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SENSE PROJECT

DELIVERABLE REPORT

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Executive Summary

In response to the Paris Agreement, more and more governments, associations, and businesses are setting bold climate targets. As set out in the European Green Deal, the ambition for the European Union is to be the first climate-neutral continent in the world by 2050. This will be achieved with a two-step approach designed to reduce CO_2 emissions by 50%, if not 55%, by no later than 2030[1].

The deployment of greener and cleaner freight vehicles, trains, barges, ships, and airplanes as well as low emission energy solutions is forecasted to be too slow to deliver on the European Commission's 2030 climate change targets. In parallel to the development of lower and zero tailpipe emission vehicles and low emission energy, it is fundamental to leverage opportunities for increased logistics efficiency. We envision large gains and benefits to all stakeholders by doing more with less in the freight and transport industry. The existing idle capacity of assets in all modes of transport and storage could be better utilised, and flows could be managed in a more consolidated way using and combining transport modes smartly. Open and interconnected logistics services and networks (building the Physical Internet[2]- PI) will maximise capacity utilisation meeting current and future demands. Value creation through efficiency should be used to speed up the transition to greener and cleaner assets, instead of price reductions and margin erosion resulting from the use of current assets.

Indeed, in a scenario in which all identified potential efficiencies are achieved, the forecasted 300% increase in transport demand[3] could be reached with an increase of only 50% in assets[4]. Environmental sustainability could be achieved in an economical and socially feasible way.

Physical Internet will support the transition towards Zero Emissions Logistics

The Physical Internet is probably the most ambitious concept towards efficiency and sustainability in transport logistics. It stands for a far-reaching transition of freight transport and logistics so assets and resources can be used in a much more efficient way. The PI builds on the extensive and systemic consolidation of flows and the network of networks concepts. The Physical Internet proposes a full consolidation of logistics flows from independent shippers (e.g. extended pooling and shared networks). Additionally, and to deliver customer value, the Physical Internet proposes to pool resources and assets in open, connected, and shared networks (i.e. connecting existing (company) networks, capabilities and resources) so they can be used seamlessly. The Physical Internet develops and interconnects Logistics Nodes and Networks creating a Systems of Logistics Networks through which physical flows (and associated information and financial flows) are moved seamlessly. The Physical Internet includes transport, storage and physical handling operations of load units such as containers, swap-bodies, pallets, boxes, etc.

This document is a comprehensive roadmap towards the Physical Internet (PI). The roadmap sketches a path from now to 2040 showing important milestones, required technologies and first implementation opportunities for the PI. Advanced pilot implementations of the Physical Internet concept are expected to be operational and common in industry practice by 2030, contributing to a 30 % reduction in congestion, emissions and energy consumption from the transport sector.

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1 U. von der Leyen (2019) A Union that strives for more. My agenda for Europe
2 Ballot É., B. Montreuil, R. Meller (2015), The Physical Internet: The Network of Logistics Networks, Documentation Française. For more information: visit www.etp-alice.eu and watch a video.
3 OECD (2019. ITF Transport Outlook 2019
4 Barbarino (2018). Towards Zero Emissions via Physical Interner: Opportunities, Challenges & perspective. IPIC 2018

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Chapter 1 introduces the Physical Internet, its foundations and development[5] to deliver pooled logistical flows through interconnected logistics networks. It address the main benefits and reasons why we need to advance toawrds the Physical Internet to achieve climate change objectives effectively, supporting climate impact mitigation and bringing resiliency to supply networks.

In Chapter 2, the detailed roadmap towards the PI is detailed addressing five key and complementary areas. The roadmap describes expected evolutions in Logistics Nodes, Logistics Networks and the Systems of Logistics Networks, that are in a "Generation 1" status today, to transform them in PI Nodes, PI Networks and the System of Logistics Networks. These three areas can develop independently generating near term benefits. Complementary to these three areas, access and adoption and governance are addressed in the roadmap. Figure 1 includes a summary of the roadmap highlighting the planned development along the five main areas and their expected evolutions (here called generations) that are further described in Chapter 2[6].

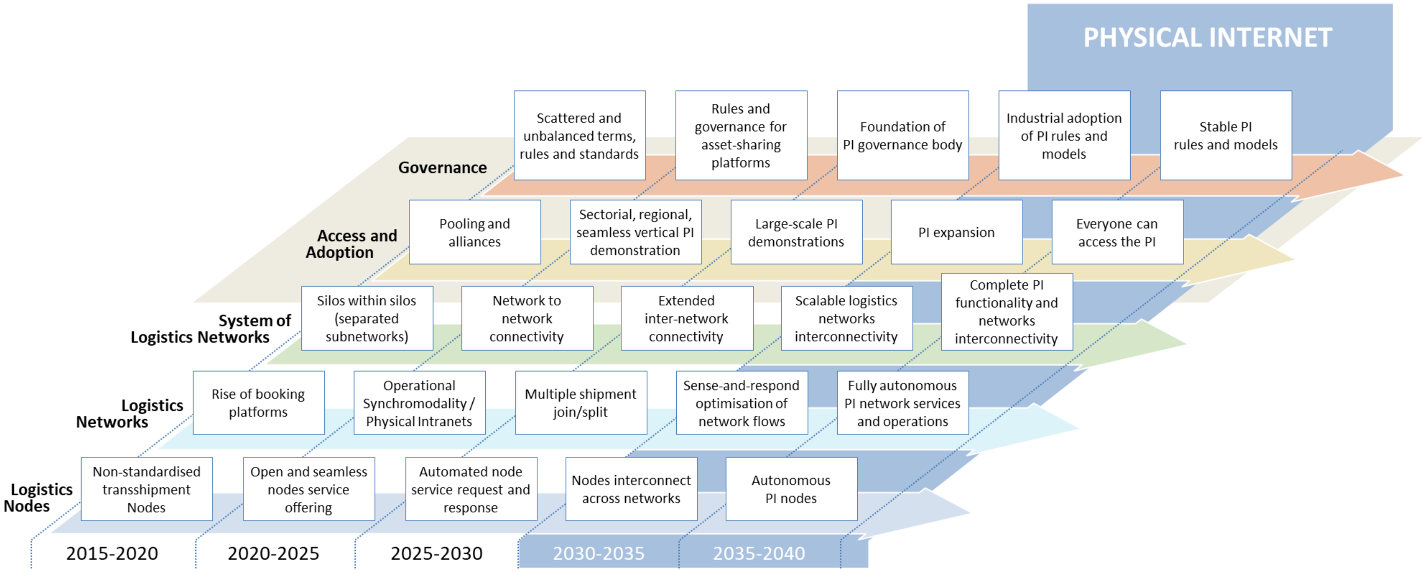

Figure 1: The Physical Internet Roadmap[7]

As a summary, the five main areas are described as follows:

1. **From Logistics Nodes to PI Nodes** – In Logistics Nodes, goods are consumed, stored, transformed, or transhipped from one transport mode to another. Ports, airports, logistics hubs, terminals, distribution centres, warehouses, and depots are examples of Logistics Nodes. The Physical Internet envisions the development of Logistics Nodes into Physical Internet nodes in which operations are standardised and the usage of a family of standard and interoperable modular load units from maritime containers to smaller boxes is extensive. Services in PI nodes are visible and digitally accessible for planning, booking and execution of operations.
2. **From Logistics Networks to Physical Internet Networks** – Logistics networks include Logistics Nodes as well as the transportation services connecting the nodes and servicing the destination of shipments. Logistics networks are under the control of a single company (e.g., a shipper, a freight forwarder, a transportation company or a logistics service provider) covering their value chain (i.e., customers and suppliers). PI networks are expected to build seamless, flexible and resilient, door-to-door services consolidating and deconsolidating all shipments within the network in which all assets, capabilities and resources are visible, accessible and usable to make the most efficient use of them.

[5] Further details and monitoring of PI development can be found in the SENSE deliverable 3.4 on Physical Internet Monitoring and in the PI Knowledge Platform: https://knowledgeplatform.etp-logistics.eu
[6] The roadmap is also explained in a 6 min. video: https://www.youtube.com/watch?v=DD1z5PBe7Kk&t=46s
[7] Vertical networks in the meaning of company-internal logistics networks with suppliers and customers;
Horizontal networks involves different logistics networks linking resources and capabilities from different providers.

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3. **Developing the System of Logistics Networks towards the Physical Internet** – A System of Logistics Networks includes several individual logistics networks. These networks are interconnected and, therefore, the assets, resources and services in the individual logistics networks can be accessed by the individual logistics network owners. The System of Logistics Networks forms the backbone of the Physical Internet and requires secure, efficient and extensible services for the flow of goods, information and finances across the networks.
4. **Access and Adoption** – Access and adoption describes the main requirements to access the Physical Internet through a logistics network. It also includes different steps and mind shifts required for organisations to adopt Physical Internet concepts.
5. **Governance** – Governance includes the developments needed to evolve the Logistics Nodes, logistics networks and the System of Logistics Networks into the Physical Internet, i.e., the rules defined by the stakeholders managing the various networks and nodes and users of their services as well as the trust building processes and mechanisms required to ensure that the PI operates to the advantage of all stakeholders.

Finally, moving forward requires collaboration and contribution from different kinds of stakeholders. Chapter 3, following the rationale of the ALICE embraced collaboration framework (Figure 2), includes key recommendations for specific types of stakeholders within the different stakeholder groups.

Figure 2: Stakeholders to whom recommendations are directed.

Additionally, to this Roadmap, the SENSE project has delivered:

- An *Executive version of the Roadmap to the Physical Internet*[8] aiming at reaching a broader audience for those companies and organizations willing to get an overview of the concept and the expected evolution.

- The *Physical Internet Knowledge Platform*[9] allows the Physical Internet Community and interested stakeholders to find relevant information on the Physical Internet (i.e. the market initiatives and companies, projects and programmes supporting Physical Internet implementation, main physical internet reference documents as well as the contributions to the International Physical Internet Conferences). It facilitates engagement of individual stakeholders to share their experiences and projects in the field of Physical Internet. Currently, it gathers more than 700 users.

- The *Report on Physical Internet Development Monitoring*[10] assessing the state of play and implementation of the Physical Internet concept in the different areas of development and generations including several examples and current development paths.

- The *Recommendations to the Research & Innovation Programs calls after* H2020 (i.e. Horizon Europe) *and CEF (TEN-T)*[11].

- A collection of videos[12] and dissemination materials of the physical Internet concept.

[8] The roadmap is available at http://www.etp-logistics.eu/?p=3980
[9] Physical Internet Knowledge Platform: https://knowledgeplatform.etp-logistics.eu/
[10] SENSE project Deliverable D3.4. *Final Report on Physical Internet Development Monitoring*
[11] SENSE Project Deliverable D4.7 *Recommendations to the Research & Innovation Programs calls after H2020 and CEF (TEN-T) Innovation Part*
[12] Physical Internet videos: https://www.youtube.com/watch?v=14wAEP1nXBY&list=PLxdsc7eCmCO55wBV0Wm6v1Rk7OEjHNi2m

The SENSE project consortium consists of:

Part. No	**Participant organisation name (short name)**	**Country**
1 (Coordinator)	Alliance for Logistics Innovation through Collaboration in Europe, ALICE AISBL (ALICE)	BE
2	Procter & Gamble Services company NV (PGBS)	BE
3	FM Logistic Corporate (FM)	FR
4	Dutch Institute for Advanced Logistics (DINALOG)	NL
5	Posteitaliane (POSTE)	IT
6	Interporto Bologna SPA (IPBO)	IT
7	Vlaams Instituut voor de Logistiek VZW (VIL)	BE
8	Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung E.V. (IML)	DE
9	Centro Nacional de Competencia en Logística Integral (CNC)	ES
10	Instytut Logistyki I Magazynowania (ILIM)	PL
11	Technische Universiteit Delft (TUD)	NL
12	Association pour la Recherche et le Développement des Méthodes et Processus Industriels (ARMINES)	FR
13	Kühne Logistics University gGMBH (KLU)	DE
14	Bluegreen Strategy SRL (BG)	IT
15	FIT Consulting SRL (FIT)	IT
16	VNL – Verein Netzwerk Logistik	AT

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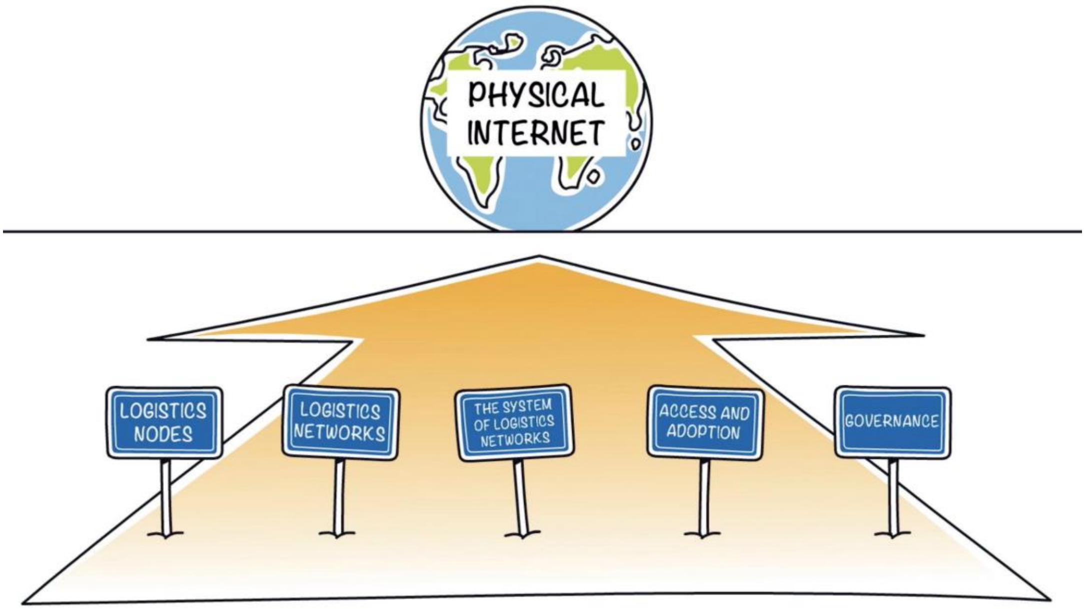

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1 Introduction

SENSE is translating the Physical Internet principles into an industry roadmap in which shorter term benefits in terms of productivity and efficiency can be realised. SENSE is also building consensus on different generations and the short-term evolution of freight transport and logistics having in mind Physical Internet concepts.

This deliverable includes a comprehensive roadmap leading to the Physical Internet (PI). The roadmap sketches different pathways from now until 2040 showing important milestones, required technologies and first implementation opportunities of the Physical Internet. Possible migration paths from current freight transport and logistics practices to PI-based systems are shown together with new business models, especially for the integration of SMEs

1.1 The Physical Internet Concept: foundations and development

The Physical Internet is probably the most ambitious concept towards efficiency and sustainability in transport and logistics. It stands for a far-reaching reorganisation of freight transport and logistics. The model for the new concept is the Internet.

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

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

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

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

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

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

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

The Physical Internet should be inclusive, open and for the benefit of all stakeholders including SMEs. However, without proper steering and guidance, this transformation may not lead to a desirable future. The Physical Internet could develop in a different way, for example, as a monopolistic, very-profitable business but not necessarily open, accessible, and supporting sustainable solutions[13].

The Physical Internet Concept was outlined by Prof. Benoit Montreuil in the Physical Internet Manifesto in 2009, elaborated in the OpenFret project[14] between 2009 and 2010 with Profs Eric Ballot and Rémy Glardon and first published in 2011 by Prof. Benoit Montreuil[15]. The Physical Internet Manifesto evolved until 2012[16] when it was finalised.

At that moment, the PI was defined as an *open global logistics system founded on physical, digital, and operational interconnectivity, through encapsulation, interfaces and protocols. The Physical Internet concept aimed at transforming the way physical objects are moved, stored, realised, supplied and used, pursuing global logistics efficiency and sustainability*.

The Physical Internet concept and its foundations have been evolving[17]. In 2014, ALICE, the Alliance for Logistics Innovation through Collaboration in Europe, developed its research and innovation roadmaps[18] aiming to achieve a 30% improvement in efficiency and sustainability of logistics by 2030. During this process, there was a growing convergence within the ALICE network on the following statement: *"the realisation and implementation of ALICE roadmaps would lead to a paradigm aligned with the Physical Internet concept".*

In the last decade, there has been a growing interest on the Physical Internet by researchers and companies. In 2017, the first published literature review, based on publications from 2016 and earlier, found 46 articles[19]. In early 2020, ScienceDirect's scientific publications database found 300 published articles about the "Physical Internet", most of them in the last 5 years.

Moreover, research and innovation projects (e.g., ATROPINE, CLUSTERS 2.0, DIsPatch, ePIcenter, GS1 MTV Germany, ICONET, LEAD, MODULUSHCA, PHYSICAL, PLANET, SENSE and ULaaDS), various

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

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

15 Montreuil, B. (2011) 'Toward a Physical Internet: meeting the global logistics sustainability grand challenge', Logistics Research, 3(2–3), pp. 71–87.

16 Montreuil, B. (2012) *Physical Internet Manifesto* https://es.slideshare.net/physical_internet/physical-internet-manifesto-eng-version-1111-20121119-15252441

17 Ballot É., B. Montreuil, R. Meller (2015), The Physical Internet: The Network of Logistics Networks, Documentation Française.

18 ALICE 2014 roadmaps are available at: http://www.etp-logistics.eu/?page_id=13

19 Henrik Sternberg, Andreas Norrman, (2017) "The Physical Internet – review, analysis and future research agenda", International Journal of Physical Distribution & Logistics Management, Vol. 47 Issue: 8, pp.736-762, https://doi.org/10.1108/IJPDLM-12-2016-0353

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companies and numerous start-ups (e.g., CONTAI, CRC-Services, FREIGHTERA, LastMile-Team, MixMove, OGOSHIP, PONERA, Stockbooking) are addressing or are founded on the Physical Internet concept[20]. To the best of our knowledge all the companies who started operations related to the PI concept are still in the market, even if none of them are yet a game-changer.

An example of a new business model is that of CRC. CRC is a French start-up founded at the end of 2015 after the successful investigation of the routing business models for less than truck load operations for FMCG companies in France. CRC started by operating downstream routing centres (distribution) providing limited services. Full trucks depart from suppliers with shipments for several retailers in the same region and are cross docked in the CRC to be delivered in almost full truck load to each retailer distribution centre. CRC can be seen both as a new service provider and as a network. CRC has integrated both a freight consolidation model in its cross-dock activities and a network flow model for optimising outbound vehicle tours based on the flow of goods handled in the cross-dock operations. The combination of these two models leads to greater efficiency in freight operations and lower carbon emissions. These models are now integrated in CRC's IT system. Like Marlo's MixMoveMatch system (exploited currently by MIXMOVE), this system allows CRC to run its operations efficiently and scale up its business. It will be interesting to follow-up the development of CRC and other similar start-ups as they implement PI like systems over the next few years.

Numerous other companies, building on sharing and platform economy business models (e.g., ALIBABA, AMAZON, FLEXE, FLEXPORT, UBER), are potential service providers delivering Physical Internet like services. Additionally, developments in which retailers such as El Corte Ingles or INDITEX have launched "omnichannel" programmes where online orders can be fulfilled from any location with the desired inventory including the full store network or distribution centres are steps towards a PI like model. SONAE, through the ICONET project, is developing and testing a dynamic multi delivery fulfilment network strategy. Another interesting example is www.todostuslibros.com, a platform in which 600+ Spanish book shops owners are pooling their book stock and making this pooled stock accessible to their customers.

The Physical Internet has developed sufficient interest that an annual conference[21] is held for the international Physical Internet community involving hundreds of participants. Several explanatory videos are also available online[22].

Although the original timeframe for the realisation of the Physical Internet was the year 2050, the acceleration of digitalisation, the fast growing sharing and platform economy, as well as the urgent need to increase transport and logistics efficiency to meet climate change objectives, indicate that the process must be accelerated and 2030 is now the timeframe to have advanced implementations of the Physical Internet and 2040 the timeframe for full Physical Internet realisation.

1.2 Delivering pooled logistical flows through interconnected logistics networks

The PI builds on the idea of flow consolidation and the network of networks concept. It is well known that the larger the flows are the more efficient transport can be organised. Current trends show a growing fragmentation of shipments (driven by eCommerce) and a demand for smaller order sizes (driven by just-in-time ordering policies). To overcome the negative impacts of these trends on

[20] For more information on research papers, projects and companies, check ALICE's knowledge platform at: https://knowledgeplatform.etp-logistics.eu/

[21] www.pi.events

[22] ALICE Youtube channel includes several explanatory videos. https://www.youtube.com/channel/UC-1_szlCtw6ZTQC9PmfK9Ag

transport efficiency the Physical Internet enables the consolidation of logistics flows (e.g., extended pooling networks[23]). Additionally, the Physical Internet enables the pooling of resources and assets in an open, connected, and network of shared networks (i.e., connecting existing (company) networks, capabilities, and resources) so they can be used efficiently by all PI participants. By pooling demand and resources, it is expected that the usage of the resources will be more efficient allowing users to do more with less.

To realise the PI, multiple challenges must be addressed including the development of standard handling units (e.g., as addressed by the MODULUSHCA and CLUSTERS 2.0 projects) and increased interoperability of the full portfolio of logistics handling units (e.g., containers, pallets, etc.), the development of standard processes and operations for the handling of goods and for sharing information, as well as rules for "co-operation" between the different companies using the PI. These rules need to include service levels, define shared quality of services, liability and payment agreements, and other contractually important service requirements. Within the PI service level is a complex set of requirements including lead-times, volume of handling units, weight of shipments, allowed environmental conditions (temperature, shock levels, humidity, etc.), information access, visibility and traceability, as well as responsibilities and liabilities.

To address this complexity, the Physical Internet can be addressed from different perspectives, the nodes and the links between the nodes. (See Figure 3).

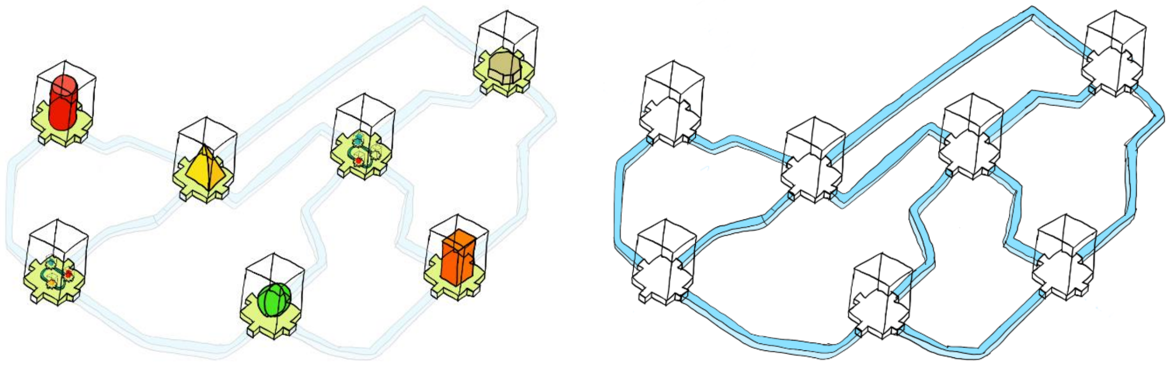

Figure 3: Different perspectives on the same network (Left: node level, right: link level)

More operationally, the PI can be divided into three different layers with different capabilities and usages: The Logistics Nodes (Figure 4), the Logistics Networks (Figure 5) and the System of Logistics Networks (Figure 6-9).

The **Logistics Nodes** are physical locations, such as warehouses, Distribution Centres, ports, airports, inland hubs and terminals, and even cities. Nodes have different characteristics, purposes and settings that determine the operations and services provided (see Figure 4).

One of the biggest issues in today's logistics networks is the management of complexity. The PI concept can help to reduce the level of complexity by hiding internal operations of big nodes (e.g., ports, logistics hubs and cities). More complex nodes may be seen externally as a single node but internally could be organised following an architecture like the PI's general architecture (i.e., including internal Logistics Nodes, networks and System of Logistics Networks). This concept is transferred from the Internet where company networks are hidden behind routers and firewalls with a dedicated connection to the public internet (see Figure 5).

[23] See for example FM LOGISTIC pooling network: https://www.fmlogistic.ru/eng-gb/Our-services/Transport-Distribution/Pooling

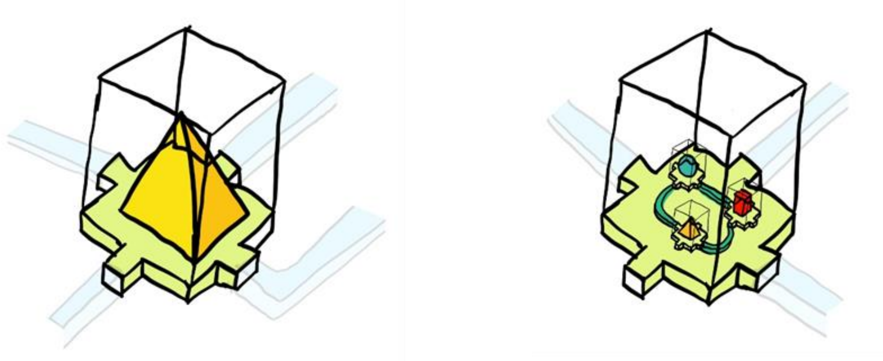

Figure 4: Internal operations in nodes

The **Logistics Networks** include the Logistics Nodes and the (transport) links between them that are under the direct control of a single company whether a shipper, a retailer, a logistics service provider, or a freight forwarder. Logistics Networks may involve many companies under the orchestration of a single company in charge of the inventory management, transport planning, routing, and capacity management (see Figure 5). Logistics networks could be potential physical intranets if they were compliant to PI protocols and processes (e.g., including full visibility and accessibility of resources and capabilities and pooled demand).

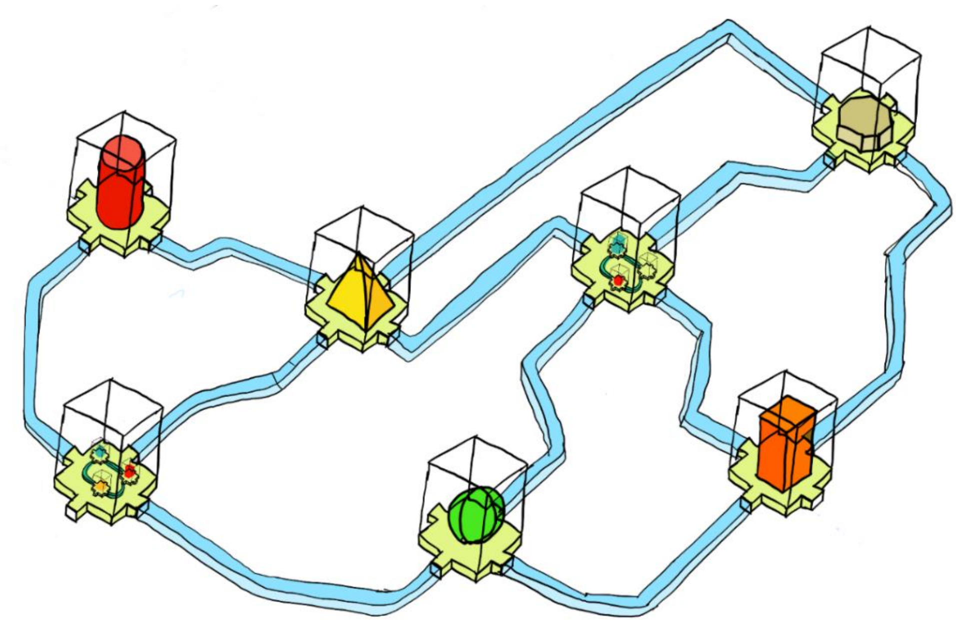

Figure 5: Logistics Network

The **System of Logistics Networks** describes the combination and interconnectivity of several Logistics Networks with assets, services and resources that can be used openly by the users of the system under pre-defined rules and governance (e.g., mutually defined by the owners of the independent logistics networks or by the companies bringing resources, capabilities and services to the System of Logistics Networks). The System of Logistics Networks may serve different types of goods that may or may not be combined (See Figures 6 to 9).

Figure 6 shows a System of Logistics Networks, which is built from three different Logistics Networks, highlighted in orange, red and blue. These networks can be considered as one Physical Internet, or a "network of networks" due to the principle of encapsulation, interfaces and protocols addressing their

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interconnectivity. Figures 7, 8 and 9 show different routes for different types of handling units and goods within the System of Logistics Networks. The routes have been selected based on specific shipment requirements and the availability of capacities. Wherever the needs coincide, and the physical combination of units is allowed, routes can be combined.

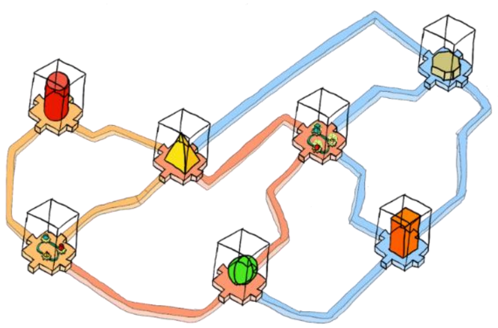

Figure 6: Network of networks from three different partners

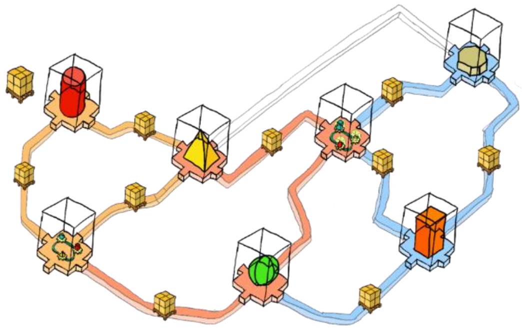

Figure 7: Subset of network for transport of pallets

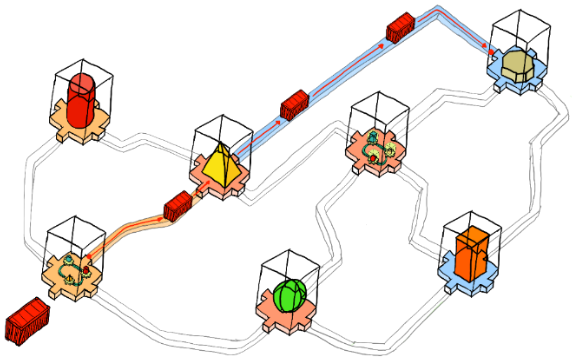

Figure 8: Subset of network for transport of containers

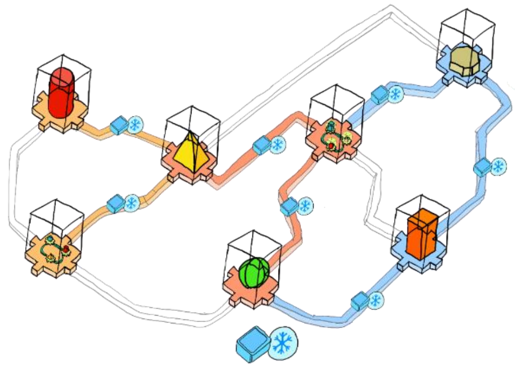

Figure 9: Subset of network for frozen goods

The PI also combines different flows on different levels: the flow of physical goods (physical transport), the flow of data and information (virtual level) and the flow of money through the financial system. The infrastructure stays largely the same and functions according to the same principles, but the flows on the different levels are combined in PI, see Figure 10.

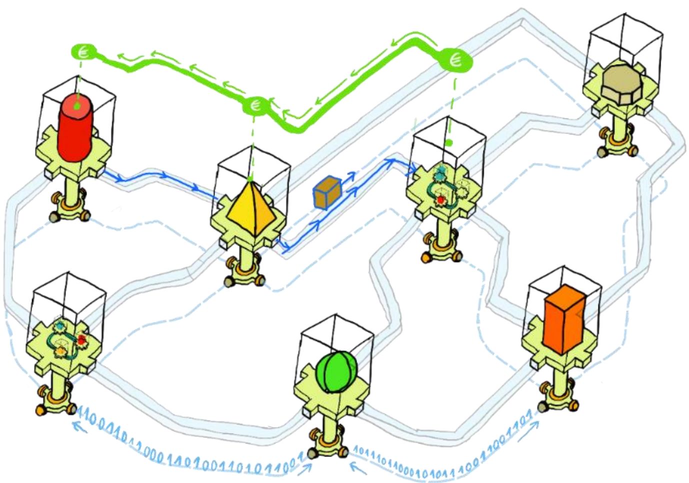

Figure 10: PI combines flow of goods, information and money

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In October 2018, the SENSE project organised a 2-day workshop focused on the Physical Internet in Munich. Participants in this workshop (ALICE members and external stakeholders with a focus on industry and interest in the PI initiative) discussed the five areas for PI development identified by the SENSE project (Access and Adoption, Governance, System of Logistics Networks, Logistics Network and Logistics Nodes) and determined the objectives and milestones that need to be achieved in order to fully realise them. According to the outcome of the workshop, **the realisation of the PI will require the following:**

- A mental shift is needed at different levels: 1. from retailers and shippers so they rely more on the capabilities of the logistics service providers and freight forwarders being less prescriptive and demanding of dedicated assets, services and infrastructure in the way the services are delivered with emphasis in service level and quality, 2. logistics service providers and freight forwarders to openly give access to other logistics networks to build on their capabilities, assets and resources defining common and standard processes that could facilitate interoperability of services and networks and, 3. to ease cooperation among humans and autonomous systems in logistics, defining the roles for each of them. In relation to the latter, the development of the autonomous handling of goods, the definition of functions and services of hubs are topics of interest and to be further developed under the area of Logistics Nodes.
- There is a need to increase education and skills related to Physical Internet concepts such as serious games, models, and simulation tools to communicate the functioning and benefits of shared logistics networks providing services for pooled demands (i.e., the Physical Internet).
  - It is hard for a company to project itself in the PI vision as its own role is not depicted. The PI is modelled as a single system and even if decentralised decisions are taken in models, the business approach was not represented. At this level the different points of view of several players need to be well addressed.
  - A game was developed by MINES-ParisTech to represent a transport market where players try to win transport orders based initially on a traditional market. Players are next given the possibility to reallocate their orders to a central node that represents the simplest type of interconnection. The game demonstrates the advantage in terms of gains for those who practice interconnection[24]. A study of players' behaviour and the reduction of barriers to interconnection has been undertaken with TU-Delft.
- New theories, mechanisms and practical examples need to be developed on how to build trust among partners and users of shared networks, platforms, collaborative and autonomous systems.
- The information/data sharing mechanisms are not well defined and described thus fuelling all kinds of speculation about business impacts. At this level, the Digital Transport and Logistics Forum[25] is addressing this challenge in a wider perspective. The DTLF developed the concept of the federated Network of Platforms[26] that is consistent with the PI vision and its decentralised architecture. EU funded projects FENIX[27] and FEDERATED[28] are implementing these concepts in practices and could be the foundation of data sharing principles for the Physical Internet.

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[24] Lafkihi, M., Pan, S., Ballot, E., 2019. The Price of Anarchy for Centralising or Decentralising Freight Transport Organisation Through Serious Gaming. IFAC-PapersOnLine. 52 (13), 1657-1662. https://doi.org/10.1016/j.ifacol.2019.11.438.

[25] The Digital Transport and Logistics Forum is an Expert Group Launched by the European Commission in 2015 (https://www.dtlf.eu/)

[26] DTLF 2018. *Enabling organisations to reap the benefits of data sharing in logistics and supply chain.*

[27] https://fenix-network.eu/

[28] http://www.federatedplatforms.eu/

1.3 Why do we need the Physical Internet? Achieving climate change objectives effectively, supporting climate impact mitigation and bringing resiliency to supply networks

In response to the Paris Agreement that fixed as a target keeping climate change within 1.5-2.0 ºC temperature increase and the required decrease in GHG emissions to achieve that target, more and more governments, associations and businesses are setting bold climate and emissions reduction targets. As set out in the European Green Deal, the ambition is for the EU to be the first climate-neutral region in the world by 2050. This will be achieved with a two-step approach designed to reduce CO_2 emissions by 50%, if not 55%, by no later than 2030.[29]

Emissions from freight transport and logistics are still growing significantly, despite combating climate change being a clear international priority. Transport is currently the 2nd major contributor to climate change.

Cities recognise problems caused by private and commercial freight transport vehicles such as air pollution, noise, and congestion. As a result, many cities are regulating to protect urban environments by implementing stricter access regulations and vehicles standards to avoid pollution and congestion. They must strike a difficult balance between maintaining the lifeblood of the city - the accessibility of goods and services - and the quality of life of the inhabitants. This concern is growing as consumer shopping habits are incurring a paradigm change with the surge of e-commerce, which is creating a significant increase in traffic flows in cities. Physical Internet applications in the city context will benefit cities, citizens, and companies[30].

Logistics companies, manufacturers and retailers are struggling to deliver emissions reductions whilst remaining competitive and ensuring proper access and value to their customers and society. Low profit margins combined with the high cost of low emission technologies and uncertain total cost of ownership projections make investments challenging for carriers. As the fight against climate change becomes more of a priority, pressure is rising on the logistics industry to act.

The Alliance for Logistic Innovation and Collaboration in Europe (ALICE) is aware of the challenges and transformation required of freight transport and logistics operations to meet climate goals, maintain Europe´s competitiveness and our standard of living. That is why ALICE developed a roadmap entitled *"Towards Zero Emissions Logistics 2050"*[31] to clearly state the challenge and establish a direction for addressing the challenge.

In the roadmap, consensus was reached on the assessment that the ongoing development and deployment of greener and cleaner vehicles, trains, barges, ships and airplanes alone will be too slow to deliver on our climate change targets. In parallel to developing green vehicles and assets, more focus needs to be given to leverage opportunities for efficiency gains in freight transport and logistics.

We envision large efficiency gains and benefits to all stakeholders by doing more with less. The existing idle capacity of assets in all modes of transport, poor utilisation of storage facilities, and inefficient and unconsolidated flows – all are opportunities for improving efficiencies. Open logistics services and seamlessly connected networks will help the different stakeholders to maximise capacity utilisation. Value creation by efficiency should be used to speed up the transition to greener and cleaner assets

29 U. von der Leyen (2019) A Union that strives for more. My agenda for Europe

30 For more information, visit the Physical Internet video in the city context: https://youtu.be/O-8OQZYqNi4 and the developments of the joint POLIS & ALICE strategic dialogue group: http://www.etp-logistics.eu/?p=2770

31 Roadmap Towards Zero Emissions Logistics 2050. http://www.etp-logistics.eu/?p=3152 ALICE (2019)

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instead of a focus on transport price reduction and an erosion of margins employing current business models.

Studies show that transport inefficiencies cause businesses €160 Billion in lost revenues and 1.3% of EU27 CO_2 footprint[32]. The Physical Internet could facilitate higher freight unit consolidation (higher asset utilisation and fewer empty miles), intelligent combinations of loads across supply chains, smart consolidation and reallocation of flows in supply networks (increasing modal shift), and Synchromodality. The impact of the environment based on these changes together (note that this is only part of PI impact) could lead to an efficiency increase in freight transport of 15%, achieving total savings of €100 billion/year and 15% of EU27 transport CO_2 footprint reduction[33] in the short term according to a survey.

In the framework of the SETRIS project, ALICE launched a survey among its members[34]. Most of the participants believed that in the 2020-time frame, the Physical Internet would be able to generate energy and emission savings of 5-10%, and cost savings from 3 to 5%. In the medium term (2030), energy savings in the range of 10-20% are expected and even higher emissions reductions (10-25%) are possible. In addition, cost savings between 5-15% are predicted. In the long term (2040), the participants believe that savings of 20-30% in energy consumed, cost savings above 30%, and emission reductions in the range of 25-40% will be achieved. However, more detailed studies and research, as described below, shows even higher potentials are possible.

The European CO3 project[35] developed interesting case studies that illustrate how horizontal collaboration (in which companies share services for mutual advantage) leads to a reduction of GHG emissions and cost. Two Fast Moving Consumer Goods (FMCG) shippers (Nestlé & PepsiCo), a logistics service provider (STEF) and a neutral trustee (TRI-VIZOR) built a collaboration community in fresh and chilled retail distribution[36]. Consolidating, balancing and synchronising the loads of Nestlé and PepsiCo into Full Truck Loads (FTL), cost savings of 10-15% and similar CO_2 reductions were achieved. In another case, two shippers with two separate supply chains but similar lanes, P&G and Tupperware, collaborated to deliver products from Belgium to Greece optimising light and heavy goods mix in the trucks. The resulting collaborative supply chain saved 150,000 truck-km, improving from 55% to 85% cube and weight fill, and attaining 17% cost savings. More recent projects such as NEXTRUST[37] and CLUSTERS 2.0[38] have shown similar benefits on additional horizontal collaboration processes. Unfortunately, these horizontal collaboration cases are, in most cases, not sustained in time (due to changes in the supply chain of a company), are complex to scale, and fail to establish any long-lasting governance models.

The Physical Internet proposes a more systematic approach to goods consolidation as described in Section 1.1. Systematic initiatives such as MixMoveMatch[39] have increased truck fill rates and reduced emissions and costs for shippers such as 3M. Indeed, 3M reported having reduced transport costs by 35% and CO_2 emissions by 50% using the MixMoveMatch system.

32 Final Report Summary – WINN project.

33 Response of ETP ALICE to the "STAKEHOLDER CONSULTATION ON POTENTIAL PRIORITIES FOR RESEARCH AND INNOVATION IN THE 2018-2020 WORK PROGRAMME OF HORIZON 2020 SOCIETAL CHALLENGE 4 'SMART, GREEN AND INTEGRATED TRANSPORT".

34 SETRIS Project, D3.1 ALICE Research and Innovation Roadmap on the Physical Internet.

35 CO3 project, Collaboration Concepts for Co-modality. http://www.co3-project.eu

36 Horizontal Collaboration in Fresh and Chilled Retail Distribution. D4.3, CO3 project.

37 *"Building sustainable logistics through trusted collaborative networks across the entire supply chain"* NEXTRUST H2020 project. https://nextrust-project.eu/

38 Open network of hyper connected logistics clusters towards Physical Internet, CLUSTERS 2.0 H2020 project http://www.clusters20.eu/

39 https://www.mixmove.io/en/

One of the initial studies on the impacts of the Physical Internet[40], based on simulations of logistics of top French retailers Carrefour and Casino, and their 100 top suppliers[41,42], showed that moving to a "*Physical Internet Model*" could:

- shift 50% of goods transport from road to rail,
- cut costs by 32%,
- reduce t.km by 15%
- increase fill-rate from 65% to 85%
- reduce greenhouse gas emissions by 60%.

Several other studies conducted in Europe, Canada and the USA confirmed this potential and most of them were published in scientific journals and successfully passed the peer-review process[43]. Some publications declare that the cost savings, based on actual figures, may be under-estimated. The history of the maritime container shows a cost reduction by an order of magnitude over 50 years with the development of specific ships and cranes, modular and standard transhipment technologies.

In a scenario in which all potential Physical Internet efficiencies are achieved the forecasted 300% increase in transport demand could be handle with only 50% increase in assets[4]. Figure 11 shows an estimation of the potential emission reductions applying Physical Internet concepts (it includes better fill-rate, more direct shipments, and modal-shift). In brief, this is the aggregated contribution of different solutions to increase efficiency managing better the freight transport demand, making the best use possible of transport modes, and increasing asset and vehicle utilisation.

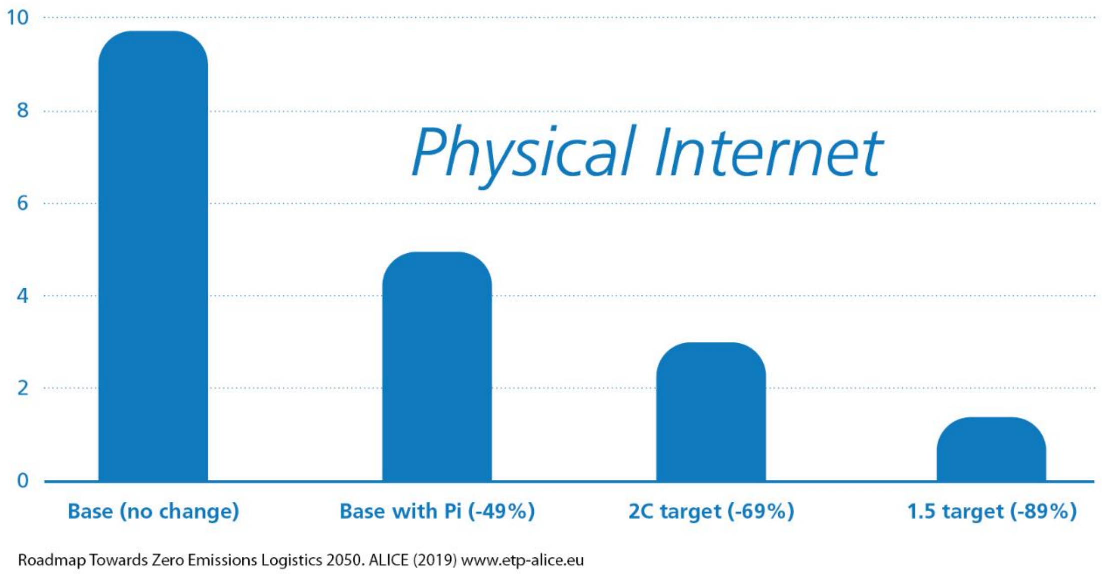

Figure 11: Scenarios for freight-transport emissions in Europe including Physical Internet (PI) (in billion tonnes CO2)[4]

[40] Sarraj, R. et al. (2014) 'Interconnected logistic networks and protocols: simulation-based efficiency assessment', International Journal of Production Research. Taylor & Francis, 52(11), pp. 3185–3208. doi: 10.1080/00207543.2013.865853.

[41] Ballot, E. (2012) Simulation de l'Internet Physique : contribution à la mesure des enjeux et à sa définition. Edited by PREDIT. Paris: MEDDAT.

[42] Ballot É., B. Montreuil, R. Meller (2015). The Physical Internet: The Network of Logistics Networks, La Documentation Française.

[43] References could be found at the Physical Internet Knowledge Platform: https://knowledgeplatform.etp-logistics.eu/course/index.php?mycourses=0&categoryid=7&categorysort=default

Realising these outcomes would lead to congestion reduction in urban areas and large savings in investments in infrastructure capacity. These costs savings are not considered in the above-mentioned studies, but according to the last report of the EC on transport external impacts[44] the savings could be doubled by considering congestion and pollution.

A second impact of the Physical Internet, one less studied, is the **resilience** of such a meshed network**.** By design, the interconnection of logistics networks offers several routes from anywhere to anywhere. This property inherited from the Internet is generally considered "nice to have." But considering the Covid-19 pandemic, we can see the benefits of a system capable of engaging all its capacities in a dynamic manner, including routing and delivery. To our knowledge, only one study has been carried out to develop a PI response model to node disruptions. According to the first published results, the PI outperforms the response of traditional logistics networks to disruptions[45]. This has enhanced relevance considering the increased frequency of disruptions (e.g., climate, infrastructure collapses) for which the Physical Internet could mitigate the impact in terms of costs and losses. Additionally, the requirements of infrastructure to be resilient by design could be relaxed as the logistics system would bring a more cost-effective approach to address infrastructure failure events, therefore being a clear strategy to consider for climate impact mitigation strategies.

The third impact of the Physical Internet is the **agility.** Interoperable resources (vehicles, boxes, warehouse space, etc.) and human resources accessible and functional for different supply chains can support variability in demand. During COVID-19 certain supply chains surged while other plunge creating high transport/logistics/resources demand on some supply chains and unused capacity in others. Modular and interoperable resources and capabilities may have made it easier to allocate and access resources.

When talking about Physical Internet deployment and its impact on society, additional aspects to be considered and not fully addressed yet are:

- Effects on the labour market – mainly fewer jobs for lower skilled people and more jobs for higher skilled people with and impact on flexibility of labour (time, place, type)
- The value and potential contribution of the Physical Internet to small companies that could access high quality logistics networks and serve customers worldwide. This concept is already being developed by some market players[46].

[44] European Commission (2019) Handbook on the external costs of transport. Brussels. doi: 10.2832/27212.

[45] Yang, Y., Pan, S. and Ballot, E. (2016) 'Mitigating supply chain disruptions through interconnected logistics services in the Physical Internet', *International Journal of Production Research*. Taylor & Francis, pp. 1–14. doi: 10.1080/00207543.2016.1223379.

[46] https://www.ogoship.com/

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2 Roadmap to the Physical Internet

The SENSE project developed a Physical Internet roadmap summary (Figure 10) to explain the development of the PI over the next twenty years. The PI matrix shows the development path of five specific areas for the Physical Internet:

1. **From Logistics Nodes to PI Nodes** – In Logistics Nodes, goods are consumed, stored, transformed, or transhipped from one transport mode to another. Ports, airports, logistics hubs, terminals, warehouses, depots are examples of Logistics Nodes. The Physical Internet envisions the development of the Logistics Nodes into Physical Internet nodes in which the operations are standardised and the usage of a family of standard and interoperable modular load units from maritime containers to smaller boxes is extensive. Services in PI nodes are visible and digitally accessible and usable including planning, booking and execution operations.
2. **From Logistics Networks to Physical Internet Networks** –Logistics Networks include Logistics Nodes as well as the transportation services connecting the Logistics Nodes and reaching to the destination. Logistics Networks are under the control of a single company either a shipper, a freight forwarder or a logistics service provider reaching their value chain (i.e., customers and suppliers). PI Networks are expected to build seamless, flexible and resilient, door-to-door services consolidating and deconsolidating all shipments within a logistics network in which all assets, capabilities and resources are seamlessly visible, accessible and usable to make the most efficient possible use of them.
3. **Developing the System of Logistics Networks towards the Physical Internet** – Includes individual logistics networks that are interconnected. Therefore, the assets, services and resources of the individual logistics networks can be accessed by the logistics networks owners and users. The System of Logistics Networks forms the backbone of the Physical Internet and require secure, efficient and extensible services for the flow of goods, information and finances across logistics networks.
4. **Access and Adoption** – This area describes the main requirements to access the Physical Internet through a logistics network part of it. It also includes different steps and mind shift required to adopt Physical Internet concepts.
5. **Governance** – Governance includes the developments needed to evolve the Logistics Nodes, logistics networks and the System of Logistics Networks into the Physical Internet, i.e. the rules defined by the stakeholders forming or using them as well as the trust building processes and mechanisms.

Developments in each of the areas have already started (2015-2020). The roadmap shows the possible developments in "*generations*" until 2040. Generations define possible evolutions towards the PI and can be scenarios or parts of PI-like implementations. Generations at medium- and long-term involve more technical, operational, and business complexity. In some cases, generations can be jumped (i.e., stakeholders or companies may directly jump into the 3rd or 4th generation without necessarily passing through the previous one).

PI-like operations will be well established by 2030. The shown developments from 2030 to 2040 focus on improvements on the way to achieve autonomous, open and shared PI operation.

The five areas with the defined generations will be explained in detail in the following sections.

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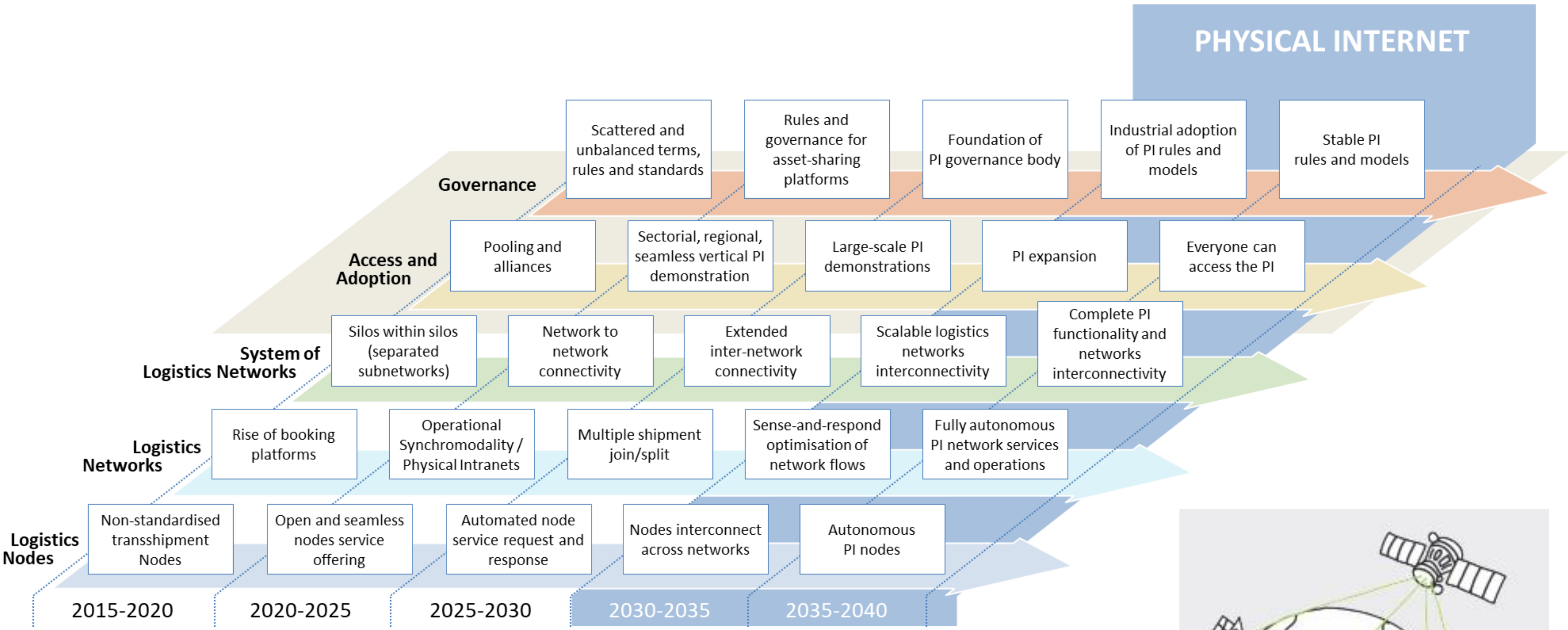

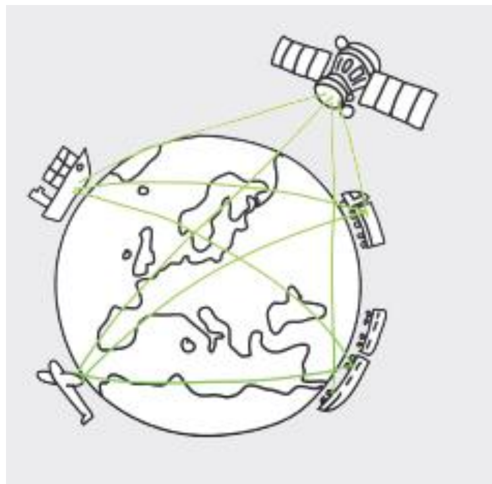

Figure 12: The Physical Internet roadmap

2.1 Logistics Nodes

Logistics Nodes are physical locations, such as depots, warehouses, Distribution Centres, ports, airports, inland hubs, and terminals or even cities in which goods are consumed, stored, transformed, handled, or transhipped from a transport mode to another. These have different characteristics and settings that determine the operations and services provided (e.g., execute customs, sanitary, or other procedures, co-packing, etc.).

The rising demand for higher levels of efficiency calls for further standardisation of crossdocking and transhipment processes. There is the need to overcome the current rigidity, complexity and fragmentation of the services, processes, procedures, and information flows related to the node's operations. Especially, for railway and inland waterway terminals it is urgent to upgrade the level of the services offered and their digital connectivity to users, pursuing automation strategies and following the port terminals' examples. Facilitating operations at nodes is a key factor for a better use of transport modes.

Consolidation and deconsolidation of goods needs to be done seamlessly so operational costs are largely offset by gains in transport. Additionally, idle warehouse, terminal capacity as well as transportation slots could be opened to other companies through digital services and standard procedures. In this direction, the main focus points are: improvement of the services' visibility, implementation of solutions enabling the accessibility and usability of the services in a standardised automated/ digital manner, full automation of the nodes/terminal processes and procedures, starting from terminal services booking, up to the services execution.

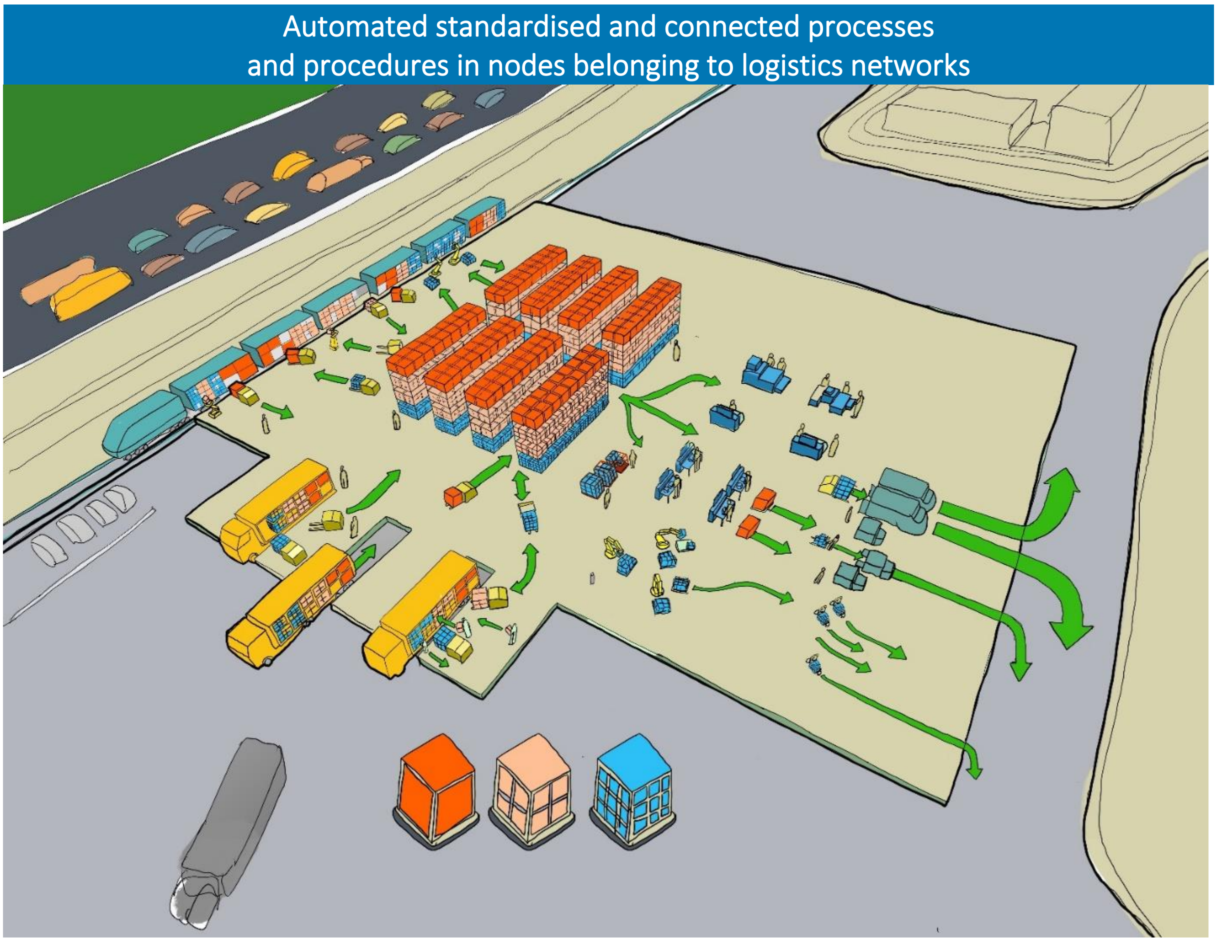

Figure 13: representation of PI nodes

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The Physical Internet envisions the development of the Logistics Nodes into Physical Internet nodes in which services definition and operations are standardised. Services in PI nodes are visible, digitally accessible to companies, and address planning, booking/transactions, execution and information sharing.

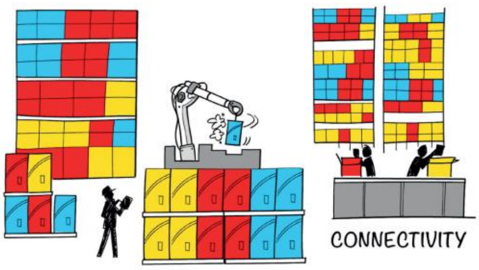
What do we want to achieve by 2030/2040?

1. Further standardisation of modular loading units (boxes in particular) and development of further compatibility across transport and handling units (e.g., maritime containers, swap bodies, intermodal units, pallets, trays, boxes, etc.).
2. Standard processes and procedures for automated material and cargo receiving/handling/transhipment.
3. Standard services, processes definition and information sharing across actors enabling higher efficiency in the use of nodes services and resources.
4. Full visibility, accessibility, and usability of nodes services to companies in a digital/automated manner.
5. Business models supporting autonomous interactions and provision of nodal services.

How could the steps look like for the next five years?

1. Sharing of characteristics, capabilities, and services of nodes to create visibility and accessibility for stakeholders, to realise ease of booking for cargo owners or service providers to services provided in the nodes. Definition and implementation of standard processes and interfaces.
2. Develop the framework and implement the federated network of platforms concept at nodes level.
3. Extensive adoption of standardised boxes used in multi-retail/multi-manufacturers networks to create maximum use of assets.
4. Develop and implement advanced transhipment technologies to facilitate intermodality and organise goods handling.
5. Identification and definition of business models for the collaboration and interconnection of nodes.

Logistics Nodes may have different roles and can be classified according to the combinations of main characteristics defined them as PI Nodes. For example:



- **PI Node – Type 1**: Warehouse/Depot.
    - storage capacity,
    - cargo consolidation/deconsolidation
- **PI Node – Type 2**: Intermodal Terminal.
    - cargo consolidation/deconsolidation
    - change of transport mode
- **PI Node – Type 3**: Intermodal/Multimodal Logistics Hub. (Figure 13)
    - storage capacity, added value services
    - cargo consolidation/deconsolidation
    - change of transport mode

Based on the infrastructural characteristics and the services offered, a node can belong to one of the three types of Logistics Nodes identified. Many traditional services can be provided in these different Logistics Nodes such as custom clearance, co-packing, customisation, local transport etc.

An important aspect to be considered in the medium term is the need for a PI node taxonomy, meaning the classification of entities, attributes and services defining the different nodes and their characteristics in a clear and standardised manner.

Generations of Logistics Nodes

The roadmap defines five generations for the development of Logistics Nodes into PI nodes (see figure 14).

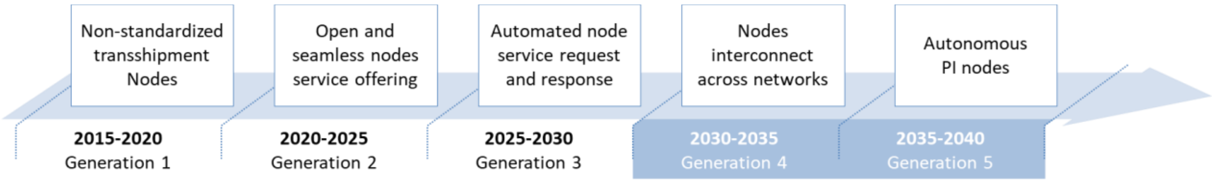


Figure 14: Overview on generations (possible development steps) for Logistics Nodes

Generation 1: Non-standardised transhipment Nodes (current status)

Nowadays, the logistics nodes are characterised by structured processes dealing with a multitude of well-known and used standard loading units. Pallets and containers have enabled huge efficiency gains at the levels they can be used (e.g., maritime transport, palletised goods transport). However, the interaction between different units (e.g., pallets and maritime containers, maritime containers and road transport) as well as between transport modes transhipment operations (e.g. non-crane proof trailers and swap bodies, lack of alternative transhipment technologies) is far from being standard and seamless creating inefficiency and barriers for a truly integrated transport system[47].

At a different level, retailers have proprietary and not standardised handling systems (boxes and trays) that add complexity for manufacturers and logistics companies. This issue has been addressed by the Modulushca project[48] (FMCG and retailers' networks and it is currently being implemented in a partial way through the GS1 MTV project[49]). The Physical Internet envisions the usage of the PI-containers that are universal[50] and can be easily combined.

Moreover, the services and capabilities of the different nodes are not visible (digitally published) in a unique and unambiguous way and therefore not easily accessible to potential users; this set up prevents the overall network from its optimisation and efficiency. Furthermore, the fragmentation of the information flow and the heterogeneity of the IT systems in nodes and interaction with the users represents a critical aspect.
The main services currently provided by a logistics node (depending on the type of node) are:

- cargo storage
- cargo handling (including consolidation/deconsolidation)

[47] ACARE, ALICE, ERTRAC, ERRAC and WATERBORNE. (2017) A truly Integrated Transport System for Sustainable and Efficient Logistics. http://www.etp-logistics.eu/?p=1298

[48] Landschützer, C. Ehrentraut, F. & Jodin D. (2015) *Containers for the Physical Internet: requirements and engineering design related to FMCG logistics.* Logistics Research 8.

[49] GS1 MTV project is addressing this issue. See Haubenreißer, M. (2019). *Transparent, sustainable and cost-effective: the GS1 SMART-Box in manufacturers to retail networks.* IPIC 2019.

[50] Montreuil, B. Ballot, B. Tremblay, W. (2015) *Modular Design of Physical Internet Transport, Handling and Packaging Containers.* Progress in Material Handling Research: 2014, 13, MHI, 2015, International Material Handling Research Colloquium, 978-1-882780-18-3. ffhal-01487239f

- change of cargo transport mode
- last mile from the node to destination.
- customs (extended gates), co-packing, customisation and other value-added services.
- Empty depot – inspection, cleaning repair

Generation 2: Open and seamless nodes service offering (2020 – 2025)

Concrete Benefits:
Better information about inbound and outbound flows and capacities; better information quality e.g., for planning; decrease of lead-time; reduced inefficiencies by using standard boxes (retailers + manufacturers networks) and reduced hurdle for transhipment across modes and nodes.

In Generation 2 logistics hubs and nodes start to act and offer services to their users in an open and digitally accessible way, their characteristics and capabilities are published. The definition of services and capabilities evolve to be more standard/interoperable and broadly adopted by nodes and users. Users may book and enter in business operations by accessing those services with much less administrative and negotiation burden than it is the case today. As an example, FLEXE and Stockbooking are platforms for open and shared warehouse space. However, integration of new partners and users is still time consuming due to the lack of established protocols and standardised APIs and procedures.

The Covid-19 outbreak gives an actual proof of the power of digitalisation and the need for more standardised and autonomous processes to keep operations continuity. It is expected that these processes are accelerated in the next five years.

In the last period of this generation, the capabilities and services of the different Logistics Nodes will be pooled in platforms that will be access points for a rudimentary Logistics Nodes network. Based on that, the logistics service providers, freight forwarders and cargo owners or shippers who aim at using the Logistics Network for their shipments, will easily book the Logistics Nodes services in the locations integrated/pooled in these platforms.

Additionally, current projects (e.g., GS1 MTV) for the usage of standard boxes in multi-retailers/multi-manufacturers networks will be expanded and a common practice in industry.
Needed activities to implement generation 2:

Combination of technology, organisational (orgware) and process innovations is required to address this generation. In this generation:

- <u>Seamless transhipment between modes and between modes and warehouses</u> will be developed in those areas not yet fully covered (e.g. intermodal terminals).
- <u>Logistics Nodes will emerge as digital platforms</u> publishing the nodes services in an open and accessible manner. As showed by airlines capacity management, it doesn't imply to share sensitive data such as total capacity or the remaining capacity at a given time but moving to B2B e-commerce nodes service offerings.
- Investing in <u>automation for container/material handling and loading/unloading</u> to reduce its cost and lead-time.
- Supporting initiatives for <u>uniform services definition and data sharing</u> within nodes.

An example in this direction to be taken as reference model, is represented by the Cluster Community System (CluCS) that has been developed by Clusters 2.0 (H2020 programme) project[51] and that will be implemented in the market through the FENIX project. The FEDERATED project is building similar capabilities. CluCS is a platform that supports Logistics Nodes to offer services to their users in an open

[51] www.clusters20.eu/

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and digital way. This platform aims at establishing co-ordination and collaboration between different stakeholders and nodes in a proximity network providing the required visibility and operations management capabilities to all services offered by the nodes. To become part and partner of the CluCS network, each stakeholder involved in the node, such as LSPs, shippers and terminal operators, has to:

- integrate the existing IT systems with CluCS (collaboration IT platform);
- Send/share their service catalogues;
- Send/share their demand for transport needs;

The communication network of CluCS guarantees a secure and reliable exchange of documents and data (structured, non-structured and/or binary). The nodes share their offering of services in a digital and open way to stakeholders that can access and book in a seamless way. They may decide which part of their available capacity is offered in this way (i.e., allocated capacity to PI). Based on the different offerings, a process of further integration and definition of nodes characteristics and services in a more standard/interoperable way is kicked off: type of nodes, service offering, capabilities and access requirements. Definition of infrastructural requirements (storage area characteristics) and cargo handling procedures and automation that can be used as reference (or standards) by the Logistics Nodes.

Generation 3: Automated node service request and response (2025 – 2030)

Concrete Benefits:
Faster response time; automated (re-) planning; Increase of opportunities for reconfiguring and re-planning; higher throughput and extensive use of modular standard boxes in the logistics network. Standard process definitions are widely adopted and systems interfaces in place for seamless access to node services.

In Generation 3, the nodes functionalities and their role within a Logistics Network will take a further step by preparing the ground (infrastructures and procedures) for more automated operations. In Generation 3, Logistics Nodes will interact with the Logistics Networks (e.g., freight forwarders, shippers and the LSPs) by answering services requests (storage space capacity, cargo handling, cargo transport…) in an automated manner, creating seamless booking systems backed by smart contracts.

For this purpose, standard protocols and operations will be defined facilitating easy access to nodes services and resources.

The Logistics Nodes will ensure a smooth integration with LSP's IT solutions; this action allows each node to interact as a single entity within the Logistics Network and along the chain. Logistics Nodes such as ports or hubs develop and valorise collaboration opportunities across partners and users of the Logistics Nodes (e.g. consolidation of cargo, definition of new services, etc.).

At a different level for warehouses and distribution centres (handling, stacking, transport and transhipment of containers is already established) a fundamental step is to implement and build at each node the facilities that can:

- handle modular boxes;
- match, couple and decouple modular boxes optimising the load factor of transport.

Needed activities to realise generation 3:

- Harmonising the service offering, capabilities and characteristics definition of the Logistics Nodes.
- Seamless connectivity of Logistics Nodes services to user systems for automated services requests and responses

- Secure and reliable exchange of documents and data (structured, non-structured and/or binary) is in place adopting a standardised message exchange protocol that ensures interoperable, secure and reliable data exchange, such as AS4[52].

Generation 4: Nodes interconnect across networks (2030 – 2035)

Concrete Benefits:
Expansion of reach; increase of scale and scope of activities (especially for service providers)

In Generation 4 the main objective and focus is the interconnection between nodes belonging to different Logistics Networks (System of Logistics Networks area). G2 and G3, defined the "identity card" of a node, including the rules and specifying the guiding manual for a node making it ready to become a PI node. G4 phase introduces a fundamental pillar toward the full Physical Internet implementation: the Logistics Nodes services can be accessed in an interoperable and seamless way. Logistics Nodes will be certified and comply with the rules and standards defined in previous generations so they can form part of the Physical Internet as a PI node.

The Generation 4, as result, will ensure:

- Full visibility and accessibility to the services offered in the nodes belonging to the PI;
- Automated management and handling of the cargo in the Logistics Nodes.

Needed activities to realise generation 4:

- Business and operational models for business, physical and digital interconnection of Logistics Nodes. It will be crucial to identify the cost and benefit positions for the stakeholders involved and to raise the awareness of these cases across the value network. With this knowledge and common understanding, possible business options can be identified and analysed to further define the innovation and its impact on the existing network of stakeholders. From an operational point of view there is the need to coordinate the activities within and between collaborating different networks.
- Integration of different Logistics Nodes (of networks) in a federated network of platforms[53]. Each node will be part of a network managed by a platform (node manager, logistics service provider or freight forwarder depending on the type of node). The nodes will be part of a federated network of platforms adopting access point mechanisms. Each node at a certain level will be able to "dialogue" (as information exchange) with the logistics networks, with the upper node (father) and with all the nodes of a lower level (children). Each network of nodes (Cluster) will exchange data and collaborate.
- Automated material handling and autonomous handling of cargo will be common practice at all levels.

Generation 5: Autonomous PI Nodes (2035 – 2040)

Concrete Benefits:
Gateway to PI; One-stop-shop to take orders and guarantee deliveries (network functionality); autonomous reaction to local changes in network (congestions, breakdowns, etc.)

[52] AS4 (the modern successor of AS2 protocol) is an open technical specification for the secure and payload-agnostic exchange of data using Web Services and it has been adopted in e-SENSE initiative.
[53] See DTLF (www.dtlf.eu)

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The main objective of Generation 5 phase will be to bring the PI node at full scale, thus enabling autonomous interaction, both physical and digital, between the nodes in the System of Logistics Networks. The System of Logistics Network, formed by various subnetworks, will cover and serve the world as geographical area and will involve LSP's and nodes worldwide.

Cargo owners and shippers will be just senders and receivers which will push their cargo in the Logistics Networks specifying the destination; the cargo will be sent to its destination by:

- following pre-defined paths and routes,
- Utilising one or more services,
- using one or multiple transport modes,
- involving one or various LSPs that manage the logistics networks.

Needed activities to realise generation 5:

- Full adoption of PI logic in Logistics Nodes: modular loading units, cargo transport procedures PI-like, System of Logistics Networks (federated network of platforms).
- Trusted operations through digital identity checking.
- Autonomous processes and procedures for material and cargo receiving/handling/transhipment.
- Business models supporting autonomous interactions and provision of PI node services.

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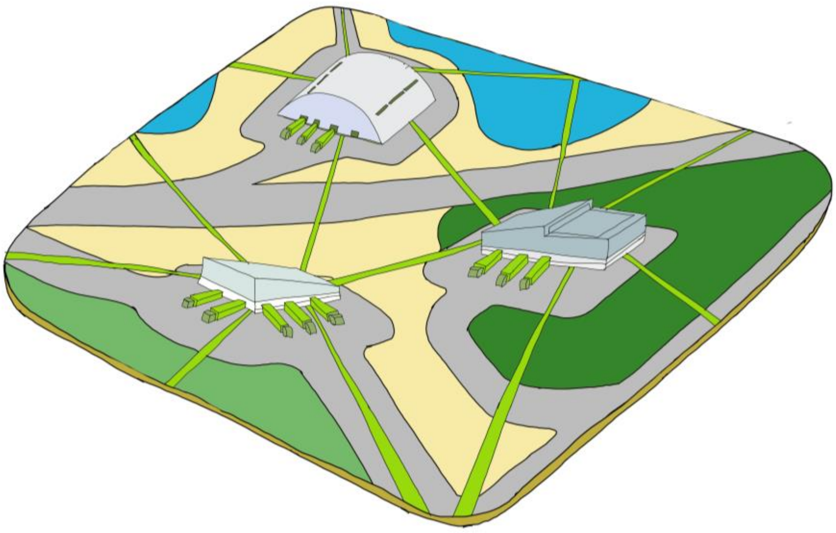
2.2 Logistics Networks

Logistics Networks include the Logistics Nodes and the (transportation) links and services connecting them. Logistics Networks are currently mostly under the direct control of a single company whether a shipper, a retailer, a logistics service provider, or a freight forwarder reaching their value chain (i.e., customers and suppliers) but with no visibility beyond the boundary of its supply network. Logistics Networks may involve many companies under the orchestration of a single company in charge of the inventory management, transport planning, routing, and capacity management. Networks are expected to build seamless, agile, flexible and resilient, door-to-door services consolidating and deconsolidating all shipments within a logistics network in which all assets, capabilities and resources are seamlessly visible, accessible and usable within the logistics network to make the most efficient and effective use resources. These logistics networks could be potential physical intranets (or PI based logistics networks) if they are compliant to PI fundamentals (e.g., full visibility and accessibility of resources and capabilities to serve a pooled demand from a broad portfolio of customers).

Seamless, flexible and resilient,
door-to-door services for all shipments



What do we want to achieve by 2030/2040?

1. Door-to-door: the network allows the user to state his primary transport demand requirements between origin(s) and destination(s), leaving the execution of the service to the service provider – to focus offerings on user level service quality[54]
2. Seamless network: The network usage adapts to minimize negative impacts and changes in modes and routes through effective combination of transport and storage resources. Physical Intranets are created in which the focus is on maximizing the network performance and ensuring service level.
   - The Logistics Network can adjust assignments and routings to satisfy changes in demand and is able to adjust routings to absorb disturbances in performance, to be flexible for demand changes and resilient to disturbances in supply.
   - All shipments: in principle, the above service is provided for any shipment, anywhere, anytime, with the agreed service levels, to create a simple and attractive, one-stop shop service pooling various customers' demands in an efficient delivery network.

[54] As mentioned, service quality should be understood in a broad manner as a set of requirements to apply to the unit load : it covers not only lead-time, but also chock, temperature, packaging…

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- Inventory is positioned closer to consumption. Logistics Networks allow and demonstrate the benefit of decentralised inventory positions in the pooled logistics network allowing low speed transport for (re)-positioning stock levels and answering short term lead times with closer to consumer inventory positions. (e.g. full visibility of inventory positions in retail networks extended to suppliers and logistics service providers).

How could the steps look like for the next five years?

1. Develop and adopt widely agreed standard network operation protocols, that allow services to be executed in a more flexible and less proprietary way (e.g., pooled demand in the logistics network, shared warehouses and inventory positions).
2. Develop and adopt the new business models that allow to offer new synchromodal forwarding services as well as flexible transport capacity sourcing and sharing.
3. Develop and adopt advanced ICT systems necessary to run a synchromodal transport system including, for example, ICT for planning, booking, execution, network sensing, performance management and reporting as well as to manage flexible lead times in ERPs.
4. Consider the non-economic, external impacts of the network (environmental and social impacts, local and global) during the design of the above and prepare responsibility structures and proper mitigating measures, including correcting incentives.
5. Identification of potential regulatory barriers for the execution of freight transport and logistics services in an optimal way within a network making efficient use of the resources (e.g., cabotage rules[55]).

Logistics Network development involves a process of gradual enhancement of capabilities of the current freight and logistics networks.

The first key developments are the full integration, visibility, availability and usage status of all means and resources within a logistics network (for example within a Logistics Service Provider and its suppliers), the creation of fully operational synchromodal networks in which service providers or freight forwarders have the capability and the flexibility to modify the assignment of transport modes or transport lead times for certain shipments still meeting customers' service level and quality agreements. Logistics Service Providers may have the freedom to relocate stocks and inventory positions making use of empty spaces (e.g., push and retrieve flows depending on the stock levels in each location and the forecasted demand). These concepts allow delivering door-to-door flexible and responsive services to shippers, at a much higher performance level than today (e.g., positioning inventories close to final customers, in-route flexibility, and resilience against major disturbances). This requires Logistics Service Providers and Freight Forwarders to develop these capabilities and that shippers move towards shared logistics networks instead of dedicated services.

The second key development is the enhanced collaboration and connectivity between logistics service providers and its suppliers and customers. This collaboration – through operational standards, management contracts and systems interconnectivity – may follow similar rational as the one followed in the System of Logistics Networks. It is key to develop plug and play technology allowing customers and suppliers to connect to the logistics network[56].

There are many developments in this direction already, particularly in the container industry. The access to the physical transport network has been made easy by global protocols for shipping creating fully developed logistics networks and evolving to end to end transportation services for containers[57].

[55] https://ec.europa.eu/transport/modes/road/haulage/cabotage_en
[56] ALICE (2014). *Information Systems for Interconnected Logistics R&I roadmap.* (https://www.etp-logistics.eu/wp-content/uploads/2015/08/W36mayo-kopie.pdf)
[57] MAERSK Door to door solutions from any location. https://www.maersk.com/transportation-services/inland-services

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This does not only relate to the terms of services provided by carriers but also to standards for material and services and regulations for access (e.g. driver hours regulation, operational licenses) and information exchange (obligations for documentation). Operations through networks are guided by commonly used terms and definitions of services (e.g., definition of "availability" or "arrival"). These agreements constitute the "operational protocol stack" for the use of the PI like Logistics Network. In this layer we deal with PI intranets but the adoption at the level of players for themselves favours the interconnection at system level including parallel developments for digitalisation and standardisation[58]. As shipping is gradually evolving towards the Physical Internet not only at network level but also at system level, these protocols will evolve as well in other less advanced segments (e.g., industry supply networks, manufacturing-retailer networks, etc.) to answer to the societal demands to be more efficient and to meet emissions reduction targets and required models to make feasible the use of more expensive assets based on zero emissions energy sources.

The dominant direction of change in network services is the availability of network level intelligence, across individual shipments, owners and shippers, and its use to provide additional flexibility in the configuration of transport movements, before and during transport managed by a freight forwarder or a logistics service provider. The purpose of this flexibility is that it allows further optimisation of flows, beyond what is possible today[59]. Flexibility and dynamics are needed because both demand and supply are uncertain through time (e.g., during disruptions such as climate events or lately COVID-19 crisis), so the logistics network needs to be able to adopt to surge in demand in certain sectors while others plunge which requires interoperable resources and managerial capabilities.

Network level intelligence includes information about:

- the specification of the demand for services (origin, destination, required arrival time/reliability, quality parameters etc.),
- the current state of the networks and its users (visibility and managerial capabilities of assets and resources, tracking locations of loads, monitoring capacities of modes and congestion levels, monitoring warehouses spaces and terminal availabilities)
- predictions of the foreseeable future state of the states of the shipments and the network.

The use of network level intelligence for optimisation can be organised in several different ways, with important implications for the available opportunities (the "solution space"), information access and, eventually, Logistics Network governance. Central use of network level intelligence requires that one party can access all information about its network (it could be the freight forwarder or the logistics service provider). A decentral approach assumes that sub-centres or hubs will need to know about parts of the network or areas that fall under their control. Peer-to-peer approaches will allow intelligence to be kept at the lowest level, that of the hub and its connected links. Hubs and links will exchange information bilaterally. Collective intelligence across nodes then becomes an emergent property of the network. Important information elements related to the free capacity in vessels, trains and vehicles and the shipments are available for the internal use of the logistics network and open services could be derived accordingly to offer un-used capacity at the right price. In contrast to the current situation, the information about modes and loads is decoupled.

[58] As an example: The Digital Container Shipping Association (https://dcsa.org/) was launched in 2019. DSCA envisage a digitally interconnected container shipping industry in which customers have a choice of seamless, easy-to-use services that provide the flexibility to meet their business and sustainability goals.

[59] Note that the objective of optimisation is to go beyond client specific and can relate to service (e.g. speed, reliability) or costs.

Optimisation of network flows[60] involves one or more of the following decisions: routing, joining and splitting of shipments, delaying/storage or acceleration of shipments, switching between modes through synchronisation and transhipment, changes of destination and even changes of ownership. The availability of different modes of transport and inventory positions allows maintaining a diversified service package, with different levels of service relating to prices, times, and emission levels.

A major condition for the PI based logistics networks to materialise is the integration of different existing networks (even if they *"belong"* to the same company i.e., forming a platform). Integration is needed with intermodal transport services; vertically between LSPs/forwarders and their customers: shippers and receivers; as these steps need significant re-organisation and alignment between organisations, the evolution of the Logistics Networks may be time-consuming and fraught with uncertainty. However, specific players have started offering this type of services in specific domains such as FLEXPORT in maritime containers, FREIGHTERA[61] for intermodal transport in US and CANADA and SENNDER[62], a digital freight forwarding services for Full Truck Loads (FTL). The challenge is however to evolve integrated Logistics Service Providers including not only transport but also all other services (e.g., distribution, inventory management, co-packing, customisation, etc.)

Generations of Logistics Networks

Generations define possible evolutions towards PI and can be scenarios or parts of PI-like implementations. The generations should not be mutually exclusive but mark some important trajectories that need to be followed to arrive at PI-like services.

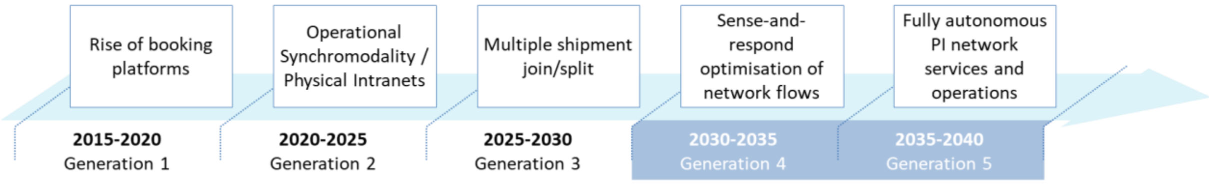

Figure 15: Overview on generations (possible development steps) for Logistics Networks

Generation 1: Rise of booking platforms (current status)

The digitalisation of logistics processes has spurred the automation of planning, booking and administration processes. In the past five years, we have seen a rapid development of digital booking platforms for logistics services. Despite the large investments made, very few can offer independent door-to-door services (see Figure 16). Only those platform services that are connected to larger forwarders can provide long distance shipping services for a variety of markets. Crowd shipping platforms for shorter distances (e.g., Nimber, Deliveroo) rely on the service of non-professionals, which creates questions about social and fiscal regulation of new service markets.

60 Note also that optimisation at the network level may involve preferential treatment of one shipment at the cost of another. Eventually, the PI will have compensation mechanisms that will partly transfer the benefits of such actions to the disadvantaged parties. This is an essential assumption to allow system level optimisation.

61 https://www.freightera.com/

62 https://www.sennder.com/

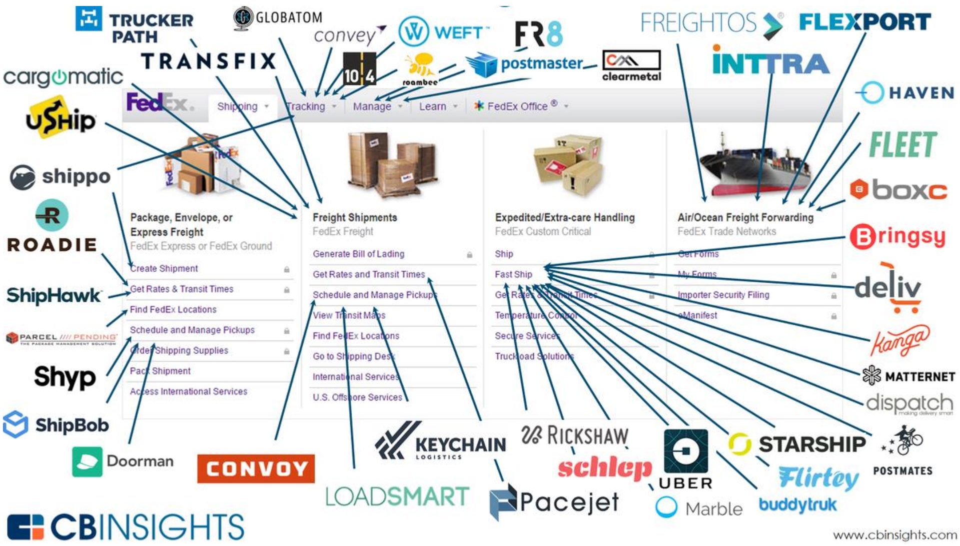

Figure 16: Overview of start ups as digital platforms addressing specific services of traditional integrators[63].

On the physical side of logistics, breakthroughs can be observed in the composition and provision of transport services. Collaborative networks for road transport have been created that can compete with major carriers. Synchromodal services have been developed for container transport, effectively postponing the choice of mode until briefly before time of departure of ships or trains. Alliance formation amongst maritime carriers has progressed to a level not seen before: the major ocean carriers are now grouped into only 3 major alliances, 15 less than 20 years ago. Continuing globalisation has created a contraction of global transport networks around a global conveyor belt of main ports around the world.

Generation 2: Operational Synchromodality / Physical Intranets (2020 – 2025)

Concrete Benefits:
(Full) load flexibility; booking of door-to-door services (not only single modes); more resilient and flexible use of logistics networks; use of transport modes with less emissions, faster integration of suppliers and customers;

The second generation will entail a continuation and consolidation of the current trend. Logistics Service Providers and Freight forwarders start to be digital platforms for service management and offering. Major logistics service providers and forwarders will develop internal connections between their departments responsible for different modes and logistics services (e.g., warehousing, etc.) and will develop systems and technologies to create full visibility and management capability to access resources (owned or contracted) seamlessly, into the so-called "physical intranets". These will allow managing flows and services in a more seamless way by shifting freight quickly between modes of transport, using common waybills and synchronised schedules, internal to the company or their close partners or use empty transport capacity[64]. To relocate inventory positions closer to consumption. This development will follow the current synchromodal systems of forerunners like ECT-Rotterdam and will be extended beyond containers transport. Common internal rules, services and protocols will be defined for routing to run parts of the network, for specific sectors.

Needed activities to implement this generation:

63 https://www.cbinsights.com/
64 See for example CHEP initiative on Eradicating empty transport miles: https://brambles.com/zero-waste-world/eradicating-empty-transport-miles.html

- Strengthen support for the current development of software (algorithms, data handling, user interfaces, apps) for synchromodal operations directed at all parts of the goods' (parcel, pallet, container, boxes) journey: cities, long distance overland transport and global maritime networks.
- Support and guide harmonised development of software across all parts of the journey, by creating common standards for data exchange and software functionality.
- Develop convergence programmes to ensure the connectivity of private with public (e.g. single window, city access) and private with private (customers and suppliers) applications.
- Demonstrate the benefits to shippers and retailers of shared logistics network services provided by logistics service providers enabling pooled shipment and storage of goods.

Generation 3: Multiple shipment join/split (split-in-transit and remerge-in-transit) (2025 – 2030)

Concrete Benefits:
Shipment flexibility; get higher fill rate; better combinations of parts of load; better control of parts of the loads (or even load units)

Building on the second generation, the third generation is marked by a stronger vertical connection between the service providers (including their transport suppliers and carriers) and shippers. Strings of platforms and/or forwarders and/or carriers can easily connect thanks to door-to-door harmonised service protocols, providing guaranteed and flexible schedules door-to-door. Digital transportation documents or better, trusted information sharable sets need to be developed in a way that they are not mode-specific or can be managed in a more flexible way (cf., Rotterdam Rules, a maritime transport law revision initiated in 2008 but still not fully adopted) to allow intermediate, unplanned, third- or fourth-party handling or in route change of mode. Digitisation of transport administration (e.g., eFTI[65]) will accelerate this development. In terms of logistics performance, this breakthrough will have the effect that decoupling becomes possible between grouped shipments and individual shipments. As shipments can be split in transit and re-merged later, new opportunities for bundling emerge for new groupage networks, which increases the utilisation of transport modes. In this regard, it is important that the rules are established in a way that the system is not misused and moving into the wrong direction. This opportunity, in turn, will speed up the development of new services, related to shipment tracking and integration (a necessary input for fulfilment towards clients), as well as capacity forecasting and assignment (a necessary input for maximising utilisation).

Needed activities to implement this generation:

- Accelerate identification and tackling of administrative barriers for highly flexible, shipment level, intermodal transport-service propositions. Continue with the digitalisation efforts eFTI[76] and DTLF type of forums are key for this.
- Support the development of systems and technologies for fast identification and management of resources and capabilities (from transport to supply chain operators) that build on shipment level flexibility. Support the development of software and shared ICT infrastructure for shipment level synchromodality.

[65] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on electronic freight transport information. COM/2018/279 final - 2018/0140 (COD)

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- Transition the operational logistics functioning: from shippers dedicated logistics chains to open and shared logistics networks (see Access & Adoption) in which logistics service providers and other stakeholders manage pooled flows of goods[66] in a flexible way.

Generation 4: Dynamic, sense-and-respond optimisation of network flows (2030 – 2035)

Concrete Benefits:
Predictive control of the network itself; real-time adjustments; more accurate timing, more flexibility and reliability

Vertically connected networks can now provide seamless services door-to-door in a full synchromodal and pooled way. In addition, dynamic capabilities for real-time management are developed. The sense-and-respond propositions of the network, creating robustness against supply disruptions and flexibility for demand change can now be fully developed. The addition of dynamic planning and re-routing means that the system becomes more responsive to disturbances from the supply side (e.g., power outage, capacity constraints, service breakdown, infrastructure disruptions), and to changing requirements from the demand side (e.g., increase of demand, changes in shipment size or destination). Dynamic recovery and re-planning algorithms will be developed side-by-side with advanced monitoring and prediction of all operations in hubs and on the multimodal network. In this generation, almost full functionality of the Logistics Network is available, compartmentalised in intranets. Shippers will be able to specify quick-response, flexible contracts with logistics service providers, which will make their supply chains more agile, as transport can now respond to emerging needs in sourcing, marketing, sales, and inventory management functions. A new layer of control software is developed to allow model based, AI driven, predictive control of network operations. One of the promising candidates for this is digital twin technology, based on a fast cycle (real time) of simulation and optimisation, supported by sensing and data analytics.

Needed activities to implement this generation:

- Logistics service providers in the lead of software development (in collaboration with vendors), internal capabilities and transition management strategies to transition towards a full and holistic logistics network management, including all resources (own or by partners/suppliers) and capabilities, providing customers with a flexible offer of services including synchromodal door-to-door services, inventory repositioning in open and shared warehouses networks and dynamic fulfilment strategies.

- Shippers to provide more freedom to LSPs on logistics execution and ready to define standard service level and quality agreements as well as the operational links with the LSPs or to develop their own logistics network capabilities regaining and building stronger supply chain sovereignty[67] (e.g., managing flows in an agile way dealing with fluctuations and/or temporary modifications by diversifying supplier base to hedge).

- Help the logistics sector to connect to manufacturers' supply chains by supporting the creation of new logistics business propositions that focus on flexibility, agility, and resilience.

Generation 5: Fully autonomous PI network services and operations (2035 – 2040)

Concrete Benefits:

[66] See for example initiatives in the urban domain: Proximus and L'Oréal partner up for the delivery of telecom and hair salon products by electric bicycle https://www.proximus.com/news/2019/proximus-and-loreal-partner-up-for-the-delivery-of-telecom-and-hair-salon-products-by-electric-bicycle.html#

[67] https://www.govisible.org/

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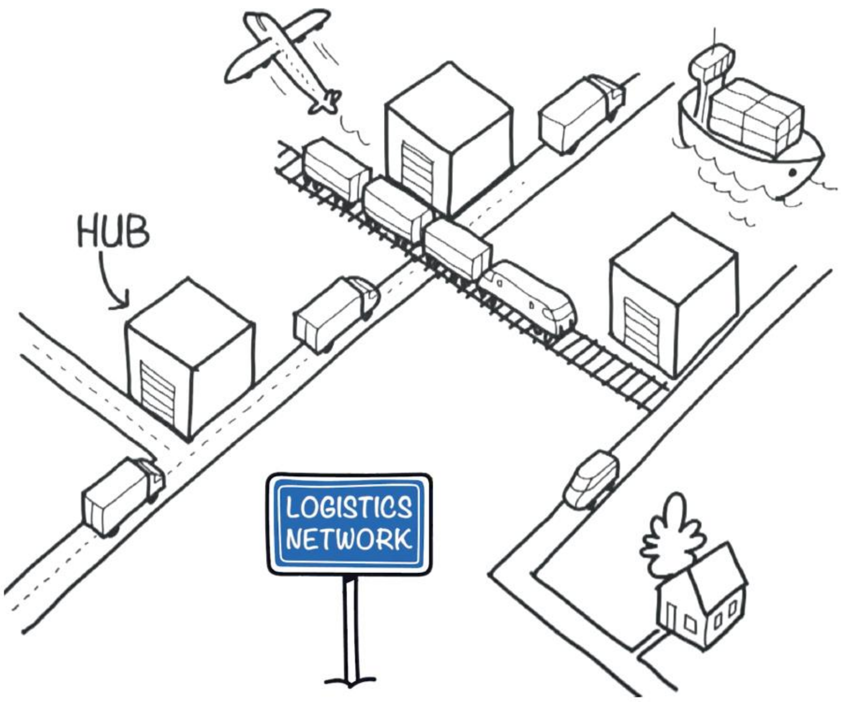
Planning is replaced by proactive and responsive network; Savings (because of no planning); higher flexibility; decrease of response time.

Generation 5 marks the further autonomous logistics networks operations. This requires the creation of a vertical integration that brings together proprietary processes and information from those that can conditionally be shared, and from those that are public and with whom supply chains can be composed in a fully autonomous way with predefined smart contracts and execution protocols being proactive in the smart use of resources and capabilities.

Needed activities to implement this generation:

- Develop capabilities to plan and execute autonomous logistics operations at network level (i.e., involving synchromodal transport services and inventory management strategies) and involving companies in the value chain.
- Identify and address regulatory and business barriers for fully autonomous Logistics Network services and operations.
- Assess positive and negative impacts of fully autonomous Logistics Networks.
- Monitor the response of markets and governments, to guide the development of the global Autonomous Logistics Network services and operations.



2.3 System of Logistics Networks

Within this area the System of Logistics Networks towards the Physical Internet is developed. Indeed, we foresee further connectivity across logistics networks that will require specific functionalities. These will be expanded so there is an organic growth of interconnected logistics networks as described in the previous chapter finally creating a Physical Internet when there is a standard- and industry-agreed procedure to be part of that System of Logistics Networks.

The System of Logistics Networks includes and connects logistics networks and therefore the assets, services and resources in the individual logistics networks that will be seamlessly accessible by multiple networks. The System of Logistics Networks forms the backbone of the Physical Internet and requires secure, efficient, and extensible services for the flow of goods, information, and finances across the logistics networks. The agreements across networks follow pre-defined rules and governance structures (e.g., defined by the owners of the independent logistics networks or by the companies bringing resources, capabilities, and services to the System of Logistics Networks). These rules and governance structures are scalable so logistics networks can connect and disconnect to other logistics networks seamlessly. The individual logistics networks can therefore make use of the resources made available at the system level.

Whereas now this is only possible with a dominant shipper/logistics service provider or forwarder (depending on the case) who maintains control over the entire chain, the rules and governance models will allow maintaining the integrity of the transport and logistics chain without such an overall single responsibility.

A System of Logistics Networks, such as the PI, has two important additional characteristics that go beyond efficiency. The first of these two characteristics were initially exposed in early work by Paul Baran at RAND.[68] Baran noted that a "mesh" network exhibited redundancy of network links. This characteristic of mesh networks made the failure of any link in the network unproblematic since the likelihood of such a failure affecting connectivity within the network was diminishingly small. Alternative paths would be available so that rerouting around the failed link would allow for the maintenance of communications between nodes even without the link. Baran went further to demonstrate that the failure of multiple links in a mesh network of sufficient size would again have negligible impact on communications between nodes in the network due to the redundancy of links between nodes.

The ability of a mesh network to withstand the failure of multiple links means that a System of Logistics Networks is extremely robust to infrastructure failures, or disruptions due to node failures. Alternative routings can always be found and, based on the discussion in the paragraph below, these alternative routings are not necessarily significantly poorer in performance than the originally planned routing.

Besides the robustness of mesh networks to link failure, research has shown that these networks tend to be "scale free."[69] By "scale free" is meant that as the networks add nodes, the actual number of links between nodes remains relatively constant. This phenomenon, now popularly captured in the phrase "six degrees of separation"[70] a term that arose from Stanley Milgram's work on small worlds,[71] means that as a System of Logistics Networks add additional networks (links and nodes) the distance, as measured in transit points, between two nodes remains relatively constant. This fact allows the

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68 Baran, P., 1964. On distributed communications networks. *IEEE transactions on Communications Systems*, *12*(1), pp.1-9.

69 Schnettler, S., 2009. A structured overview of 50 years of small-world research. *Social networks*, *31*(3), pp.165-178.

70 Guare, J., 1990. *Six degrees of separation: A play*. Vintage.

71 Milgram, S., 1967. Small world experiment. *Psychology Today*, *1*, pp.61-67.

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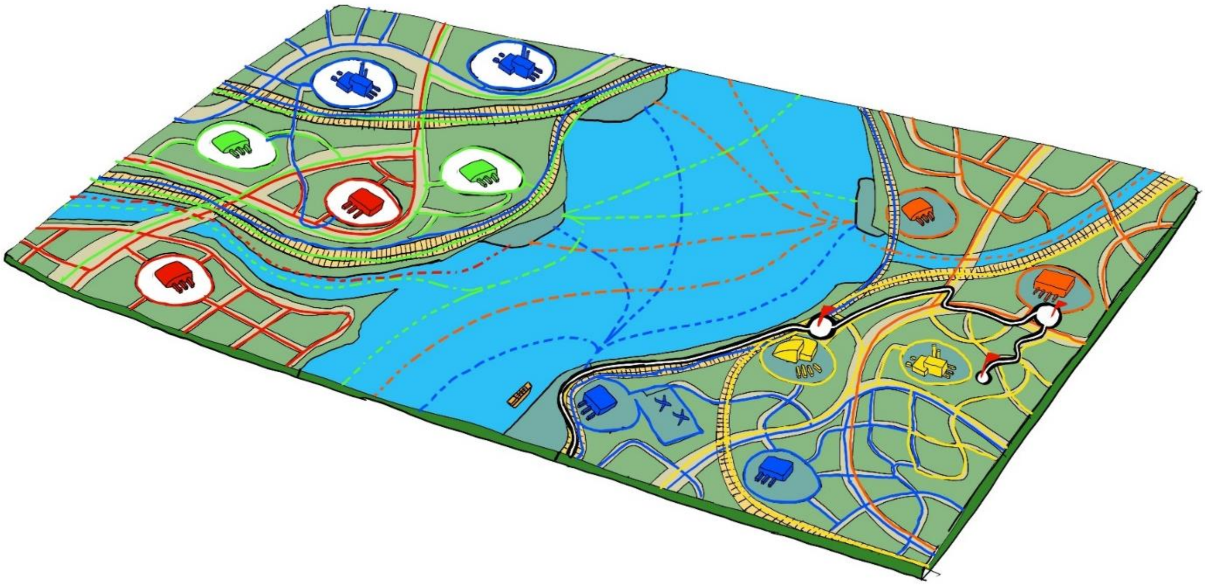
System of Logistics Networks to scale easily without creating congestion or to quickly respond to failures without significantly impacting performance.

Secure, efficient and extensible services for the flow of goods, information and finances across logistics networks



What do we want to achieve by 2030/2040?

1. Secure protocols and services are developed to ensure security, privacy and trust so logistics networks are interoperable, and resources are accessible to users and partners in the system.
2. Protocols and services designed to ensure operational efficiency of freight movement irrespective of mode, nodal operations, and freight characteristics to increase the efficiency and effectiveness of the transport and logistics systems.
3. Extensible protocols and services designed to be extended as new business models, uses, and services to be able to address the unknown future in an agile and resilient way accommodating innovative freight and logistics models.
4. Accommodating goods, information and financial flows: protocols and services designed to handle not only the secure and seamless flow of physical goods, but also the flow of information and payments in an end-to-end manner to allow users to track, analyse, contract, declare and clear goods as well as to make and receive payments.

How could the steps look like for the next five years?

1. Development of operational protocols implemented in marketplaces and/or a small number of logistics networks (starting with two independent logistics networks) for the secure management of flows over a System of Logistics Networks.
2. Deployment of layered protocol stack to facilitate common management of lanes, nodes and insertion points to ensure end-to end service consistency.
3. Continual testing of end-to-end flows across different logistics networks to improve protocols, identify gaps, and design new coordination mechanisms that will pave the way for new business models from the industry.
4. Continued development and adoption by lead service providers of the new and/or improved protocols as their formal requirement for interconnecting with other service providers.

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5. <u>Monitoring of the performance of the System of Logistics Networks to assess if the benefits originally envisioned are realised.</u>

Today major shippers, logistics service providers, and asset owners use single purpose/company dedicated assets and operations to ship and manage products in their supply networks around the corner or across the globe. Maritime shipping, where goods from many different owners travel in a consolidated way within the ship, is an exception and an example to be further realised in other domains.

The focus of these dedicated networks is on internal cost, simple control, and optimisation. Unfortunately, these dedicated networks do not focus on overall system optimisation (e.g., as flows and assets cannot be combined with other networks) and simply lead to operational inefficiencies such as empty running of vehicles, sub-optimal transit routing, higher overall costs, and generally inefficient asset utilisation. Other issues include lack of transparency, poor mode selection, limited load consolidation, congestion, poor last mile performance, and negative environmental and societal impacts. To address these issues, on top of the potentials already described in the evolution of logistics networks, it is required that a system of open operational protocols is developed so that the dedicated networks of current operators gradually become connected networks leading to system wide optimisation, load and asset balancing, and lower societal and environmental impacts from transport. This implies an important shift of mind from shippers and retailers that need to either bring more freedom to their logistics service providers or be able to connect and open access to their own logistics networks. This section of the report focuses on a preliminary discussion of how such a set of protocols might be developed leading to the outcome that is identified as the Physical Internet.

The basic operational premise of the Physical Internet is like the Internet. That premise is that simplicity, independence of technology and openness must drive all system level protocols and controls. Such a premise provides users with the opportunity to innovate without burdening them with overhead that inhibits creativity.

With respect to the PI, this premise implies that the PI only needs a small amount of information concerning the shipments that are entrusted to it for delivery to ensure their delivery. This minimal amount of information includes the destination for the shipment, information concerning the physical characteristics of the containers being shipped (weights, dimensions, special handling requirements, etc.), required delivery date, ownership (for billing and contact during transit), and any information required by regulatory authorities for the type of goods being transported (mainly for hazardous goods and goods transiting national borders). Additional Quality of Service (QoS) requirements may be stipulated depending on the exact nature of the goods being shipped and the protocols established and agreed upon (e.g., containers must not be separated from one another during shipment, expedited shipment, etc.).

The protocols to be employed by the System of Logistics Networks in the PI also should reflect the minimalist nature of the protocols employed in the Internet. While the Internet's protocols have grown more complex over the years, the PI should attempt to start out as the Internet did with an extremely simple protocol structure and allow circumstances to drive the modification of these originating control processes. As a starting point, the protocols for the PI should control how nodes forward shipments, how costs are collected, how errors and exceptions are to be handled, how end-to-end control is to be maintained, how node-to-node control is to be maintained, how congestion is to be managed, how differing physical layers are to be managed, how QoS parameters should be handled, and how users can access data concerning each of these managed activities.
Building on the premise of simplicity, an alpha concept of a protocol control stack, based on the five-layer DARPA or Internet model rather than the seven-layer OSI model, can be constructed (Figure 17).

It should be noted that the use of the five-layer Internet protocol model and the services defined in Table 1, for each layer of the model differs from previous work concerning a protocol model for the Physical Internet[72]. This variance from prior work should not be looked at as a repudiation of these efforts. Indeed, this prior work informs the current work, which is also preliminary in nature.

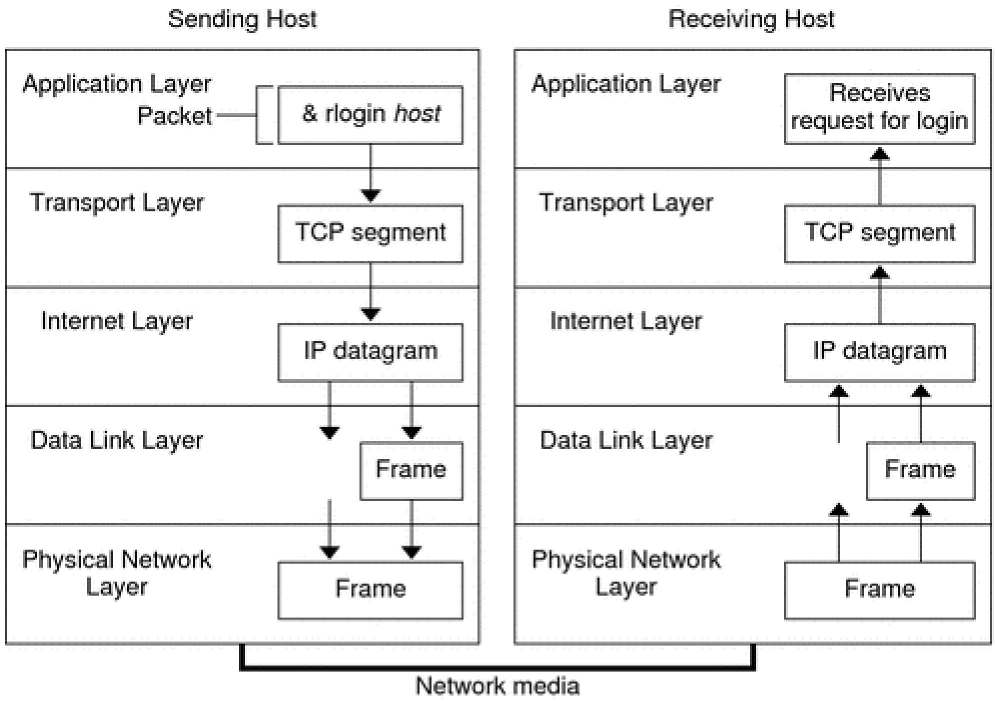

Figure 17: Internet Five Layer Protocol Stack

Table 1: Physical Internet Conceptual Protocol Stack

Protocol Layer	Description
"Application" Layer	This layer is where the actual goods are "defined" and human-readable information about the goods is created. It is in this layer that this information and these goods are prepared for transmission/transport to their destination. As with the Internet, this packet of information and the associated physical goods (the shipment) is our "message."
"Transport" Layer	At the transport layer shipments are broken up into sizes that are transportable by standard sized containers or network defined standard transport mechanisms (for goods not amenable to standard containers). In addition, the transport layer provides services that ensure delivery of the shipment and manage flows between the sending location and destination. The standard loads that are shipped out from the transport layer are our "segments."
"Network" Layer	The network layer takes the "segments" constructed in the transport layer and manages all services required to deliver these "segments" to their destination. This layer defines how all nodes between source and destination should respond to handling and controlling the goods that are in the segments. The information concerning handling and control of the segments is attached to the segment and the combination of this information and the shipment segment forms our "datagram".

[72] Montreuil, B., Ballot, E. and Fontane, F. (2012) 'An open logistics interconnection model for the physical internet', in *IFAC Proceedings Volumes (IFAC-PapersOnline)*, pp. 327–332.

"Link" Layer	The link layer takes the "datagram" from the network layer and passes it from the current node to the next node in the network. The services that the link layer provides depend on the mode of transport between nodes. The encapsulated "datagram", which includes all information on how the particular transport mode is to handle the shipment, is called a "frame."
"Physical" Layer	The physical layer of the Physical Internet moves the "boxes" between the linked nodes. The services provided are both link- and mode-dependent and depend heavily on mode, carrier, regulatory bodies, etc.

Based on the outlined protocols and the concept of simplicity, the PI is envisioned to operate in a manner that encourages use by traditional shippers, freight forwarders, and asset owners. A simple example of specific PI functioning for a transporting goods service from A to B is as follows:

1

Provide information for shipping prices according to schedule and quality of service requirements of the shipper

The System of Logistics Networks (i.e., PI when its reach is extensive and there are industry agreed procedures and protocols to be part of it) provides holistic information about the applicable prices for the shipper's loading unit from source A to destination B (e.g., through LSPs or freight forwarders portals). The information provided considers all possible lanes, carriers, paths and node prices for the different routes that are part of the System of Logistics Networks, which are available for the shipment in the given timeframe and compliant with quality of service required. The necessary data to provide this information about service prices, service levels, quality and time will be supplied by service providers, node operators and transport operators to the System of Logistics Networks.

2

Shipper decides for particular shipment quote/scenario

When the shipper decides for a certain shipment service the shipment plan will be integrated into the planning systems of the intermediaries and providers so that execution activities can be planned by service providers and the network loads are updated by lane to allow for the ongoing planning of other activities and shipments.

3

Delivery of loading unit into the System of Logistics Networks/PI

The starting point for the transport of a loading unit can either be the first Logistics Node or outside of the Logistics Network. If the location of the loading unit is outside the Logistics Network, an operator of the first Logistics Node manages the pick-up of the loading unit. Afterwards the set-up of all operators, carriers and service providers begins and the loading unit starts the journey to its destination.

4

Movement within System of Logistics Networks/PI

Moving through the System of Logistics Networks/PI, the loading unit communicates its status and interacts with the different Logistics Nodes and Networks. Each node will be notified of the scheduled arrival and will respond based on its current state whether it can accept the shipment according to its original commitment or, if insufficient capacity or an unanticipated problem has arisen, indicate that it is unable to accept the load. If the load cannot be accepted, actions described in paragraph E below will be initiated so the loading unit can continue to move seamlessly to its destination.

E

If route changes are required due to equipment breakdown, poor performance, unexpected loads, even better offers, or network re-planning processes, they will be communicated upstream in real time before the prior node sends the loading unit downstream or, if problems arise when the unit is between nodes, during transport. The prior node determines, based on data provided by the PI, whether there are alternative less congested nodes, links, or routes available that will ensure a delivery of the loading unit according to its QoS and initial cost requirements. A rerouting of the unit is possible based on a transit route reassessment through the publication of available services from nodes or subnetworks. If problems make the fulfilment of the agreed delivery impossible, the shipper will be informed and the liability of the provider identified so the shipper can decide how to proceed (similar to what happens today). According to the shipper's decision, the data will be updated in the System of Logistics Networks and the transport process can be continued.

5

Arrival at last logistics node on route

Once the loading unit arrives at the last PI node on its route, the final distribution will occur as the final delivery does for Internet packets. The last PI node is not necessarily the unit's final destination. Transport to the final destination is similar to the delivery process to the first logistics node. The last logistics node manages a certified transport of the loading unit to the delivery address with any special services such as scheduled delivery times, unboxing, or cleaning. The end of the process initiates the resolution of contracts involved, payment included.

The Digital Internet provides information and data along this by several layers like IP protocols between node management and TCP across network management

Several steps in the previous example require elaboration. First, as the PI must project future loads along lanes, integrate costs, and develop near real time estimates of changes in delivery parameters, the PI will require that certain data be stored concerning the state of the system. The location for storage of these data is assumed to be "in the cloud" for each node, links between nodes, and transport means over the links. The data can be maintained by each entity that generates the data or aggregated in some manner by a data consolidation node. However, the data is maintained, the PI will not maintain the data per se. The PI will maintain meta-data on the various entities operating within the PI and shipments traversing the PI. The entities that do maintain actual data will be required to adhere to PI protocols for data access to allow the PI to perform the forward-looking planning, cost development, and tracking functions mentioned in the example above. Much work is still required to define the numerous protocols that will be needed to operate the simple processes outlined. As each of the sections in this document evolve, modifications in how the PI will work will be required. However, at this preliminary stage of development, the outline above provides an example on how a PI could work for that specific service of transporting a unit (or a full consignment from A to B).

Generation of System of Logistics Networks

While the Physical Internet is still only a vision, there are examples today of how transport networks, and networks of transport networks work. The development of workable PI protocols, incentive mechanisms, market-places, demonstration pilots, and commercial pressures will determine whether these examples coalesce into a true Physical Internet or maybe stay at the level of Systems of Logistics Networks (i.e., different alliances of logistics networks that provide resources across them). This section discusses the current state of progress towards the Physical Internet vision and needed changes/advancements to move the vision forward from generation to generation. Benefits and value creation are envisaged in the different generations.

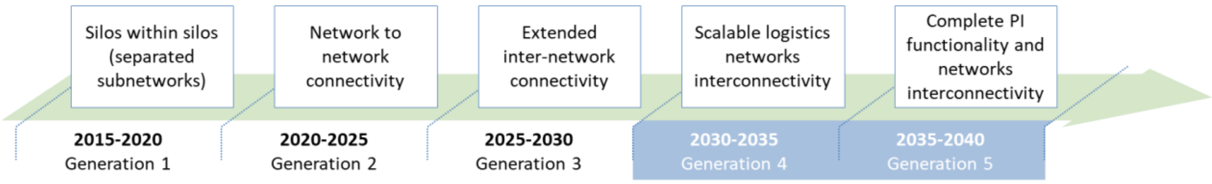

Figure 18: Overview on generations (possible development steps) for System of Logistics Networks

Generation 1: Silos within silos (separated subnetworks - current status)

The current "as is" state of global freight transport is highly fragmented with individual organisations either forced to develop their own transport networks or outsource this activity to a freight forwarder. Freight forwarders, in turn, have either developed their own global networks to manage multiple customer requirements for transport or banded together to form partnership networks in which local partners perform parts of the transport operation and then hand off the shipment to a partner organisation for further movement of the freight. Still, these global networks are not interconnected, and the goods cannot seamlessly flow across them. Asset owners, who may also be freight forwarders or shippers, generally partner with other asset owners to extend their services to different modes or regions. The complexity of these overlapping and interwoven networks demonstrates both the difficulty in moving freight on an international scale and the opportunity for rationalising linkages through the development of agreed protocols and their adoption by existing international network organisations.

Large international freight forwarders are prototypical models of what a transport Physical Intranet might look like (e.g., for more information see Logistics Network section). These freight forwarders have developed internal systems and protocols for managing the movement of freight tendered by multiple customers over networks that integrate numerous transport companies and link almost every origin and destination that a shipper could think of. The systems and protocols developed by these freight forwarders address most of the issues that the PI will need to address, but from an inwardly focused and proprietary context. Each freight forwarder can project forward general capacity along lanes, costs associated with a transport operation, delivery date adherence, regulatory requirements, etc. Their systems can track goods as they transit their networks and they can accurately bill customers for services performed. All these functions the PI will need to provide, albeit in an open, shared connected and more scalable manner.

Other network operators, such as the smaller freight forwarders and asset owners that join together in what are called groupage networks or pallet networks, parcel companies, and even large ecommerce companies such as Amazon, JD.com, and Alibaba all exhibit similar network developments to the international freight forwarders based on their need to address customer requirements for international shipments. Once more, each of these entities has developed inwardly focused and proprietary approaches to addressing these problems precluding the more open interconnection service envisioned by the PI.

The only interconnected system at international level in the domain are the state-owned postal services. The Universal Postal Union, the oldest UN agency, oversees the definition and implementation of rules for all parties involved. This system works very well across the world and is notably and widely used by Chinese suppliers to ship items sold on marketplaces all over the world. However, it also suffers several major drawbacks. It is limited to state-owned operators and a limited set of universal services not at all design to cope with the needs of businesses.

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Generation 2: Network to network connectivity (2020 – 2025)

Concrete Benefits:
Less interfaces; more consistent processing of shipments across networks; more accurate and timely information about shipments; comparability between different networks; better use of resources.

As interconnection protocols are developed over the next several years, they will enable current proprietary networks to experiment with connecting to one another or new partners. These protocols and connectors, the rudimentary precursors of what is hoped to be more robust and full featured PI protocols, should allow organisations to replace hard coded connections to internal partners with open, standards-based protocols. By experimenting with operational protocols via internal connections, organisations will be able to reduce risks associated with a protocol failure and provide valuable feedback to the technical teams on needed enhancements for the proposed protocols. In addition, these leading-edge organisations will be able to begin documenting the real benefits from collaboration further developing evidence for the PI concept.

Obviously, the work required to obtain early adopters will need the formal development, testing and piloting of a protocol stack to interconnect independent logistics networks. This will not be an easy or straight forward process as numerous entities will be involved in specifying how such protocols should be constructed, how these protocols should work, who should control their development, etc. The mechanisms for planning, costing, tracking network state, providing visibility, etc. will also all have to be roughed out so that rudimentary operations can be tested. As none of this basic structure exists today, there will be considerable work to do over the next few years to move forward with this first-generation.

Needed activities to implement this generation:

To achieve the outcomes from generation 2 discussed in the paragraphs above will require the following actions:

- <u>Funding of research into the specification, simulation modelling and piloting of the first generation of interconnected logistics networks protocols</u> for planning, scheduling, controlling, tracking/tracing, allocating, monitoring, collecting costs, and paying service providers. The mechanism design theory could help to align incentives for independent players as well as to limit data exchange between them.

- <u>Demonstrate the value of the protocols to logistics service providers</u> to obtain commitment to employ the protocols in pilots of interconnected logistics networks.

- <u>Monitoring pilots by both the service providers and the protocol developers</u> to ensure that the objectives and performance expected from the use of the PI protocols are realised.

- <u>Examination of the results of the initial pilot implementations</u> to determine the effectiveness of the protocols and a determination by commercial and governmental assessors that the protocols and the PI project are ready to move into the next generation.

Generation 3: Extended inter-network connectivity (2025 – 2030)

Concrete Benefits:
Faster integration of logistics networks and resources into the System of Logistics Networks; quicker response time; better use of resources and move to greener assets is facilitated by increased usage benefiting electric and renewable energy based assets.

Once, network operators have tested the initial protocols and provided their feedback on improvements, the protocols and attendant operational systems will be improved and made ready for actual use in inter-company network operations. Inter-company connection protocols, similar to the Internet's Boundary Gateway Protocols (BGPs), will allow companies to connect their networks with one another in "as needed" situations, reducing the need to "hard wire" connections and facilitating the ability of these organisations to create "on demand" extended networks in a manner similar to how the System of Logistics Networks would operate. Once more, feedback on how these rapid connect/disconnect operations work, on the costing, planning, routing, etc. protocols perform as well as the incentive mechanisms will allow the engineering teams to further enhance and improve the protocols needed for a fully functional PI.

Needed activities to implement this generation:

To achieve the outcomes from generation 3 discussed in the paragraph above will require the following actions:

- Extended demonstration pilots and implementation cases (geographical reach, nr. of logistics networks interconnected, variety of services provided) compared to Generation 2
- Development of gateway protocols to enable "quick connect/disconnect" actions of service providers so they can form "on demand" network interconnection activities based on user requirements.
- Encourage additional service providers to become involved in using protocols to connect to other logistics networks and resources.
- New pilots focused on the dynamic formation and execution of multi-party logistics services, demonstrating operational and business protocols and benefits from these approaches.
- Measurement and demonstration of the benefits in terms of use of resources and throughput capacity of the System of Logistics Networks.

Generation 4: Scalable logistics networks interconnectivity (2030 – 2035)

Concrete Benefits:
Sharing of resources across different networks; easy to scale and expand network interconnectivity; extended multiparty connectivity between logistics service providers; higher utilisation rates, bigger network reach; lower costs, kick off autonomous operations across logistics networks

Up to this point the protocols that will have been developed will have focused on basic interoperability and data transfer between a few network partners. Moving forward more sophisticated protocols will need to be developed to allow the simple relationships tested to this point to scale and increase in scope. During this period, work will focus on developing groupage like networks in which multiple independent transport networks are linked and the PI used to plan and execute multiple customer shipments. More robust forward planning, billing, cost accounting, routing, and control protocols will need to be developed to ensure that the scale and scope of the PI increases while customers expand their usage.

Needed activities to implement this generation:

To achieve the outcomes from generation 4 discussed in the paragraph above will require the following actions:

- Development of protocols and procedures that allow simple scalability of the System of Logistics Networks adding capabilities and services from other networks seamlessly.

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- Measurement and demonstration of the benefits in terms of use of resources and throughput capacity of the System of Logistics Networks.
- Monitoring of new pilots focused on the dynamic and scalable formation of collaborative extended multi-party networks by the service providers.
- Adoption by lead service providers and broad interconnection with other logistics networks.

Generation 5: Complete PI functionality and networks interconnectivity (2035 – 2040)

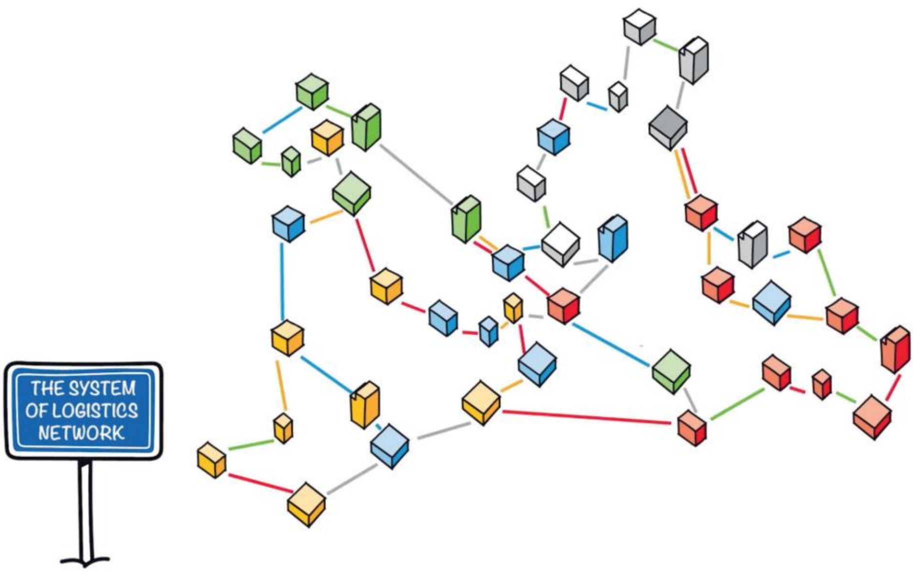
Concrete Benefits:
Plug-and-play connectivity for users and providers; seamless access to PI; new networks can become part of PI or leave PI any time;

The "final" stage of PI development will occur with the full rollout of the PI. This period will see all PI functionality, that originally envisioned, modified, and added over time, made available to users. Global systems of logistics networks will be interconnected, and services will be provided on top of them. Full protocol stack services, incentive mechanisms, reporting processes, cost control, planning, billing, and exception handling capabilities will have been matured to a state where operational concerns are minimised. Additional functionality will continually be added and enhancements to operational services will continue to be made. At this point in time the maturity of the PI will be such that an accurate appraisal of its real impact on the environment and society can be determined and its operational benefits understood.

Needed activities to implement this generation:

To achieve the outcomes from generation 5 discussed in the paragraph above will require the following actions:

- Enhanced protocols and systems to allow plug-and-play connectivity between logistics networks.
- Standardise and well-functioning protocols to join or leave the systems of logistics networks (i.e., the PI) at any time. This may involve publishing and opening access to specific services or fully connecting or disconnecting.
- Ongoing monitoring of the performance of the PI to ensure that the benefits originally envisioned are realised.



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2.4 Access and Adoption

This area describes the main requirements to access the Physical Internet through a logistics network. It also includes different steps and mind shifts required to adopt Physical Internet concepts.

In current practice, we see relatively small networks exist with a limited scope of activities (pooling of cargo, limited to sectors, etc.). Many companies are not able to organise networks on their own or get access to existing networks. This especially is true for SMEs. For big companies, still there are many silos in terms of access to services and offerings.

One of the main objectives is to show companies within their current business setting that cooperation, even with competitors in logistics, is not only a good idea but it is also easy to execute and implement directly or through logistics service providers. It is also important to help companies to make first steps in this respect. There are new ways of sharing assets, services and resources between stakeholders in vertical integrated supply chains and in horizontal collaborative networks.

Platforms are evolving fast and the need for further integration of networks is already clear and not alien to logistics. It is important to develop mechanisms to support companies in defining their role and their business model in a connected society.

This requires insight in new business models, easily accessible tools that enable integration in networks, new skills for personnel that is able to understand the access to new forms of integrated networks in the logistics sector.

A mind shift towards an easy accessible, non-discriminatory PI

What do we want to achieve by 2030/2040?

1. Easy, secure and trusted connection to global logistics networks and System of Logistics Networks to all users, including SMEs. Low threshold plug and play access points to logistics networks are available.
2. Logistics Service Providers and Freight Forwarders are willing to collaborate in the formation of systems of logistics networks with standard procedures and protocols making it easy for them to access pooled resources and capabilities.
3. Stakeholders in main logistics hubs pool their services and resources into Logistics Nodes platforms.
4. Shippers and retailers move from dedicated supply and logistics networks services to shared supply networks clearly defining service level and quality agreements and giving more freedom to LSPs in the execution of logistics operations (so they can organise the usage of the assets).

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5. A clear framework of benefits for every stakeholder in the supply chain which makes sure that adoption of PI makes business sense and contributes to societal challenges such as climate change.

How could the steps look like for the next five years?

1. Identification and development of digital access points to Logistics Nodes, logistics networks and System of Logistics Networks (including SMEs).
2. Demonstrate the benefits of building Physical Internet capabilities at company and logistics network and governmental levels.
3. Show the benefits to shippers and retailers of going beyond dedicated and proprietary logistics solutions.
4. Realise education and training programmes for logistics professionals on network integration, shared resources and capabilities and pooling of goods in real business practice.
5. Develop advanced simulation tools and models to visualise how operations, roles and governance models could look like.
6. Broad advocacy and pioneering companies in each logistics function moving to PI functionalities.

It is important that all stakeholders further define and elaborate the Physical Internet concept, see the potential benefits and realise them in practice. The benefits will become clearer and clearer as more examples of cases of sharing assets, vehicles, warehouses and infrastructure are implemented. Therefore, the burden to understand basic PI concepts needs to be reduced. There is a great need of modelling and visualisation of PI, which in each generation has different requirements.

The roles will evolve as the concept is implemented and will be taken by current or new stakeholders. Logistics service providers, for instance, will operate their network making use of suppliers' resources and eventually resources from other networks and will develop the capability to manage pooled customers' demands to increase efficiency. This will require sophisticated ways of organising flexible operations within and between networks. The ports and hubs in PI will have an advanced role, being able to provide services answering to the demands pooling the services of the stakeholders integrated through them. The user perspective will also change as the shipper will rely on PI services to organise the route and mode of a shipment according to their requirements, instead of being in control over the shipment all the time. As the role of companies will change, the role of professionals within these companies will change as well. Last but certainly not least, mind shifts are needed as described in the table above. This will gradually take place when moving from generation to generation. Additionally, each generation requires new skills from logistics professionals.

The realisation of the PI will require the following:

- A mental shift is needed at different levels:
  1. from *retailers and shippers* so they rely more on the capabilities of the logistics service providers and freight forwarders being less prescriptive and demanding of dedicated assets, services and infrastructure in the way the services are delivered with emphasis in service level and quality,
  2. *logistics service providers and freight forwarders* to openly give access to services and rely on services of other logistics networks to build on their capabilities, assets and resources defining common and standard processes that could facilitate interoperability of services and networks and,

3. From *people to ease cooperation among humans and autonomous systems* in logistics, defining the roles for each of them. In relation to the latter, the development of the autonomous handling of goods, the definition of functions and services of hubs are topics of interest and to be further developed under the area of Logistics Nodes.

- There is a need to increase education and skills related to Physical Internet concepts such as serious games, models, and simulation tools to communicate the functioning and benefits of shared logistics networks providing services for pooled demands (i.e., the Physical Internet).
- New theories, mechanisms and practical examples need to be developed on how to build trust among partners and users of shared networks, platforms, collaborative and autonomous systems

Generations of Access and Adoption

Generations define possible evolutions towards PI and can be scenarios or parts of PI-like implementations.

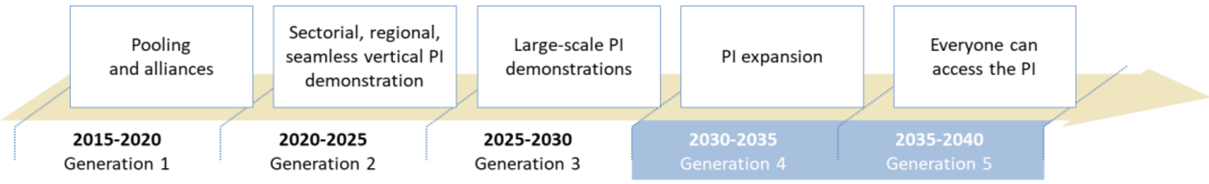

Figure 19: Overview on generations (possible development steps) for Access and Adoption

Generation 1: Pooling and alliances (current status)

The logistics sector is currently showing first signs of network integration. However, the larger part of the sector is still organised in vertical supply chains which operate independently from each other and still with many interconnectivity barriers with suppliers and customers. Stakeholders within a chain cooperate based on existing operational contracts, they act independently from each other with a minimum of information sharing. The coordination function within supply chains is fragmented and differs among different chains. At the professional level we see a wide awareness of the need for cooperation. However, trust and sharing of information are still barriers to achieve further integration.

On the operational level, pooling of resources and alliances exist and are based on non-commercial incentives. For instance, alliances of transport companies exist because individual companies cannot deliver full geographical coverage or pooling of employees is triggered by scarcity in the labour market.

The benefits of cooperation within the logistics sector at this level is, that companies can provide a better coverage with higher efficiency. For shippers this leads to higher reliability in the supply chains. Where sufficient scale is achieved an upfront decision can be made to use other modes of transport than truck.

Generation 2: Sectorial, regional, seamless vertical PI demonstration (2020 – 2025)

Concrete Benefits:
Increased connectivity for all stakeholders within a vertical supply chain or a logistics network; Better understanding of operational benefits through evidence based vertical integrated supply chains

In generation 2, a better connectivity within a vertical chain or a logistics network will be achieved. Better information sharing between logistics chain stakeholders leads to better forms of optimisation. However, this is still based on vertical integration, network integration is still only seen on a regional scale. Asset utilisation optimisation is a common practice within vertical supply chains and logistics networks.

The level of IT infrastructure and architecture leads to the benefit of seamless sharing of information between stakeholders on an end-to-end basis. The realised scale of regional cooperation leads to increased efficiency but also to the opportunity to make use of other modes of transport.

Logistics networks providing end-to-end supply chain coordination and execution will exist reaching a higher level of integration within specific tiers in the supply chains. On the operational level, LSPs will provide a more integrated service covering more stages in the supply chain. Sustainable partnerships with long-term horizons will exist.

The value of cooperation is widely acknowledged within the sector, which is demonstrated in the increasingly intrinsic motivated managers working on closer collaboration within the specific supply chain setting.

Needed activities to realise this generation:

- Realisation of convincing business cases including revenue models, gain sharing and description of different stakeholders' roles. These models should be based on further vertical integration and optimised supply chain execution within a chain.
- Mapping of potential and available access points in Logistics Nodes or through logistics networks.
- Realise visualisation and simulation models and tools to understand the practical use of PI for different stakeholders and to show the potential benefits based on actual cases. These models should first build upon the existing and more advanced forms of vertical integrated supply chains but should also be able to provide an outlook for each stakeholder facing transition in Logistics Nodes and networks.
- Setup education and training programmes to prepare people for PI (e.g. using gamification for education), keeping in mind that the knowledge provided can be adopted in current day-to-day practice. Many games and education materials are available, these should be evaluated and brought together. It is important to set up programmes to achieve a wide 'audience' of professionals in the sector.
- Develop plug & play tools for system integration and connectivity, based on more standardised forms of information sharing, making access to sectorial or industrial networks easier for SME's.
- Provide an overview and common understanding of legal frameworks and regulatory barriers for the setting of integrated vertical collaboration as well as synchromodal networks and systems of logistics networks.

Generation 3: Large-scale PI demonstrations (2025 – 2030)

Concrete Benefits:
Clear operational synchromodal benefits for integrated supply chains are defined. Easy-to-adopt decision support tools for integrated vertical supply chain planning and first demonstrators of operational systems of logistics networks.

In the third generation of access and adoption, knowledge and visibility of supply chains are realised with broader vertical impact (Logistics Networks) and kicking of the first examples in practice of systems of logistics networks. Not only end-to-end visibility is widely adopted, but for instance decision support for use of mode is readily available. Data sharing between supply chain stakeholders and between modes of transport has become common practice. Network integration exists within specific sectors of industry, which implies the existence of horizontal collaboration or systems interoperability between sectorial supply chains.

The integration and collaboration between logistics networks lead to a wider scale, which leads to more efficient decision making based on larger volumes and that are consolidated and resources and capability to serve the demand. The benefits are that model shift can be realised for a larger pool of supply chains. In this generation we will see operational synergies with significant impact on CO2 footprint of supply chain activities. Asset utilisation will be a common objective and moving towards real asset sharing between supply chain stakeholders. Shippers will deal with more reliable and flexible logistics systems.

The role of supply chain stakeholders will change as shippers are open to share assets and resources to deliver their products and logistics service providers are able to coordinate flows of goods from different customers over several networks within industry verticals.

Personnel and organisations are sharing best practices without barriers. Supply chain professionals are sector specialists that move between several supply chains and see synergies outside the boundaries of their organisation.

Needed activities to realise this generation:

- Successful demonstration of connected and integrated networks within a multimodal setting or multi-tier vertical integrated network, based on an end-to-end scope of operations
- Further harmonisation and digitisation on sectoral level that enables the further integration of networks.
- Education programmes for students and professionals covering cooperation skills which are needed in further integrated vertical or multimodal networks and first realisation of logistics networks interconnectivity.
- Easy to use and embedded/integrated gain sharing solutions in operational systems that are trusted by network participants. This includes the successful long-term operational demonstration of these models, also considered scenario's for entry or exit of partners.
- Decision support tools enabling multimodal – multitier route analysis, including new sets of KPI's that are relevant for different settings of integrated networks.

Generation 4: PI expansion (2030 – 2035)

Concrete Benefits:
Cross-network analysis and integration tools; entry- and exit-strategies for actors; possibilities to share assets, personnel, capacity within horizontal integrated supply chains.

International reach and multisectoral horizontal and vertical integration characterise the fourth generation of access and adoption in which logistics networks are fully integrated with full capability to manage own resources and assets and access to external services in an open and standardised way. Opportunities for economies of scale in integration with larger volumes enabling the optimal use of all transport modes and logistics locations are fully utilised. Standardisation of assets, protocols and procedures as well as practices and data communication are standardized unifying operations and eases network integration and flexible and agile logistics solutions can be realized. Governance reaches beyond sectors enabling and safeguarding the operation of the multi-sectoral Physical Internet.

With wide access and adoption, synergies between sectors are fully validated. The efficiency of the Physical Internet is now evident. There is a seamless flow of information and finances across chains, modes and sectors and maximal asset sharing between actors in multiple chains; shared infrastructure, shared warehousing and shared moving assets.

Logistics Service Providers are part of and operate the Physical Internet based on standards and protocols and shippers provide shipment scenarios. The assignment of operators is a logical outcome of the information and options within the own resources and services and with those made available through the Physical Internet. Actors are functioning as networked organisations within the Physical Internet, collaboration following the tasks of shipments, flexibly changing under all circumstances. Employees at all levels are comfortable with this agility and have the skills of network professionals.

Needed activities to realise this generation:

- Successful European demonstration of scalable models to organically grow systems of logistics networks (i.e., various connected networks are extended in a scalable and seamless way)
- Development of training and skills to be part of networked organisations and to autonomous and self-organising systems.
- Further standardisation of assets and data sharing possibilities for plug and play connectivity.
- Monitoring of performance of the Physical Internet is available and transparent.
- Cross-network calculations and modelling, adaptive to entry-exit strategies.

Generation 5: Everyone can access the PI (2035 – 2040)

Concrete Benefits:
Open access to PI network, leading to autonomous optimal re-allocation of goods and assets between networks; adoption of PI is embedded in professional's way of working and plug-and-play connectivity is available for all.

In generation 5, the Physical Internet is fully accessible and widely adopted. Here, all logistics modes and services can be combined by main logistics service providers operating the Physical Internet and are accessible to users of the Physical Internet.

The Physical Internet is enabled by a unified digital data network building on the federated network of platforms concept (DTLF). This provides information and data along several layers like IP protocols between node management and TCP across network management. The loading unit is connected to the network and moves through the different nodes, interaction facilitates continuous route reassessment in case of disruptions or optimisation opportunities. The full efficiency potential can be met.

Needed activities to realise this generation:

- Plug and play connectivity for all type of stakeholders and for all type of purposes.
- Accepted governance structure able to provide for trusted monitoring of solutions.

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2.5 Governance

Governance includes the developments needed to evolve the Logistics Nodes, logistics networks and the System of Logistics Networks into the Physical Internet, i.e., the rules defined by the stakeholders forming or using them as well as the trust building processes and mechanisms.

There are different approaches to define the Physical Internet governance:

- A bottom-up approach where Logistics Nodes, networks and systems of logistics networks develop their own governance mechanisms, growing and progressing in an organic way. Companies and consortia develop governance for their networks and convergency is created as the models are advancing. This could lead to the creation of islands or subsets of Physical Internets with their own standards and protocols. The challenge arises when these islands touch each other, and standards appear to be different or even if they stand alone as competitive alternatives providing PI-like services but without a global reach. Therefore, a central body constituted by representatives' stakeholders of the different subnetworks will take care of harmonising the basic PI principles, governance rules and standards addressing regulatory and other barriers identified in the process.
- A top-down approach where there might be two options:
    - Public lead. A central body plans and organises the Physical Internet under the supervision of governments that consider transport and logistics as a universal and public service/infrastructure, even if services are provided by companies in a fully regulated framework. This approach would require a strong public-sector action at European/global level, supported by massive investments, to enforce standards and ensure that market competition rules are not infringed. Although this is not likely to happen/necessary, addressing climate change might require concerted actions and public intervention if companies are not able to deliver enough emissions reductions. Moreover, some countries are developing infrastructures and supporting logistics stakeholders to join semi-public platforms that could steer the creation of this public lead initiative.
    - Industry lead. Big corporations integrate with each other's and/or build strong logistics networks capabilities that afterwards open to other stakeholders as a service. These digital logistics platforms can deliver services to all type of companies and users up to end consumers making, and organising use of their network and partners resources and capabilities. More details on potential development scenarios are described by Dans (2019)[73]. In this scenario, it is also likely that either there are different Physical Internets like networks with dominant players or there are certain rules established among these big players and respecting competition rules reaching to a Physical Internet.

The bottom-up approach is considered as the only viable one for organic growth of the PI, as it will ensure a more gradual and business-driven creation of the Logistics Network. It is also the approach

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

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that mirrors the PI progressive evolution through the generations as explained above and that we can envision for the moment. It is also likely that other forms of governance appear (e.g., mixed models compared to the ones described above).

Governance concept, bodies, rules and trust building measures

Rules of "co-operation" for the different companies need to be defined and agreed on. These rules need also to include service level agreements, define shared quality of services, liability and payment. Even if PI is aiming towards a seamless network, within the network, different paths and routes will be used based on individual requirements. Within PI the service level is not only the lead-time but a set of requirements on lead-time, allowed containers, temperature, shocks, reception by consignee, etc.

What do we want to achieve by 2030/2040?

1. Governance processes for different layers/areas (system, data, operations...), comprising both centralised vs. federated governance models, to establish a trustworthy business ecosystem.
2. Implement rules for letting the network open, favouring bottom-up development with the support and supervision of public bodies (EC) in high-level governance (following the 4G and 5G example), to ensure participation in networks of all types of stakeholders: large companies, SMEs and public authorities.

How could the steps look like for the next five years?

1. Mapping and analysis of governance models of current asset-sharing networks in freight transport and logistics (postal, pallet networks, groupage networks, etc.) and in utility sectors (telecommunications, energy) their forms and business models as well as possible pathways for adoption and or scalable models.
2. Definition of harmonised terms and rules for vertically integrated networks that are scalable to easy integrate external stakeholders.
3. Definition of asset-sharing, service access and competition rules in systems of logistics networks.
4. Definition of governance processes and body for defining the rules, addressing barriers and support companies willing to move to open, shared and connected logistics networks.

A proper governance structure will ensure a "network of networks" approach, building on existing (private) networks and freight transport and logistics services offering. A good governance ensures that:

- The Logistics Nodes/logistics network/System of Logistics Networks evolution is managed cooperatively, ensuring that all involved organisations are properly represented in decision bodies on the network extension and on the update of rules, agreements, and governance structures.
- The System of Logistics Networks is open to all types of organisations (shippers, LSPs, services providers), based on shared rules and protocols for operations which companies need to agree upon and fulfil.
- Service levels are defined, and their accomplishment is mapped to ensure that basic quality-of-service standards are met/delivered by/to all participants.
- Routing of cargo through the network and service assignments are managed transparently according to common agreed rules, to ensure fair allocation of costs, risks and responsibilities among the involved providers.

The **main challenges** to be addressed to meet these objectives concern two key aspects of governance: the governance approach to be taken, i.e., top-down or bottom-up (or a combination) definition of the governance structure and rules, and the governance scope, i.e., on which topics should research and innovation activities be focused in the short-, medium- and long-term horizon. Concerning the topics' focus, discussion within the PI community in several workshops and occasions has led to identification to some key activities foreseen for each of the planned PI generations (see "Needed activities to realise generation" in next Section).

Generations of Governance

Generations define possible evolutions towards PI and can be scenarios or parts of PI-like implementations.

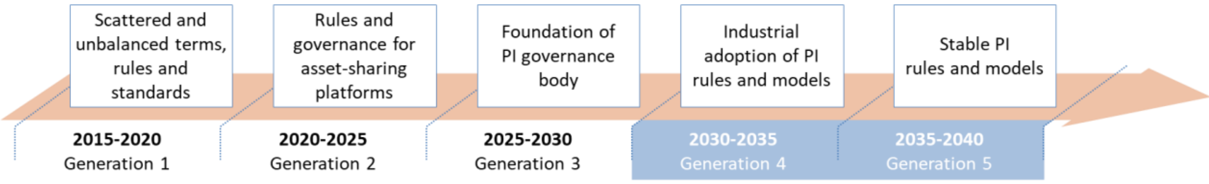

Figure 20: Overview on generations (possible development steps) for Governance

Generation 1: Scattered and unbalanced terms, rules and standards (current status)

The current state of play concerning governance of Logistics Nodes, logistics networks and Systems of Logistics Networks is characterised by a scattered and unbalanced set of terms, rules, standards and regulations (see logistics networks chapter). There is not yet a harmonised reference agreed governance framework. However, the Digital Transport and Logistics Forum is developing governance models for the creation of a federated network of platforms that could indeed be a seed for a potential Physical Internet governance structure.

On the horizontal collaboration side, some pilot projects have been under development in the last decade. In all such cases, governance has been relying on one-to-one cooperation agreements between individual shippers, ad hoc designed and studied by law firms and consultant teams. Some research initiatives have been piloting "trustee" business models as collaboration facilitators. Still, these models are based on one-to-one mediation and thus are difficult to scale-up and extend out of the initial group of shippers.

Currently, digital ecosystems and collaborative platforms are experiencing these challenges too and legal frameworks are lacking.

Similarly, vertical cooperation and integration along and across supply networks are hindered by the existing contractual and regulatory frameworks. Long-term contractual frameworks on supply chain level prevent opportunistic sharing of load units and transport capacity on the go. More open contracts need to be available to make use of flexible fulfilment (mode, lead time, etc.).

Generation 2: Rules and governance for asset-sharing platforms (2020 – 2025)

Concrete Benefits:
Simplified, easier and safer asset-sharing on existing platforms, thanks to specific rules setting services providers liabilities, security, and documentation standards.

In generation 2, a limited initial first step will be taken towards a shared governance framework for interconnected networks. These initial Logistics Networks will emerge from the existing asset-sharing or service platforms that are currently growing and developing their business models, see VINTURAS[74] for example.

As a result of generation 2 development, the current services and asset sharing networks' governance structures and organisational models will be studied, understood and shared across the logistics industry community. Multilateral or individual to ecosystem contracts will be developed. As such, they will constitute a first concrete example of reference common terms for sharing assets and logistic services across different supply networks.

In generation 2 the business models of assets-sharing platforms will be addressed complying with regulations on EU level. In particular, anti-trust regulations will have to be addressed and other potential regulation barriers will be clearly identified. Common rules concerning shippers and logistics services providers' liabilities, security and documentation standards, as well societal and environmental aspects of these platforms will be developed.

Evolution from the current ad-hoc trustee-based models is expected, leading to a replicable set of rules and tools addressing all aspects of asset sharing, from mutual liability to gains redistribution.

Needed activities to realise this generation:

- Mapping and analysis of current asset-sharing networks, their forms governance models.
- Identification of potential regulatory barriers to implement flexible schemes, synchromodal transport procurement practices access to shared assets and services, transactional aspects dealing with stockholding and inventory positions and other use cases defined in this document.
- Definition of harmonised rules for integration of customers and suppliers in open logistics networks and Logistics Nodes such as ports and airports.
- Consensus on core rules for individual platforms' addressing, e.g.: administration, expansion, liability, security, sustainability, anti-trust.
- Rollout of the Digital Transport and Logistics Forum governance model application to Physical Internet networks.

Generation 3: Foundation of PI governance body (2025 – 2030)

Concrete Benefits:
Raise consensus and pool interest on the Physical Internet development and governance definition. Growth of vertically integrated intermodal logistics networks thanks to harmonised terms and rules.

In generation 3, a step forward will be taken towards vertical integration of different services, capabilities and resources in logistics networks. The governance structure will be defined by the organisation in control of the logistics networks and in agreement with customers and suppliers. Harmonised terms and rules for vertically integrated synchromodal logistics networks including sharing of transport and warehouses will be developed.

The ratification and adoption of the Rotterdam rules is expected, i.e., United Nations Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea[75]. The still-unratified Rotterdam rules will facilitate adoption of collaborative management of intermodal transport,

[74] https://www.vinturas.com/
[75] https://www.uncitral.org/pdf/english/texts/transport/rotterdam_rules/Rotterdam-Rules-E.pdf

simplifying and harmonising management of liabilities and of carriers-shippers' relationships along the chain.

Additionally, a body for the definition of the System of Logistics Networks governance will be created.

Needed activities to realise this generation:

- Research on scalable governance models for growing systems of logistics networks.
- Create an open association as the initial PI governance body to define governance, rules and protocols for shared and connected logistics networks forming systems of logistics networks.
  - Definition of governance functions: what needs to be governed on different levels (standards, contractual, operational, etc.) and how (monitoring, enforcement, self-regulation).
  - Involvement of public and private stakeholders, definition of roles and rollout roadmap.
  - Definition of governance structure and stakeholders with respective functions and responsibilities. In particular, the issue of centralisation will be addressed, identifying which functions will be addressed by a PI governance framework.
  - Identification of potential regulatory barriers for advanced generations
  - Learn from existing networks, such as electricity or communications. For example, how revenue distribution is organised in energy consumption and how the governance is arranged.
  - Define what data should be shared and how, so that all parties are able the create value.
- Rotterdam rules ratification.

Generation 4: Industrial adoption of PI rules and models (2030 – 2035)

Concrete Benefits:
Growth of integration across different supply chains and systems of logistics networks generation, thanks to commonly accepted asset-sharing rules and business models, protocols for connected logistics networks.

In generation 4 the governance framework will be extended to support scalable governance models to increase the reach of existing systems of logistics networks. The boundaries between vertically integrated supply chains will be removed through mutual agreements between leading shippers and logistic services providers generating systems of logistics networks. This will allow asset sharing and route planning and re-planning of shipments through Logistics Nodes belonging to different networks.

Also, generation 4 will address the issue of unexclusive participation of shippers and logistics services providers to multiple Logistics Networks, enabling future transition towards more open Logistics Network configurations. To this purpose, the PI governance framework will have to consider socio-economic impacts of asset-sharing, especially on fair competition and anti-trust issues.

Needed activities to realise this generation:

- Scalable organisational models and rules for asset-sharing in systems of logistics networks (unexclusive participation, mutual liability, gain sharing, fair competition, antitrust, ...).
- Definition of governance architecture: some key aspects could be driven/controlled by a global organisation (e.g. association created in generation 3), but in other areas governance could also be distributed over the network.

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Generation 5: Stable Physical Internet rules and models (2035 – 2040)

Concrete Benefits:
Sustained growth of PI network(s) thanks to globally established rules framework and governance bodies.

In generation 5 the governance framework will be fully designed and implemented, including all required governance processes and a well-established body for defining the rules and addressing barriers for establishing shared and connected logistics networks building the Physical Internet.

The generation 5 governance framework will cover all relevant business and regulatory aspects that must be addressed to make Logistics Network nodes and services available to the global business community, including:

- Establish PI governance in a global context.
- Identification of global regulations incompatibilities as barrier of the PI development

Needed activities to realise this generation:

- Governance processes for different layers/areas (system, data, operations), comprising centralised vs. federated governance models.
- Implement rules for letting the network open, involving public bodies (EC) for specific rules in high-level governance (following the 4G and 5G example).

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3 Recommendations

In this chapter, recommendations towards relevant stakeholder groups are provided. The stakeholders group targeted are:

The Quadruple Helix (Carayannis & Campbell, 2011) Roadmap Towards Zero Emissions Logistics 2050. ALICE (2019) www.etp-alice.eu

3.1 Recommendation for Companies

Topics	Activity description	Main actor	Required public-private cooperation
System of Logistics Networks	Definition of plug and play collaboration, business and service models for connected and shared logistics networks.	LSPs	Carriers, Manufacturers, Retailers, R&D
	Definition of governance processes, bodies and rules for open global logistics networks.	LSPs, Forwarders, Carriers	R&D & Government
	Publish mechanisms and practical examples on how to build trust among users of shared networks, platforms and collaborative systems.	LSPs, Forwarders, Carriers, Shippers	R&D
	Plug and play access to logistic networks based on standard processes and services.	LSPs	Shippers
Nodes	Open publishing of nodes capabilities and services for easy booking.	Ports, airports, warehouses and logistics platforms	Transport carriers
Standard setting and adoption	Expansion and adoption of standardised modular boxes and packaging units that are used everywhere by all type of stakeholders.	Shippers (Manufacturers & Retailers)	LSPs
	Identify regulatory barriers for fully autonomous Logistics Network services and operations.	LSPs, Forwarders, Carriers	Shippers, R&D, Government
	Implementation of flexible contracts giving freedom for design and operation of multi-modal transport networks to avoid fixed specifications for routes, modes, inventory locations and timeslots.	LSPs, Forwarders, Carriers, Shippers	R&D
	Seamless modal transhipment processes and technologies	Cargo handling companies	R&D, intermodal terminals, transport modes

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3.2 Recommendations for Government

Topics	Activity description	Main actor	Required public-private cooperation
Rules & policies	Explore the development of supportive rules and policies that allow collaborative and shared logistics networks to function.	European Commission	Companies and their associations
	Implement European wide frameworks and standards for data-sharing and electronic transfer of freight documents (eFTI and beyond).	European Commission	Member States, Companies and their associations
	Integration of Physical Internet as an integral part of the European mobility system.	European Commission	

3.3 Recommendations for Research & Development Partners and Academia

Topics	Activity description	Main actor	Required public-private cooperation
Identification of impact	Further investigate the economical and societal impact of PI.	R&D	Government
	Document the performance of connected and shared logistics networks and compare to actual forecasted performance.	R&D	Companies
	Identify increases in resilience of the freight transport and logistics systems using PI concepts.	R&D	Corridors, Infrastructure Managers
Technology development	Develop rapid electronic data interchange translation tools available to all.	Technology Centres, IT R&D	Companies
	Development of reference IT architecture, layered protocol stack and operational protocols for the secure management of all flows, lanes, nodes and insertion points over logistics networks.	R&D	Companies and Government
	Address physical interoperability barriers between manufacturing end of line, the family of modular load units from boxes to (intermodal) containers and intermodal transport & transhipment	R&D	Load units pools, logistics handling equipment and transhipment

3.4 Recommendations for Civil Society

Topics	Activity description	Main actor	Required public-private cooperation
Training and awareness raising	Promote the net benefits of the PI based on the concept of the triple bottom line: people, planet, profit.	Civil society	Government, Companies and their associations
	Realise education and training programs for logistics professionals to increase the level of network integration skills in real business practice.	Training and Education providers	Companies and their associations