Report on best practices, recommendations on further integration of IWT in synchromodal logistics chains D1.3

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List of abbreviations

Abbreviation	Explanation
AEOLIX	Architecture for EurOpean Logistics Information eXchange project
AI	Artificial Intelligence
AIS	Automatic Identification System
AIRIS II Synchro	Synchromodal Traffic & Transport Information Services project
ALICE	Alliance for Logistics Innovation through Collaboration in Europe
AR	Augmented Reality
CCNR	Central Commission for the Navigation of the Rhine
CESNI	European Committee for drawing up standards in the field of inland navigation
CO-GISTICS	COoperative loGISTICS for sustainable mobility of goods project
CSIRT	Computer Security Incident Response Team
DINA	Digital Inland Navigation Area
DIONYSUS	Integrating Danube Region into Smart and Sustainable Multimodal & Intermodal Transport Chains project
DIWA	Project Masterplan DIWA
DR	Danube Region
DTLF	Digital Transport and Logistics Forum
EC	European Commission
eFTI	Electronic Freight Transport Information
ePicenter	Enhanced Physical Internet compatible earth-friendly freight transportation answer project
EU	European Union
EUSDR	EU Strategy for the Danube Region
FEDeRATED	FEDeRATED – Network of Platforms
FENIX	FENIX Network - A European Federated Network of Information eXchange in LogistiX project
GDPR	General Data Protection Regulation
GPS	Global Positioning System
HR	Human Resources
JIT	Just in time
ICT	Information and Communication Technologies
ICONET	New ICT infrastructure and reference architecture to support operations in future PI logistics networks project
IMO	International Maritime Organisation
INCOTERMS	International Commercial Terms
IoT	Internet of Things
IPCSA	International Port Community Systems Association

Abbreviation	Explanation
IT	Information Technology
ITS	Intelligent transportation system
IWT	Inland Waterway Transport
IW-NET	Innovation-Driven Collaborative European Inland Waterways Transport Network project
LOGISTAR	Enhanced data management techniques for real time logistics planning and scheduling project
ML	Machine Learning
MAGPIE	Smart Green Ports as Integrated Efficient Multimodal Hubs project
NoTN	Network of Trusted Networks
NOVIMOVE	Novel inland waterway transport concepts for moving freight effectively project
PIANC	World Association for Waterborne Transport Infrastructure
PIONEERS	Portable Innovation Open Network for Efficiency and Emissions Reduction Solutions project
PhysICAL	Physical Internet through Cooperative Austrian Logistics project
PCS	Port Community System
PLANET	Progress towards Federated Logistics through the Integration of TEN-T into a Global Trade Network project
RD&I	Research, Development and Innovation
RPA	Robotic Process Automation
RIS	River Information Services
RIS COMEX	Project RIS Corridor Management Execution
RPIS 4.0	Project RPIS 4.0 - smart community system for the Upper Rhine Ports
SaaS	Software as a service
SELIS	Towards a shared European Logistics Intelligent Information Space project
SYNCHRO-NET	Synchro-modal Supply Chain Eco-Net project
SW	Single Window
TEN-T	Trans-European Transport Network
UNECE	United Nations Economic Commission for Europe
VR	Virtual Reality
VTS	Vessel Traffic Service
WG	Working Group
WP	Work-package

Executive summary

Greater use of multimodal transportation can substantially improve the environmental performance of freight transportation. Despite big efforts taken by policy-makers to alter the freight modal split, most companies still rely heavily on road transportation, while modal shifts to rail and inland waterways are still modest.

The European transport and logistics sector is one of the key business sectors in Europe, performing billions of operations by millions of companies and people every day. Assuring the integration of these operations across national borders is a cornerstone of EU policy and a basis for the competitiveness of the economy. The insufficiency and partial absence of common processes, a common language and common standards for interoperability are key obstacles to achieving integration. Moreover, any supporting technology to be applied should be highly reliable, accessible, affordable and as generic as possible. Interactions between stakeholders must be easily established at a cost affordable to all. Supply chains need to be more efficient by providing state-of-the-art visibility and collaboration capabilities. Above and beyond the proper design of infrastructures and services, the operational control of the execution of transport processes should be optimised through, for example, improved synchronisation.[1]

Synchromodality is defined as an "*evolution of inter- and co-modal transport concepts, where stakeholders of the transport chain actively interact within a cooperative network to flexibly plan transport processes and to be able to switch in real-time between transport modes tailored to available resources. The shipper determines in advance only basic requirements of the transport such as costs, duration and sustainability aspects. Thus, transport processes can be optimized and available resources sustainably and fully utilized*"[2].

According to PIANC, Guidelines and recommendations for river information services (2022), synchromodality provides the most efficient and appropriate transport solution in terms of sustainability, transport costs, duration, and their reliability, in which the configuration of the transport chain is not static during transport, but is flexible. It is thus able to adapt the mode of adequate transport according to the conditions in real time of infrastructure and capacity, through collaboration and the exchange of information in real time of all modes of transport, the terminal facilities and the actors involved in the transport logistics chain

Synchromodality developed and established in the Benelux region in the last decade provides a framework within which shippers can manage their multimodal supply chains more flexibly to further increase the potential for modal shift. Despite its importance, synchromodality is at an early stage both from research and practice perspectives. The existing contributions are sparse and treat only one or a few aspects of the matter.

The transport sector is fundamental to our economies and societies, but it is also responsible for a multitude of negative side effects including air emissions, noise and congestion. This calls for a modal shift toward a more efficient and effective reorganization of the whole transport system. To this end, synchromodality is a logistics concept which strives to increase the share of rail and inland waterway transport. Switching smoothly between these two modes and road transport takes place in near real-time, which is made possible since shippers book their transport service "mode-free", i.e., without any need of specifying their transport mode in advance. The transport company is thus able to bundle the flows of goods from different customers and optimizes the cargo. Synchromodality requires close cooperation between all stakeholders along the transport chain and allows moving goods in a flexible and resource-efficient way.[3]

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[1] Corridors, Hubs and Synchromodality, Research & Innovation Roadmap, ALICE, https://www.etp-logistics.eu/wp-content/uploads/2015/08/W26mayo-kopie.pdf, p.16

[2] Historical Evolution of Synchromodality: A First Step Towards the Vision of Physical Internet. Proceedings of the Second Physical Internet Conference, Haller, A., Pfoser, S., Putz, L.-M., Schauer, O. 2015, 6- 8 July, Paris, France.

[3] Critical success factors of synchromodality: results from a case study and literature review, Sarah Pfoser, Horst Treiblmaier, Oliver Schauer, University of Applied Sciences Upper Austria, 2016

The concept of synchromodality is being presented in the present report from a supply chain[4] perspective. When supply chain impacts are considered, there is a high possibility to significantly increase the share of multimodal transportation, without increasing total logistics costs or reducing the service levels. For these purposes, synchromodality can contribute to significantly reduce the environmental impact of freight, allowing costs savings since the best and most efficient transport mode is selected.

Therefore, in a nutshell, synchromodality is the coordination between and within chains at the level of infrastructure, services and transport, such that, given the aggregated demand for transport, the right mode is used at any given time[5]. This coordination aims to provide efficient, reliable, flexible, and sustainable services. It is done through the coordination and cooperation of stakeholders and the synchronization of operations driven by information and communication technologies (ICT) and intelligent transportation system (ITS) technologies.

The main purpose of synchromodality is reducing costs, emissions, and delivery times while maintaining the quality of supply chain service through the smart utilization of available resources and synchronization of transport flows. Implementation of the synchromodality concept and some research projects based on this practice have already shown how different kinds of logistics objectives can be achieved or significantly improved, including avoiding empty capacity, reacting to disruptions as well as reducing transportation by trucks in favour of trains, ships and barges.[6] Thus, synchromodality including the further greening of the IWT sector together with climate-resilient vessels and digitalised vessels, can be a tool to further support modal shift. However, the current deliverable does not focus on the greening initiatives, and it has to be noted that the road and rail transport sector are also engaged to a high extent in greening and digitalisation. Therefore, IWT must also make progress and increase connectivity and transparency to keep pace with the other modes.

The main element of synchromodality is to plan transport processes based on current capacities of the different transport modes in real-time. The shipper gives the logistics service provider the possibility to choose the appropriate combination between available modes of transport. Other parameters such as costs, pollution and time might also be considered when planning on the complete supply chain level.

Thus, a real time switch is possible and sustainable transport processes can be efficiently integrated in the transport chain. **A core criterion for a working synchromodal chain is to generate a cooperation network between all stakeholders.** To foster the successful implementation of synchromodal transport chains the status quo of synchromodal transport as well as potential key enablers such as the standardised exchange of data and the efficient use of ITS must be defined.

Based on a literature review[7] and various discussions in the research community, several categories of potential **key enablers** have been determined, such as:

- **network/cooperation/trust** - A new way of thinking is required to generate a synchromodal network which is concentrated on trust and the advantages of cooperation instead of competition.
- **sophisticated planning/simulation** - Sophisticated dynamic planning and simulation of transport routes and transport patterns are essential to create a functioning synchromodal transport network. Customer preferences, busy routes and available resources of hubs and transport modes have to be evaluated and examined. Forecasts and simulations are essential to learn about repeated connections and to be able to optimize transport performances. Thus, a core freight network has to be identified

[4] A supply chain concerns the entire production and distribution chain from raw materials to final customer and finally “reverse logistics”.

[5] Final report Implementation Roadmap Synchromodal Transport Systeem, TNO, 2011

[6] Synchromodal logistics: An overview of critical success factors, enabling technologies, and open research issues, Riccardo Giustia , Daniele Manerbaa,b , Giorgio Brunoa , Roberto Tade, 2019

[7] Critical success factors of synchromodality: results from a case study and literature review, Sarah Pfoser, Horst Treiblmaier, Oliver Schauer, University of Applied Sciences Upper Austria, 2016

using demand mapping and forecasting tools. A comprehensive supply framework to efficiently utilize available container capacity in intermodal transport services is needed for well-organized synchromodal processes. Following the Physical Internet paradigm and being induced by potential cost savings, transport operators and infrastructure managers will be motivated to collaborate and consequently more data will become available for analysis. As capacity data of transport operators is becoming increasingly available, it is getting easier to efficiently fill up of free capacity. Additionally, a better collaboration of fragmented transport flows, required to make them economically viable, can facilitate new transport solutions.

- **information/data** - Providing high quality and standardized data as well as sharing and mutually exchanging information (open data) are key to creating new and innovative services.
- **ICT/ITS** - It is essential to implement ITS and ICT systems in order to dynamically provide data and to be able to optimize transport planning. Long-term and automated planning need to consider the crucial role which data and information play in a synchromodal supply chain. Additionally, issues dealing with data security /data protection and relevant cybersecurity aspects must be solved. Cybersecurity aspects are described in Deliverable 4.3 of the PLATINA3 project.
- **physical infrastructure** - Different aspects of terminal and port infrastructure were mentioned quite often within the reviewed literature. The basic prerequisite is that smart hubs must exist, and they must be connected by smart corridors. The location of the ports and production sites influences the infrastructure network configuration and its efficiency. The terminal design is relevant as well. The overall aim is to obtain an attractive utilization of this infrastructure which is realized by bundling transport flows to synchromodal transport streams.
- **legal/policy issues** - Harmonized transport regulations applicable for all transport modes and geographical areas are indispensable for a functioning synchromodal network. Another important legal question is the one of liability for the transport, especially for any delay, loss or damage, which might not always be clear when the mode is switched spontaneously. Concluding unambiguous service level agreements topped up with proper insurance agreements is therefore highly recommended. Boundary conditions for data sharing are also vital with regard to the necessary collaboration between the stakeholders. Basically, legal security must be ensured for all involved parties.
- **awareness/mental shift** - It is important to raise awareness on the advantages of synchromodal transport and to generate a mental shift among customers. If customers insist on booking specific modes on specific transport routes, the logistics service provider lacks the necessary freedom to optimize his transport flows in a synchromodal way. The mental shift also includes that all players must be aware that not the preparation of the transport itself is the primary feature of the service performance, but rather the capability to respond to certain incidents and choose the right alternative in this case.
- **cost/service/quality** - Pricing, cost and service are important aspects within a synchromodal transport network. Synchromodal transports should be provided with at least the same level of benefits (price, carbon footprint) compared to traditional or unimodal transports. Quality and the offered service (such as on-time delivery, reliability and flexibility) must also fit customer's needs, otherwise synchromodality is no suitable and competitive logistics concept. Unplanned waiting times for example must be penalized. Moreover, the pricing of synchromodal services is quite complex. Since the transport mode and the specific route are not determined in advance (rather on the spot), it is difficult to determine the actual occurring cost-price and to translate this into a market price. This conflicts with the need that customers require certainty to know the price well in advance. Similar complexities arise in terms of insuring the transport. Finally, prerequisites for high-quality services are reliable infrastructure and the availability of some first movers to invest in innovation and new technologies, which means taking risks as supplier of synchromodal transport services.

There are **drivers** which can accelerate the door-to-door supply chain towards connective networks within a synchromodal framework:

- Technological advancements such as network computing, Big Data, artificial intelligence
- The high and unstable price of fuel that triggers the necessity for cost-saving transport solutions,
- The enormous rise in congestion road infrastructure and limited options to expand road capacity
- The increased environment-consciousness and public awareness about road traffic side-effects on local communities,
- The strict environmental regulations at EU and international level to reduce emissions by 2030/2040/2050
- Similarly to the situation with passenger transport, regulatory advancements allowing for multi-modal ticketing of freight where minimum conditions are guaranteed irrespective of the mode.

However, there are still important **challenges** for applying the synchromodal transport framework. Firstly, itis a **networking and collaboration** with the core of trust and customer relationship concept. The establishment of such a network is based on mutual respect and trust, as the most important prerequisite for synchromodal processes. Due to the fact that many entities may not be willing to cooperate with competitors and/or do not yet see the benefits, a new way of thinking is required to generate a synchromodal network which is concentrated on trust and the advantages of cooperation and benefit sharing instead of competition. This requires a mind shift which poses a barrier.

The second limitation is **complexity in planning**. Planning and also the simulation of transport routes are vital to create an effective synchromodal transport network. Items such as new customer preferences, route traffics, and accessible resources of logistics nods should be assessed and examined prior to planning. Monitoring and forecasting are crucial factors for optimising transport performances. Accordingly, a freight transport network is to be set up based on the demand mapping and forecasting tools.

The third restriction is the **connectivity of the existing different IT systems and data-sharing platforms**. A high-quality data-sharing platform is a key to have a mutual exchange of data from different stakeholders such as shipping company, freight forwarders, and port terminal. GDPR and data-sharing is a key issue, indeed. Economic operators, customers and logistic companies, they all are very reluctant to share their data. It seems that there could be a way if the data-sharing platform could be able to share only very limited information to each actor, depending on the role with maximum respect to data protection and privacy For example, the transporter does not need to know what the content of the goods is (just a category, maybe) nor who is the (first) sender and the (ultimate) receiver. The transporter only needs to know that a certain amount of goods (volume, weight, packaging) needs to be taken from A to B.

The interview results (as described in chapter 8) suggest that the contacted experts representing the private sector agreed on the basic conditions which shall ensure the success of synchromodal transport chains. All statements that were received have been clustered and assigned to three categories (transport related, infrastructure related and framework related criteria) that have been developed based on the literature review.

Cooperation, efficiency, flexibility, service levels and sufficient volumes are five identified characteristics deemed by all involved experts as necessary for each functional transport system. Indeed, the shipped freight volumes must be high enough to ensure that real time switching and bundling of goods work within the synchromodal network.

Half of the respondents doubted that companies are willing to cooperate in such an intensive way that they are able to synchronize their transport flows as part of the network. Pricing strategies, legal and political framework as well as the mental shift are other important factors mentioned during the discussions. Accurate planning as well as ICT/ITS and other information systems have been rated as relevant, the experts partly mentioned that some of these systems already exist and are ready for being used to coordinate synchromodal transports on particular logistics legs.

In conclusion, existing shortcomings on the freight transport markets, e.g. the lack of reliability and punctuality of inland waterway transport services is a source of dissatisfaction among customers representing all market segments causing potential customers to consider IWT as incapable of meeting their logistical needs in a synchromodal environment.

Therefore, the IWT sector must prepare for a rapid and substantial evolution. It will have to think differently about its value propositions, continuously developing and improving products and services that evoke extreme responses, uncover missed customer segments, look, check and adopt services developed in other sectors that can be a source of inspiration of good practices.

This will require all stakeholders to question long established principles and practices and to develop more sustainable and promising market opportunities by thinking faster, by thinking differently**, by thinking partnerships and open collaboration.** The cooperation with actors from other modes will be key in order to apply innovations form other sectors and to develop high quality and seamless mobility solutions. This requires liaising with relevant stakeholders, most definitely including the logistics industry.

To this end, **a Europe-wide Synchromodal Platform or a federation of platforms** capable to interact with (a) local/national/regional logistics platforms to provide pan-European real-time solutions/offers and (b) individual carriers seeking alternative solutions/offers will be able to overcome the existing barriers by connecting the existing data sources and platforms. This platform should serve as the collection point of data from the providers and function as a decision-support tool. Such a European wide platform will be highly dependent on technological developments in automated data collection and exchange. EU projects FENIX 1.0 (further detailed later in this deliverable) and the ensuing FENIX 2.0 (still in its infancy) may contribute directly to that.

As a first step, a one-stop shop **solution building upon the corridor approach** and the concept of physical internet will be able to aggregate data across several platforms for capacity and transport demand and offer both protection of critical data and the possibility to connect to operative elements used in production to carry out transport tasks.

1 Introduction

The present EU modal shift and emission reduction targets (deriving from policy initiatives such as the European Green Deal, A Clean Planet for All, A Europe that protects: Clean air for all, A Europe fit for the Digital Age) contribute to improving the competitive position of the inland waterway transport sector in the overall transport modal split. An efficient infrastructure, environmentally friendly and modern inland waterway vessels, an optimum integration of inland waterway transport into the multimodal logistics chains, qualified staff as well as the use of digital services are basic prerequisites and at the same time the main targets for a competitive and smart waterway mode.

Inland Waterway Transport (IWT) is one of the most energy efficient inland transportation modes per tonne kilometre. Therefore, the full potential of the IWT sector in balancing the other land transport modes by means of promoting multimodal transport and synchromodality can be used. This ensure European competitiveness in logistics and mobility services and can reduce the external costs such as congestion, noise, accidents and the climate and environmental impact of supply (value) chains. The latter requires that IWT will also make significant progress to develop towards a (near) zero-emission performance, to keep pace with rapid developments expected for the road trucks. The development of integrated and at the same time flexible transport systems contributes to facing the current challenges of the transport sector. Strategic actions to improve the integration and interoperability with other modes of transport across Europe and beyond will create a sustainable future for inland navigation.

According to the European Green Deal presented by the Commission in December 2019, a substantial part of the 75% of inland freight carried today by road should be shifted onto rail and inland waterways. This will require measures to better manage and to increase the capacity, predictability and reliability of inland waterways for market segments with a higher potential for transport on European inland waterways and beyond. At the same time, attracting new markets to use IWT as a reliable option in their supply chains requires the consideration of the following aspects:

- Investigate and implement new integrated logistics concepts along the Rhine-Alpine and Rhine-Danube TEN-T corridors;
- Support liner services for intermodal transport;
- Establish/improve port services on demand;
- Improve cooperation between modes and within the sector;
- Encourage entrepreneurship;
- Facilitate access to finance and funding;
- Improve the administrative and regulatory framework for development;
- Abolish administrative barriers to IWT operations (e.g. border crossing procedures);
- Ensure a level playing field/avoid competition distortions;
- Improve coordination between relevant public services.

There is also a need to improve reliability and lead-times in order to attract more shippers, and as a consequence increase the market share. The IWT offer needs to be clear and transparent for shippers; available and updated timetables through standardized communication for instance.

Production volumes, trade patterns, trade relations and agreements within Europe, across the Black Sea and with other regions as well as the presence of new initiatives (e.g. the Trans-Caspian International Transport Route (Middle Corridor)[8], Belt and Road Initiative, EU Eastern Partnership) contribute greatly to generating a higher demand for efficient and sustainable transport solutions, while meeting the targets on climate change. Freight transport should progressively continue to evolve into integrated bundled services, such as systems-

[8] https://middlecorridor.com/en/

of-systems services, to increase the load factor, to avoid empty runs and progressively minimise both transhipment time and complexity time between different modes of transport.

There are large opportunities for efficiency gains in freight transport and logistics by making use of modern technologies, innovations and digitalisation tools to ensure navigation safety and better logistics integration. Currently, several relevant EU-funded projects (e.g. DIWA, RIS COMEX, etc.) investigate on the digital requirements arising from the needs of the IWT sector to become a competitive option and thus a relevant and suitable partner in the synchromodal international supply chains.

The adoption of digital technologies and data exchange systems, River Information Services, Vessel Traffic Services and traffic management on inland waterways is a significant step forward to a sustainable and efficient transport mode, while promoting the modal integration even further. Moreover, the Commission's initiatives DINA (Digital Inland Waterway Area - Towards a Digital Inland Waterway Area and Digital Multimodal Nodes) and DTLF (Digital Transport and Logistics Forum) support the sector to improve its digital interoperability in logistics and freight transport across Europe.

Even though synchromodality is a promising new concept to promote modal shift, it is mostly unused in most European countries except for the Benelux countries. In synchromodal transport chains, real-time switching between transport modes enables efficient supply chains in which shippers book their transport service "mode-free".

Integration of transport volumes and modes, better use of infrastructure capacity, service flexibility, resource efficiency, and cooperation between all actors along the logistics chain are required to reach optimality and full sustainability within current EU logistics corridors. Disruptions resulting, amongst others, in congestions, delays and the slowing or even breakdown of the supply chain cancel all efforts. Moreover, late or cancelled deliveries trigger numerous cascading effects impacting on both the companies involved directly in the supply chain and the economy and social wellbeing, such as increased transportation costs reducing profit margins, company reputation, production delays/stops, loss of sales, shortages (including in food supplies), unemployment.

The consolidation of goods volumes is essential in order to promote modal shift and increase the share of combined transport in Europe. Consolidating loads creates the volume needed to sustain regular new services and regular services will in turn attract higher cargo volumes. When frequent and reliable connections between larger and smaller transport hubs are in place, the modalities of rail, short sea shipping and inland waterway transport will have an improved chance of competing with road-only transport options. However, modal shift actions require more than just physical connections. The European focus has recently changed from Intermodality, to Co-modality, to the latest concept of synchromodality, where all transport options are offered alongside one another at transport hubs and selected according to destination, required turnaround time and sustainability concerns.[9]

In order to facilitate transition towards more efficiency and sustainability in the freight transportation sector, the holistic concept of the Physical Internet was introduced. The Physical Internet, inspired by the digital internet, aims to make the global logistics system more connected, leveraging technologies and algorithms. As such, separate logistics networks and services are integrated into one hyperconnected network, which includes multiple transportation modes. Transporting freight over such an integrated network raises the opportunity to realize a modal shift, which is a promising method to accomplish significant decarbonization in the freight transportation sector. This modal shift implies that transportation modes such as rail and inland waterway transportation gain importance over road transportation, because they are less carbon intensive. Currently road transportation prevails, representing approximately three- quarters of all inland freight transportation in the EU (Eurostat, 2018), in spite of having the highest carbon intensity per ton-km. It is then rather evident

[9] Corridors, Hubs and Synchromodality, Research & Innovation Roadmap, ALICE, https://www.etp-logistics.eu/wp-content/uploads/2015/08/W26mayo-kopie.pdf, p.19

that increasing the share of alternative transportation modes can result in substantial carbon emission reductions.

In fact, one of the key goals of the Transport 2050 plan is a 50% shift from road to rail and inland waterways by 2050. In addition, these transportation modes are often available at a lower unit transportation cost, which is even more favourable for the companies involved. However, more energy efficient large scale transportation modes such as barges and trains are typically less flexible as they have a restricted infrastructure, longer shipping times and require larger quantities to make them economically advantageous.

This emphasizes the need for innovations that exploit the advantages of each transportation mode at all times, in order to encourage the modal shift and improve sustainability. One such innovation is presented by the concept of synchromodality, which emerged during the past decade. Synchromodal freight transportation is defined by the usage of multiple modalities when planning shipments, depending on the characteristics of the freight, where switching between transportation modes is possible. The integrated view of different modalities allows for optimization of trade-offs between the different transportation modes. The innovative aspect of synchromodality is that transportation decisions can be made based on real-time information about the transportation network. In other words, transportation routes are not fixed in advance but can be adapted to real-time information, under the reasoning that more informed decisions are better. Consequently, the best transportation mode is chosen at all times, given the characteristics of the freight and the prevailing network conditions (ALICE, 2014). For instance, less urgent shipments can use slower, but more sustainable transportation modes, while shipments with a closer due date make use of faster transportation modes. This approach provides more planning flexibility, which facilitates in dealing with uncertainty in the network (e.g.: transit time, service availability, etc.). That is why LSPs (Logistics Service Providers), under shippers' pressure, often choose road to go faster and comply with delivery times since road is often seen as the most reliable transport mode. It reassures shippers. The information on slower modes has to be linked in a proactive manner to inventory levels. Interoperability of ERP (Enterprise Resource Planning), TMS (Transport Management System), TOS (Terminal Operating System), PCS (Port Community System) systems is thus crucial

The present deliverable collects information based on literature review on the most relevant initiatives in relation to synchromodality in the European transport chains, on the drivers and arising challenges, on the importance digitalisation and the use of digital tools play in allowing inland waterway transport to become a viable option in the synchromodal logistics and value chains, targeting several fields of interest such as for example policy aspects, checking on the activities of dedicated working groups, offering an overview of ongoing sector initiatives and dedicated projects proposing best practice solutions which are meant to support IWT in becoming a reliable partner in synchromodal logistics.

At the same time, the report looks at enabling technologies and tools, with the scope to further investigate the requirements arising from the needs of IWT to become a reliable partner in integrated transport networks with the support of synchromodality as a tool for decarbonization and optimization of logistics.

As synchromodality implies cooperation between all supply chain actors, several interviews have been conducted with key stakeholders involved in the different stages of the supply chain (cargo owners, terminal operators, logistics service providers, shipping companies). The report ends with a set of recommendations meant to facilitate the further integration of IWT in synchromodal logistics chains.

2 Synchromodality from a supply chain perspective

2.1 Logistics context

Freight transportation forms an imperative pillar of our society and economy. However, with the currently projected growth of international trade and cargo demand as well as the change of cargo types, the current infrastructural capacities are put under pressure, resulting in congestion problems, safety issues, environmental concerns and decreasing reliability of services.

Modal shift has long been seen by policy makers and politicians as the most promising way of easing the environmental and congestion problems associated with goods movement. One of the reasons for the modal split being so difficult to change is that many stakeholders have not been taking adequate account of the overall supply chain impact of multimodal transportation. Trains or barges are in general cheaper and greener, but they lack the flexibility in delivery quantity, frequency and scheduling. As a consequence, logistics managers tend to perceive a straight shift from trucks to trains and barges as likely to have a negative impact on the overall supply chain performance.

More specifically, in the absence of any associated adjustment to supply chain processes, a shift from trucks to trains and barges often leads to increases in inventory. As rail and inland waterway services are generally slower and less frequent than the equivalent road trips, in-transit inventories and stock levels might be higher at both ends of the journey. Trains and barges also require large and stable shipment volumes in order to be cost-efficient, making it difficult for them to cater for flows that are subject to widely fluctuating demand. Comparative freight rates, however, are only one of many factors influencing the freight modal split at both micro- and macro-levels. Other criteria, such as transit time, reliability, accessibility, flexibility as well as safety and security, are also important determinants of modal selection.[10]

The end-to-end impact of the modal shift requires a change in the logistical decision-making process. Freight modal choice is, after all, a part of the supply chain strategy and needs to be jointly optimized with other supply chain activities, like inventory management and customer service levels. This involves the shipper more directly in the process and puts some onus to alter their schedules to accommodate changes in transportation mode. It also requires changes in consumer patterns, the true accelerators of changes in the logistical decision-making process.

Synchromodality, also referred to as “synchronized intermodality”, employs multiple transport modes in a flexible, dynamic way in order to induce a modal shift towards more environmentally friendly transport modes like rail and inland waterways, without compromising responsiveness and quality of service. It is characterized by the synchronized parallel usage of different transport modes and/or the ability to switch freely between transport modes at particular times, while a consignment is in transit, taking into account real-time stock levels and service requirements of the shipper.

Synchromodality often seems to be related only to the synchronization of transportation modes, and thus, covers only the corresponding activities of supply chain management. However, Dong et al. (2018) recently pointed out that synchromodality has the potential to address several activities of supply chains in addition to transportation. Hence, in our vision, synchromodal logistics should be considered in a broader sense, possibly involving the coordination of all relevant operations in supply chain management

Combining elements from different transport modes, synchromodality aims to create a flexible transport network, to sustainably use available transport resources and optimize transport processes. Since the transport sector is highly responsible for emission problems and other negative externalities, the need for promoting modal shift is evident.

[10] Investigating synchromodality from a supply chain perspective, Chuanwen Dong, Robert Boute, Alan McKinnon, Marc Verelst, June 2017

Synchromodality, with its ambition of flexible integration of transport modes, differs from regular multimodal transport because of the focus on the additional requirements for flexible integration. In a regular multimodal transport solution, the operational characteristics of the modes, the mode-specific legal frameworks, and the preference of the cargo owners still play an important role. As a result, the integration that is achieved is not complete, and often the result implies a lot of manual work 'behind the scenes.[11]

Synchromodality's additional requirements are:

- Optimal operational flexibility in the transport system;
- Active bundling of cargo;
- Monitoring and control on the performance of the transport system;
- An overall system approach to transport planning underpinned by digitalisation.

Optimal operational flexibility means that switching from one mode to another, either because it is planned, or ad-hoc e.g. as a result of a calamity, is not impeded at all. The only remaining activity that still takes time is the physical transfer of the cargo, but this time can be planned and taken into account in the lead time calculation.

Active bundling of cargo is important because any complex multimodal transport solution requires substantial volumes of cargo, that are synchronized in terms of time, conditions, and place. Active bundling means that there is a specific party that pro-actively aims to bundle cargo from different shippers in a certain region. This can be, for instance, an industry association, a commercial company, or a government department. For facilitating collaboration between the same group of stakeholders, a neutral body has definitely a crucial role since it inspires confidence. Besides the different listed bodies, the trustee could be added since therole is dedicated to creating confidence between stakeholders.

The additional requirements of operational flexibility and bundling of cargo often demand timely and accurate information on transport performance, regional cargo offers, available capacity, and so on. In addition, flexibility also requires information on the occurrence of calamities and other causes of delay, preferably before they happen.

Therefore, monitoring and control is an important requirement for synchromodality. Finally, the integrated operation of multiple modes, multiple infrastructure networks, correctly capacitated nodes, information requirements and bundling of cargo demands a coherent vision from the start. Therefore, transport planning shall move towards an overall systems level approach.[12]

In the Netherlands, several successful pilot projects exist which demonstrate its viability. The best-known is the implementation of the synchromodality network between Rotterdam, Moerdijk and Tilburg. This pilot project included a trimodal network with mode-free bookings by shippers. For each container, the best transport route has been selected and all parties worked together in optimizing the whole transport chain. In this way, a stable modal split was achieved at the Rotterdam Maasvlakte terminal with 19% truck transport, 46% ship transport and 35% rail transport. This already exceeds the port's overall goals for 2033 which amount to 35% truck share, 45 % ship share and 20% rail share (ECT, 2012).

2.2 Synchromodality in practice

New production and distribution trends (e.g. globalisation, lean manufacturing, just-in-time inventory) as well as emerging digital technologies have introduced new kinds of challenges to the supply chain. Together with resilient and smart infrastructures, new concepts, innovative solutions and better cooperation of operators

[11] Inland Waterways Transport, Good practice manual and reference guide, p.53, STC-Nestra for the World Bank, 2015

[12] Inland Waterways Transport, Good practice manual and reference guide, p.54, STC-Nestra for the World Bank, 2015

are needed for freight transport to minimise its the negative impacts, shorten the transition time, while taking in account cost reductions as feasible.

Among other requirements displayed in Figure 1, reliability is assumed as the most perceived value that customers are looking for from the purchase of a transport service and the most relevant indicator when developing a transport service. It is critical that cargo is delivered efficiently, on time and intact. Comprehensive and accurate logistics information is necessary to enable to find out about problems sooner and adjust plans proactively, minimising the impact of deviations or other exceptions and maximising commercial opportunities.[13]

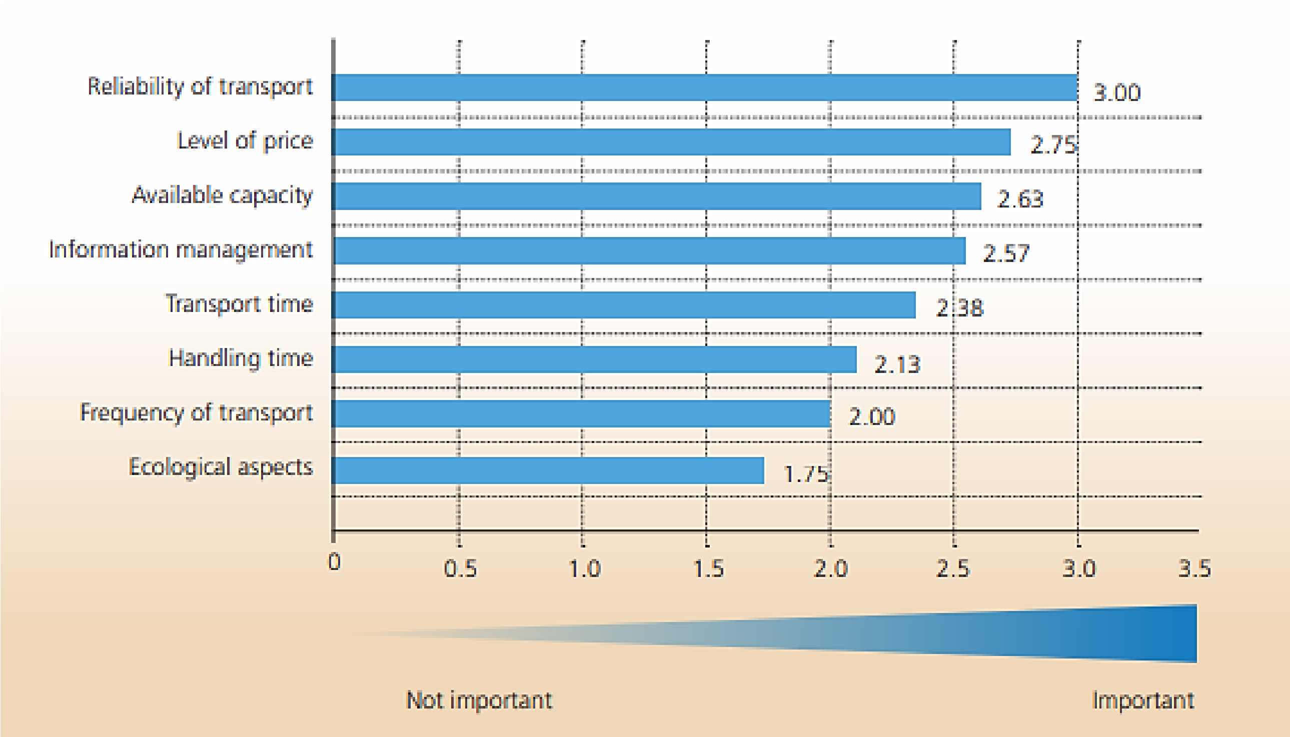

Figure 1: Freight customer requirements (© ALICE, CER, 2011)

Since 2011, the paradigm has changed with different and new requirements. Moreover, the result should vary according to the size of the shippers. A large shipper with significant cargo flows does not have the same concern. Indeed, an established large shipper will rank the ecological aspect at the top regarding the new consumers pressure while SMEs will have financial and reliability concerns. The scope is not the same according to the size of the shipper.

Furthermore, according to its definition, the main purpose of synchromodality is reducing costs, emissions, and delivery times while maintaining the quality of supply chain service through smart utilization of available resources and synchronization of transport flows.

Implementation of the synchromodality concept and some research projects based on this practice have already shown how different kinds of logistics objectives can be achieved or significantly improved, including

[13] Corridors, Hubs and Synchromodality, Research & Innovation Roadmap, ALICE, https://www.etp-logistics.eu/wp-content/uploads/2015/08/W26mayo-kopie.pdf

avoiding empty capacity, reacting to disruptions, and reducing transportation by trucks in favour of railroads, ships, and barges.[14]

The main element of synchromodality is to plan transport processes based on current capacities of the different transport modes in real-time. The shipper gives the logistics service provider the possibility to choose the appropriate combination between available modes of transport.

Thus, a real time switch is possible and sustainable transport processes can be efficiently integrated in the transport chain. **A core criterion for a working synchromodal chain is to generate a cooperation network between all stakeholders.** To foster the successful implementation of synchromodal transport chains the status quo of synchromodal transport as well as potential key enablers such as the standardised exchange of data and the efficient use of ITS must be defined.

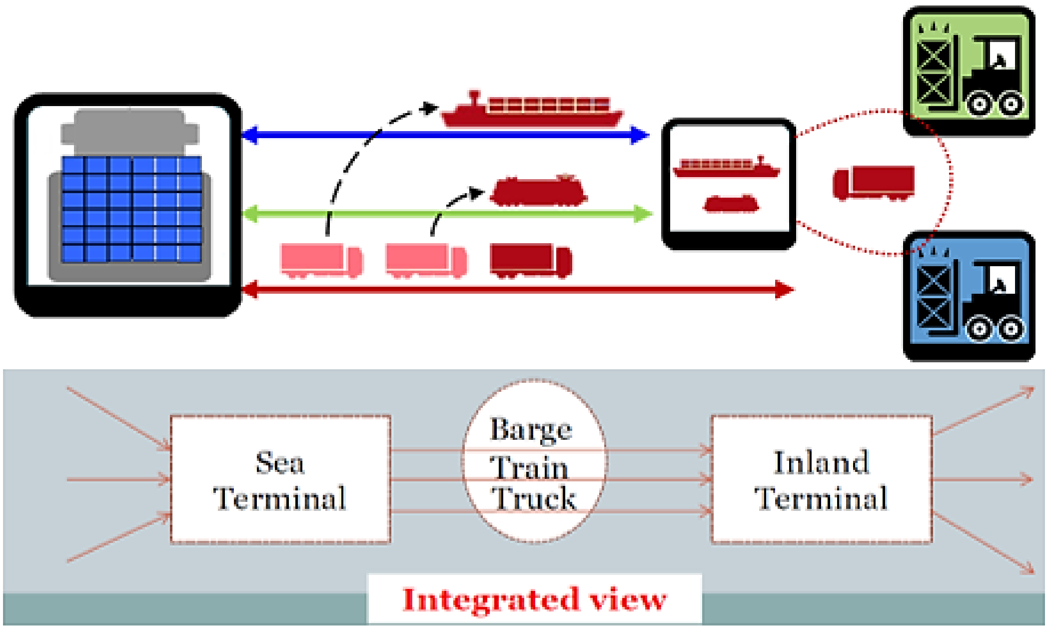

Figure 2: Synchromodality concept (© TU Delft)

With the help of digitalization in the transport and logistics area, real "synergy" can be set up between the actors involved in the cooperation network. As a result, the synchromodality concept was created beyond other concepts of Uni-modality, Multi-modality, and Inter-modality, in order to have an optimal use of transport available capacity. As a concept, synchromodality tries to give more role to rail and inland waterway transport while suggesting an effective and smooth switch between these two modes and road transport.[15]

[14] Synchromodal logistics: An overview of critical success factors, enabling technologies, and open research issues, Riccardo Giustia , Daniele Manerbaa,b , Giorgio Brunoa , Roberto Tade, 2019

[15] Synchromodality as a tool for decarbonization and optimization of logistics, Reza Karimpour, Fabio Ballini

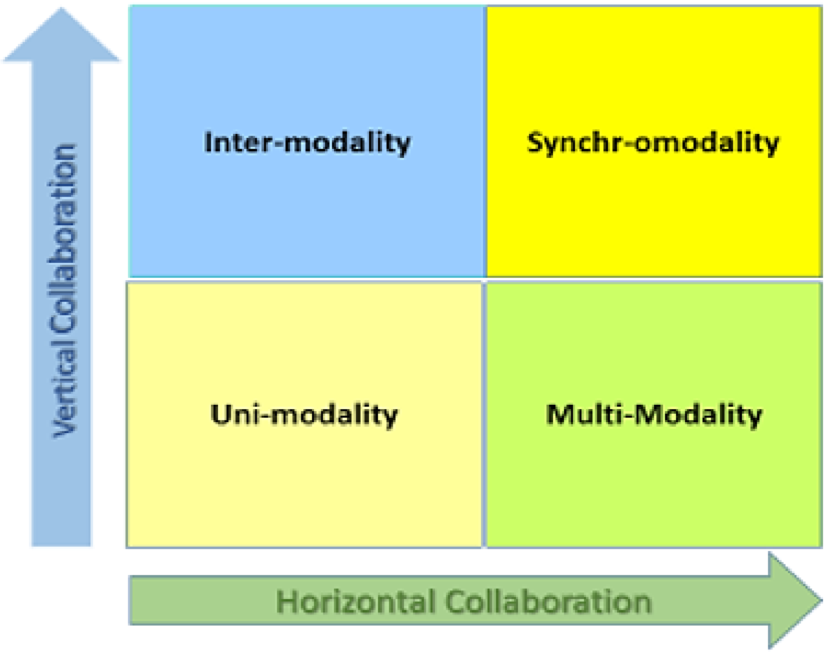

Figure 3: Collaboration in hinterland transport © Circle SpA

The cornerstone of synchromodality is the integration of different modalities to provide flexibility in handling transport demand. Whereas intermodal freight transport focuses on the vertical integration of logistic services within one intermodal transport chain, the distinctive feature of synchromodality is the horizontal integration within a whole transport system.[16] Intermodal transport comprises sequential usage of multiple transport modes, whereas synchromodal transport provides the opportunity for simultaneous usage (in the sense that cargo volumes can be split to several modes of transport), of which one of these modes could be an intermodal service.[17]

The parallel usage of multiple transport modes is equivalent to the multi-mode dual sourcing problem. The dual sourcing problem determines how and when each of the sources is to be used, trading off the lead time and cost differences of the sources. One source is typically low cost but has long lead times (similar to intermodal transport), whereas the other provides quicker response but at a higher (environmental) price (direct trucking).

In order to apply synchromodal planning to existing transport chains and networks, several aspects need to be considered:

- Definition of methods supporting an integrated network planning for intermodal networks operated by a network orchestrator
- Definition of methods for real-time network planning – creating a transportation plan in real-tine and updating it continuously as new information arrives
- Creating planning flexibility supported by all stakeholders involved

Synchromodal planning refers to a solution that identifies the best possible combination of transport modes to serve incoming transport orders that are dynamically selected based on costs, duration, reliability, and sustainability. Existing (multimodal) planning solutions incorporate algorithms that treat the status of the

16 Intermodality and synchromodality, Tavasszy, LA., Behdani, B., Konings, R. (2015)

17 Investigating synchromodality from a supply chain perspective. Transp Res D Transp Environ, 61(part A), Dong, C., Boute, R., McKinnon, A., Verelst, M. (2018a), p. 42-57

networks as static and use this status as deterministic input. Most of the research on intermodal transport focuses on strategic decisions, such as network design and location of terminals. Yet operational aspects, like mode choice and routing decisions for incoming shipments including real-time data have received limited attention. However, the execution of the logistics operation, also when multimodal solutions are envisaged, often works out differently than planned. Hinterland carriers and logistics service providers face unexpected delays, e.g., traffic jams, missed connections, breakdowns. In these situations, there are limited options to perform a re-planning that considers existing capacities and real-time data. The main challenge here is to connect to the right data and to adjust, preferably automatically, the input data used by a synchromodal planning algorithm.

2.3 Drivers, needs and challenges

Factors such as EU and national governmental initiatives, regulations and environmental laws, e.g., on CO2 emissions, tax benefits on sustainable transport practices and reducing dependence on road transport, increasing competition, global shift of transportation sector towards a service-based-information-intensive business, easy access to contextual events data (weather, traffic-disruptions, accidents) are triggering transport companies to change their business-as-usual approach and adopt new, smarter transport practices.

As a result, transport companies would need to switch from a "planning and control" approach to a "sense and respond" approach. To this end, synchromodality is a promising logistics concept which may facilitate real-time switching between transport modes enabling efficient supply chains management decisions.

There are **drivers** that are considered the main ones which can accelerate the door-to-door supply chain toward connective networks within a synchromodal framework:

- Technological advancements such as network computing, Big Data, artificial intelligence
- The high and unstable price of fuel that triggers the necessity for cost-saving transport solutions,
- The enormous rise in congestion road infrastructure and limited options to expand road capacity
- The increased environment-consciousness and public awareness about road traffic side-effects on local communities,
- The strict environmental regulations at EU and international level to reduce emissions by 2030/2040/2050
- Similarly to the situation with passenger transport, regulatory advancements allowing for multi-modal ticketing of freight where minimum conditions are guaranteed irrespective of the mode.

Based on a literature review[18] and various discussion in the research community, several categories of potential **key enablers/needs** have been determined, such as:

- **network/cooperation/trust** - A new way of thinking is required to generate a synchromodal network which is concentrated on trust and the advantages of cooperation instead of competition.
- **sophisticated planning/simulation** - Sophisticated dynamic planning and simulation of transport routes and transport patterns are essential to create a functioning synchromodal transport network. Customer preferences, busy routes and available resources of hubs and transport modes have to be evaluated and examined. Forecasts and simulations are essential to learn about repeated connections and to be able to optimize transport performances. Thus, a core freight network has to be identified using demand mapping and forecasting tools. A comprehensive supply framework to efficiently utilize available container capacity in intermodal transport services is needed for well-organized synchromodal processes. Following the Physical Internet paradigm and being induced by potential

[18] Critical success factors of synchromodality: results from a case study and literature review, Sarah Pfoser, Horst Treiblmaier, Oliver Schauer, University of Applied Sciences Upper Austria, 2016

cost savings, transport operators and infrastructure managers will be motivated to collaborate and consequently more data will become available for analysis. As capacity data of transport operators is becoming increasingly available, it is getting easier to efficiently fill up of free capacity. Additionally, a better collaboration of fragmented transport flows, required to make them economically viable, can facilitate new transport solutions.

- **information/data** - Providing high quality and standardized data as well as sharing and mutually exchanging information (open data) are key to creating new and innovative services.
- **ICT/IT** - It is essential to implement ITS and ICT systems in order to dynamically provide data and to be able to optimize transport planning. Long-term and automated planning need to take into account the crucial role which data and information play in a synchromodal supply chain. Additionally, issues dealing with data security and data protection must be solved.
- **physical infrastructure** - Different aspects of terminal and port infrastructure were mentioned quite often within the reviewed literature. The basic prerequisite is that smart hubs must exist and they must be connected by smart corridors. The location of the ports and production sites influences the infrastructure network configuration and its efficiency. The terminal design is relevant as well. The overall aim is to obtain an attractive utilization of this infrastructure which is realized by bundling transport flows to synchromodal transport streams.
- **legal/policy issues** - Harmonized transport regulations are indispensable for a functioning synchromodal network. Another important legal question is the one of liability for the transport, especially for any delay, loss or damage, which might not always be clear when the mode is switched spontaneously. Concluding unambiguous service level agreements is therefore highly recommended. Boundary conditions for data sharing are also vital with regard to the necessary collaboration between the stakeholders. Basically, legal security must be ensured for all involved parties.
- **awareness/mental shift** - It is important to raise awareness on the advantages of synchromodal transport and to generate a mental shift among customers. If customers insist on booking specific modes on specific transport routes, the logistics service provider lacks the necessary freedom to optimize his transport flows in a synchromodal way. The mental shift also includes that all players must be aware that not the preparation of the transport itself is the primary feature of the service performance, but rather the capability to respond to certain incidents and choose the right alternative in this case.
- **cost/service/quality** - Pricing, cost and service are important aspects within a synchromodal transport network. Synchromodal transports should be provided with at least the same level of benefits(price, carbon footprint) compared to traditional or unimodal transports. Quality and the offered service (such as on-time delivery, reliability and flexibility) must also fit customer's needs, otherwise synchromodality is no suitable and competitive logistics concept. Unplanned waiting times for example must be penalized. Moreover, the pricing of synchromodal services is quite complex. Since the transport mode and the specific route are not determined in advance (rather on the spot), it is difficult to determine the actual occurring cost-price and to translate this into a market price. This conflicts with the need that customers require certainty to know the price well in advance. Similar complexities arise in terms of insuring the transport. Finally, prerequisites for high-quality services are reliable infrastructure and the availability of some first movers to invest in innovation and new technologies, which means taking risks as supplier of synchromodal transport services.

However, there are still important **challenges** for applying the synchromodal transport framework. Firstly, it's a **networking and collaboration** with the core of trust and customer relationship concept. The establishment of such a network is based on mutual respect and trust, as the most important prerequisite for synchromodal processes. Due to the fact that many entities are not willing to cooperate with competitors, a new way of thinking is required to generate a synchromodal network which is concentrated on trust and the advantages of cooperation instead of competition. This requires a strong mind shift and a different culture, which is difficult to accomplish on the short term.

The second limitation is **complexity in planning**. Planning and also the simulation of transport routes are vital to create an effective synchromodal transport network. Items such as new customer preferences, route traffics, and accessible resources of logistics nods should be assessed and examined prior to planning. Monitoring and forecasting are crucial factors for optimization of the transport performances. Accordingly, a freight transport network is to be set up based on the demand mapping and forecasting tools.

The third restriction is the **connectivity of the existing different IT systems and data-sharing platforms**. A high-quality data-sharing platform is a key to have a mutual exchange of data from different stakeholders such as shipping company, freight forwarders, and port terminal.

Apart from the mentioned constrains, there are four other groups of barriers for the application of a synchromodal transport network (valid also for multimodality as such):

- Operational related problems such as train decoupling, Terminal working hours, use of rail infra for both passenger/freight transport.
- Organizational cooperation problems like coordination between actors and networking among different partners.
- In some cases, economic barriers due to higher transhipment cost and need for specific equipment such as load units
- Lack of promising business models which utilize new technologies which need higher integration and data information sharing to create synchronized services.

Administrative barriers have to be considered. Indeed, for instance in France, the national rail company is a public body which does not facilitate the use of rail freight. If a rail operator intends to use a train path, he must book it the year before in December otherwise he will have to wait for 1 more year. These kinds of rules slow down the increase of rail freight market share in France, for instance. A reduction of the administrative rules is necessary and this within the European framework

However, the synchromodal benefits overweight and motivate the involved stakeholders, in particular, multimodal transport companies and logistics hubs, for a modal shift to synchromodality. According to a study conducted by Joana Cunha at the University of Lisbon[19], benefits originating from the application of synchromodal framework at port and shipping logistics are:

- Increasing the flexibility in transport choices
- Increase the utilization of rail and inland waterways
- Optimal use of available capacity on the network, and
- Possible reduction of the carbon footprint of logistic and transport services

In short words, the goal of synchromodality is to substitute a long-term transition from unimodal transport to smart, flexible and sustainable networking transport. Within this framework, multiple transport modes are used from intermodality while the element of efficiency is borrowed from the concept of comodality. In this way, the existing resources of transport are used in an optimized and sustainable approach. Implementing effective synchromodality depends on various requirements. As the concept basically builds upon synergy and systematic coordination between stakeholders along the transport chain, it means that **close cooperation is the core concern with the result of efficient and the flexible use of resources.**

[19] Synchromodality as a solution to improve the efficiency in freight transportation, Joana Cunha, Instituto Superior Técnico, University of Lisbon Av. Rovisco Pais, 1049-001, Lisboa, Portugal

3 Synchromodal Transport and the Physical Internet

3.1 Context

The concept of Physical Internet (PI), which is high on the agenda in the long-term digitalisation strategy of the European Union should be achieved by 2050, with synchromodality being a major requirement to achieve this vision. Physical Internet and synchromodal transport concepts present opportunities to improve the current unsustainable freight transportation, by increasing fill rates and inducing a positive modal shift from roads to rails and inland waterways.

On one hand, synchromodal transport concerns operational aspects such as real-time re-routing of loading units over the network to cope with disturbances and/or customer requirements. On the other hand, the Physical Internet is to replicate the digital internet by mimicking digital flows in the physical world; the same way messages are delivered via the internet, the goods could be delivered via the Physical Internet.[20]

One of the key elements identified by the European Technology Platform ALICE[21] as the vision to contribute "to a 30% improvement of end-to-end logistics performance by 2030" is the Physical Internet (PI) concept. PI is pursuing an open global logistic system founded on physical, digital, and operational interconnectivity, through encapsulation, interfaces and protocols design, aiming to move, store, realize, supply and use physical objects throughout the world in a manner that is economically, environmentally and socially efficient and sustainable.[22]

Broadly defined, the Physical Internet is defined as a transport system in which modular packages are routed from source to destination through a network of hubs and spokes[23]. Major elements of such a transport network are more or less existing for parcels, pallets, containers and "swap bodies". Carriers of these types of loading units do optimize between various alternative routes in their networks, e.g. by bypassing hubs, either in advance through offering more time definite services, or real time during the actual transport. A full-fledged physical internet may be built upon all these elements with the holistic integration of these existing elements and concepts as the main challenge.

The Canadian professor Benoit Montreuil can be seen as the pioneer in the field of the Physical Internet. He names the main elements which form the foundation of the Physical Internet, which can be summarized as follows (Montreuil, 2011):

- Standardized containers, parcels, warehouses and turnover points need to be installed to guarantee a barrier-free and seamless transport in the Physical Internet.
- By installing a standardized infrastructure also processes such as transhipment can be standardized in a broader sense and may minimize the risk of discrepancies.
- These standardized transport units and processes lead to a reliable and resilient smart network in which the units (e.g. a parcel or a warehouse) communicate almost independently.
- This smart network should be open for all supply chain stakeholders and on a global level.
- In total, this makes simplification and standardization possible, since transport units choose the best transport route on their own and interact with other transport units and stations.

[20] Synchromodal Transport and the Physical Internet – The cornerstones of future long-distance Digital Twin application, Tomas Ambra, April 2020

[21] ALICE – Alliance for Logistics Innovation through Collaborative Logistics, https://www.etp-logistics.eu

[22] Corridors, Hubs and Synchromodality, Research & Innovation Roadmap, ALICE, https://www.etp-logistics.eu/wp-content/uploads/2015/08/W26mayo-kopie.pdf

[23] Hub and spoke is a form of transport topology optimization in which traffic planners organize routes as a series of "spokes" that connect outlying points to a central "hub".

- This makes a human interaction almost unnecessary (e.g. planning transhipments from one transport mode to another).

ALICE has identified five different areas that need to be specifically analysed and addressed in terms of future research and innovation needs to achieve its mission. These areas are:

- EffIcient and low emission assets and energy**Corridors, Hubs and Synchromodality**
- EffIcient and low emission assets and energyGlobal supply network coordination and collaboration Urban Logistics

As a step towards the vision of the Physical Internet, the technologies and logistic approaches behind synchromodality need to spread more widely to more segments of freight transport. As in the Physical Internet, synchromodality combines individual private networks into one super network and allows combinations of services of different providers. The result of this increased flexibility is that the best possible mode is used at all times, given the logistics requirements and the prevailing network conditions. As such, synchromodality creates more efficient transport services that are more responsive to customer needs and more resilient to changing external conditions.

A major challenge is to design a multifaceted decision support system for the physical internet, with partly automated execution via intelligent agents. Radical new business models based on openness and sharing of resources are required, as opposed to the current local ownership and control of resources. The notion of openness is almost in contrast with the core of e.g. supply chain security. Therefore, the adoption of a Physical Internet will require radical changes with respect to the roles and responsibilities of many stakeholders. Achieving such a combination of physical and electronic infrastructure is just one step, stimulating shippers and logistics operators to connect to it, is an even bigger challenge. And obviously, bulk freight flows lend themselves less easily to a Physical Internet approach.[24]

One of the roadmaps of the Physical Internet initiative elaborated by ALICE is the existence of co-modal transport services within a well synchronized network, supported by corridors and hubs, providing optimal support to supply chains. It involves a step change from the current individualistic system, in which shippers and logistics service providers optimize their own networks and transport flows, towards the ultimate hyperconnected Physical Internet vision, synchronizing intermodal services between modes and with shippers. This concept aligns equipment and services on corridors and hubs and proposes a transition from small individual corridors and hubs towards one hyperconnected PI system.[25]

The development steps and the main characteristics of the different transport concepts towards the Physical Internet are summarized in the next figure. As illustrated, the different concepts aim to use existing transport resources more efficiently in order to avoid inefficiencies which may lead to negative environmental impacts and higher costs.

[24] Sustainable, Safe and Secure Supply Chain. Research & Innovation Roadmap, ALICE, https://www.etp-logistics.eu/wp-content/uploads/2015/07/W16mayo-kopie.pdf, p.17

[25] Corridors, Hubs and Synchromodality, Research & Innovation Roadmap, ALICE, https://www.etp-logistics.eu/wp-content/uploads/2015/08/W26mayo-kopie.pdf

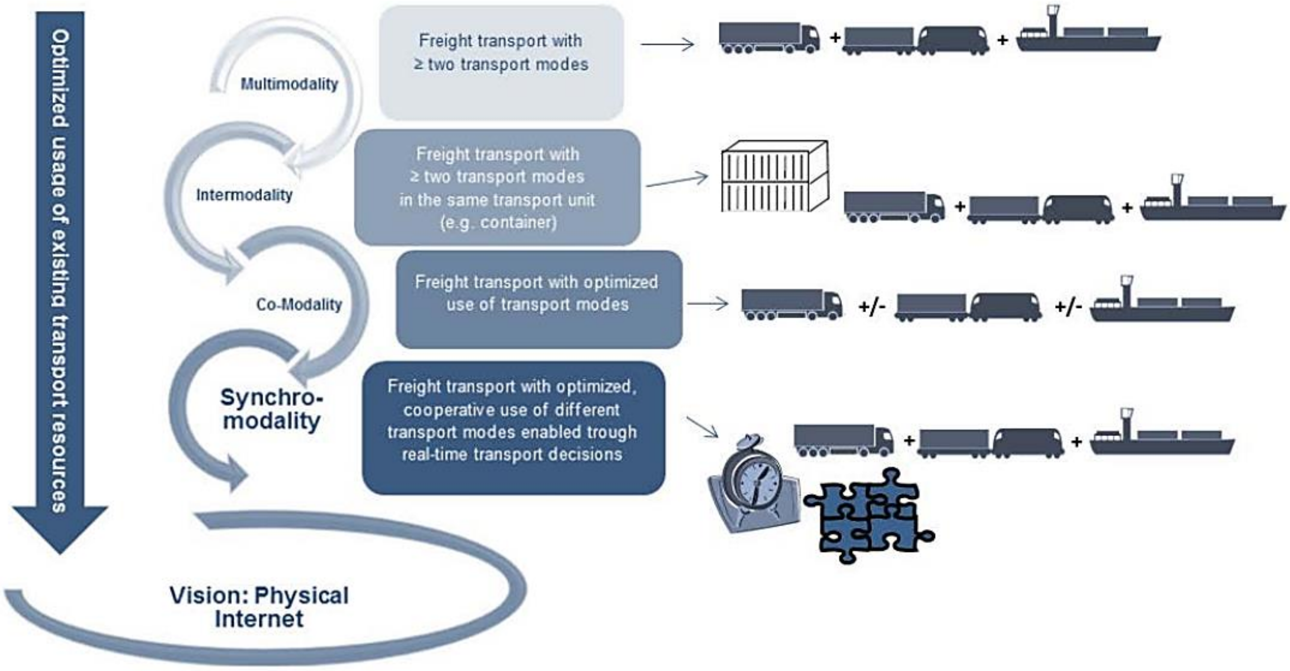

Figure 4: Innovative transport concepts ©University of Upper Austria, Sarah Pfoser

3.2 Drivers, needs and barriers

Drivers and needs

Various drivers can be identified which encourage the development of the Physical Internet: Currently, means of transport such as trucks are not fully loaded in most cases and also packing material accounts for a lot of space. Thus, means of transport could be loaded more efficiently and empty runs should be reduced. Also, the working conditions in the transport sector could be increased. For example, truck drivers are on the road for a long time, which can have negative effects on their health and social life. In 2020, around one-fifth of the total road freight transport performance (in vehicle-kilometres) in the EU was carried out by empty vehicles. The share of performance by empty vehicles is somewhat higher for national transport (24%) than for the total (20%), and is significantly higher compared with international transport (13%).[26]

In addition, products are often not stored at the places where they are consumed, leading to high inventory costs (at the wrong places) and long delivery times. As a consequence, production and storage facilities are currently not efficiently used. In addition, a high percentage of produced products is not used/consumed at all (e.g. in the food industry).

Due to globalization, products can be ordered from almost every country which leads to an increasing transport distance. Thus, efficient transhipment and a combination of different transport modes (multimodal transport) is required to coordinate these transport flows. Currently, multimodal transport still needs a lot of coordination and is connected with handling costs for transhipments. In addition, trends such as urbanization and the increasing importance of sustainability have to be respected in multimodal transport. At the moment, existing transport networks still lack security and robustness which makes collaboration between different stakeholders of the supply chain even more difficult because of the lack of trust in collaboration (REWWay[27], 2016).

Potential barriers

[26] A fifth of road freight kilometres by empty vehicles - Products Eurostat News - Eurostat (europa.eu)

[27] Research & Education in Inland Waterway Logistics, https://www.rewway.at/en/

The Physical Internet is still a new area of operation for most companies and therefore connected with uncertainty. Therefore, a mind shift is necessary to encourage the integration of the Physical Internet in companies. One main aspect of the Physical Internet is the concept of sharing – sharing assets such as trucks and warehouses which means less property and as a consequence less control for one company.

Sharing information about customers, shipping routes and markets which can be seen as most valuable assets of a company in some cases should also be shared in the Physical Internet. It is not surprising that a lot of companies have the fear to lose their market advantage and are not very open minded for this concept. Another fact is that the idea is to have a network instead of one-to-one agreements between few actors in the supply chain. Furthermore, at the moment products and containers are not standard/modular which makes transshipment complicated and bundling effects are difficult to realize. In summary, especially the needed mind shifts and therefore building of mutual trust is needed in many cases to guarantee the success of the physical internet (REWWay, 2016).[28]

[28] D5.4.4 Danube Ports and the Physical Internet, University of Upper Austria, 2018, p.6

4 Synchromodality as a tool to promote supply chain sustainability and optimisation of logistics

Sustainability is mostly defined as "doing more with less" and pertains to avoiding waste, using less energy, exploiting renewable resources wherever possible, and advancing the repair and re-use of products and materials. In a broader sense, sustainability has three dimensions, corresponding to the "people, planet, profit" paradigm, i.e.:[29]

- Economic dimension: efficiency, cost-effectiveness, quality, responsiveness.
- Environmental dimension: emissions and waste reduction, natural resources utilisation, materials/products repair and recycling.
- Social dimension: safety and security enhancement, noise reduction, healthy working environment

4.1 Context

Overall, in Europe, freight transport demand has grown significantly since the mid-1990s, thereby making it increasingly difficult to limit transport's impact on the environment. Therefore, fundamental changes are needed in the transportation sector in order to reverse the growth in GHG emissions. According to Schipper et al[30]. this will involve the application of a broad range of measures, falling into four categories:

- activity (reducing the demand for transportation),
- structure (shifting freight to lower carbon modes),
- intensity (improving its energy efficiency) and
- fuel (switching to lower carbon energy sources).

Likewise important is an efficient combination of the multiple modes of transportation like rail, ship and truck within an integrated system. This is to be achieved without any handling of the freight itself when changing modes. The method reduces cargo handling, and enhances security, reduces damage and loss, and allows freight to be transported at faster speed. The door-to-door supply chain has the potential to experience a bigger jump beyond the intermodality approach, thanks to new innovations in ICT and data-systems integration.

From the environmental dimension as described above, while the majority of attention is on transport decarbonization as per individual measures, a systemic synergic approach in logistics, hinterland, and transport can significantly promote the environmental performance of freight transport.

In 2020, road accounted for more than half of all tonne-kilometres performed in the EU (54.7 %). Maritime transport came next, with less than a third of the total transport performance (29.0 %), followed by rail (11.9 %) and inland waterways (4.1 %).[31]

Different aspects characterize the main issues related to sustainable freight mobility: they encompass the use of integrated resources and transport modes, the uptake of new, 'green' and 'smart' vehicles, the planning of new transport infrastructures and the improvement of the existing ones by defining their territorial role in the wider EU Corridors' context.

Well-integrated, synchronized operational processes and environmentally friendly co-modal transport networks all depend on efficient and synergized hubs as well as on vehicles using either (renewables'-based)

[29] Sustainable, Safe and Secure Supply Chain. Research & Innovation Roadmap, ALICE, https://www.etp-logistics.eu/wp-content/uploads/2015/07/W16mayo-kopie.pdf, p.17

[30] Flexing the Link between Transport and Greenhouse Gas Emissions, Schipper, L., Marie-Lilliu, C. & Gorham, R., 2000

[31] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Freight_transport_statistics_-_modal_split

electricity or sustainable alternative fuels as an energy source. Efficiency and sustainability are further enhanced throughout the network if cooperation between hubs and other relevant stakeholders enables re-orchestration of functions in the network and along the whole supply-chain, especially in case of congestion or other factors decrease the system stability and regularity.

However, the forces of market economy usually prevent holistic optimization as many providers of transport and logistics services are "locked-in" their current ways of working and acting. To get to the next levels, shippers (manufacturers, retailers), carriers and other providers of logistics services should take the broader sustainability goals into the economic equation. This requires ways to base decision making in the system on financial and market criteria but also on safety, security and environmental/ecological aspects. In particular, transnational governance and regulation is needed to achieve such a cultural shift, and to encourage collaboration, coordination and horizontal partnerships.[32]

Generally, the objectives of sustainable supply chains are the following:

- Transport reduction (percentage of overall value)
- Improved carrier/Unit Load Device utilization (volume/weight)
- Emission reduction
- Energy efficiency
- Increased re-use
- Supply chain cost reduction
- Supply chain service improvement (quality and due date reliability)

4.2 Transition towards sustainable and synchronized logistics chains

In a few years, better and faster systems will enable new forms of collaboration. Dynamic and flexible interrelations between value chain actors will characterize the logistics market just as transparency, traceability, and rapid response systems.

Flexible and adaptive ICT systems in the cloud will dominate the market and logistics service providers will be able to respond quickly to changing market requirements caused by the booming e-commerce for example. There is a need to focus on changing the way supply chains are designed and operated in order to meet both economic and environmental, as well as safety and security requirements.

This also involves the development of business models supporting the implementation of new logistics concepts and technical solutions. At the same time, we note that roles are changing. Companies may decide not just to outsource only logistics functions but the entire sourcing and procurement function as well. Enlarging the scope to fully include decisions made at the supply chain level means considering not only "how to transport" but also "what to transport". That is, transport shall not be considered as an independent component, but as part of strategic decisions on a supply chain level, measuring also its economic, ecological and social effects.

There is a need for new approaches where shippers´ planning and control processes and models are coordinated with transport actors´ capacities and processes, and vice versa. Various kinds of network approaches may also support a holistic analysis.

Research on collaborative logistics management is important to define new roles for different actors, shippers as well as service providers, in different contexts.

Flexible information management is key to implementing logistics solutions that can support sustainable synchronized supply chains. The use of information systems will influence the way logistics partners reshape

[32] Sustainable, Safe and Secure Supply Chain. Research & Innovation Roadmap, ALICE, https://www.etp-logistics.eu/wp-content/uploads/2015/07/W16mayo-kopie.pdf, p.16

and optimise their integrated supply chains by, for instance, recognising alterations in inventory levels, market demands, and transport constraints.

The transformation to sustainable logistics solutions supporting synchromodality will require changes in business models regarding both demand and supply as well as the further greening and digitalization of the operations. A gain sharing model could be also considered which could be enabled by a trustee.

Greater cooperation makes it possible to focus, simultaneously, on customisation, business process integration and sustainability. Knowledge about the relationships between shippers' demand specification and their needs is crucial in understanding the requisites of transport services. Such information would make it possible for logistics service providers to fully utilise the potential of their systems.[33]

Given the features of synchromodality, transport planning is classified under the operational short-term planning level, as a synchromodal systems operate in a dynamic environment, with decisions being made in response to real-time data. Once disturbances concerning changes in demand flow and traffic conditions that influence the transit time appear, the transport planning needs to be adjusted by making use of adaptive routing solutions.

4.3 Synchromodality as a key solution to Europe's inland waterway congestion – example from Western Europe

DP World's Vice President of inland and logistics for Europe is urging shippers to buy into synchromodality "to combat North Europe's systemic barge congestion" as he acknowledges the two-to-three-day waits along the inland waterways servicing Antwerp and Rotterdam.

According to DP World, "What we're trying to offer to combat this is synchromodality, where we don't focus on the means, but rather on the objective i.e. getting goods to the customer. To achieve this, we are expanding the barge and rail services, which provides us the flexibility to reassign shipments between the two modes – if we spot a delay on rail services, we can send via barge, and vice versa."

As such, synchromodality becomes essential to address the congestion and the inherent lack of capacity, that frequently means even seven-day waits.

"What is needed is that all stakeholders share vital information with each other, so goods can move faster and more efficiently. To this end, synchromodality, in essence, sees the terminal operators acting as the spider in the web," concludes DP World."

DP World will continue its efforts, seen over the past two to three years, to expand its presence in intermodality and synchromodality to 12 locations across Belgium, France, Germany, the Netherlands, Switzerland, Romania and Serbia. Such efforts will be in vain if capacity is not understood holistically, and those locations are not integrated further afield with their regional counterparts in Southern Europe.

DP World operates four barges on the Upper Rhine as well as charters vessels and values its business relation to barge owners, taking the price for its quite high utilisation rates of 75-80%, which is above the peer groups, which appears to be around 60%.

Synchromodality is thus essential in addressing congestion and lack of capacity. Both are made worse by a **lack of accurate forecasting**, particularly from carriers, who recur to **overbooking** in the expectation that varying demand is accommodated. **But what is the exact impact of overbooking on capacity? And how well do carriers forecast?**

Both questions are complex. In broad terms, an overbooking ratio value of 50% means that, for example, a container terminal accommodates 50% more incoming reservations than the actual capacity. On the other

[33] Sustainable, Safe and Secure Supply Chain. Research & Innovation Roadmap, ALICE, https://www.etp-logistics.eu/wp-content/uploads/2015/07/W16mayo-kopie.pdf, p.24

hand, according to CMA CGM S.A.[34], less than 50% of container carriers actually forecast their capacity needs, and less than ½ of those are forecasting properly. This continues lack of adequate forecasting impacts negatively on the implementation of synchromodality as it disables a synchronised allocation of capacities, often to the disfavour of IWT and in favour of more polluting modes.

4.4 Policy framework and relevant initiatives

4.4.1 The European Green Deal

Introduced in December 2019, the European Green Deal is at the heart of the European Union's ambitious goal to become the first climate-neutral continent by 2050. It is a roadmap meant to foster the transition of the European Union towards a climate-neutral economy by reducing climate emissions towards 55% by 2030 and achieving carbon neutrality by 2050. The core objective of the Green Deal is to serve as "(…) a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use" (European Commission 2019: 2, bold in the original).35

The main objectives of this policy framework can be summarized as follows:

- Increasing the EU's climate ambition for 2030 and 2050;
- Supplying clean, affordable, secure energy;
- Mobilising industry for a clean and circular economy;
- Building and renovating in an energy and resource efficient way;
- A zero-pollution ambition for a toxic-free environment;
- Preserving and restoring ecosystems and biodiversity;
- Farm to Fork: a fair, healthy and environmentally friendly food system;
- Accelerating the shift to sustainable and smart mobility.

The highlighted objective is of particular importance for the digitalisation process of the Danube IWT sector. A shift towards smart and sustainable mobility can only be achieved by dedicated actions and measures to adequately support the efficient integration of IWT in the new digital era.

4.4.2 Sustainable and Smart Mobility Strategy

The Sustainable and Smart Mobility Strategy presented by the European Commission on 9 December 2020 lays the foundation for how the European transport system can achieve its green and digital transformation as outlined in the European Green Deal.

The document outlines the development direction of the European transport policy in order to reduce greenhouse gas emissions and transport's reliance on fossil fuels. The successful implementation of the goals set by the European Green Deal depends on the sustainability of the transport system. Digitalisation is in this regard an indispensable driver for climate neutrality.

Important to highlight is the fact the European Commission recognizes the challenges faced by waterborne transport in terms of decarbonization due to the limited uptake of innovative technologies, an issue affecting both ports and vessels. Moreover, the document stresses the importance of ports as key facilitators of international connectivity and their capacity to become multimodal mobility and transport hubs.

The strategy is structured around three key objectives:

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[34] CMA CGM S.A. is a French container transportation and shipping company. It is the world's 3rd largest container shipping company.

[35] The European Green Deal

- Sustainable mobility: shift to zero emission mobility by making all transport modes more sustainable.
- Smart mobility: supporting sustainable choices by taking advantage of digitalisation and automation to achieve seamless, safe, and efficient connectivity. Another ambitious plan is to boost innovation and the use of data and artificial intelligence for smarter mobility.
- Resilient mobility: reinforce the Single Market, make mobility fair and just for all, increase transport safety and security across all modes.

Of particular interest for the process of digitalisation of the Danube IWT sector is the objective Smart Mobility. To make “smart mobility” a reality, the strategy proposes the following flagships (key areas for action):

- Making Connected and Automated Multimodal Mobility a Reality
  - Take full advantage of smart digital solutions and intelligent transport systems (ITS).
  - Support the development of connected, cooperative and automated mobility.
  - Paperless options in all modes of transport.
  - Efficient capacity allocation and traffic management: further development of Vessel Traffic Monitoring and Information Systems (VTMIS).

- Innovation, Data and Artificial Intelligence for Smarter Mobility
  - Favourable conditions for the development of new technologies and services.
  - Research and deployment of innovative and sustainable technologies in transport.
  - Highest level and performance of digital infrastructure.
  - Data availability, access, and exchange.
  - European Common Mobility Data Space.

4.4.3 Combined Transport Directive (92/106/EEC)

The Combined Transport Directive fosters the modal shift from road freight to transport modes with lower emission such as inland waterways, maritime transport and rail. In light of the Sustainable and Smart Mobility Strategy, this initiative will review which transport operations should be supported and which support measures would be most effective. The 1992 Combined Transport Directive is **one of** the legal instruments supporting shifting road freight to lower emissions transport modes, such the inland waterways. However, difficulties in its implementation led the European Commission to propose a revision in 2017. Ensuing institutional negotiations were blocked due to differences at Council level surrounding the exemption from cabotage in international combined transport, which resulted in the Commission´s decision to withdraw the proposal. A Stakeholder expert group meeting was organized in October 2022 to discuss on the “Impact assessment support study on amendment of CTD”.

4.4.4 NAIADES III Action Plan

The NAIADES III action plan seeks to “(...) shift more freight transport on inland waterways, and set the sector on an irreversible path to zero-emissions, underpinned by a **paradigm shift towards further digitalisation**, as well as accompanying measures to support the current and future workforce. Meeting these core objectives will require an integrated approach and a basket of measures incorporating transport, environmental, digital, energy and fiscal policies, backed up with financial incentives (...)".[36] It was tailored to accomplish the ambitious climate goals of the European Commission, acting as the pillar of the pathway towards a climate-resilient, digital, and reliable inland waterborne transport system.

[36] NAIADES3, page 2.

Digitalisation plays in the frame of NAIADES III a central role with a dedicated action plan to support the development of a smart inland waterway transport. It foresees the following objectives:

- Revision of the RIS Directive (expected to be finalised in 2023);
- Technical assistance for a permanent operational structure for a single point of access for the provision of RIS-based Corridor Information Services (in 2024);
- An integrated and operationalized vision for the digital transformation of the current traffic and transport related business models and processes in the sector (in 2023);
- CEF technical assistance project to strengthen public-private cooperation in inland waterway transport and facilitate implementation of the digital vision (in 2023);
- Facilitate the development, demonstration and the deployment of holistic Smart Shipping Concepts for the digital integration of inland waterway transport in the synchromodal supply chain, including RIS, through Horizon Europe and CEF (from 2022).[37]

4.4.5 The CCNR's Mannheim Declaration

On 17 October 2018, the Ministers of the five Member States of the CCNR (Belgium, Germany, France, the Netherlands, Switzerland) adopted the Mannheim declaration.[38] Recalling the sector's high potential for development and innovation, they vowed to reinforce the role of inland navigation as an economically relevant means of transportation with a high potential for development and innovation by promoting faster and more efficient inland vessel cargo handling in seaports and tighter integration of IWT into digital and multimodal logistic chains across Europe. The Declaration further emphasizes the need to work towards better coordination between national development programmes and provide transparent information about them, all the while promoting constructive collaboration between the CCNR and the European Union (EU), the other river commissions, the United Nations Economic Commission for Europe, the associations recognised by the CCNR, and all other relevant inland navigation players.

4.4.6 River Information Services

River Information Services (RIS) are modern traffic management services enhancing a swift electronic data transfer between water and shore through in-advance and real-time exchange of information. These services are designed to enhance safety and efficiency of IWT by optimising traffic and transport processes. Focal aspect is a swift demand oriented electronic data transfer between water and shore through a real-time exchange of information. As such, RIS aims to streamline the exchange of information between IWT stakeholders. The 2005 adopted **RIS Directive** provides minimum requirements for the implementation of RIS and its agreed standards in order to enable the cross-border compatibility of national systems, functioning as the main pillar of digitalisation in IWT. The following figure represents a general overview of the current status of RIS and its functionalities.

Mid-2021, the Commission released the Inception Impact Assessment (Roadmap) for the revision of Directive 2005/44/EC on harmonised river information services which aims to inform citizens and stakeholders about the Commission's plans in order to allow them to provide feedback on the intended initiative and to participate effectively in future consultation activities. One year into the revision, the raised discussions and collected input went around subjects such as the difference in scope of eFTI and RIS, personal data protection, the need

[37] NAIADES3, page 16.

[38] CCNR, "Mannheim Declaration "150 years of the Mannheim Act – the driving force behind dynamic Rhine and inland navigation", 17 October 2018, https://www.ccr-zkr.org/files/documents/dmannheim/Mannheimer_Erklaerung_en.pdf.

for having additional guidelines, the referral to ES-RIS technical specifications created and adopted by CESNI, and the difficulty in making an electronic reporting obligation on EU level.

In regions/countries outside the EU, RIS can/is being implemented based on locally applicable decisions and legislation, e.g. through CCNR resolutions. Selected applicable projects can be found in Annex 1.

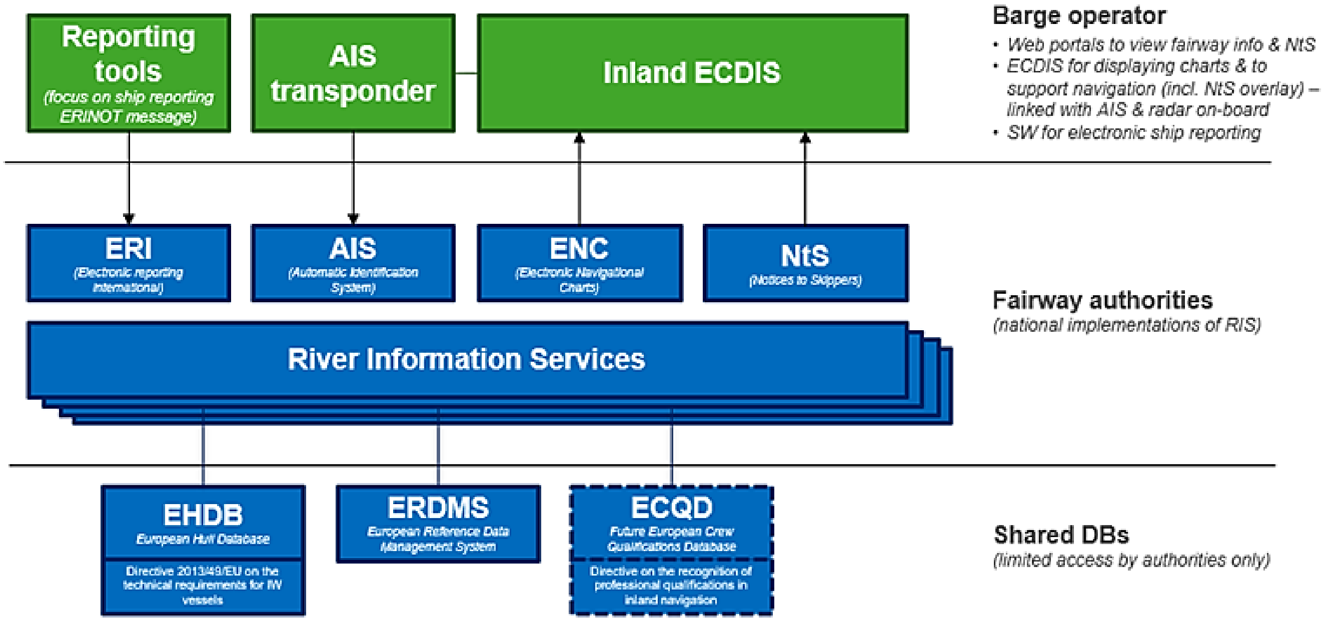

Figure 5: RIS overview

In order to support synchromodal solutions, it is highly recommended that the fulfilment of the reporting requirements with RIS is seamlessly taken over to all eFTI procedures, thus the economic operators are provided with reporting only once soutions.

4.4.7 eFTI – Electronic Freight Transport Information Regulation

The regulation establishes a legal framework that allows economic operators to share with enforcement authorities information in an electronic format concerning the transport of goods by road, rail, inland waterways and air in the European Union (EU). Knowing that the movement of goods is accompanied by a large number of information which is still exchanged in paper format among businesses and authorities, the Regulation sets the legal framework for the electronic communication between authorities and economic operators (mainly companies involved in freight transport and logistics).

Its core objective is to encourage the digitalization of freight transport and logistics in order to significantly reduce administrative costs and improve the efficiency and sustainability of transport.

Essential characteristics of the Regulation stipulate the functional requirements applicable to eFTI platforms to enable the data exchange process among the involved actors, including requirements to third-party platform service providers. The following figure provides an overview of the key elements of the eFTI Regulation:

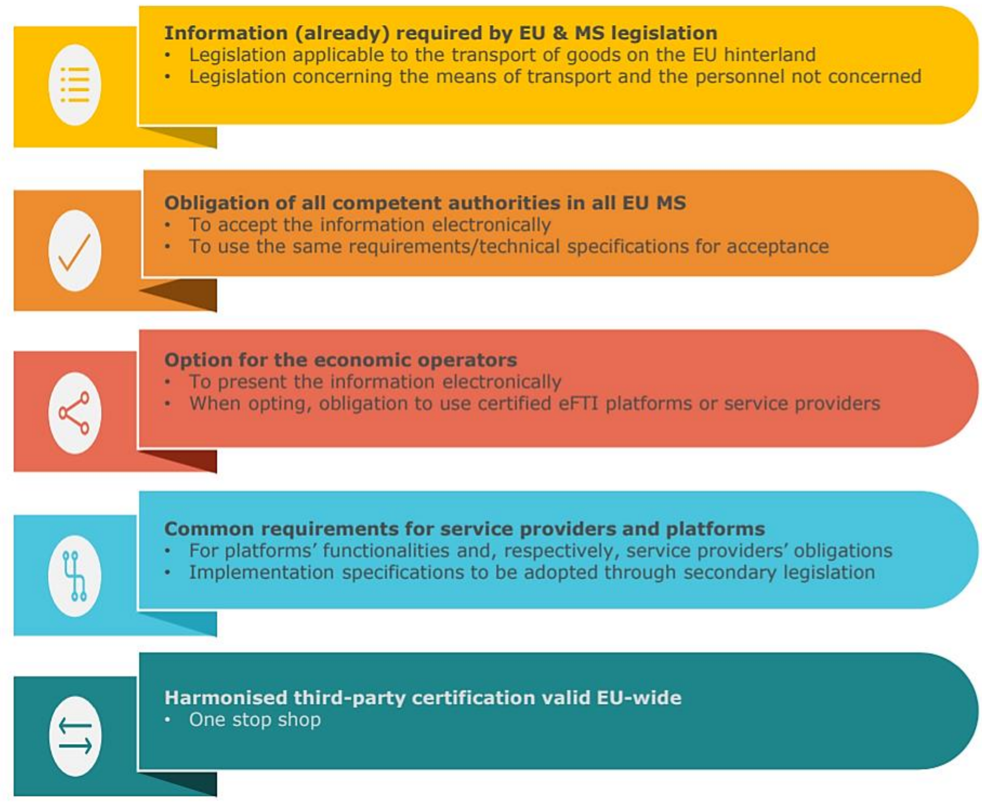

Figure 6: Key elements of eFTI, © EC

Operators are not obliged to make regulatory information available electronically to a competent authority. However, when they choose to make this information available electronically, operators must:[39]

- use data processed on a certified eFTI platform and, if applicable, by a certified eFTI service provider;
- make data available in machine-readable format via an authenticated and secure connection to the data source of an eFTI platform, and, when the data is requested for inspection, communicate to the authorities a unique identifying link to that data;
- present data in human-readable format if requested by the competent authority, on the spot, on the operator's device.

Relevant authorities must:

- accept regulatory information made available electronically by operators;
- accept waste shipment regulatory information without the agreement referred to in Regulation (EC) No 1013/2006;
- be able to access and process electronically the eFTI data made available by operators;
- provide official validation, such as stamps or certificates, electronically, where such validation is required as part of the regulatory information.

Relevant authorities, eFTI service providers and operators must keep commercial information confidential and ensure it is accessed and processed only when authorised.

[39] https://eur-lex.europa.eu/EN/legal-content/summary/electronic-freight-transport-information.html

4.4.8 Data Governance Act

Synchromodality requires access to large amounts for the digital systems that enable it, to function properly. On another note, the volume of data generated by humans (for example, via their mobile phones) and machines has increased dramatically, yet most data is unused or sits inside a few (large) companies. The Data Act ensures fairness in the digital environment by stimulating a competitive data market for data accessible and open to all. The Regulation establishes who has the right of access to data generated by products and services, under what conditions and on what basis, in all economic sectors. It also provides for the development of interoperability standards for data (e.g.: for smart contracts) to be reused between sectors with the view to creating a European Data Act.

4.4.9 The Cyber Resilience Act

Cyber resilience (security) is an existential issue. Synchromodal systems must thus be built “cyber resilient by design”. Hardware and software products we use are targets of (several) cyberattacks a day, some extremely successful, at time paralysing entire countries as it was the case with Estonia in 2007. Once approved and if applied to IWT, this new proposal will establish rules for placing on the market of products with digital elements, ensure essential requirements for the design, development and production of certain products as well as essential requirements for handling vulnerabilities during the whole life cycle.

5 Synchromodality, physical internet, terminals and ports

5.1 Context

Ports play a crucial role as regulators of freight flows in supply chains. Seaports and especially dual ports are key parts in both national and international supply chains, facilitating international trade of goods and thus challenging and linking hinterland transportation.

In the last two decades, the majority of seaports around the world have experienced a remarkable increase in their container throughput. Seaports are confronted with peaks and bottlenecks which are also transferred to inland ports as they play an important role in the hinterland transport of seaports. Consequently, improving the hinterland transport has become a priority. This is becoming even more important, as the quality of the access to and from the hinterland and the inland ports differs between seaports and affects their competitive position.

Positive experiences with synchronized intermodal services exist in port-hinterland container transport, in proprietary transport chains of integrators and in the hybrid (dual-mode) supply chains of certain shippers. Still, in most cases, the choice of mode and route is either fixed long time ahead, or is not made with consideration of all the latest options. Networks of modes are still decoupled at intermodal terminals, be it physically, financially or administratively, and synchronization between modal operations is limited or absent.

By applying the concept of synchromodality – as a first step towards the Physical Internet - peaks and bottlenecks in ports may be tackled by an efficient use of existing capacities. In research, the main focus has been on increasing the efficiency of logistics processes in seaports rather than in inland ports. However, the importance of inland ports as crucial hinterland connections has increased in recent years.

In the past years, inland ports have evolved to broad logistics zones offering traditional port functions such as transhipment, but also other logistical services such as container-repair services. Increasing transport volumes from seaports cause challenges in inland ports in terms of limited capacity and quality of logistical services.

On European level, inland ports – especially in Eastern Europe – lack adequate infrastructure which may hamper the efficient handling of cargo. In order to guarantee the competitiveness of inland ports, logistical processes have to be organized more efficiently. The concepts of synchromodality and the Physical Internet represent measures which could counteract the current bottlenecks in inland ports by organizing transport flows more efficiently.[40]

In addition, ports also need to look into the bunkering/charging needs of the future 'green' ships. This is not only to ensure that the ports are complying with the current and foreseen legislation, but that they can also continue to attract at least the same level of freight as in the past. And the greening of the IWT sector as a whole is not a standalone process, but also related to the greening of the other transport modes, with which the ports will have to interact via their hinterland connections.

Trends such as Industry 4.0, smart production or self-driving trucks are buzzwords which are currently well known in the transport industry. Thus, these trends are also affecting the port industry.

The Port 4.0 can be seen as the next evolution in shipping. The port 4.0 represents the fifth development step in the development steps of ports.

[40] D5.4.4 Danube Ports and the Physical Internet, University of Upper Austria, 2018, p.8

According to Lee and Lam (2016), the five stages of the port development are structured as follows:

- Level 1: pure cargo port
- Level 2: logistics port including warehouse services
- Level 3: Supply Chain Manager (SCM) port with bilateral information flows
- Level 4: globalized SCM Port
- Level 5: customer-centric port platform

Depending on the size of the port, inland ports are now usually at Levels 2-3, where systems and processes are coordinated with each other as part of port digitization procedures. In addition, a mutual exchange of information between customers and the port administration already takes place at Level 3. At Level 4, the extent of the exchange of information with port infrastructure users and with hauliers is even more advanced, but the focus of the port is mainly on its own optimization and profitability. The fifth stage, which is expected to develop in the near future, puts the interests of the community in the foreground in order to make the port part of a seamless transport chain. The optimum satisfaction of the customer's wishes and the achievement of a total optimum are the main drivers on this level.

As can be seen in the next figure, the economic value creation (y-axis) is expected to increase from one level to the other. However, also the complexity (x-axis) in ports and port processes increases on the different levels. Due to an increasing number of market players, the market on which a port operates is becoming larger. Simultaneously competitive pressure is also increasing. Due to an increased number of stakeholders also the complexity of day-to-day processes increases. The handling of higher volumes requires the support of the authorities in order to be able to comply with geographical and local restrictions. Complex supply chains also require higher security standards and better protection of the entire network. Since port activities are linked with negative external effects on the environment, the aspect of sustainability has to be respected in the different development levels. Due to complex supply chains, disruptions such as strikes or accidents have a higher impact on operations. Thus, ports should become resilient systems, able to efficiently react to disruptions.[41]

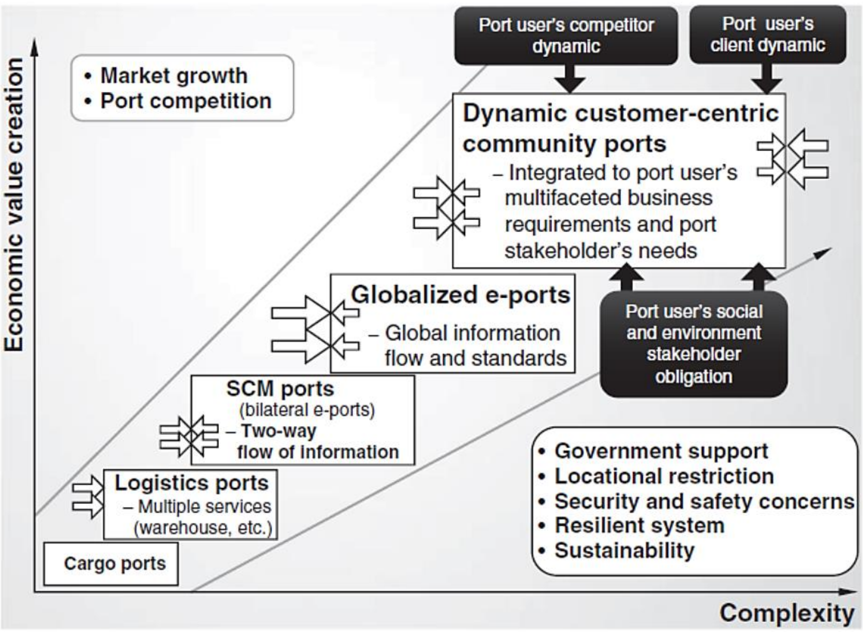

Figure 7: Development process of ports (© Lee and Lam, 2016)

[41] D5.4.4 Danube Ports and the Physical Internet, University of Upper Austria, 2018, p.9

In order to realize the vision of the Physical Internet in inland navigation on the long-term, infrastructural and technical measures are necessary. In addition, transport can be organized in a different way (e.g. no transport modes are defined by shipper). Inland ports, as modern multimodal logistics hubs, can be seen as information and aggregation hubs in a transport network.

Finally, there is a need to ensure that the entire ‘land component’ of the synchromodal system is also well connected to the developments that are taking place in the case of ships’ digitalization. This is key for both inland and dual ports, as it will allow an efficient interaction with sea-borne trade and ensure a smooth and fast ‘first leg/mile’ in the inland logistic chains.

Due to the longer transport times of inland navigation compared to other transport modes such as road, inland waterway transports should be planned very well to avoid delays. Due to these preconditions, mainly raw materials and bulk cargo, cargo for which time is not a critical factor in most cases compared to last-mile logistics for example, are transported on inland waterways. A new perspective can be introduced when IWT is embedded into urban logistics,

The trend of digitalization can be seen as an opportunity for inland ports to position themselves as important information and logistical hubs in the European freight transport sector. This can also lead the way to implement the concepts of synchromodality and the Physical Internet in inland ports.

The following aspects may be seen as critical success factors for implementing the Physical Internet in inland ports:

- Adequate infrastructure for seamless and efficient transshipment
- Efficient hinterland connections for inland ports
- Real-time communication between all inland ports and other relevant transshipment sites
- Transparency of time and cost of transport processes and communication to customers and other relevant stakeholders
- Seamless integration of inland navigation in national and international transport
- International expansion and maintenance of transport infrastructure
- Political promotion of ship transport by inland waterway
- Standardized technical equipment and networking of port/terminal infrastructure, superstructure, traffic routes, carriers and means of transport

5.2 Examples of best practices

In inland navigation, especially in the Netherlands, the concept of synchromodality in form of pilot actions is being used. This is because of its core competence, as a leading force in transshipment and handling of goods, its know-how in logistics and its pioneer spirit. In addition, the Netherlands offers the infrastructural (extensive waterway network) and economic (volume to be transported) prerequisites in inland navigation for the success of this concept.

Concepts such as the Physical Internet are also finding their way into inland shipping in the form of various pioneers such as "smartPORT Logistics" in the port of Hamburg. The aim is to optimize the land-based transport because of the limited capacity by connecting the transport providers with the goods and thus optimally coordinating transport processes. With the help of a cloud-based platform, which was provided by SAP[42], the different actors can exchange the relevant information and thus optimally plan the transports. By tracking truck movements using GPS, alternative routes can be proposed in the port to avoid long waiting times.

[42] https://www.sap.com/

Departures and exits are also controlled to make the transports and transhipment processes as efficient as possible.

This shows that the trend of innovative transport concepts is also particularly relevant for inland shipping. New decision-making processes or the exclusion of the individual preferences of decision-makers can overcome current prejudices and strengthen the position of inland navigation as alternative means of transport.

Ports can serve as particularly relevant transhipment points in future transport networks, allowing to realize bundling effects, which in turn are of benefit to inland waterway transport. In addition, inland waterway transport still offers sufficient spare capacity to meet this increasing demand. Data exchange will play a decisive role in the future. Here, too, existing inland shipping systems such as DoRIS (Danube River Information System) can be integrated into a larger network in order to exploit further potential for improvement.

Indeed, seaports are forerunners in relation to the synchromodal trend. Several ports around the world have introduced digital programmes as part of their strategic agendas. In Europe, several seaports such as Rotterdam, Amsterdam, Hamburg, Antwerp, Barcelona, Valencia, etc. have already built-up impressive experience in dealing with new technologies in most cases for their container terminals, which allows them to be key actors in the synchromodal logistics chains. In case of inland ports, these solutions shall be downscaled and tailored to the needs and characteristics of the respective inland ports.

Further selected good practice examples can be found in Annex 1: Non-exhaustive list of projects financed by the European Commission dealing with synchromodality and the physical internet.

6 Enabling technologies and tools in the transport and logistics sector

Today's technological achievements enable new and more efficient information systems, which can assist transport organisations and ensure higher efficiency in the form of greater detail of user and travel information for both companies and the people performing the actual transport function. In this sense the focus is on "Smart Solutions" which should cover the topics such as: Information and Communication Technologies, E-Freight, Telematics' Applications, E-Customs, Tracking and Tracing and Satellite Communication. [43]

Currently, the integration of the transport and logistics processes of supply chain participants is limited by the complexity of current systems technologies, the lack of communications and information standards, high costs, conflicting regulatory requirements, incompatible business processes, and outdated business practices.

Improvements in information and computing technologies, via simplification and standardization, business practice revisions, and business process harmonization will allow stakeholders in the transport and logistics domain to more cost effectively integrate their operations, manage the complexities of their supply networks, and improve asset utilization and lower social and environmental impacts. In addition, through better understanding of how these networks are used (through better data analytics), additional improvements in efficiency and operations should be achievable.

6.1 Artificial Intelligence

Artificial intelligence is changing the transport sector. From helping cars, trains, ships and aeroplanes to function autonomously, to making traffic flows smoother, it is already applied in numerous transport fields. Beyond making our lives easier, it can help to make all transport modes safer, cleaner, smarter and more efficient. Artificial intelligence-led autonomous transport could for instance help to reduce the human errors that are involved in many traffic accidents. However, with these opportunities come real challenges, including unintended consequences and misuse such as cyber-attacks and biased decisions about transport. There are also ramifications for employment, and ethical questions regarding liability for the decisions taken by artificial intelligence in the place of humans.

The EU is taking steps to adapt its regulatory framework to these developments, so that it supports innovation while at the same time ensuring respect for fundamental values and rights. The measures already taken include general strategies on artificial intelligence and rules that support the technologies enabling the application of artificial intelligence in transport. In addition, the EU provides financial support, in particular for research.

AI does not refer to one technology, but rather to a vast set of diverse approaches, methods and technologies, which to different degrees and in different ways show intelligent behaviour (such as logical reasoning, problem solving and learning) in various contexts. AI can be hardware based (for instance, in devices such as robots), or present in software (such as Google Maps). AI is only one of the several key technologies used in an intelligent port. Its applications/usage range from problem-solving and pattern recognition to machine learning. In port operation systems, it is used for instance in port equipment scheduling (to optimise the use of cranes and vehicles) and berth availability planning. In a number of ports in the United States, Asia and Europe, AI is used to run automated loading cranes and vehicles. AI makes decisions about which containers to unload first and how to stack them. It also helps with predictive maintenance of port equipment. With inland navigation also moving in the direction of more automation and autonomy, EU action on and financial support for the harmonisation of river information services is key for real-time exchange of electronic data. Furthermore, the

[43] Corridors, Hubs and Synchromodality, Research & Innovation Roadmap, ALICE, https://www.etp-logistics.eu/wp-content/uploads/2015/08/W26mayo-kopie.pdf, p. 19

European Commission has explored the potential for digitalisation in inland waterway transport, by defining the concept of a digital inland waterway area and mapping legal and commercial barriers to data sharing. [44]

6.2 Robotic Process Automation

Robotic Process Automation (RPA) uses the software technologies to automatically handle computer tasks that are repetitive, rules driven, and tedious for employees. Usually, back-office employees, spend up to 80 % of work hours filling in forms, making repetitive calculations, processing orders or such routine activities which could be more efficiently performed by machines.

RPA is a very good solution for optimizing processes, and reducing durations, but cannot be implemented in all cases. There are clear criteria that are to be followed. In addition, in order to benefit from a rapid Return. On Investment (ROI), the best fit for RPA implementation are processes that passed through a transformation initiative.

RPA is the use of software to handle high-volume, repeatable tasks that previously required humans to perform. Various port operators continue to use their existing applications without having a satisfactory level of alignment to the new EC requirements in regard to data exchange, such as Directive 2010/65/EU with its recent revisions or the European Maritime Single Window Environment (EMS We) initiative.

The study on RPA elaborated in the frame of the Dionysus[45] project aims at leveraging port administration/authority attributes in order to trigger participative actions from the Danube ports partners to summarize existing applications and study the opportunity to make them "talk to each other"/exchange data through RPA. The Robotic Process Automation for ports is a strategic approach/functionality, this ascending automation trend being introduced and developed in the recent years in order to improve port efficiency.

6.3 Digital Twin

A digital twin is a virtual model designed to accurately reflect a physical object. An object — for example, a wind turbine — is outfitted with various sensors related to vital areas of functionality. These sensors produce data about different aspects of the physical object’s performance, such as energy output, temperature, weather conditions and more. This data is then relayed to a processing system and applied to the digital copy. Once informed with such data, the virtual model can be used to run simulations, study performance issues and generate possible improvements, all with the goal of generating valuable insights — which can then be applied back to the original physical object. The difference between digital twin and simulation is largely a matter of scale: While a simulation typically studies one particular process, a digital twin can itself run any number of useful simulations in order to study multiple processes. In short, a digital twin is a virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation, machine learning and reasoning to help decision-making.

With the implementation of digital twins in logistics, the management of warehouses, products and global hubs will become more efficient as the replica will provide companies the opportunity to rectify errors in their logistics network without damaging the actual product, network or data.

Logistics hubs such as airports and ports are complex systems to manage— imperfections in the system or human errors can create bottlenecks. For example, Ericsson and the port of Livorno in Italy are working to create a digital twin to remove the inefficiencies in freight handling and loading and unloading of shipments.

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[44] Artificial intelligence in transport, Current and future developments, opportunities and challenges, European Parliament, Maria Niestadt with Ariane Debyser, Damiano Scordamaglia and Marketa Pape Members' Research Service, 2019

[45] www.interreg-danube.eu/dionysus

This is being achieved by creating a real-time digital replica of the port area using 5G network, smart sensors, and advanced cameras. Digital twins can also use satellite and aerial photography and navigation systems to assess in real time the entire journey of shipments - be it on land, air, or sea.

Digital twins can also create exact virtual layouts of warehouses and distribution centers. This allows companies to rethink how new designs could enhance activity without damaging current operations.

Further, with recent advancements in warehouse technologies such as automated robots, counting systems, goods-to-person picking, and automated storage and retrieval equipment, companies can combine data generated from these systems to improve physical warehouse layouts while increasing worker productivity.

For example, DHL partnered with food packaging manufacturer Tetra Pak to simulate all activities and machinery using a digital twin at one of their warehouses. It allowed them to study movement of packages and functionality of machinery to enhance productivity.[46]

6.4 Blockchain technologies

Blockchain can be defined as a chain of blocks containing information. It is an information storage architecture that guarantees the invariability of historical data. Blockchain is a decentralized, distributed and often public digital ledger consisting of records called blocks. Each block contains the block’s previous hash, timestamp, and transaction data. The timestamp proves that the transaction data existed when the block was posted to get to its hash. Since each block contains information about the previous block, they form a chain, and each additional block strengthens the blocks before it. Transport can draw a lot from blockchain; it’s almost a technology built specifically for the sector. However, more and more solutions are already being developed that support transport businesses, and it is expected that the share of blockchain in this industry will continue to grow. Blockchain helps overcome many challenges of the logistics sector. Many logistics companies are measured by low transparency and non-standardized processes, varying levels of technology adaptation or the imposition of manual operations such as data entry and paper documentation. These problems can be addressed and eliminated by using blockchain, which is already the case in many logistics companies. In addition to increasing the visibility and predictability of logistics operations, the use of this technology can accelerate the physical flow of goods. The traceability of goods can help build responsible and sustainable supply chains. In addition, blockchain-based solutions expand the possibilities and the emergence of new, more innovative logistics services.[47]

6.5 3D printing

According to President Obama´s State of the Union address in February of 2012, “3D printing has the potential to revolutionise the way we make almost everything”. Bill Anker at Transport Solutions considers 3 D printing a logical extension of technologies that gave industry computer-aided designs and drafting (CADD) and high-end laser scanning. 3D printing is machine-based printing that builds layers of material using a computer aided 3D design to create a three-dimensional product. Products can be printed at any location and smaller printers can already be bought by a (relatively) small price.

From the point of view of transportation, 3D printing, in large scale, will bring (in a horizon of 5 to 10 years) the possibility to speed up repairs and cut costs in the production of parts for transportation. For example,

[46] GEP, Digital twins in logistics: real gains from real-time models, https://www.gep.com/blog/mind/digital-twins-logistics-warehouse-shipments

[47] Binarapps, What is blockchain in transportation? How is it used?, https://binarapps.com/what-is-blockchain-in-transportation-how-is-it-used/

manufacturing giant Siemens stated that 3D printing will allow for the repair of damaged turbine burners to be cut from 44 weeks to 4.

From the point of view of synchronised modality, the concept itself may well change as a result of production (or part of it) being handled locally and not globally. Global logistics chains (requiring several synchronised points) would then give way to local logistics chains, near to the end users or businesses printing their own products. If this happens, different truck patterns and types will emerge, long distance port traffic and air cargo may reduce and shorter distance inland waterway transportation may come out reinforced. Synchro modality as we know it today would then change as it would be catered for a multitude of smaller routes, networked, and no longer large complex supply chains.

7 Working groups and related initiatives

7.1 DTLF

The DTFL is a group of experts in the field of transport and logistics. It provides a platform where Member States and relevant transport and logistics stakeholders can exchange technical knowledge, cooperate and coordinate with a view to support measures aimed at promoting efficient electronic exchange of information in transport and logistics. Its task is to assist the Commission in developing and implementing policy measures. It identifies challenges and areas where common action in the EU is needed, provides recommendations, and supports the implementation of these recommendations where appropriate. The following figure provides an overview on the DTLF, its tasks and responsibilities:

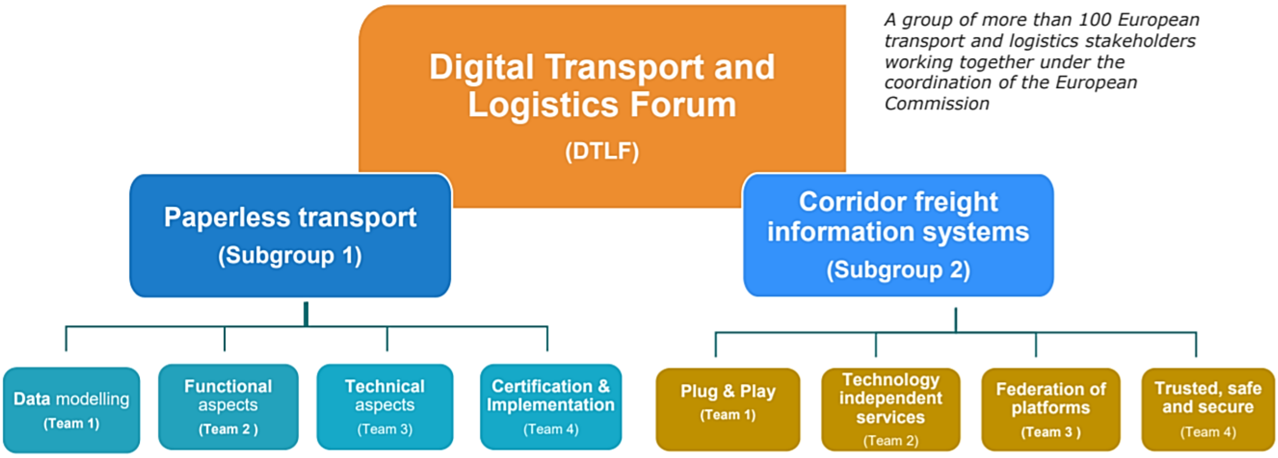


Figure 8: DTLF © EC

7.2 DINA

The "Digital Inland Waterway Area - Towards a Digital Inland Waterway Area and Digital Multimodal Nodes" study was finalised in October 2017. The study helps to frame the discussion on the digitalisation of the inland waterways transport sector. DINA is a concept which aims to interconnect information on infrastructure, people, operations, fleet and cargo in the inland waterway transport sector and to connect this information with other transport modes.

DINA identified three areas where digitalisation is critically important for IWT:

- The improvement of navigation and management of traffic: this is necessary to make more efficient use of the capacity of the infrastructure and to reduce fuel costs for vessel operators.
- The integration with other modes of transport, especially in multimodal hubs: this is necessary to optimise processes in terminals and to allow for improved integration of IWT in supply chains and multi-modal logistics operations, thereby potentially attracting additional customers.
- A reduction of the administrative burden: reducing the number of business-to-government declarations (thereby saving costs & improving efficiency) and making law-enforcement more efficient and effective.

The following figure provides an overview on the involved actors in the digitalisation process of IWT:

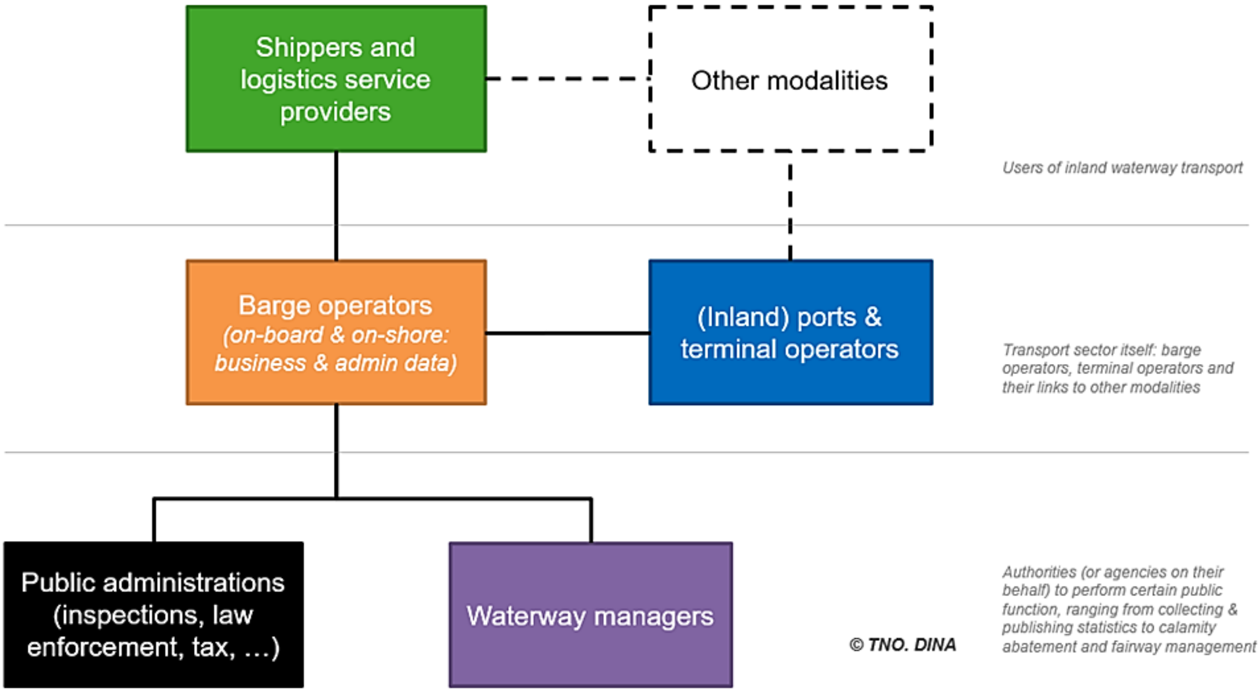
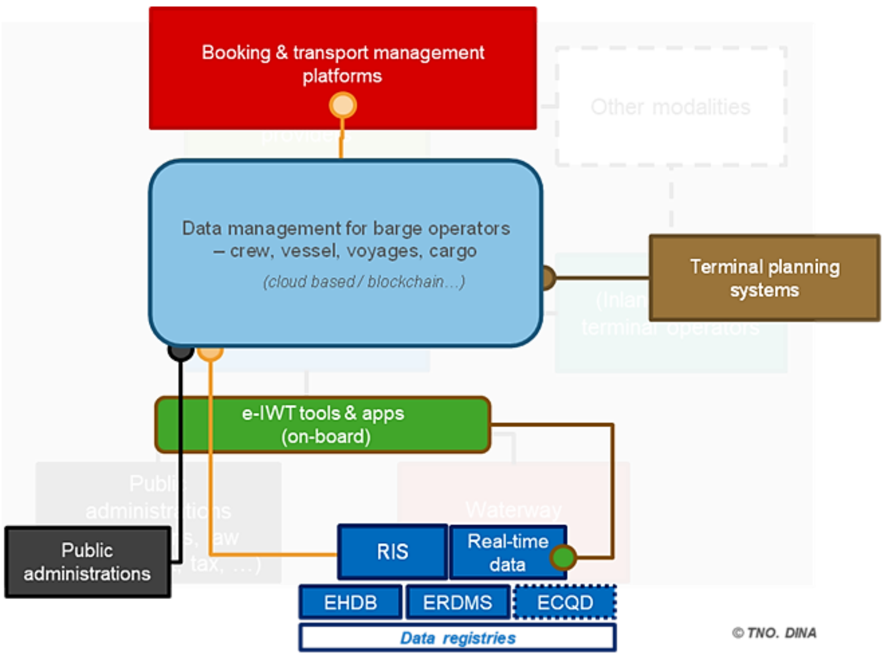


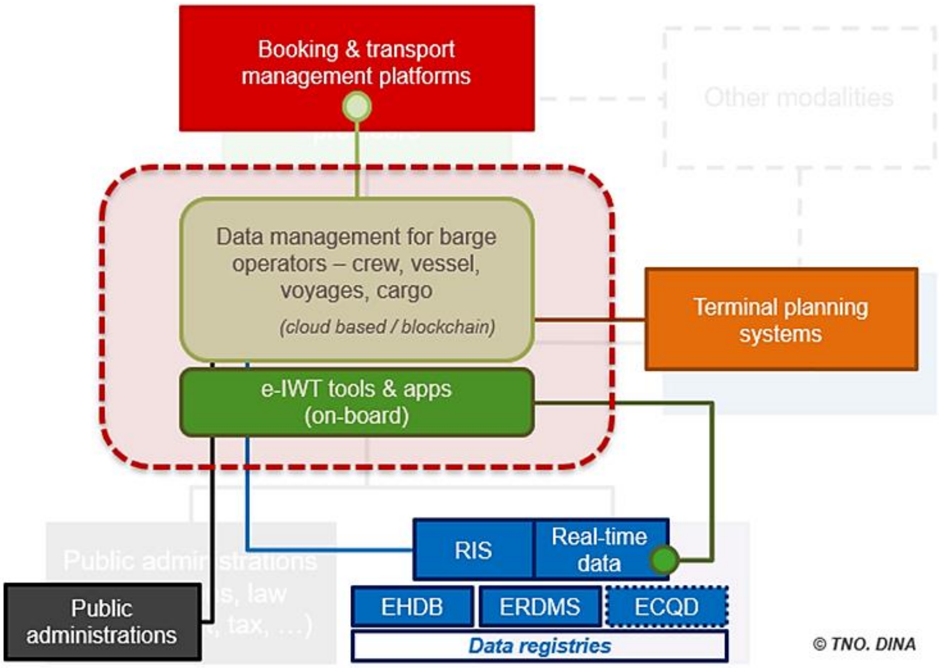
Figure 9: Overview of the actors involved in the digitalisation of IWT.

The following figures provide a precise overview on the proposed controlled sharing of information which can serve as a platform for future developments:



Based on this, the following future developments are expected to facilitate the further development of digitalisation in IWT:

- An **extension of RIS**: providing additional (real-time) data between infrastructure managers and barge operators, making it more interoperable and useable for barge operators using new on-board e-IWT tools and applications.
- **Data platform(s) for barge operators**: allowing them to control their own data and operations. This should allow barge operators to share data in a controlled way with other stakeholders such as public authorities (for reporting purposes), (inland) ports and terminals.
- **Integration with booking and transport management platforms** of shippers and logistics service providers. This should provide better visibility and better integration of IWT in the full logistics chain covering multiple modalities.



- **A data platform for barge operators**: allowing them to control their own data and operations. This should allow barge operators to share data in a controlled way with other stakeholders such as public authorities (for reporting purposes), (inland) ports and terminals.

7.3 CESNI/TI Working Group

The CESNI was set up in 2015 in order to adopt technical standards in various fields, in particular as regards vessels, crew and information technology. The respective regulations at the European and international level, including those of the European Union and the CCNR, may refer to these standards with a view to their application.

CESNI has set up a dedicated working group on information technologies in 2018. Its core objectives are:

- to develop proposals for the development and revision of technical standards in the field of information technologies, in particular for River Information Services (RIS), including proposals for the revision of standards made mandatory by EU and CCNR regulations;

- to promote the proper implementation of standards in the field of RIS and other areas of information technologies;
- to provide advice and analysis on information technology standards (including RIS), in particular to support policy initiatives on digital instruments in inland navigation and the gradual introduction of electronic documents.

In the specific field of RIS, CESNI develops, updates and adopts the European Standard for River Information Services (ES-RIS). The ES-RIS encapsulates all RIS-related technical specifications. ES-RIS also contains the rules defining operational and performance requirements, testing methods, and required test results in order to be able to verify in a harmonised way that an item of equipment complies with the aforementioned specifications. Former European RIS expert groups have been integrated in CESNI/TI to develop ES-RIS. As mentioned in 4.4.3, the European Union is envisaging in the currently ongoing RIS-directive to refer to the ES-RIS for minimum technical requirements to respect in the field of RIS.

7.4 ALICE – Alliance for Logistics Innovation through Collaboration in Europe

The European Technology Platform ALICE is set-up to develop a comprehensive strategy for research, innovation and market deployment of logistics and supply chain management innovation in Europe. ALICE has been set-up to develop a comprehensive strategy for research, innovation and market deployment of logistics and supply chain management innovation in Europe with the mission: "to contribute to a 30% improvement of end-to-end logistics performance by 2030". By means of its dedicated Roadmap in the field of Corridors, Hubs and Synchromodality, ALICE aims towards the achievement of EU wide synchromodal services for a smart and seamless network, based on corridors and hubs, together facilitating efficient and effective supply chains. It involves a step change from the current system towards the ultimate vision of the Physical Internet, by synchronizing services and equipment on corridors and hubs and integrating these into networks.

7.5 Digital Initiatives Observatory

The Digital Initiatives Observatory collects information about digitalisation initiatives along the European logistics chains in line with RIS deployments, EU digitalisation policy goals, legislation, and measures in relation to IWT. Hosted by the Danube Ports Network website, the Observatory enables the visitor a fast and easy access to the most relevant information. By means of digital filters, the visitor can select the information which interest him/her the most, choosing between the following pre-defined categories: country, transnational projects, policy initiatives, dedicated working groups and funding opportunities. The Digital Initiatives Observatory is fully operational on the DPN website since February 2021 and is continuously being updated.
It can be accessed here: https://www.danubeports.eu/digital-initiatives-observatory

7.6 CEF Building Blocks

The CEF Building Blocks are tools consisting of **eID**, **eSignature**, **eDelivery**, **eInvoice** and **eTranslation** which aim to ensure interoperability between IT systems and to facilitate the delivery of digital public services across borders, while the relevant rules and regulations (the eIDAS Regulation and the GDPR being in this regard the most important aspects) are fully complied with.

The **eIDAS Regulation** is cross-border and cross-sectoral legislation which provides a clear regulatory environment to enable secure and seamless electronic interactions between businesses, citizens and public authorities. eIDAS Regulation provides legal certainty for electronic identification and trust services going beyond national borders. More specifically, the Regulation ensures that people and businesses can use their own national electronic identification schemes (eIDs) to access public services in other EU countries where eIDs are available.

The **GDPR** is the primary legislation regulating how companies protect the personal data of EU citizen. Its requirements apply to each member state of the EU, aiming to create more consistent protection of consumer and personal data across EU nations. Some of the key privacy and data protection requirements include:

- Requiring the consent of subjects for data processing;
- Anonymizing collected data to protect privacy;
- Safely handling the transfer of data across borders.

7.7 Report “Towards Future-Proof Inland Waterway Transport in Europe”

The report initiated by MEP Caroline Nagtegaal and adopted by the European Parliament recognizes IWT's crucial role in achieving the ambitious objectives of the European Green Deal. In achieving IWT's ultimate goal in becoming climate neutral, the report stresses that adequate "investments in expanding, updating and upgrading the physical and digital infrastructure of inland waterways" are essential prerequisites. Likewise important is the development of inland and seaports as multimodal nodes in the transnational logistics system as well as the human-resources aspects in providing appropriate working conditions, modernising the inland navigation education and training system, and last but not least, to encourage the development of research and innovation within the sector. The report dedicated a section to digitalisation and automation, highlighting that “(…) digitalisation and data collection can contribute to a cleaner environment and improved safety on board”. Equally important, digitalisation is seen as a contributor to emission reduction stressing the need to provide adequate funding opportunities.

7.8 The WaterborneTP Ports & Logistics Strategic Research and Innovation Agenda

The WaterborneTP ‘Ports & Logistics’ Strategic Research and Innovation Agenda (SRIA) is a key document for the waterborne transport European community that addresses concurrently the challenges of decarbonization and seamless integration of ports in the logistics chains, in particular through digital transformation. The SRIA focuses on RD&I activities, but with the aim to bring the research results as close to the market needs as possible, both in terms of technical and functional specifications. This will consequently ensure a faster and solid market roll-out of the newly developed products and solutions.

The decarbonization-related developments need to consider adapting to the current and foreseen policy requirements as well as to evolution of the different modal forms of transport, with priority given to the movement of vessels and cargo. It is thus important to ensure novel, safe technologies and procedures for bunkering at ports and offshore, a higher level of electrification sourced from renewables, and systems for reducing emissions in climate-resilient ports. Furthermore, accidents and spillage during bunkering or other transport-related activities not only have an impact on safety, but are also a significant source of water pollution and environmental degradation, something that must also be avoided.

At present, there is still no integrated vision and approach to the development of fuel supply for alternative energy solutions, both for the waterborne transport but also for the wider transport systems as a whole. Furthermore, there is a lack of technical standards (as well as specific regulations) for bunkering, leading to a fragmentation of bunkering options throughout European ports. Lastly, there is still much uncertainty on safe storage and bunkering for several alternative fuel options. By developing standards, creating flexible fuel storage and supply options for different energy suppliers and integrating them into the overall smart port energy grid, the fast adoption of bunkering of different alternative fuels in all European ports can be guaranteed. This will in turn ensure that the ports and waterways are suited to take more cargo from the road sector while at the same time operating in tandem with the inland logistic chains.

Besides ‘net’ zero GHG and other pollutant emissions solutions, urgent actions are needed to strengthen the resilience and adaptation of ports. Both gradual changes, such as temperature and sea-level rising, fluctuating water levels for IWT and the expected increase in the frequency and severity of extreme weather events are already affecting transport infrastructures, equipment and operations. Infrastructures deteriorate at a faster pace over their life-cycle and transport services face an increase in possible disruptions and accidents. This leads to a need to develop innovative changes in planning, design, construction, operation and management of integrated waterborne infrastructure and vessels to ensure adequate protection and adaptation. Such developments also need to be in tandem with the ones developed in the hinterland connections.

Moreover, there is a need for automated intelligent maritime port call synchronisation and optimisation patterns to properly integrate logistics operations. Mitigation strategies for port stakeholders and the design of the logistics and operational supply chain for waterborne transport are either far from the market needs or lacking altogether.

Regarding the seamless integration of ports in the logistic chains, besides the energy-related aspects another key element is the digital transformation. Ports are key industrial and multimodal nodes linking with hinterland logistics, moving cargo from/to industrial and service hubs. Therefore, waterborne transport, seaports and inland ports cannot be considered in isolation and their challenges concern the whole logistics and transport system. Furthermore, 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 issues, for example, through the development of new concepts, such as the Physical Internet1 (P.I. port). These developments involve innovations in modularisation, collaboration schemes, robotisation, artificial intelligence and other IT technologies and their ultimate goal should be to achieve integrated door-to-door transport and logistics solutions where the waterborne transport sector is used at the maximum potential.

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. Some of its main elements are:

- improved forecasts, analysis and predictions (weather, energy, transport capacity, etc.);
- assisted port operations for a more efficient use of resources: dynamic optimisation systems, predictive maintenance systems, advanced dredging materials management, just-in-time ship arrivals, etc.;
- shared frameworks and standards that need to be implemented at a European level;
- new technologies, equipment and devices allowing intelligent, passive and active interactions with passengers and goods, e.g. new advanced identification technologies and solutions;
- security solutions with an integrated and holistic approach for monitoring, control, decision support systems and management.

Automation, including robotisation, will play a decisive role in this case for port operations and transport. The increased automation of vessels will play a major role in improving the overall ship operations, both during transit and the loading/unloading operations. And the development in vessel automation will need to be matched by the ports. In this regard, a wide range of solutions needs to be better defined and assessed for the implementation of an effective pathway towards a fully connected and automated ports: 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. 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, including energy efficiency aspects.

Such developments will also require the need for 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. 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, will need to be properly addressed in the context of these developments.

8 Findings from discussions conducted with supply chain stakeholders

As synchromodality implies cooperation between all supply chain actors, several interviews have been conducted with key stakeholders involved in the different stages of the supply chain (cargo owners, terminal operators, logistics service providers, shipping companies).

Currently, most companies involved in IWT still rely on manual procedures to either solve potential service issues, retrieve and understand information/data and to adapt to disruptions.

The interview results suggest that the experts agreed on the basic conditions which shall ensure the success of synchromodal transport chains. All statements that were received have been clustered and assigned to three categories (transport related, infrastructure related and framework related criteria) that have been developed based on the literature review (see table below).

Cooperation, efficiency, flexibility, service levels and sufficient volumes are five identified characteristics deemed by all involved experts as necessary for each functional transport system. Indeed, the shipped freight volumes must be high enough to ensure that real time switching and bundling of goods work within the synchromodal network.

Half of the respondents doubted that companies are willing to cooperate in such an intensive way that they are able to synchronize their transport flows. Pricing strategies, legal and political framework as well as the mental shift are other important factors mentioned during the discussions. Accurate planning as well as ICT/ITS and other information systems have been rated as relevant, the experts partly mentioned that some of these systems already exist and are ready for being used to coordinate synchromodal transports on particular logistics legs.

Similar feedback was received from the Platina3 Advisory Board. To this end, it might be very difficult to establish the synchromodality concept in practice, as for market players using conventional business models it could run counter to the usual principles of market economy and competition between companies. Some might still think that data regarding customers and commercial activities should be kept secret, in order to avoid the enticement of customers.

Moreover, synchromodal supply chains need to make economic sense to the respective logistics companies, whereas cooperation among and between those are to be further exploited based on good practices such as the alliance between MSC and Maersk, whereas the size and market share of such key logistics players are representative factors in shaping the market conditions.

Transport related decision factors	Infrastructure aspects	Framework conditions
• Service levels, reliability, pricing, total supply chain costs	▪ Hardware & software, ICT/ITS technologies, tools & applications	➢ Cultural view, mind shift, trust, cooperation versus competition, data sharing,
• Stock levels/volumes, resource planning, modal choice	▪ Network of nodes and routes	➢ Legal framework, agreements, governance, INCOTERMS
• Automatic data exchange, Data analytics	▪ Tactical, strategic and operational planning	➢ New business models, market uptake

Transport related decision factors	Infrastructure aspects	Framework conditions
• Demand planning/forecasting, optimisation	▪ HR skills	➢ RD&I
• Supply chain visibility, reliability of transport schedules, lower lead times, Just In Time (JIT) operations, higher responsiveness	▪ Renewable energy sources	➢ Risk factor reduction

Table 1: Factors influencing the decision of supply chain actors in relation to synchromodality

9 Findings from PLATINA3 related events to promote synchromodality in IWT

9.1 1st Stage event - Budapest Sessions - Session dedicated to the role of Inland Waterway Transport in European synchromodal logistics chains

Organised on the 8th of April 2021 within the frame of the first PLATINA3 Stage Event, session 6 entitled "Let's make IWT a reliable partner of synchromodal logistics chains using smart waterways", addressed key aspects dealt with by two separate PLATINA3 project tasks, but at the same very complementary, – on the one hand Task 1.3 dealing with assessing the needs and requirements for integrating IWT into synchromodal logistics chains and, on the other hand, Task 4.3 touching upon digital & automation tools for inland navigation, inland & seaports.

Pro Danube Management GmbH together with the Austrian waterway administration viadonau held a three and a half hour interactive session with highly experienced speakers representing both the policy perspective as well as the industry needs & trends, speakers that have agreed to join forces and reflect on the challenges and opportunities to achieve a fully integrated transport system within a well synchronized and smart European transport network, with IWT being a reliable partner in the logistics chains.

In this sense, the perspectives of several speakers representing four focus areas have been successfully introduced, such as:

- The policy framework side: the speaker from the European Commission/DG MOVE provided an insight into several relevant EU policies & actions in relation to transport & digital related initiatives, taking into account the environmental targets, initiatives meant to support - for example - the use of smart technologies that provide reliable fairway & port information and hence contribute to attracting new cargoes and volumes.
- The logistics alliance ALICE, the alliance for logistics innovation in Europe – representing the bridge towards the logistics sector arena, introducing the prerequisites for manufacturers/shippers and their supply chains to promote synchromodality and include IWT in their distribution network as well as to promote a smooth integration with the other modes of transport.
- The third area covered was the industry side, having a dedicated focus on supply chain solutions – three top actors from the Danube Region active along European supply chains (among which the oil&gas company OMV, the trimodal container terminal WIENCONT & the logistics service provider Rhenus Logistics) reflected on smart technologies, tools and applications they are currently using in their daily operations as well as various requirements for - depending on which side of the supply chain they are - making use/providing fully integrated supply chain solutions & services.
- The project side & their contributions – Besides the introduction to the PLATINA3 project, the session presented three other funded projects (DIWA, PhysICAL, RIS COMEX) looking into solutions to support the sector in the digital development, giving the audience an insight to their research results.

At the end of the session, Pro Danube has highlighted its overarching approach to streamline the results achieved in the past years by means of dedicated projects and initiatives (for details please refer to https://www.prodanube.eu/) for the benefits of the Danube waterborne transport.

Special thanks went to the organisers & moderators Mr Robert Rafael, Ms Ruxandra Florescu and Mr Juha Schweighofer, all speakers (Mr Mario Sattler, Mr Fernando Liesa, Mr Thomas Herics, Mr Harald Jony, Mr Gerhard Gussmagg, Mr Matthias Prandtstetter and Mr Mario Kaufmann) as well as participants for their valuable contributions and the interactive exchange of ideas aiming to a higher share of the competitive inland waterway transport in the complete logistics chains. Presentations are available at: https://platina3.eu/event/budapest/

9.2 Joint workshop on IWT digitalisation

On the 23rd of November 2021 more than 100 stakeholders from the public and the private sector participated in the transnational workshop on digitalization in Inland Waterway Transportation (IWT). The workshop was a joint initiative of the European projects Platina3, Masterplan DIWA, RIS COMEX and DIONYSUS and the sector organizations Pro Danube Management, EICB and the IWT Platform.

The workshop focused on how digital transformation can support business activities and reporting formalities in the upcoming years. Participants provided valuable inputs regarding further requirements on synchromodality, ICT infrastructure, River Information Services and Smart Shipping, data sharing & integration, cybersecurity and compliance.

During the plenary part of the workshop, the 4 projects were introduced by short interviews moderated by the Master of Ceremony Henk van Laar. The workshop perfectly fitted into the timelines of each project, as currently project partners of PLATINA3, Dionysus and the masterplan DIWA are working on collecting input for their dedicated studies, yet at the same time giving them the chance to share intermediate results with a wide range of experts. The RIS COMEX project will launch its European fairway information portal 'EuRIS' in the course of 2022.

Four themes
After the break, the participants joined either one of the four break-out rooms to go into more detail and moreover to share opportunities, requirements and discuss how relevant authorities together with the industry representatives can support a successful digital transformation in IWT.

The themes of the four break out rooms were:

- Smart Shipping
- Synchro modality
- River Information Services
- Sea and inland ports

This thematic approach resulted in lively discussions and new expert inputs relevant for all of the European projects. During the final plenary part, the results of the discussions in the break-out rooms were shared with all the participants. Representatives from European Commission's DG MOVE congratulated the initiative and highlighted the need for similar future cooperation activities of the IWT sector in Europe.

10 Recommendation and requirements for the further integration of IWT into synchromodal logistics chains

Future supply networks require a synchromodular transport system, which requires that shipments are to a large extent automatically routed in an optimal way. The optimization process should consider many viewpoints simultaneously. In a market economy, effectiveness and efficiency will always prevail, but resilience and various safety, security and environmental perspectives must be considered as well. No general high-level security & safety frame can be required from all kinds of supply chains as economic and societal goals must be balanced.

In the frame of synchromodality, the ALICE motto is as secure, safe, green or resilient as needed, not as possible.[48] This implies that in the case of IWT stakeholders need to respect the existing framework conditions and ambitions, and adopt their businesses in the best reasonable manner. Market players shall not overdo and overestimate the targets, but rather aim towards a well-functioning logistics chain including all applicable transport modes. Synchromodality including the further greening of the IWT sector together with climate-resilient vessels using smart and digital tools and applications, is a trigger to further support modal shift and the above described synchromodal logistics chains. It has to be noted that all transport modes in the chain have to respect greening and digitalisation requirements, thus as a final result all modes have to have their proper share in the transport mix.

According to the Roadmap of ALICE[49], synchromodal services require an integrative network strategy for multimodal freight transport within Europe. Network integration involves a close fit of corridors and hubs into a holistic EU freight network. Hubs need to be nominated, equipped and connected by corridors in a consistent way, **from TEN-T level to last-mile level**, in order to allow services to achieve the economies of scale and the integration scope of multimodal networks. Pan-European approaches for performance management of freight corridors need to be put in place, whereas information systems brought forward by independent ITS applications need to be harmonized. Of course, a prerequisite is a full internet coverage of waterways with a high-speed connection. This is not obvious as some areas are for time being not covered.

Besides taking stock of good practice examples and promoting marketing measure for synchromodal solutions, on a more practical perspective, **a Europe-wide Synchromodal Data Platform or a federation of platforms** capable to interact with (a) local/national/regional logistics platforms to provide pan-European real-time solutions/offers and (b) individual carriers seeking alternative solutions/offers will be able to overcome the existing barriers by connecting the existing data sources and platforms. A centralised solution building upon the corridor approach will be able to aggregate data across several platforms for capacity and transport demand and offer both protection of critical data and the possibility to connect to operative elements used in production to carry out transport tasks.

The Platform's decision support system shall help operators optimize their choices from a multi-objectives, multi-technology, and multi-modality viewpoints and the respective impact on their business resilience. This system shall propose optimized solutions based on operational (e.g. costs, time), environmental (e.g CO2), and socio-economic (e.g. used resources, impact on infrastructure capacity) resilience performance. The system shall not only incorporate the possibility of using alternative combinations of routing solutions (e.g. switching from one transport solution to another), but it shall give the users the possibility to collect/incorporate data from a variety of complementary technologies (e.g. e-seals, IoT, sensors, Blockchain) so as to create a large

[48] Sustainable, Safe and Secure Supply Chain. Research & Innovation Roadmap, ALICE, https://www.etp-logistics.eu/wp-content/uploads/2015/07/W16mayo-kopie.pdf, p.15

[49] Corridors, Hubs and Synchromodality, Research & Innovation Roadmap, ALICE, https://www.etp-logistics.eu/wp-content/uploads/2015/08/W26mayo-kopie.pdf

database that will help the system to optimize on different solutions in real-time (i.e. AI approach). To this end, the Platform shall, among others:

- provide real time information about the status of different freight corridors gathering data from multiple sources i.e. position data from mobile phones for route transport, water level data to determine payload levels of vessels, space data, traffic obstructions through crowdsourcing, available capacity on the move etc.;
- allow to react quickly upon disruptions proposing pre-defined alternative routes with reduced CO2 emissions and "what if" scenarios;
- analyse past disruptions, the solutions proposed and their impact to integrate this intelligence to the AI-based platform;
- simulate the impact of transferring cargo from one route/mode to another in current and future scenarios using climate modelled data, allowing logistics providers to take informed decisions upon disruptions;
- provide intermodal freight corridor uniform performance indicators;
- propose remote-control solutions for flexible transport assets (e.g. vessels), real-time routing to optimise transport routes in a semi-autonomous way.

Complementary, there is a clear need for reviewing and defining new data governance structures for synchromodal solutions, define business models (cost efficient and green) as well as define regulatory roadmaps and policy recommendations. A sharing data governance should be also tackled since it will facilitate synchromodality and collaboration between logistics stakeholders.

As synchromodality involves multiple stakeholders (shippers, LSPs, terminals, authorities etc.) it is necessary to focus on how recent data sharing activities can facilitate data and information exchange via standards and protocols among multiple players. Over the past years, many initiatives have developed at EU level around data and data sharing (EU Data Strategy & Data Act). Important legislation around handling and sharing of data has been created and is (almost) implemented. A significant number of initiatives has been started to create architectures and operational processes in line with the general EU philosophy: data should be easily shared and a level playing field should be created in which all stakeholders can benefit from the added value data sharing can deliver. Furthermore, the new EU programs (CEF2, Common European Data space and Horizon Europe) put a lot of emphasis on holistic interoperability between modes and nodes.

The EU intends to create "Data spaces" in which stakeholders in specific processes can easily exchange data. The European Mobility Data Space will benefit from new architectural designs like GAIA-X that are all built on the principles the EU maintains: safe and secure data sharing.

All in all, promoting synchromodality on the logistics service providers level shall be a facilitator for inland waterway transport, whereas a shift towards a more environmental-friendly transport mode is urgently needed in order to decarbonise the European logistics sector, the synchromodal concept being of no doubt a promising solution for the future of freight transport. The IWT sector still needs to cope with overarching challenges (e.g. fairway conditions, predictability & plannability) in order to be a reliable partner in a synchromodal logistics chain. This sets the timeline from the IWT perspective for the mid/long term.

The above-described recommendations can be materialised as part of:

- the expert discussions at the relevant expert/working groups such as DINA, DTLF, etc.
- RD&I action(s) in the Horizon Europe programme
- Webinars, online events and conferences calling together experts to further fine-tune the concept

These can be triggered by the PLATINA 3 Team and taken further in a follow-up initiative.

11 Conclusions

The European transport and logistics sector is one of the key business sectors in Europe, performing billions of operations by millions of companies and people every day. Assuring the integration of these operations across national borders is a cornerstone of EU policy and a basis for the competitiveness of the economy.

Despite efforts to shift freight traffic from road to rail and waterborne transportation have been made, modal split has changed to a small extent over the past two decades. Innovations are urgently required in order to promote a substantial modal shift to alternative, more environmentally-friendly modes. Implementing effective synchromodality built upon synergy and systemic coordination between stakeholders along the transport chains provides an alternative to uni-, multi- and inter-modality, and at the same time provides an opportunity by synchronizing intermodal services between modes and with shippers, contributing to the set-up of a European core freight network of smart hubs and corridors, supporting the emerging needs of the transport industries to serve smart, resilient and highly responsive supply chains.

Shortcomings on the freight transport markets, e.g. the lack of reliability and punctuality of inland waterway transport services is a source of dissatisfaction among customers causing potential customers to consider IWT as unable of meeting their logistical needs in a synchromodal environment.

Therefore, the IWT sector must prepare for a rapid and substantial evolution. It will have to think differently about its value propositions, continuously developing and improving products and services that generate customer responses, uncover missed customer segments, look, check and adopt services developed in other sectors that can be a source of inspiration of good practices.

This will require all stakeholders to question long established principles and practices and to develop more sustainable and promising market opportunities by thinking faster, by thinking differently**, by thinking partnerships and open collaboration.** The cooperation with actors from other modes will be key in order to apply innovations form other sectors and to develop high quality and seamless mobility solutions. This requires liaising with relevant stakeholders, most definitely including the logistics industry.

In order to promote the concepts of synchromodality as well as of physical internet, several aspects need to be considered, such as:

- create awareness – by presenting the concept of synchromodality in university lectures, through dedicated activities as well as by means of workshops and events
- initiate RD&I projects accompanied by pilot actions and demonstrations
- technologies and logistic approaches behind synchromodality need to spread more widely to other segments of freight transport
- engage in international cooperation – on the one hand, these are necessary as synchromodal networks will most likely best perform on a multinational scale meaning that a trans-European solution is needed. On the other hand, other countries (like the Netherlands) are already one step further and have the first operating pilots resembling synchromodal networks. It is therefore convenient to learn from the best/first and build on their knowledge. Cooperation with those companies included in synchromodal pilots will most probably lead to further developments.

The synchromodality concept will also need to be developed in tune with and include the steps that the waterborne transport is undergoing in this period in order to reach the zero-emission goal. The new 'green' ships, including their increased digitalization, must be accounted for when developing the new processes, business models, etc. in the port operations and the hinterland logistics chain as part of the synchromodal approach. This also means the inclusion of electricity and sustainable alternative fuel supplies, as they will bring a paradigm shift in some areas for the IWT transport, moving away from the fossil fuel-based model that is now still largely taken 'for granted' in the transport sector. All these developments also need to include a resiliency aspect given the increased effects of climate change which will manifest for a long period of time for now on. Applicable recommendations are formulated in Chapter 10.

Annexes

Annex 1: Non-exhaustive list of projects financed by the European Commission dealing with synchromodality and the physical internet

The following represents a qualitative inventory of known actions and projects, including investments in digital technologies. The quantification of investments in Euro was not subject of this task.

Project name: **Synchromodal Traffic & Transport Information Services**

Abbreviation: **AIRIS-II SYNCHRO**

Funding programme: **CEF Transport**

Timeframe: **2019-2022**

Link: https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport/2018-es-tm-0025-s

This Action is a part of a Global Project to increase the efficiency and capacity of the Guadalquivir River and the Port of Seville through the transformation of the port into a state-of-the-art logistic reference node by implementing new technologies, innovative technological and business driven systems.

The main objective of this Action is to demonstrate the feasibility of the development of innovative systems to increase the efficiency of the Port of Seville by favouring synchromodality of port operations.

The Action covers the following activities needed to develop the pilots and demonstrate the feasibility of the planned course of synchromodal development: River Information Services preliminary and detailed studies, pilots deployment, integration and validation as well as large-scale implementation study.

It is expected that the pilots will demonstrate that the following advantages can be gained further to the improvement of the efficiency of the operational procedures:

- decrease in operating costs of port users;
- improved transit time;
- reduction of waiting times.

Project name: **Masterplan Digitalisation of Inland Waterways**

Abbreviation: **DIWA**

Funding programme: **CEF Transport**

Timeframe: **2019-2022**

Link: https://www.masterplandiwa.eu/

The objective of the Action is to develop the Masterplan Digitalisation of Inland Waterways that will be a joint, uniform and integral digitalisation strategy for IWT under the responsibility of the participating fairway authorities, ready for the execution in the period from 2022 until 2032. The Masterplan will consider the adaptation to the evolution of the policy and it will be based on (inter)national business developments related to the inland waterways traffic and transport domain, as well as on the game-changing technological developments of recent and coming years.

The Masterplan will consider the requirements put on this digital transition related to cybersecurity, standardisation, rules and regulations, security and privacy. A digital information infrastructure requires also more and more attention for the quality of data and information. The Masterplan will focus in this context on procedures and processes for quality management during implementation and operation of the digital waterway infrastructure. It will include a set of implementation scenarios covering technical, organisational, financial and operational consequences each Beneficiary will face in the digitalisation process.

These boundaries of the Masterplan will be related to the required (future) facilitation of internal and external stakeholders, business models in inland waterborne traffic, transport and logistics as well as operational and administrative processes.

It will have a sound basis in the RIS developments and national and European implementation projects, since it will be based on the implementation status of RIS and will build on the results of the recent RIS enabled Corridor Management projects CoRISMa (TEN-T project No 2012-EU-70004-S – RIS Enabled European IWT Corridor Management) and COMEX (CEF Action No 2015-EU-TM-0038-W – River Information Services Corridor Management Execution). It is also expected that it will become a basis for digitalisation of inland waterways transport for other fairway authorities. Involvement of other fairway authorities in the implementation of the Action through the Reference Groups will create awareness of the Masterplan and facilitate the dissemination of results.

Project name: **Enhanced data management techniques for real time logistics planning and scheduling**

Abbreviation: **LOGISTAR**

Funding programme: **Horizon 2020**

Timeframe: **2018-2021**

Link: https://logistar-project.eu/?p=2922

Aligned with the European policies and the ALICE roadmap, LOGISTAR objective is to allow effective planning and optimizing of transport operations in the supply chain by taking advantage of horizontal collaboration, relying on the increasingly real-time data gathered from the interconnected environment. For this, a real-time decision-making tool and a real-time visualization tool of freight transport will be developed, with the purpose of delivering information and services to the various agents involved in the logistic supply chain, i.e. freight transport operators, their clients, industries and other stakeholders such as warehouse or infrastructure managers.

Project name: **New ICT infrastructure and reference architecture to support operations in future PI logistics networks**

Abbreviation: **ICONET**

Funding programme: **Horizon 2020**

Timeframe: **2018-2021**

Link: https://www.iconetproject.eu/

ICONET will significantly extend state of the art research and development around the PI concept in pursuit of a new networked architecture for interconnected logistics hubs that combine with IoT capabilities and aiming towards commercial exploitation of results. ICONET strives to achieve the end commercial goal of allowing shipments to be routed towards final destinations automatically, by using collaborative decisions inspired by the information centric networking paradigm, and optimizing efficiency and customer service levels across the whole network. According to this vision, cargo regarded as smart physical packets will flow between hubs based on 'content' of the cargo influencing key commercial imperatives such as cost, optimisation, routing, efficiency and advancing EU's Green agenda. Consequently, the consortium are discernibly aimed at three (3) avenues of commercialisation and exploitation from the ICONET innovation, specifically targeted in the areas of (a) Warehousing as a service, (b) E-commerce fulfilment as a service, and (c) Synchromodality as a service.

PI based logistic configurations will be simulated, prototyped and validated in the project. Modelling and analysis techniques will be combined with serious game type simulation, physical and digital prototyping, using living lab (LL) requirements scenarios and data. With analyses and simulations, optimal topologies and distribution policies for PI will be determined. The project implementation will be based on a succession of phases of modelling and design/prototyping, learning and experimentation and feedback and interaction with the wider business community, including the ALICE logistics platform as well as members of the partner Associations ESC, UIRR and ELUPEG. Through its Living Labs, the project will address under the PI paradigm both Supply Network Collaboration and Supply Network Coordination.

Project name: **Enhanced Physical Internet compatible earth-friendly freight transportation answer**

Abbreviation: **ePIcenter**

Funding programme: **Horizon 2020**

Timeframe: **2020-2023**

Link: https://cordis.europa.eu/project/id/861584

The seamless transport of goods is a top priority of the trade and logistics sector. Focussing on the technological and operational opportunities that the physical internet, synchromodal operations and other disruptive technologies provide, the EU-funded ePIcenter project will develop new solutions aimed at increasing the efficiency and sustainability of global supply chains. This will enable all players in global trade and international authorities to cooperate with ports, logistics companies and shippers and to respond to volatile political and market changes. Headed by a consortium of 35 partners representing leading ports, forwarders, cargo owners, logistics providers, knowledge institutions and technology firms, the overall aim of the project is to create a sustainable logistics chain of the future.

Project name: **Towards a shared European Logistics Intelligent Information Space**

Abbreviation: **SELIS**

Funding programme: **Horizon 2020**

Timeframe: **2016-2019**

Link: https://selisproject.eu/

SELIS embraced a wide spectrum of logistics perspectives and created a unifying operational and strategic business innovation agenda for Green Logistics, with a clear path towards reduction of energy consumption and greenhouse gas emissions. In an industry still marked by territoriality and insufficient collaboration, SELIS (Shared European Logistics Intelligent Information Space), a €17 million flagship European Commission-funded research project, was set up to address the challenges associated with siloed logistics chains, more specifically (1) to improve information sharing between logistics stakeholders, (2) to provide a platform that is easy to use by companies of all sizes, enabling a plug-and-play approach to sharing and analysing supply chain data, and (3) to facilitate real-time availability of information.

Project name: **AEOLIX - Architecture for EurOpean Logistics Information eXchange**

Abbreviation: **AEOLIX**

Funding programme: **Horizon 2020**

Timeframe: **2016-2019**

Link: https://aeolix.eu/

AEOLIX focused its work on the following activities:

- Gain a thorough insight in the lessons learned, needs and requirements in the domain of ICT applications for logistics
- Design an architecture for a collaborative IT infrastructure for operational connection of logistics information systems
- Implement an appropriate data access management model
- Build a common but user-tailored interface and tools to enable the IT infrastructure
- Test, validate and implement the AEOLIX prototype in 11 living labs of logistics business communities across Europe
- Monitor the impacts of AEOLIX based on environmental, economic and social impactsDevelop an exploitation business model to enable roll-out and deployment of the concept across Europe, and possibly rest of the world

Project name: **Synchro-modal Supply Chain Eco-Net**

Abbreviation: **SYNCHRO-NET**

Funding programme: **Horizon 2020**

Timeframe: **2015-2018**

Link: https://cordis.europa.eu/project/id/636354

SYNCHRO-NET demonstrates how a powerful and innovative SYNCHRO-modal supply chain eco-NET can catalyse the uptake of the slow steaming concept and synchro-modality, guaranteeing cost-effective robust solutions that de-stress the supply chain to reduce emissions and costs for logistics operations while simultaneously increasing reliability and service levels for logistics users.
The core of the SYNCHRO-NET solution is an integrated optimisation and simulation eco-net, incorporating: real-time synchro-modal logistics optimisation (e-Freight-enabled); slow steaming ship simulation & control systems; synchro-modal risk/benefit analysis statistical modelling; dynamic stakeholder impact assessment solution; and a synchro-operability communications and governance architecture. One of the most important output of SYNCHRO-NET was the demonstration how slow steaming, coupled with synchro-modal logistics optimisation delivers amazing benefits to all stakeholders in the supply chain: massive reduction in emissions for shipping and land-based transport due to modal shift to greener modes and optimised planning processes leading to reduced empty kms for trucks and fewer wasted repositioning movements.

Project name: **Innovation-Driven Collaborative European Inland Waterways Transport Network**

Abbreviation: **IW-NET**

Funding programme: **Horizon 2020**

Timeframe: **2020 – 2023**

Link: https://cordis.europa.eu/project/id/861377

IW-NET will deliver a multimodal optimisation process across the EU Transport System, increasing the modal share of IWT and supporting the EC’s ambitions to reduce transport GHG emissions by two thirds by 2050. Enablers for sustainable infrastructure management and innovative vessels will support an efficient and competitive IWT sector by addressing infrastructure bottlenecks, insufficient IT integration along the chain and slow adoption of technologies, such as new vessel types, alternative fuels, automation, IoT, machine learning.

Project name: **Novel inland waterway transport concepts for moving freight effectively**

Abbreviation: **NOVIMOVE**

Funding programme: **H2020**

Timeframe: **2020 – 2024**

Link: https://novimove.eu/concept/

The ability of ports to ensure efficient cargo transfers is central to their overall function and an important factor that influences port terminal attractiveness. The EU-funded NOVIMOVE project will conduct research on how to improve the logistics of this transport system. With a consortium consisting of logistics operators, ports, system developers and research organisations in the Netherlands, Belgium, Germany, Switzerland, Sweden and Norway, the project will reduce waiting times at seaports by improving river voyage planning and execution and facilitating smooth passages through bridges and locks. Focussing on the Rhine–Alpine water corridor from Rotterdam/Antwerp all the way to Basel, it will validate its new technology with virtual simulations, scaled model tests and full-scale demonstrations.

Project name: **RIS COMEX – RIS Corridor Management Execution**

Abbreviation: **RIS COMEX**

Funding programme: **CEF**

Timeframe: **2016 – 2022**

Link: https://www.riscomex.eu/

The RIS COMEX project aims for implementation and operation of cross-border River Information Services based on operational exchange of RIS data. These RIS-based Corridor (information) services shall allow for traffic management by the authorities and transport management by the logistics sector. They make use of available national infrastructure and services. The main objectives of RIS COMEX are:

- Development of an overall Corridor RIS Management concept (starting from CoRISMa results) in dialogue between RIS providers and logistics users (e.g. shippers, boat masters, vessel and fleet operators, terminal operators) to ensure the relevance of the implemented services.
- Implementation and permanent operation of selected parts of the overall concept providing increased quality and availability of Fairway-, Traffic- and Transport Information Services resulting especially in a considerable increase of efficiency within Inland navigation transports and also directly contributing to the utilisation of the general benefits provided by RIS, i.e. increase of safety, efficiency and environmental friendliness of inland navigation as transport mode.
- Defined and agreed operational arrangements (legal, organisational, financial, technical, quality) to ensure sustainable further development, implementation and operation of infrastructure and services for harmonised RIS enabled Corridor Management beyond the lifetime of the project.
- Harmonisation of data exchange concepts for RIS data through the cooperative development and specification of RIS enabled Corridor Services avoiding the rise of different data exchange concepts.
- Progress on harmonisation of transport information services on European and/or Corridor level based on existing solutions and concepts (e.g. IVS90, imagine, ERI agent, R2D2).
- RIS COMEX, as the platform bringing together public and private actors in RIS enabled corridor management, will facilitate the dialogue between providers of River Information Services and logistics users (e.g. shippers, vessel and fleet operators, terminal operators).
- RIS COMEX will develop harmonized River Information Services for inclusion in the DINA initiative and will bring RIS one step further to integration with other transport modes.

Project name: **Physical Internet through Cooperative Austrian Logistics**

Abbreviation: **PhysICAL**

Funding programme: **Mobility of the Future Programme of the Federal Ministry for Climate Protection and the Austrian Research Promotion Agency**

Timeframe: **2020 – 2024**

Link: https://physical-project.at/

Under the lead of Fraunhofer Austria, seventeen partners are actively engaged in the PhysICAL project – “Physical Internet through Cooperative Austrian Logistics" - having the core objective to efficiently implement physical internet in cooperative logistics, using different types of smart technologies and applications.
The main strategic goal of PhysICAL is to demonstrate by 2024 that cooperative logistics brings economic benefits to shippers and the transport industry in Austria. Specifically, this goal relates to the reduction of transport costs expected in the framework of the foreseen four pilots which amounts of up to 10% (in pilot "Booking platform", pilot "Smart logistic", pilot "CEP last mile", pilot "Supply Chain 3.0") by:

- Significant simplification and shortening of the intermodal booking process (up to 70% faster) through an open booking platform;
- Increased rail competitiveness through the use of cooperatively used containers in the circulatory system (in the framework of the pilots KEP & wood logistics) and thus reduction of transport costs;
- Reduced logistics process costs (up to 30%) by using the open platform and the containers;
- Lower turnaround times (up to 50%) through improved planning within the framework of the open platform;
- Reduced empty trips (up to 15%) through the use of the open platform and Supply Chain 3.0 approach as well as cooperative CEP delivery and smart wood logistics;
- Improving the resilience of the entire network and thus the safety and quality of the transports through the digital twin;
- Support in establishing fair competitive conditions in intermodal transport through equality and integration of all modes of transport;
- Easy way for SMEs to participate in eCommerce through the global supply chain 3.0 pilot.

Project name: **COoperative loGISTICS for sustainable mobility of goods**

Abbreviation: **CO-GISTICS**

Funding programme: **CIP – Competitiveness and innovation framework programme**

Timeframe: **2014 – 2017**

Link: https://cordis.europa.eu/project/id/621112

Key logistics stakeholders from seven European cities/logistics hubs (Bordeaux, Frankfurt, Thessaloniki, Trieste, Arad, Bilbao and Vigo) have joined forces to deploy, validate and set-up after project life of five piloted cooperative logistics services combining cooperative mobility services and intelligent cargo with real-life logistical aspects. CO-GISTICS services will increase energy efficiency and equivalent CO_2 emissions, bringing additional benefits in road safety and cargo security. To achieve these goals public authorities, fleet operators, freight forwarders, industrial partners and other stakeholders will jointly implement five services: CO_2 Footprint Estimation and Monitoring, Cargo Transport Optimisation, Intelligent Truck Parking and Delivery Area Management, Eco-Drive Support, Priority and Speed Advice. These services will be piloted over one year of real-life driving. Each of the pilot sites have full stakeholder chain in their partnership for successful after-project life. The user groups will include commercial users, such as truck and van drivers, as well as logistics and fleet operators. In total the consortium aims to pilot 330 vehicles with about 230 users, 300 intelligent cargo items. The service components used have already been developed and extensively trilled. Some of the components are already operational since a number of years while others have been implemented and trialled through research projects. In addition to proving the benefits, the project aims at identifying deployment opportunities, barriers and finding solutions for those. Furthermore, clear business models and exploitation plans will be developed. Last, but not least, CO-GISTICS will also take an active role in the relevant standardization bodies, primarily ETSI and CEN. All these aspects hold a promise that CO-GISTICS services will prove extensive benefits to all key stakeholders and prove that sustainable implementation is possible.

Project name: FENIX Network - A European Federated Network of Information eXchange in LogistiX

Abbreviation: **FENIX**

Funding programme: **CEF**

Timeframe: **2018 – 2021**

Link: https://fenix-network.eu/about/

FENIX will develop the first European federated architecture for data sharing serving the European logistics community of shippers, logistics service providers, mobility infrastructure providers, cities, and authorities in order to offer interoperability between any individual existing and future platforms. The idea of FENIX comes from the work and recommendations of the European Commission's Digital Transport and Logistic Forum (DTLF) to create a viable and valid federative network of platforms as enabler for Business to Administration (B2A) and Business to Business (B2B) data exchange and sharing by transport and logistics operators.
FENIX main objectives are:

- establish a federated network of transport and logistics actors across Europe, enabling sharing of information and services needed to optimise TEN-T (A2&A3)
- demonstrate the operational feasibility and benefits through the organised national pilots –focus on testing the achieved interoperability capabilities (A4)
- set up the EU corridor community building programme and to promote the benefits to the participants in terms of reduced costs and GHG emissions (A5&A6)

Project name: **RPIS 4.0 – Smart community system for Upper Rhine Ports**

Abbreviation: **RPIS 4.0**

Funding programme: INTERREG V A

Timeframe: **2019 – 2022**

Link: http://www.upper-rhine-ports.eu/en/our-projects/the-interreg-v-a-project-rpis40.html

RPIS 4.0 aims to improve the performance and competitiveness of multimodal transport through the integration of digital solutions in the global supply chain and thus be able to promote modal reporting on clean transport modes such as inland navigation. The project focuses on three main objectives:

1. **Strengthening multimodal freight transport**
2. **Improving the offer of cross-border services for Rhine navigation operators**
3. **Strengthening sustainable mobility in freight transport**

The Platform will also contribute to the continued development of new digital services for the port community, notably by local start-ups.

Project name: **Integrating Danube Region into Smart and Sustainable Multimodal & Intermodal Transport Chains**

Abbreviation: **Dionysus**

Funding programme: INTERREG **Danube Transnational Programme**

Timeframe: **2020 – 2022**

Link: https://www.interreg-danube.eu/approved-projects/dionysus

The project's overarching goal is to facilitate the integration of DR ports into multimodal and intermodal freight and passenger transport systems. To this end, a growing consensus recognizes the need for a smart and sustainable Danube port development planning together with an overall national transport infrastructure planning and regional economic development plans. The project will carry out a multi-layered assessment (the infrastructure layer, the transport market layer and the logistics & port services layer) across different levels of infrastructure planning and governance (local, national and regional) in line with Danube Inland Waterway Transport (IWT) market, trade (volume and structure) considerations and realities, with a particular focus on Danube port-related infrastructure needs. As a result, it will highlight, promote and carry out activities across levels of governance in line with relevant specific objectives of EU policies (Transport, TEN-T and Cohesion) in order to ensure scope and development priorities alignment among port planning, overall transport infrastructure planning and national plans for Regional Economic Development benefiting DR ports. Also, the project aims to further strengthen DR connectivity with the EU Eastern Partnership and with Black Sea riparian countries by addressing transport infrastructure connectivity. Ports digitalisation capabilities shall be assessed at the corridor level and dedicated measures proposed.

Project name: **Smart Green Ports as Integrated Efficient Multimodal Hubs**

Abbreviation: **MAGPIE Smart Green Ports**

Funding programme: **H2020**

Timeframe: **2021 – 2026**

Link: https://www.magpie-ports.eu/

The EU-funded MAGPIE project will embark on 12 pilot activities in three key areas: alternative energy sources; smart technologies applied to power operations; and river and rail connections with the hinterland. The ports of Rotterdam (Netherlands) and Sines (Portugal), as well as Haropa Port (France) and the DeltaPort association (Germany) are supporting the project. MAGPIE will combine the accelerated introduction of green energy carriers with logistics optimisation in ports through automation and autonomous operations. The project will demonstrate technical, operational and procedural energy supply solutions to stimulate green, smart and integrated multimodal transport, and guarantee their implementation through the European Green Ports of the Future Master Plan.

Project name: **Portable Innovation Open Network for Efficiency and Emissions Reduction Solutions**

Abbreviation: **PIONEERS**

Funding programme: **H2020**

Timeframe: **2021 – 2026**

Link: https://pioneers-ports.eu/

PIONEERS addresses the challenges faced by European ports to reduce their environmental impact while remaining competitive in a sector characterised by continuous growth. As one of its focuses, PIONEERS will demonstrate highly efficient logistics operations for integrated sea/river-port hinterland connections through several demonstrations that enable modal shifts and system-wide door-to-door multimodal passenger mobility and freight transport. A Digital Twin supporting port operations decision making in relation to environmental impact, as well as a 3D representation of real time port activities will reveal opportunities that will allow the continuous improvement of the PIONEERS' demonstrations. In order to develop eco-friendly and financially viable transport alternatives, a multimodal route planner for port commuters and cargo flows will be demonstrated, as well as the monitorization of real-time traffic flow. Additionally, autonomous vehicles will be introduced allowing the optimal transport of trailers to operational points while hoping to prove the positive effects of this automated vessel technology in the Port of Antwerp-Bruges. Lastly, to ensure cyber-resilience jointly with all the stakeholders of the ports' communities, the cyber-security risks will be analysed.

Project name: **FEDeRATED – Network of Platforms**

Abbreviation: **FEDeRATED**

Funding programme: **CEF**

Timeframe: **2019 – 2023**

Link: http://www.federatedplatforms.eu/index.php

EU project for digital co-operation in logistics, FEDeRATED aims at developing the foundations for a secure, open and neutral data sharing infrastructure provision through practical Living Labs. This is an interoperable network of virtual worlds based on digital twins and connecting Events that can be accessed at the same time by millions of users, who can exert property rights over virtual items. Data holders and data user can meet and conduct business. Security and scaling are essential. Ecosystems must be interoperable, connected through the functional requirements and technical specifications of the data sharing grid. The organisational requirements set the terms for login, registration and certification safeguarding interoperability.

Using data and providing services to another through a EU data sharing grid - EU Mobility Data Space - would most likely change the way logistic operators experience the internet, with the advent of things like navigation apps, transport monitoring and container and cargo tracking systems, situational awareness and smart mobility Apps also to facilitate eEnforcement, eCustoms and eCompliance, therefore the FEDeRATED project assists the EC in developing a future proof data sharing grid.

In order to develop a future proof federated concept of platforms, the FEDeRATED project will execute a both-feet-on-the ground approach that:

- Involves the builders.
- Makes use of what is already available.
- Support rationalisation, harmonisation and interoperability.
- Invites public and private parties to co-operate and execute tangible pilots and living labs.
- Connects all parties concerned, also those that normally do not co-operate.
- Creates a platform and knowledge base for all parties.

Project name: **Progress towards Federated Logistics through the Integration of TEN-T into a Global Trade Network**
Abbreviation: **PLANET**
Funding program: **Horizon 2020**
Timeframe: **2020 – 2023**
The Trans-European Transport Network (TEN-T) consists of hundreds of projects aimed at ensuring cohesion, interconnection and interoperability of all modes of transport across the EU. With TEN-T projects located in every EU member state, numerous challenges are associated with assessing the impact of emerging global trade corridors on the TEN-Ts. The EU-funded PLANET project will address this issue by demonstrating the emerging concepts of the physical internet and technologies such as the Internet of Things and blockchain in three EU–global real-world corridors (China–EU–US). The project will model, analyse, demonstrate and assess EU–global T&L networks (EGTN). It will deliver a symbiotic digital clone for EGTNs as well as an active blueprint and roadmap towards their realisation.

Annex 2: List of questions addressed at the bilateral interviews

1. Please name three main factors which in your opinion contribute to facilitating synchromodality for your business.

2. How would you describe the digitalisation level of your supply/logistics chain(s)?

3. Are you using any dedicated software solutions to support you in choosing your carrier(s)?

4. Are you using any dedicated software solutions to support you in planning your transport?

5. How do you see the integration of IWT into the synchromodal logistics chains?

6. How is data sharing being handled in your supply/logistics chain?

7. How do you assess the existence and the use of a Europe-wide platform to provide real-time synchromodal transport solutions?

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