New <u>IC</u>T infrastructure and reference architecture to support <u>O</u>perations in future PI Logistics <u>NET</u>works

D1.9 Generic PI Case Study and associated PI Hubs Plan Final

Document Summary Information

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
EU	European Union
GHG	Greenhouse gases
GPICS	Generic Physical Internet Case Study
GPS	Global Positioning System
GSCM	Green supply chain management
ICT	Information and Communication Technologies
KPI	Key Performance Indicator
LL	Living Lab
NUTS	Nomenclature of Territorial Units for Statistics
PI	Physical Internet
SCM	Supply chain management
SLR	Systematic Literature Review
T&L	Transport and Logistics
TEN-T	Trans-European Transport Network
WISA	What-if scenario analysis
WP	Work Package

In addition, this document contains references to Eurostat data where countries are referred to by the following two-letter country code.

European Union (EU)

Belgium	(BE)	Greece	(EL)	Lithuania	(LT)	Portugal	(PT)
Bulgaria	(BG)	Spain	(ES)	Luxembourg	(LU)	Romania	(RO)
Czechia	(CZ)	France	(FR)	Hungary	(HU)	Slovenia	(SI)
Denmark	(DK)	Croatia	(HR)	Malta	(MT)	Slovakia	(SK)
Germany	(DE)	Italy	(IT)	Netherlands	(NL)	Finland	(FI)
Estonia	(EE)	Cyprus	(CY)	Austria	(AT)	Sweden	(SE)
Ireland	(IE)	Latvia	(LV)	Poland	(PL)		

United Kingdom

United Kingdom	(UK)

European Free Trade Association (EFTA)

Iceland	(IS)	Norway	(NO)
Liechtenstein	(LI)	Switzerland	(CH)

Figure 1: EUROSTAT two-letter country code

1 Executive Summary

This deliverable sets up and specifies, with the contribution of all relevant stakeholders, the parameters of a Generic PI Case Study, unifying ICONET's 4 Living Labs under a common PI framework, and producing the final release of the respective PI Hubs Plan.

The work has been based on the previous release of the deliverables (D1.7, D1.8 – "Generic PI Case Study and associated PI Hubs Plan v1, v2") which identified the key elements of the Physical Internet as documented in previous studies, reports and projects, through state-of-the-art reviews in the field, followed by a parallel process to understand and abstract the business needs of the project's living labs use cases and insights of ICONET's Advisory Board, ALICE and Consortium members.

The Generic PI Case Study and associated PI Hubs Plan Final version focuses on the analysis different aspects to facilitate the adoption of PI by companies. It defines the new roles of PI and how the companies are related to those roles. An operational procedure for managing transport operations through the PI network is also described. It describes the main points of connection between the physical network and the digital network. Furthermore, it is described how the connection of the companies' legacy systems with the PI network could be done.

Finally, the European PI Hubs plan is defined based on an analysis of freights flows at European level. From the cargo data between regions (NUTS 2), applying concepts of GPIC models and services such as Networking or Routing, the size of a plan PI Hubs network and its relative size have been estimated according to the amount of cargo that would pass through each node in a transport plan based on PI.

This deliverable is also the epicenter of the project methodology, which combines the notions of a PI Hub, a PI Corridor, and an urban logistics network PI (e-Commerce Fulfilment), all supported by the e-Warehousing as a Service. Each of these four Key PI capabilities corresponds to each of ICONET's Living Labs. Finally, it covers the PI Hubs Plan suitable for the GPICS' defined geographic region and business needs, through a disciplined methodological approach and taking into account input and advice of all involved stakeholders, within or supporting the ICONET Consortium.

2 Introduction

This deliverable serves a two-fold purpose:

1. The GPICS Specification version 2. The GPICS represents the core of the project methodology. The four industry-driven PI Living Labs of the project provide the main PI competences: PI Hub, PI Corridor and PI Network

2. To produce the PI Hubs Plan that is suitable for the geographic region and business needs of the defined GPICS. All this considering a methodological approach and consulting with the interested stakeholders present in the ICONET Consortium, ICONET Forum and ALICE cluster.

The ICONET Generic PI Case Study (GPICS) was raised as the epicenter of the project's methodology, so that the objectives of this specific ICONET deliverable are highly relevant to the project in general. The starting point of the ICONET methodology points to a fundamental understanding of PI business models and enablers, culminating in the Generic PI Case Study (GPICS) and PI Hubs Plan, with the help of simulation (as it is extended in the following paragraphs). The next step is to translate the fundamental understanding previously achieved to a Cloud-based PI Control and Management Platform that supports the design and implementation of solutions in the third step, ICONET LLs. This third step involves both a digital transformation driven by PI in LLs, the provision of data for simulation, testing and user-driven innovation.

The objective was to align the deliverable and its main outputs, this is the definition of GPICS and its associated PI Hubs Plan, with the previous works as far as possible. The Systematic Literature Reviews (SLRs) consisted in the analysis of the existing research works to date. References to key documents have been reflected in the corresponding section of this document. The SLRs was complemented with the study of the available results and outputs of current projects related to PI. The main related project, which is one of the most recent, is "SENSE - Accelerating the Path Towards Physical Internet".

This project also has direct connections with the SENSE project, but with different objectives. SENSE strategic objective is to accelerate the path towards the Physical Internet (PI), so advanced pilot implementations of the PI concept are well functioning and extended in industry practice by 2030, and hence contributing to at least 30 % reduction in congestion, emissions and energy consumption. To that end, SENSE aims to increase the level of understanding of PI concept and the opportunities that bring to transport and logistics. By building stronger and wider support of industry, public bodies and research worlds towards the PI we may reach consensus and enable coordinated strategic public and private investments in research and innovation embracing Physical Internet that could lead us to a new much more efficient and sustainable paradigm.

The document is addressed to the ICONET project partners. In addition, it is also intended to inform shippers, logistics service providers and other interested parties of the results of the ICONET project.

2.1 Deliverable Overview and Report Structure

This document is divided into 8 chapters. The first is the chapter of the executive summary that outlines the key goals and findings of this report.

The second chapter is an introductory section focused on the relationships between the content of the document and the outputs of the ICONET project. It also contains an overview of the structure of the document.

The third chapter discusses the main aspects of the state of the art of reference models and PI foundations taken into account to define the case study of the Generic Physical Internet of ICONET. This chapter also includes references about the integration between the actual logistics networks and the PI.

The fourth chapter describes the GPICS Framework and its dimensions. The GPICS Framework provides the basic concepts for defining the ICONET physical internet study case in a common and orderly manner.

The fifth chapter describes a guide to facilitate the adoption of PI by transport and logistics companies, and the connection between the physical and digital network.

The sixth chapter deals with the definition of the European PI Hubs plan is defined based on an analysis of freights flows at European level.

The seventh chapter has the conclusions of the document and

The eight chapter enumerates the references used in the document.

3 Physical Internet Framework

The goal of this chapter is to review relevant PI publications, regardless of the publication outlet, to align the ICONET Generic PI Case Study with previous research and existing work to date. It also has the goal of providing guidelines to facilitate the integration of the PI framework for companies involved in transport and logistics.

To align ICONET with previous research, we have used academic databases and academic search engines that look for the term 'Physical Internet'. Moreover, we have screened publications from conferences on (e.g., the International Physical Internet Conference) and groups interested in (e.g., the Physical Internet Initiative, ALICE). Finally, we have identified and analyzed the main on-going projects related to PI.

This chapter provides minor refinements with respect to the initial release of the document. The state of the art, the research and the literature review and PI background analysis was performed at the beginning with the objective of defining a holistic GPICS framework with all the dimensions needed to have several GPICS instantiation along the ICONET project.

Moreover, this chapter takes a close look on the Logistics Industry in an effort to identify the links between the Supply chain reality of today and the PI. The generic modelling of the components of the PI network is designed to reflect these interconnections and requirements that the industry has to make the GPICs ever more relevant.

The PI literature is constantly growing. The very first publication on the PI dates from 2006 while the concept of actual PI was initially introduced in 2010 by Montreuil et al. in [2], who laid its foundations and received the attention of academics and practitioners. The number of publications in PI has increased considerably in recent years. Most PI publications are conceptual and try to provide practical solutions for certain PI components. Similarly, there are many studies and simulations aimed at providing real-life solutions for some of the PI components (e.g., simulations for the operations of PI-hub, PI-store and PI-sorter) but there are few case studies or experiments focused on the analysis of the potential impact and benefits at the level of the PI network.

ICONET's GPICS Framework is aligned with the foundations of the PI components identified to date. The table below summarizes the alignment between key ICONET GPICS elements and the PI foundations extracted from the literature review process.

Table 1: Correspondence between ICONET GPICS and PI literature main aspects

LITERATURE MAIN ASPECTS	ICONET GPICS
Three key types of physical elements such as Physical Internet enablers: the PI containers, PI nodes and PI movers. Containers are the fundamental unit loads that are moved, handled and stored in the Physical Internet. The nodes correspond to the sites, facilities and physical systems of the Physical Internet. The movers transport, convey or handle containers within and between nodes of the Physical Internet.	GPIC modelling components include these three types of physical elements ▪ GPICS container ▪ GPICS hub ▪ GPICS transport/mover
PI nodes are locations specifically designed to perform operations in PI containers, such as receiving, testing, moving, routing, sorting, handling, placing, storing, picking, monitoring, labelling, paneling, assembling, disassembling, folding, snapping,	GPICS HUB includes a wide range of functionalities to perform logistics operations: source, sink, assembly, split, queue, store, switch, bridge, sort and gateway.

unsnapping, composing, decomposition and shipment of PI containers	
Physical Internet aims to enable an efficient and sustainable Logistics web. In general, a web can be defined as a set of interconnected actors and networks. In the context of the physical Internet, the types of actors and networks can be characterized, which leads to defining a web as a set of interconnected physical, digital, human, organizational and social agents and networks.	The GPICS Network is formed by all the modelling components: GPICS Containers, GPICS Hubs, GPICS Movers/transport, GPICS Corridors and GPICS Routes. All together enables the interconnection of actors and networks.
Physical Internet is a global and open system. It has a large number of components that do not have the capability to independently enable an efficient and sustainable Logistics Web. It is through their well-designed relationships and interdependencies that the system as a whole can achieve its purpose completely. It has to be based on the same conceptual framework regardless of the scale of the involved networks.	GPICS base configuration rules establishes the basis for the relationships and interdependencies of the physical elements of the PI Network. GPICS Framework allows defining a GPICS case study independently of the scale or the scope by selecting the suitable geographic area and master data and configuring the setting rules accordingly.
Whereas the Digital Internet networks have the following physical elements: cables, hosts and routers, the Physical Internet faces a more complex reality in terms of the physical elements: ▪ PI Container: encapsulation of merchandise ▪ Hub: place of orientation -sorting-, change of mode, service provider ▪ Supplier/consumer: place of containerization and de-containerization ▪ Transport services: punctual or regular transport between two nodes	Apart from the three basic physical elements: GPICS container, GPICS hub, GPICS transport/mover, the GPICS framework also includes elements such us the US GPICS corridor and routes which support the digital internet analogy. Moreover, GPICS Framework also maps the supplier/consumer points with their sender/receiver roles.

ICONET Generic PI Case Study is also aligned with research and outcomes from PI related on-going projects. Main reference is SENSE – Accelerating the Path towards Physical Internet. SENSE project strategic objective is to accelerate the path towards the Physical Internet (PI), so advanced pilot implementations of the PI concept are well functioning and extended in industry practice by 2030, and hence contributing to at least 30 % reduction in congestion, emissions and energy consumption. To that end, SENSE aims to increase the level of understanding of PI concept and the opportunities that bring to transport and logistics. By building stronger and wider support of industry, public bodies and research worlds towards the PI we may reach consensus and enable coordinated strategic public and private investments in research and innovation embracing Physical Internet that could lead us to a new much more efficient and sustainable paradigm. There is a detailed description of interaction with SENSE project in previous version of this deliverable.

3.1 Integration between the logistics networks and the PI

Nowadays there is a lack of real integration among all the stakeholders in collaborative logistics communities. As it was described in ICONET deliverable D1.2 (*D1.2 PI business and governance models*) a networked collaborative community can be described as "Open logistics networks consisting of competing and non-competing stakeholders through which goods are transported and stored in the most efficient way based on open logistics standards and governance and market based pricing mechanisms."

Although there are different horizontal collaboration business models which currently exist there are too many gaps which exist between the existing horizontal collaboration business models and the collaborative networked logistics communities with a special focus on scaling and interconnecting existing horizontal logistics collaboration models as a basis for the Physical Internet.

As it was detailed in the ICONET deliverable D1.2[1] document the openness of collaboration models refers to the fact that any stakeholder should be able to join a collaborative community to contribute to the increase its overall efficiency. Stakeholders can contribute to the efficiency of the community in many different ways. Some examples of stakeholder contributions are given below:

1. Freight owners can contribute through offering their freight volumes to the community.
2. Asset owners can contribute through offering their warehouses to the community.
3. Asset owners can contribute through offering their transportation assets to the community.
4. Service providers can contribute through offering their routing solutions to the community.
5. Service providers can contribute through offering freight tracking solutions to the community.
6. Trustees can contribute through offering governance mechanisms to the community.

3.1.1 Who are the actors in Logistics today

There are multiple ways to classify the main actors in the supply chain. In document D4.6[2] of this project lists of the main actors in the supply chain are included. In one scenario of Corridor-centric PI Network the main actors and their main roles

- End User/ Shippers like P&G
- Freight forwarders
- End Customers/ Retailers like SONAE
- Consumers/ Shoppers
- Shipping Companies
- Container leasing companies
- Mobile Network Operators

In the LL1 there are different operators (Deep Sea terminal Operators, Rail Way operators, Infrastructure managers (public and private)) for all other stakeholders, which are indicatively:

- infrastructure manager
- railway undertakings
- industrial sites
- freight forwarders
- breakbulk/intermodal terminal operators
- Combined Transport operators

[1] Deliverable 1.2 Concept of Collaborative Logistics Communities
[2] Deliverable 4.6 Business Plan and Exploitation Actions

- tank storage operators

Depending on the scope, the PI users could be different. In LL3 e-Commerce centric PI Network, the main players consist of over 650 stores operated by SONAE from different retail outlet profiles (urban hypermarkets, large supermarkets, proximity supermarkets, non-food goods and dark stores). And additionally, 3rd party pick-up points and 3rd party delivery agents such as Uber drivers may also be examined.

In the last Living Lab, LL4 Warehousing-as-a-Service (WaaS) the main Customer are Shippers demanding storage space, industrial companies and building works (construction) companies and Logistics providers offering storage space and transporters or retailers operating their own logistics services for internal operations.

3.1.2 Needs and requirements for PI adaption

In document D4.6 of this project (D4.6 Business Plan and Exploitation Actions) there is an extensive analysis of the main needs of the actors in the supply chain for the adoption of PI.

The needs of companies have been analyzed from different points of view. From the point of view of companies that perform road transport, their main needs are:

- Low complexity (low because of full truck scenario)
- Consists of 3 steps only
- Loading
- Road Transportation
- Unloading
- Easy to manage with low interdependency
- E2E Supply Chain Visibility Solutions available

From the point of view of companies and customers that are related to city urban environment, eCommerce , the main needs would be :

- Buy grocery for the family
- Manage the family budget
- Save time for more important things
- Get the grocery home/ upstairs
- Store the grocery in cupboard and fridge
- Manage/ reduce grocery waste
- And the main “pains” for this group of companies are:
- Delayed grocery deliveries, if needed to be home at delivery time
- Needs to meet expectations of the family members
- Last minutes needs, that must be included in the order
- Products that are important and urgent are not included in the delivery
- User-unfriendly app
- Does not like to miss promotion from in-store offers
- Limited parking space in front of his house for large vans/ problems with neighbors
- Hates too much plastic waste in groceries
- Spoiled products
- Misuse of personal data protection

Analyzing the needs from the point of view of product manufacturing, focused in the industrial distribution the main problems these companies found are the following:

- Store own products or Suppliers' products
- Make sure that products' storage meets requirements for safety and quality, especially for perishable or flammable goods etc. s
- Manage stock levels
- Manage Master data of the products, the codification and labels
- Manage business processes for selling and storing the products
- Manage tractability of the goods
- Manage shrinkage
- Manage reverse logistics
- Manage legal and tax requirements for transactions and documentation
- Manage ordering, product shipment or delivery processes
- Manage CO2 or ecological impact of deliveries
- Manage the end to end exchange of information besides tractability itself but also for information purposes and coordination of the teams and predictability.

Finally, as a general summary the main advantages that these companies perceive as potential benefits are the following list:

- Lower fixed cost
- More flexible variable cost
- Less personnel intensive processes
- Concentration on core business
- SC Visibility and Transparency
- Shorter planning period/ shorter contractual commitment
- More flexible planning and routing
- Exchange of information
- Increase of scalability, agility and flexibility in operations and business

3.1.3 Collaboration in the supply chain

Openness implies also that there is a dynamic dimension to collaborative communities. On one hand stakeholders should be able to join and leave the network at any time, which means that the composition of the community is dynamic and continuously changes over time. On the other hand, stakeholders should be able to change their contributions to the consortium. Freight volumes can indeed change as a result of changing business conditions and strategies. Assets can be added or withdrawn from the collaboration. Routing and freight tracking solutions can change due to evolutions in technology and business models. Trustee services might evolve due to automation and changes in legislation.

Beside the fact that logistics collaborative communities need to be open, they also need to be networked.

As a primary objective, logistics collaborative communities should form small networks in which efficiencies are generated through the freight consolidation and optimized asset utilization. These logistics collaborative communities operate in the same way as Digital Intranets and can as such be considered as Physical Intranets.

Not only should the network aspect of logistics collaborative communities be limited to the Physical Intranet level, but. Networking also implies that there should be interconnectivity in between different logistics collaborative communities.

It should indeed be possible that freight travels from its origin to its destination through different logistics collaborative communities. All logistics collaborative communities or Physical Intranets should be directly or indirectly networked into one overarching logistics collaborative community which is the Physical Internet. This concept is very similar to the Digital Internet which is basically an interconnected network of Digital Intranets.

ICONET GPICS framework is a concept that goes beyond the state of the art due to it provides all the necessary elements to model integration of networked collaborative communities with private logistics facilities and resources and future PI networks. GPICS framework provides, among other the following capabilities:

- Modeling components that allows to model both, private and PI shared logistics facilities. Each modeling component provides its functionalities (based on a set of functionalities of the PI nodes) and their main attributes (warehousing space, lead time, transport mode capacity, …).
- The modeling components allows to configure private networks (or private parts of networks such as distributions centers, warehouses, transports, etc.) and public (in the sense of PI paradigm) networks, for example promoted by public administrations such as ports, airports, etc. Altogether provides a full PI network.
- Configuration rules that allows to model different scenarios of collaboration in the collaborative logistics communities.
- Interconnectivity: a set of common attributes for all the modelling components and the definitions of PI roles and their participation in each PI event provides the interconnectivity capabilities.

Based on this, simulation models and LL instantiate the GPICS framework according to its specific needs.

The GPICS and the instantiations to each simulation model and LL specific requirements provide a great value for the logistics community. It would be impossible to achieve valuable conclusions, in terms of the impact of PI, without a common framework. Before ICONET project there was not a common approach to evaluate PI impact among different scenarios (location and functions of nodes, communication between nodes, linkage between private networks and PI public elements, etc). After ICONET GPICS framework definition logistics stakeholders have a set of resources to define and simulate scenarios in order to evaluate from a quantitative point of view the potential impact of PI paradigm.

Finally, not only the analysis of the Logistics realities of today in terms of players and requirements and expectations offers a clearer more reliant playfield on what the GPICS is required to do but also the GPICS identifies and standardizes in that process, the scope and shape of the PI services through which Logistics service providers can easily relate to, integrate more easily and in a better fashion to the context and offerings of the PI vision.

4 GPICS Framework

The goal of this chapter is to present the ICONET's GPICS Framework and its dimensions. This chapter remains unchanged with respect to the initial release of the deliverable since the GPICS Framework, which is one of the key concepts of the project, was fully defined in the initial release and it must be kept unaltered among versions to provide valuable and comparable results and conclusions.

4.1 General Overview

ICONET's Generic PI Case Study (GPICS) was raised as the epicenter of the project's methodology as it is shown in the following figure. The starting point (01) aimed for a fundamental understanding the PI business models and enablers, culminating in Generic PI Case Study (GPICS) and PI Hubs Plan.

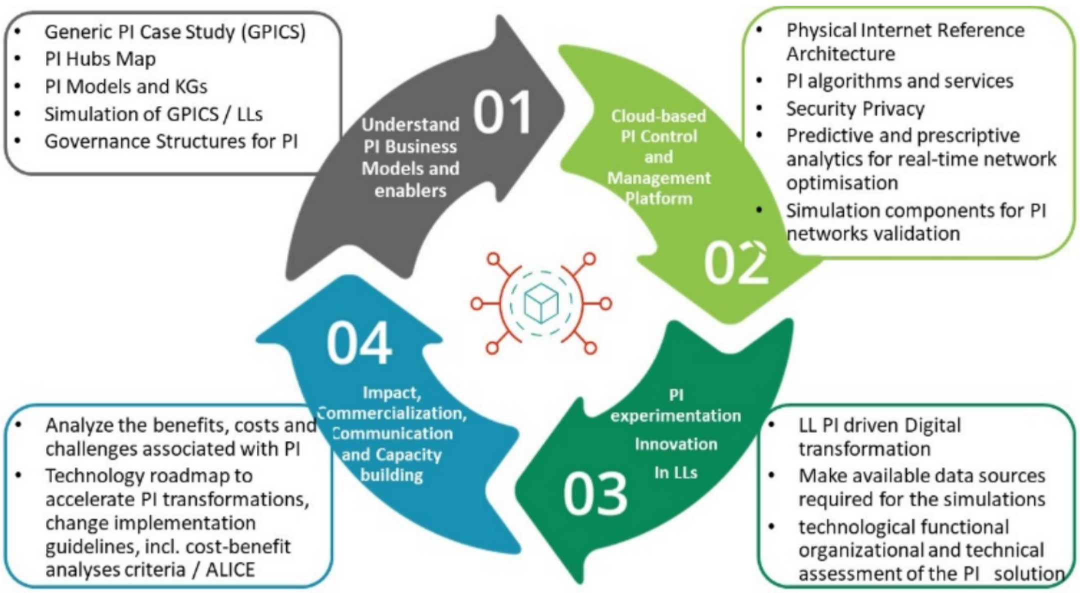


Figure 2: ICONET'S methodology

As part of the core of the project, the initial approach of GPICS, described in Figure 3, posed to combine the notion of a PI Hub (Antwerp port LL1), a PI Corridor (the North Sea – Mediterranean Corridor LL2), a PI (urban logistics) Network (SONAE LL3) all supported by e-Warehousing as a Service. Each of these four Key PI Capabilities would be combined into a generic case study, which will be modeled as an intra-continental inter-country PI network. Simulation would be used to establish a PI Hubs Plan and to investigate specific use cases proposed by the associated Living Labs.

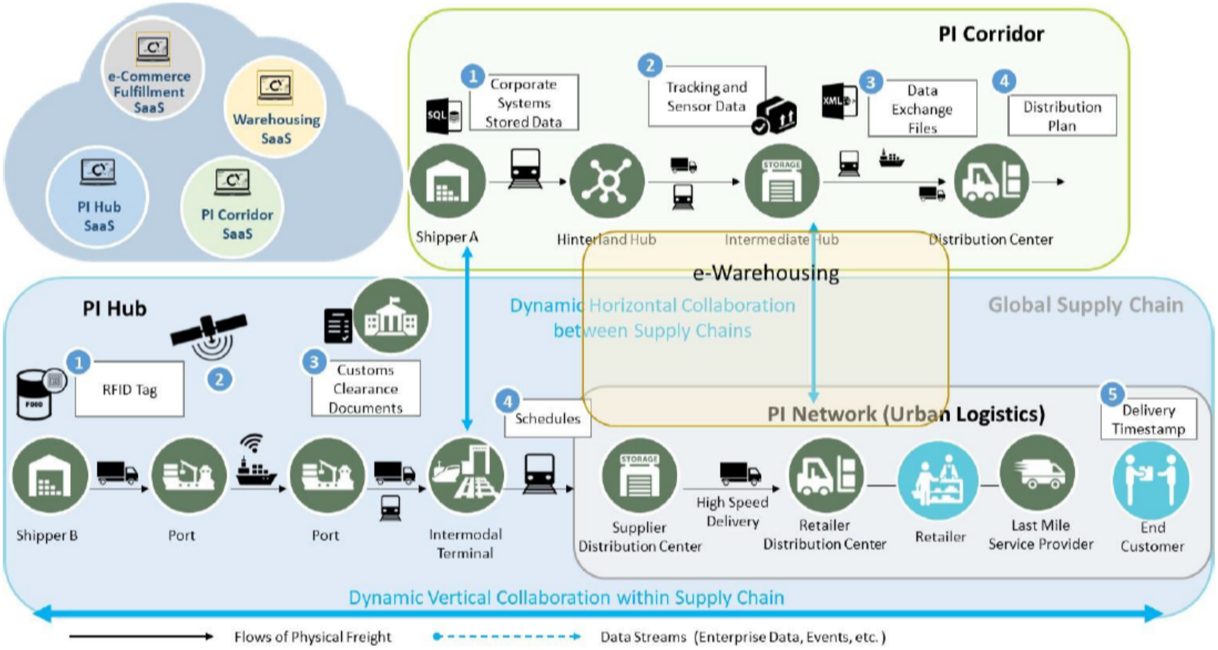


Figure 3: ICONET'S GPICS overview

GPICS represents an abstraction of a PI supply chain network, based on the four Key PI capabilities which correspond to a different LL within ICONET. GPICS makes a representation of a real-world system by creating a conceptual model for a generic geographic area, a series of descriptive elements, the logical relationships relative to the components of the system, the input and output data and a set of capabilities for different scenarios configuration.

In McLean and Shao (1992) [3] a representation is defined as a set of conventions on how to describe a class of things. A description makes use of a representation to describe some particular thing. McLean and Shao (1992) [3]also defines the four fundamental parts of a representation:

- Lexical – determines what symbols are allowed in the representation vocabulary
- Structural – describes constraints on how symbols can be arranged
- Procedural – specifies access procedures to create modify, and query descriptions
- Semantic – establishes a way to associate meaning with descriptions

Six-dimensional GPICS model covers those fundamental parts of a representation. Because representation and description are not the actual "thing or things" that are being modelled, there is always the possibility of introducing errors each time a representation or description is created. Figure 5 illustrates the general concept of abstraction. On the left side, we start with something real, i.e., the target "thing(s)" objective to model. They can be real "things," such as the nodes of the supply chain, processes, systems, or facilities. It is also possible that "thing(s)" are descriptions based on some form of representation, e.g., a drawing of an installation. A manager, engineer, simulation analyst, performs an abstraction process and creates an output representation and/or description. The abstraction process may involve observation, analysis, simplification, approximation, substitution, representation, and/or description. The outputs are new conceptual representations or descriptions of the "thing(s)" with the possible introduction of errors.

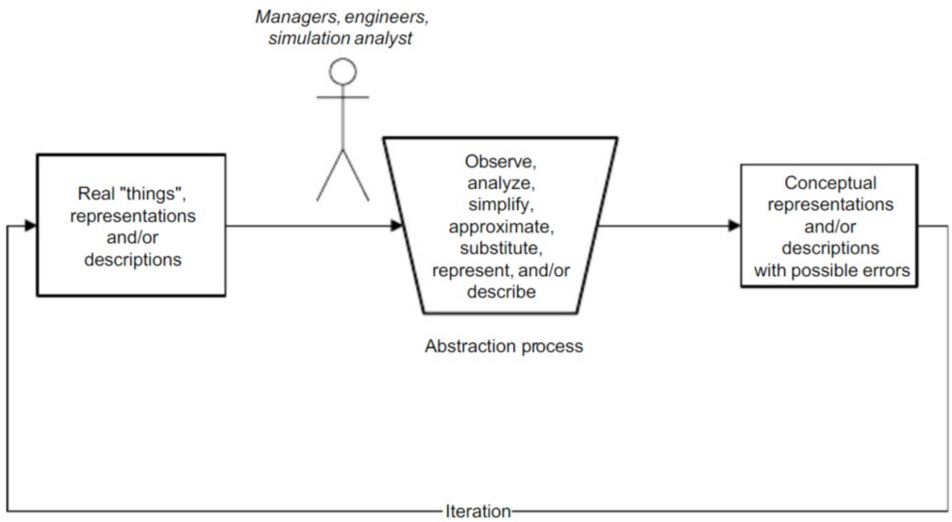


Figure 4: Abstraction process

GPICS definition and its associated PI Hubs Plan are approached as an iterative process in three versions. The current second version of PI Hubs Plan is based on the first release, version 1, and represents an incremental iteration over the initial version. The main difference between these two versions is the scope, in terms of complexity in the instantiation process of the six-dimension GPICS Framework. As a consequence of that, the version 2 of the PI Hubs Plan will be also more detailed and will cover a wider geographical area.

The GPICS framework consists of six dimensions that are interrelated, in fact, these six dimensions that make up the GPICS are more than interrelated, they are interdependent, in the sense that each of them is the input to the next. The GPICS framework provides not only the components needed for a case study definition but also a process or cycle to drive it. GPICS dimensions are also indivisible due to the fact that none of them makes any sense without the others since the whole set is what really enables the instantiation and, therefore, the definition of GPICS.

The final purpose of the Generic PI Case Study (GPICS), based on the ICONET Living Labs, was to investigate and produce a PI Hubs Plan with the position, size and number of hubs needed to efficiently link the long-distance network to urban areas, and use it for simulation of key PI scenarios to analyze PI performance at different scales and granularity levels, in terms of Key Performance Indicators (KPIs). To make this possible, the GPICS of ICONET has been addressed as a conceptual framework or an abstraction of the sum of each Living Lab project. As shown in Figure 6 GPICS is defined on the basis of six interrelated dimensions covering from the necessary **modelling components and the rules of base configuration (Modelling Kit)** up to the capabilities of **scenarios' definition/parameterization** (based on operational rules, business models and vertical and horizontal collaboration strategies among different roles in the supply chain) including **Master Datasets**, which concern and are relevant to a **Geographic Area** within the EU, which will allow the instantiation of the GPICS and the creation of the PI Hubs Plan. As mentioned above, the GPICS also includes a set of key performance benchmarks **Baseline Key Performance Indicators** for the evaluation of different PI scenarios, based in different combination of the configuration capabilities of those scenarios.

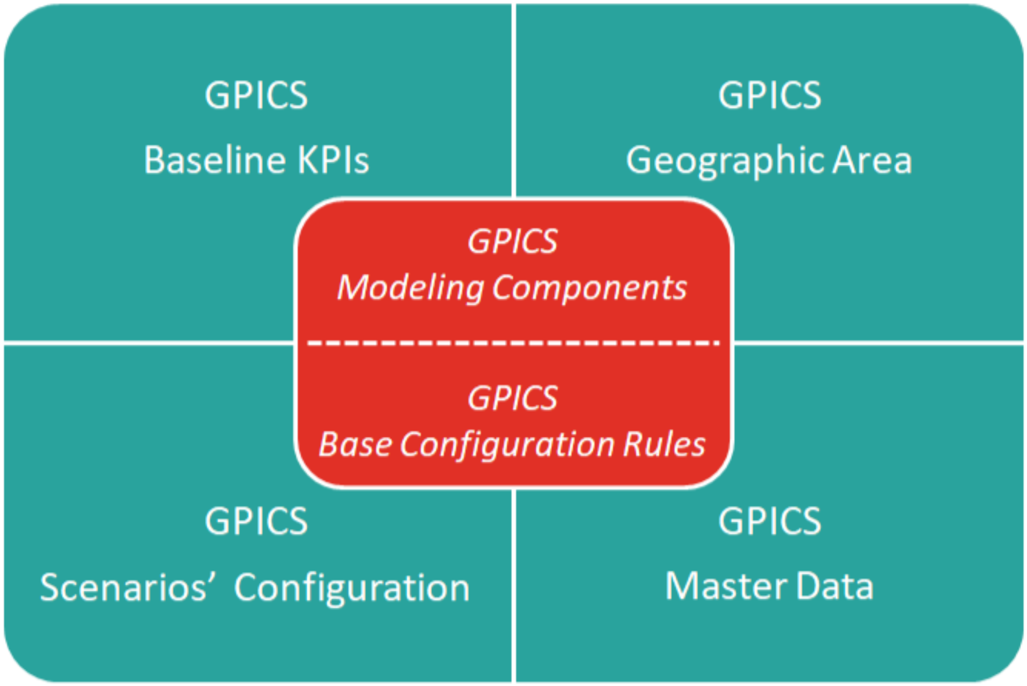


Figure 5: GPICS Framework/Dimensions

The instantiation of each of these six dimensions, for example the selection of a specific region with its master data or the determination of a concrete configuration of the modelling kit, establishes a GPICS definition.

The GPICS framework is directly related to the ICONET's living labs. The modeling components and base configuration rules in the Modeling Kit meet the PI challenges posed by LL and at an abstraction level allow the integration of the four Key PI capabilities which correspond to each of them. GPICS framework is the basis for the PI Hubs Plan. The instantiation of the GPICS framework results in a GPICS definition and the subsequent application of outputs and results, mainly methodology and algorithms, of "T1.3 PI Network optimization strategies and hub distribution policies" generates the plan of PI Hubs plan to the defined GPICS.

The GPICS framework is also the basis for simulation models. GPICS modeling elements and base configuration rules, which are included in the dimension "Modeling Kit", have a direct correspondence with simulation models. On the one hand, the modeling elements, such as hubs/nodes or corridors, have their representation in the simulation as objects, the so-called 'Atoms', and on the other hand these 'Atoms" have a behavior based on the basic configuration rules defined in the GPICS framework and instantiated in the GPICS definition.

In addition, the GPICS capabilities for different scenarios configuration also provide additional inputs to the simulation in terms of configuration parameters and data. The Simulation models implement these specific configurations of scenarios and are fed with this information. Another link between the GPICS and the simulation is the KPIs. GPICS defines a set of three-categories of key performance indicators. Those selected in a GPICS definition (instantiation of GPICS framework) are calculated based on the results obtained from each simulation scenario launched.

4.2 GPICS Dimensions

The “Geographic Area” is the first dimension of the GPICS definition. The geographical area defines the EU regions covered by the case study and represents the main GPICS parameter. As it is detailed in section 5, geographic area selection must be based on EU state members and its associated NUTS-2 regions classification. The geographical area, which creates an instance of GPICS, has no limitations and can be as wide as required. It can vary from an area or set of areas in an isolated member state of the EU, to all of Europe, through the combination of a set of member states and a selection of regions within them. The only restriction for the selection of a geographical area should be the availability of the Master Data Set for the selected EU member states and regions. Actually, this is only a constraint but not a restriction due to Master Data can be simulated, but the more real the Master Data associated with the geographic area is, the more precise the GPICS KPIs values will be and the more valuable the values will be. The conclusions will be, based on the simulation models that support and implement GPICS. This dimension is detailed in section 5 of this document.

The second dimension that composes the GPICS is the “Set of Master Data” associated with the geographic area selected in the previous dimension. If the geographic area has been considered the initial parameter of the GPICS, the master data sets are the rest of parameters which complement the scale and the European-wide scope of the GPICS. This master data characterizes the current supply chains in the GPICS geographical area in terms of specific ports, multimodal hubs, TEN-T corridors, urban distribution centers, population coverage, cargo/freight load distribution, transport demand/flow, warehousing capacity, transport modes and frequencies, lead times, taxonomy of T&L actors involved, etc.

The GPICS Master data sets are defined on either or both of the two levels at which the GPICS geographic area is defined, that is, EU member and NUTS-2 region classification. The Master data sets represent a starting point for the GPICS, which show the current movements of the supply chains and constitute the minimum necessary data that allows the GPICS to work through the simulation models. At the same time, these sets of master data are the basis of the definition of the scenarios, since many of them are configured through variations and combinations of these input parameters, creating what-if scenario analysis. As it was mentioned above, real Master Data Set should be available for the selected EU member states and regions. Actually, this is only a constraint but not a restriction due to Master Data can be simulated, but the more real the Master Data associated with it, the more accurate the GPICS KPIs values will be and the more valuable the conclusions will be, from the simulation models which support and implements the GPICS. This dimension is detailed in section 6 of this document.

The core of the GPICS is the Modeling Kit, which consists of two dimensions. On the one hand, it includes the “Modeling Components” and, on the other hand, the “Base Configuration Rules”. The modeling components are a set of elements that represent physical elements in a PI network, such as: PI hubs/nodes, PI corridors, PI containers, etc., as well as, a set of roles which interact and have an active participation in a supply chain in PI. Amongst these roles, we can highlight: PI sender, PI receiver, PI transport & logistics service provider or PI network coordinator. These two dimensions are detailed in sections 7 and 8 of this document.

The fifth dimension which is part of GPICS, is the “Scenarios' Configuration Capabilities”, based on What-if scenario analysis (WISA). WISA is a business planning and modelling technique used to yield various projections for some outcome based on selectively changing inputs parameters. A scenario, in this context, is a potential circumstance (i.e. parameter change) or combination of circumstances (i.e. combination of different parameters changes) that could have a significant impact -- either positive or negative -- in an organization. A company can use what if scenario analysis to see how a particular outcome, such as costs, can be affected by changes in particular variables, such as late delivery of supplies or lack of availability of key personnel.

GPICS scenarios' configuration capabilities define those user-adjustable variables that modify the GPICS start point (defined by master data sets) to measure and evaluate the impact in terms of the defined GPICS KPIs in the next dimension of the GPICs in the PI supply chains. GPICS scenarios’ configuration dimension provides the ability to define multiple scenarios based on the mater data, the modelling components and their basic configuration rules, which represent the entire supply chain data. This dimension is detailed in section 9 of this document.

The last dimension of GPICs consists of a set of “Generic Key Performance Indicators”, which will allow a standard and common evaluation of the performance of the PI supply chains configured in the GPICS, between different scenarios. The GPICs Key Performance Indicators have the mission to provide a comprehensive vision of the impact of PI with respect to the current situation and to be an instrument capable of shedding light on the strengths and weaknesses of different PI scenarios. These scenarios will be defined using the scenarios’ configuration capabilities included in the previous GPICS dimension and, subsequently, they will be simulated through the GPICS simulation models implemented in WP2. The GPICS performance measurement system will analyze the PI supply chain at two different levels, on one hand, at individual level, that is, each actor in the supply chain, and on the other hand, globally, that is, the supply chain as a whole. This dimension is detailed in section 10 of this document.

4.3 GPICS Geographic Area Aggregation

The goal of this chapter is to describe in detail GPICS Geographic Area Aggregation dimension. As far as this dimension is concerned, a comprehensive definition and description was provided since the initial release of the document.

The geographic Area aggregation dimension of GPICS, establishes its scope and boundaries, as indicated by its name, is the geographic area covered. The regions within this area will be those that will be part of the analysis and studies through the definition of scenarios and PI simulation models.

Considering that the final objective of GPICS is the creation of a PI HUBS Plan to analyse and study different PI scenarios using simulation technologies, the GPICS geographic area selection begins and allows the GPICS definition process, since the Plan PI HUBS must be specific for a specific geographic area, oriented to its needs, such as: freight flows, transport demand, warehousing capacities, transport availability, etc. This means that geographic area establishes the main framework for the definition of GPICS and its associated HUBs Plan.

Once the geographic area within the GPICS scope has been determined, it can be configured and parametrized initially using the GPICS Master Data, then it can be dimensioned in terms of main parameters (population, freight flows, transport demands, etc.) and have a clear overview of its representativeness and European dimension, extrapolate the results and draw conclusions based on GPICS KPIs. The geographic area in the GPICS is defined in two levels. The upper level represents the EU state members, while the lower level represents the NUTS-2 regions (Nomenclature of Territorial Units for Statistics) that belong to the countries included in the top level. The current NUTS classification lists 104 regions in NUTS 1, 281 regions at NUTS 2 and 1348 regions in NUTS 3 level. The NUTS classification (is a hierarchical system for dividing the EU´s economic territory in order to:

- The collection, development and harmonisation of European regional statistics
- Socio-economic analyses of the regions
    - NUTS 1: major socio-economic regions
    - NUTS 2: basic regions for the application of regional policies
    - NUTS 3: small regions for specific diagnoses

The EU state members are in geographic areas that are too wide, so it is it is considered difficult to achieve valuable results and conclusions focused only at this level. An additional level, in this case NUTS-2 level, gives the GPICS the opportunity to have more detailed models at the same time that they could provide aggregate and realistic values and figures in EU state members dimension.

The key reason why lower level of GPICS geographical area definition has been based on NUTS-2 classification is due to the availability of a common statistical standard through the European Union, because the NUTS levels are geographical areas used to collect harmonized data in the EU. This assures the decoupling of GPICS and the specific geographical area, thus creating a real generic PI case study which can be instantiated on the basis of the selected EU Members and their corresponding NUTS-2 areas.

NUTS-2 classification provides and supports the GPICS with additional advantages:

- The NUTS-2 provides optimal geographical extension. While the country or NUTS-1 classifications are too broad and the NUTS-3 regions are too small, in terms of supply chains, NUTS-2 provides the midpoint between them.
- The NUTS-2 classification generally reflects the territorial administrative division of the Member States, which is generally aligned with the main logistics facilities and the origins and destinations of freight flows.
- The NUTS-2 classification provides common and uniform data with similar dimensions and levels of aggregation across countries and regions, regardless of the geographical area selected that will allow expanding the GPICS and its associated HUBs Plan from initial version (v1) to final version (v2).
- The NUTS-2 classification has been used since 1988, so historical data are available, if necessary.
- The NUTS classification can be modified, but in general no more than every three years. The changes are generally based on changes in the territorial structure in one or more Member States, so the GPICS continuity and the future validity of GPICS is highly guaranteed.

4.4 GPICS Master Data

The goal of this chapter is to describe in detail GPICS Master Data dimension. As far as this dimension is concerned, a comprehensive definition and description was provided since the initial release of the document.

The dimension of GPICS Master Data Sets includes different information records associated with the geographical area selected in the previous dimension. If the geographical area is considered the initial parameter of the GPICS, the master data sets are the rest of the parameters that complement the scale and the European-wide scope of GPICS. This master data characterizes the current supply chains in the GPICS geographical area in terms of specific ports, multimodal hubs, TEN-T corridors, urban distribution centers, population coverage, cargo/freight load distribution, transport demand/flow, warehousing capacity, transport modes and frequencies, delivery times, taxonomy of involved T&L actors, etc.

The GPICS Master data set information can refer to either or even both levels in which the GPICS geographical area is defined, that is, EU member and NUTS-2 region classification. If the information only refers to the classification of the NUTS-2 region, an aggregation process must be carried out to obtain information at the level of the EU member state. In case the information is only available at the higher level, a disaggregation process based on a distribution methodology in proportion between the NUTS-2 regions should be carried out.

The Master data sets represent a starting point for the GPICS definition in terms of size and configuration, showing the current movements of the supply chains and constitute the minimum necessary data that allow GPICS to work through the simulation models. The additional configuration information for simulation models comes from the location and routing algorithms from task T1.3.

Additionally, master data sets are the basis for the scenario's simulation definition, since many of them are configured through variations and combinations of these input parameters creating what-if scenario analysis. As it was mentioned above, the real set of Master Data should be available either for the selected EU member states or for their NUTS-2 regions. Actually, this is only a limitation, but not a restriction because the Master Data can always be simulated, but the more real the Master Data associated to the geographical area is, the more precise the KPIs values of GPICS will be and the more valuable will be the conclusions, obtained from the simulation models which support and implements the GPICS.

The GPICS Master Data Sets can be classified according to two criteria, the function in the framework and its origin. According to their function in the GPICS, the data sets can be classified into two categories, data for the GPICS dimensioning and data for the GPICS configuration.

- The dimensioning data provides an overview of the scale at European-wide scope of the GPICS. Typical data within this category are for example: population, number of ports or multimodal terminals, market share of logistics service providers, etc.
- The GPICS configuration data sets are those that provide a kind of background information related to the PI network, such us the transport flows that must be managed by the PI components (PI Hubs, PI Movers, etc.) and computed in simulation models, or static data, such as logistics and transport costs, transport emissions or logistics activities of the carbon footprint. The GPICS base configuration data is complemented by data derived from the instantiation of the base configuration rules defined in the GPICS Modelling Kit (e.g. levels of HUBS, transport modes) and the application of the methodology and the algorithms resulting from the "T1.3 PI Network optimization strategies and hub distribution policies" (positions of PI HUBS and the PI network based on the configuration of the basic connections).

Regarding the origin, the master data sets can be classified as real or simulated data. The real data in turn can be public/open or private data. Open data are pieces of information from statistical sources of information or research and study processes, while GPICS private data is information from members of the ICONET consortium, who lead or participate in any of the living labs. Public and private data are complementary and the latter can refine the former or even allow the configuration of more precise and specific scenarios for the assessment of a specific circumstance in a particular company.

The following table summarizes the master data sets included in the GPICS Framework and their classification according the two defined criteria.

Table 2: GPICS Framework master data sets

	ORIGIN	FUNCTION
POPULATION	PUBLIC	SIZING
PORTS	PUBLIC	SIZING
INTERMODAL TERMINALS	PUBLIC	SIZING
LSP MARKET SHARE	PUBLIC/PRIVATE	SIZING/CONFIGURATION
TRANSPORT MODES	PUBLIC	SIZING/CONFIGURATION
TRANSPORT FLOWS	PUBLIC/PRIVATE	SIZING/CONFIGURATION
TRANSPORT COSTS	PUBLIC/PRIVATE	CONFIGURATION
LOGISTICS COSTS	PUBLIC/PRIVATE	CONFIGURATION
TRANSPORT CAPACITY	PUBLIC/PRIVATE	CONFIGURATION

TRANSPORT EMISSIONS	PUBLIC/PRIVATE	CONFIGURATION
WAREHOUSING CAPACITY	PUBLIC/PRIVATE	CONFIGURATION

From the simulation models perspective, and to make possible the different simulation models to implement and execute functionalities, additional and specific information may be necessary.

4.5 GPICS Modeling Components

This section details the components defined in the GPICS framework to model the PI physical elements, considering diversity of elements, different levels of complexity and considering the Living Lab and Logistics industry needs. There are different types of PI physical elements approaches in the literature. As far as this dimension is concerned, a comprehensive definition and description was provided since the initial release of the document. Section 7.2 has been completed from the initial version with the correspondence of GPICS HUBS hierarchical structure and the requirements of all LL since in the initial version two the Living Labs were not enough developed. Section 7.7 has been slightly redefined and widen in this second release of the deliverable. In this version, different levels of detail and sophistication have also been included in the definition of the modeling components, taking into account the needs of the project partners. As shown in Figure 7, [2] Montreuil, Meller and Ballot (2010) proposed three key types of physical elements as enablers of Physical Internet: the PI containers, the PI nodes and the PI movers.

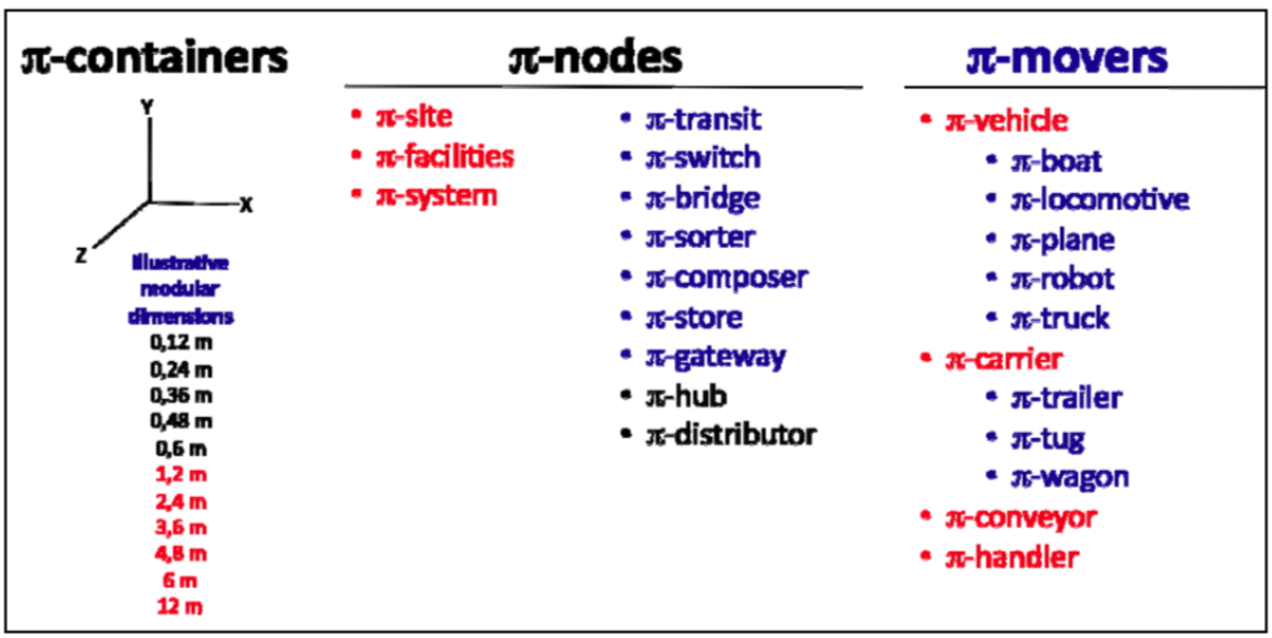


Figure 6: Types of physical elements

PI containers are described by Montreuil, Meller and Ballot (2010) in [2] as the unit loads that are manipulated, stored, moved and routed through the systems and infrastructures of the Physical Internet. Physical Internet containers come in modular dimensions, that means their approach is they must be logistics modules standardized worldwide and defined according to open norms.

In the Physical Internet, PI containers are generically moved around by PI movers. Moving in this context is used as a generic equivalent to different logistics and transport activities or processes such as transporting, conveying, handling, lifting and manipulating. The main types of PI movers include PI transporters, PI conveyors and PI handlers. The latter are humans that are qualified for moving PI containers. All PI movers may temporarily store PI containers even though this is not their primary mission.

PI nodes are defined by Montreuil, Meller and Ballot (2010) in [2] as locations expressly designed to perform operations on PI containers, such as receiving, testing, moving, routing, sorting, handling, placing, storing, picking, monitoring, labelling, paneling, assembling, disassembling, folding, snapping, unsnapping, composing, decomposing and shipping PI containers. They propose a variety of PI nodes delivering services of distinct natures, from the simple transfer of PI carriers between PI vehicles to complex multimodal multiplexing of PI containers.

Generically, the PI nodes are locations that are interconnected to the logistics activities. The activities at a PI node may affect physical changes, such as switching from a transportation mode to another. They may result in contractual changes for the PI containers. To each PI node is associated at least one event for each PI container to ensure traceability of its passage through the PI node.

The PI nodes are publicly rated on a number of key attributes, such as speed, service level adherence, handled dimensions of PI containers, overall capacity, modal interface and accepted duration of stay. Clients will use this kind of information for decision making relative to PI container deployment. Other pertinent Physical Internet entities will also exploit it for routing purposes, through the Physical Internet routing protocol.

Generically, PI nodes conceptually encompass PI sites, PI facilities and PI systems that are respectively sites, facilities and systems designed to act as physical nodes of the Physical Internet. Usually, PI sites include PI facilities and external PI systems, while PI facilities contain internal PI systems.

The PI node types proposed by Montreuil, Meller and Ballot (2010) in [2] vary in terms of mission orientation, scope and scale, as well as in terms of capabilities and capacities, however all have in common that they are explicitly specialized to deal with PI containers at the physical and informational levels. The main types of PI nodes include p-transits, p-switches, p-bridges, p-sorters, p-hubs, p-composers, p-shops, p-bridges.

In [4] Sarraj and Montreuil (2014) proposed a set of physical elements by establishing an analogy between the Digital Internet and the Physical Internet and expressed through three main characteristics: the interconnection of networks, the structure of the network of networks and the routing of objects through networks.

While the structure of the networks of networks is directly connected with architectural aspects such as regions, areas, etc. and the routing of objects across networks is related to the physical transport operations (such us loading, unloading, composition, etc.) and the decisions for the selection of next destination for the PI containers, the interconnection of networks is the key domain which defines the physical elements.

The idea of the PI is to interconnect all logistics service networks through the transposition of the principles of the Internet. Therefore, the objective is the universal interconnection of the logistics networks.

Sarraj and Montreuil (2014) in [4] argue that while the Digital Internet networks have the following physical elements: cables, hosts and routers, the Physical Internet faces a more complex reality in terms of the physical elements. Figure 8 shows the physical elements proposed by Sarraj, Ballot et al Sarraj and Montreuil (2014) in [4], and its correspondence with Digital Internet.

Network	Internet	Physical Internet	Interconnection function
Flow	Datagram	π-Container	Encapsulation of merchandise
Node	Router	Hub	Place of orientation (sorting), change of mode, service provider.
	Host (unique address)	Supplier or consumer	Place of containerisation and de-containerisation
Arc	Wire or wave connection	Transport services	Punctual or regular transport between two nodes.

Figure 7: Analogy between Digital Internet routers and Physical Internet Hubs.

Sarraj and Montreuil (2014) in [4] raise that, physically, a logistic service is carried out in accordance with a transport service based on a network consisting of nodes (including distribution centres, warehousing, plants, etc.), arcs to define the means of transfer of goods by means of freight services (road, rail, maritime service, etc.) and the final shippers/receivers (companies, organizations or individuals). Applying the Internet analogy, a shipper sends his merchandise to a nearby node that manages it, stores it and sends it to its destination through one of the numerous accessible logistics plans. For this purpose, as in the case of Internet data, the merchandise is encapsulated in the form of standardized packets: PI containers.

Based on the current state of the art of the research of modelling PI physical elements and with the valuable insights from ICONET's forums and living labs, ALICE cluster and Advisory Board of the project, a new approach of modelling components has been defined. GPICS makes an abstraction of a real PI world system by creating a conceptual model and such a representation must be defined by four fundamental parts: lexical, structural, procedural and semantic. In this regard, the GPICS modelling components cover and support two of these parts of the representation. On the one hand, the lexical part of the representation, which deals with the description of the symbols allowed in the vocabulary of representation, and on the other hand the semantic aspects of the representation that establish a way of associating meaning with the descriptions. This is one of the reasons why the GPICS modelling components are considered a fundamental part of the ICONET's GPICS framework.

The GPICS modelling components are designed to allow the composition of a generic PI network trough standard modelling elements. Through the appropriate configuration, these elements represent different types of supply chain flows. The structure of the generic model consists of the following main elements:

Table 3: GPICS modelling components

GPIC structure	
GPICS Container	Unit load manipulated, stored, moved and routed through the systems and infrastructures of the Physical Internet.
GPICS Node/Hub	Location specifically designed to carry out logistics and transport processes and activities on PI containers.

GPICS Transport	Moving element used to carry PI containers through the PI nodes/hubs.
GPICS Corridor	Connection between two PI Nodes/Hubs directly connected.
GPICS Route	Set of GPICS corridors which connect a GPICS Node origin and a GPICS Node destination.
GPICS Network	Set of containers, nodes, movers/transport, corridors, and routes.
GPICS Roles	Actors/Agents involved in the operation of the PI Network.

The following sections describe in detail each of the GPICS modelling components.

4.5.1 GPICS Container

The GPICS container represents load units that are manipulated, stored, moved and routed through the systems and infrastructures of the Generic Physical Internet Case Study.

The PI container is a key element of the Physical Internet and therefore a lot of research and design work have to be conducted in order to define them for the best fit with “movers” and treatment in “nodes”. The container has been central to the Physical Internet since its origins, due to the analogy to the Digital Internet [2]. By simile with data packets, the goods are encapsulated in modularly dimensioned easy-to-interlock smart containers, called PI-containers, designed to efficiently flow in hyper-connected networks of logistics services.

The ubiquitous usage of PI containers is to allow any logistics service provider to handle and store products of any company, since it will not handle or store the products by itself. The PI container is the load reference unit for moving products within the PI network. This GPICS modelling component is of fundamental importance from the simulation perspective. Each PI container will be an especial Agent that can be transported, handled or delivered. The Basic information that defines a GPICS container is the following:

Table 4: GPICS Container basic information

GPICS Container	
idContainer	Unique identifier of the GPICS container through the Physical Internet
idOrigin	Unique identifier of origin node in the GPICS network
idDestination	Unique identifier of the destination node in the GPICS network
idSender	Unique identifier of the sender of the container. The initial owner of the products.
idReceiver	Unique identifier of the receiver of the container.
deliveryTimeMax	Maximum delivery time
deliveryTimeMin	Minimum delivery time
GPSLatitude	Latitude GPS coordinates
GPSLongitude	Longitude GPS coordinates

From the simulation models perspective and to enable the execution of the different simulation models, additional and specific information could be required for the GPICS container.

4.5.2 GPICS Node/Hub

One of the key modeling components developed in the ICONET project is the Generic Hub, as the main element from the Generic Physical Internet Case Study (GPICS). The Generic Hub represents a node in the PI network, where goods are stored, transferred or manipulated between movements. The GPICS HUB, can also be referred as Generic Hub, since it can potentially have all the necessary functionalities in a Physical Internet network. In order to create an instance of the GPICS framework to define a specific case study, the GPICS HUBS allow the ability to have different functionalities that map the behavior of the real logistics hubs.

According to the literature review Sarraj and Montreuil (2014) [4] and Montreuil (2011) [5], the basic functionalities defined in ICONET GPICS framework for the Generic HUB include the following:

- Source: functionality that creates a new PI Container in the corresponding GPICS Hub
- Sink: functionality that removes an existing PI Container in the corresponding GPICS Hub
- Assembly: functionality that merges existing PI Containers into a new PI Container in the corresponding GPICS Hub
- Split: functionality that divides an existing PI Container into several PI Containers in the corresponding GPICS Hub
- Queue: functionality that queues up an existing PI Container for a limited period of time in the corresponding GPICS Hub
- Store: functionality that stores an existing PI Container during agreed upon target time windows in the corresponding GPICS Hub
- Switch: functionality that transfers uni-modally PI containers from an incoming PI Mover to a departing PI Mover in the corresponding GPICS Hub
- Bridge: functionality that transfers multi-modally PI containers from an incoming PI Mover to a departing PI Mover in the corresponding GPICS Hub
- Sort: functionality that receives PI Containers from one or multiple entry points and sorts them so as to ship each of them from a specified exit point in the corresponding GPICS Hub
- Gateway: functionality that receives PI Containers in the corresponding GPICS Hub and releases them so they can be accessed in a private network not part of PI.

These functionalities, included in the GPICS framework for the GPICS Hubs can be instantiated, this means can be activated or not, for different Hubs in each GPICS definition and they should be implemented in the simulations models accordingly and using the simulations capabilities. The goal of the GPICS is to make a representation of a PI supply chain network based on the four Key PI capabilities which correspond to a different LL within ICONET. The definition of the GPICS Hub is part of this abstraction process. In this sense, the Generic Hubs contribute, on the one hand, to the simplification and approximation, and on the other hand to the representation, and description of the PI supply chain.

Simplification and approximation are made through the approach that each Generic Hub has an area of influence. This means that, for example, if there is a Generic Hub in a certain Location, each GPIC Order that is delivered near this Location, its destination will be the Generic Hub in the area of influence. The area of influence of a Generic HUB can vary from 50 to 300 kilometers, according to different criteria, such as the population density of the real logistics facilities in that area.

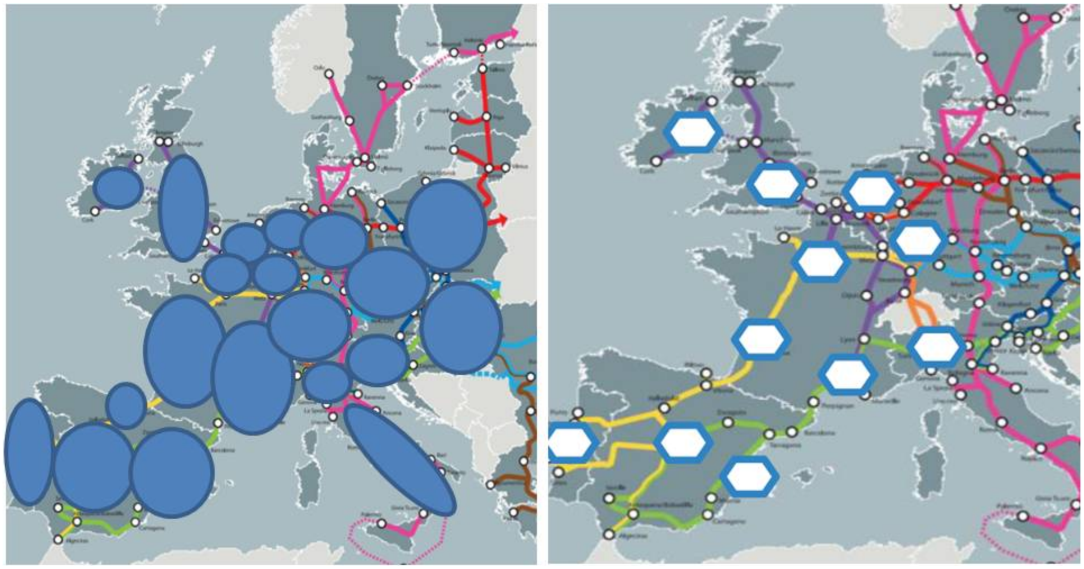


Figure 8: GPICS Hub area of influence representation

GPICS has to address and bring together the requirements of the four Living Labs. As part of the abstraction process and taking into account the specificities of each of them, the representation and description are made through the creation of a hierarchical structure and the dependency of the GPICS Hubs. More specifically, a three-level structure (due to the maximum levels required by LL) of HUBS has been defined. Therefore, when defining, each Generic HUB belongs to L1, L2 or L3, in the instantiation process for a specific generic definition of a case study. The dependency is based on a simple rule: a L2 Hub depends directly on a L1 Hub and a L3 Hub depends directly on a L2 Hub. Indirectly, a L3 Hub depends on the corresponding L1 Hub.

This allows to address the specific requirements of the living labs and matches the Hub & Spoke methodological approach defined in T1.3 that will be used to define the Generic Hubs Plan in the GPICS definition.

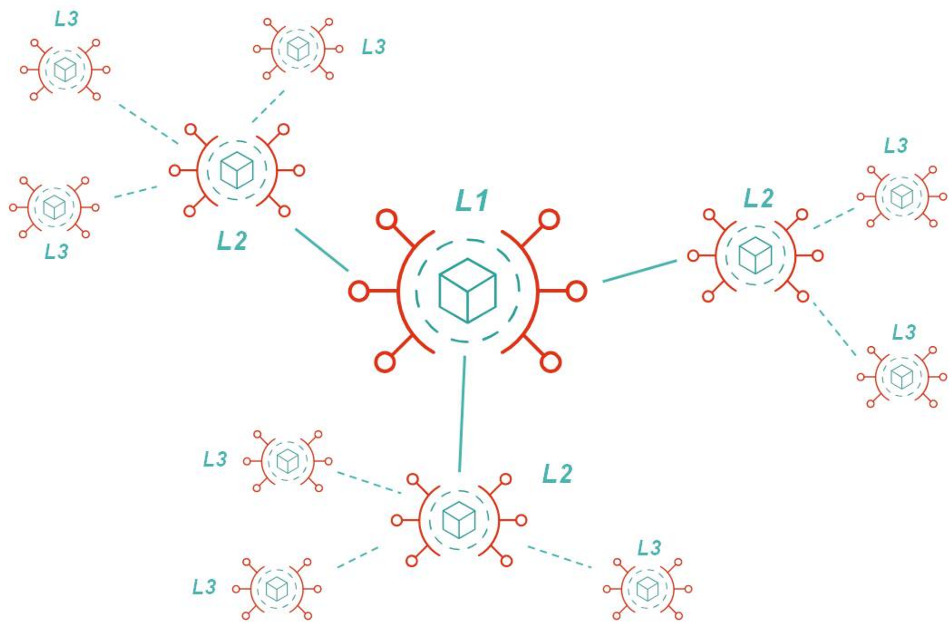


Figure 9: GPICS three-level structure of HUBS

The correspondence between the Living Labs requirements and the hierarchical structure of Generic Hubs is shown in the following table:

Table 5: Correspondence of GPICS HUBS hierarchical structure and LL requirements

	GPICS	SONAE / PI URBAN LOGISTICS NETWORK	STOCKBOOKING / WAREHOUSING AS A SERVICE	ANTWERP / PI HUB	P&G /PI CORRIDOR
LEVEL 1	COUNTRY	BLACK WAREHOUSE	CENTRAL WAREHOUSE	PI HUB PORT GATEWAY	MULTIPLE PI HUBS IN THE CORRIDOR GROM ORIGIN TO DESTINATION
LEVEL 2	NUTS - 2	SHOP	REGIONAL WAREHOUSE	INTERNAL BUNDLING AREA	PI HUBS IN THE CORRIDOR GROM ORIGIN TO DESTINATION
LEVEL 3	URBAN	POINT OF DELIVERY	SATELITE WAREHOUSE	DEEP SEA TERMINAL	PI HUBS IN THE CORRIDOR GROM ORIGIN TO DESTINATION

The basic information that defines a GPICS Hub is the following:

Table 6: GPICS HUB basic information

GPICS Hub	
idNode	Unique identifier of the GPICS HUB through the Physical Internet
idLevel	Level of the HUB in the hierarchical structure (L1 to L3)
IdNodeDep	Identifier of the node on which depends (N.A. for L1 nodes)
List of functions	Set of basic functionalities assigned to the Hub
AttWhCapacity	Available Warehouse capacity for PI
GPSLatitude	Latitude gps coordinates
GPSLongitude	Longitude gps coordinates

From the perspective of the simulation models, in order to implement the functionalities and execute the different simulation models, additional and specific information may be necessary for GPICS hub.

4.5.3 GPICS Node details

According to Montreuil (2011) [5] the PI node need to have the following functional capabilities:

- Enabling fast and reliable input and output performance.
- Seamless interfacing with vehicles and systems moving products in and out, as well as with client software systems for tracking and interfacing with the containers.
- Monitoring and protecting the integrity of containers
- Securing the containers to the desired level
- Providing an open live documentation of their specific performance and capabilities and of their demonstrated performance and capabilities, updated through ongoing operations.

In the previous chapter, we have defined a generic PI node, with the main functionalities to operate with different types of containers and transport. Inspired in [5] we can define more specific node types, with a group of functionalities for specific purposes.

- PI switch node: The purpose is to transfer between transport, carrying containers from their inbound transport to their outbound transport. The switch can be made between different types of transport, for example between truck and train, or between ship and train.
- PI sorter node: The main functionality is receiving containers from one or multiple entry points and sorting them so as to ship each of them from a specified exit point, potentially in a specified order.
- PI composer node : This node builds PI containers from specified sets of smaller PI containers, usually according to a specified 3D layout, and/or dismantling composite PI containers into a number of PI containers that may be either smaller unitary or composite PI containers.

- PI store node: This node allows you to perform temporary storage operations. Storing containers during agreed upon target time windows.
- PI gateway node: This node is an entry point to the rest of the PI network. Receiving containers and releasing them so they and their content can be accessed in a private network not part of the Physical Internet, or receiving containers from a private network out of the Physical Internet and registering them into the Physical Internet, directing them toward their first destination along their journey across the Physical Internet.

In the Physical Internet deployment, it is possible to find nodes that perform only one of these functions. It is also possible to find facilities that perform several functionalities in the same place. For instance, in some of the warehouses it is possible to realize "store node" actions and "sorter node" actions.

4.5.4 GPICS Link

The GPICS Link modelling component also helps to do its bit in the GPICS abstraction process. The links between two GPICS Hubs, made by the modelling component of the GPICS Link, enable the representation of many different configurations of connections.

The existence of a Link, from an origin to a destination, implies that a transport between these two PI Hubs is potentially possible. To make a transport reality, this Link must be configured in at least one GPICS route with at least one GPICS Move/Transport, it must be configured in that route and with parametrised stops in those two GPICS Hubs. The basic information that defines a GPICS Link is the following:

Table 7: GPICS Link basic information

GPICS Link	
idLink	Unique identifier of the GPICS Link in the Physical Internet
idNodeStart	Identifier of the origin node of the Link
idNodeEnd	Identifier of the destination node of the Link
typeLink	Link type according to the selected transport mode (road, rails, sea…)
attCapacity	Attribute to indicate the capacity of the transport.
attCongestion	Increment of the transit time due to external incidences.
atTransitTime	Average trip duration from start to end of the link

From the perspective of the simulation models, in order to implement the functionalities and execute the different simulation models, additional and specific information may be necessary for GPICS Link.

- *GPICS Link details*

The general characteristics of each of these links can be extended by special features as shown in the following list:

- Congestion: Depending on the corridor type, transports could face with delay issues due to congestion on it.
- Weather conditions: Weather conditions can affect to transports in the corridor, reducing their maximum speed or stopping the traffic on it.
- Taxes / Toll: in some corridors some kind of tax is needed to use them (tolls in some highways, time slots in railways…)
- Link Quality: Information on the state of the connection, such as bumps, dirtiness, construction work...

With this type of properties, the PI model could include elements like a **PI Road Link r**oad node connection for connections between cities, normally used by trucks of different types and vans. **PI City Link,** transport routes for access and distribution of freight in cities. Currently, big cities are under strict access controls for certain types of vehicles due to environmental policies. In addition to distance, its main characteristic is congestion and the type of vehicle it allows to circulate (electric, pedestrian...). **PI Train Link, r**ailway connections between the main nodes of a region in general, they refer to the railway tracks for freight. They may be travelled by different types of trains. In addition to cargo stations, they have a special type of node for the classification of wagons "bundling nodes”.

4.5.5 GPICS Route

The GPICS Route modelling component is a set of GPICS Links that connect two GPICS Hubs, a source and a destination. These two GPICS Hubs do not have to be directly connected. This is where the great difference lies between the GPICS Link and GPICS route lies.

The GPICS Route modelling component also contributes to the GPICS abstraction process. On the basis of the defined GPICS Links, a grouping of GPICS Routes can be defined, some of them matching existing real routes (those of long distance, such as TEN-T Corridors or Motorways of the Sea), those of medium distance, (as milk routes between different warehouses or logistics facilities. or short distance routes like urban delivery paths) and some of them, simulated routes in the definition of the specific generic case study. Each GPICS Route also defines its allowed stops, since a route can traverse a set of GPICS Hubs, but it may not stop at all of them. The basic information that defines a GPICS Route is the following:

Table 8: GPICS Route basic information

GPIC Route	
idRoute	Unique identifier of the GPICS Route in the Physical Internet
listLinks	List of Links included in the route
listStops	List of stops included in the route

From the perspective of the simulation models, in order to implement the functionalities and execute the different simulation models, additional and specific information may be necessary for GPICS Route.

4.5.6 GPICS Transport

The GPICS Transport modelling component represents the means of transport used to carry GPICS containers through the GPICS Network infrastructures, which are made up of GPICS Nodes/Hubs and the GPICS Links which, in turn they form the GPICS Routes.

GPICS Transport is also a recurrent physical element present in Physical Internet since its origins, according to Montreuil, Meller and Ballot (2010) [2] PI – movers , convey or handle containers within and between nodes of the Physical Internet.

As in the case of others GPICS modelling components, GPICS Transport brings a level of abstraction to the case study definition. A GPICS Transport can represent a specific and existing mean of transport between two points (i.e. a freight train with a fixed timetable and schedule stops) but it can also represent a generic moving element between an origin and a destination (two GPICS Hubs) aggregating different existing transport alternatives in terms of total capacities, average lead times, etc. In the same way it can also represent a simulated mean of transport supporting the movements through the connections generated as consequence of application of outputs of T1.3. The basic information that defines a GPICS Move/Transport is the following:

Table 9: GPICS Transport basic information

GPICS Transport	
idMover	Unique identifier of the GPICS-mover through the Physical Internet.
typeMover	Identification of type of transport: Generic, Road, Rail, Ship.
idPath	Unique identifier of the GPICS route followed by the Mover.
typeFrec	Identification of the type of frequency of the transport: As needed, Daily, Weekly, Non-Stop, OnlyOneTrip.
attCapacity	Attribute to indicate the capacity of the transport.
attFillingRate	Attribute to indicate the filling rate of the transport.

From the perspective of the simulation models, in order to implement the functionalities and execute the different simulation models, additional and specific information may be necessary for GPICS Transport.

- *GPICS Transport details*

In addition to the common characteristics, specific attributes can be included in some of the models used to identify the special characteristics of specific transports.

- Transport type: truck, train, barge, delivery van, etc. Each transport type has its own properties and constraints.
- Capacity: Depending on the transport type and the minimum cargo size, max capacity of the transports will vary.
- Frequency: Frequency of repetition of the trip, for example weekly, fortnightly or daily.

- Max travel time per day (tachometer): in certain type of transports, a maximum time of travelling is allowed in a single day, to ensure safety. That can limit the distance travelled a day and enable a higher accuracy on simulation models.
- Delay patterns. Probability of having delays. Amount of time delay.

4.5.7 GPICS Network

The GPICS network represents a universal, open and collaborative Physical Internet network for a case study definition. The GPIC Network is not in itself a new or additional modelling component of the GPICS. The GPIC Network is formed by, and it is the result or the consequence of the rest of the modelling components: GPICS Containers, GPICS Hubs, GPICS Movers/transport, GPICS Links and GPICS Routes. Altogether, each of them with its basic information properly configured, make up the GPICS Network.

Due to the abstraction of the GPICS Framework, part of the GPICS Network may represent a long-distance Link such as a TEN-T corridor, linking Level 1 GPICS Hubs, but it may also represent a PI urban logistics (e-Commerce Fulfilment) Network, linking Level 2 or Level 3 GPICS Hubs for last mile delivery.

4.5.8 GPICS Roles

To have a complete description of a Generic Case Study framework, the different roles involved in PI operations should be described. These roles are less critical in a generic definition of case study but are relevant in terms of the number of freight forwarders or final recipients involved in a case study. These players can have different roles, depending on the activity that they perform on the network.

The implementation of the actions of these roles, in the simulation models, will depend to a great extent on the simulation technology.

The first version of the GPICS defined an initial set of PI roles according to the information on the literature and on the state of the art of reference models and PI foundations taken into account.

This second release of the GPICS slightly redefines these roles as a result of the interaction of the GPICS with the Living Labs and the external insights from experts obtained due to the ICONET participation in the IPIC - 2019, 6th international Physical Internet Conference.

Sender

This role is the abstraction of a person or company that creates a GPICS Order and, therefore, activates the flow, that is, the movement of goods through the GPICS Network (GPICS Hubs, GPICS Movers and GPICS Links) by using the corresponding functionalities. This role has the initial information about the destination of the products and the delivery time interval.

Receiver

This role is the abstraction of a person or company to whom a GPICS order is delivered. In general, it is not a very active role, which could, at most, establish the allowed interval for the delivery time (delivery time window) but anyway, to have a complete description of a GPICS, the receiver must be defined.

Transport & Logistics Service Provider

This role has the responsibility of moving containers through the network and also of carrying out the handling operations with the containers. In the PI framework, traditional transport companies, single mode transport (e.g., road, train, or ship) could coexist with intermodal companies. Intermodal freight transport involves the transport of freight in an intermodal container or vehicle, using multiple modes of transport (e.g., rail, ship, and truck), without any handling of the freight itself when changing mode.

Logistics service providers (also known as Third-party logistics providers) typically specialize in integrated operations, warehousing, and transport services that can be scaled and customized to customers' needs based on market conditions, such as the demands and delivery service requirements for their products and materials.

Some actors involved in international transport operations that could belong to this role are the following:

- **Road Transport Operator**: Is responsible for the physical execution of the transport of goods on behalf of others, for which it has its own fleet, or in many cases subcontracted, of portfolio vehicles, responding the load to the shipper.
- **Air Company**: They carry out the air transport itself, leaving the commercialization in the hands of freight forwarders-freight agents.
- **Courier**: Urgent "door to door" transport of documents and small packages, national and international. It includes the collection at the sender's address and the delivery at the recipient's address, in addition to the different transport sections, in which more than one mode can be used, in order to minimize the time period for the entire process.
- **Integrators**: Companies that develop courier activity, serving each and every one of the transport chain segments, with their own means.
- **Shipping Company**: Company in charge of the physical execution of maritime transport. Also called "shipowner." In tramp traffic, its only task is this in most cases, since even stowage / unloading and loading / unloading operations are usually carried out by the loader.
  - The service offered is "port to port" or "FIOS freight", which is the most common condition in tramp freight traffic per trip. In liner traffic, the shipping company is generally the owner of the vessels and containers. The marketing of your wineries can be done directly through your own local agencies, delegations or indirectly through freight forwarders.
- **Railway operator**: Operator responsible for the physical execution of railway transport, for which he has the necessary means: traction elements, wagons or platforms, etc

Node Operator

This is one of the most important roles in the PI framework. This role has the responsibility of different activities such as: make the handling operations or the temporal storage of the containers. Moreover the node also manages the connections with the nearest nodes in the PI-network so that, the node operator plays an important part in the making decision process (e.g. routing, next step, etc.) and has to handle highly detailed information about the transports involved, current tariffs or delays and congestion situations.

Some actors involved in international transport operations that could belong to this role are the following:

- **Handling Agent**: Due to the technical peculiarities of air transport, the operation of the handling agent is required, who receives the cargo at the airport and prepares it properly for its subsequent boarding and flight. A distinction is made between terminal and ramp handling agent, the first being in charge of receiving and preparing the goods and the second for transporting the plane and boarding.
- **Stevedore**: Carries out the loading / unloading operations of the merchandise at the port. It can be contracted by the charterer or by the shipowner, depending on the conditions of the charter.
- **Integral logistic operator**: Operator that covers transport, traction, storage, auxiliary transport services, transit, customs, physical distribution functions, handling, splitting and groupage, labeling, packaging and cargo preparation, the organization of systems of information and flow management, reaching commercial operations such as billing and chartering and other logistics engineering services.

Coordinator/Monitor

In [6] Sallez, Pan, Montreuil, Berger and Ballot (2016), make a description of some communication and decision capabilities needed to be executed by PI containers or coordinators. For example, a decision-making capacity: PI containers must be able to make decisions autonomously, for example, ultimately determine the optimal transport route from an origin to a destination at the network level, or optimize movements of classification and handling at the PI Hub level. Communication capabilities: these capabilities are important for traceability and condition monitoring problems.

In the simulation model, all these capabilities must be centered on one type of Coordinating Agent. This agent can have an overview of the state of the system and can provide answers to the decision question of other agents (such as containers o transports). In the simulation model, all these decisions are centralized in one agent, but in the real world, this decision could be distributed through different elements if there is interconnectivity between them.

This role can also monitor the PI network performance and trigger alarms in case of low performance situations of certain PI components: PI nodes, PI routes, PI movers, etc.

Some actors involved in international transport operations that could belong to this role are the following:

Freight Forwarder: acts as an organizer of the international transport of goods in any of its nodes (air, road, rail, sea or intermodal), including all the operations that this entails: transport contracting, customs operations, packaging, consolidation and deconsolidation of goods, warehousing, insurance, banking and documentary procedures, etc. The activity of the forwarding company, marketing and coordinating all types of transport, focuses especially on groupage transport. The freight forwarder, as a service company in international transport, can be an IATA agent (International Air Transport Association), a specialist in air cargo transport, a consolidating agent in all modes of transport, a road transport agency and a multimodal transport operator. When the freight forwarder carries out its activity in the field of air transport, it is called air cargo agent. They market the warehouses of the airlines, constituting the air cargo distribution system, and coordinate the demand for air transport with the offer of the companies.

- **Air Cargo Agent**: When the freight forwarder carries out its activity in the field of air transport, it is called air cargo agent. They market the warehouses of the airlines, constituting the air cargo distribution system, and coordinate the demand for air transport with the offer of the companies.
- **Ship consignee**: The consignee or shipping agent is the person or company that, on behalf of one or more shipping companies in one or more ports, will attend to the needs and interest of these ship companies when docking in ports. The consignee, nowadays, contracts the transports for the ship that consigns and coordinates these until its final destination, thus reducing the role of the captain to that of a specialist in the technique of navigation and the ship.
- **Broker**: Agents whose function is to put in contact several companies interested in hiring a transport and offer them the officially in such hiring, commonly, maritime insurance, sale, use or construction of ships.
- **Integral Logistic Operator**: Operator that covers transport, traction, storage, auxiliary transport services, transit, customs, physical distribution functions, handling, splitting and groupage, labeling, packaging and cargo preparation, the organization of systems of information and flow management, reaching commercial operations such as billing and chartering and other logistics engineering services.
- **Customs agent**: Natural or legal person who charters a vessel for its exploitation in the way he considers more convenient. The charterer and the actual owner of the vessel establish the appropriate contracts that make the charterer the effective carrier to the shippers.

4.6 GPICS Base Configuration Rules

This section details the basic configuration options for a specific definition of a GPICS. These configuration rules have been named "base", because they establish a GPICS macro-configuration, or in other words, a strategic definition of a concrete generic PI case study. As far as this dimension is concerned, a comprehensive definition and description was provided since the initial release of the document.

Once this strategic definition of the generic case study is done, additional configurations, or it would be better to say, further parameterizations of the GPICS could be possible through the scenarios' configuration capabilities of the GPICS framework. In this sense, it could be said that, base configuration rules establish a static behaviour of the GPICS while scenarios' configuration provides a dynamic functioning on top of it. An illustrative example: configuration rules will define the levels of PI HUBS/Nodes in the GPICS, from a minimum of one to a maximum of three, and how this HUBS are connected and its hierarchical dependence but configuration scenarios can change the warehousing capacities of the HUBS/NODES, the lead time between them or the number of transport and logistics service providers collaborating in the GPICS.

In other words, while the basic configuration rules of the GPICS modelling kit provide strategic configuration abilities for the case study, the scenario's configuration capabilities bring tactical and operational configuration.

The selection of specific options for each configuration rule will instantiate a specific GPICS, that is to say, it will create the backbone of the GPICS definition which will be complemented with the decision of the geographic area, its associated master data sets, and the corresponding key performance indicators, resulting on a whole and holistic GPICS definition.

GPICS makes an abstraction of a real world system by creating a conceptual model and such a representation must be defined by four fundamental parts: lexical, structural, procedural and semantic. In this sense, GPICS base configuration rules, largely represent in particular two of these parts of the representation. On the one hand the structural part of the representation dealing with the description of the constraints and restrictions on how symbols can be arranged, and on the other hand the representation's procedural aspects which specify access procedures to create modify, and query descriptions.

This is one of the reasons why GPICS base configuration rules, together with GPICS the modelling components, are considered basic components of ICONET's GPICS.

In addition, GPICS scenarios' configuration capabilities complement the GPICS base configuration rules and therefore allow this framework to fully cover these two parts of the PI supply chain network representation. The following sections describe in detail each of the GPICS base configuration options.

4.6.1 Levels of Hubs

This rule provides the ability to configure the hierarchical structure and dependency of GPICS Hubs for a GPICS definition. The GPICS framework defines a three-level structure due to the maximum levels required by the living labs: L1, L2 and L3. Since GPICS framework follows the abstraction principle, a level can have different meanings in two different GPICS definition. For example, in a case study L3 can represent a point of delivery while in other case study L3 itself can represent a local warehouse.

The allowed options for this base configuration rule are as follows:

- L1, L2, L3: all levels are present and configured
- L1, L2: two levels are present and configured
- L1: only one level is present and configured

The selection of the suitable option will depend on the complexity and requirements of each case study.

4.6.2 Maximum number of Hubs

This rule provides the ability to configure the maximum number of Hubs in each level of the three-level hierarchical structure. This configuration rule allows the specific definition for a use case, i.e. the maximum of the delivery point managed from a store or number of regional warehouses that depend on a central warehouse.

The options allowed for this basic configuration rule are the following:

- L1: 2 – n. To make a case study of the Physical Internet possible, at least 2 first level Hubs must be configured.
- L2: 0 – n. In the simplest case study, there may be no Hubs on the second Level (this means there will be no L3 Hubs)
- L3: 0 – n. In the definition of a more complex case study there must be L3 Hubs, this means all the levels are defined.

4.6.3 Hubs functionalities

This rule provides the ability to configure the functionalities instantiated in each Hub among the set of functionalities defined for the Generic Hub:

- Source: functionality that creates a new PI Container in the corresponding GPICS Hub
- Sink: functionality that removes an existing PI Container in the corresponding GPICS Hub
- Assembly: functionality that merges existing PI Containers into a new PI Container in the corresponding GPICS Hub
- Split: functionality that divides an existing PI Container into several PI Containers in the corresponding GPICS Hub
- Queue: functionality that queues up an existing PI Container for a limited period of time in the corresponding GPICS Hub
- Store: functionality that stores an existing PI Container during agreed upon target time windows in the corresponding GPICS Hub
- Switch: functionality that transfers uni-modally PI containers from an incoming PI Mover to a departing PI Mover in the corresponding GPICS Hub
- Bridge: functionality that transfers multi-modally PI containers from an incoming PI Mover to a departing PI Mover in the corresponding GPICS Hub
- Sort: functionality that receives PI Containers from one or multiple entry points and sorts them so as to ship each of them from a specified exit point in the corresponding GPICS Hub
- Gateway: functionality that receives PI Containers in the corresponding GPICS Hub and releases them so they can be accessed in a private network not part of PI.

This rule provides flexibility for the definition of the case study, for example, it could be configured if a certain Hub has the ability to store PI Containers or not. The behavior and performance of a case study definition may vary depending on the configuration of this rule.

The options allowed for this basic configuration rule are any combination of the defined functionalities.

4.6.4 Connections between Hubs

This rule provides the ability to establish the way to connect the GPICS Hubs of different levels in the generic three-level hierarchical structure.

This rule provides flexibility and the capability to define highly complex case study definitions. A simple parameterization would allow connecting a L1-Hub with its dependents L2-Hubs (catchment area) and with others L1-Hubs. A more complex parameterization would allow connecting L1-Hubs with L1-Hubs and L2-Hubs, whether are dependent or not.

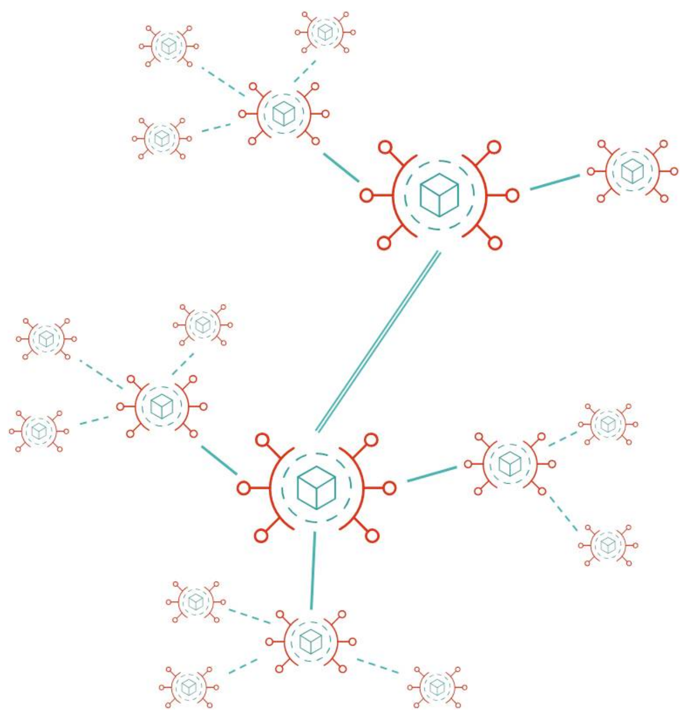


Figure 10: Example Connections between Hubs

Allowed options for this base configuration rule is any combination of connection among different levels.

4.6.5 Mover types between Hubs

This rule provides the ability to define the available means of transport between different Hubs, provided that there is a connection between them. This rule provides abstraction and simplification capacity to the GPICS definition since a generic mean of transport can be selected. For more complex case studies specific or even multiple of them can be chosen.

Allowed options for this base configuration rule are as follows:

- Generic
- Road
- Rail
- Ship

- A combination thereof.

4.6.6 Special requirements

This rule provides the ability to configure a case study in which freight may need special conditioning for the logistics and transport processes. This rule provides ability to define highly complex case study definitions with the handling of cold chains or hazardous materials.

Allowed options for this base configuration rule are as follows:

- Generic
- Cold
- Hazard
- None

4.6.7 KPIs categories

This rule provides the ability to configure the performance assessment areas (operational, environmental and cost) for a case study definition. This rule provides ability to configure either a cross-area assessment or a single area evaluation in terms of the corresponding KPIS.

Allowed options for this base configuration rule are as follows:

- Operational
- Cost
- Environmental
- A combination thereof

4.6.8 PI Node sophistication level

For the proper deployment of the Physical Internet networks, various levels of sophistication are needed in the main elements of the network. Depending on the type of analysis the level of sophistication required in the modelling components may change. Two levels of sophistication have been defined, low detail level and high detail level. In the low detail level, only basic parameters and variables essential to the PI Operation. At the high detail level, more variables and functionalities are defined. The following paragraphs identify the main functionalities of the PI Elements according to their level of sophistication.

<u>Low detail level in nodes:</u>

- Node level: Level of the PI network to which the node belongs. Nodes are arranged in hierarchy levels, depending on the importance, size and position in the network. These levels can be used to configure routing rules.
- Capacity: Parameter for defining the capacity of the node. Limitation of the number of containers that can be managed simultaneously in a node.
- Node type: Nodes can be classified by types according to their main functions. There can be ports, stores, warehouses, general hubs…
- Processing time: The period of time from when a container enters a node to when it leaves it.

<u>High detail level in nodes includes:</u>

- Stock available: Information related to the available stock in the node.
- Node Resources : Resources available in the node to process the containers
- Limited resources: Specific element resources used in the node. Some handling activities requires from any actor that can't be overloaded (cranes, railway slots, pickers…)
- Node fees (cost): At the time PI Containers travel through the network, they require to be handled, stored and moved.
- Emissions: Amount of equivalent emissions emitted by the node handling activity.

Table 10: GPICS Node detail level

	Low	High
NodeLevel	X	X
Capacity	X	X
Node type	X	
Processing time	X	
NodeResources		X
NodeCostResource		X
StockAvailable		X
Node Fees		X
Emissions		X

<u>Low detail in links includes:</u>

- Transit time: Period of time needed by the transports to travel from A to B through the corridor.
- Transport type: Type of corridor according to the transport used. Some corridors can be restricted to certain transports (train, ship, etc).
- Distance: Physical distance between origin and destination, also average speed per transport type.
- Average Speed : Average connection speed under normal conditions.

<u>High detail in links includes:</u>

- Link Capacity: Maximum transport capacity of a Link. Some corridors capacity is limited due to its physical constraints. Railways can't handle multiple trains at the same time. On the other side, roads can.
- Congestion: Information of operational status, depending on the corridor type, transports could face with delay issues due to congestion on it.
- Weather conditions: Weather conditions can affect to transports in the corridor, reducing their maximum speed or stopping the traffic on it.
- Taxes / Toll: Tax needed to use some corridors (tolls in some highways, time slots in railways…)
- Link Quality: Information on the state of the connection, such as bumps, dirtiness, construction work...

Table 11: GPICS Link detail level

	Low	High
TransitTime	X	X
TransportType	X	X
Distance	X	X
AverageSpeed	X	X
Link Capacity		X
Congestion		X
WeatherConditions		X
Taxes / Toll		X
Link Quality		X

Low detail in transports includes:

- Time in node: transports must stay a minimum time in the node they have arrived. This time can be used for loading/unloading cargo, to complete the delivery, refueling…
- Transport type: truck, train, barge, delivery van, etc. Each transport type has its own properties and constraints.
- Capacity: Depending on the transport type and the minimum cargo size, max capacity of the transports will vary.
- Frequency: Frequency of repetition of the trip, for example weekly, fortnightly or daily.

High detail in transports includes:

- Max travel time per day (tachometer): Maximum driving time, in certain type of transports, a maximum time of travelling is allowed in a single day, to ensure safety. That can limit the distance travelled a day and enable a higher accuracy on simulation models.
- Speed conditions / Max speed: Transports limitation about the maximum speed of the corridor they are in, they have their own speed limitations if max speed is greater to it.
- Delay patterns. Probability of having delays. Amount of time delay.
- Transport Time Table: Table of transit times of the transport through the different nodes of the associated route.

Table 12: GPICS Transport detail level

	Low	High
Time in node	X	X
TransportType	X	X
Capacity	X	X
Frecuency	X	
Max travel time per day		X
Delay patterns		X
Max speed		X
Transport Time Table		X

Low detail in orders includes:

- Max lead time: Period of time allowed when an order is asked, it is done under some conditions. One of most important conditions is the maximum lead time.
- Origin / Destination: As important as the lead time is arriving at the right destination. An order can't be completed if there's no fixed destination.

High detail in orders includes:

- Preferred transport type: Preference of transport method for some orders, because of company issues, can prefer a transport type over the rest of them.
- Time / Price criteria: Depending on the order type, the client and the urgency, travelling criteria may vary. When an order is not so urgent, the priority may be on taking the cheaper trip, despite the longer time it will take to arrive at its destination. On the opposite, some orders must be as soon as possible at its destination. In that case, time is the main target, no matter the money spent.
- Order Type: Orders that have to be handled under specific conditions. Orders can be temperature controlled, biohazard or standard.

Table 13: GPICS Order detail level

	Low	High
Max lead time	X	X
Origin	X	X
Destination	X	X
Preferred transport type		X
Time/Price criteria		X
Type		X

4.6.9 PI Node Living Lab Classification

In this project, inside each living lab there are specific node elements, depending on their specific role in the supply chain. In the following list, the characteristic of the main nodes in each the Living Labs are listed.

LL1: PI Hub-centric Network (PoA):

- Container port terminal: the nodes from where orders and containers enter in the Port.
- Railway bundling Facilities: in these nodes, the bundling optimization service is called and train wagons are arranged according to the priority and the destination they have.
- Train time slot management system: System for managing train arrival and departure times.

LL2: Corridor-centric PI Network (PG):

- Tracking Containers (IoT): Tracking devices, integrated in containers, to determine the physical conditions of transport.
- Smart routing (weather / congestion): Routing strategies using the live coordinates of the containers and the corridor status. The routing service can select the best route to avoid weather or congestion issues and achieve the best performance in terms of time and distance.

LL3: PI urban logistics Network (SONAE):

- Stores: Specific nodes where orders are prepared or picked up. There are levels of store according to their size, stock availability and preparation and delivery capacities.
- Stock control: Stock level is monitored for product families to avoid stock outs.
- Multi company delivery: Collaborative urban distribution scenario, multi company network is available. Multiple companies share the network and their transporters

LL4: e-Warehousing as a Service (SB)

- Warehouses as a service: System for the Dynamic Management of Space Reservations in Warehouses.
- Dynamic Stock Selection: Stock monitoring in the warehouses, to dynamically select the best warehouse to serve the orders avoiding the stockouts.

4.7 GPICS Scenarios Configuration

This chapter details the scenarios' configuration capabilities, which is the fourth dimension of the GPICS framework. GPICS scenarios' configuration dimension provides the ability to define multiple scenarios on the basis of the mater data, the modeling components and its basic configuration rules, representing the entire supply chain data. These scenarios will be implemented and run through the corresponding simulation models in order to be assessed using "What-If" Scenario Analysis (WISA) and in terms of the set of KPIs instantiated in the GPICS definition.

In this context a scenario is defined as a potential circumstance (i.e. parameter change) or combination of circumstances (i.e. combination of different parameters changes) that could have a significant impact -- whether positive or negative -- on the performance of Physical Internet.

GPICS scenarios' configuration define the adjustable variables which may modify the GPICS starting point, defined by master data sets and that can be referred as scenario base, to measure and assess the impact of those modifications in terms of the GPICS KPIs. These parameters have been defined around five categories: PI deployment, costs, network, business requirements and environment. Next subsections detail these categories and their parameters.

4.7.1 PI deployment configuration

The PI deployment configuration category covers all the parameter changes related to the degree of implementation and development of Physical Internet.

In particular this category enables the change of the following parameters:

- Increase - decrease of amount of freight flows managed through Physical Internet.
- Increase - decrease of amount companies of different roles (senders, receivers and T&L service provider) participating in the Physical Internet.

4.7.2 Costs configuration

The costs configuration category covers all the parameter changes dealing with logistics costs which may relate to the charges for various transportation methods, including train travel, trucks and ocean transport. Additional logistics costs may include fuel, warehousing space, packaging, security, materials handling, tariffs and duties.

In particular this category enables the change of the following parameters:

- Increase - decrease of transport costs for all or for specific means of transport.
- Increase - decrease of logistics costs: for loading/unloading, handling and warehousing activities.
- Increase – decrease of empty space costs: to take into account the unused space in transport vehicles.

4.7.3 Network configuration

The network configuration category covers all the parameter changes related to the modelling components which form the GPICS network. Due to these elements are quite different from each other, each of them has particular variables or attributes that can be configured.

In particular this category enables the change of the following parameters:

- Hubs: Increase – decrease of warehousing capacity or throughput (time operation) of logistics activities.
- Movers: Increase – decrease of number of available vehicles (i.e. trucks), capacity of transport (i.e. number of PI Containers in a vehicle) and lead time of transport.
- Link: Increase – decrease of congestion.

4.7.4 Business requirements configuration

The business needs configuration category covers all the parameter changes related to the needs of any of the roles defined in the GPICS, this is: sender, receiver, T&L service provider and coordinator.

In particular this category enables the change of the following parameters:

- Sender: Increase – decrease of service level, this is the amount of orders or services delivered to customers on time and in full
- Receiver: Increase – decrease of orders lead time, this is change in the delivery time or in the delivery time window.

4.7.5 Environment configuration

The environmental configuration category covers all the parameter changes related to carbon footprints, CO2 and other greenhouse gases (GHG) emissions.

In particular this category enables the change of the following parameters:

- Movers: Increase – decrease of CO2 emissions.
- Hubs: Increase – decrease of carbon footprint related to the logistics activities.
- Network: limitation of the maximum CO2 emissions or global carbon footprint per order or container.

4.8 GPICS KPIs

The goal of this chapter is to describe in detail GPICS KPIs dimension. As far as this dimension is concerned, a comprehensive definition and description was provided since the initial release of the document.

ICONET's GPICs is also formed by a set of generic Key Performance Indicators which will allow a standard and common assessment of PI supply chains performance among different scenarios.

Supply chain performance is defined as the ability of the supply chain to deliver the right product to the correct location at the appropriate time at the lowest cost of logistics (Treiblmaier, Mirkovski and Lowry (2016) [7]). This definition takes into account the time of delivery, cost, and value for the end consumer. The authors believe that this definition includes the most important aspects of the supply chain. There are three basic criteria of performance:

- Efficacy – the relationship between the achieved results and the pursued objectives; it is related to the level of customer satisfaction with respect to the resources committed for this purpose.
- Efficiency – the relationship between efforts and resources involved in the operation and the actual utility value as a result of the action; it is linked to the achievement of objectives at a lower cost.
- Effectiveness – is related to the satisfaction with the results.

Supply chain performance is the ability (of the entire supply chain) to meet end-customer needs, associated with ensuring the availability of product, deliver it on time in the right way and ensure appropriate inventory levels. It also exceeds the functional boundaries of organizations, i.e. production, distribution, marketing and sales, research and development. The functioning of the supply chains should be constantly improved. Therefore, measures to support the improvement of the performance of the global supply chain should be used, not only those that relate to the individual companies and their functions.

Performance measurement is defined as the process of quantifying the efficiency and effectiveness of the undertaken actions. Effectiveness is understood as the degree of fulfilment of customer expectations, while efficiency is a measure of the extent to which business assets are used to provide a given level of customer satisfaction. In turn, the performance measuring system should be understood as a set of indicators used to quantify the efficiency and effectiveness of operations.

GPICs Key Performance Indicators have the mission of giving a comprehensive vision of the impact of PI with regard to current situation and being an instrument able to shed light of strengths and weaknesses about different PI scenarios. These scenarios will be defined in terms of different parameterization of GPICS configuration elements/configuration dashboard and simulated through the simulation models of GPICS implemented in WP2. GPICs performance measurement system will analyse PI supply chain on two different levels:

- individual performance indicators: each actor in the supply chain
- a set of performance indicators: supply chain as a whole

Developing a framework for assessing the performance of the supply chain requires certain assumptions, including the ones related the areas of its measurement. Based on review of literature it may be noted that the authors look at the problem of assessing the performance of the supply chain from different angles. They distinguish indicators according to the level of the decision-making process: strategic, tactical, and operational. They are also divided into cost and the non-cost ones or qualitative and quantitative. Examples of qualitative measures can be customer satisfaction, flexibility, information and material flow integration, effective risk management, supplier performance.

The holistic vision of GPICS and its integrated assessment have been organized around three key performance indicators' categories, which are: Operational, Economic and Environmental. Each of these perspectives focus on a key aspect of supply chain and its logistics and transport related processes and activities.

The KPIs included in these three categories have been defined and agreed in close collaboration with ICONET’s Advisory Board, ALICE and Consortium partners, particularly with those leading and participating in the project's living labs.

Main features of selected KPIs:

- They are specific: Each indicator is focused in a particular dimension.
- They are relevant: Each indicator addresses a pertinent domain or aspect within its category.
- They are measurable: The necessary information for the calculation of each indicator is available.
- They are quantitative: Due to simulation will be the technology for scenarios validation and assessment, final customer insights and feedback will not be available.
- They are not PI exclusive, that means they also are meaningful in current non-PI world, so that, they allow compare current situation with a generic PI configuration.
- They compose a two-level hierarchical system to keep things as simple as possible. The highest-level forms the “primary tier” which provides general information of the specific dimension (operational, economic and environmental). The lowest level, the “secondary tier”, details and gives additional information to support the behave understanding of upper level’s indicators.

The Sections below details each of the KPI categories.

4.8.1 Operational Perspective

This category encompasses several capabilities such as: flexibility, service (responsiveness, order delivery lead time, final product delivery reliability), asset management and to some extent quality.

- Flexibility in the supply chain is its agility in responding to random changes in the marketplace in order to gain or maintain competitive advantage. Flexibility is thus a performance dimension that considers how quickly an organization (manufacturer or a logistics service) provider can respond to the unique needs of customers.
- Supply chain responsiveness refers to how quickly a supply chain delivers products to the customer. It involves the time that elapses from a customer’s order being received to completed delivery.
- Order delivery lead time encompasses the fulfilment of the average percentage of orders among supply chain members that arrive on time, complete and damage-free, satisfying customer requirements. Measures should focus on reduction through elimination of delays and delivering continuous improvement on target times.
- Supply chain delivery reliability refers to the performance of the supply chain in delivering the correct product to the correct place at the correct time in the correct condition and packaging in the correct quantity with the correct documentation to the correct customer. Reliability is not at odds with long lead times.

- Asset management refers to the effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets.

Operational KPIS included in the GPICS Framework are:

- Use of infrastructure;
- Total transit time;
- Total waiting time;
- On Time Delivery;
- Real route distance vs Ideal route distance;
- Total distance travelled empty and full;

4.8.2 Cost Perspective

Cost is an important performance supply chain indicators' category. Supply chain costs include all costs associated with operating the supply chain, including the cost of goods and total supply chain management cost. Supply chain costs are associated with forecasting, administration, transportation, inventory, manufacturing and customer service or supplier relationship management. Because cost performance is critical, it is tracked more carefully and comprehensively than any other aspect of competitive performance. Cost control and cost reduction capabilities must be intrinsic to structure, processes, culture and technology foundation for an organisation to survive and thrive.

This category covers not only costs measurement within an individual or isolated organisation but also total supply chain management cost (across the supply chain).

The KPIS related to costs included in the GPICS Framework are:

- Transport cost
    - Cost of transportation ABC principles (activity base cost)
    - Cost/km
- Handling costs
    - Storage
    - Handling
- Inventory holding cost

4.8.3 Environmental Perspective

Supply chain activities can pose a significant threat to the environment in terms of carbon monoxide emissions, discarded packaging materials, scrapped toxic materials, traffic congestion and other forms of industrial pollution. Green supply chain management (GSCM) is considered an environmental innovation. The concept of GSCM is to integrate environmental thinking and doing into supply chain management (SCM). GSCM aims to minimize or eliminate wastages including hazardous chemical, emissions, energy and solid waste along supply chain such as product design, material resourcing and selection, manufacturing process, delivery of final product and end-of-life management of the product. As such, GSCM plays a vital role in influencing the total environment impact of any firm involved in supply chain activities and thus contributing to sustainability performance enhancement.

ICONET's environmental indicators category focuses mainly on emissions and energy in intra-logistics activities, long-haul transport and final delivery of products. Environmental KPIS included in the GPICS Framework are:

- CO_2 emissions per fleet
- Consumed fuel or energy

In the following you can see all these KPIs classified per category:

	Considerations	KPIs
Operational Perspective	Encompasses several capabilities such as: • Flexibility • Supply chain responsiveness • Order delivery lead time • Supply chain delivery reliability • Asset management	• Use of infrastructure • Total transit time • Total waiting time • On Time Delivery • Real route distance vs Ideal route distance • Total distance travelled empty and full
Cost Perspective	Covers not only costs measurement within an individual or isolated organisation but also total supply chain management cost (across the supply chain)	Transport cost o Cost of transportation ABC principles (Activity Base Cost) o Cost/km Handling costs o Storage o Handling Inventory holding cost
Environmental Perspective	Focuses mainly on emissions and energy in intra-logistics activities, long-haul transport and final delivery of products	• CO2 emissions per fleet • Consumed fuel or energy

5 GPICS adoption guide

This chapter contains a possible description of the roles and procedures that logistics and transport companies (LSPs) will need in order to operate under the Physical Internet framework.

The objective is that it should provide guidance, inspiration, to understand how companies can integrate or operate in PI networks and expand their business model by collaborating with other companies efficiently and reducing the environmental impact of operations.

5.1 Mapping the GPICS roles to the PI stakeholder

The GPICS framework provides not only the components needed for a case study definition but also a process or cycle to drive it. One of the most valuable contributions to the Logistics community, apart from the GPICS definition itself, is the Role representation. The definition of the different actors, their functions and responsibilities. This definition helps LSP organizations to identify which role, or roles, are closest to their actual activity, and how these organizations can participate within the PI environment.

With the evolution towards a PI model, the roles of some organizations in the supply chain may change. The current roles of logistics and transport companies are based on individual transactions. Generally, the company owns the assets. The company is responsible for point-to-point transportation. In the PI model, handling and transportation activities are shared among several companies. Responsibility for execution is also shared. The following table includes a brief description of the actual supply chain main activities related with the new roles of the PI framework.

Sender	Receiver	Transport Operator	Node Operator	Coordinator
• Creates a PI Order • Activates the flow • Initial information	• Receives the order • Delivery time window	• Responsibility of moving containers. • Proof of delivery	• Handling operations • Prioritizing movements	• Communication capabilities. • Overview of the state of the system

Figure 11: PI Role definition and main functionalities

In general, the main roles in PI are the sender, the company that wants to send the goods, and the receiver, the company that will receive the goods. According to the following image Figure 12 different companies could assume different roles.

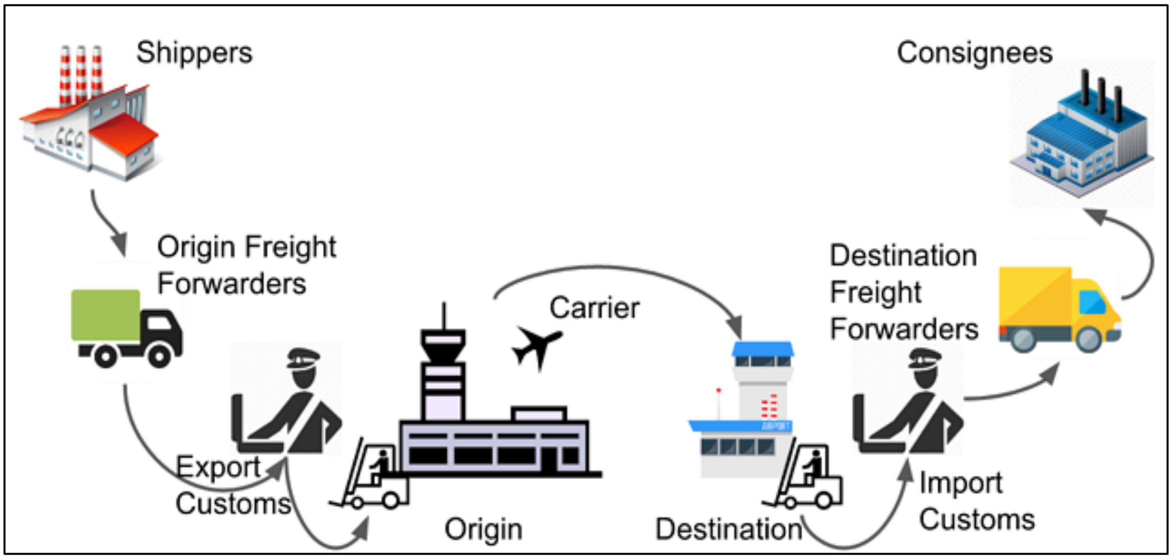


Figure 12: LSP main actual players

The following table illustrates an example of assignment of the main actors, from living labs chapter 3.1.1(Who are the actors in Logistics today in the supply chain) to the roles of the physical Internet in the following

Table 14: GPICS Role examples

	Generic Example	Living Lab Examples
Sender	Shippers, eCommerce Owner	Shippers (PnG)
Receiver	Final Customer, Consignees	Shoppers (SON)
Transport Operator	Freight Forwarders, Carriers, Last Mile Delivery	Freight forwarders, Shipping Companies. Rail operator (INFRABEL)
Node Operator	Warehouse, Port Terminal, Airport	Industrial sites, intermodal terminal operators (PoA),Regional Warehouse (SB), tank storage operators
Coordinator	Infrastructure manager, Transport Authorities	Port infrastructure manager (PoA)

This initial assignment corresponds to some illustrative examples of current companies in the framework of the physical Internet. It is possible that in the evolution towards the total adoption of the physical Internet, new companies will appear which specialize in some of these roles.

For example, there might be a company that has the role of a PI broker that specializes in coordination actions for physical Internet.

5.2 GPICS Operational procedure

In order to achieve full Physical Integration, some Operational Procedure or PI certification procedures may exist to help LSP or other companies to determine the appropriate steps through the PI adoption, and also to ensure that the companies with which we are collaborating fulfill the minimum standards for working under the PI procedures. Some of the initial information required for this checklist are the following:

- Registration Procedure
  - Registration in PI network (digital and physical identification)
  - Registration PI available infrastructure (nodes, network, routes…)
  - Registration PI actual capacity (for transport, storage capacities, tariffs)
- Execution Procedure
  - Pricing and Planning a PI execution. Initiation of transport execution
  - Monitoring transport execution
  - Complete delivery notification
- Post-Execution Procedure
  - Financial management (payments, distribution of funds among all the actors involved)
  - Quality Process Management (feedback for companies about the quality of the transport execution)
  - Return Management (if there is a problem during the execution of the transport, provide a procedure to return the shipment to the origin)

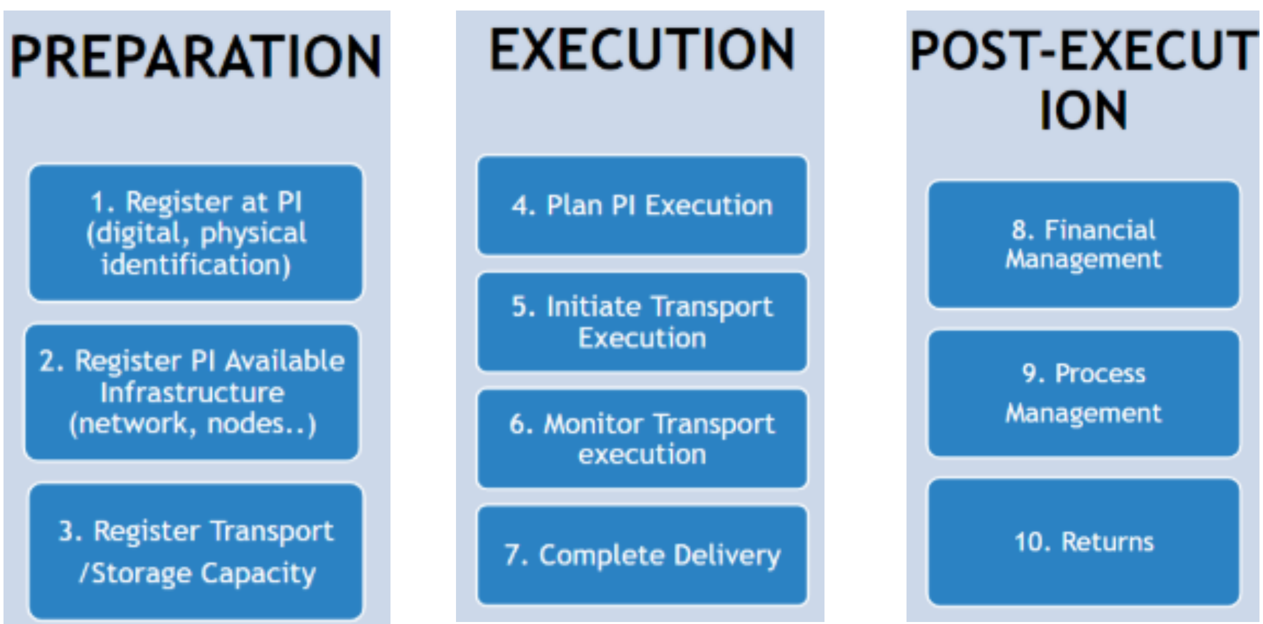


Figure 13: GPICS Operational procedure

5.3 Interconnection between Physical Internet and Digital Networks

The interconnection between Physical and Digital networks in essence is a requirement to enable a Physical Internet: an open global logistic system founded on physical, digital, and operational interconnectivity, enabled through encapsulation of goods, standard interfaces and protocols.

Milestones	
2020	Interoperability between networks and IT applications for logistics.
2030	Full visibility throughout the supply chain.
2040	Fully functional and operating open logistics networks.
2050	Physical Internet.

Figure 14 ALICE Roadmap for Physical Internet [10]

According to ALICE PI Roadmap [10] some of the major gaps that need to be addressed to meet the vision are related with information technologies:

- The ability to rapidly connect to, and disconnect from, supply networks at two levels; the business level and the technical ICT level.
- The simplification of ICT systems, information interfaces and business models so that domain users are shielded from having to become technology experts and can focus instead on the efficient execution of transport and logistics operations;
- The simplification and standardization of device interconnections so that the rapid connection and disconnection of sensor enabled transport items is facilitated.
- The adoption, integration and use of smart infrastructures, Intelligent Transport Systems (ITSs), IoT devices and other intelligent edge-based technologies in supply chains to increase the efficiency, effectiveness and control of supply networks.

The use of information and communication systems to improve productivity in all segments of business has been demonstrated by numerous research efforts as well as through anecdotal case studies. The proprietary nature of most systems in the industry, coupled with a lack of communications standards, has led to the fact that the interconnection of industry players is costly and time consuming.

Many large industry players have developed their own proprietary systems because of this fact, investing considerable funds each year in the maintenance and updating of these systems. Small scale players have either had to use applications provided by local or niche software providers or, as is quite common in the smaller players in every industry sector, not utilize any applications or technologies beyond normal office applications.

In terms of technology(ies), ITS and different ICT (e.g., Radio Frequency Identification (RFID)), wireless sensor nodes and localization systems play vital roles in improving the performance of the freight transport system by saving energy, reducing service costs and increasing cargo throughput. To achieve these requirements, the application of reliable heterogeneous communication systems among all communicating objects becomes a paramount objective.

5.3.1 Processes to promote interconnection between physical and digital networks.

The ICONET platform provides different points where the activities of the physical network and the digital supply network are synchronized.

First of all, the information capture of the current status of the physical network can be determined, among other factors, by the IoT equipment. These elements can inform about the position of a container in real time and other characteristics such as temperature, humidity or vibrations (shocks). The updating frequency of this information could vary depending on the battery or the power consumption that is available. In general, updated status data can be obtained every 30 to 10 minutes, even at higher frequencies if necessary, in critical situations. With this type of devices, we can find out if a container arrives on time or if it has suffered any delay in transport or other type of incident.

IoT devices are the most reliable elements to obtain the information about the current situation of the freight in the transport network. But in addition to these IoT devices there are other types of transactions which inform us about different events that happen in the physical network and which trigger reactions in the digital network.

The ICONET system is based on a group of services, organized in different layers, which contain the necessary information for the execution of the transport order. The messages to the services could arrive from legacy systems or new apps. During the execution of the transport there are different events that are reflected in the digital world through the different types of services.

We can define three types of event groups in the route of a container through a physical Internet network. In the following list, there are some examples of physical events which are reflected in the digital network.

GE1: Group Events - Start of journey:

- Transport Order Assignment: Assign transport orders to an available transporter
- Output from a PI Node: The container leaves the PI Node with a transport.
- Updated departure time: The planned departure time of the container has been updated.

GE2: Group Events - During the journey:

- Normal trip: Periodic update of the trip status
- Congestion: Congestion detected by delay in estimated travel time.
- Vibration or high temperature: The IoT devices can send information if they detect a difference from the target values.

GE3: Group Events - End of journey:

- Entrance to PI node final: Notification of the arrival at the PI Network's end node
- Proof of delivery: Event of delivery of goods to the final recipient
- End of the Transport Order: Completion of the execution of the transport activities for the container

In the following diagram there is description of the instance of an application case of the physical and digital events in a PI-Container traveling through the PI network. These events can use different services and the may be digital [D] or physical [P]. The services used by containers in the PI are shipment, routing, consolidation and routing. With these four services a container can travel through the PI network following the basic operating protocols that ensure decision making in a PI style. There are additional services which increase confidence in the PI network, such as blockchain and tracking services. Some of the events can be physically triggered (bumping, entering a new node...) or may need some physical or digital input (Container enters PI network, routing service...). The diagram also includes information about the origin of the information and how the results of the services are transmitted. *Message* means that the information must be manually inputted or when it is an input and it also means that the operator can read the information when it is an output. *Digital* input or *digital* output is used when the service information is used only for traceability and information management purposes.

Physical input/output means that the information is obtained from IoT devices or requires some external action on the container (handling, consolidation...).

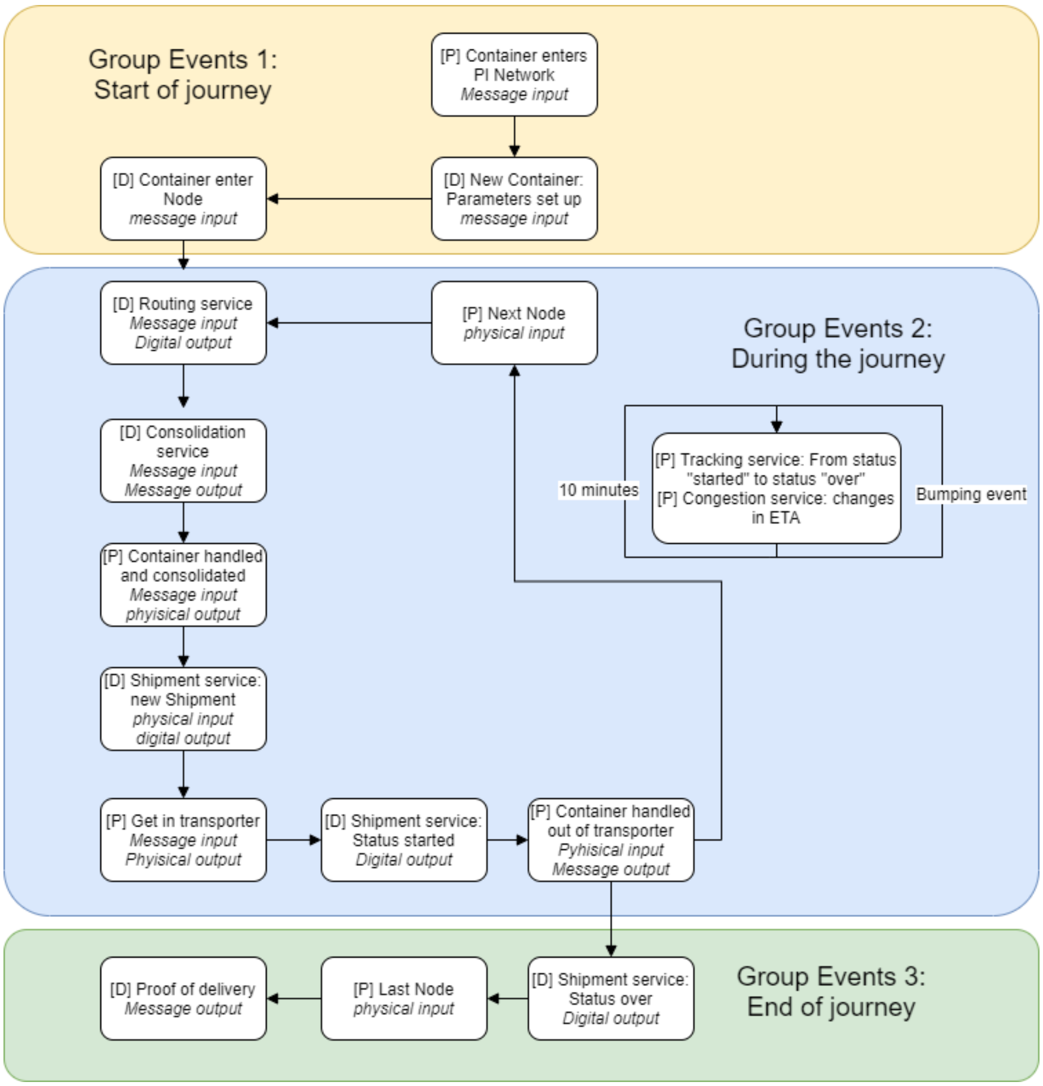


Figure 15 Example of Digital [D] and Physical [P] Events

5.4 Integration with legacy systems

When we evaluate the IT systems in transport and logistics companies, we often encounter legacy systems while connecting different applications across organizations. Legacy systems can have compatibility issues (e.g., a legacy system is rarely compatible with newly purchased systems), isolated from other applications, and could have a lack of security support. Many companies are operated under historical business systems (historical legacy systems) that do not allow them to facilitate “flow through” operations and provide data to the stakeholders operating and coordinating the different transport modes.

Flow synchronization through the various modal switching nodes involved in PI requires new approaches to managing the inflow, outflow and operations within these nodes. Whether the goal is synchromodal operations or the Physical Internet, switching nodes become the locus for ensuring efficient supply chain operations.

Software must be developed allowing these switching/transfer points (PI nodes) to act like routers and switches in the Internet enabling the implementation of the Corridors, Hubs and Synchromodality roadmap and laying a foundation for the Physical Internet. Therefore, the following areas need to be addressed:

- Node management software is required to facilitate the efficient and synchronous flow of goods through the various nodes in a network.
- Routing and planning software to properly route shipments in a dynamic manner across appropriate infrastructures and nodes.
- Dynamic matching algorithms to rapidly match (changed) goals with available services and capacity.

There are three main applications in the management of logistics and transport processes. **Legacy systems** that are essential to manage the flow of materials and information between the PI users and PI network. They are the following:

- <u>ERP (Enterprise Resources Planning)</u>

It is an accounting-oriented information system for identifying and planning the enterprise wide resources needed to take, make, ship and account for previous orders. Actually, ERP tools share a common process and data model, covering broad and deep operational processes, such as those found in finance, HR, distribution, manufacturing, service and the supply chain.

ERP applications automate and support a range of administrative and operational end-to-end business processes across multiple kind of users and industries. Two typical users that use the ERP for their interaction with PI are the sender and the receiver.

The first interacts with the ERP to register a shipment by entering what he wants to send and where. The ERP acts as a tool that receives this information, initiates the generation of the necessary documentation based on the route to follow and launches the necessary orders to be executed so that the shipment can be carried out.

The second interacts with the ERP by entering into the system that the shipment has arrived, the date it has arrived and the state in which it has arrived. The ERP receives this information and provides feedback to the sender. In the next picture (Figure 16) we can see the typical modules included in an ERP user application.

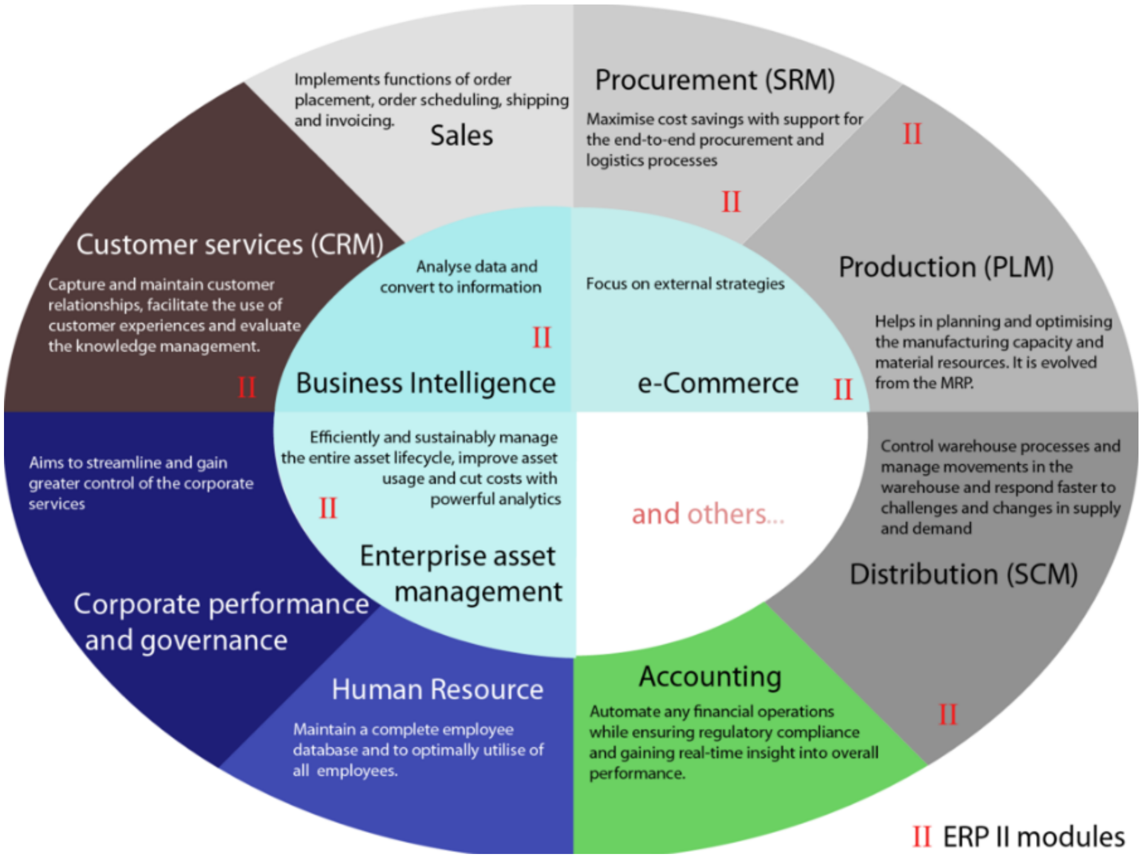


Figure 16 : Typical modules included in an ERP user application

- <u>WMS (Warehouse Management System):</u>

A warehouse management system (WMS) is a software application that helps control and manage the day-to-day operations in a warehouse. WMS software guides inventory receiving and put-away, optimizes picking and shipping of orders and advises on inventory replenishment.

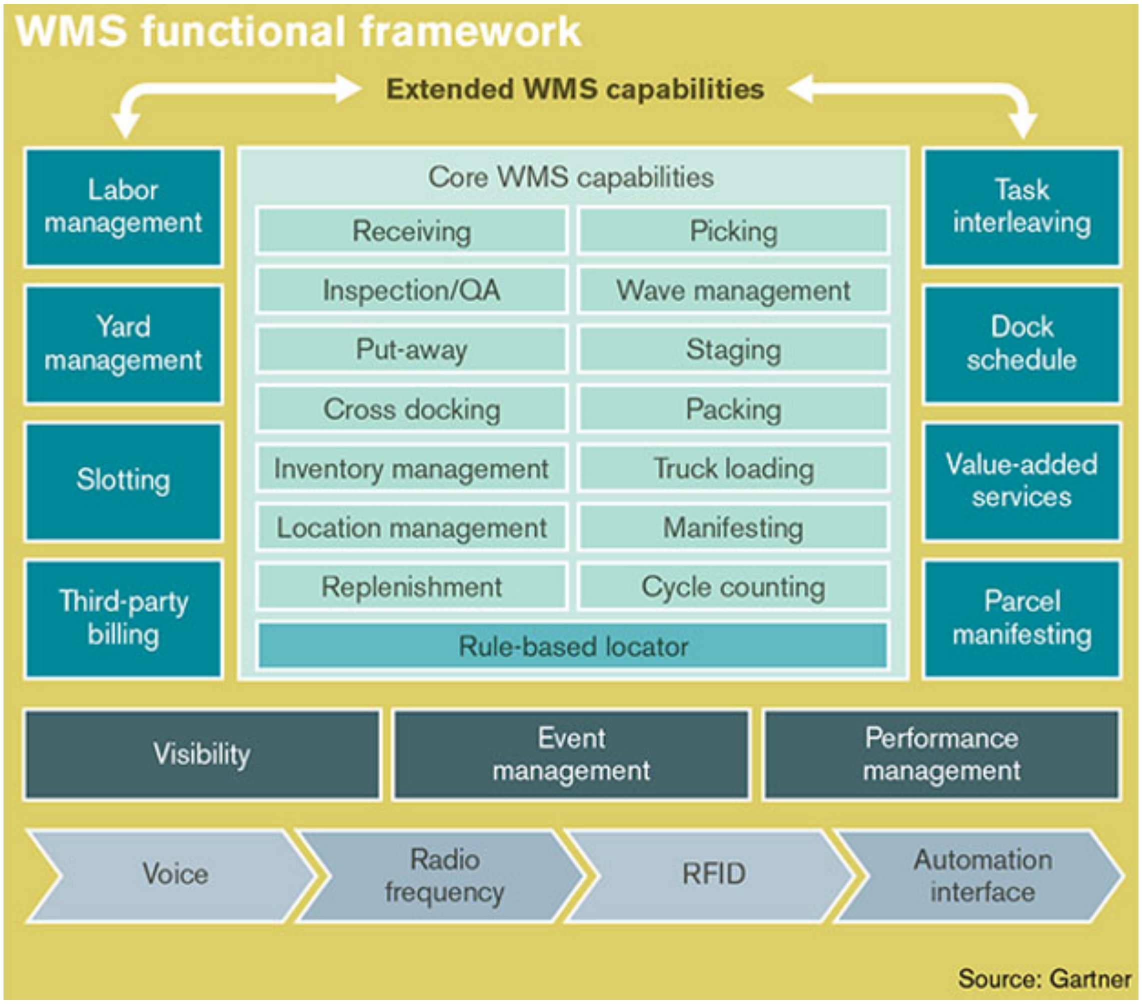


Figure 17 WMS main functionalities

The overall goal of a warehouse management system is to achieve a paperless environment that directs employees automatically on the optimal picking, put-away and shipping of the products. A typical user who regularly uses the WMS for its interaction with PI is one that belongs to the node operator role.

This type of user (for example a storage or handling company) receives product from other nodes or users and offers its storage capacity and available resources to the PI network. WMS is the tool through which the operator records all material flow management and operational handling activities.

From the WMS this user can report relevant and necessary aspects to PI requests to configure the distribution routes such as: available capacity, loading / unloading schedules, format of the necessary documentation, etc.

- <u>TMS (Transport Management System):</u>

It is a logistics platform that uses technology to help businesses plan, execute, and optimize the physical movement of goods, both incoming and outgoing, and making sure the shipment is compliant and proper documentation is available between PI users and PI network. This kind of system is essential for executing transport actions within the PI.

Sometimes known as a transportation management solution, a TMS provides visibility into day-to-day transportation operations, trade compliance information and documentation, and ensuring the timely delivery of freight and goods within the PI. Transportation management systems also streamline the shipping process and make it easier for businesses to manage and optimize their transportation operations, whether they are by land, air, sea or intermodal.

A typical user of a TMS could be one that belongs to the role of a transport operator. An example could be a trucking company that puts its transport resources at the service of IP network. In this case, the standard information requested by the PI could be the availability of trucks, the load capacities, traffic restrictions, necessary documentation depending on the route, etc. This company would use the TMS application to provide all this information, record all cargo orders received and launch them, assigning the necessary resources according to a series of criteria or parameters to accomplish the orders.

In the next figure you can see the existing interconnection between different PI users according to their role and the PI network at the level of information flow:

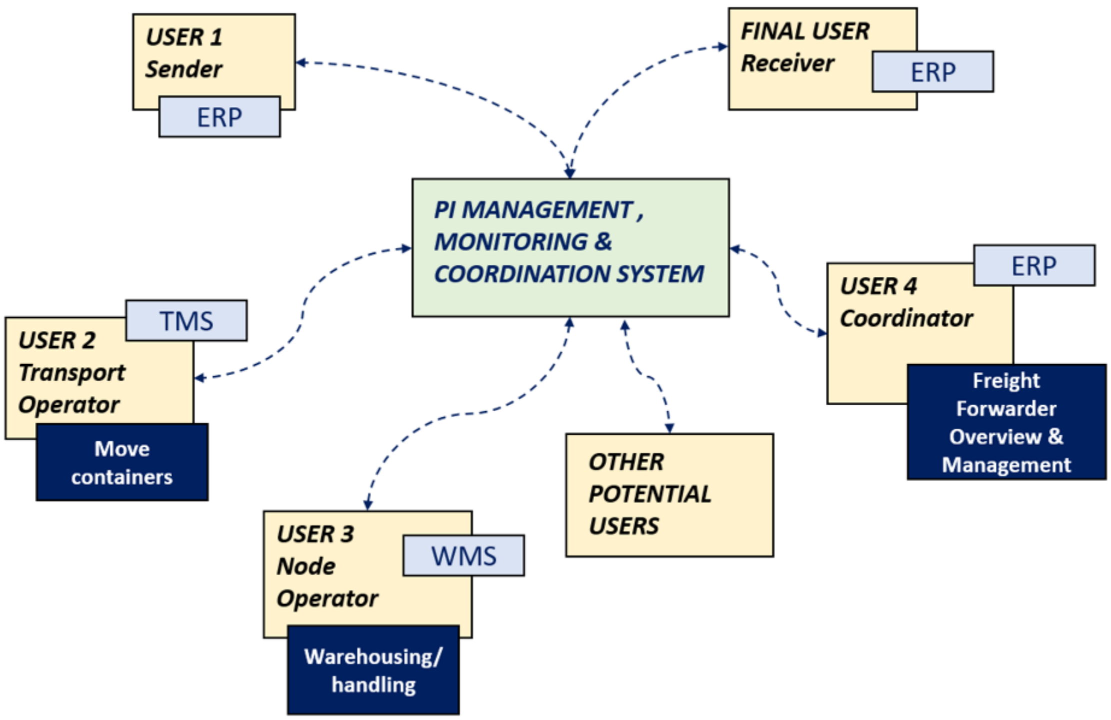


Figure 18 Interaction between Legacy Systems

In the Figure 18, each kind of user uses the appropriate system (ERP, WMS, TMS) according to its role in the PI network. For example, one user acting as a node operator role, receive the orders for the preparation of the containers received from other user or node, execute these orders inside (e.g.: handling) and, finally, give continuity to the material flow reporting to the PI the final status of all these movements.

Previously, this user should have been requested by the PI (e.g.: coordinator role) about its available capacity or any other information that the system considered necessary to choose the best option for the material flow within the PI network. These 3 systems are not independent. There may be users in PI who use more than one of these applications in managing their operational activities. It depends on the functions they perform and the role they have within the PI.

The following figure (Figure 19) represents the main information flows between these three applications. Basically, it can be said that they are all interconnected in one way or another. The ERP systems manage the most administrative and high-level information, the WMS manage the handling orders (intralogistic) and finally, the TMS manage everything related to the movement and transport of the flow of materials within the PI network.

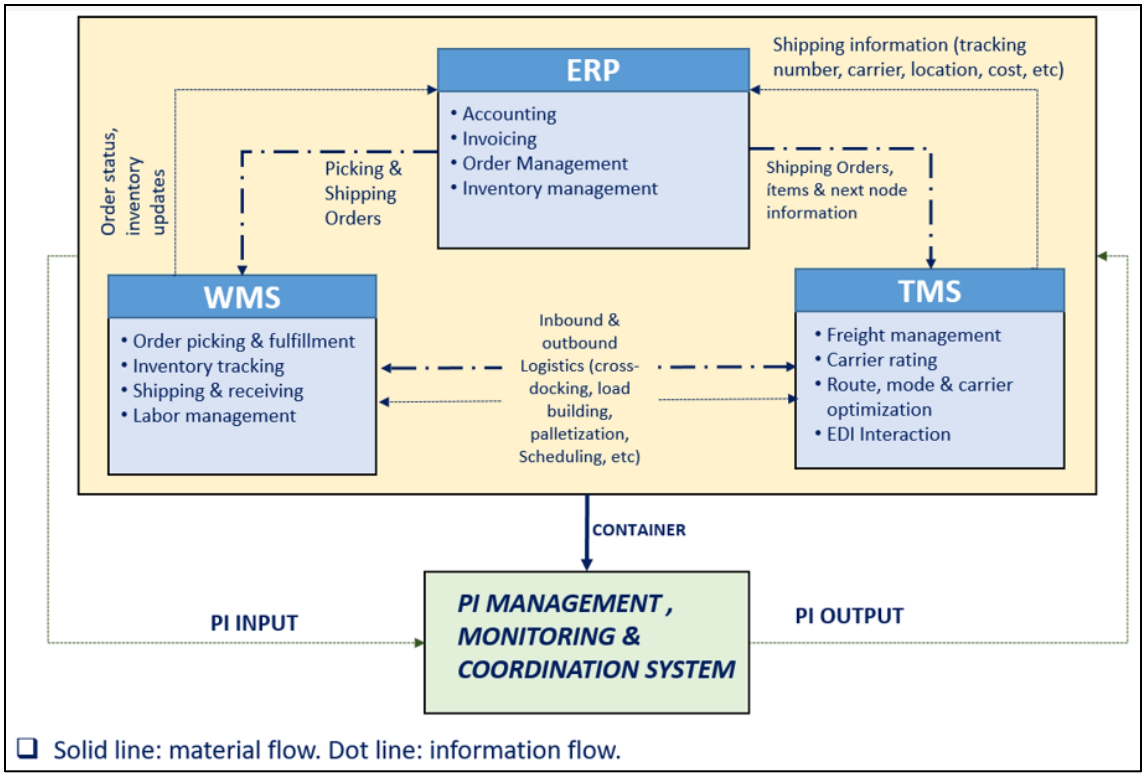


Figure 19 Main information flows

Each user of the PI network interacts with the PI through one of these 3 systems depending on the role they have. In each interaction the system provides some input to the PI (for example, what am I going to send and where I want to send it) and additional information such as size, delivery date, etc. Likewise the system receives feedback (example: date of receipt at destination, delivery status).

In case the user is not a simple sender but offers its services to the PI somehow, the system may request information about them in order to have enough data to make the best decisions based on certain criteria (e.g.: resources availability as mentioned before).

Once the interaction between these management systems and their connection with the rest of PI elements has been set, we can focus on identifying which messages and documents they usually use to communicate and interact. They depend of the way of transport: Road, Rail, Ship or Intermodal.

Regarding the messages and communication systems, one of the standards is EDI (Electronic Data Interchange). It consists of a set of internationally agreed standards, directories, and guidelines for the electronic interchange of structured data, between independent computerised information systems and could be the way nodes of PI interchange messages to get a continuous flow of material in the PI network.

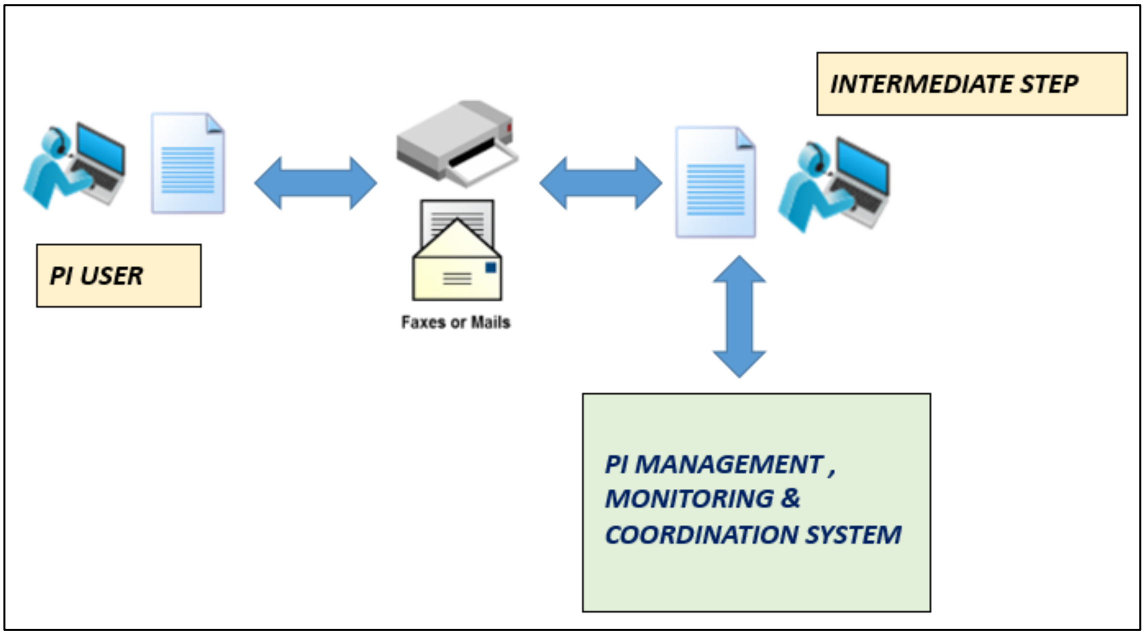


Figure 20 Order communication & messages without EDI

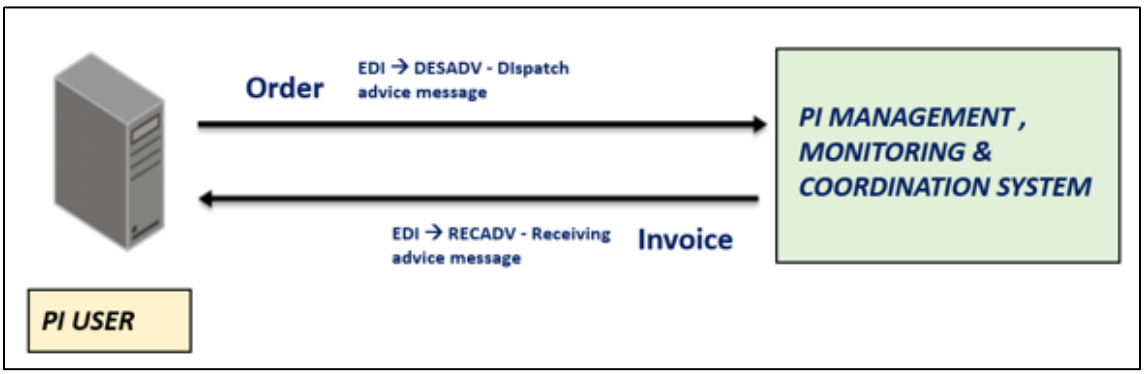


Figure 21 Order communication & messages with EDI:

The two images above illustrate the interaction between an IP user and the network itself. However, the way to establish this communication is completely different.

In the first case (Figure 20) there is a manual interaction. Human resources are needed to introduce the inputs into the management system and launch, for example, a shipment to the PI (through, for example, a fax or email). Likewise, the information that gets the PI has to be read by manual methods and re-entered into the PI network management system. So, there are two manual interactions on both sides of the communication between the user and the PI. In the same way, the reverse flow of information also presents this manual interaction.

In the second case (Figure 21), this communication is fully automated and integrated through EDI-type communications. On the user side, the necessary inputs are automatically generated to carry out a shipment and execute it and, likewise, an automatic feedback is generated from PI which informs us, for example, of the correct arrival of the information or the shipment to the destination point. Consequently, it is very important to have technologies that simplify the manual entry of information to reduce errors and automate and simplify information flows in the PI network.

It can be seen in the picture two typical standard EDI input/output messages (example):

- **DESADV: Dispatch advice message (waybill)**. It is a message that specifies details for goods dispatched or ready for dispatch under agreed conditions. They are used as Delivery Dispatch Advice and Returns Dispatch Advice messages. The message intent is to advise of the detailed contents of a consignment. Each message relates to a single dispatch point and single or multiple destination points. It may cover a number of different items or packages. The message can be used both to indicate the dispatch of the goods to be delivered, as well as the dispatch of the goods that are returned. It allows the receiver:
    - To know when the material has been dispatched or will be ready.
    - To have the precise details of the consignment.
    - To take initial steps towards customs clearance in the case of international consignments.
    - To enable matching between dispatched goods and the following invoice.
- **RECADV: Receiving advice message**. It is a message used to report the physical receipt of the goods and whether they reflect what was initially ordered. This provides visibility about discrepancies and a warning of the rejection or acceptance of goods to streamline the process. When the goods are checked and discrepancies are sorted out, the invoice can be generated with the certainty that it will not have to be modified.

The main aspects of EDI communication to take into account are the following:

- **Computer-to-computer**: EDI replaces postal mail, fax and email. While email is also an electronic approach, the documents exchanged via email must still be handled by people rather than computers. Having people involved slows down the processing of the documents and introduces errors. Businesses typically use an EDI translator (either as in-house software or via an EDI service provider) to translate the EDI format so the data can be used by their internal applications (legacy systems) and thus enable straight through processing of documents:

  EDI documents can flow straight through to the appropriate application on the node receiver's computer (e.g., the Order Management System, ERP) and processing can begin immediately. For example, these orders, once integrated in the ERP system, can be deployed to WMS or TMS to send the container to the next node.
- **Business documents**: These are any of the documents that are typically exchanged between nodes. The most common documents exchanged via EDI are purchase orders, invoices and advance ship notices. But there are many others such as bill of lading, customs documents, inventory documents, shipping status documents and payment documents.
- **Standard format**: Because EDI documents must be processed by computers rather than humans, a standard format must be used so that the computer will be able to read and understand the documents.

There are several EDI standards in use today, including ANSI, EDIFACT, TRADACOMS and ebXML. For each standard there are many different versions, e.g., ANSI 5010 or EDIFACT version D12, Release A. When two nodes decide to exchange EDI documents, they must agree on the specific EDI standard and version. Regarding the documents necessary to accomplish international regulations related to the role of a transport operator, you can see a representative list in Annex 1

6 European PI Hubs Plan.

This chapter describes the initial European Associated PI Hubs Plan applying the concepts and learnings of the Project, extended to the European transport network. In previous versions of this document (D1.8) contains a short explanation of the methodology applied to create the PI Hubs Plan and finally the PI Hubs Plan version 2.

The content of this release is focused in the definition of the PI network focuses on the size of the main European IP Hubs according to the current goods flows between the NUTS2 regions of the EU. Previous versions have defined IP Hubs networks in specific countries, with detailed descriptions of how to set up the different levels of the IP network in those countries. In the current version the focus is on the complete European network, above all on the definition and approximate dimensioning of the main nodes of the possible IP network.

6.1 Geographic area

This subsection details the geographic area. As it was explained in chapter 5, the GPICS geographic area dimension is organized on two levels, EU state members and NUTS-2 regions.

The upper level for the GPICS v2 specification is composed by a total of eight EU state members. As far as geographic area dimension of the GPICS Framework is concerned, the table below resumes the evolution and main differences between the initial and the current versions of the GPICS specification and clearly shows the growing complexity of the case study.

Table 15: GPICS evolution in terms of geographic area

	GPICS VERSION 1	GPICS VERSION 2	GPICS VERSION 3
EU STATE MEMBERS	3	8	28
NUT-2 REGIONS	53	135	279

6.1.1 Master Datasets

This subsection details the sources of information used to gather Master data set for version 2 of the GPICS specification. The primary source of information used continues to be [8], the statistical office of the European Union whose mission is to provide high quality statistics for Europe. Main reason of using Eurostat as primary source of information is the same than for the first release of the GPICS, not only the availability of the required information but also its professional independence. Eurostat provides the European Union with statistics at European level that enable comparisons between countries and regions, so that it offers a common framework and data at different levels, mainly at EU state member and NUTS classification level, that is what the GPICS Framework need for the Master Datasets dimension.

To initiate the design of the PI Hubs plan, we begin with the research performed in task *"T1.3 PI Network optimisation strategies and hub distribution policies"* and described in document *"D1.4. PI network optimisation strategies and hub location problem modelling"*. This document describes the PI Network design at a long-term, strategic level. The scope of the network optimization is Europe and the transport demand that the network needs to cover is the transported tons between NUTS2 regions.

The road network in Europe and the multimodal TEN-T corridors form the basis for the network model. This means that the nodes in the network consist of the centres of the NUTS2 regions and the connecting cities in the TEN-T network. The links in the network are given by road connections between all NUTS2 regions and rail and/or inland waterway connections depending on the lanes that are available in the TEN-T network.

Data used in this task (T1.3) to design a PI network consists of transport demand data and transport supply data. By transport demand data we mean data about shipments from origins to destinations with characteristics like type of goods, weight, volume, transport mode used, etc. By transport supply data we mean data about railway tracks, terminals, rail services, etc. The Main data sources for transport demand include EUROSTAT COMEXT (trade data), UN COMTRADE (trade data), and EUROSTAT (transport data, primarily road freight and port related data). In addition, national statistic agencies also publish aggregate data. An example of the information used is shown in the following image (xxx).

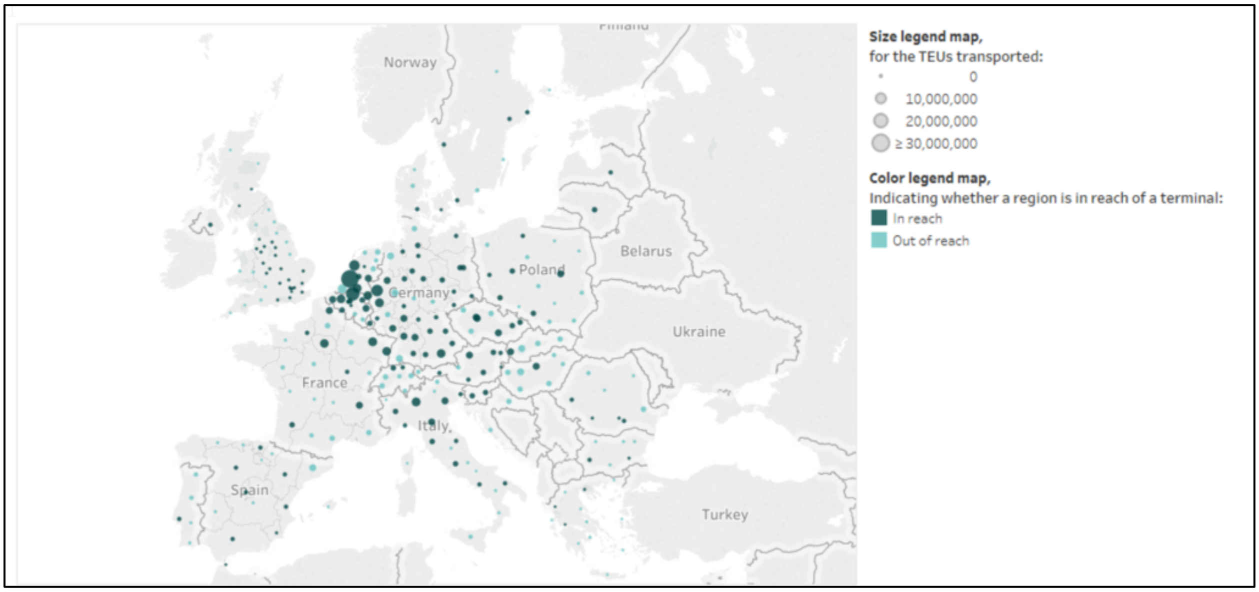


Figure 22: Main regions used for the analysis (Deliverable D1.4[3])

To perform the PI Hubs plan analysis, the same database of movements from D1.4[2] has been used. The database has a Europe-wide scope (28 countries). The list of countries included is shown in the image below (Figure 23). Within each region the flows are detailed at NUTS2 region level, as also shown in the image on the right of the picture.

[3] *D1.4 ICONET PI network optimisation strategies*

CountryCode
AT
BE
BG
CH
CY
CZ
DE
DK
EE
EL
ES
FI
FR
HR
HU
IE
IT
LT
LU
LV
NL
PL
PT
RO
SE
SI
SK
UK

NUTS2_load	NUTS2_unload	Flow_Tons
AT11	BE10	553
AT11	BE21	5855
AT11	BE22	2603
AT11	BE23	3818
AT11	BE24	1248
AT11	BE25	4077
AT11	BE31	282
AT11	BE32	1637
AT11	BE33	1922
AT11	BE34	1136
AT11	BE35	450
AT11	BG31	326
AT11	BG32	357
AT11	BG33	338
AT11	BG34	251
AT11	BG41	2869
AT11	BG42	1573
AT11	CH01	10515
AT11	CH02	13642
AT11	CH03	12435

Figure 23: List of countries included (left). Detailed flow data for each NUTS2 region (right)

6.1.2 Modelling Components

The following modelling components have been used for the dimensioning analysis of the PI Hubs plan.

Table 16: PI Hubs Plan modeling components

Modelling Component	Description
Node	The nodes in this PI network corresponds to the most important nodes in the TENT Network, a group of 130 nodes in 28 countries in Europe

Link	For the link definition it is considered the main connections of the TENT network in Europe including rail, road and river connections. Used in the routing service from deliverable D2.5 [4]
Transport	For this macro analysis it is assumed and unrestricted capacity for transports in the main corridors of the TENT network.
Orders	The demand corresponds to the main flows between the 281 NUTS 2 regions considered in deliverable D1.4[5].

6.2 PI Hubs Plan Methodology

To identify the location of the main group of nodes, It is taken as a reference the work developed in the ICONET task “T1.3 PI Network optimization strategies and hub distribution policies” and its associated deliverables“D1.3 -PI network optimization strategies and hub location problem modeling v1” and deliverable “D1.5 -PI network optimization strategies and hub location problem modeling”.

Based on the cargo movement data described, the following process is performed in order to determine the size the PI Hubs plan network.

- Assignment of PI Entry Hub for each region (NUTS2). To generate this assignment, each NUTS2 region has been geolocated with its latitude and longitude and it has been assigned to the nearest PI Hub an entry/exit point for the PI Network.
- Routes between the PI Hubs. To calculate the route between the source and destination points it is used the PI-specific routing algorithm designed in task “T2.2 Networking, routing, shipping and encapsulation layer algorithms and services” and described in the ICONET document called “D2.5 PI networking routing shipping and encapsulation layer algorithms and services”. This routing algorithm identifies the best sequence of nodes (PI Hubs) using the information of distance and capacity of the PI services to arrive from an origin to a destination through a PI network
- Calculation of the flows that pass through each PI Hub. Based on the previous steps, it is evaluated in each node of the network the quantity of goods that has passed, taking into account the initial origins and final destinations in order to obtain information in each of the nodes.

With this process it is possible to obtain an estimation of which will be the movement of freight that will pass through each PI Hub in Europe, by applying the concepts of Physical Internet to the main flows between the regions.

[4] D2.5 PI networking routing shipping and encapsulation layer algorithms and services
[5] *D1.4 ICONET PI network optimisation strategies*

6.3 Analysis of the results

The results on the dimensioning of the PI Hubs plan obtained by applying the methodology described in the previous section and with the transport flow data from the document "D1.4. PI network optimization strategies and hub location problem modelling" are shown below. These calculations are a rough estimation based on rail and road freight movements between the main regions in Europe. In the following picture (xxx) the relative sizes of the different PI Hubs across Europe can be seen. The size of each PI Hub is indicated in tons of freight flow passed through in the PI Hub.

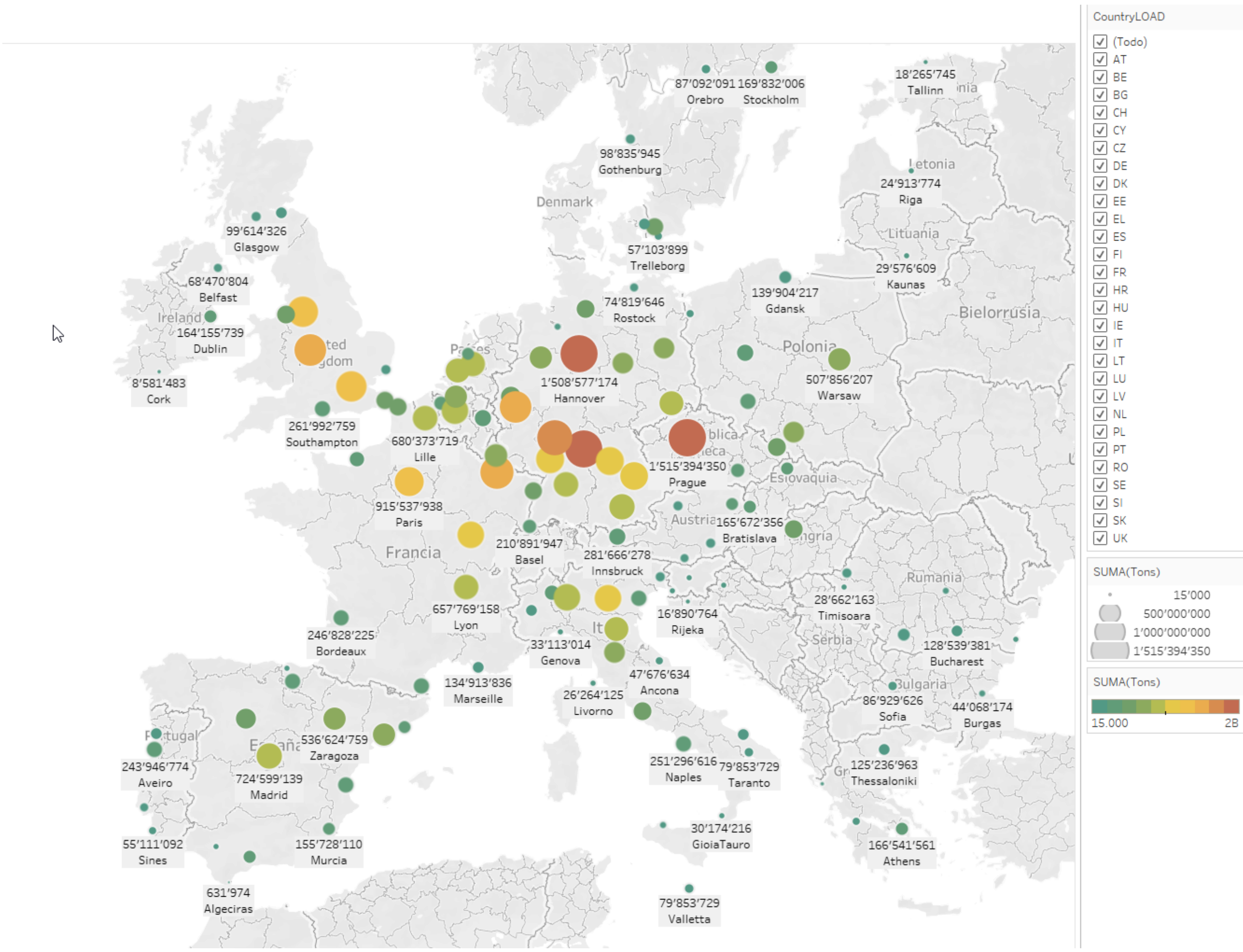


Figure 24: List Relative size of the main PI Hubs

It can be seen from the previous picture that there is a greater concentration of larger PI hubs in central Europe, in the regions of southern Germany, northern France, Belgium, the Czech Republic, northern Italy and the UK.

In the following images (Figure 25, Figure 26) it is possible to observe in a more detailed way the position of the main points of the network with the amount of equivalent tons that would circulate through each node annually.

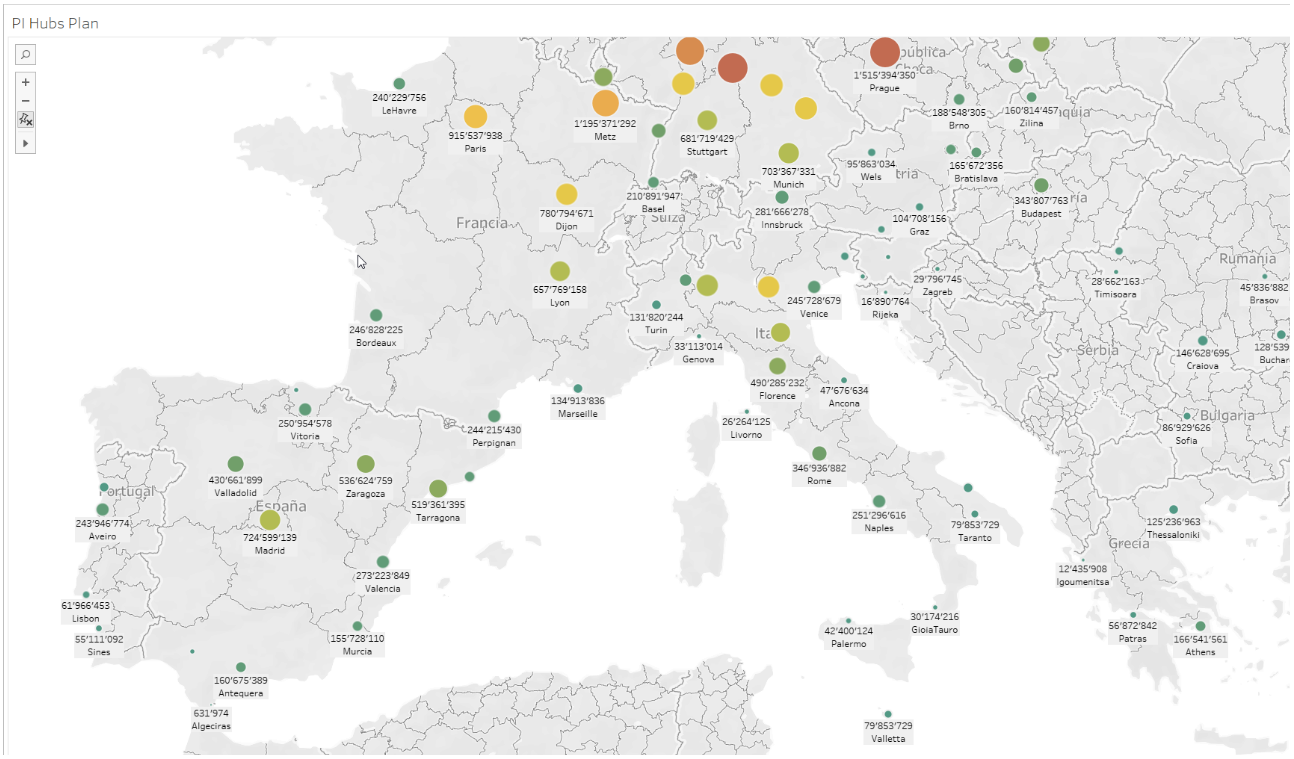


Figure 25: List of PI Hubs (south of Europe)

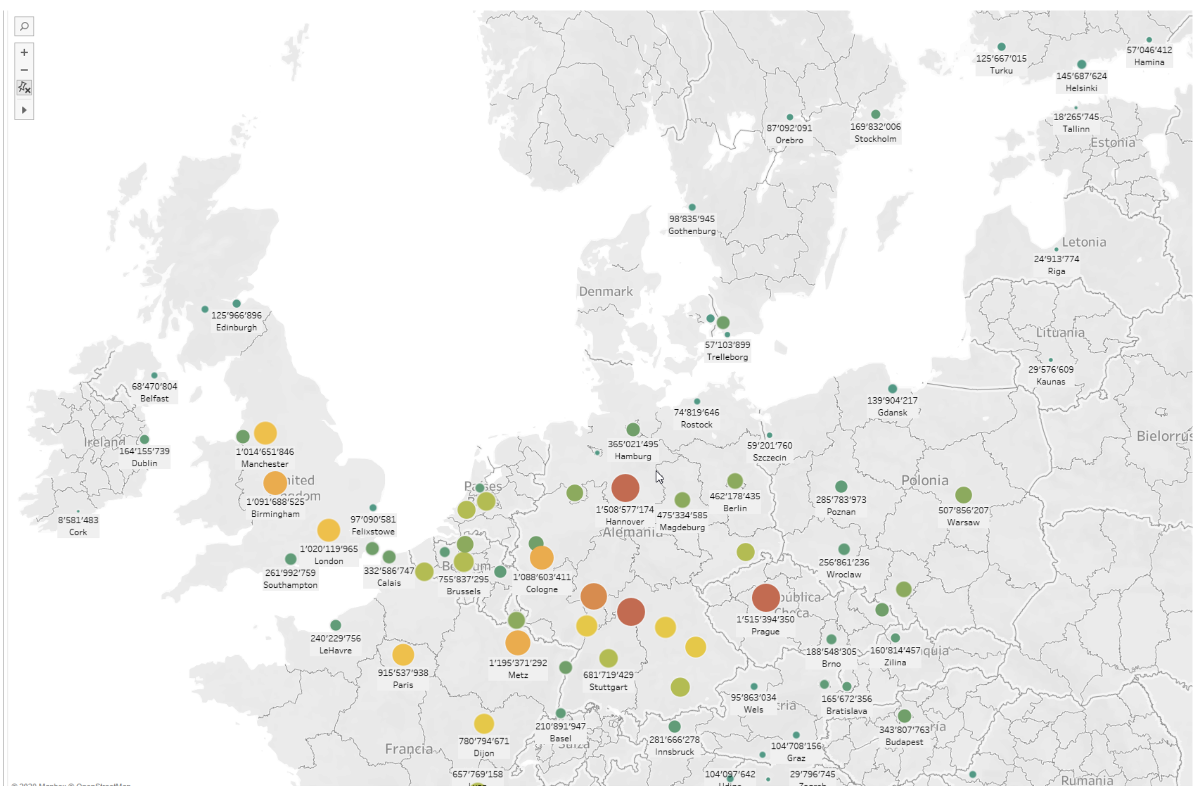
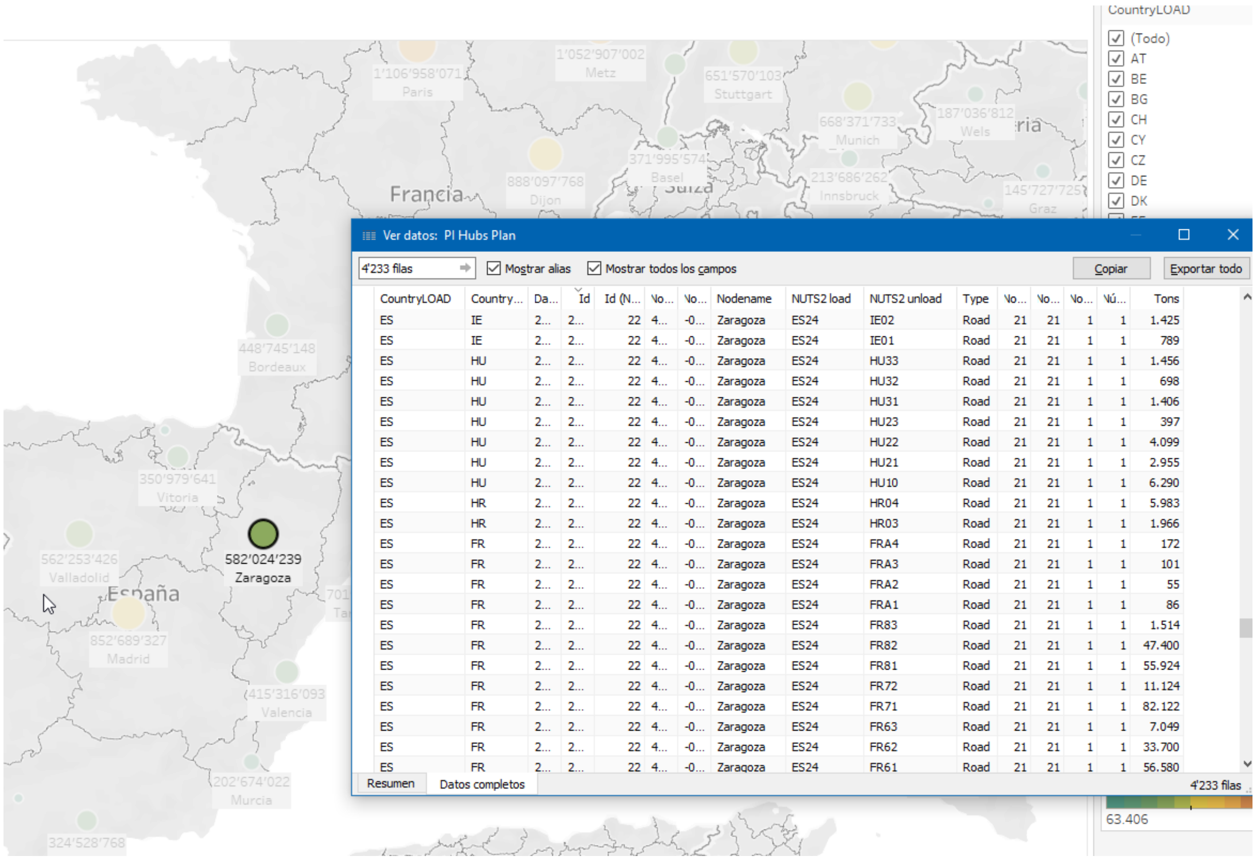


Figure 26: List of PI Hubs (north of Europe)

With the calculation methodology, in each PI Hub it is possible to see the flows of the different NUTS2 regions that pass through the node. As an example, in the following image we can see the detail of the estimated flows that would pass through the PI Hub of Zaragoza (Spain). In this case, they are flows from Spain and Portugal to several European destinations, and vice versa, flows from different European regions to a destination in Spain or Portugal.



CountryLOAD	Country...	Da...	Id	Id (N...	No...	No...	Nodename	NUTS2 load	NUTS2 unload	Type	No...	No...	No...	Nú...	Tons
ES	IE	2...	2...	22	4...	-0...	Zaragoza	ES24	IE02	Road	21	21	1	1	1.425
ES	IE	2...	2...	22	4...	-0...	Zaragoza	ES24	IE01	Road	21	21	1	1	789
ES	HU	2...	2...	22	4...	-0...	Zaragoza	ES24	HU33	Road	21	21	1	1	1.456
ES	HU	2...	2...	22	4...	-0...	Zaragoza	ES24	HU32	Road	21	21	1	1	698
ES	HU	2...	2...	22	4...	-0...	Zaragoza	ES24	HU31	Road	21	21	1	1	1.406
ES	HU	2...	2...	22	4...	-0...	Zaragoza	ES24	HU23	Road	21	21	1	1	397
ES	HU	2...	2...	22	4...	-0...	Zaragoza	ES24	HU22	Road	21	21	1	1	4.099
ES	HU	2...	2...	22	4...	-0...	Zaragoza	ES24	HU21	Road	21	21	1	1	2.955
ES	HU	2...	2...	22	4...	-0...	Zaragoza	ES24	HU10	Road	21	21	1	1	6.290
ES	HR	2...	2...	22	4...	-0...	Zaragoza	ES24	HR04	Road	21	21	1	1	5.983
ES	HR	2...	2...	22	4...	-0...	Zaragoza	ES24	HR03	Road	21	21	1	1	1.966
ES	FR	2...	2...	22	4...	-0...	Zaragoza	ES24	FRA4	Road	21	21	1	1	172
ES	FR	2...	2...	22	4...	-0...	Zaragoza	ES24	FRA3	Road	21	21	1	1	101
ES	FR	2...	2...	22	4...	-0...	Zaragoza	ES24	FRA2	Road	21	21	1	1	55
ES	FR	2...	2...	22	4...	-0...	Zaragoza	ES24	FRA1	Road	21	21	1	1	86
ES	FR	2...	2...	22	4...	-0...	Zaragoza	ES24	FR83	Road	21	21	1	1	1.514
ES	FR	2...	2...	22	4...	-0...	Zaragoza	ES24	FR82	Road	21	21	1	1	47.400
ES	FR	2...	2...	22	4...	-0...	Zaragoza	ES24	FR81	Road	21	21	1	1	55.924
ES	FR	2...	2...	22	4...	-0...	Zaragoza	ES24	FR72	Road	21	21	1	1	11.124
ES	FR	2...	2...	22	4...	-0...	Zaragoza	ES24	FR71	Road	21	21	1	1	82.122
ES	FR	2...	2...	22	4...	-0...	Zaragoza	ES24	FR63	Road	21	21	1	1	7.049
ES	FR	2...	2...	22	4...	-0...	Zaragoza	ES24	FR62	Road	21	21	1	1	33.700
ES	FR	2...	2...	22	4...	-0...	Zaragoza	ES24	FR61	Road	21	21	1	1	56.580

Figure 27: Detail of the flow information passing through a node

This analysis indicates that due to the different interactions between the regions of Europe, the distribution of PI Hubs is not uniform. The largest PI Hubs are located in the central area of Europe, and their size is reduced towards the periphery. There is a high amount of flow of goods in the central part of Europe (Germany, Belgium, France and the Czech Republic). In this area there is a high concentration of large PI hubs, which will require large scale exchange centres with a high degree of automation to be able to handle the complete flow of goods. There are also high flow points in the UK, Northern Italy, France and Spain.

6.4 PI Hubs Size classification

Following the methodology described in the previous chapters, the list of potential PI Hubs at European level can be obtained from the data described in (6.1.1) on the flow of freight by road and rail. The following image provides a graphical representation of the allocation of the main PI Hubs in the main nodes of the TEN-T network, sized according to the volume of freight that passes through them.

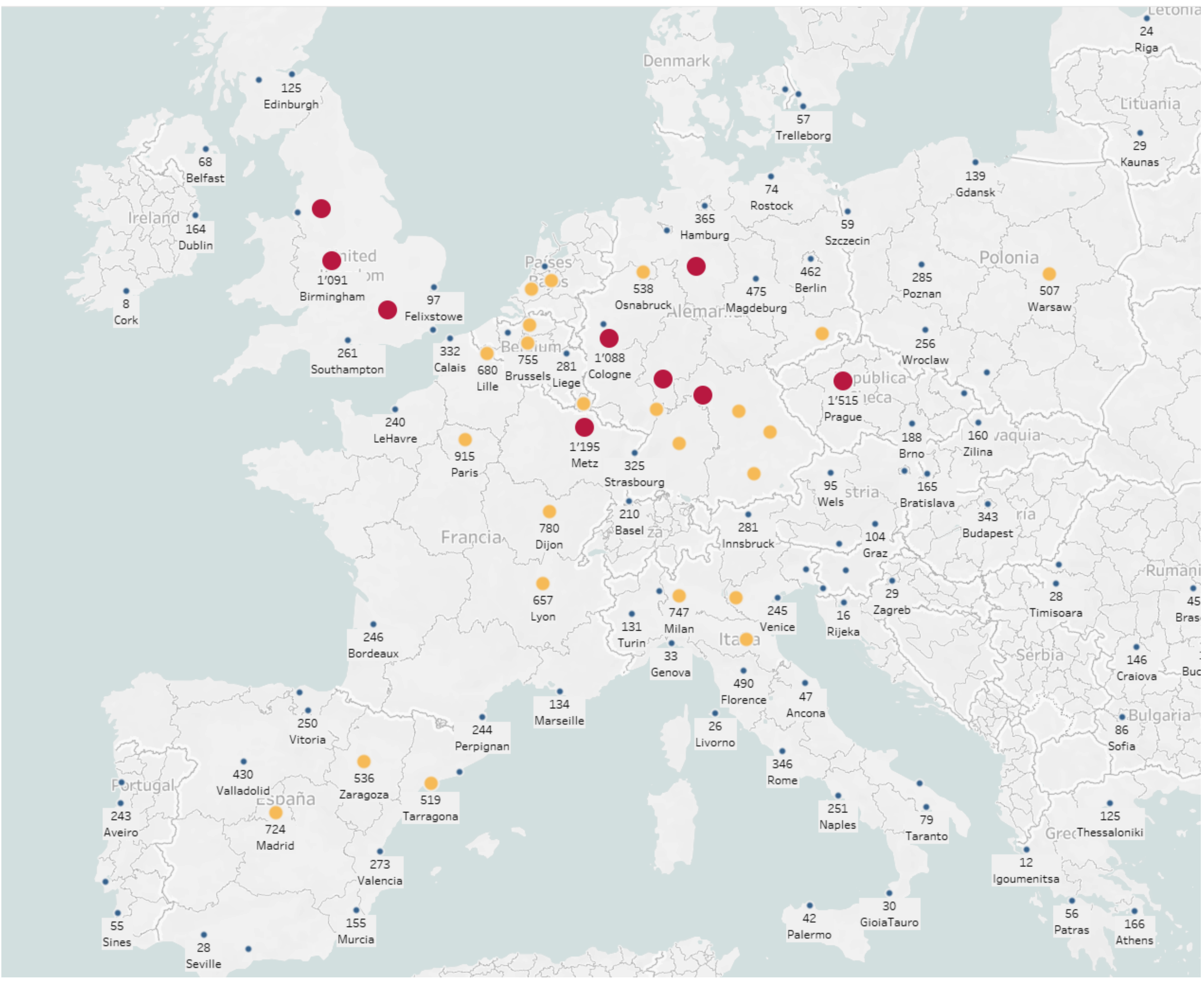


Figure 28: Diagram representing the main European IP Hubs (Millions of Ton per year)

In the results of the analyses it can be observed that the amount of freight flow from each node is very different. In order to be able to establish a categorization of PI Hub types, PI Hubs have been grouped according to the quantity of goods moving through each of them.

First of all, the nodes with the highest amount of movement in the network are grouped together. The nodes that are going to have a higher amount of flow of cargo. In the figure (Figure 28) they are marked as red dots. These are PI hubs with annual movement of more than one billion tons. These PI hubs are located in Central Europe and also in the UK. The list of these IP hubs is shown in the following table Table 17)

Table 17: TOP PI Hub in Europe

	Millons of Ton per year
Prague	1515
Hannover	1508
Wurzburg	1497
Frankfurt	1342
Metz	1195
Birmingham	1091
Cologne	1088
London	1020
Manchester	1014

The second category of PI Hubs is formed by the group of intermediate Hubs, which have an equivalent annual traffic between 0.5 and 1 billion of tons. In the figure (Figure 28) they are marked as orange dots. The following table contains the list of this group of PI Hubs and the estimated cargo for one year.

Table 18: GPICS Framework master data sets

	Millions of Ton per year		Millions of Ton per year
Paris	915	**Utrecht**	664
Mannheim	863	**Lyon**	657

Nuremberg	862	**Dresden**	637
Regensburg	836	**Bologna**	629
Dijon	780	**Rotterdam**	623
Verona	775	**Luxembourg**	561
Brussels	755	**Osnabruck**	538
Milan	747	**Zaragoza**	536
Madrid	724	**Antwerp**	524
Munich	703	**Tarragona**	519
Stuttgart	681	**Warsaw**	507
Lille	680		

The third category of PI Hubs is composed of the rest of PI Hubs, with an annual traffic of less than 500 million tons per year. The complete list is included the following images (Figure 30).

id	Nodename	Mtons
1	Prague	1515
2	Hannover	1508
3	Wurzburg	1497
4	Frankfurt	1342
5	Metz	1195
6	Birmingham	1091
7	Cologne	1088
8	London	1020
9	Manchester	1014
10	Paris	915
11	Mannheim	863
12	Nuremberg	862
13	Regensburg	836
14	Dijon	780
15	Verona	775
16	Brussels	755
17	Milan	747
18	Madrid	724
19	Munich	703
20	Stuttgart	681
21	Lille	680
22	Utrecht	664
23	Lyon	657
24	Dresden	637
25	Bologna	629
26	Rotterdam	623
27	Luxembourg	561
28	Osnabruck	538
29	Zaragoza	536
30	Antwerp	524

id	Nodename	Mtons
31	Tarragona	519
32	Warsaw	507
33	Florence	490
34	Magdeburg	475
35	Katowice	465
36	Berlin	462
37	Valladolid	430
38	Dusseldorf	418
39	Ostrava	374
40	Hamburg	365
41	Liverpool	353
42	Rome	346
43	Budapest	343
44	Malmo	332
45	Calais	332
46	Dover	332
47	Strasbourg	325
48	Poznan	285
49	Innsbruck	281
50	Liege	281
51	Valencia	273
52	Southampton	261
53	Wroclaw	256
54	Naples	251
55	Vitoria	250
56	Bordeaux	246
57	Venice	245
58	Perpignan	244
59	Aveiro	243
60	LeHavre	240

Figure 29: European PI Hub list (1/2)

id	Nodename	Mtons
61	Novara	222
62	Basel	210
63	Gent	195
64	Brno	188
65	Stockholm	169
66	Athens	166
67	Bratislava	165
68	Dublin	164
69	Zilina	160
70	Antequera	160
71	Amsterdam	157
72	Vienna	157
73	Murcia	155
74	Barcelona	153
75	Craiova	146
76	Helsinki	145
77	Gdansk	139
78	Marseille	134
79	Copenhagen	133
80	Turin	131
81	Bucharest	128
82	Edinburgh	125
83	Turku	125
84	Thessaloniki	125
85	Porto	118
86	Bari	117
87	Graz	104
88	Udine	104
89	Arad	103
90	Glasgow	99

id	Nodename	Mtons
91	Gothenburg	98
92	Felixstowe	97
93	Wels	95
94	Orebro	87
95	Sofia	86
96	Taranto	79
97	Valletta	79
98	Rostock	74
99	Belfast	68
100	Klagenfurt	64
101	Lisbon	61
102	Szczecin	59
103	Trelleborg	57
104	Hamina	57
105	Patras	56
106	Sines	55
107	Ancona	47
108	Brasov	45
109	Burgas	44
110	Palermo	42
111	Bremen	40
112	Constanta	33
113	Genova	33
114	Ljubljana	32
115	GioiaTauro	30
116	Zagreb	29
117	Kaunas	29
118	Timisoara	28
119	Seville	28
120	Livorno	26
121	Riga	24
122	Trieste	24
123	Bilbao	24
124	Tallinn	18
125	Rijeka	16
126	Igoumenitsa	12
127	Cork	8
128	Limassol	1
129	Algeciras	1
130	Lefkosia	1

Figure 30: European PI Hub list (2/2)

7 Conclusions

The work carried out to define the final version of the GPICS specification and its associated PI Hubs Plan, was built upon on the initial version of the GPICS, significantly evolving initial findings. It is based on a review of the state of the art, and an evolution about it. GPICS has followed an operational approach that allows the deployment of PI models using the services and concepts that have been developed in the project.

It is important that companies visualize the impact and benefits that PI can have for them. For this reason, a chapter has been developed to facilitate the adoption of PI by current logistics and transport companies. In addition, the main actors have been identified and the current needs for the adoption of PI have been analysed. A series of generic roles have been defined to be carried out by the companies. These are five generic roles that help to identify the tasks and responsibilities of each actor in the IP network. Data integration is also important for companies, therefore an analysis of the main information flows from current legacy systems (ERP, WMS, TMS) has been performed to identify their connection with PI services.

To facilitate the adoption of PI by companies, different roles have been defined, which companies can assume within an PI network. An operational procedure for managing transport operations through the PI network is also described. Furthermore, it is described how the connection of the companies' legacy systems with the PI network could be done.

The GPICS Framework enables the comprehensive representation of a real PI world system by creating a conceptual model that can be simulated. The dimensions included in the GPICS Framework and the instantiation process (selection or configuration of specific parameters) of each of them, provide all the necessary to specify ICONET's PI case studies in a common and orderly way. The specification of the different ICONET Generic PI Case Studies during the project period, follows an iterative approach. GPICS is an evolution in different versions, where elements and experiences of the learning made with the living labs have been incorporated.

In order to determine the PI Hubs Plan, an analysis has been carried out using statistical data on the main flows of goods in Europe between regions. Flow data from 279 NUTS 2 regions in 28 EU countries were used. Applying the GPICS concepts and the calculation methodology defined, an estimation of the amount of goods that will pass through each IP Hub has been obtained. Three large categories of PI Hubs have been identified, according to the quantity of goods that will circulate through them. The largest PI Hubs are located in the central area of Europe, and their size is reduced towards the periphery. This analysis may serve as a reference for sizing the logistics structures required to support future logistics flows based on PI transport networks.

The methodology proposed for the definition of the PI Hub plan is flexible and easily replicable at any scale. This includes both the continent level, the country level or even the region level.

Regarding the way forward, we envision further evolution and the wider adoption of those concepts so that companies are mobilized to collaborate, using the defined services, adopting the relevant roles, integrating their systems to collaborate and sharing logistics and transport resources consequently promoting the PI vision as part of their normal operation.

8 References

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Annex 1: Main documents for transport

Sea Transport	
Customs formalities	
	It is the document that is used to declare the merchandise to Customs and comply with the customs formalities necessary in operations, whether they are import, export or transit. It also serves as the basis for the tax declaration, in fact the presentation of the DUA has the effect of the liquidation of a tax
CARGO MANIFEST	It is the document used to declare the departure, by sea, of the goods to which it gives a customs destination. It makes it easier for Customs to comply with their customs surveillance obligations. It is also the document on which the Port Authorities are based to proceed with the settlement of the port taxes applied to the merchandise. It contains a compilation of all cargo, ordered by bill of lading and by destination. Customs compares what is declared in the Manifesto with the DUA data, so it is an essential document for the merchandise to be dispatched.
	It is the document used to declare the arrival, by sea, of the goods to which it gives a customs destination. It makes it easier for Customs to comply with their customs surveillance obligations. It is also the document on which the Port Authorities are based to proceed with the settlement of the port taxes applied to the merchandise.
Procedures before the official inspection services (export / import)	
	(Official Service of Inspection, Surveillance and Regulation of Foreign Trade): It is an official control and inspection certificate of a series of food products included in the Annex of Order PRE / 3026/2003, of October 30, by which they dictate inspection and control standards for the Regional and Territorial Directorates of Commerce, products other than fresh fruits and vegetables. This certificate is required for the dispatch of certain products as a guarantee of compliance with quality standards, commercial specifications and those concerning their containers and packaging.
CERTIFICATE OF CONTROL CEE / SOIVRE FRUITS AND VEGETABLES	Analogous to the previous one for fresh fruits and vegetables.

	The sanitary certificate certifies that the exported / imported merchandise is fit for human consumption and complies with the sanitary regulations.
PHYTOSANITARY CERTIFICATE	It is a document of control and fight against pests. Certain plants, plant products and other plants and objects related to them must be accompanied by their corresponding plant passport at the time of issue or entry into the EU
	This document is a proof of the conclusion of a transport contract by sea, port to port. It is also a certificate of delivery of the cargo to the carrier, It can be negotiable
FTC B/L	The FTC transportation certificate certifies that the transit is responsible for the goods in the expedition and delivery, in accordance with the instructions received and transcribed in this document. The delivery of the goods can only be made against the presentation of this document
	This document is issued by the Shipowner or the shipping agent's consignee and certifies the receipt of the cargo on board the ship, covering only the journey between two ports, origin and destination, in the same ship.
FIATA	• **FIATA FCR**: FIATA certificate of receipt of the goods by transit (green). • **FIATA FCT**: transport agent certificate. When a FIATA FCT is issued, the freight forwarder assumes the responsibility of dispatching and delivering the specific shipment in accordance with the instructions received from the vendor as indicated in the document. • **FBL**: the negotiable multimodal freight transport knowledge (FCL) is a document for all types of transport established by FIATA to be used by freight forwarders who act as multimodal transport operators (MTO). Negotiability of the combined transport invoice (blue). • **Fixed FBL**: FIATA multimodal freight bill negotiation (blue) replacing the previous combined freight • **STD**: it is the declaration of the dispatcher of transport of dangerous goods, it allows him to identify the merchandise and clarifies the subject of responsibilities in case of accident or deterioration. • **FWR**: it is the warehouse receipt / delivery note to be used, in operations that include warehousing, by transit agents. It is a standardized document, used mainly at the local level.
CONTRACT OF CARRIAGE / CONSIGNMENT NOTE (CIM)	It is the proof of the transport contract between the client and the railway administration. This document states the quantity, type and weight of the merchandise, as well as destination, route to follow and other instructions.

	The sender must be a natural or legal person, in his own name or on behalf of the shipper. Once the goods have been delivered to the agreed place, the sender will receive the corresponding copy of the consignment note stamped by the railway administration, serving as proof of the goods transport contract. In the case of a groupage shipment being made through a freight forwarder, this will issue a receipt certificate to the client / exporter as proof of the transport contract, instead of the corresponding copy of the CIM, as a global one has been prepared in front of the administration for the entire expedition.
	Document for goods transported by rail between two EU and EFTA member states, as well as for goods destined for third countries in transit through EU countries. The CPI covers the entire route and, therefore, the railway will respond to the Administration for possible irregularities upon the arrival of the merchandise at the agreed point.
TIF	Document indicated for the transport of goods by rail that is used to cross the customs of several countries, equivalent to the TIR certificate of road transport
	Agreement concerning the international transport of dangerous goods by rail. The regulations contain a detailed list with headings for most of the goods transported (coded according to a numbering established by the UN) and the regulatory requirements that apply to each case. It is not only applicable to international transport, in Europe, compliance with this regulation is mandatory for all transport of dangerous goods within the territory of any member country. The requirements established in this regulation also affect companies that load and unload dangerous goods, as well as those companies that manufacture elements and materials related to the transport, packaging and handling of these goods.
Air Transport	
	All air transportation of merchandise must be carried out under a contract called "air waybill" (AWB). This document can be issued by the transport company itself or by its authorized freight forwarders. The validity of the transport contract begins when the air waybill or the document that replaces it is formalized. The validity of the same expires when the shipment is delivered to the recipient listed therein. Air waybill can only be used for the transport of individual or consolidated shipments, in this case also called "Master" (MAWB), but never for individual shipments of a consolidated, since the consolidator must use their own particular documents, called ` House "(HAWB).
Road Transport	
	The Contract for the International Transport of Goods by Road, covered by the International Bill of Lading, is subject to the agreement relating to the contract for the international transport of goods by road (CMR).

	It is the main document in the operation of transport of goods by road for those countries not members of the European Union. As in the other existing means of transport, the CMR must contain all the data corresponding to the sender and recipient, complete data of the merchandise, as well as the delivery conditions agreed with the carrier. Transport agencies issue the corresponding certificates of receipt to exporting clients, as proof of receipt and transport of the merchandise
EUROPEAN AGREEMENT ON THE INTERNATIONAL CARRIAGE OF DANGEROUS GOODS BY ROAD (ADR)	Establishes the rules on how to pack, transport, document, and any other aspect of the transport of dangerous goods by road, including loading, unloading and storage of dangerous goods. It also establishes the responsibilities of each participant in transport operations. To avoid damage to humans, animals, the environment or property. It is not only applicable to international transport, in Europe, compliance with this regulation is mandatory for all transport of dangerous goods within the territory of any member country. The requirements established in this regulation affect both carriers and companies that load and unload dangerous goods, as well as those companies that manufacture elements and materials related to the transport, packaging and handling of these goods.
	Document accrediting the load in road transport
CARRIER RECEIPT CERTIFICATE (FCR)	This document gives freight forwarder the responsibility to deliver to its shipper a title of possession itself, which serves as a receipt. The FCR is delivered for the freight forwarder to the customer by passing it at the time of taking possession of the merchandise.
	Document indicated for the transport of goods by road in which the customs of several countries are crossed without handling the goods
ATP CERTIFICATE	ATP certificate for the transport of goods of perishable products under controlled temperature. All regulations are subject to the European ATP agreement.