Roadmap to Physical Internet

BACKGROUND DOCUMENT WORKSHOP ALICE/SENSE IPIC 10TH JULY 2019 8.30 – 10.30

Activities performed in the frame of SENSE *"Accelerating the Path Towards the Physical Internet".*
The SENSE project has received funding
from the European Union´s Horizon 2020 research and innovation Programme under grant agreement No. 769967

ALICE/SENSE PI Roadmap Workshop

The project SENSE: *Accelerating the Path Towards the Physical Internet* has received funding from the European Union´s Horizon 2020 research and innovation Programme under grant agreement No. 769967. ALICE is coordinating SENSE project and one of the main aims of it is to develop an industry driven roadmap towards physical internet realization. It should anchor on the short- and medium-term benefits that Physical Internet concepts may bring to logistics stakeholders.

This roadmap is expected to have a solid link with current market state of the play and define the paths in which the Physical Internet should be developed. Therefore, the roadmap needs to be recognizable by industry but also a source of inspiration for the research and academic community.

In this session, chaired by ALICE, we will share and discuss the main elements of the current draft roadmap with the Physical Internet Community and will gather your feedback that will define the main pathways of development and support for ALICE Accelerating the path towards the Physical Internet.

Any Comment or Contribution to this document is always welcome at fliesa@etp-alice.eu and andreas.nettstraeter@iml.fraunhofer.de

Content:

1 The Physical Internet (PI) Concept and the role of SENSE project

The concept of PI aims at realizing full interconnectivity (information, physical and financial flows) of several (private) freight transport and logistics services networks and make them ready to be seamlessly usable as one large logistics network. The seamless physical, digital and financial connectivity of the logistic networks will include transport, storage and physical handling operations of load units like containers, swap-bodies, pallets, boxes, etc. The barrier for becoming part of the network giving access to private services and resources and the use of the resources and services available in the PI network should be very low. In the long term, plug and play connectivity will be offered to supply chain stakeholders by the different network operators and service providers. Full visibility and management of supply chains for each player according to its operations will be ensured.

1.1 Why do we need the Physical Internet?

- Emissions from freight transport and logistics are still growing, despite combating climate change being a clear international priority. Transport is currently the 2nd major contributor to climate change. Cities recognise problems caused by freight transport and logistics such as air pollution, noise, and congestion. As a result, many cities are regulating to protect urban environments by implement stricter access regulations and vehicles standards. They are having to strike a difficult balance between maintaining the life blood of the city - the accessibility of goods and services and the quality of life of the inhabitants.

- The development of green vehicles, trains, barges and ships; and the supporting technologies which enable more environmentally friendly transport fleets deployment, is currently forecasted to be too slow to hit our climate change targets

- Logistics companies, manufacturers and retailers are struggling to deliver emissions reduction whilst remaining competitive and ensuring proper access and value to their customers and the society. Low profit margins combined with the high cost of low emission technologies make investment challenging. As the fight against climate change becomes more of a priority the commitment and pressure is rising on the logistics industry to take action.

- There are large opportunities for efficiency gains in freight transport and logistics through better use of assets, such as trucks, railways, warehouses and barges and reducing fragmentation, which stifles innovation and the prevents the massive deployment of highly efficient and productive logistics networks.

- One source of solutions to these challenges is the *Physical Internet*. The idle capacity of the assets could be better used if it could be open, available and accessible for the stakeholders in the logistic chain. For that, freight transport and logistics services need to be interconnected allowing a more flexible use of the resources, cargo consolidation and routing.

- One of the initial studies on the impacts of the physical internet[1], based on simulations of logistics of top French retailers Carrefour and Casino, and their 100 top suppliers, showed that moving to "*Physical Internet Model*" could:
  - shift 50% of goods transport from road to rail,
  - cut costs by 32%,

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

- reduce greenhouse gas emissions by 60%.

1.2 The Role of SENSE project

SENSE project aims at translating the Physical Internet academic vision into an industry roadmap in which shorter- and longer-term benefits in terms of productivity and efficiency can be realized. SENSE is building consensus on different generations and short-and longer-term evolution of freight transport and logistics having in mind physical internet concepts. It is expected that the increase of efficiency and productivity that these next generations will deliver the savings supporting companies to pay for the required asset transition required (i.e. from current vehicles and technologies to greener ones).

SENSE is mapping different projects, industry initiatives and start-ups heading into physical internet concepts. Through SENSE, ALICE is gathering these initiatives and creating a knowledge platform (https://knowledgeplatform.etp-logistics.eu/) that will serve to all interested stakeholders to access latest developments on the physical internet. For the moment, around 100 start-ups and projects have been identified and are being analysed.

These initiatives are linked to the different defined generations in the roadmap, so examples and some business cases are already included in the roadmap description and broadly shared. The aim is to speed up, the take-up and implementation of the concepts.

SENSE and ALICE will share these developments with all participants of the International Physical Internet Conference to be held in London from 9th to 11th of July (www.pi.events).

ALICE will run a workshop on the 10th of July to share and discus the latest version of the roadmap, the envisioned generations and identified linked initiatives and use cases. The Physical Internet knowledge platform will be launched in London. Looking forward to meeting you in London!

2 Roadmap to the Physical Internet

The SENSE project developed a Physical Internet roadmap summary (Figure 1) to explain the development of PI in the next years. The PI matrix shows the development path of five specific areas for the Physical Internet:

1. **PI Nodes** - Roles of and operational model for physical nodes;
2. **PI Network Services** – PI protocol stack and network management;
3. **Governance** - Governance concept, bodies, regulations and trust building measures;
4. **Access and Adoption** – Benefits of PI and mental shift towards PI
5. **System Level Functionality** - PI architecture, building blocks and information exchange

Each of the areas are starting today (2015-2020) and show the possible developments in "*generations*" until 2040. Generations define possible evolutions towards PI and can be scenarios or parts of PI-like implementations. PI-like operation will be established from 2030 on, the shown developments from 2030 to 2040 focus on improvements on the way to fully autonomous PI operation.

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

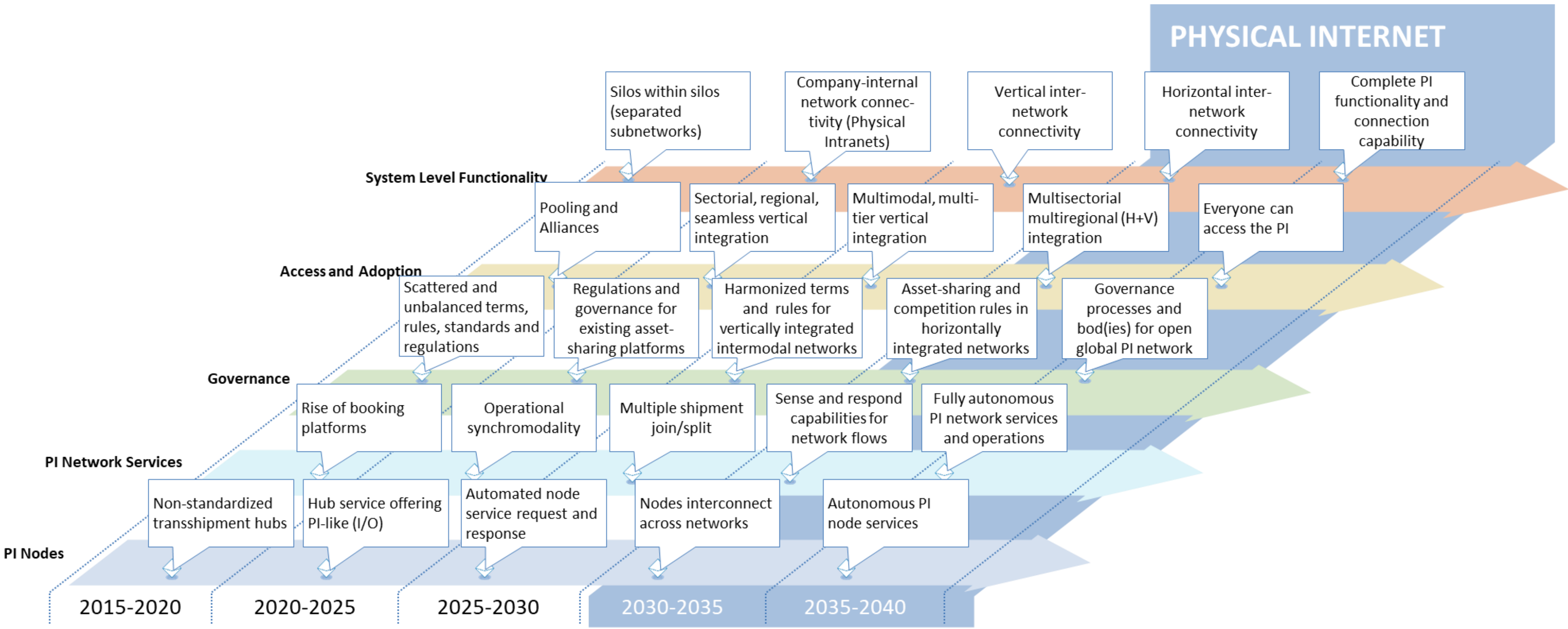

Figure 1: The Physical Internet roadmap

2.1 PI Nodes

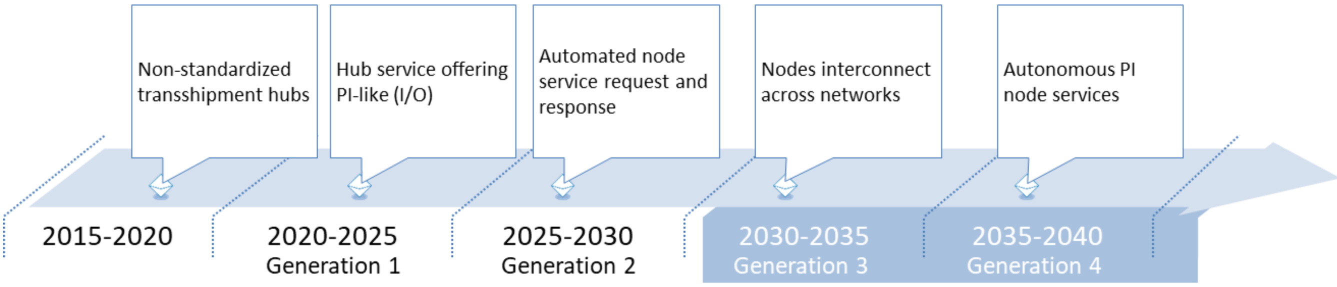

Figure 1: Generations of PI Nodes

The area of PI Nodes deals with different roles of physical nodes (points of freight transhipment and handling) and existing or new operational models. The PI nodes can be classified as follows:

- **PI Node – Type 1**: Warehouse/Depot. Main characteristics:
  - storage capacity,
  - cargo consolidation/deconsolidation
- **PI Node – Type 2**: Intermodal Terminal. Main characteristics:
  - cargo consolidation/deconsolidation
  - change of transport mode
- **PI Node – Type 3**: Intermodal/Multimodal Logistics Hub. Main characteristics:
  - storage capacity,
  - 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 typologies of PI nodes identified. Many services can be provided on these different PI Nodes such as custom clearance, co-packing, customization, 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.

2.1.1 Generations of PI Nodes

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

Generation 0: Non-standardized transhipment hubs (current status)

Nowadays, the logistics networks are characterized by structured processes dealing with rigid loading units (pallet, containers). The services and capabilities of the different nodes are not visible in a seamless way and therefore not easily accessible to potential users; this set up prevents the overall network from its optimization and efficiency. Furthermore, the fragmentation of the information flow and the heterogeneity of the IT systems along the supply/transport chains or logistics networks still represents a critical aspect.

The main services currently provided by a logistics node (depending from the type of node) are:

- cargo storage
- cargo handling (including consolidation/deconsolidation)
- change of cargo transport mode

However, the capability of this service is not shared in an open way.

Generation 1: Open and seamless hub service offering (2020 – 2025)

In Generation 1 logistics hubs and nodes act and offer services to their users in an open way. Services such as cargo storage, cargo handling and interchange are easily accessible and bookable in a seamless way. Users may book and enter in business operations by accessing those services with much less administrative and negotiation burden than today.

G1 will build upon existing procedures and initiatives which are ruling the service offered by a hub in the main three categories: cargo storage, cargo handling and cargo transport to define common requirements, characteristics or standards to be adopted by a hub to become a PI hub and be part of the PI connected network.

In the first phase of G1 the different types of nodes will openly share their characteristics and capabilities. In the evolution within this generation, the services offered by the various LSPs within each node will be analysed and studied so definition of services and capabilities will evolve in their definition to a more standard/interoperable. The services and capabilities published will start to be compatible and seamlessly accessible for the stakeholders.

In the last period of this generation, the capabilities and services of the different PI nodes will be pooled in platforms that will be access points for a rudimentary PI Nodes network. Based on that, the Cargo owners or Shippers who aim at using the PI network for their shipments, will easily book the PI Node services in the locations integrated/pooled in these platforms. For example, they will be able to book directly a storage space for their cargo in the network of PI Hubs along their chain.

Needed activities to implement generation 1:

- Current 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 kick off: type of nodes, service offering, capabilities and access requirements. Definition of infrastructural requirements (storage area characteristics) and PI cargo handling procedures that can be used as reference (or standards) by the PI Nodes

- Nodes services offering is pooled in platforms by independent LSPs so stakeholders can access to a network of nodes (i.e. a PI nodes network). This means the development of such platforms by LSP's.

Generation 2: Automated node service request and response (2025 – 2030)

In Generation 2 the hubs functionalities and their role within the PI networks will take a further step towards the PI logic, by preparing the ground (infrastructures and procedures) for more automated operations. The main objective of this Generation 2 phase is to enable the PI hubs and nodes to interact with the PI network and the LSPs by offering and booking services (storage space capacity, cargo handling, cargo transport…) in an automated manner, creating a seamless information flow.

The PI nodes will ensure a smooth integration between their community platform and the LSP's IT solutions; this action allows each node to interact as a single entity within the PI network and along the chain. Another fundamental step is to implement and build at each node PI-like facilities (warehouses, cargo storage areas, handling areas…); the requirements and characteristics of those facilities will be defined as a "standard" to be used by each node that aim at becoming a PI node. The facilities have to be capable to:

- handle modular loading units;
- match, couple and decouple single modules optimizing the load factor of the unit;
- store the modular units and the related modules.

Furthermore, the procedures needed to handle the modal shift of the cargo according to PI will be defined and taken as "standards" by each node that aim at becoming a PI node.

The implementation of facilities and procedures dedicated to PI nodes will enable their collaboration within the PI network. (Collaborative Network of nodes)

Needed activities to realise generation 2:

- Harmonizing and connecting different PI Nodes and related services and networks.
- Dedicated facilities PI Nodes standards compliant for managing PI cargo
- Definition of standard procedures for PI cargo handling such as harmonization of transport modes exchange
- Modularization and seamless transhipment between modes
- Collaboration between modes and nodes

Generation 3: Nodes interconnect across networks (2030 – 2035)

In Generation 3 the main objective and focus is the interconnection between nodes belonging to different networks. G1 and G2, defined the "identity card" of a PI node, including the rules and specifying the guiding manual for a node to become a PI node. G3 phase introduces a fundamental pillar toward the full Physical Internet implementation: the identification and definition of the most suitable business models capable to enable and support the collaboration between different networks. The business model will define how the PI nodes collaborate one each other, how they can make money by sharing assets, volumes and clients, how the business relationships and the responsibilities boundaries have to be set up and managed.

The tool supporting for the collaboration and interconnection of different nodes belonging to different networks will be the PI system, which will interconnect PI networks and the network of networks. The PI system will allow to manage PI networks and to manage the cargo along the networks.

The Generation 3, as result, will ensure:

- end-to-end visibility of the cargo/transport;
- seamless collaboration along the supply/transport chain, within PI networks and between PI networks;
- automated management and handling of the cargo along the supply/transport chain across PI networks.

Needed activities to realise generation 3:

- Business models for Collaboration between networks
- Integration of different networks (of networks) via PI system
- Automated material handling and Autonomous handling of cargo

Generation 4 : Autonomous PI node services (2035 – 2040)

The main objective of Generation 4 phase will be to bring the PI node at full scale, thus enabling autonomous interaction, both physical and digital, between the nodes in the PI network. The PI network, formed by various PI sub-networks, will cover and serve the world as geographical area and will involve LSP's and nodes worldwide.

The PI network will be exploited at its full potential, functioning as digital internet is functioning now, thus transporting and handling the cargo in an autonomous way, following defined rules and optimization logic. This will improve the overall transport world, minimizing or cancelling all the inefficiencies and the black spots.

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

- following pre-defined paths and routes,
- Utilizing one or more services,
- using one or multiple transport modes,
- involving one or various LSPs.

The logic behind these decisions will rely on the PI system.

Needed activities to realise generation 4:

- Full adoption of PI logic: modular loading units, cargo transport procedures PI-like, PI system (IT platform)
- Standard processes and procedures for material and cargo receiving/handling/transhipment
- Investments in automatic machines for cargo/material handling and loading/unloading
- Business model supporting autonomous interactions and provision of PI node services.

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2.1.2 Existing examples for PI Nodes

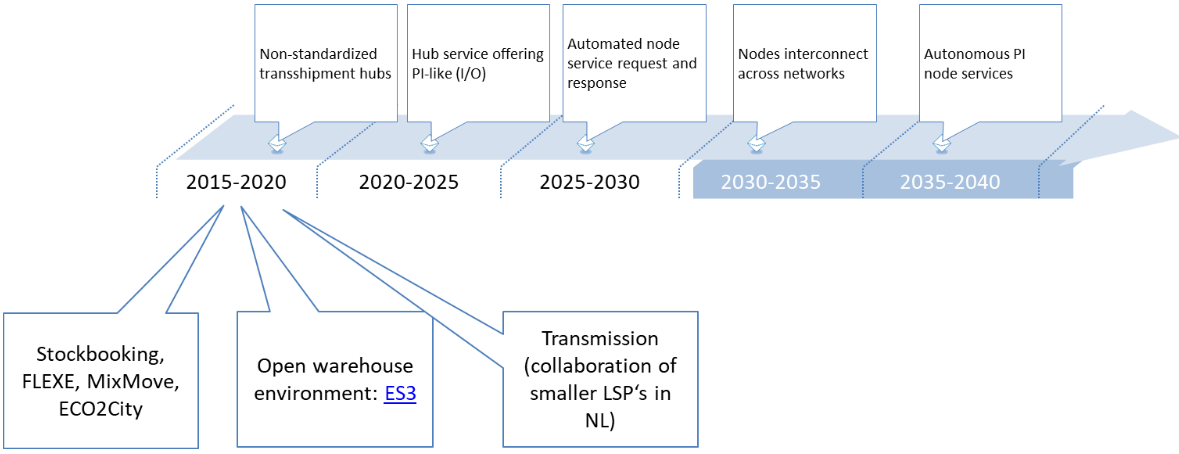


Figure 2: Examples for PI Node implementations

Stockbooking: Stockbooking is a collaborative platform dedicated to the cargo storage. The platform matches space needs with availability and storage offerings. Formed by decentralized chains and shared links, Stockbooking will provide connected and centralized tracking to gain simplicity and efficiency. The main objective of Stockbooking is to make the logistics market more fluid, more accessible and flexible. The logic behind this platform is to synchronously run all partner warehouses as a single virtual warehouse, helping the reduction of the risks and costs of setting up logistics operations. The major pros of Stockbooking are:

- the fluidification of exchanges and removal of constraints and interconnections;
- the promotion of open trade policies for fair and dynamic prices.

FLEXE: FLEXE is a warehousing company that connects organizations in need of additional space to organizations with extra space. The company's cloud-based platform powers unified warehouse sourcing and set up, while also streamlining material handling operations. FLEXE requires no technology investments, long-term leases, or process interruptions. As a result, adding storage capacity is now easier, more flexible, and more cost effective than ever before.

MIXMOVE: MIXMOVE is a cloud logistic solution that enables an open and collaborative network across multiple systems. The MIXMOVE Match solution offers intelligent, horizontal collaboration between shipper, carrier, hub, distributor and the end customer. It doesn't require any changing in the existing systems. The Match solution aims at increasing load factors in order to increase efficiency and reduce costs, while at the same time creating more sustainable supply chains.
This logistics process is based on splitting logistics units down to parcel level so that cross-docking can be used to produce logistics units with vastly improved load factors. It provides the necessary functionalities to run the logistic network, such as TMS, WMS, and a supply chain dashboard. The solution is suitable for shippers and logistics service providers with complex logistics operations and high volume.

2.2 PI Network Services

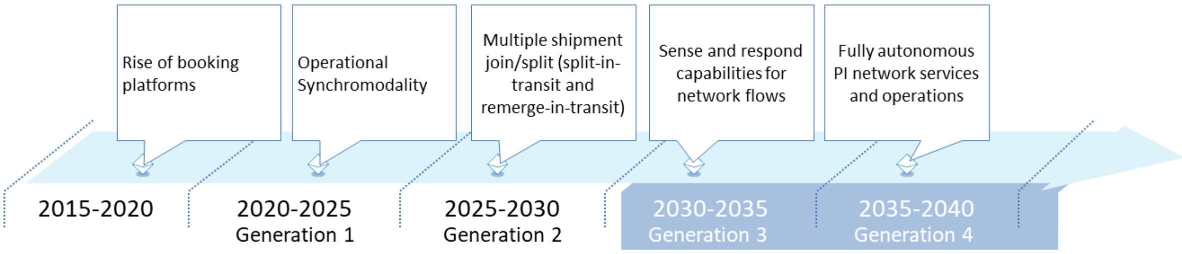


Figure 3: Generations of PI Network Services

In parallel with the digital internet, access to and transportation over the physical transport network is made easy by global protocols for shipping. This does not only relate to the terms of services provided by carriers (e.g. current Incoterms) but also to standards for material and services (e.g. definition of a TEU) 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 Physical Internet. As the current way of shipping will gradually transform towards the Physical Internet, these protocols will evolve as well.

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. The purpose of this flexibility is that it allows a further optimization of flows, beyond what is possible today[2]. Flexibility and dynamics are needed because both demand and supply are uncertain through time, so no planning is possible that optimizes execution of transport ex ante. Therefore, optimization can only be done in response to events that occur during transport.

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 (tracking locations of loads, monitoring capacities of modes and congestion levels)
- predictions of the foreseeable future state of the states of the shipments and the network as a whole.

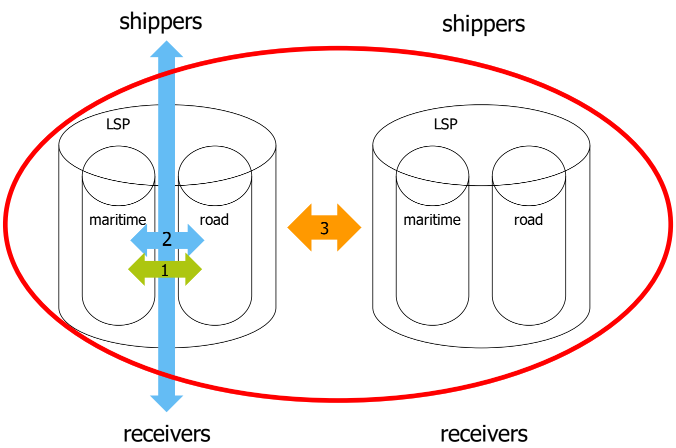
The use of network level intelligence for optimization can be organized in several different ways, with important implications for the available opportunities for optimization (the “solution space”), information access and, eventually, PI network governance. Central use of network level intelligence requires that one party can access all information about the network. A decentral approach assumes that sub-centers or hubs will need to know about parts of the network or areas that fall under their jurisdiction. 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

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

intelligence across nodes then becomes an emergent property of the network. Important information elements relate to the free capacity in vessels, trains and vehicles and the shipment's logistics requirements. In contrast to the current situation, the information about modes and loads is decoupled.

Optimization of network flows[3] involves one or more of the following decisions: routing, joining and splitting of shipments, delaying/storage or acceleration of shipments, switching between modes through synchronization and transhipment, changes of destination and even changes of ownership. The availability of different modes of transport allows to maintain a diversified service package, with different levels of service relating to prices, times and emission levels.

A major condition for the PI to materialize, and also the paradigm carrying the roadmap for PI Network Services, is the integration of different existing networks. Integration is needed between modes of transport; vertically between forwarders, shippers and receivers; and horizontally, between forwarders. As these steps need significant investments, re-organization and alignment between organizations, the evolution of the PI Network Services will be time consuming and fraught with uncertainty.



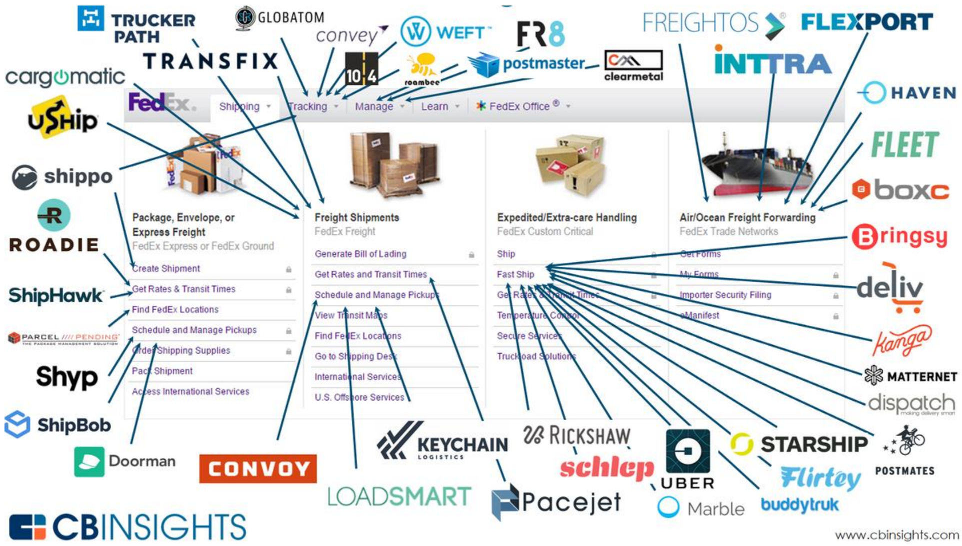
2.2.1 Generations of PI Network Services

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

Generation 0: Rise of booking platforms (current status)

The digitalization of logistics processes has spurred the automation of planning, booking and administration processes. In the past 5 years we have seen a rapid development of digital booking platforms for logistics services. Despite the large investments made, very few are able to offer an independent door-to-door service. Only those platform services that are connected to larger forwarders can provide long distance shipping services for a variety of markets. Crowdshipping 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.

[3] Note also that optimization 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 optimization.



On the <u>physical</u> side of logistics, several minor but still significant 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 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 globalization has created a contraction of global transport networks around a global conveyor belt of mainports around the world.

Generation 1: Operational Synchromodality (2020 – 2025)

The first generation of the PI will entail a continuation and consolidation of the current trend. Digital platform governance is developing on a local basis, to re-introduce regulation, and practices are shared widely around the world. Major logistics service providers and forwarders will develop internal connections between their departments responsible for different modes, into the so-called “physical intranets”. These will allow to , manage flows and services in a mores seamless way by shift freight quickly between modes of transport, using common waybills and synchronized schedules, internal to the company or their close partners. This development will follow the current synchromodal systems of forerunners like ECT. Common rules, services and protocols will be defined for routing to run parts of the network, for specific sectors.

Generation 2: Multiple shipment join/split (split-in-transit and remerge-in-transit) (2025 – 2030)

Building on the first generation, the second generation is marked by a stronger vertical connection between service providers and shippers. Whereas now this is only possible with a dominant forwarder who maintains control over the entire chain, standardized platforms now allow to maintain the integrity of the transport chain without such an overall responsible. Strings of platforms and/or forwarders and/or carriers can connect easily thanks to door-to-door harmonized PI service protocols, providing guaranteed and flexible schedules door-to-door. Bills of lading need to be developed in a way that they are independent from the mode of transport (cf. Rotterdam Rules, a maritime transport law revision initiated in 2008) and Incoterms need to be reviewed to allow intermediate, unplanned, third- or fourth party handling. This breakthrough will also have the major 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 utilization of transport modes. 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 maximizing utilization).

Generation 3: Sense and respond capabilities for network flows (2030 – 2035)

The third generation will build on the combination of generation 1 and 2. Horizontally connected networks (operationally weakly connected, as intranets - mostly within fixed cooperatives, alliances or forwarders) can now be combined with the vertical capability to provide seamless services door-to-door. The sense-and-respond propositions of the PI-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), 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 sensoring in hubs and on the multimodal network. In this generation, almost full functionality of the PI Network is available, compartmentalized in intranets.

Generation 4: Fully autonomous PI network services and operations (2035 – 2040)

Generation 4 marks the further horizontal integration of the physical intranets of generation 3. This requires the creation of a network layer which can build on intranets, but separates the proprietary processes and information from those that can conditionally be shared, and from those that are public. A higher level of network governance is needed to ensure that widely accepted protocols for exterior routing (across or in between intranets) are developed, kept and maintained. Concerns about maritime competition regulation and further consolidation of alliances – a major development from the current work on the Block Exemption Rule – need to be addressed. Once horizontal integration is completed, the PI will work at a global level.

2.2.2 Existing examples for PI Network Services

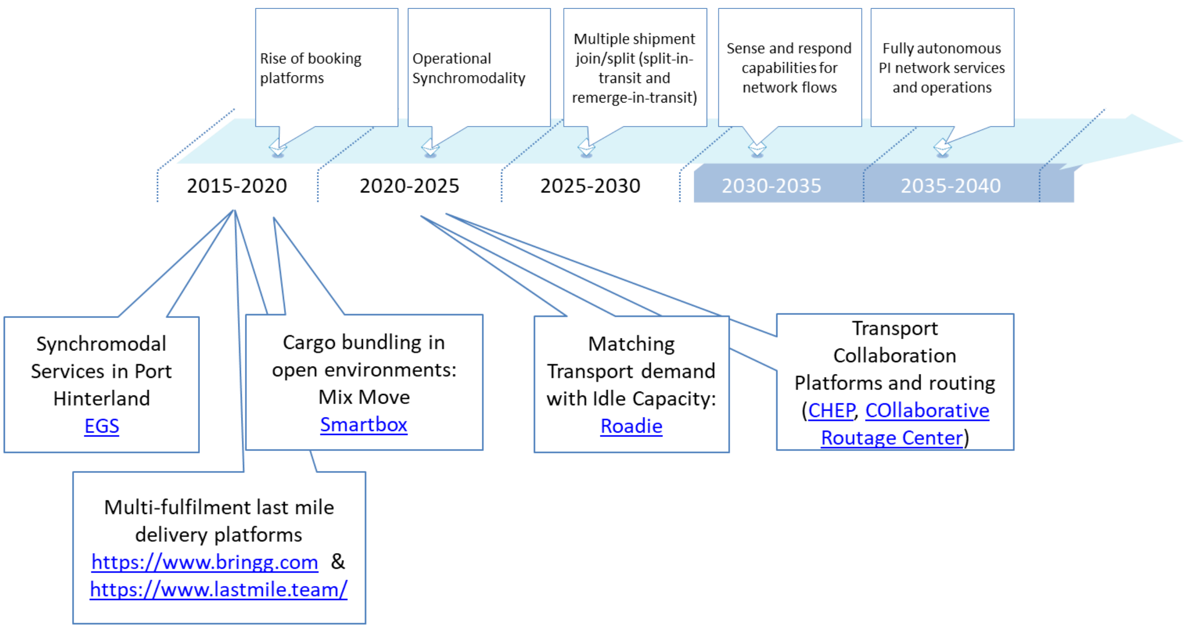


Figure 4: Examples for PI Network Services implementations

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2.3 Governance

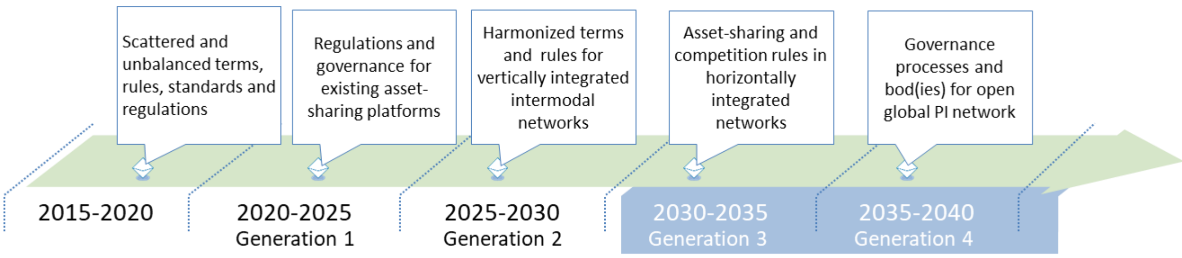

Figure 5: Generations of Governance

A proper governance structure will ensure that the PI is established and operated as a "network of networks", building on existing (private) networks and freight transport and logistics services offering. The PI governance is ensuring that:

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

2.3.1 Generations of Governance

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

Generation 0: Scattered and unbalanced terms, rules, standards and regulations (current status)

The current state of play concerning governance of collaboration and coordination in supply network is characterised by a scattered and unbalanced set of terms, rules, standards and regulations. There is not yet available a harmonized reference governance framework to facilitate and support horizontal collaboration and vertical coordination across different supply networks.

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.

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. This would actually

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go against the currently common terms in terms of, e.g.: liability towards shippers, security, documentation standards, pricing and so on.

Generation 1: Regulations and governance for existing asset-sharing platforms (2020 – 2025)

In generation 1, a limited initial first step will be taken towards a shared governance framework for Physical Internet networks. These initial PI networks will emerge from the existing asset-sharing platforms that are currently growing and developing their business models.

As a result of PI generation 1 development, the current asset sharing networks' governance structures and organizational models will be studied, understood and shared across the logistics industry community. As such, they will constitute a first concrete example of reference common terms for sharing assets and logistic services across different supply networks.

In PI generation 1 the business models of assets-sharing platforms will be addressed by specific regulations on EU level, to establish common rules concerning shippers and logistics services providers liabilities, security and documentation standards, as well societal and environmental aspects of these platforms. In particular, anti-trust regulations will have to be addressed.

Needed activities to realise generation 1:

- Mapping and analysis of current asset-sharing networks, their forms and business models
- Consensus on core rules for individual platforms' addressing, e.g.: administration, expansion, liability, security, sustainability, anti-trust.

Generation 2: Harmonized terms and rules for vertically integrated intermodal networks (2025 – 2030)

In generation 2, a step forward will be taken towards vertical integration of different supply chains into Physical Internet networks. To this purpose, a shared governance framework will be established setting harmonized terms and rules for vertically integrated intermodal networks.

The first step in this direction will be ratification and adoption of the Rotterdam rules, i.e., United Nations Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea[4]. The still-unratified Rotterdam rules will facilitate adoption of collaborative management of intermodal transport, simplifying and harmonizing management of liabilities and of carriers-shippers relationships along the chain.

The next step will be definition of next-generation Incoterms, taking into account collaboration along the supply chain as integral part of international commerce relationships.

Needed activities to realise generation 2:

- Rotterdam rules ratification.
- Definition of next generation Incoterms.

Generation 3: Asset-sharing and competition rules in horizontally integrated networks (2030 – 2035)

[4] https://www.uncitral.org/pdf/english/texts/transport/rotterdam_rules/Rotterdam-Rules-E.pdf

In generation 3 the governance framework will be extended to support collaboration and asset sharing in horizontally-integrated supply networks. The boundaries between vertically-integrated supply chains will be removed through mutual agreements between leading shippers and logistic services providers. This will allow asset sharing and opportunistic routing and re-planning of shipments through PI nodes belonging to different networks.

As a result of PI generation 3 development, new organizational models and contractual frameworks will be studied and implemented to support asset-sharing in horizontal networks. 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.

Also, PI generation 3 will address the issue of unexclusive participation of shippers and logistics services providers to multiple PI networks, enabling future transition towards more open PI network configurations. To this purpose, the PI governance framework will have to take into account socio-economic impacts of asset-sharing, especially on fair competition and anti-trust issues.

Needed activities to realise generation 3:

- Organizational models and rules for asset-sharing in horizontal networks (unexclusive participation, mutual liability, gain sharing, fair competition, antitrust, ..)

Generation 4: Governance processes and bodie(s) for open global PI network (2035 – 2040)

In generation 4 the governance framework will be fully designed and implemented, including all required governance processes and bodie(s) for an open global PI network.

The generation 4 PI governance framework will cover all relevant business and regulatory aspects that have to be addressed to make PI network nodes and services available to the global business community, including:

- Definition of PI-based business models for new and changed roles along the supply chain.
- Definition of governance functions: what needs to be governed on different levels (regulatory, contractual, operational, ..) and how (monitoring, enforcement, self-regulation ..).
- 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.

Needed activities to realise generation 4:

- Develop new business models for nodes and networks services operating in the open global PI network.
- Governance processes for different layers/areas (system, data, operations, ..), comprising both centralised vs. federated governance models.

2.3.2 Existing examples for Governance

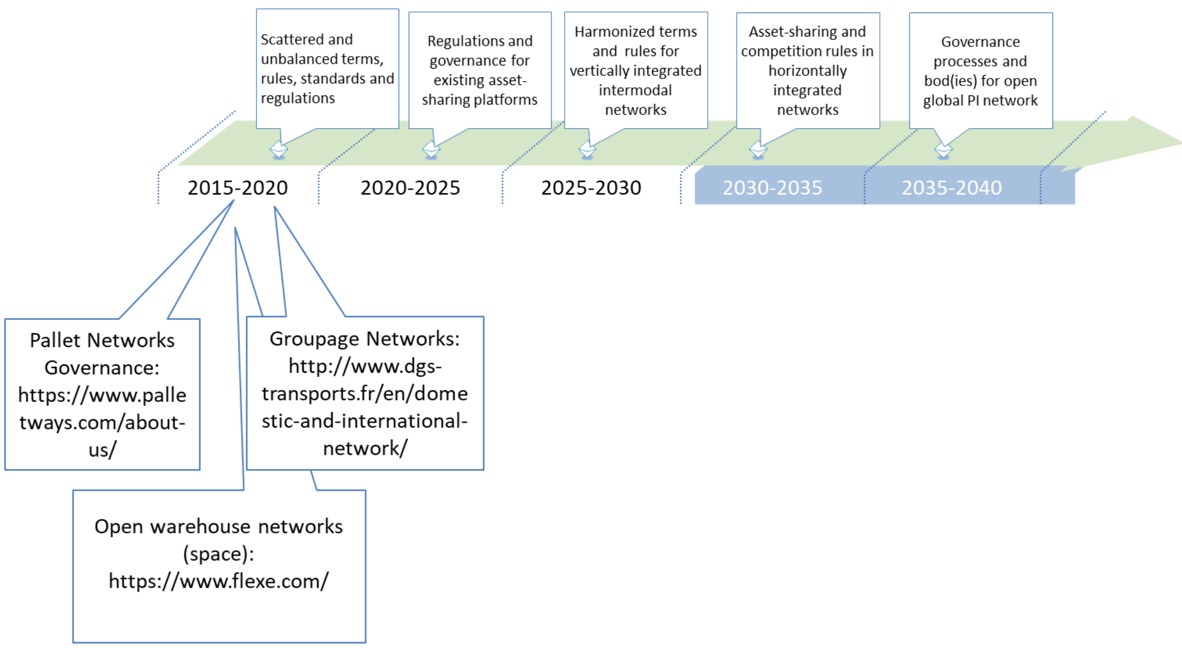

Figure 6: Examples for Governance

Some embryonal examples of PI governance include:

- **Pallet Networks Governance**. Pallet Networks (e.g., www.palletways.com) represent a growing segment in the logistics services industry, founding their business model on the collection, delivery and management of pallets through continental networks where key assets (pallets) and capacity are shared among shippers. Their governance structure is based on a membership program where members are accepted on fulfilment of certain requirements, collaborate through a shared technology platform and can participate to the "Business Clubs": an informal forum where members have the opportunity to share business ideas and are involved in development of the overall network.

- **Groupage Networks** (e.g., Cargoline http://www.dgs-transports.fr/en/domestic-and-international-network/) are networks of independent transport companies, both local and international, connected to one or more strategic hubs through which groupage services can be organized to various destinations optimizing the capacity of the member companies. Typically, governance is operated through a board of representatives of the involved stakeholders: member carriers, hubs and authorities' representatives.

- **Open Warehouse Networks** (e.g., Flexe http://www.flexe.com) are networks of warehouses whose capacity can be shared among individual users, typically manufacturers or e-commerce companies. The users enjoy advantages in terms of minimal supply-chain setup costs and time, and reduced costs by sharing warehouse capacity. The warehouse network manager is typically an asset-less company (often a startup), operating through a sophisticated ICT infrastructure, which takes care of the warehouse network governance through a "platform" business model.

2.4 Access and Adoption

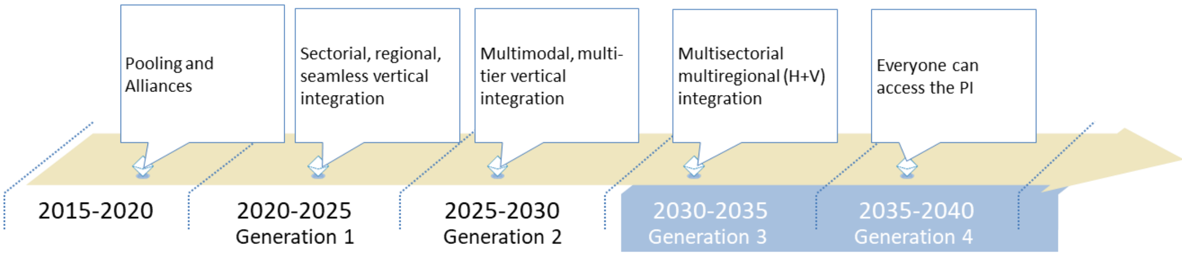

Figure 7: Generations of Access and Adoption

In order for the concept of PI to be successful, it is important that the stakeholders in the logistics sector understand the concept, see the benefits it will bring for their business and activities and engage in the transition towards PI. Therefor we need to reduce the burden to understand PI; be very clear about the benefits and see how we can achieve a mental shift. In the end PI needs to be accessible for everyone.

Given the different generations towards PI benefits for different stakeholders in the logistics sector will evolve. As business models will (gradually) change over time the specific benefits per stakeholder will change as well. However, in general you can say that the benefits will become clear as it will be more easy and logical to share assets, vehicles, warehouses and infrastructure. This will lead to a more productive and efficient sector as a whole. These benefits need to be very clear in terms of KPI's for the individual stakeholder.

We have to realise that over time new roles will be defined within the sector. Some are adoptable by current stakeholders and as a consequence their business models will need to change. Some roles will be taken up by new stakeholders. Although we do not know exactly how the PI eventually will evolve, we can say a few things already now concerning the changing roles. Logistics service providers, for instance, will operate in a complex set of networks in which they are involved. This requires a more sophisticated way of organising flexible operations between these networks. The ports and hubs in PI will have an advanced role, being able to quickly responds to overall network needs and flexibility to provide recourses where necessary at a certain point in time. The user perspective will also change as the shipper will rely on PI to organise the flow of a shipment according to their requirements, instead of being in control over the shipment all the time.

Over time, moving from one generation to the other, the stakeholders with access or willing to have access to the PI generation, will need to see and experience how the network is organised. There is a great need of modelling and visualization of PI, which in each generation has different requirements.

Last but certainly not least we need to realise that for adoption of PI and the generations we need a mind shift. This will gradually take place when moving to the next generation, but each generation requires new additional skills form logistics professionals. As the role of companies will change, the role of professionals within these companies will change as well. Every implementation in the course towards PI (small or large) needs to consider the individual mind set of professionals and the way organisations behave and adopt. A very important task for the education sector.

2.4.1 Generations of Access and Adoption

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

Generation 0: 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. 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 provide for a 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.

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.

Generation 1: Sectorial, regional, seamless vertical integration (2020 – 2025)

In generation 1 a better connectivity within a vertical chain will be achieved. Better information sharing between 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 is becoming common practice within vertical supply chain settings.

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

New actors with end-to-end supply chain coordination and execution will exist reaching a higher level of integration within specific supply chains. Shippers and end-customers will facilitate this on a strategic and tactical level. 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 generation 1:

- Description of convincing business case including revenue models, gain sharing and description of different stakeholders

- Mapping of existing European hubs and networks (for simulation on existing infrastructure)
- Simulation model to understand the practicality of PI
- Prepare people for PI (e.g. using gamification for education)
- Plug & play tools for system integration, based on more standardised information sharing
- Common understanding of judicial frameworks given a setting of integrated vertical collaboration.

Generation 2: Multimodal, multi-tier vertical integration (2025 – 2030)

In the second generation of access and adoption, knowledge and visibility of supply chains is realised with broader vertical impact. 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 also between modes of transport has become common practice. Network integration exists within specific sectors of industry, which implies the existence of horizontal collaboration between sectorial supply chains.

The integration and collaboration between supply chains leads to a further increase of scale, which leads to more efficient decision making based on larger volumes that are consolidated. 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 be faced with a much more reliable and flexible system.

The role of supply chain stakeholders will change as shippers are becoming colleagues (in supply chain management scope) instead of competitors. Logistics service providers will need to be able to coordinate flows of goods over several networks within industry verticals. An independent coordination function will exist monitoring flows of goods and information in order to oversee responsibilities (ownership of goods, gain sharing, etc.).

Personnel and organisations are sharing best practices without barriers. It makes common sense that organisations can learn and improve from each other even if there is no direct collaboration. 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 generation 2:

- Successful Regional Demonstration (i.e. two connected networks)
- Harmonised and digitised data on sectoral level
- Education programmes for students and professionals covering cooperation skills.
- Easy to use and integrated gain sharing solutions in operational systems
- Decision support tools enabling multimodal – multitier route analysis

Generation 3: Multisectoral multiregional (H+V) integration (2030 – 2035)

Multisectoral horizontal and vertical integration characterises the third generation of access and adoption. Opportunities for economy of scale in integration with larger volumes enabling the optimal use of all modalities are fully utilised. Standardisation of assets as well as practices and data communication is unifying operations and eases network integration and flexible and agile logistics solutions. Governance reaches across 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.

As shippers provide shipment scenarios, the assignment of operators is a logical outcome of the information and options within the Physical Internet system. Actors are functioning as a networked organisation 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 generation 3:

- Successful European demonstration (i.e. various connected networks in an scalable way)
- Mindshift and new management leadership in order to achieve true horizontal collaboration
- Cross-network calculations and modelling, adaptive to entry-exit strategies

Generation 4: Everyone can access the PI (2035 – 2040)

In generation 4, the Physical Internet is fully accessible and widely adopted. Here, all logistics modes and services can be combined by any player to meet each individual and all needs with the same system approach and independent of the technology. Based on information provided by the PI system on all possible lanes, carriers, paths and nodes and prices for different routes given the timeframe, the shipper decides for a particular shipment scenario.

The Physical Internet is enabled by a unified digital data network. 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.

Shippers are contacted in case the delivery times or other fulfilment requirements cannot be met and their network professionals decide on alternative scenarios. Their decision will trigger the updating of the data in the PI System and the transport process can be continued. After delivery, payments across the entire network are automatically calculated, processed and distributed along the system partners.

Needed activities to realise generation 4:

- Easy connection through all planning systems in the logistics sector to PI services

- Accepted governance structure able to provide for trusted monitoring of solutions.

2.4.2 Existing examples for Access and Adoption

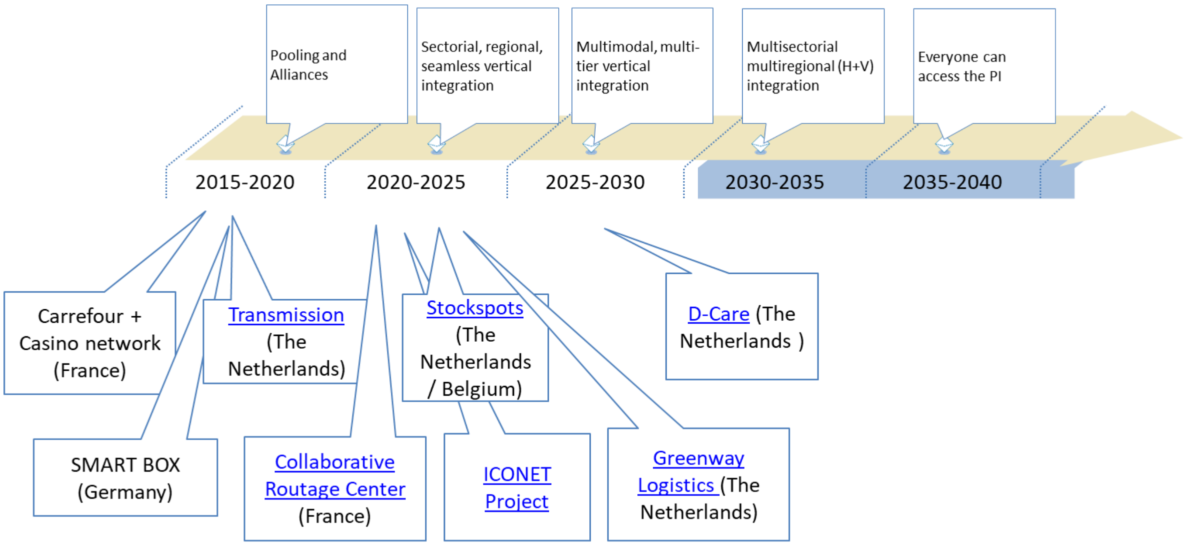

Figure 8: Examples for Access and Adoption

Transmission: Transmission is an alliance of over 25 transport companies in the Benelux. The cooperation is based on geographical coverage of each transport company. Order which cannot be managed within the own region is managed by the network. Companies joining Transmission are able to use the name as a brand in the market.

Carrefour + Casino network: tbd

Smart Box: tbd

Stockspots: Stockspots is an online marketplace for on-demand warehousing in The Netherlands and Belgium mainly. Stockspots is flexible and fast; shippers can select what they need and when they need it, select a location and Stockspots arranges warehousing with short-term contracts. The services are not limited to space alone, some locations offer logistics services as loading and unloading, labelling and fulfilment. Stockspots is accessed by a smart management system in the cloud. This way, the shipper maintains control of their stock, shipments and warehouse capacity. www.stockspots.eu

CRC: CRC is a start-up funded in France at the end of 2015 after successful investigation of the routing business model for less than truck load operations for FMCG. CRC started to operate with limited functionalities downstream routing centres (distribution). Full trucks depart from suppliers with shipments for several retailers in the same region and are cross-docked in the CRC to be delivered full truck load with several suppliers to each retail distribution centre.

Greenway Logistics: Greenway Logistics is network orchestrator for the fashion and furniture industry (separated networks). Based on consolidated supply chains of different brands the level of efficiency in the inbound ocean network is large. Greenway Logistics manages operational flows through an independent control tower (VIM) which operates cross-chain. The ambition is to truly achieve end-to-end consolidation and optimised distribution.

King Netherlands / D-Care: is part of the Bunzl group of companies. D-Care provides for a full service solution in care and cure supplies for hospitals. All flows from each supplier to the end-user is consolidated in the D-Care network. This is possible through high level of horizontal collaboration between suppliers under coordination by D-Care.

2.5 System Level Functionality

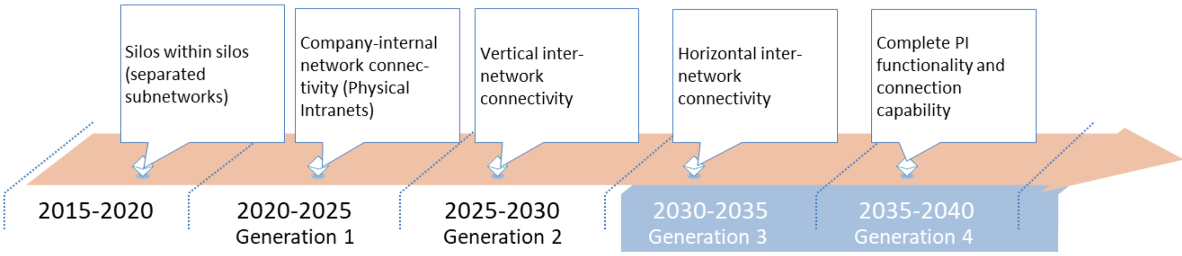

Figure 9: Generations of System Level Functionality

The basic operational premise of the Physical Internet is similar to that, that has served the Digital Internet (DI) so well over its almost 50 years of operations and growth. That premise is that simplicity 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 needs only 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 for the PI (e.g., containers must not be separated from one another during shipment, expedited shipment, etc.).

The protocols to be employed by the PI also should reflect the minimalist nature of the protocols employed in the DI. While the DI's protocols have grown more complex over the years, the PI should attempt to start out as the DI 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 onwards, 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 (Figure 4.5.1), can be constructed (Table 4.5.1). It should be noted that the use of the five-layer Internet protocol model and the services defined in Table 4.5.1 for each layer of the model differs from previous work concerning a protocol model for the Physical Internet (Montreuil et al., 2012). 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.

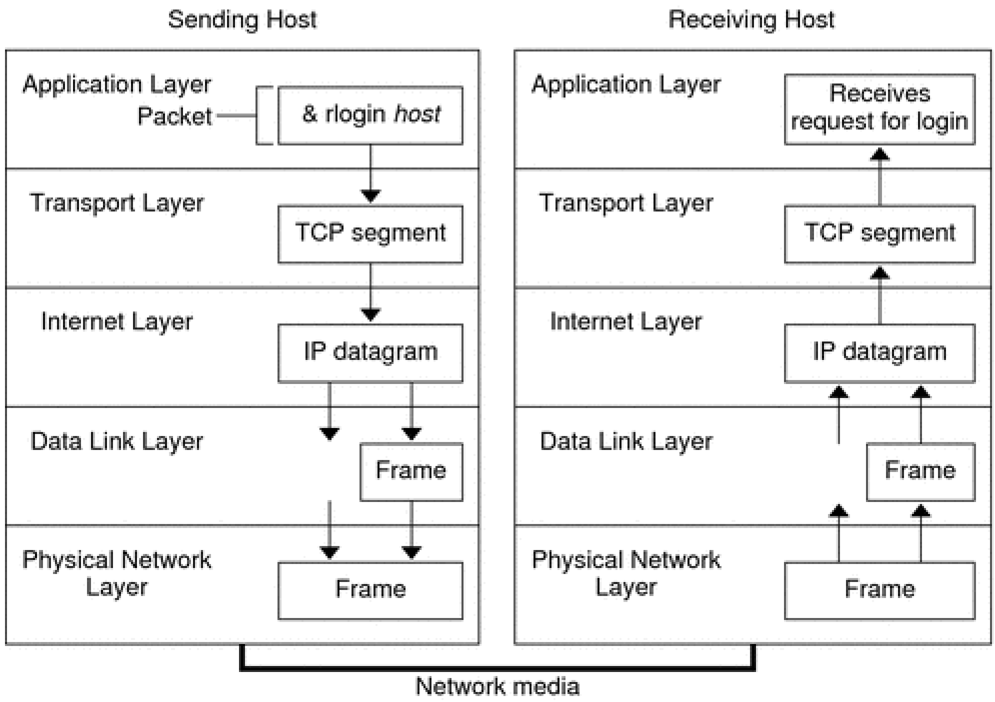

Figure 10: Internet Five Layer Protocol Stack

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

Activities performed in the frame of SENSE *"Accelerating the Path Towards the Physical Internet"*. The SENSE project has received funding from the European Union´s Horizon 2020 research and innovation Programme under grant agreement No. 769967

	segments is attached to the segment and the combination of this information and the shipment segment forms our "datagram."
"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 depends 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 actually moves the "bits" of a shipment 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 how the PI could work is as follows:

1. A shipper is interested in sending a consignment of goods from Barcelona to Hamburg. The shipper contacts their freight forwarder and asks the freight forwarder what the cost will be for the shipment providing the forwarder with delivery information, shipment information and required time of delivery.
2. The freight forwarder queries the PI to obtain an estimate of costs for the shipment, given the shipments characteristics and delivery time.
3. The PI examines the end-to-end route that the goods most likely will travel (based on historical information concerning origin-destination routings), integrates existing loads anticipated for the dates in question over the routes considered, incorporates node costs, transport costs, and any other pertinent costs for handling along the most likely route, and any known maintenance information to arrive at a preliminary cost estimate for the shipment.
4. The freight forwarder informs the shipper of the estimated costs and the fact that the shipment should be delivered on time if the shipment is tendered by a specific date.
5. The shipper accepts the quotation and prepares to tender the goods on the date specified.
6. Prior to the actual required tendering date, the PI continuously updates the freight forwarder as to any changes to the quotation. Changes could arise due to unexpected volumes being tendered for the same route during the planned time horizon, newly planned or emergency infrastructure repairs, nodal or transport asset owner changes, etc. These changes are noted by the freight forwarder and passed along to the shipper should they materially affect the price or delivery date of the shipment. Renegotiation of the shipment would occur should such a situation arise.
7. The shipper tenders the shipment on the appropriate date specified by the freight forwarder at the proper location specified and the PI takes over the movement of the shipment from Barcelona to Hamburg.
8. While in transit the goods are assigned to specific transport vehicles by the nodes through which the shipment passes. Each node determines the next leg in the transport chain by looking downstream to ensure that time and cost information originally proposed can be accommodated. If changes are required due to unexpected issues, these changes are immediately sent to the freight forwarder for transmission to the shipper (this information could also be sent directly to the shipper). The shipper, thus informed, may be required to

make a determination of whether they are willing to accept a delay or cost penalty due to the unforeseen changes or order an expedited (more costly) service to meet their delivery date.

9. Each node passes the shipment on to the next node in the chain switching carriers, consolidating the shipment with other shipments, and deconsolidating the shipment for final delivery when it reaches Hamburg.
10. The goods are delivered to the final destination address by the Hamburg node and the shipment is noted as delivered.
11. Costs, which have been accumulated during transit, are summarized and a bill for the shipment is sent to the freight forwarder (or directly to the shipper) for payment.
12. Payment for the shipment is made and the shipment is closed out by the shipper, the freight forwarder and the PI.

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. This is a process similar to how the DI implements its Simple Network Management Protocol (SNMP), tracking services, etc.

Much work is still required to define the numerous protocols that will be needed to operate the PI per the simple processes outlined above. As each of the sections in this document evolve modifications in how the PI will actually work will be required. However, at this preliminary stage of development, the outline above provides our current thinking on how a PI could work and informs the research agenda on the development of operational protocols for the PI.

2.5.1 Generations of System Level Functionality

While the PI is still only a vision, there are examples today of how transport networks, and networks of transport networks can actually work. The development of workable PI protocols, incentive mechanisms, demonstration pilots, and commercial pressures will determine whether these examples coalesce into a true PI. The sections that follow discuss the current state of progress towards the PI vision and needed changes/advancements to move the vision forward from generation-to-generation.

Generation 0: Silos within silos (separated subnetworks) (current status)

The current "as is" state of global freight transport is highly fragmented with individual organizations 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 part of the transport operation and then hand off the shipment to a partner organization for further movement of the freight. 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 rationalizing linkages through the development of PI protocols and their adoption by existing international network organizations.

Large international freight forwarders are prototypical models of what a closed PI might look like. 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 all 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 of these functions the PI will need to provide, albeit in an open 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, postal service companies, 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 have developed inwardly focused and proprietary approaches to addressing these problems precluding the more open interconnection service envisioned by the PI.

Generation 1: Company-internal network connectivity (Physical Intranets) (2020 – 2025)

As interconnection protocols are developed for the PI over the next several years, they will enable current proprietary networks to experiment with connecting to one another or new partners. These protocols, the rudimentary precursors of what are hoped to be more robust and full featured PI protocols, should allow organizations to replace hard coded connections to internal partners with open, standards-based PI protocols. By experimenting with operational PI protocols via internal connections, organizations will be able to reduce risks associated with a protocol failure and provide valuable feedback to the PI technical teams on needed enhancements for the proposed protocols. In addition, these leading-edge organizations 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 to the PI vision will require the formal development, testing and piloting of a PI protocol stack. 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 operation of the PI 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 tests of the PI.

Generation 2: Vertical inter-network connectivity (2025 – 2030)

Once network operators have tested the initial PI 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. Intercompany 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 organizations to create "on demand" extended networks in a manner similar to how the PI would operate. Once more, feedback on how these rapid connect/dis-connect operations work, on the costing, planning, routing, etc. protocols perform as well as the incentive mechanisms will allow the PI engineering teams to further enhance and improve the protocols needed for a fully functional PI.

Generation 3: Horizontal inter-network connectivity (2030 – 2035)

Up to this point the PI 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 of time, 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.

Generation 4: Complete PI functionality and connection capability (2035 – 2040)

The „final" stage of PI development will occur with the full rollout of the PI. This period of time will see all PI functionality, that originally envisioned, modified, and added over time, made available to users. 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 minimized. 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.

2.5.2 Existing examples for System Level Functionality

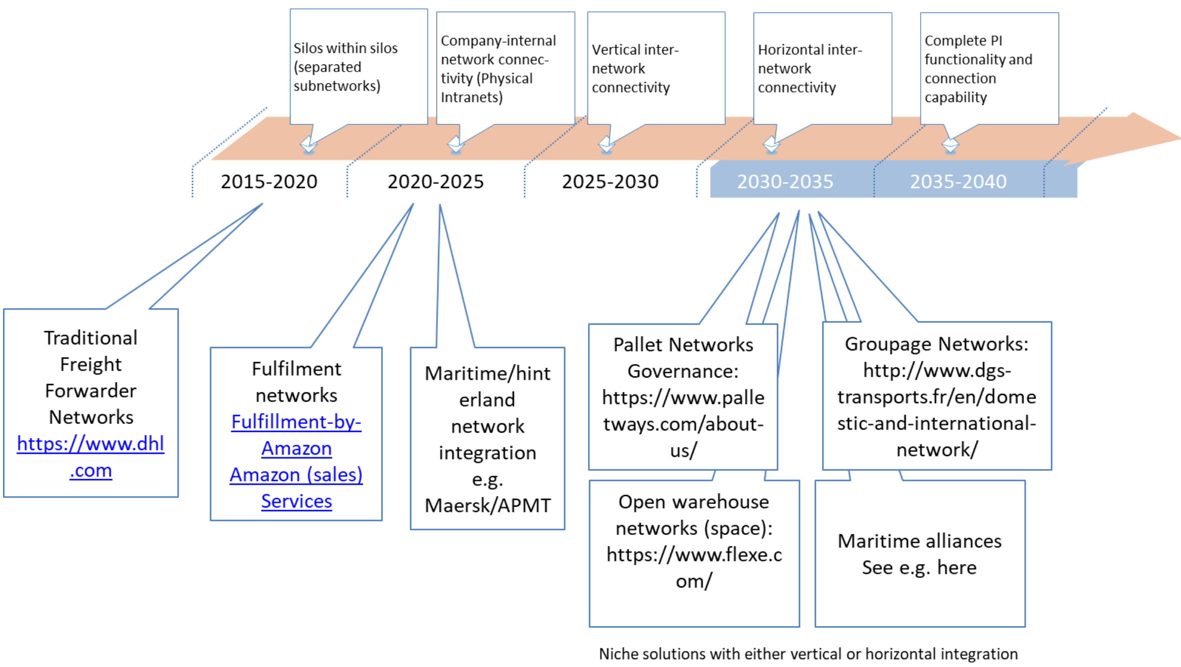

Figure 11: Examples for System Level Functionality