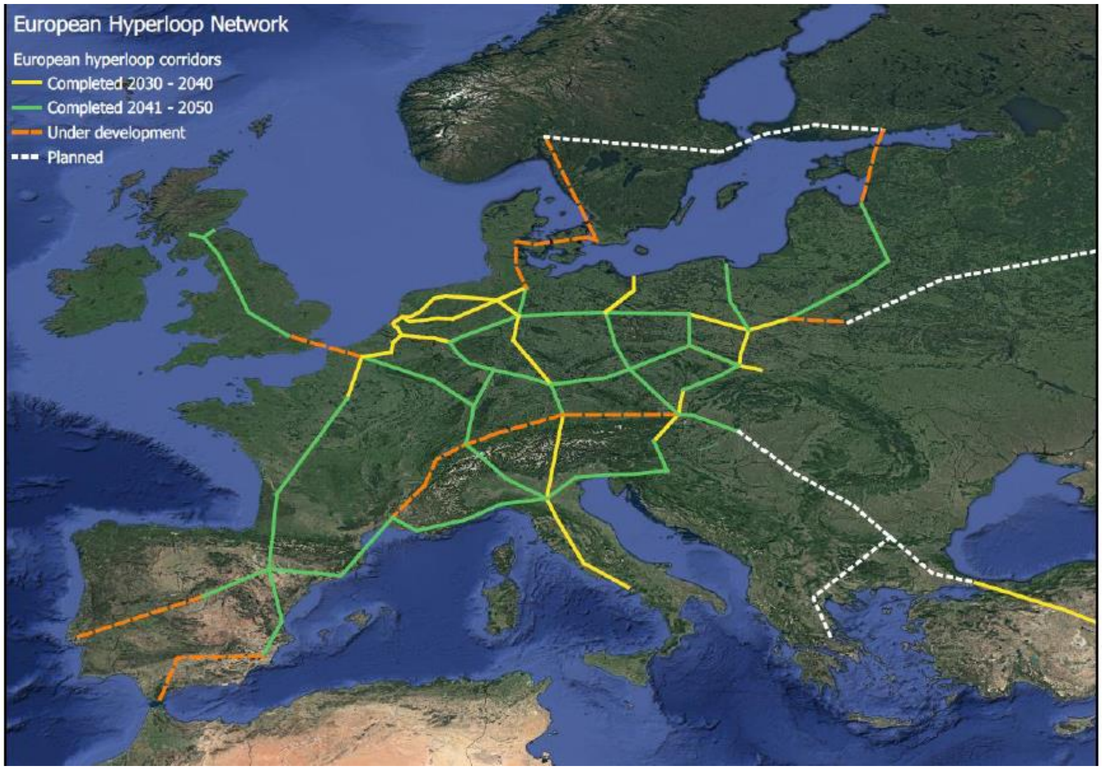


Figure 10 European hyperloop network 2050 (Hardt)

The envisioned network supports all strategic corridors within the Trans-European Transport Network policy and provides fast and sustainable connections to all major economic and population centers. The hyperloop system uses the same infrastructure for passenger and cargo transport. The differences between cargo and passenger hyperloop are mainly observed in vehicle characteristics and hub operations. Hyperloop for freight transport (Cargoloop) is expected to develop earlier than the one for passenger transport, as the regulatory framework is not expected to be as strict and also other technicalities related to people's transport don't apply.

There are potential synergies between Hyperloop technology and the PI. It has been argued that open infrastructural innovation such as the hyperloop system could be enabled through alignment with the principles of the PI. Even if it would be technically feasible to build high-speed infrastructure such as Hyperloop, their logistics performance would be impeded due to the insufficiency and unsustainability of current systems22.

The impact of the Hyperloop as an alternative transportation mode was investigated applying PLANET simulation capability in the Port of Sines Use Case (D3.9). Results shown that this disruptive technology could enhance the port's competitiveness, sustainability and connectivity with other regions and markets. Indeed, the Hyperloop represents a significant opportunity for the Port of Sines and the logistics industry. Portugal has been identified as a relevant node of the Hyperloop network in the Iberian Peninsula, serving as a point of entry for intercontinental flows. This is due to its strategic location on the Atlantic coast, which makes it a natural gateway for trade between Europe and the Americas. The Hyperloop technology may revolutionize the logistics industry by providing fast, efficient, and sustainable transportation of goods over long distances.

[22] Pfoser, Sarah & Berger, Thomas & Putz, Lisa-Maria & Schauer, Oliver & Hauger, Georg & Wanjek, Monika & Berkowitsch, Claudia & Schodl, Reinhold & Eitler, Sandra & Markvica, Karin & Prandtstetter, Matthias. (2017). Hyperloops: New transport mode enabled by the Physical Internet?. 10.13140/RG.2.2.25830.32328.

7.7.2 Roadmap for 2022-2030:

In the near future it is expected additional research, development and testing to increase the TRL level of this mode of transportation. Different initiatives will deploy operational pilots. It is worthy to highlight at European level the Horizon Europe Framework Programme, that will boost the development of a hyperloop industrial roadmap and a demonstrator to support the proof of concept addressing convergence between different solutions currently explored23. One of the key issues will be the development of standards. The full-scale demonstrator at TRL6 of the hyperloop technology, will cover all elements associated to the possible implementation of the solution by 2030, such as elements related to investment and operational costs, materials, traffic, capacity, demand, etc.

In parallel, the EC intends to table a proposal for EU regulatory framework for hyperloop in the third quarter of 2023.

7.7.3 Roadmap for 2030-2050

During the second stage the creation of a European network beyond pilots and trials is expected after the validation of the concept. It is argued that this mode of transportation has lower costs than any other comparable transport option, however cost of construction is high. Thus, it is expected that initially, Hyperloop will compete with air freight and added value goods (potential especially for high value freight transports). High investment and development of governance models will be required to implement new routes and increase end-user’s acceptance of the solution.

7.7.4 Roadmap beyond 2050

Beyond 2050, the European network of hyperloop will be connected with international initiatives that have progressed at a faster pace such as in China and the Middle East, strengthening the role of Europe in global trade and logistics.

7.7.5 Role of stakeholders in advancement Hyperloop technology for PI

Table 11 presents the role of the T&L stakeholders in the roadmap of Hyperloop for PI realization.

Table 11 Role of stakeholders in advancement of Hyperloop for PI

Stage	Activity	Main Stakeholders
2022-2030	Further research to increase TRL (pilots, standards)	Knowledge Institutes, Technology Companies, T&L companies
	Regulatory framework	European authorities
2030-2050	Infrastructure creation	Operators, authorities
	Increase adoption	T&L companies
	Governance models	Knowledge Institutes, Technology Companies,
	First implementations in “small-scale” real environments (such as between port terminals)	Port or airport operators, T&L companies

[23] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-er-ju-2022-fa7-03

Beyond 2050	Infrastructure creation (expansion of the network)	Operators, authorities
	Link between networks	European and international governments

8 Legislation and EU Policy to impact EGTN technological aspects

In the different workshops carried out under this task, regulatory uncertainty has been identified as one of the main potential obstacles for the future deployment of the technologies considered in this document. In this regard, PLANET WP1 evaluated different European legal & policy initiatives and investigated their impacts on EGTN layers, attributes and development (D1.7).

There were identified three main legal initiatives impacting positively the technology layer of the EGTN: The Maritime Single Window Environment, Rail Freight Corridors regulation (to be revised in 2023), and the TEN-T regulation.

However, the following key implementation barriers were found:

- Need for effective coordination between institutions on the Eurasia routes for data interoperability
- No digital document platform (transport, customs) is in place on the Eurasian routes
- Lack of adequate supervision by Authorities.

Moreover, there are four EU policy initiatives impacting positively on the EGTN development and its technology layer: The Smart and sustainable mobility Strategy, EU Regulation on electronic freight transport information (eFTI) stemming from the Digital Transport and Logistics forum (DTLF), the Corridor Information Systems (also stemming from the DTLF), and the EU Taxonomy for sustainable activities. The first three policy initiatives will have a significant positive impact on EGTN development by facilitating the introduction and exploitation of innovative technologies such the ones considered in this document in logistics operations on the EGTN and also the implementation of the PI concept (PI containers, PI nodes, PI moves etc.) in EGTN corridors. The EU taxonomy will support private investments related to the TEN-T, regarding hard infrastructure (ports, inland terminals, road charging stations etc.) or the implementation of digital solutions.

EU policies may be established with the intention of them becoming future Regulations and legislations, but in practice there are some key implementation barriers that may affect the adoption of these policies in the near future. Barriers to adoption of the DTLF policies may hamper their adoption in the future. A possible delay in the adoption of the DTLF policies within the EU will significantly influence the improvement of the existing TEN-T T&L network and subsequently hamper PLANET's vision on the future development of the EGTN. The lack interoperable standards (and IT solutions) for the exchange of transport documents and ITS data between businesses and authorities across different modes of transport and different Member States is highlighted as one of the key implementation barriers to the DTLF policies in PLANET D1.7. This document recognizes the need of interoperability and implements it in the different stages of the technology roadmaps.

9 Incorporation of PI-facilitating technologies into current roadmaps

The objective of this section is to contribute to the PI roadmap and all related ICT exponential technologies examined and researched in PLANET project, by facilitating the incorporation of the PLANET results in the ETP's roadmaps such as ERRAC for Rail and WATERBORNE for Sea and Inland Waterways. Consequently, the synergies could deliver benefits and accelerate time to market according to the PLANET roadmap.

The methodology is based on the analysis of official ERRAC and WATERBORNE documents and synoptic comparison with PLANET for selected and most relevant aspects. Detailed information regarding the profiles, vision and strategic roadmaps of both platforms can be found in Annex 1 ERRAC - European Rail Research Advisory Council and Annex 2 WATERBORNE – the European research and innovation platform for waterborne industries

9.1 PLANET versus ERRAC and WATERBORNE - Selected points of attentions

This section analyzes the most significant points of attention among PLANET, ERRAC and WATERBORNE regarding the following elements:

- Network focus
- Co-modal and multimodal approach
- Supply chain level focus
- ICT functionalities
- Demonstration approach and time to market

In the next sub sections, the individual points are shortly commented bringing some information limited to PLANET since for ERRAC and WATERBORNE the information can be derived from the Annex 1 and Annex 2, respectively.

9.1.1 Network focus

PLANET formalizes a set of guidelines (a roadmap) to facilitate the EGTN realization and signify the development of the Smart, Green and Integrated Transport and Logistics Network of the future to efficiently interconnect infrastructure (TEN-T, Rail-Freight Corridors) with geopolitical developments, as well as to optimise the use of current and emerging transport modes and technological solutions. At the same time, it is required to ensure equitable inclusivity of all T&L participants, increase the prosperity of nations, preserve the environment, and enhance citizen's quality of life.

However, EGTN has a realistic approach toward the PI concept implementation, acknowledging that it is not feasible to implement the PI concept to the entire network by 2030. For this reason, EGTN will be a network that has prioritized corridors and nodes for PI development. Based on current and forecasted flows, it will define a sub network of corridors and nodes that will benefit the most from the PI in order to establish policies and to provide incentives for the development of PI infrastructure and services.

A **Single European Railway Area** means that, in principle, any European railway undertaking may operate services on any rail network in any country of the European Union. In recent years, the EU has adopted four railway packages which aim to open the railway market to competition, increase the interoperability of national railway systems and define the framework for a Single European Railway Area. The EGTN will only be demonstrated its benefits with the full realisation of a harmonised European infrastructure network (for example parameters such as train length, axel load, speed…)

Table 12 Selected points of attention – Network focus Source NewOPERA

Selected Points of Attentions	PLANET	ERRAC/S2R/EU Rail	WATERBORNE
Network focus	While TEN-T has a focus on the main arteries of the Pan-European transport network, the EGTN takes a broader perspective with an increased focus on regional logistics through the development of infrastructures and services enhancing operations at regional level. The approach increases the inclusiveness of the disadvantaged regions. The New routes are specifically addressed. The Nodes are key locations for optimization of flows and services. The network Integration includes physical, technological and governance dimensions.	The TEN-T network is considered as general EU policy including technology and governance. The EU perspective supports the objective of a Single EU Rail Area with ports as priority. The Economic development vision does not address geographical segmentation and disadvantaged regions. Lines are considered the key physical infrastructures. The New routes are not specifically addressed when targeting capability increase. Sustainability is the overwhelming priority target focusing on reducing pollutants. Passengers are the prevailing perspective.	The TEN-T network is considered as general EU policy including technology and governance. The Vision is overall and has EU and Global perspective. The Economic development vision does not address geographical segmentation and disadvantaged regions. The New routes are not specifically addressed when targeting capability increase. Sustainability is the overwhelming priority target focusing on reducing pollutants. The Ports are key physical and technological infrastructures. Integrating Sea and Internal Waterways is addressed as specific topic.

9.1.2 Co-modal & multimodal approach

The second point of attention considered in the document is the co-modal and multimodal approach. Differences among PLANET and ERRAC/S2R/EURail and WATERBORNE platforms are shown below.

Table 13 Selected points of attention – Co-modal & multimodal approach Source NewOPERA

Selected Points of Attentions	PLANET	ERRAC/S2R/EU Rail	WATERBORNE
Co-modal & multimodal approach.	Logistics is based on sustainable efficiency. Management drives individual Modular Unit Loads as well as overall flows in intercontinental, regional and local segments. Management of individual Modular Unit Loads and General flows are coordinated according to co-modal optimization due to the integration of physical, technological and governance dimensions.	The prevailing focus is the Rail ecosystem (fleet with granularity up to train and wagons, Rail Industry supply). Maximization of Rail as the most sustainable inland mode is a lever to influence the best co-modal mix. The focus on cargo is targeting the Unit Load and its end-to-end chain. The Urban logistics integration is considered downstream from Rail Scope.	The prevailing focus is the Waterborne ecosystem "ports and ships". The focus on cargo is targeting the Unit Load and its end-to-end chain. Maximization of waterborne as the most sustainable mode - where applicable - is a lever to influence the best co-modal mix. The Urban logistics integration is considered applicable to ports' proximity.

The main differences between PLANET and both ERRAC and WATERBORNE are the consequence of:

- Scope difference because of passengers traffic (especially for ERRAC) and physical infrastructures (especially for WATERBORNE) prevailing attention, while PLANET prevailing attention is represented by traffic flows of goods.

- Focus difference because of terminal to terminal cargo traffic prevailing attention in ERRAC and WATERBORNE, while PLANET focus is represented by end-to-end Supply Chain.

As a consequence, and a confirmation of the above, the Logistics Service Providers managing the end-to-end traffic flows are almost not represented both in ERRAC and WATERBORNE.

On the contrary the Rail supply and Ship building sectors are well represented as significant sustainability targets for reducing pollution coming from transportation means such as noise, weight limits, gas emissions, congestion, fossil fuels, etc.

Also the infrastructural sector is well represented and the ICT priorities are mainly concerning applications to transport means, infrastructures and related interconnections.

ERTRAC and ACARE, are not in scope of this document. They have similar structural differences with PLANET as outlined for ERRAC and WATERBORNE.

While the visions of ERRAC and WATERBORNE fully incorporate advanced transport vision on a point to point, ALICE is embracing the entire supply chain as well as PLANET.

The recent and ongoing projects mix underlines the above mentioned differences. A more consistent alignment between vision and individual initiatives will be achieved in a time perspective.

The funding policies and their consistency with ERRAC and WATERBORNE objectives and priorities influence the program contents and their related timings.

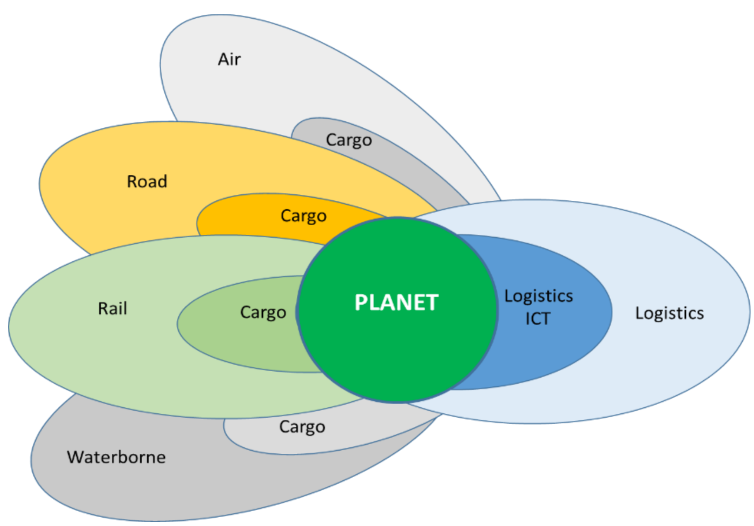


Figure 11 - Scope of different Modes ETPs versus Logistics, ICT Logistics and PLANET – source NewOPERA

9.1.3 Overall Supply Chain focus versus individual Industry segments

The Physical Internet (PI) is considered to be the visionary paradigm supplying an integrated approach to address logistics integration and collaboration issues, and to pave the road forward to deploying efficient supply chains. Its governance layer assures access to everybody. ERRAC and WATERBORNE, on the other hand, are more focused on their individual industry segments (Table 14). The expected improvements in the Supply Chain virtual integration are pushed by the industry. While waiting more general progresses from technology, the industry is in parallel researching its own solutions in the frame of vertical integration.

Table 14 Selected points of attention – Overall Supply Chain versus individual industry segment focus Source NewOPERA

Selected Points of Attentions	PLANET	ERRAC/S2R/EU Rail	WATERBORNE
Overall Supply Chain versus individual Industry segments focus	The Extended Supply Chain is the native focus aiming to involve "democratically" all players in the system. The Sustainability adopts optimized co-modal setting and its dynamic management. Information without conflicts between competing players are managed with systemic vertical transparency and neutral approach.	Priorities regard improving capabilities of key Rail players such as Supply Industry, RUs and Infrastructure. The system is Production driven with limited focus on shippers and receivers perceived behind the Rail ecosystem being users more than players. The attention remains focused to rail cargo more than the end-to-end supply chain scope.	Priorities regard improving capabilities of key players such as Shipping, Ports, Ship Builders. The system is Production driven with limited focus on shippers and receivers perceived behind the Waterborne ecosystem being users more than players. The attention remains focused to waterborne cargo more than the end-to-end supply chain scope.

9.1.4 ICT functionalities enabling new capabilities

Different focus on ICT functionalities are shown in Table 15.

Table 15 Selected points of attention – ICT functionalities enabling new capabilities Source NewOPERA

Selected Points of Attentions	PLANET	ERRAC/S2R/EU Rail	WATERBORNE
ICT functionalities enabling new capabilities	PI is leading exponential technology feeding and integrating several ICT evolutions. New capabilities are explored with Supply Chain focus and accessibility for all actors such as Dynamic decision making, Unit Load tracking, Smart Contracts, etc.. The Data integration is extended to all available data. The Cloud Architecture is accessible for all players as well as for On demand service penetrating the market, etc…	The Focus is on improving capabilities of key players such as the Supply Industry, RUs and Infrastructure, for incorporating innovations in highly complex Rail Systems (example data integration connecting rail players). The Data integration is extended to the main Rail ecosystem data. The lever is on ICT capabilities internal to Rail companies and their supply system more than external (WEB, Cloud, etc....)	The Focus is on improving capabilities of key players such the Supply Industry, Shipping and Infrastructure, for incorporating innovations in highly complex waterborne Systems (example data integration connecting waterborne players). The Data integration is extended to the main Waterborne ecosystem data. The lever is on ICT capabilities internal to the Waterborne companies and their supply system more than external (WEB, Cloud, etc...)

9.1.5 Demonstration approach and target time to market

PLANET follows a Living Labs and use cases approach, as are examples of those EGTN regional ecosystems. In the LLs, local and global actors are collaborating for implementing technological solutions which meet ecosystem needs for optimised logistics operations. These ecosystems will be enriched and PLANET tools will contribute to regional PI hubs infrastructure planning and further logistics operation enhancement in the view of the 2030-time horizon. They encompass multi-modal and intercontinental routes with the overarching objective of optimizing end to end supply chains. ERRAC/WATERBORNE demonstration approach is mainly vertical within the rail/water ecosystems.

Table 16 Selected points of attention – Demonstration approach and target time to market - Source NewOPERA

Selected Points of Attentions	PLANET	ERRAC/S2R/EU Rail	WATERBORNE
Demonstration approach and target time to market	Multi-model quantitative pipeline reinforced by LLs, showing how operational and generalized utility models can be jointly deployed to assess quantitatively the effect of technology at the macroscopic level. The accelerated time to market is induced by LLs demonstrators involving wide and qualified partnership including large scale market movers. Business/industry requirements need to be bridged to EU policy and infrastructure planning.	Monographic approach is prevailing according to projects' segmentation and scope. The individual initiatives are structurally coordinated (S2R & EU Rail funded). The demonstration approach is vertical within the Rail ecosystem. S2R/EU Rail joint undertaking contributes to regular funding with priority in short/medium term targets and topics selection (2030). ICT is significant in individual initiatives to be overall coordinated as a transversal topic.	Monographic approach is prevailing according to projects' segmentation and scope. The individual initiatives, including individual joint undertaking, are coordinated in a few big clusters. There is no multi years structured funding. ICT is not expected to be a transversal topic as pervasive in any initiative, but with major systemic impact not in the next years (not before 2030 - almost aligned with ALICE projections).

9.2 PI uptake acceleration

The following reasons can propitiate an accelerated uptake of the PLANET concepts and practices in ERRAC and WATERBONE strategies:

- **PI as an environmental priority**

The implementation of the PI concept within the PLANET approach aims to achieve the *Green* attribute of the EGTN and aligns with the EU taxonomy for sustainable activities, which in turn aims to direct investments towards sustainable projects and activities with goal to meet the EU's climate and energy targets for 2030 and reach the objectives of the European Green Deal. According to the *Roadmap to Physical Internet*, published by ALICE, in a scenario in which all Physical Internet potential efficiencies are achieved the forecasted 300% increase in transport demand could be achieved with only 50% increase in assets. Furthermore, according to the ETP on Logistics ALICE the potential emission reductions stemming from a better use of resources and the application of Physical-Internet concepts can help significantly towards fulfilling the goal of temperature reduction (Paris Agreement)." (PLANET D2.1)

- **Exploitation of synergies between PI and other exponential technologies/applications**

The benefits of the PI become even greater through Blockchain technologies, as they offer better tracking of data across T&L networks, safer contract execution through smart contracts and increased security protection through encryption. Smart contracts, in particular, play an instrumental role in the roadmap towards the PI.
Alongside the PI, the concept of synchromodality, another emerging topic in T&L is heavily affected by Blockchain and smart contracts. Synchromodality can be defined as the provision of efficient, reliable, flexible, and sustainable services through the coordination and cooperation of stakeholders and the synchronisation of operations within one or more supply chains driven by information and communication technologies (ICT) and intelligent transportation system (ITS) technologies. (PLANET D2.17)

- **Acceleration of time to market**

PI and other related technologies, with the mutual relationships between technologies as indicated in PLANET, in ERRAC and WATERBORNE are pointed out as relevant targets also due to the collaboration with ALICE in different teams. Also, the time perspective is broadly aligned with ALICE projections.
The incorporation of PLANET results in both ERRAC and of WATERBORNE current roadmaps, can easily be managed since the roadmaps have periodical updates and no constraints can be envisaged in their adjustments provided more general less complex solutions, and lead time, are adopted.
Under this assumption the time perspective may be adjusted also in ALICE should PLANET deliveries demonstrate better timing potential.

- **Maximization of capabilities development and geographical exploitation**

The improvements can be achieved not only in the technological contents and better time perspective, but also in granularity of the objects to be managed in the full chain of all multimodal segments leading to end-to-end fully integrated perspective: the Modular Load Unit can replace the Unit Load that is the current ordinary minimal granular detail considered in ERRAC and WATERBORNE so opening up to the integration of a number of additional Supply Chain services such as e-commerce, urban logistics, etc….
Also the geographical dimension in "locating" technological and logistic roles in strategic nodes may be part of the contents that PLANET may share with ERRAC and WATERBORNE enhancing inclusion possibilities, leveraging the emerging new routes development.

- **PLANET roadmap**

The PLANET road map is addressing several actions facilitating potential acceleration of PI into industry operating model in the frame of ETPs innovation support.
LLs results, beside their demonstration target, are already embryonic implementation of largely innovative application of integrated PI solutions. The leading companies participating to such LLs will be pioneers in developing further the innovations and their application in an industrial scale.
The dissemination efforts included in the PLANET program

- actively involving many qualified stakeholders

- the “public” availability of most results

are opening the space for fast up taking of the project’s results by the industry in a time frame that may be more optimistic of current ETPs.

It is desirable that in the next updating of ERRAC and WATERBORNE, in their revision in view of “close” 2030 time line, they incorporate inputs from PLANET as well as from ALICE and other relevant initiatives.

10 Conclusions

In this report, delivers PI-facilitating technology roadmaps towards the EGTN. Using desk research and gathering experts' opinions in workshops and other validation exercises, the different technologies considered in PLANET (actual implementations or simulations) are investigated, their current TRL assessed and, interdependencies identified. It allows to prioritize and set milestones in a timeline for the technologies supporting the EGTN.

Expanding the current coverage of the 5G and increasing the IoT implementation along the T&L network in real-life settings have been identified as key enablers of the other technologies considered, and for the further development of the PLANET services. In addition to IT solutions, the role of European Institutions in the standardization (at digital and physical levels, ie PI containers) is identified as essential for the realization of the project concepts. It is out of the scope of this document, but the availability of professionals with the right knowledge and skills in the field has also been identified as a critical factor for realising the path towards the EGTN. For this, the role of authorities and knowledge institutions will be critical in the development of new curricula and training programmes.

Regulatory uncertainty may affect technology adoption and deployment. This report also summarizes the different legislation and EU Policy to impact EGTN technological aspects.

A synoptic comparation between the strategic roadmaps of ERRAC and WATERBORNE versus PLANET is done in the last Chapter of the present document with the objective of contributing to the PI roadmap and all related ICT exponential technologies examined and researched in PLANET project, by facilitating the incorporation of the PLANET results in the modal roadmaps. WATERBORNE for Sea and Inland Waterways. The uptake of the PLANET concepts and practices in those strategies can be accelerated due to the environmental priority behind the PI concept, the exploitation of synergies between PI and other exponential technologies/applications, the maximization of capabilities development and geographical exploitation and the LLs as PI/EGTN instances.

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Annex 1 ERRAC - European Rail Research Advisory Council

a. ETP General profile

The European Technology Platforms (ETPs) are industry-led stakeholders' organizations developing short to long-term research and innovation agendas with roadmaps for action at EU and national level, supported by both private and public funding.

ERRAC is the ETP with Rail scope. The work leading to this invention has received funding from the European Union Seventh Framework Program (FP7/2007-2013) under grant agreement n° 516424.

"The European Rail Research Advisory Council (ERRAC) was established in 2001 to serve as a much-needed single European body with both the competence and capability to help revitalise the EU's rail sector and make it more competitive by fostering increased innovation and guiding research efforts at European level. Since its conception, ERRAC has managed to gather all major rail stakeholders in its ranks.

The council comprises of 45 representatives from both the sector and outside of it: manufacturers, operators, infrastructure managers, the European Commission, EU Member States, academics and users' groups. ERRAC covers all forms of rail transport, ranging from conventional, high speed and freight applications to urban and regional services." [24]

"The Steering Committee comprises: the Chairperson, 2 Vice-Chairs selected within the academic community, 2 representatives of end-user associations (freight & passenger), 2 representatives of associations representing the railway operating community, 1 representative of the rail supply industry association, 1 representative of the vehicle keeper association, 1 representative for combined transport by rail, 1 representative of the urban rail operator association, 3 representatives of companies from the Railway Operating Community (ROC), 3 representatives of the rail supply industry, 2 representatives of the urban operators and the Secretariat."

"ERRAC's primary objective is to communicate the railway sector's common Research & Innovation vision to the European institutions and other important stakeholders. By doing so, the council aims to help shape a favourable funding landscape for railway research initiatives that drive innovation via calls for projects and joint undertakings like the influential Shift2Rail Joint Undertaking and its successor programme Europe's Rail.

ERRAC aims to act as the single voice for the railway sector's research and innovation efforts in Europe. The objective is to materialise the concept of a "European Research Area" for rail, which would optimise the sector's research and innovation potential within the Union."

b. Vision and Roadmap 2050

"ERRAC has produced a number of key documents since its foundation in 2001, including the *Joint Strategy for European Rail Research – Vision 2020*, the *Strategic Rail Research Agenda* (SRRA) and its successor document, the

[24] https://errac.org/

FOSTER RAIL Roadmaps. Building on these documents, it published its latest strategy document, *Rail 2050 Vision*, in December 2017." [25]

"*Rail 2050 Vision* represents the vision of the rail sector for the needs of the future railway system at the heart of seamless, sustainable and comfortable mobility in Europe. It sets out the important role that rail already plays in delivering economic and societal benefits in Europe. The railways have the opportunity to contribute much more, taking advantage of the latest technical developments. For this to happen, the document points out that research and innovation (and other supporting elements, including appropriate regulatory structures) are critical and that end-user and public support for research, development and innovation in the railways of the future is essential. The key message is that the rail sector is capable of making a significant contribution to integrated mobility solutions and of meeting expectations in terms of both passenger and freight/logistics, supporting economic growth, social cohesion and competitive markets by facilitating mobility. Putting customers first, collaboration with other transport modes will be the key to delivery of this ambitious vision as part of an overall transport solution." [26]

Rail 2050 Vision pays significant attention to exponential technologies as key enabler of expected innovations.

"The emergence of enabling technologies, such as artificial intelligence, the *internet of things*, robotics, vehicle-to-vehicle and vehicle-to-infrastructure communications, autonomous driving and block-chain will provide a wide range of possibilities for innovation in the rail system and to change the way it operates, supporting improvements in rail based logistics and mobility in the short run"[27].

"To deliver the 2050 vision the rail industry is underpinned by technical and scientific research in Europe and around the world. The development and widespread deployment of a host of related technologies include some that represent the evolution of current developments:

- Digitalisation: the instrumentation of assets, processes and personnel with powerful Information and Communications Technology (ICT) capabilities, able to sense, detect, process, receive, transmit and analyse digital information across secure, reliable and ubiquitous networks, making them all participants of a global internet of things;
- Distributed cognitive computing: endowing machines with the ability to become aware of and understand their surroundings, to recognize patterns, to generate meaningful insights from large amounts of distributed data, and to learn;
- Robotics: endowing machines with the ability to perform goal-oriented tasks autonomously;
- Distributed immutable shared ledgers: e.g. blockchain technology, allowing the secure recording of transactions without centralized control or coordination;
- New intelligent materials with self-healing properties and the ability to shape themselves in response to external stimuli.

These technology trends are based on the current state of technology and the near-term developments which are possible using existing scientific and technical knowledge. Transformative future research and scientific advancement have the possibility to change technology dramatically. Long-term progress is guided by the emergence of technologies which have not yet been imagined or realised. The 2050 vision acknowledges this uncertainty and embraces yet unknown possibilities which may significantly influence all aspects of rail transport. The future of rail lies in flexibility, crucially depending on its ability to adapt to and incorporate future technological advances". (Rail 2050 Vision – chapter 2)

In the document *Rail 2030 (2019) – Research and Innovation priorities* published in 2019, ERRAC defines updated priorities as indicated in the picture below.

[25] https://uic.org/research/european-rail-research-advisory-council-errac/
[26] https://uic.org/research/european-rail-research-advisory-council-errac/
[27] https://errac.org/publications/rail-2050-vision-document/

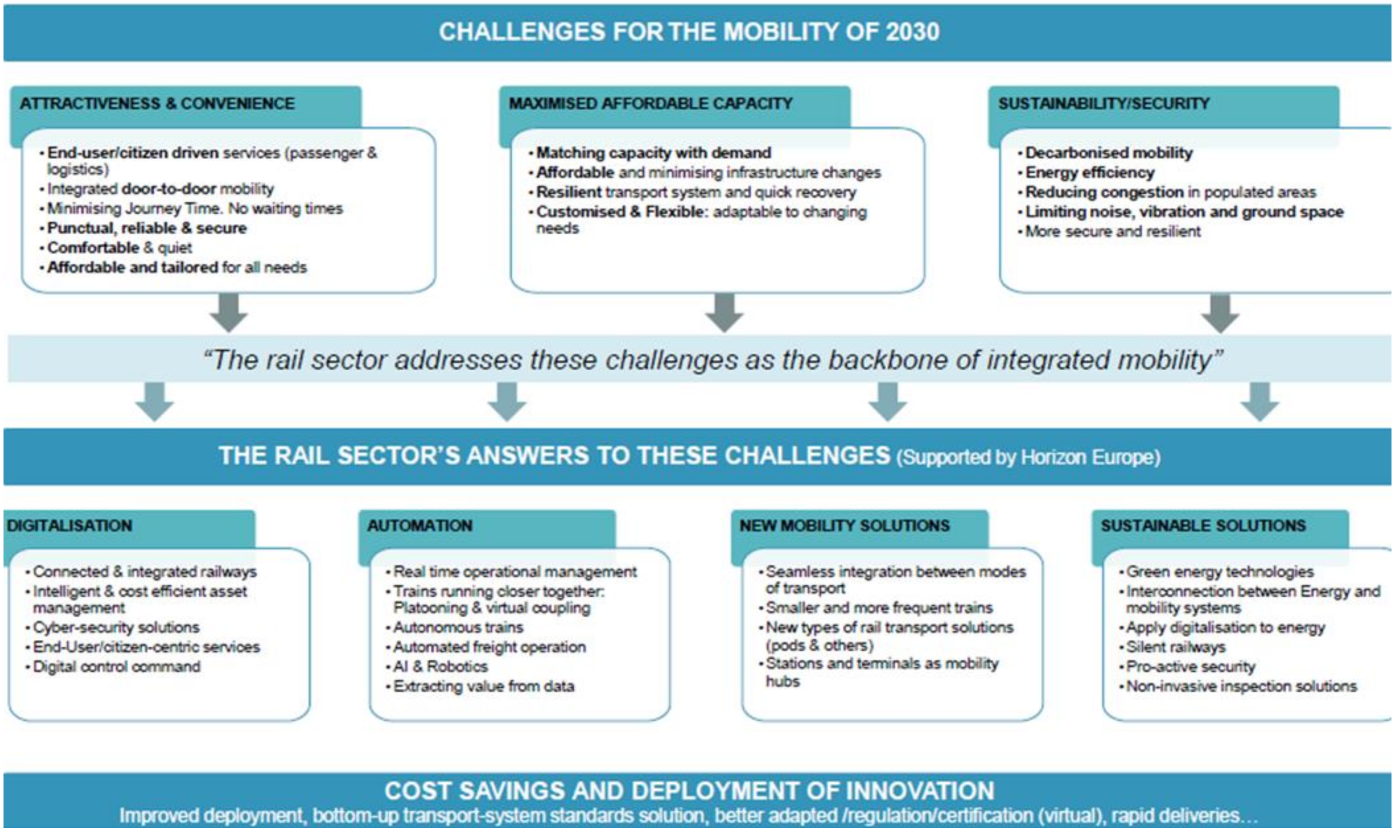

Figure 12 - ERRAC research priorities [28]

In the following document "Rail Strategic Research and Innovation Agenda" (December 2020) Rail policies objectives are addressed in a segmented way as input to the European Rail Partnerships.

See in the following picture the paragraph "Europe's Rail Joint Undertaking (EU-Rail)".

[28] https://errac.org/publications/rail-2030-research-and-innovation-priorities-2/

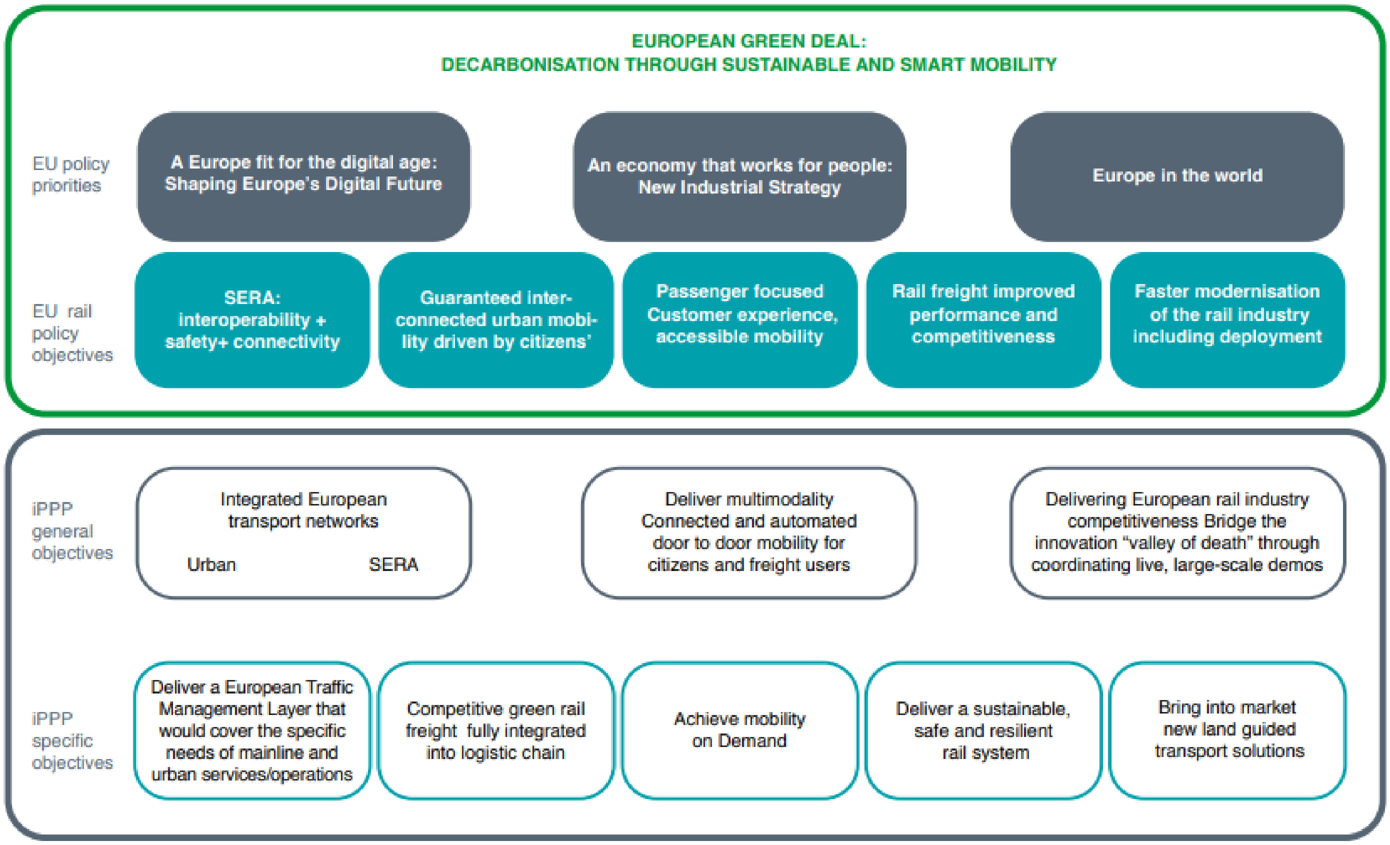

Figure 13 - EUROPEAN GREEN DEAL: DECARBONISATION THROUGH SUSTAINABLE AND SMART MOBILITY - 'Draft proposal for a European Partnership under Horizon Europe Transforming Europe's Rail System' – Source RAIL STRATEGIC RESEARCH & INNOVATION AGENDA SRIA (Version 1 July 2020)[29]

[29] https://errac.org/publications/rail-strategic-research-and-innovation-agenda-december-2020/

c. Shift2Rail (S2R) as main Rail Ecosystem Innovation program

In coordination with ERRAC and with the purpose of taking actions in implementing the 2050 vision, the Shift2Rail program has been developed building the partnership between EU and the main players of the industry with a prevailing profile of manufacturers of rail equipment.

Private Partners include:

- Founders members: ALSTOM Transport, Hitachi Rail STS, Bombardier Transportation, Construcciones y Auxiliar de Ferrocarriles, Network Rail Infrastructure, Siemens Aktiengesellschaft, Thales, Trafikverket
- Associated members: AERFITEC, Amadeus IT Group SA, AZD Praha s.r.o., Competitive Freight Wagon Consortium, CS Group, Deutsche Bahn AG, EUropean Rail Operating community Consortium, Faiveley Transport, HaCon, Indra, Knorr-Bremse, Kontron Transportation Austria, MerMec, Smart DeMain Consortium, Smart Rail Control, SNCF Mobilités, Swi'Tracken consortium, Patentes Talgo S.L.U., Virtual Vehicle Austria consortium+).

The European Commission participates to S2R program by shifting funds from the general transport research programs (H2020) in a co-investing model with private partners.

d. S2R - 2014 program

"The EU's new programme for research and innovation (R&I), Horizon 2020 (H2020), will run from 2014 to 2020 with an estimated total budget of EUR 77 billion, of which roughly EUR 6.339 million will go towards support to smart, green and integrated transport. Of this, EUR 450 million has been earmarked for rail research and innovation activities. This represents close to three times more than the EUR 155 million in Union funding than was available under the previous research framework programme (FP7), which ran from 2007 to 2013.

A key objective of H2020 is to improve the efficiency of EU funding and better address societal challenges by pooling together existing R&I efforts and expertise, namely through Public-Private Partnerships (PPPs) in the form of Joint Undertakings.

In line with this, the Shift2Rail Joint Undertaking (S2R JU) was established by Council Regulation (EU) No 642/2014 of 16 June 2014. The S2R JU is a public-private partnership, providing a platform for the actors of the European rail system to work together with a view to driving innovation in the years to come by implementing a comprehensive and coordinated research and innovation strategy." (Shift2Rail Strategic Masterplan 2014).

Some actions of the 2014-2020 program are planned to completion up to first quarter 2023.

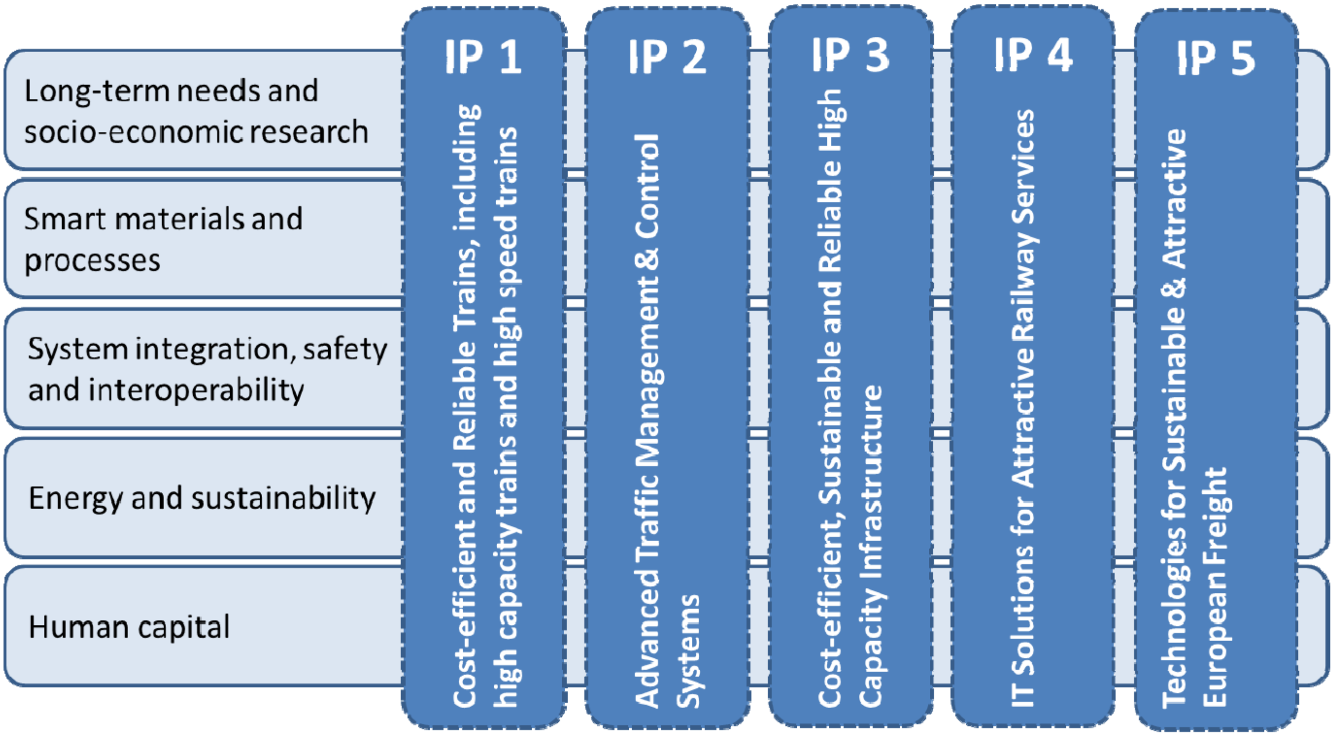

Figure 14 - Shift2Rail systems approach and cross-cutting themes – Source Shift2Rail Strategic Masterplan 2014[30]

In the following paragraphs are reported selected information about Freight Rail (IP5) and Cross Cutting Activities (because including ICT) as most relevant for the objective of this document.

Priority research and innovation activities – IP5 (Freight Rail)

"Implementation Strategies and Business Analytics

- Socio-economic cost-benefit analysis of innovative solutions and implementation strategies
- Operational solutions for European-wide migration to innovative solutions with major system impact
- Development of multi-partner business models for migration to innovative solutions in rail freight

Freight Electrification, Brake and Telematics

- *By wire* Communication and Electro-Pneumatic Brake System Electric power supply/connection on freight wagons, including interface to intermodal loading units (e.g. to reefer units), train integrity function and control
- Freight wagon/train and goods status monitoring and data management/supervision, tracking, condition based maintenance
- Advanced condition monitoring, localization and diagnosis of locomotive and freight wagons in operation
- Friction Brake Technologies, Disk Brakes, Wheel Slide Protection for Freight Wagons
- Brake Module Kit, interoperable UIC-GOST Control Valve
- Automatic Couplers, smart technologies for wagons coupling/uncoupling in terminals and marshalling yards
- Automated Train Formation, automated brake test definition and harmonized braking regimes

[30] https://_https%3A%2F%2Frail-research.europa.eu%2Fwp-content%2Fuploads%2F2016%2F03%2FS2R-JU-GB_Decision-N-4-2015-on-the-adoption-of-the-S2R-Master-Plan.pdf&usg=AOvVaw0VjDlNMpz03hSSMN7TtyU5

- On-board automatic solution for freight track gauge change

Access and Operation

- Collection and processing of combinations of different transport chains for individual transport units (door to door planning system)
- Combination of border crossing train path allocation and slot management, including "code-sharing" of train paths, e.g. by long trains
- Provision of real time data
- Improvement of the interoperability and maintained safety, reducing barriers to interoperability and preventing safety from being misused for discrimination of RUs
- Promotion of market opening
- Creation of incentives for product innovation and service quality networks.
- Vitalisation of the wagon load market
- Sharing of train and marshalling yards capacity

Wagon design

- Wagon design including new bogie solutions, running gear for higher speed, lower noise, running stability, lower wear and tear, intelligent safety sensors, disc brakes, power-pack and generator aiming at reduced overall costs/high safety
- Asset intelligence, i.e. monitoring of vehicle status component condition for predictive maintenance
- Pocket wagon frame construction for higher speed, dynamic stability, de ice and snow protection and safety systems
- Platform wagon frame for high speed, stability and stiffness to wagon and also safety solutions especially for dangerous goods transports
- Measures for low-noise wagons and low-vibration wagons; reduction of dynamic forces in the wheel/rail-interface.

Novel Terminal, Hubs, Marshalling yards, Sidings

- Support the MIX TRAINS implementation (flexible, multiple stops services with versatile and intelligent wagons, …)
- Innovative systems for improved data gathering, steering, operation and coordination
- Endorse the Management Orchestration (quick-stop, network and dynamic path allocation, integrated node-path management, dynamic planning)
- Minimise operations (shunting through fast trains, automated couplers, reduction of handling time, automation in damage recognition, brakes check)
- Hybridisation of Shunting Fleet, including retrofitting

New Freight Propulsion Concepts

- Greater Flexibility and Interoperability and resilience (ability to operate under all climatic conditions in Europe)
- Reduction on the operation costs (€/ton x km) through the operation of Longer Trains and Dual Power (master-slave operations)
- New power technologies, sustainable and environmentally friendly solutions, including battery solutions.
- Compatibility to New Generation of Wagons (interaction with TD5.1 – Freight Electrification, Brake and Telematics of IP5)

Sustainable rail transport of dangerous goods

- New wagon and transport equipment/packaging design, including technologies to prevent train accidents and incidents and reduce impact of such accidents and incidents
- ICT and systems to collect and distribute data related to transport of dangerous goods by rail, including telematics applications based on TAF-TSI, with a view to monitor traffic and movement of dangerous goods and facilitate intervention of emergency services in case of incidents and accidents

Long-term vision for an autonomous rail freight system

- Design concept of a rail freight system based on autonomous movement of intelligent wagons and its integration in intermodal supply chains" (Shift2Rail Strategic Masterplan 2014)

Shift2Rail adopted a demonstration approach gathering main segments such as freight transport together with High speed / mainline passenger rail, Regional passenger rail, Urban and suburban rail.

Table 17 Project developed in Shift2Rail IP5 (Freight Rail) [31]

Project ID		Project title	Topic	Period	Project value
arcc.png	ARCC	Automated Rail Cargo Consortium: Rail freight automation research activities to boost levels of quality, efficiency and cost effectiveness in all areas of rail freight operations	S2R-CFM-IP5-02-2015	01/09/2016 - 30/04/2021	€ 3 600 360,00
DYNAFREIGHT.png	DYNAFREIGHT	Innovative technical solutions for improved train DYNAmics and operation of longer FREIGHt Trains	S2R-OC-IP5-02-2015	01/11/2016 - 30/06/2018	€ 999 822,50
FFL4E.png	FFL4E	Future Freight Loco for Europe	S2R-CFM-IP5-03-2015	01/09/2016 - 31/07/2019	€ 3 375 017,00
FR8HUB.png	FR8HUB	Real time information applications and energy efficient solutions for rail freight	S2R-CFM-IP5-01-2017	01/09/2017 - 28/02/2021	€ 9 900 990,00
FR8RAIL.png	FR8RAIL	Development of Functional Requirements for Sustainable and Attractive European Rail Freight	S2R-CFM-IP5-01-2015	01/09/2016 - 31/08/2019	€ 7 826 783,00
tblzllygjgg.png	FR8RAIL II	Digitalization and Automation of Freight Rail	S2R-CFM-IP5-01-2018	01/05/2018 - 31/12/2021	€ 12 450 389,86
sjf3kflmgva.png	FR8RAIL III	Smart data-based assets and efficient rail freight operation	S2R-CFM-IP5-01-2019	01/09/2019 - 31/08/2022	€ 13 061 601,01
yasweiceet3.png	FR8RAIL IV	Use-centric rail freight innovation for Single European Railway Area	S2R-CFM-IP5-01-2020	01/07/2020 - 31/03/2023	€ 17 705 027,89
innowag.png	INNOWAG	INNOvative monitoring and predictive maintenance solutions on lightweight WAGon	S2R-OC-IP5-03-2015	01/11/2016 - 30/06/2019	€ 1 500 562,50
gmxsby1ieez.jpg	LOCATE	Locomotive bOgie Condition mAinTEnance	S2R-OC-IP5-01-2019	01/11/2019 - 31/10/2021	€ 1 499 072,50
5kpxkoolqnv.jpg	M2O	MAke RAil The HOpe for protecting Nature 2 future OPERATION	S2R-OC-IP5-01-2018	01/12/2018 - 31/12/2020	€ 599 955,00
optiyard.png	OPTIYARD	OptiYard - Optimised Real-time Yard and Network Management	S2R-OC-IP5-01-2017	01/10/2017 - 30/09/2019	€ 1 499 900,00
smart.png	SMART	Smart Automation of Rail Transport	S2R-OC-IP5-01-2015	01/10/2016 - 30/09/2019	€ 999 598,75
ggsysd4w2dk.jpg	SMART2	Advanced integrated obstacle and track intrusion detection system for smart automation of rail transport	S2R-OC-IP5-02-2019	01/12/2019 - 30/11/2022	€ 1 708 737,50
smartrail.png	SMARTRAIL	SMARTRAIL	MG-2.2-2014	01/05/2015 - 30/04/2018	€ 5 999 213,00
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[31] https://projects.shift2rail.org/s2r_projects.aspx

Cross-cutting themes and activities

"In addition to the five Innovation Programmes, the work of Shift2Rail will also be structured around five cross-cutting themes that are of relevance to each of the different sub-systems and take into account the interactions between these sub-systems.

These cross-cutting activities will ensure that the R&I activities within the different Innovation Programmes are closely aligned in terms of their objectives and their requirements, as well as the methodologies for evaluation and assessment of impacts. These activities include elements already taken into account in the different Innovation Programmes that require horizontal coordination (such as energy and noise management) and additional research that will be necessary to complement the technical work of Shift2Rail". (Shift2Rail Strategic Masterplan 2014)

Table 18 Project developed in Shift2Rail CCA (Cross Cutting Activities[32]

Project ID		Project title	Topic	Period	Project value
dy3mto5ykzt.jpg	BENRAIL	Benefits at rail, top down holistic approach of impact and benefits to make rail attractive for stakeholders	S2R-OC-CCA-01-2021	01/10/2021 - 30/06/2022	€ 169 985,00
DESTINATE.png	DESTINATE	Decision supporting tools for implementation of cost-efficient railway noise abatement measures	S2R-OC-CCA-03-2015	01/11/2016 - 31/10/2018	€ 1 271 812,50
fine1.png	FINE 1	Future Improvement for Energy and Noise	S2R-CFM-CCA-02-2015	01/09/2016 - 31/10/2019	€ 3 017 281,68
wfre0dnqv0b.jpg	FINE-2	Furthering Improvements in Integrated Mobility Management (I2M), Noise and Vibration, and Energy in Shift2Rail	S2R-CFM-CCA-01-2019	01/12/2019 - 30/11/2022	€ 8 179 973,07
gosaferail.png	GOSAFE_RAIL	Global Safety Management Framework for RAIL Operations	S2R-OC- CCA-04-2015	01/10/2016 - 30/09/2019	€ 1 298 750,00
IMPACT-1.jpg	IMPACT-1	Indicator Monitoring for a new railway PAradigm in seamlessly integrated Cross modal Transport chains – Phase 1	S2R-CFM-CCA-01-2015	01/09/2016 - 30/04/2018	€ 674 958,39
IMPACT-2.jpg	IMPACT-2	Indicator Monitoring for a new railway PAradigm in seamlessly integrated Cross modal Transport chains – Phase 2	S2R-CFM-CCA-01-2017	01/09/2017 - 31/08/2022	€ 7 096 427,80
in2rail.png	IN2RAIL	Innovative Intelligent Rail	MG-2.1-2014	01/05/2015 - 30/04/2019	€ 17 998 546,00
NEAR2050.png	NEAR2050	Future challenges for the rail sector	S2R-OC-CCA-01-2015	01/10/2016 - 30/04/2018	€ 399 891,25
OPEUS.png	OPEUS	Modelling and strategies for the assessment and OPtimisation of Energy USage aspects of rail innovation	S2R-OC-CCA-02-2015	01/11/2016 - 31/10/2019	€ 797 130,00
plasa.png	PLASA	Smart Planning and Safety for a safer and more robust European railway sector	S2R-CFM-CCA-03-2015	01/09/2016 - 31/08/2018	€ 786 349,00
itghca53zso.png	PLASA-2	Smart Planning and Virtual Certification	S2R-CFM-CCA-01-2018	01/09/2018 - 31/12/2020	€ 1 853 347,78
roll2rail.png	ROLL2RAIL	MG.2.3-2014. New generation of rail vehicles	MG-2.3-2014	01/05/2015 - 31/10/2017	€ 16 000 000,00
archmz24rgn.jpg	SILVARSTAR	SILVARSTAR SoIL Vibration and AuRalisation Software Tools for Application in Railways	S2R-OC-CCA-01-2020	01/11/2020 - 31/10/2022	€ 949 999,50
SMARTE.png	SMARTE	SMaRTE - Smart Maintenance and the Rail Traveller Experience	S2R-OC-CCA-01-2017	01/09/2017 - 31/10/2019	€ 769 958,75
smartrail.png	SMARTRAIL	SMARTRAIL	MG-2.2-2014	01/05/2015 - 30/04/2018	€ 5 999 213,00
4hkze35waor.jpg	TRANSIT	TRAin pass-by Noise Source characterIsation and separation Tools for cost-effective vehicle certification	S2R-OC-CCA-01-2019	01/12/2019 - 30/11/2022	€ 1 308 718,75
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[32] https://projects.shift2rail.org/s2r_projects.aspx

The achievements of Shift2Rail in Digital technologies (indicated as e.g. Big Data, AI, General Intelligence) have been reported as “satisfactory” in 2019 documents.

Shift2Rail contributes to the development of Big Data Analytics in the railway field. The large amount of heterogeneous information requires a lot of attention in data management. Shift2Rail provides an open, standardised, seamless and secure access to data, covering aspects such as transaction of Intellectual Property Right (IPR) -protected Business to Business data, management of data with safety-critical impact, strict information assurance and related quality control procedures on data and quality gates.

Data processing through analytics techniques, such as anomaly detection, asset decay prediction, process mining and prescriptive maintenance, contribute to the improvement of interventions and activities related to railways:

- increase of asset status monitoring capabilities through anomaly detection;
- more targeted maintenance interventions based on railway asset decay prediction, increasing operational reliability (less service disruption);
- maintenance activities optimisation through predictive maintenance, guaranteeing a cost reduction both in terms of spare parts and in terms of effort;
- LCC reduction based on condition-based maintenance of railway assets and continuous improvement of components/maintenance schedules.

In its Programme on IT Solutions for Attractive Railway Services Shift2Rail proposes Business Analytics developments to improve the interaction between the passengers and the operator’s networks: assessing the best offer for a passenger accounting for their preferences and previous journeys, and the real time knowledge of the multi-modal transport offer and constraints. Business Analytics is also used to provide the operators an accurate feedback of the passenger’s needs, and to adapt their offer accordingly.

Figure 15 - Achievements of Shift2Rail in Digital technologies [33]

e. S2R program update in November 2019 (main info about Freight Rail)

While reaffirming the original program, the 2019 update takes into consideration most recent actions of the European Commission (in 2016, the European Commission published a document reporting on the pace of implementation of the 2011 Transport White Paper, in 2017, the European Commission published its communication *Investing in a smart, innovative and sustainable industry – a renewed EU Industrial Policy Strategy*, adding to the strategy a pillar intended to help in moving from research and innovation to deployment) and most recent trends such as digitalization.

In the following paragraph are reported selected information about *IP5 – Technologies for sustainable and attractive European rail freight* as most relevant for the objective of this document. In IP5 a number of elements related to ICT have been incorporated.

[33]https%3A%2F%2Ferrac.org%2Fwp-content%2Fuploads%2F2019%2F09%2FERRAC_2030.pdf&usg=AOvVaw2OY6Cojc_1R5McXKoNUvTW

“**Context and motivation**

Although rail freight markets within the EU have been open for a number of years, the modal share of intra-EU rail freight transport has slightly declined since 2010, so that the sector risks failing to fulfil the ambitious objectives which were set out in the Transport White Paper in terms of developing rail freight, namely to almost double the use of rail freight compared with 2005 and to achieve a shift of 30 % of road freight over 300 km to modes such as rail or waterborne transport by 2030, and of more than 50 % by 2050.

The industry’s stagnation can partly be explained by the existence of legal barriers restricting competition (including the infrastructure access regime, taxation, etc.), but also by problems of operational and technical natures, which affect the overall capacity and performance of the sector.

Today’s main limiting factors are:

- problems with handling freight trains on mixed traffic lines during peak passenger train hours;
- long and unreliable lead times in terminals, hubs and marshalling yards accompanied with high operational costs and lack of synchronisation of different operations;
- low reliability and high operational costs due to manual handling processes and resource planning based on experience or stand-alone IT systems;
- reduced profitability, competitiveness and investment capabilities of railway undertakings/infrastructure managers and railway service providers due to the increase in operational costs and in LCC for assets and infrastructure;
- limited train weight, length and speed due to limits in the strength of standard couplers and traction distributed among several different locomotives in the freight convoy as well as due to limits in the railway infrastructure capabilities;
- low performance and lack of flexibility in serving the first and the last mile in single-wagon traffic;
- restricted payload–deadweight ratios, especially in the most emerging market segments of containerised single goods transport;
- unelectrified freight wagons, unable to benefit from intelligent sensors and communication systems;
- shippers and end-customers unable to track goods along the supply chain because data processing is not integrated’.

The members participating in IP5 are convinced that a significant proportion of the issues mentioned above are due to:

- insufficient optimisation of infrastructure and rolling stock capacity;
- low level of automation of the operational processes;
- limitations in wagon and locomotive technology;
- lack of communication, data management, data exchange, integrated IT systems/platforms;
- lack of TAF (Telematic Application for Freight) TSI implementation, which prescribes standardised data exchange platform between stakeholders;
- lacking or restricted interoperability among the different stakeholders that participate in international railway freight transport.

The cost competitiveness and the reliability of freight services need to be considerably improved so that rail freight can be in a position to offer a cost-effective, attractive service to shippers that helps to take freight away from the already congested road network.

The challenge is twofold:

- to acquire a new service-oriented profile for rail freight services based on excellence in on-time delivery at competitive costs, interweaving their operations with other transport modes, addressing the needs of the clientele by, among other things, incorporating innovative value-added services;
- to increase productivity, by addressing current operational and system weaknesses and limitations, including interoperability issues, and finding cost-effective solutions to these problems, including optimisation of existing infrastructure and fostering technology transfer from other sectors into rail freight.

For European rail freight to become more attractive, the rail freight sector must provide customer-tailored services to its clients and be more effectively integrated into the logistics value chain. Reliability, lead times, deliveries on time and in full, frequency and cost must meet customer requirements for different goods segments. Investments in rail innovations should be compatible with expected future needs and changes brought about by macro level trends in trade and production patterns, goods types, shipment sizes and consumer behaviour.

The rail freight sector must also take advantage of and integrate new developments that are affecting other parts of the logistics chain, in particular digitisation, which can help to drastically reduce LCC and operation costs, as well as novel processes and technologies such as 3D printers or fabrication laboratory capacities, or blockchain. Standardised digital data exchange and automated, condition-based processes are key to the vision of IP5. Therefore, IP5 recognises that the development of an efficient, capable and powerful IT infrastructure is an important precondition. To make use of innovative applications, technologies and processes, and for the profitable combination of different solutions, the IT backbone has to be a focus of development. Hence, IP5 aims to develop the overall IT infrastructure to make use of the potentials of the targeted results of IP5.

Action in the rail freight sector is urgent, as it risks losing its position as the most environmentally friendly transport mode because of innovations in other transport modes and must come up with an answer to new challenging developments in the road freight traffic segment, such as the implementation of autonomous driving modes.

Objectives of the IP and expected results

To tackle this broad spectrum of challenges, IP5 follows a whole-system approach whereby the different components interplay in an optimal way to ensure value creation for customers, the rail-operating community and society.

The innovations and enabling technologies stemming from the TDs in IP5 are regarded as milestones on a trajectory towards a long-term vision of a high-performing, 24/7-operating, automated/autonomous railway that optimises infrastructure capacity, is integrated with other transport modes through fluid and seamless terminal operations, and is sensitive to changing customer demands. When disruptions occur, customers are informed about alternatives and routes that meet their specific requirements and are rebooked, and rerouted in some cases, in a seamless way. The railway of the future fully exploits the potential of digitalisation to increase its attractiveness and viability. S2R will also be instrumental in the continuous development of rail freight’s green credentials in door-to-door mobility solutions, which is a necessity, as the alternative modes are improving their environmental performance.

Driver assistance, component optimisation and advanced propulsion technologies will significantly reduce energy consumption and emissions, strengthening competitiveness while lowering the carbon footprint.

Increased flexibility through virtual train coupling and the resulting increase in freight train lengths will help to respond to the challenge of road freight productivity and enable sustainable growth in freight traffic along core European corridors.

All work developed in each TD has to take into account the present and coming (2020) TAF-TSI standards for each relevant objective/topic and the TAF-TSI Strategic European Deployment Plan. Furthermore, the current processes in regard to TAF-TSI must be followed by each TD in relation to relevant issues.”

(MULTI-ANNUAL ACTION PLAN, Amended version finally adopted on 14 November 2019)

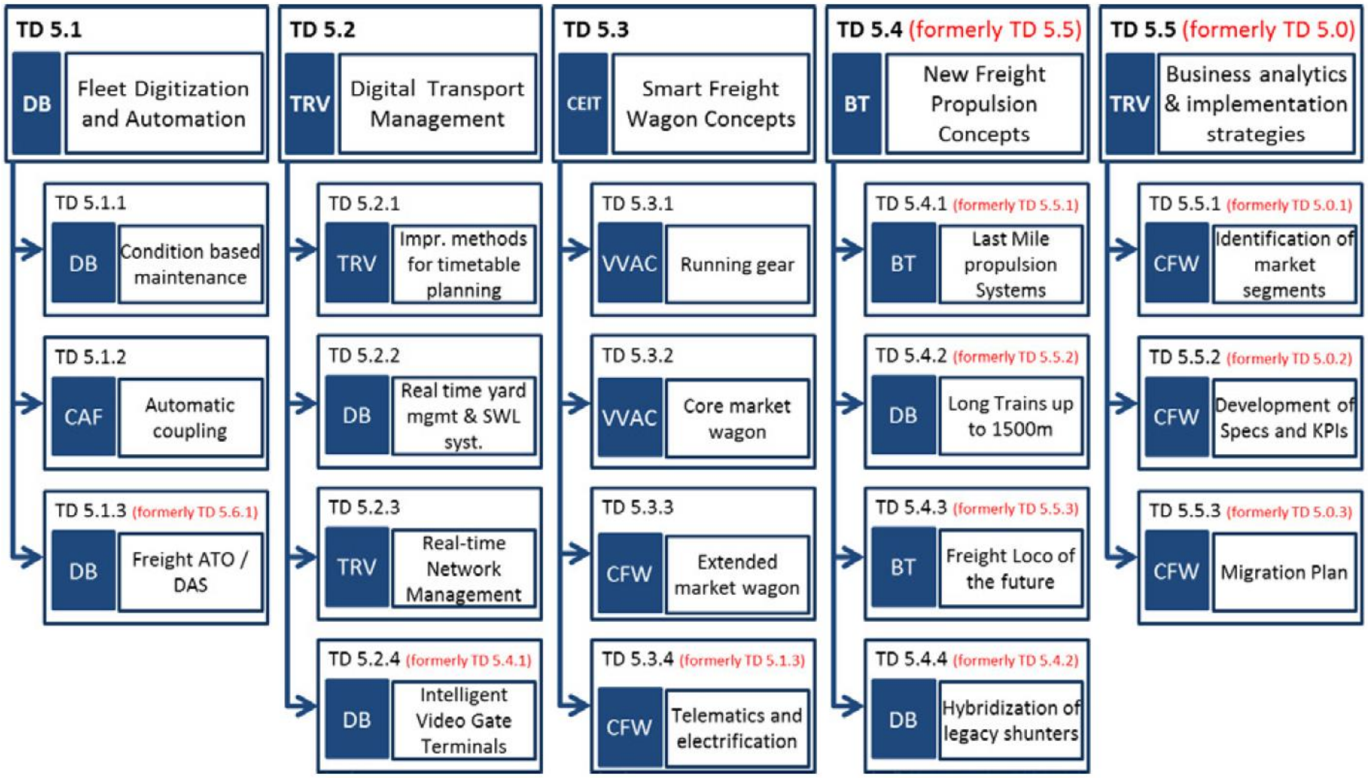

Figure 16 - Revised IP 5 structure (MULTI-ANNUAL ACTION PLAN, Amended version finally adopted on 14 November 2019)[34]

[34] https%3A%2F%2Frail-research.europa.eu%2Fwp-content%2Fuploads%2F2020%2F09%2FMAAP-Part-A-and-B.pdf&usg=AOvVaw1fD4EQvBgK5WjWiB_wfTLp

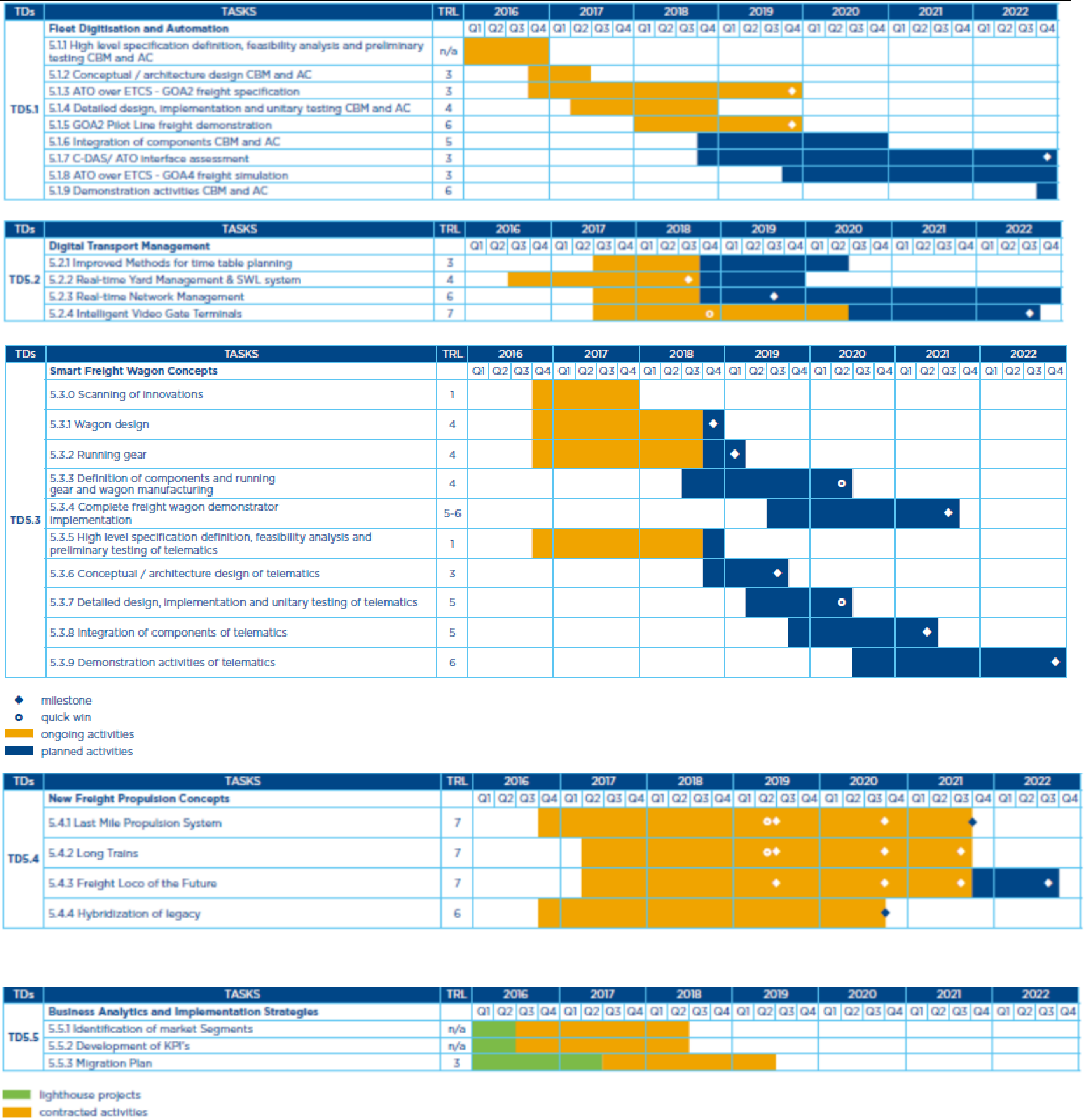

Figure 17 - IP5 Planning (MULTI-ANNUAL ACTION PLAN, Amended version finally adopted on 14 November 2019)

f. Europe's Rail Joint Undertaking (EU-Rail) – 2021-2031 - successor of S2R

"Europe's Rail Joint Undertaking (EU-Rail) is the universal successor of the Shift2Rail Joint undertaking and it is established by Council Regulation (EU) 2021/2085 of 19 November 2021 (SBA - Single Basic Act).

In accordance with the SBA, EU-Rail has defined in its Master Plan its priority research and innovation activities, overall system architecture and harmonised operational approach, including large-scale demonstration activities and flagship areas. These are required to accelerate the penetration of integrated, interoperable and standardised technological innovations necessary to support the Single European Railway Area. The Master Plan provides an overview of the ambitions and the objectives of EU-Rail and defines a systemic, long-term and result-oriented delivery strategy for research & innovation in the railway sector.

EU-Rail works towards the twin green and digital transition of Europe." [35]

EU-Rail, in continuity with S2R, ri-elaborate objectives and set directions for large and coordinated actions aiming at transforming Rail industry enabling an increase in the use of rail transport, and reducing further the greenhouse gas emissions of the railway sector itself.

Innovation activities for the period 2021 – 2031 are segmented in big clusters as follow:

- Flagship Area 1: Network management planning and control & Mobility Management in a multimodal environment
- Flagship Area 2: Digital & Automated up to Autonomous Train Operations
- Flagship Area 3: Intelligent & Integrated asset management
- Flagship Area 4: A sustainable and green rail system
- Flagship Area 5: Sustainable Competitive Digital Green Rail Freight Services
- Flagship Area 6: Regional rail services / Innovative rail services to revitalise capillary lines
- Flagship Area 7: Innovation on new approaches for guided transport modes
- Transversal Topic: Digital Enablers
- Exploratory Research and other activities

"EU-Rail will support rail freight by:

- Developing and integrating new operational and technological solutions (such as to automate services, e.g. with the use of technology enabled by the introduction of a European digital automatic coupler), including adapted logistics process and customer relations. This will shorten average transportation time and increase reliability offering more attractive and cost-efficient rail freight.
- Fully digitalizing operations, planning and management functions as well as delivering specific solutions for integrated rail cargo systems, including connected digital services (e.g. capacity and yield management, multimodality with predictive Planned Time of Arrival, load and empty flows equilibrium) and terminal improvements that drive innovation in customer interactions: the objective is to ensure rail is integrated in the logistics value chain, feeding into logistic systems of exchange of information. This should considerably increase productivity (including shortening the average transportation time and increasing capacity utilisation), reliability and flexibility of rail freight.

[35] https://rail-research.europa.eu/wp-content/uploads/2022/03/EURAIL_MAWP_final.pdf -

- Delivering innovative solutions to minimise energy consumption and associated environmental footprint for the rolling stock and infrastructure, building upon the work done in different priority areas and in synergy with other partnerships."

(Source Europe's Rail Joint Undertaking Master Plan October 2021)

The Union financial contribution from the Horizon Europe Programme to EU-Rail, including EFTA appropriations, to cover administrative costs and operational costs, shall be up to EUR 600 million.

g. Initiatives in partnership with other Modes/Technological Platforms

"ERRAC constantly seeks to identify areas where greater synergies can be developed between the railway sector and other modes of transport. This is given expression in the liaison and cooperation with other mobility ETPs (i.e., ACARE, ALICE, ERTRAC and WATERBORNE) to promote common approaches to enhance multimodal research and innovation"[36]

[36] https://errac.org/overview/

Annex 2 WATERBORNE – the European research and innovation platform for waterborne industries

a. ETP General profile

WATERBORNE is the ETP with Waterborne scope.

"The WATERBORNE Technology Platform was launched in January 2005. It builds on the successful efforts of the Maritime Industry Forum (MIF) in publishing two volumes of maritime R&D Master Plans since 1994.

WATERBORNE brings together the industry stakeholders with the EU member states, the European Commission services and stakeholders from science and society. A vision of the year 2020 (Vision 2020) was developed and was followed by the first WATERBORNE Strategic Research Agenda (WSRA) in 2007" (source strategic research agenda

OVERVIEW - ISSUE II - May 2011).

"WATERBORNE has been set up as an industry-oriented Technology Platform to establish a continuous dialogue between all waterborne stakeholders, such as classification societies, shipbuilders, ship-owners, maritime equipment manufacturers, infrastructure and service providers, universities or research institutes, and with the EU Institutions, including Member States.

The strategic objectives of the WATERBORNE TP are:

- Establish a continuous dialogue between all stakeholders in the waterborne transport sector and in other waterborne-related sectors on R&D;
- Contribute to the widest possible consensus regarding R&D and to focusing of efforts and resources;
- Develop a common medium- and long-term R&D Vision and a Strategic Research Agenda (SRA);
- Contribute to the appropriate mobilisation and allocation of the necessary financial resources (private/regional/national/EU sources);
- Contribute to the social expectations regarding clean, competitive and safe waterborne transport as well as regarding other waterborne-related activities, including education and training.

For WATERBORNE to reach its goals, it is necessary to engage all relevant stakeholders of the European maritime industry, such as classification societies, manufacturers, research institutes, shipyards, ship-owners, or universities, as well as the European Institutions and Member States. This approach should ensure that, whilst national policies will vary according to particular challenges, effective mechanisms are developed to enable adequate research coordination and cooperation between the relevant stakeholders at EU/EEA level."[37]

Membership includes representatives of Research, Academia, Associations and Observers.

Waterborne is cofounded by the European Union.

b. Vision statements

The Vision in its revisions, after first release, is presented articulated in segmented chapters.

The ones of more interest for the objective of this document have been reported in few lines.

[37] https://www.waterborne.eu/

- **Global trends and drivers - Including the paragraph ICT developments**
  "With massive growth in computational capacity and data storage capabilities, globally accessible networks and cloud infrastructure with increasing bandwidth, availability of smart devises (Internet of Things) and smart and cheap sensors, a significant increase of digitalization in all waterborne sectors is expected.
  The increasing ICT capabilities will lead to a higher interconnectivity of systems, which are more software dependent and contain of smart devices. Higher automation of systems and the availability of smart sensors will provide the opportunity to operate assets remote controlled, semi or fully autonomous. Complexity of systems will further increase and challenges the way they are tested and maintained throughout their entire life-cycle.
  With the availability of globally accessible and more powerful data networks and cloud infrastructure interconnectivity between sea and shore will increase significantly, meaning that sea-based operations will become more supported and controlled by land-based operation centers.
  The increasing interconnectivity between technical systems, the opportunities to have autonomous operations offshore, or to support and control offshore operations from shore, requires to secure systems and operations against cyber-attacks, but also against expected more severe weather conditions due to global warming.
  The growing digitalization in all waterborne sectors will result in using electronically data as substitute for current legal paper documentation. It will also require solutions related to data ownership, data access, intellectual property right issues." [38]

- **Green and clean waterborne transport**

- **Safe and secure waterborne transport**

- **Connected and automated waterborne transport**
  "Vision - Digitisation will connect smart ships and vessels as well as smart ports and smart infrastructure. It will enhance data flows. It will also lead to a higher degree of automation and autonomy, automated and autonomous systems, ship operations (both maritime and inland navigation) and remote control from the shore by 2030. Future ships and vessels will be designed so that they can be continuously updated with the digital technologies throughout their lifecycle. Connectivity and automation will not only improve nautical operations, safety or the energy-efficiency of Waterborne transport, but will also improve logistics and mobility flows.
  Mission - The European Waterborne sector will increase efficiency, flexibility and safety by means of the transformation of business models and automation of operations, thereby increasing the share of Waterborne transport in the worldwide and regional logistics and mobility chain. It will develop, implement and maintain automated and interconnected work processes in Waterborne integrated systems and infrastructures, enabled by smart and connected ships and vessels, with a focus on improving efficiency in Waterborne logistics.
  The sector will aim at the large scale introduction of resilient and secure autonomous operations in 2050 and will extend its global leading position regarding the integration and automation of Waterborne systems, utilizing its strengths in developing creative solutions and cooperation with all stakeholders. Europe will keep its leading position in terms of the deployment of integrated automated systems and will set the standard in data exchange and communications." (source https://www.waterborne.eu/vision/connected-and-automated-waterborne-transport)

- **Safe, competitive and eco-friendly shipyards and production sites**

- **Understanding and protecting oceans**

[38] www.waterborne.eu/vision/global-trends-and-drivers

- **Oceans and seas as a source of natural resources**

- **Working and living at sea**

- **Port operation**
  "Vision - By 2050, ports will offer the fastest, most reliable service with zero-waste and zero emissions in a safe and secure environment at the lowest cost. Therefore, ports will be able to achieve zero-emissions in their own port operations and to adapt to the new demands following the energy transition. Driven by automation and cyber-physical systems, blockchain, artificial intelligence (AI) and other new technologies, Industry 4.0 will allow new digital and automated port environments to assist nautical operations, ship-port communication, cargo handling and other port operations. This dynamic will improve efficiency and increase the capacity to accommodate changing cargo and passenger flows. Moreover, the evolution of new socio-economic trends (blue growth, waterborne tourism, cruisers, automated transport, etc.) will lead to new port services and operations and to the enhancement of societal responsibility (employability, accountability, etc.) of port activities.
  Mission - Port operations serve both the ship/vessel and the cargo and passengers that pass through the ports. Port operations add value to the port infrastructures to provide easy navigation and give shelter to ships and vessels with nautical services (signalling, dredging, traffic management, locks management, piloting, mooring, towing, etc.) and other complementary services (dredging, bunkering, waste management, inspection, maintenance, etc.).
  Furthermore, port operations add value to the port infrastructures to provide a smooth cargo and passenger flow in their transition to the next node in the transport chain, providing efficient cargo handling services and connections between transport modes. Finally, port operations should be adapted to meet the future challenges of the Waterborne sector, characterized by capacity, efficiency, environmental, social and security concerns, in which energy transition, the circular economy, digitalisation, robotization, inter-modality and collaboration, amongst others, will play a crucial role." [39]

- **Integrating maritime and hinterland logistics**
  "Vision - By 2050, port actors will connect and integrate maritime and hinterland logistics to a point where they offer the lowest costs and the fastest, most reliable service with zero waste and emissions in a safe and secure environment. In this regard, ports will be able to achieve zero-emission in port-hinterland logistics. Inland waterways and inland ports will evolve rapidly and play a crucial role in achieving these objectives, offering integrated multimodal solutions. Technological and logistical developments will allow real time information (digital corridors) to flow throughout the entire supply chain, providing the opportunity to transfer the cargo in a seamless way and offering customer-tailored solutions (synchro-modality, cost/time trade-off, new cargo handling solutions, etc.). This dynamic will enable an innovative business environment and will foster the smart collaborative planning of ship/vessel to hinterland logistics (capacity sharing, self-organising logistics, physical internet, coordinated inland navigation, etc.).
  The increasingly changing demands from the logistics sector (sustainable procurement, real time cargo status visibility, etc.) will enable the adoption of new concepts like modularisation of cargo to achieve secure intermodality in transport (last-mile integration, Internet of Things for Customs and security, etc.). The integration of maritime and hinterland logistics will also provide expanding services to waterborne tourism and mobility, cruises and ferries, waterbuses and water taxis.
  Mission - Maritime transport is part of complex logistics chains and transport networks where ports are key multimodal nodes linking maritime and hinterland logistics. Therefore, waterborne transport seaports and inland ports are not isolated, and their challenges are those of the logistics and transport system. The

[39] https://www.waterborne.eu/vision/integrating-maritime-and-hinterland-logistics

Waterborne sector should play a key role in the integration of maritime and hinterland logistics, paying special attention to inland waterways and multimodality. The multi-modal transport container is an example of previous developments which have taken this integration to a higher level through standardisation in an intermodal transport chain. Port community systems (PCS) and River Information Services (RIS) are other examples related to the integrated management of information. The logistics sector is facing the new challenges of the global/local - or so-called "glocal" - logistics and transport system (characterised by capacity, efficiency, environmental, social and security concerns) through the development of new concepts such as the physical internet, which involves innovations in modularisation, collaboration schemes, robotization, artificial intelligence and other IT technologies. This requires a further step forward in terms of the integration of maritime and hinterland logistics, in which the Waterborne sector, seaports and inland waterways and ports should retain a leading position and develop new versatile concepts for integrated door-to-door transport solutions." [40]

- **Port infrastructure**
  "Vision - Port infrastructures will increasingly support and become integrated with port operations and waterborne and hinterland logistics by adapting near shore extensions and offshore ports and by establishing flexible and resilient solutions for future ship and vessel types, hinterland logistics, new port activities and climate change. In this respect, new facilities for the (re)generation of zero emissions energy and green supply for ships, vessels, port activities and society will be developed. Cutting-edge adaptive secure communication and IT architecture (real time information, etc.) will be introduced to the benefit of strategic traffic and port management and ship-assist infrastructure (smart berths, towage, mooring, MARPOL, bunkering, etc.). Furthermore, city-port-nature oriented planning (building with nature, smart industry, coastal recreation, etc.) will promote leisure and business integrated hubs for passenger transport, closely linked to public transport, the cities and the local tourism sector.
  Mission - The port infrastructure is the base for port operations to serve the vessel, cargo and passengers which pass through ports. The development of port infrastructures requires capital-intensive investments, a long lead-time and therefore long-term planning. This means that the design of port infrastructures should anticipate the needs of the Waterborne, logistics and transport sector. This is an especially difficult task at a time when the transport and logistic sector is immersed in a deep transformation, as is currently the case, affecting both maritime and inland aspects (new fuels, autonomous transport and cargo handling, self-organising logistics, new business models, etc.). Furthermore, port infrastructures should also anticipate and adapt to the development of new waterborne activities (blue growth) and to other external factors, such as new extreme weather conditions resulting from climate change. There is a need to design more flexible, intelligent and resilient port infrastructures which are able to adapt to future requirements. The European Waterborne sector should identify and develop different lines of research and innovation in order to adapt port infrastructures to this vision of the future.
  The Waterborne sector wishes to lead a long-term business transition; port infrastructures will become adaptive to new ships, vessels, inland waterways and offshore activities supporting blue growth, which are suited to further scalability. Connectivity and integration will be developed to ensure continuity among different transport modalities and different ships, vessels and vehicles. Infrastructure must be resilient to environmental challenges. To accommodate the fast implementation of the energy transition, clarity is needed on the most likely transition path. Furthermore, the development of new, more flexible solutions for bunkering and energy storage is required to enhance the resilience of investments in alternative fuels. Infrastructure should also integrate intelligent technologies and efforts should be made to allow infrastructures to be able to collect data in order to meet all requirements from the point of view of the market and the maintenance of the infrastructures themselves. Within European ports, infrastructure will be developed following the paradigm of city-port-nature oriented planning, cohesively linking shipping to the territory in a sustainable manner. The social, political and regulatory elements are fundamental to future changes in the sector. The workers and the inhabitants of the cities annexed to the ports, etc. are the sector's

[40] https://www.waterborne.eu/vision/port-operation

main assets as both customers and suppliers of labour to ensure the sustainability and viability of the infrastructures through which the cargo and the associated information move." (Source)[41]

c. Roadmap 2030 - 2050

The roadmap as well as the strategy has been revised and updated with a number of iterations, as documented in published papers. While the main topics are always represented, the focus and segmentations may show some limited differences together with timing and priorities of the various subtopics.

The WATERBORNE Technology Platform was launched in January 2005. A vision of the year 2020 (Vision 2020) was developed and was followed by the first WATERBORNE Strategic Research Agenda (WSRA) in 2007. WSRA was reviewed and updated in 2011.

The strategic roadmap of the European waterborne sector, is segmented in

- Ships & Shipping
- Blue Growth
- Ports & Logistics (better presented in the following)
- Transversal Aspects

Ports & Logistics "Ensuring the development of zero emission port areas and fostering their digital transformation to achieve the seamless integration of ports. The development of safe technologies and procedures for bunkering at ports and offshore and systems for reducing emissions at climate-resilient ports will be presented here to complement some of the activities included in the Ports activities of the Strategic Research and Innovation Agenda (SRIA) of the co-programmed Partnership Zero-emission Waterborne transport (cPP ZEWT). Other aspects not included in the cPP SRIA, such as the improvement of the integration of maritime and hinterland transport at port clusters through innovations on digitalisation, automation and improved cooperation in the logistics supply chain, will also be considered."[42]

[41] https://www.waterborne.eu/vision/port-infrastructure

[42] https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwid4f3BlIn_AhU0UKQEHc-uDloQFnoECAsQAQ&url=https%3A%2F%2Fwww.waterborne.eu%2Fimages%2F210609_SRIA_non-cPP_-_4_-_Ports_Logistics.pdf&usg=AOvVaw0jHakM95jUSyQ5xkvzUgfg

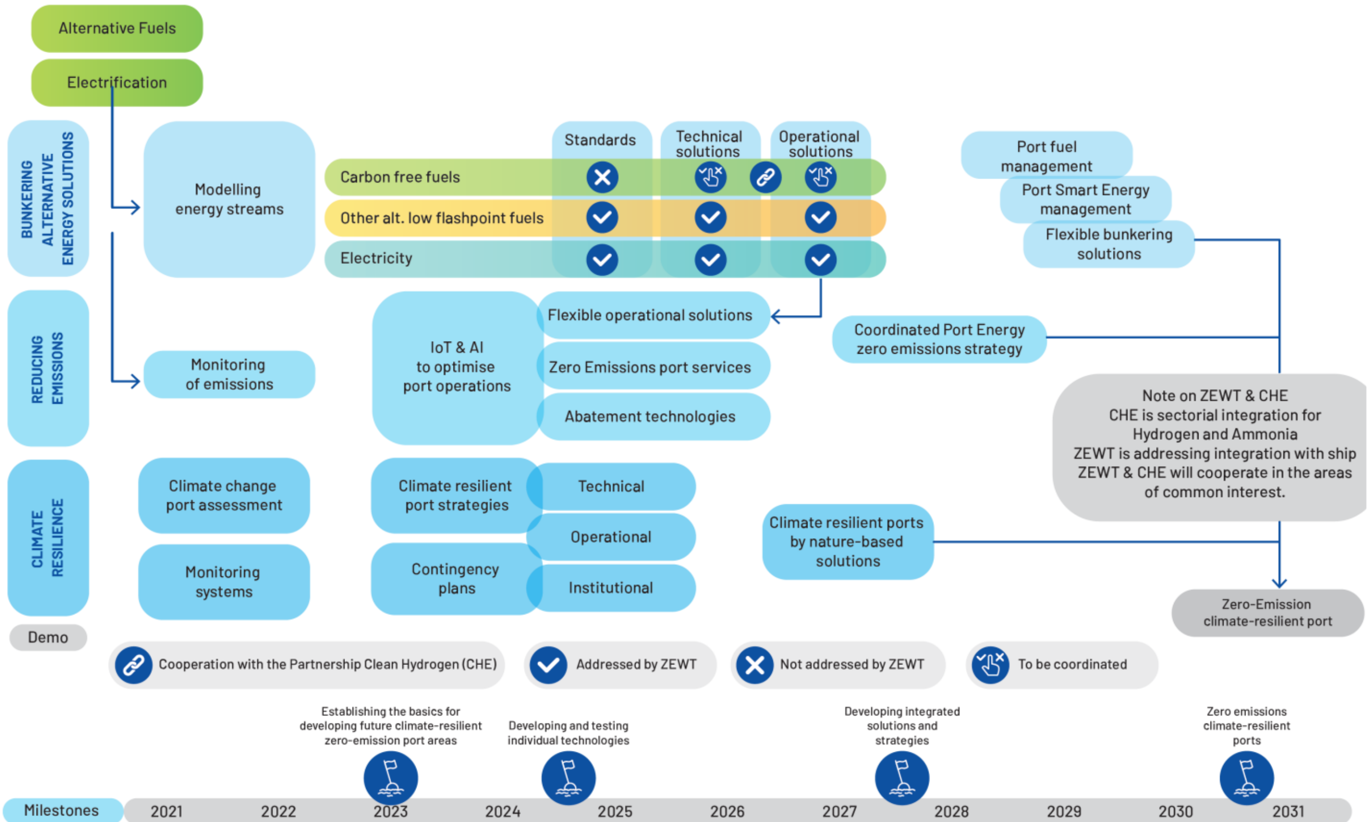

Figure 18 - Towards zero emissions ports

Amongst the different topics ICT is not “individually” considered.

“Digital technologies may find different applications in waterborne manufacturing processes, onboard ships, at ports, and for the exploitation of data sciences for Blue Growth. We have not mapped the transversal connection across Ships & Shipping (including the SRIA of Zero Emission Waterborne Transport), Blue Growth and Ports & Logistics, since digitalisation pervades all aspects of waterborne and interconnects assets, operations and stakeholders. These will cover all aspects of digitalisation, from sensorisation and Internet of Things (IoT), to cybersecurity and big data and the application of Artificial Intelligence in different cases. The reader will find complementary aspects of digitalisation across all documents

Most innovative aspects are considered in the WATERBORNE TECHNOLOGY PLATFORM SRIA are:

- **Digitalisation**
  “A deep and massive digitalisation process based on new technologies (Internet of Things - IoT, smart sensors, Big Data analytics, Artificial Intelligence, 5G, etc.) will be the trend for ports and all stakeholders involved in port operations. Consequently, forecasts, analysis and predictions will be dramatically improved and assisted port operations will achieve a more efficient use of resources (dynamic optimisation systems, predictive maintenance systems, advanced dredging materials management, just-in-time ship arrivals, etc.). However, to achieve a truly integrated approach and use the data that will become available, shared frameworks and standards need to be implemented at a European level (Digital Transport and Logistics Forum - DTLF3 and European Sustainable and Smart Mobility Strategy). The standards developed for the

maritime sector (in waterborne) need to be connected to those already set for logistical and distributional transport networks (in the framework of the Alliance for Logistics Innovation through Collaboration in Europe - ALICE). Society and the digitalisation and port automation processes will require innovative strategies to guarantee safety and security in automated and semi-automated environments and ecosystems. The development of security solutions with an integrated and holistic approach for monitoring, control, decision support systems and management will be required. The integration of cybersecurity and physical systems (sea and inland ports) related to port infrastructure is critical, particularly given the increased and frequent threats. In this regard, active cooperation between ports and countries and effective and resilient threat identification systems are urgently required. The improvement and development of new technologies, equipment and devices allowing intelligent, passive and active interactions with passengers and goods have to be considered with the aim of fostering a completely safe and secure environment. The development of new advanced identification technologies and solutions will also have to be taken into account. The development of new collaborative solutions and the corresponding tools and business models will facilitate capacity sharing along the supply chain and should take into account all the different transport flows (e.g. people and cargo movements; intercontinental flows; short-sea flows; hinterland transport network, port clusters, etc.). The maritime and inland waterways sector is characterised by the high degree of interactions of intermediaries along the supply chain, where the ports are vital players representing the primary interface between the sea/river and the hinterland, through the transportation and movement of goods."

- **Automation**
  "Automation and robotisation is an important research field for port operations and transport: autonomous and remote-controlled vessels, vehicles, cranes, etc. There is a need to enhance and develop new situational awareness systems for multiple functions, combining physical and digital assets. In this regard, a wide range of solutions (e.g. cutting-edge Vessel Traffic Service - VTS; modern control towers; innovative vehicle traffic management services; equipment control systems, autonomous and remote-controlled port services ships; automated mooring; etc.) needs to be defined and assessed for the implementation of an effective pathway towards a fully connected and automated port. The development of new advanced solutions and systems to support the progressive automation of nautical services for vessels (piloting, tugging, mooring, underwater maintenance, etc.), cargo handling and other port operations is also envisaged to overcome the current limitations. Improved solutions for human-machine interactions will be developed, including the application of new technologies, such as artificial intelligence, predictive analytics, big data and augmented reality. Therefore, traditional job qualifications will evolve and training needs will change, along with existing jobs and staff that will have to be adapted to match the new technological developments. Human factor aspects, including ethical issues, should therefore be thoroughly assessed and addressed, especially with regards to automation technologies (e.g. the dockworker of the future; remote working; cobotics4 and mobile robotics; etc.)."

- **Cooperation**
  "The expected growth of freight operations within the challenging urban environment calls for a seamless waterborne transport chain and integration of maritime and port-hinterland transport. The development of an improved linking of waterborne transport with other modes of transportation will enable seamless switching between modes - synchromodal transport (Truly Integrated Transport Systems).
  Technologies related to keeping track of cargos are fundamental to effectively promote an integrated approach for freight flows within the port and hinterland framework (reliable, highly efficient sustainable port operations). In this regard, seamless tracking and tracing devices need to be improved to enhance goods connections with transport networks along the supply chain. Moreover, innovative design and optimisation of cargo units should be able to deal with several issues that characterise the sector. Among the most relevant topics, modularity, system interoperability and overall capacity, as well as handling, should be promptly addressed. Other improvements should be considered for storage. In particular, energy-

efficient refrigeration technologies are, indeed, an appealing solution to enable sustainable maritime and inland waterway transport for different types of cargos, including perishables, pharma and electronics.
Seamless and improved track and trace technology will connect the individual goods with the means of transportation along the supply chain. The development of new freight and passenger services, as well as disruptive innovations in waterborne transport, require the development of new port infrastructure and services. First of all, the increase in the number of autonomous vessels requires new port services (vessel traffic management services, including forms of pilotage, new advanced solutions Ro-ro/Lo-lo and others, autonomous and remote-controlled port services ships, automated mooring solutions, vessel maintenance, etc.). These services should include vessels not calling at a port (e.g. cargo handling between vessels, fuelling vessels at sea, urgent delivery of small cargo, waste, ship supplies, etc.)."

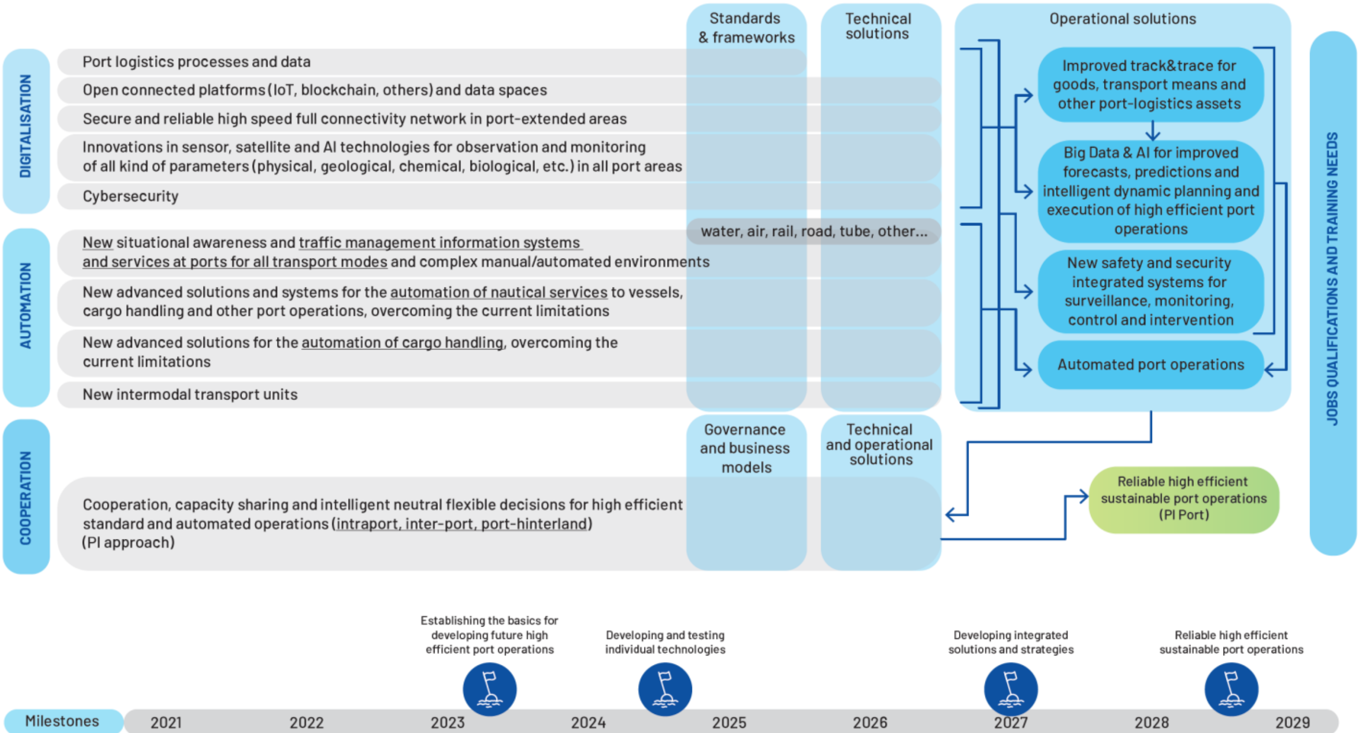

Figure 19 - The seamless integration of ports through digital transformation - (Source - WATERBORNE TECHNOLOGY PLATFORM - STRATEGIC RESEARCH AND INNOVATION AGENDA FOR THE EUROPEAN WATERBORNE SECTOR Ports & Logistics June 2021

d. Main projects and initiatives in partnership with other Modes/Technological Platforms

Funded research projects contribute to achieving the goals of the Waterborne TP.

The researches include a number of projects as segmented below – the full list of projects is provided for the most significant segments:

- Coordination projects

COLUMBUS Knowledge transfer for blue growth

DOCKSTHEFUTURE Defining the concept of the Port of the Future

LASTING Let's go for the waterborne transport research – broadening engagement and increasing impact

MESA The Maritime Europe Strategy Action

PLATINA3 Promoting IWT

SETRIS Strengthening European Transport Research and Innovation Strategies

STEERER Structuring towards zero-emission waterborne transport

- Energy Efficiency and Zero Emissions

- Ship and Shipping safety

- Digitisation and Autonomy including

AUTOSHIP Autonomous Shipping Initiative for European Waters

H2H Using EGNOS and Galileo to support Autonomous Maritime Operations

Logistics MOSES AutoMated Vessels and Supply Chain for Sustainable Short Sea Shipping

- Ship design and production
- Understanding and protecting oceans

- Offshore multi-use

- & Modal Shift

AGRO HIGHWAY Multimodal Perishable Food Liquid Transport in the EU

COG-LO Cognitive Logistics Operations through secure, dynamic and ad-hoc collaborative networks

LeMO Leveraging big data to manage transport operations

LOGISTAR Enhanced data management techniques for real time logistics planning and scheduling

RESIST RESilient transport InfraSTructure to extreme events

SYNCHRONET Improving the logistics chain through synchro modal coordination

- Port Operations

COREALIS Capacity with a pOsitive enviRonmEntal and societAL footprInt: portS in the future era 2018-21

DataPorts A Data Platform for the Connection of Cognitive Ports 2020-22

HiSea High-Resolution Water Quality Data Services

H2Ports Implementing fuel cells and hydrogen technologies in ports

PIXEL Port IOT for environmental leverage

PortForward Towards a green and sustainable ecosystem for the EU Port of the Future

RCMS Rethinking Container management System

SafePort A novel smart system for the safe management of nautical operations

Toolbot High accuracy, cost-effective and ecofriendly dredging solutions

- Inland navigation

IW-NET Innovation driven collaborative European inland waterways transport network

NOVIMAR Novel IWT and maritime transport concepts

NOVIMOVE Novel inland waterway transport concepts for moving freight effectively

PROMINENT Promoting innovation in the IWT sector

SCIPPER Shipping Contributions to Inland Pollution Push for the Enforcement of Regulation

- Education and Training