New ICT infrastructure and reference architecture to support Operations in future PI Logistics NETworks

D1.8 Generic PI Case Study and associated PI Hubs Plan v2

Document Summary Information

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Glossary of terms and abbreviations used

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

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 second release of the respective PI Hubs Plan.

The work has been based on the previous release of the deliverable (D1.7 – "Generic PI Case Study and associated PI Hubs Plan v1") 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 v2 also elaborates on GPICS Framework, and its multiple dimensions. The GPICS Framework, facilitates the representation of a real PI system through the creation of a conceptual model for a generic geographic area, a series of descriptive elements, the logical relations concerning the components of the system, the input and output data and a set of scenarios configuration capabilities. The developed six-dimensional GPICS model covers the four fundamental parts of a representation: lexical, structural, procedural and semantic.

Finally, utilizing an evolutionary and more complex instance of the GPICS Framework regarding the previous version (in terms of covered geographic area, base configuration rules, scenario configuration and KPIs) and applying the latest and more advanced and smart results of the "T1.3 PI Network optimization strategies and hub distribution policies", we formalized and released the second version of the Generic PI Case Study.

This deliverable, apart from hosting this second release of the GPICS Specifications, it 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.

This deliverable has three releases, D1.7 – "Generic PI Case Study and associated PI Hubs Plan v1" already submitted in M8, D1.8 – "Generic PI Case Study and associated PI Hubs Plan v2" planned for M16 and D1.9 – "Generic PI Case Study and associated PI Hubs Plan final" scheduled for M27. The present document covers the second release of these series. New chapters have been added on different collaborative strategies between existing logistics networks in relation to the PI. New detailed modelling option for GPICS components are included. For the GPICS evolution new node sophistication levels, with different detail levels for generic components are defined. Finally, new references included to describe the interconnection between the physical and the digital network.

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 13 chapters. The first is the chapter of the executive summary that outlines the key goals 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.

3 Physical Internet Background

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. To do so, 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

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, unsnapping, composing, decomposition and shipment of PI containers	GPICS HUB includes a wide range of functionalities to perform logistics operations: source, sink, assembly, split, queue, store, switch, bridge, sort and gateway.

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.

One of the main outcomes to date of SENSE project is the development of a comprehensive and detailed roadmap towards the Physical Internet (PI).

SENSE approach separates PI into two different levels: network and node level. The nodes in PI are physical locations, like hubs, warehouses, etc. They build the connection between networks and do transshipment of goods between different transport modes. The network level describes how the different nodes are connected within the network. On node level, the focus is on the design and operation of PI nodes including physical handling of goods and assets. On network level, the focus is on PI network design and operation in networks such as routing and how the offers meet the demands.

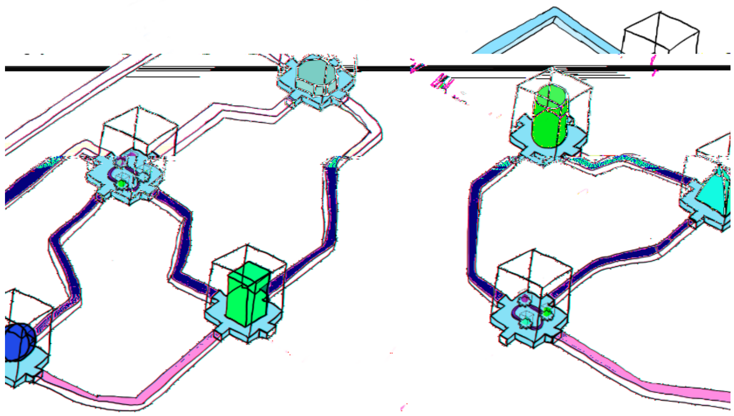

Figure 1: SENSE Network and node level in PI

According to SENSE, the PI network´s elements are the PI Nodes and the PI Network Services. In addition to these elements, the governance and regulations are the third element.

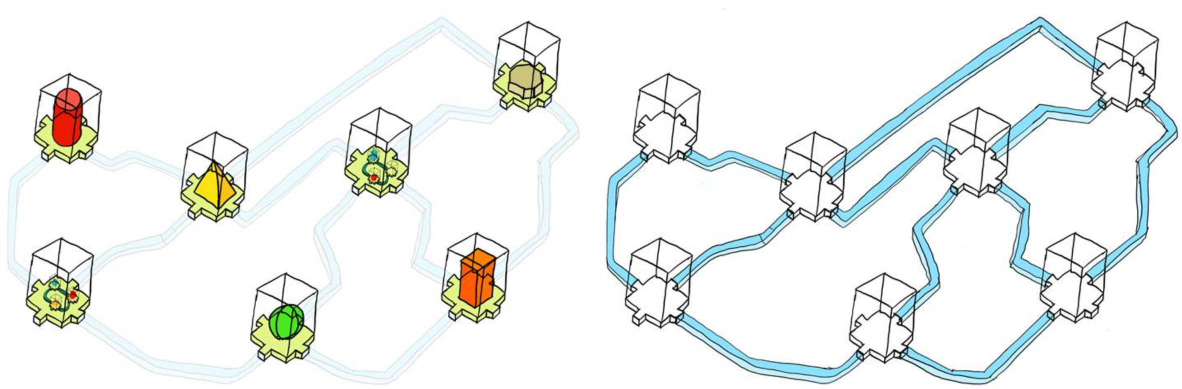

Figure 2: SENSE Different perspectives on the same network (Left: node level, right: network level)

The table below summarizes the correspondence between the ICONET GPICS key elements and the main aspects identified in SENSE, in its comprehensive and detailed roadmap towards the Physical Internet.

Table 2: Correspondence between ICONET GPICS and SENSE key elements

PI NODES - Physical nodes like transshipment hubs, warehousing hubs, etc. Internal operations of nodes are hidden for network level ▪ Several operations of PI nodes ▪ Boxes, containers and physical handling ▪ Value Adding Service providers	GPIC HUB - The Generic Hub represents a node in the PI network, where goods are stored, transferred or manipulated between movements. Simplification and approximation are made through the approach of each Generic Hub, which has an area of influence and incorporates capacities and functionalities of specific nodes in its area of influence.

▪ Customs (and other public services) will be in the nodes (as function) ▪ PI node is always consisting of physical system and it system	▪ Different functionalities of GPICS Hubs to perform logistics activities and handle GPICS containers ▪ Functionalities are hidden for the GPICS Network
PI Network - Connects PI Nodes to each other. The network level describes how nodes are connected within the network to allow door-to-door transport.	The GPICS network represents a universal, open and collaborative Physical Internet network. The GPIC Network is formed by, and it is the result or the consequence of the rest of the modeling components: GPICS Containers, GPICS Hubs, GPICS Movers/transport, GPICS Corridors and GPICS Routes. Altogether, each of them with its basic information properly configured, make up the GPICS Network.
PI Network Services – Several services offered by the PI network ▪ PI network design and operation ▪ Role of PI nodes in the network ▪ Routing algorithms and connection of transport networks ▪ PI Network Of Networks ▪ Network with different paths based on individual requirements.	GPICS Network is design through GPICS Framework and its corresponding instantiation in GPICS specification version 1. Each GPICS Hub has a set of functionalities. Routing is based on GPICS corridor and GPICS route modeling components configuration using T1.3 algorithms in GPICS Hubs Plan. The GPICS Hub provide encapsulation services. This service allows the optimal fitting of cargo into pi containers, and consolidation services. Also improves consolidating shipments to improve transport efficiency and increase load rate. The connection of different Hubs and networks (network of network) is defined by specific a GPICS base configuration rule. Different routes based on special requirements (i.e. cold, hazard) can be defined by specific a GPICS base configuration rule.
PI Governance - The PI governance is based on a regulatory and contractual framework to ensure that: ▪ All types of organizations (shippers, LSPs, services providers). ▪ Service level agreements are set at the PI level, to ensure that all participants comply with the basic quality of service standards. ▪ Routing of cargo through the network is managed transparently.	GPICS includes different roles involved in the PI operation: GPICS Sender, GPICS Receiver, GPICS Transport & Logistics Service Provider and GPICS Coordinator. Service levels are attributes of GPICS HUBS in terms of performance rates. The modification on service level requirements can be managed through' the configuration dimension of the GPICS scenarios. The routing is transparent, based on GPICS corridor and the configuration of the GPICS route modeling components, using T1.3 algorithms in GPICS Hubs Plan. Configuration rules that allows to model different scenarios of collaboration in the

	collaborative logistics communities. Also, operational rules and limits, e.g. minimum volume handling required to introduce a new node.

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 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 of this project (D4.6

Depending on the scope, the PI users could be different. In LL3 e

- 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, the main advantages that these companies perceive as potential benefits are the following:

- 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.

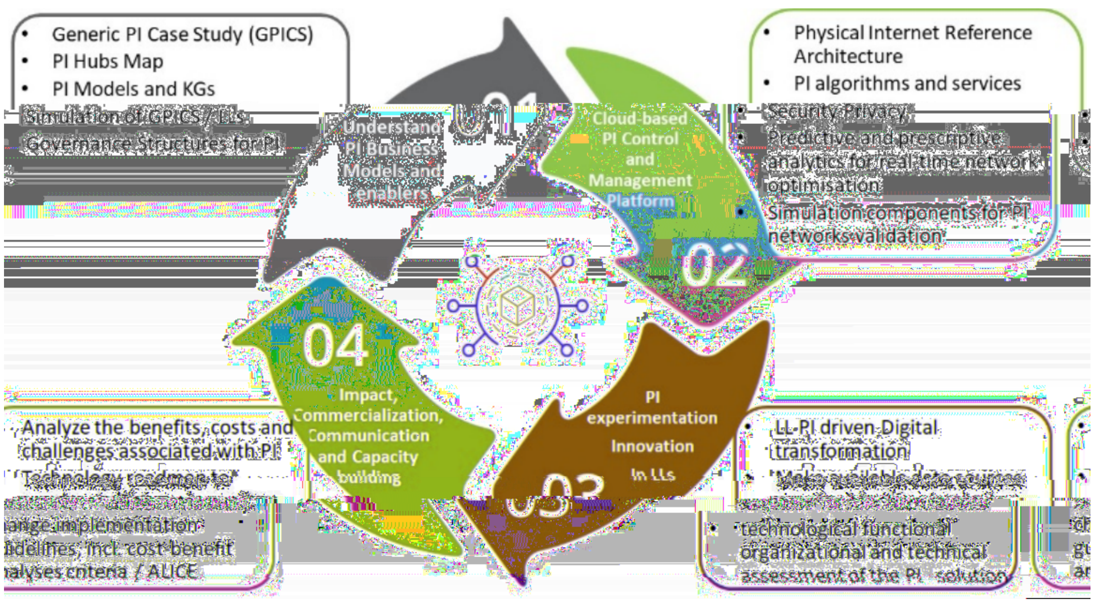

Figure 3: ICONET'S methodology

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.

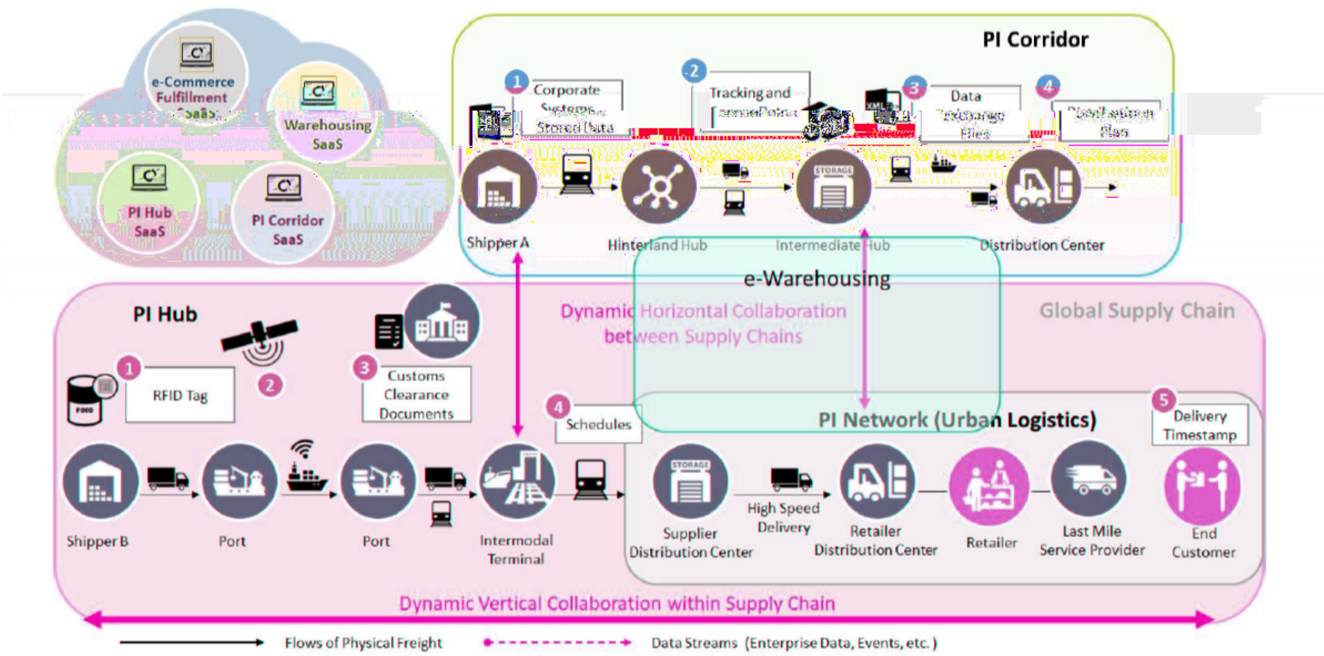

Figure 4: ICONET'S GPICS overview

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.

[redacted]

Figure 5: 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.

On the basis of these two first versions (version 1 and version 2) the final version of the GPICS definition and its associated PI Hubs Plan will be defined in the final stage of the ICONET project.

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 _________ ____ up to the capabilities of _________ ___________________________(based on operational rules, business models and vertical and horizontal collaboration strategies among different roles in the supply chain) including _______________, which concern and are relevant to a _______________ 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 ________ _________________________ for the evaluation of different PI scenarios, based in different combination of the configuration capabilities of those scenarios.

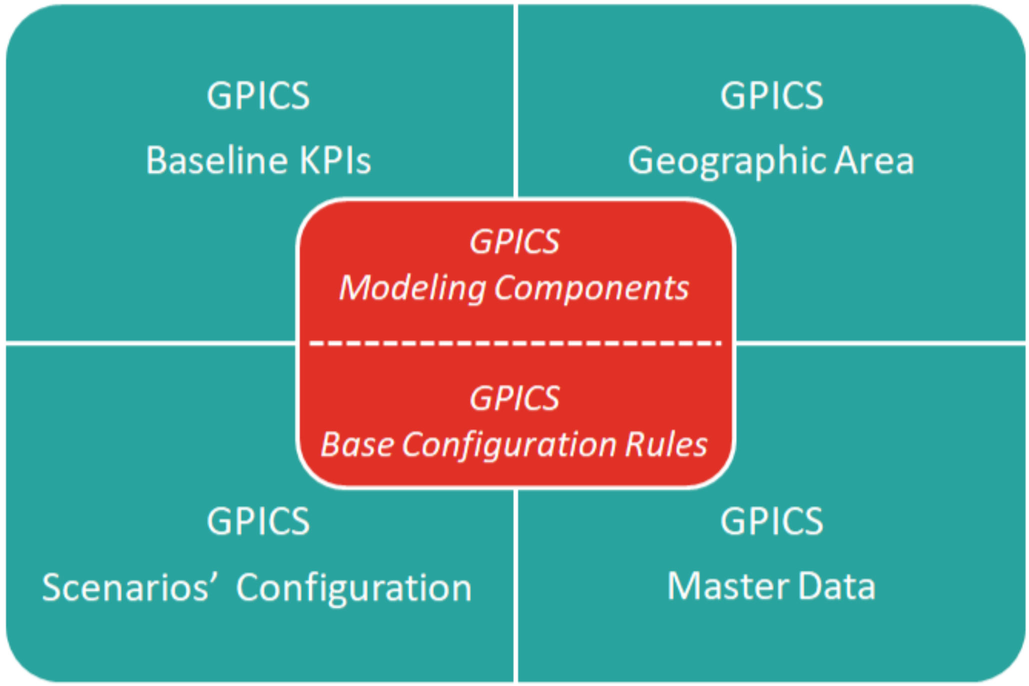

Figure 6: GPICS Framework/Dimensions

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.

5 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.

6 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.

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7 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.

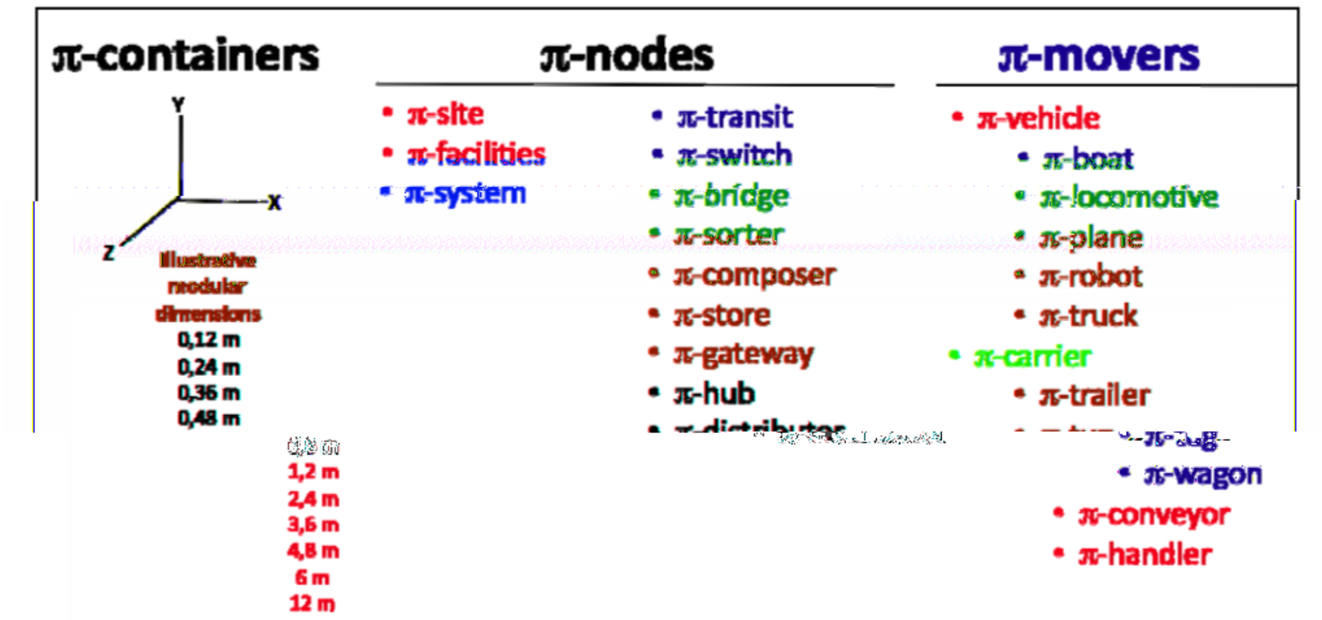


Figure 7: Types of physical elements

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 [redacted]	Transport services	Punctual or regular transport [redacted]

Figure 8: 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 4: GPICS modelling components

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.

7.1 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 5: GPICS Container basic information

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.

7.2 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.

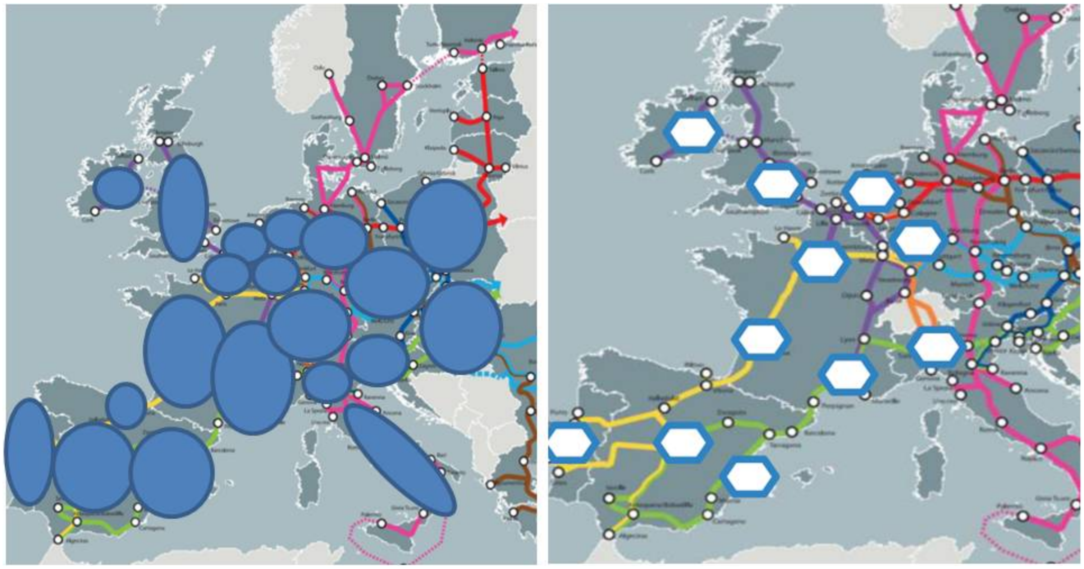


Figure 9: GPICS Hub area of influence representation

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.

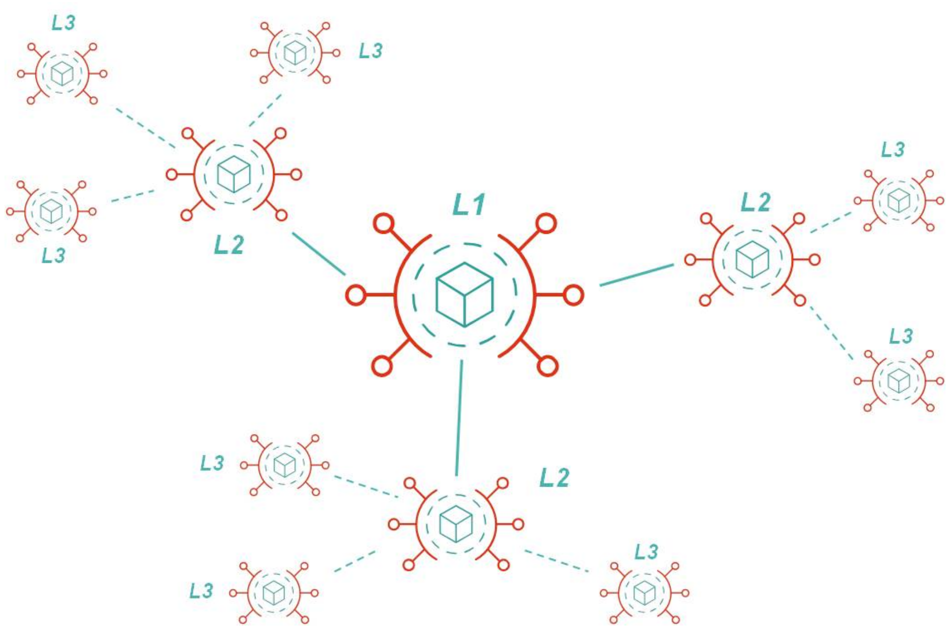


Figure 10: GPICS three-level structure of HUBS

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

Table 6: Correspondence of GPICS HUBS hierarchical structure and LL requirements

	COUNTRY	BLACK WAREHOUSE	CENTRAL WAREHOUSE	PI HUB PORT GATEWAY	MULTIPLE PI HUBS IN THE CORRIDOR GROM ORIGIN TO DESTINATION
	NUTS - 2	SHOP	REGIONAL WAREHOUSE	INTERNAL BUNDLING AREA	PI HUBS IN THE CORRIDOR GROM ORIGIN TO DESTINATION
	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 7: GPICS HUB basic information

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.

7.2.1 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

Table 8: GPICS Link basic information

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.
attTransitTime	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.

7.3.1 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 oad node connections for connections between cities, normally used by trucks of different types and vans. 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...). 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".

7.4 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 9: GPICS Route basic information

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.

7.5 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 10: GPICS Transport basic information

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.

7.5.1 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.

7.6 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.

7.7 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.

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.

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.

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.

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.

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.

7.8 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.

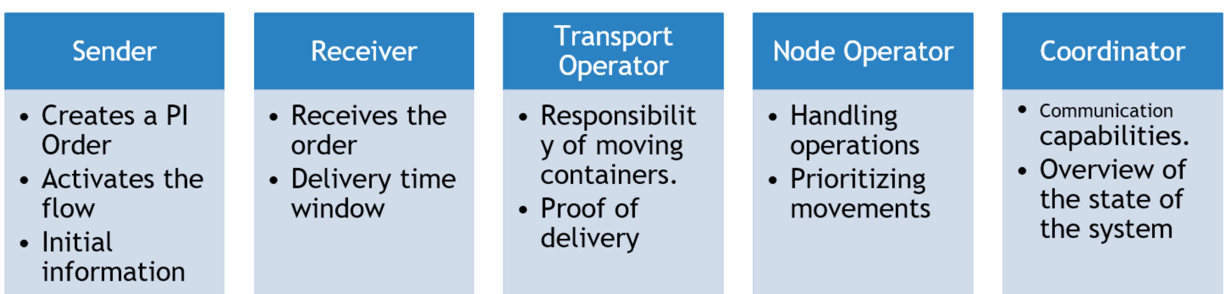


Figure 11: PI Role definition and main functionalities

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.

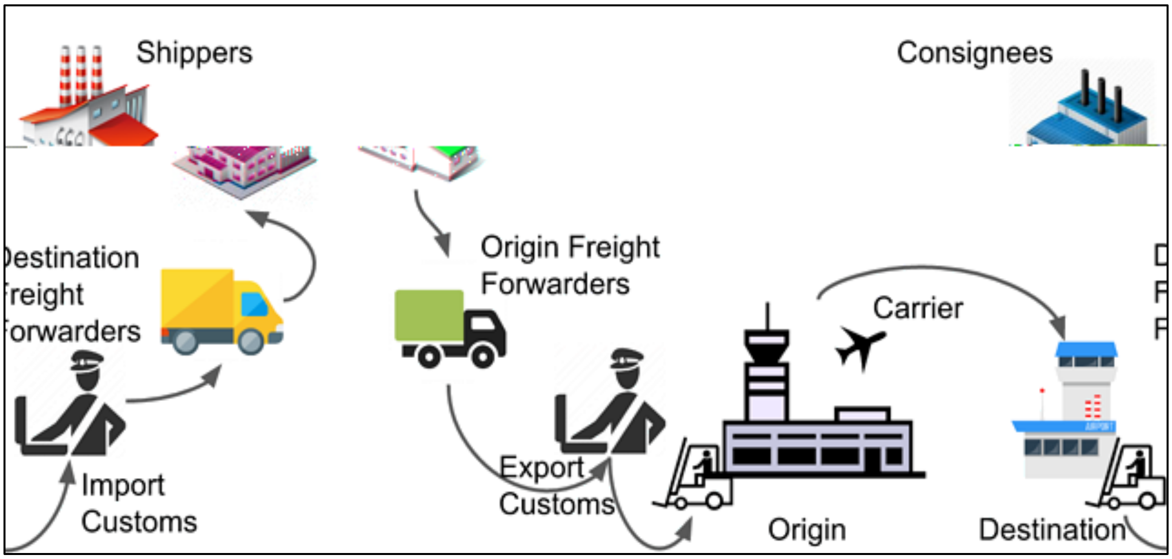


Figure 12: LSP main actual players

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 11: GPICS Role examples

	G E	L L E
	Shippers, eCommerce Owner	Shippers (PnG)
	Final Customer, Consignees	Shoppers (SON)
	Freight Forwarders, Carriers, Last Mile Delivery	Freight forwarders, Shipping Companies. Rail operator (INFRABEL)
N	Warehouse, Port Terminal, Airport	Industrial sites, intermodal terminal operators (PoA),Regional Warehouse (SB), tank storage operators
C	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.

7.9 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)

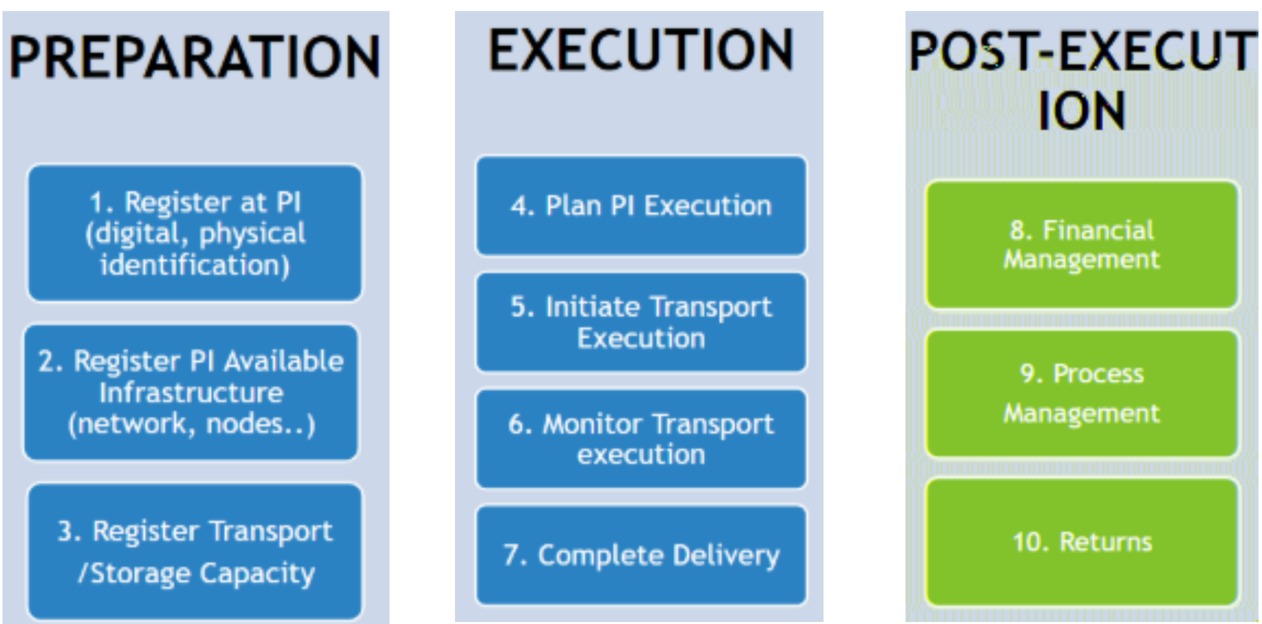


Figure 13: GPICS Operational procedure

8 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.

8.1 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.

8.2 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:

8.4 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.

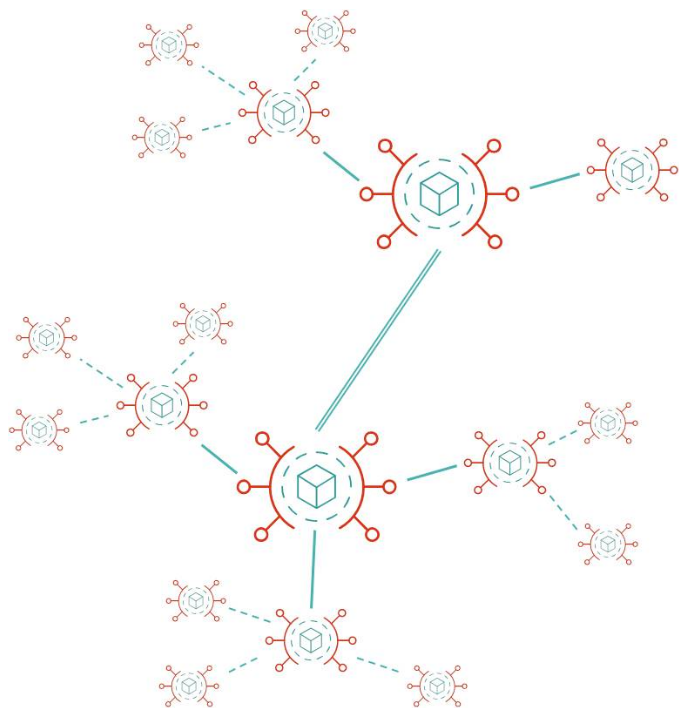


Figure 14: Example Connections between Hubs

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

8.5 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.

8.6 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

8.7 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

8.8 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.

High detail level in nodes includes:

- 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 12: 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

Low detail in links includes:

- 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.

High detail in links includes:

- 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 13: 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 14: 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 15: 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

8.8.1 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.

9 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.

9.1 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.

9.2 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.

9.3 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.

9.4 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.

9.5 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.

9.6 Interconnection between 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.

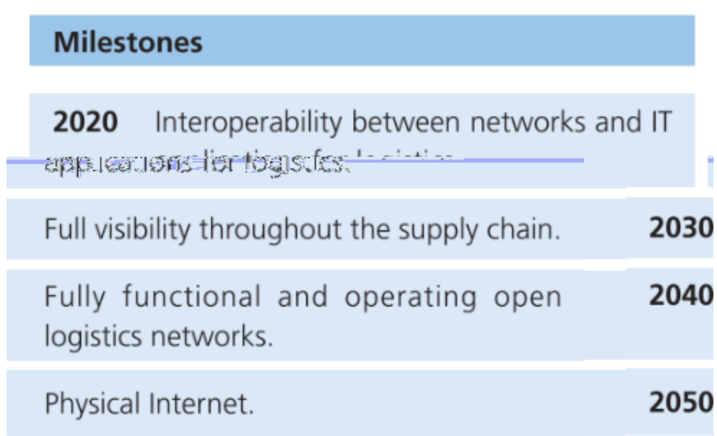


Figure 15 ALICE Roadmap for Physical Internet [10]

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.

9.6.1 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.

- Transport Order Assignment: Assign transport orders to an available transporter
- Output from a PI Node: The container leaves t&Zfiatffb OerNwres tiEnrnr OfNwr OlNwr OerV]rtNwOiENwZ OrNwdhff[illegible]

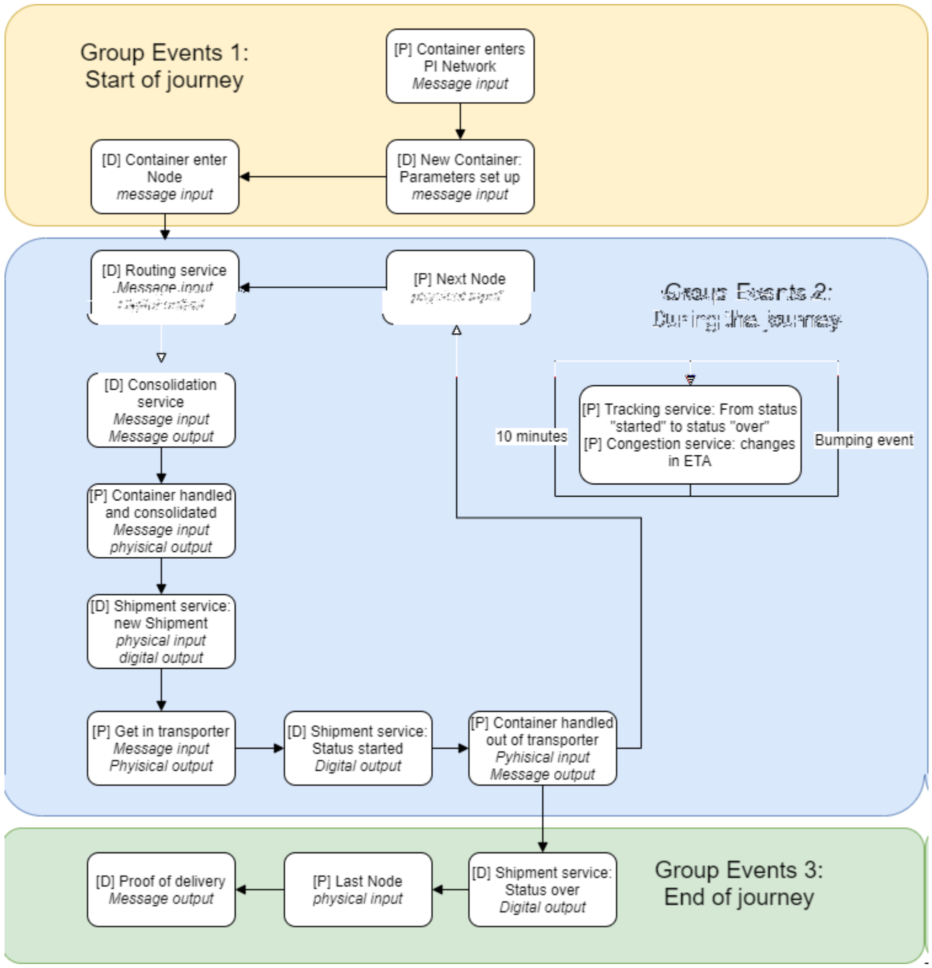


Figure 16 Example of Digital [D] and Physical [P] Events

10 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.

10.1 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;

10.2 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

10.3 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:

- CO2 emissions per fleet
- Consumed fuel or energy

11 GPICS Specification & Associated PI Hubs Plan version 2

This chapter describes the GPICS Definition & Associated PI Hubs Plan v2. In section 11.1, the GPICS Definition in its second version (based on the instantiation of the GPICS Framework) is explained, then, a short explanation of the methodology applied to create the PI Hubs Plan and finally the PI Hubs Plan version 2.

The content, descriptions, values and observations in this chapter are completely new with respect to previous versions of the document. Since this chapter is the main outcome of the task and the GPICS specification and its associated Hubs Plan, are new in each release. As well as being new, each GPICS release is an evolution and a more complex version than the previous ones but all of them are based and supported by the common framework in order to provide valuable and comparable conclusions in terms of the results of the simulation models implementing the case study.

11.1 GPICS Specification version 2

This section specifies the GPICS and its configuration for this second release of the deliverable. The GPICS definition is based on the instantiation of the GPICS Framework defined in this document. On the basis of this second version, GPICS final version will be defined in Month 27. Main difference between versions is their scope, due to GPICS definition process has been approached as an incremental task. The final version will be broader and more extensive in terms of geographic area, detail of the data, and complexity of base configuration rules and scenarios capabilities. KPIs will also be more detailed.

In addition, main parameters of the GPICS are detailed i.e. the EU geographic regions that fall within the study (i.e. specific mega-hub ports, TEN-T corridors, urban distribution centres), population coverage, cargo/freight load distribution, taxonomy of T&L actors involved, etc.

11.1.1 Geographic area

This subsection details the geographic area included in the second release of the GPICS specification. 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.

Three of these EU state members, France, Spain and Portugal, made up the geographical area of the initial version of the GPICS. In the second version of the GPICS and in order to extend the scope and the complexity of the case study, the geographic area has been broadened to a great extent, including five more EU state members: Belgium, Netherlands, Germany, Italy and Luxemburg.

Following the same criteria than in the initial version, the decision for the selection of the new EU state members, is based on the relevance of this geographic area for the other two ICONET's Living Labs, that were not considered in the first release of the GPICS due to their less development and progress in that moment (M8).

LL1, PI Hub-centric Network, will implement and validate PI concepts in the complex transport landscape of the area of Antwerp, composed of three port mega-hubs (Antwerp, Gent and Zeebrugge), each of which (due to its size) can be considered as a PI Hub-centric network. The maritime and continental hubs and terminals of these ports will be considered as the primary PI Nodes, whereas trains, trucks and barges will be the PI Means, and the respective train, road and barge lines/services will be the PI Links. The goal of the PI-centric approach in this LL is to streamline the mega-hubs' operations, reducing congestion and bottlenecks in the flow of goods, especially in left/right bank trips. The LL provides the opportunity to simulate and study PI concepts and network operations at two different scales: intra-facility inter-center network and intra-country inter-state network.

LL2, Corridor-centric PI Network, will examine the applicability of IoT through progressively transforming typical transport corridors into PI corridors, with the emphasis to enhancing the reliability of intermodal connections, paving the way to implement synchromodality at an operational level, and ultimately understanding decision making characteristics with regards to delaying or pulling forward loads or modal shift. Focusing on the North Sea – Mediterranean Corridor, smart-sensors will be engaged on the existing transport infrastructure.

Geographically, all the new EU state members included in the GPICS v2, are related to one or both Living Labs and represent either the source/destination or the normal and mandatory passing through for road and train freight flows between those two countries. This makes it necessary to include them as part of the GPICS definition in its second version in order to cover all the existing freight flows and support them in the simulation models.

NUTS-2 based level has no limitation in terms of included regions. All NUTS-2 regions which are part of these EU state members are included in the GPICS specification v2.

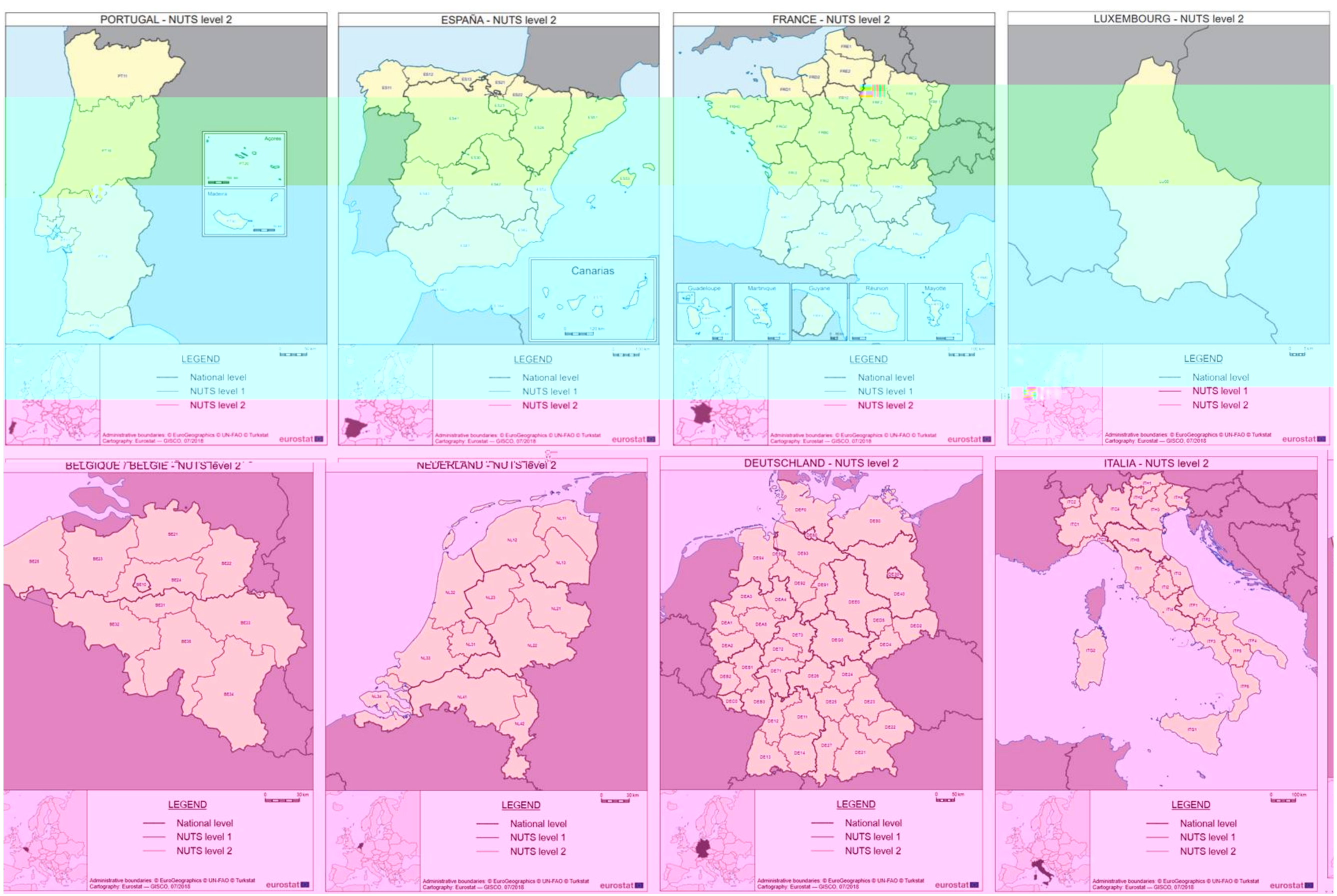


Figure 17: GPICS Specification v2 Geographic Area

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 16: GPICS evolution v1 vs v2 in terms of geographic area

	G IC E I N	G IC E I N
E A E MEMBE	3	8
N EGI N	53	135

11.1.2 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.

Moreover, using the same sources of information will allow to consistent and coherent comparisons and analysis between the two versions of the GPICS.

Details of the main Eurostat statistical information used in the GPICS specification version 2 can be found below.

According to [8], the scope of the GPICS specification version 2 in terms of populations is as follows:

GEO/TIME	2018
Belgium	11.398.589
Germany including former GDR	82.792.351
Spain	46.658.447
France	66.926.166
Italy	60.483.973
Luxembourg	602.005
Netherlands	17.181.084
Portugal	10.291.027
	296.333.642

Figure 18: GPICS Specification v2 Population Scope

Taking into account the new scope of the GPICS in terms of geographic area, the population encompassed in the current version of the PI case study is more than double of the population included in the initial version. In absolute terms, the covered population by the case study has increased from 123.875.640 to 296.333.642 inhabitants.

According to [8], the representation within the total inhabitants in the EU-28 is:

GEO/TIME	2018
European Union - 28 countries	512.379.225
Belgium	11.398.589
Germany including former GDR	82.792.351
Spain	46.658.447
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
	296.333.642
	57,83%

Figure 19: GPICS Specification v2 Population Scope vs total EU 28

According to these figures, it can be argued that the new release of the GPICS, takes into consideration more than half of the EU-28 population.

According to [8] the scope of the GPICS specification version 2 in terms of freight transport is as follows:

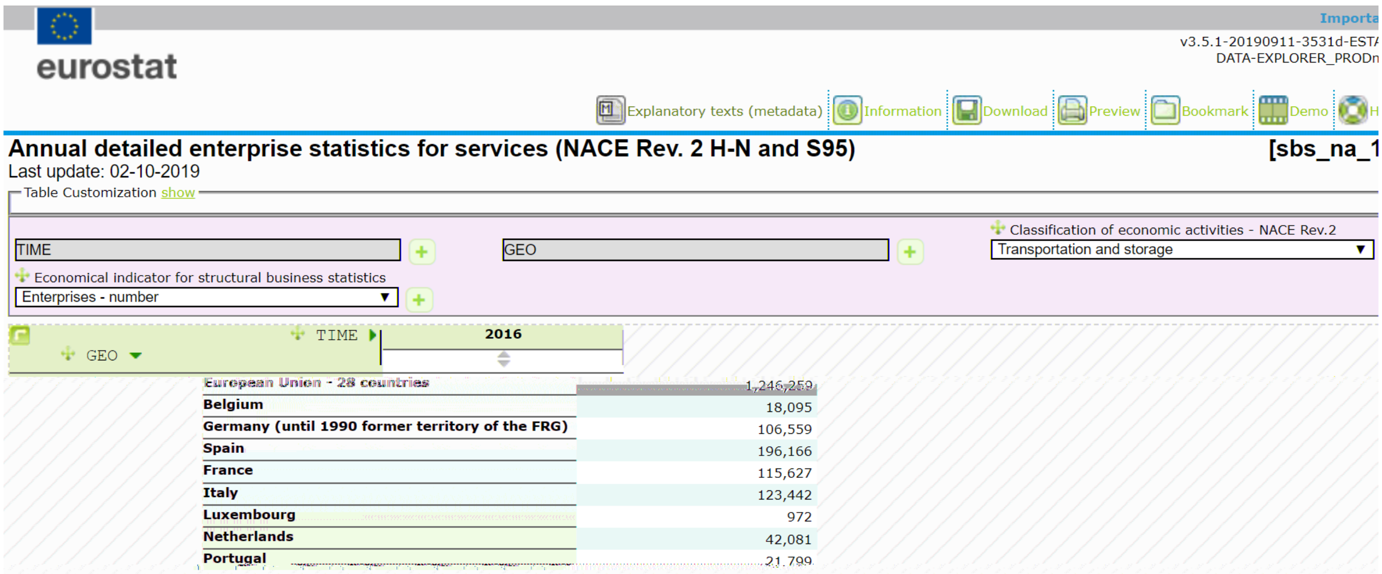
	Road (¹)	Rail	Inland waterways	Road (¹)	Rail	Inland waterways
	(million tonne-kilometres)			(tonne-kilometres per inhabitant)		
EU-28	1 852 336	403 585	147 319	3 626	790	288
Belgium	30 865	:c	10 331	2 724	:c	912
Germany	315 774	116 164	54 347	3 835	1 411	660
Italy	112 637	22 712	67	1 858	375	1
Luxembourg	9 324	201	190	16 020	345	326
Netherlands	67 964	6 641	49 398	3 991	390	2 899
Spain	216 997	12 324	–	4 668	265	–
France	155 843	32 569	8 307	2 331	487	124
Portugal	34 877	2 774	–	3 378	269	–
	944 281	**193 385**	**122 640**			
	50,98%	47,92%	83,25%			

Note: (:) not available. (c) confidential.
(¹) Road transport is based on movements all over the world of vehicles registered in the reporting country.
(²) Road: 2013 data.
(³) Rail: 2015 data.
Source: Eurostat (online data codes: road_go_ta_tott, rail_go_typeall, iww_go_atygo and demo_gind)

Figure 20: GPICS Specification v2 Freight Transport Scope

According to these figures, it can be argued that the new release of the GPICS takes into consideration around the half of the road and rail transport and more than three-quarters of the inland waterways transport in the EU-28 territory.

According to [8] the scope of the GPICS specification version 2 in terms of number of enterprises in the transport sector is as follows:


eurostat

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Explanatory texts (metadata) | Information | Download | Preview | Bookmark | Demo

Annual detailed enterprise statistics for services (NACE Rev. 2 H-N and S95) [sbs_na_1

Last update: 02-10-2019

Table Customization show

TIME | GEO | Classification of economic activities - NACE Rev.2: Transportation and storage

Economical indicator for structural business statistics: Enterprises - number

GEO / TIME	2016
European Union - 28 countries	1,246,259
Belgium	18,095
Germany (until 1990 former territory of the FRG)	106,559
Spain	196,166
France	115,627
Italy	123,442
Luxembourg	972
Netherlands	42,081
Portugal	21,799

Figure 21: GPICS Specification v2 Transport Enterprises Scope

According to these figures, it can be argued that the new release of the GPICS takes into consideration more than half (50.3%) of the transportation and storage enterprises in the EU-28 territory. In absolute terms the number of such enterprises included in the ICONET PI case study has been increased from 333.592 to 624.741 between the first version and the current release.

Additional information required for the GPICS specification version 2 related to transport and logistics sector (i.e. costs, emissions, capacities, etc.) is provided by the ICONET consortium members participating in the Living Labs.

In the scope of the GPICS specification version 2, required master data not available in the identified sources of information will be simulated. In the last release of the GPICS specification (final version - Month 27) and on the basis of the experience additional sources of information might be added.

As far as master datasets 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 17: GPICS evolution v1 vs v2 in terms of master datasets

	G IC E I N	G IC E I N
LA I N	123.875.640 (24,18% EU28)	296.333.642 (57,83% EU28)
F EIGH AN AD	407.717 MILLION TONNE-KILOMETRES	944.281 MILLION TONNE-KILOMETRES
F EIGH AN AIL	47.667 MILLION TONNE-KILOMETRES	193.385 MILLION TONNE-KILOMETRES
F EIGH AN INLAND A E A	8.307 MILLION TONNE-KILOMETRES	122.640 MILLION TONNE-KILOMETRES
AN EN E I E	333.592	624.741

11.1.3 Modelling Components

GPICS specification, from its initial version, was oriented to represent a complete Physical Internet system. To that end the definition of a comprehensive PI network was required. As it was described in Chapter 7 of this document, all the defined modelling components in the corresponding GPICS Framework dimension, are necessary to compose a generic PI network, so that GPICS specification, from its initial version, included and instantiated all the modelling components of the GPICS Framework.

The modelling components included in the GPICS specification version 2 are:

- GPICS Container
- GPICS Node/Hub
- GPICS Transport
- GPICS Corridor
- GPICS Route
- GPICS Network
- GPICS Roles

Despite the included modelling components in the current specification have not changed from the initial GPICS specification release, it does not imply that the complexity of the GPICS specification and Hubs Plan version 2 will be the same than the initial version. As it is mentioned above, the modelling components are the basis to represent a complete Physical Internet system, and to do so, all of them are needed in all GPICS versions, that is: v1-M8, v2-M16 and final-M27.

Despite the included modelling components in the current specification have not changed from the initial GPICS specification release, it does not imply that the complexity of the GPICS defintion and Hubs Plan version 2 will be the same than the initial version, in fact, GPICS version 2 is more ambitious. As it is mentioned above, the modelling components are the basis to represent a complete Physical Internet system, and to do so, all of them, are needed in all GPICS versions, that is: v1-M8, v2-M16 and final-M27.

The complexity of GPICS specification does not come from the modelling components, which are a comodity, without which them would not exist a comprehensive PI network definition, but from other of the GPICS Framework dimensions, mainly the geographic area, the base configuration rules and the scenarios configuration capabilities.

11.1.4 Base Configuration Rules

GPICS base configuration rules establish the GPICS macro-configuration, or in other words the strategic definition of a concrete generic PI case study. The base configuration rules is one of the dimensions of the GPICS Framework which allows to modulate the complexity of a specific GPICS definition.

In the scope of the base configuration rules, the complexity of a concrete GPICS specification basically depends on the allowed options for each of them. The permitted options set a level of complexity for the GPICS specification while the different combinations of all of them establish different degrees of complexity within that level.

In the current GPICS specification there are more options for each configuration rule, or it remains the same if the most complex option was already set in the GPICS initial version, so that the potential combinations have been increased. As a result, GPICS version 2 adds a further level of complexity to the ICONET PI case study.

Below, is a detail of each of the base configuration rules for GPICS specification in its version 2.

-

GPICS Framework is organized around a three-level hierarchical structure of Hubs where lower levels depend on upper levels. In this way L3 level depends directly on L2 and L2 depends on L1. This structure provides flexibility in the GPICS definition due to the levels could be applied to different uses within a case study.

GPICS specification version 1 already included all the three levels so that in its instantiation it had L1, L2 and L3 PI Hubs. Due to this configuration rule was the highest complexity in version 1, GPICS specification version 2 maintains this configuration as it was initially configured. In the frame of the GPICS version it has been included the correspondence of each level with the two Living Labs not included in the first version. The table below describes the specific correspondence of each level for all the Living Labs in the ICONET project.

Table 18: Correspondence of GPICS HUBS hierarchical structure and LL requirements

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

This configuration rule sets out the maximum number of Hubs allowed in each level for the generic case study's PI network definition.

The limitation could be potentially necessary to specify a manageable PI case study. Manageability of the GPICS specification is defined in terms of simulation models complexity and its ability to provide valuable and comprehensible results that help to understand de PI network performance and its root causes. At the same time the limitation in terms of numbers of Hubs must not affect negatively the fulfilment of the Living Lab's requirements.

As it was explained in chapter 7, each Generic Hub has an area of influence that can range from 50 to 300

- L1: up to a maximum of 25 per EU state member included in the version 2 of the case study, this is: France, Spain, Portugal, Belgium, Netherlands, Germany, Italy and Luxembourg. Therefore, the maximum number of L1 Hubs in the case study is 200.
- L2: up to a maximum of 5 per L1 Hub defined in the case study. Therefore the maximum number of L2 Hubs in the case study is 1000.
- L3: no limitation. Number of L3 Hubs had no restrictions in GPICS version 1, so that GPICS specification version 2 maintains this configuration as it was initially configured.

In the next release of the GPICS specification (final version - Month 27) and on the basis of the experience with the simulation models developed on top of GPICS version 2, this base configuration rule will be even less restrictive, increasing the number of Hubs in that version.

GPICS specification version 1 only included generic movers, therefore functionalities related to multi-modal activities were not required in that version. Due to this fact, functionalities such as Bridge that transfers multi-modally PI containers from an incoming PI Mover to a departing PI Mover in the corresponding GPICS Hub was not included in the first release of the GPICS.

Following the incremental approach of the GPICS process definition, the GPICS specification version 2 overcomes that initial restriction of generic mover types included in the first release, allowing specific means of transport between PI Hubs. Therefore, GPICS version 2 represents a full functionality specification, including all the functionalities defined in the GPICS Framework

This rule establishes the way to connect the GPICS Hubs of different levels in the version 2 of the GPICS specification. In order to increase the complexity of the case study, more direct connections between Hubs in different levels have been allowed. In this release of the GPICS specification the rules are instantiated as follows:

- From a L1 to another L1. Direct connection.
- From a L1 to a L2. Direct connection, regardless L2 depends on L1 (belongs to its catchment area) or not.
- From a L1 to a L3. From the L3 to its corresponding L2 (catchment area). From the L2 to the L1 following the rule established for (L1<->L2)
- From a L2 to a L2. Direct connection, regardless both L2 depend on the same L1 (belong to its catchment area) or not.
- From a L2 to a L3. Direct connection if L3 depends directly of L2 (L2x <->L3x). If destination L3 does not depend directly from origin L2 via the corresponding L2 and L2 (L2x <-> L2y<->L3y)
- From L3 to a L3. Direct connection if they have a L2 Hub in common (both L3 depends on the same L2). Otherwise, from the L3 to its corresponding L2 (catchment area) and following the rule established for (L2<->L2).

In the next release of the GPICS specification (final version - Month 27) and on the basis of the experience with the simulation models, more complex and direct connections will be defined.

-

Following the incremental approach of the GPICS process definition among versions, from the initial version (M8) to final version (M27), current GPICS version 2 goes one step further in terms of mover types between PI hubs.

GPICS specification version 2 considers specific movers, that is, it allows different means of transport. This configuration significantly increases the complexity of the case study compared to the initial version.

The specific mover types between Hubs included in the GPICS specification version 2 are:

- Road
- Rail

In the next release of the GPICS specification (final version - Month 27) more mover types will be included if required.

-

GPICS version 2 also takes a leap forward in terms of scope, covering the possibility of special conditioning and treatment for freight transport such as cold or hazard goods.

The special handling increases the complexity of the case study and the simulation models supporting it, due to these models have to define and implement alternative flows and they need smarter algorithms to manage, not only in transport or routing but also in logistics processes in Hubs.

In the frame of the GPICS version 2, only one the Generic option will be included. This means the current case study definition considers and takes this configuration rule into account but without regard the nature of the special condition of each good. In other words, it makes an abstraction, taking into account two options for each order or good: Special/Not Special.

In the next release of the GPICS specification (final version - Month 27) and on the basis of the experience with the simulation models, this base configuration rule may be extended to multiple special requirement options.

-

GPICS specification version 1 already allowed a holistic assessment of the different PI scenarios from the three perspectives included in the GPICS Framework. To that end all the KPIs categories were taken into account (Operational, Cost and Environmental) from the beginning, though not all the KPIs from each of them were calculated and analysed.

The second version of the GPICS continues considering all the KPIs categories defined in the GPICS framework but, unlike the first version, a wider set of KPIs will be considered in each category in this new release.

Due to the three perspectives have been taken into account from the GPICS's initial version, comparisons of different scenarios with different PI network configurations will be possible.

The next release of the GPICS specification (final version - Month 27) will include the whole set of KPIs in each of the three categories.

As far as base configuration rules 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 19: GPICS evolution v1 vs v2 in terms of configuration rules

	GPICS VERSION 1	GPICS VERSION 2
LEVELS OF HUBS	ALL	ALL
MAXIMUM NUMBERS OF HUBS	WITH LIMITATIONS: L1 -> 10/EU STATE MEMBER (MAX 30) L2 -> 3/L1 (MAX 90) L3 -> NO LIMITATIONS	WITH LIMITATIONS: L1 -> 25/EU STATE MEMBER (MAX 200) L2 -> 5/L1 (MAX 1000) L3 -> NO LIMITATIONS
HUBS FUNCTIONALITIES	SOME	ALL
CONNECTION BETWEEN HUBS	FEW DIRECT CONNECTIONS	MANY DIRECT CONNECTIONS
MOVER TYPES BETWEEN HUBS	GENERIC	SPECIFIC: ROAD + TRAIN
SPECIAL REQUIREMENTS	NO	YES
KPI CATEGORIES	ALL	ALL (More KPIs in each category)

11.1.5 Scenarios Configuration

GPICS scenarios' configuration dimension provides the ability to define multiple scenarios on the basis of the mater data, the modelling components and its basic configuration rules, representing the entire supply chain data.

The scenarios' configuration dimension, in terms of included options in a specific GPICS instantiation, is one of the GPICS Framework's dimensions that substantially contributes to the complexity of a case study.

Scenarios' configuration has been defined around five categories: PI deployment, costs, network, business requirements and environment, each of them with its own parameters. While all defined categories in the GPICS

Framework were configured and made available in the GPICS specification version 1, not all parameters within them were included.

The new version of GPICS represents a leap forward in complexity due to the fact that all the parameters within the five categories are included, as planned. As a consequence, more scenarios and more complex can be set up, simulated and assessed.

Table 20: List of Scenarios' configuration parameters included in GPICS specification version 2

PI DEPLO MEN	*CO*	*NE O K CONFIG A ION*	*B INE E I EMEN*	*EN I ONMEN*
▪ 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.	▪ 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	▪ 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. ▪ Corridor: Increase – decrease of congestion	▪ Receiver: Increase – decrease of orders lead time, this is change in the delivery time or in the delivery time window. ▪ Sender: Increase – decrease of service level, this is the amount of orders or services delivered to customers on time and in full.	▪ 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.

As far as scenarios configuration 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 21: GPICS evolution v1 vs v2 in terms of scenario configuration

	GPICS VERSION 1	GPICS VERSION 2
PI DEPLOYMENT	1 PARAMTER (S)	1 PARAMTER (S)
COSTS	1 PARAMTER (S)	3 PARAMTER (S)
NETWORK CONFIGURATION	3 PARAMTER (S)	3 PARAMTER (S)
BUSINESS REQUIREMENTS	1 PARAMTER (S)	2 PARAMTER (S)
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

11.1.6 [illegible]

In o[illegible] GPI[illegible] cor[illegible]

W[illegible] v[illegible]

[illegible] ist of KPIs included in GPICS specification version 2

OPE A IONAL	CO	EN I ONMEN AL

▪ On Time Delivery ▪ Real route distance vs Ideal route distance; ▪ Total distance travelled empty and full	▪ Consumed fuel or energy

As far as KPIs 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 23: GPICS evolution v1 vs v2 in terms of KPIs

	GPICS VERSION 1	GPICS VERSION 2
OPERATIONAL	4 INDICATOR (S)	6 INDICATOR (S)
COST	2 INDICATOR (S)	3 INDICATOR (S)
ENVIRONMENTAL	1 INDICATOR (S)	2 INDICATOR (S)
TOTAL	**7 INDICATOR (S)**	**11 INDICATOR (S)**

11.2 Methodology Hubs Plan

This chapter is directly linked to 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 "D1.4 -PI network optimization strategies and hub location problem modeling v2". In the previous version of this report we presented the foundations of the methodology for the identification of locations for 'Tier-1' PI hubs. Tier 1 hubs essentially provide the backbone for PI, similar to how core routers provide the backbone for the (digital) Internet traffic. In contrast, Tier 2 hubs collect local traffic and forward it to their destinations via Tier-1 hubs, in a multi-hop manner.

The methodology developed in the frame of the task "T1.3 PI Network optimization strategies and hub distribution policies" has evolved from D1.3 to D1.4 reports and deliverable D1.4 provides a new release of the methodology and algorithms for the distribution of the PI hubs/nodes. A detailed description of the methodology and algorithms can be found in the corresponding deliverable.

In the previous version of the report, we restricted the identification of Tier 1 hubs to three EU countries (France, Spain and Portugal) in order to align with the focus of the Project's Living Labs. In this version of the report we widen the scope in terms of countries/regions to address the Geographic area defined in the GPICS version 2, and based on the methodology, both, Tier-1 and Tier-2 hubs locations are determined, for each country in the case study.

11.3 PI Hubs Plan v2

To apply the methodology, we consider the following countries: France, Spain, Portugal, Luxemburg, Belgium, Netherlands, Germany and Italy.

We have selected a number of intermodal stations and seaports, as the ‘seed’ for establishing the initial core PI network. We defined a radius of 200km as the catchment area of each Tier 1 Hub. Of course, the borders of a catchment area are not crisp. On base of that, the methodology proposes that Tier-2 hubs are selected based on their proximity to Tier 1 hubs. However, the boundaries of ‘proximity’ (upper and lower limits) need to be quantified. Pre-hauling (transporting goods to the first hub) operations must be of appropriate length/duration compared to the overall length of the goods travel. Pre and post hauling operations are usually done via road. Although exact definitions vary, a common view of long haul trucking can be defined as farther than 200-300 kilometres from the truck’s home terminal.

The methodology proposes therefore that proximity to a Tier 1 hub is defined as the coverage of a circle with a radius of approximately 100km and centred at the Tier-1 hub. Regarding the selection of suitable locations within the 100km radius the methodology proposes according to the above suggestion to use population sizes as proxies for demand size.

The following figure shows the Level 1 PI hubs spread across the countries that are part of the GPICS greographic area version 2.

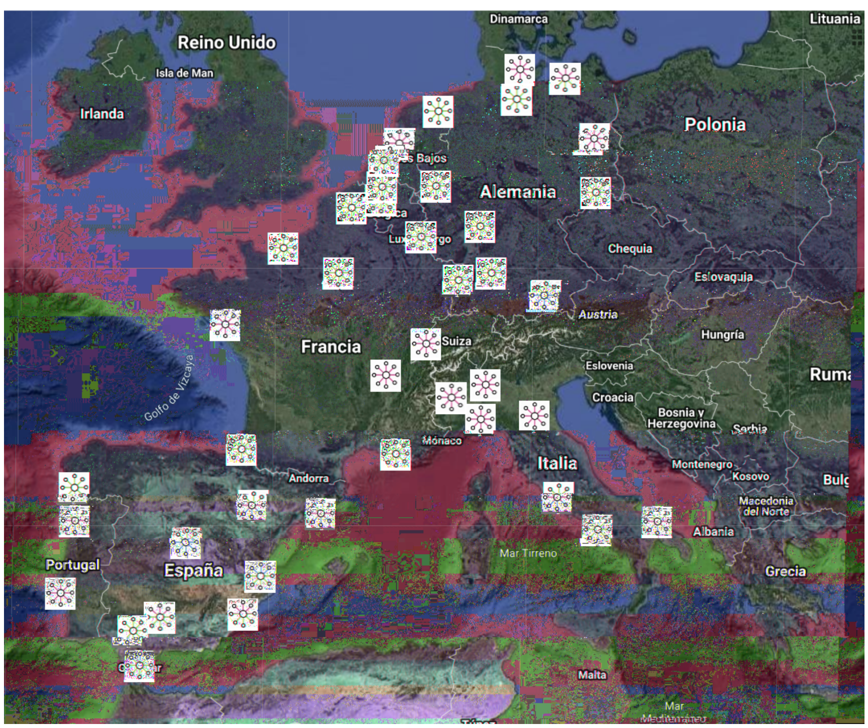

Figure 22: Tier-1 PI Hubs Plan v2

The following figure shows the Level 2 PI hubs spread across the countries that are part of the GPICS greographic area version 2.

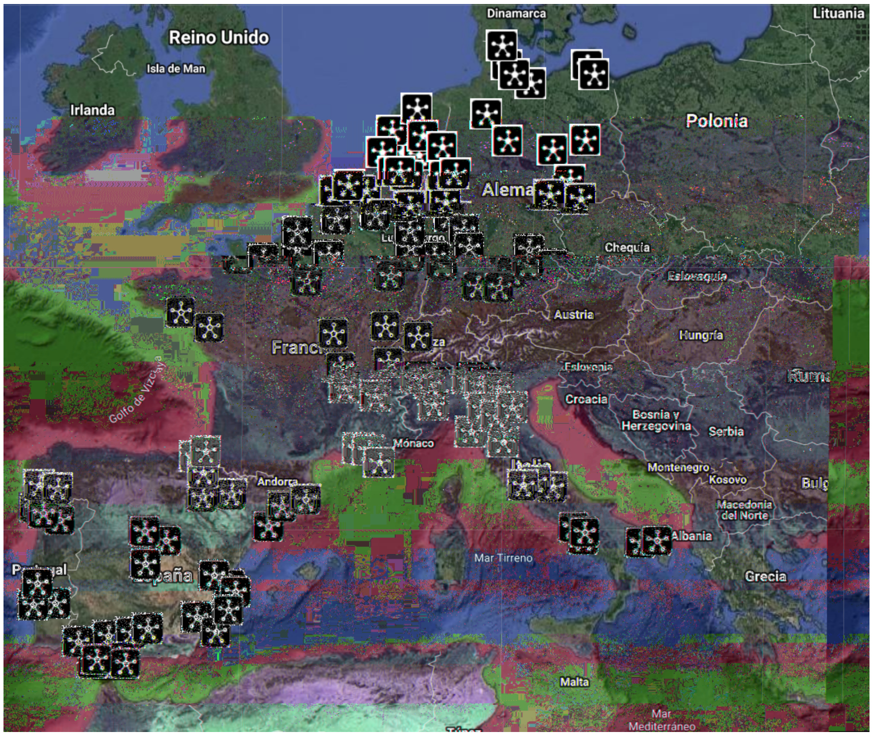

Figure 23: Tier-2 PI Hubs Plan v2

The following figures show in detail the location of all PI Hubs, Tier 1 and Tier 2, in different areas. No connections between hubs are shown, as several possible connection rules could be established depending of the configuration rules. The peering agreements (which will determine how sparse or dense the PI network will be) will evolve over time- however the exact shape of evolution cannot be predicted, rather alternative scenarios can be explored by simulation and other techniques.

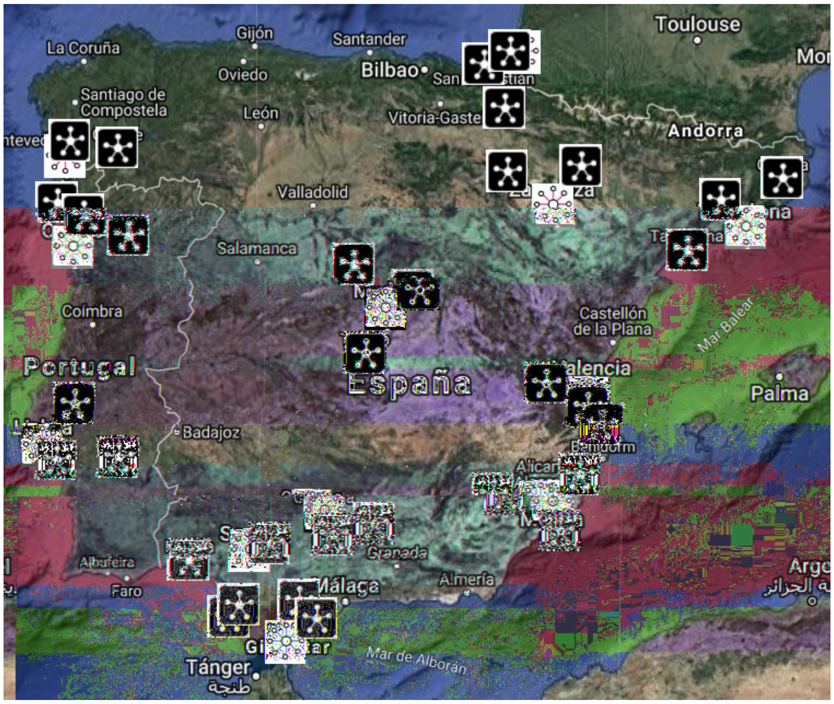

Figure 24: Tier-1 & Tier-2 PI Hubs Plan v2 Spain and Portugal

Figure 25: Tier-1 & Tier-2 PI Hubs Plan v2 France and Luxemburg

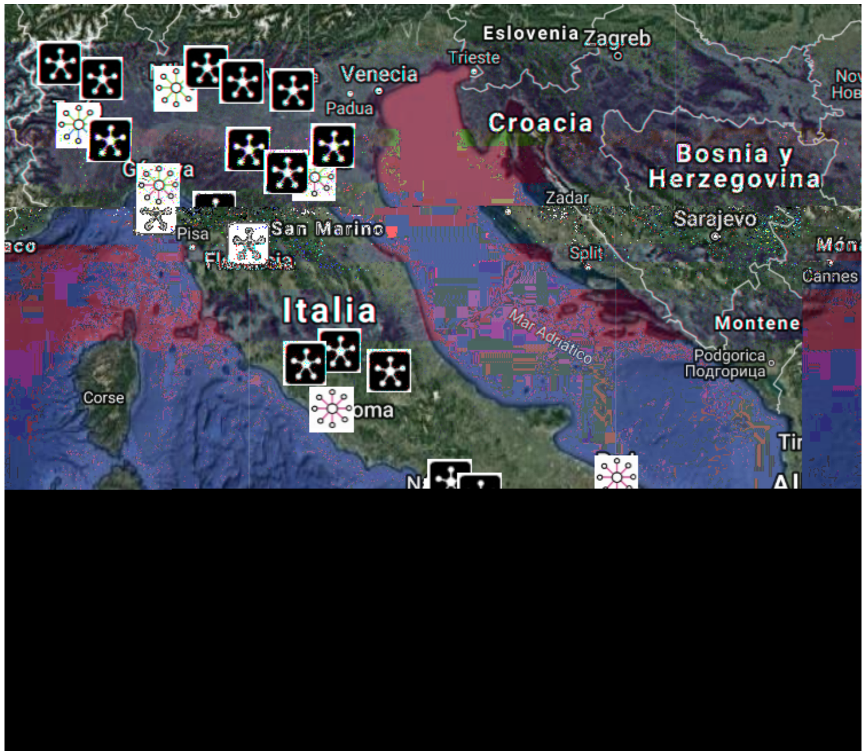

Figure 26: Tier-1 & Tier-2 PI Hubs Plan v2 Italy

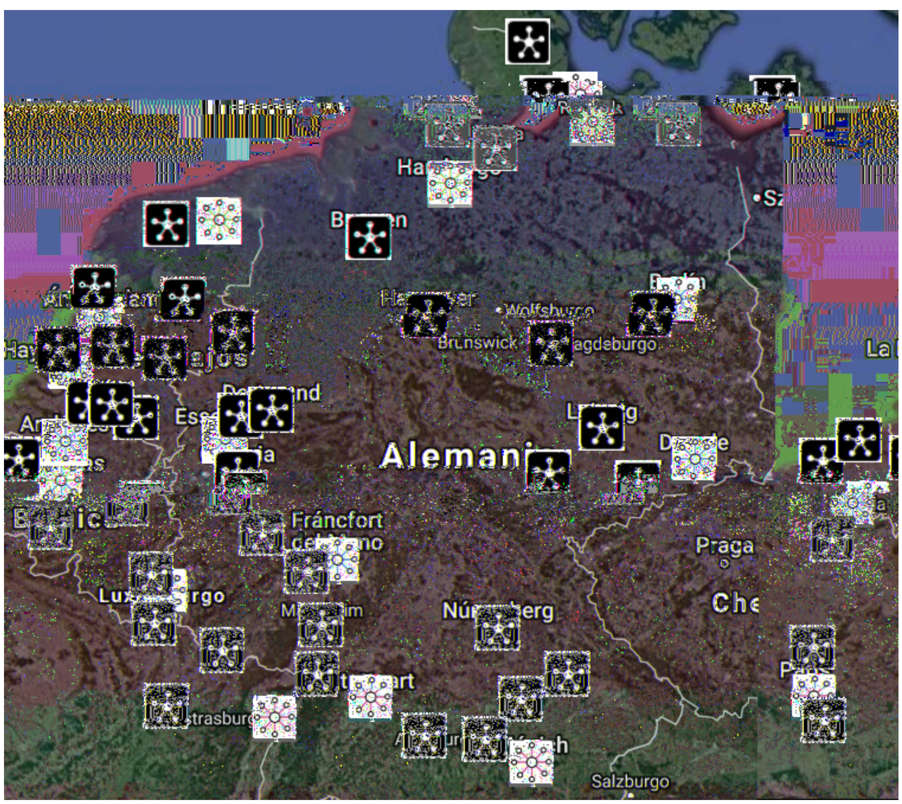

Figure 27: Tier-1 & Tier-2 PI Hubs Plan v2 Germany, Belgium, Netherlands

Table 18 summarizes the list of Level 1 and Level 2 PI hubs, their location, country of establishment, and the dependence in the hierarchy.

Table 24: List of Tier-1 & Tier-2 PI Hubs – PI Hubs Plan version 2

	Spain	Algemesi, , Requena, Candia
	Spain	Tarragona, Manresa, Girona
	Spain	Carmona, Montilla, Martos
	Spain	Guadalajara, Segovia, Toledo
	Spain	Caravaca de la Cruz, Cartagena, Alicante
	Spain	Ronda, Marbela, Cadiz
	Spain	Huelva, Jerez
	Spain	Braga, Pontevedra, Ourense
	Spain	Huesca, Tudela
	France	Melun, Maux, Creil
	France	Caen, Rouen, Dieppe
	France	Arras, Dunkirk
	France	Saint Etienne, Grenoble, Roanne
	France	Miramas, Aix en Provence, Toulon
	France	Donostia/St Sebastian, Pamplona, Biarritz
	France	Vannes, Nantes
	France	Stuttcart, Nancy, Saarbrucken
	Switzerland	Bern, Geneva, Bensacon
	Portugal	Santarem, Sentubal, Evora
	Portugal	Vila Real, Braca, Viana do Castelo
	Luxemburg	Esch-sur-Alzette, Wiltz

	Belgium	Liege, Charleroi
	Belgium	Ghent, Ostende
	Netherlands	Utrecht, Arnhem, Alkmaar
	Netherlands	The Hague, Eindhoven, Breda, Tilburg
	Netherlands	Leewarden, Zwolle, Enschede
	Germany	Postdam, Magdeburg
	Germany	Bremen, Hannover, Lubeck
	Germany	Koblenz, Wiesbaden, Mainz
	Germany	Karlsruhe, Nuremberg, Mannheim
	Germany	Ulm, Ingolstat, Regensburg, Augsburg
	Germany	Leipzig, Chemnitz, Jena
	Germany	Stralsund, Greifswald
	Germany	Rendsburg, Neumunster, Flensburg
	Germany	Cologne, Bonn, Essen, Dortmund
	Italy	Bergamo, Brescia, Verona
	Italy	Asti, Biella, Aosta
	Italy	La Spezia, Parma
	Italy	Florencia, Modena, Ferrara
	Italy	L'Aquila, Terni, Viterbo
	Italy	Salerno, Caserta, Avellino
	Italy	Taranto, Brindisi

12 Conclusions

The work carried out to define the second 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.

The basis for the GPICS specification version 2 and its associated Hubs Plan has been on one hand the instantiation of the GPICS Framework, considering previous PI research knowledge and state of the art, and on the other hand amalgamation of the latest results of task "T1.3 PI Network optimization strategies and hub distribution policies". Furthermore, this latest edition took a close look on the Logistics networks characteristics as analyzed in section 3.1. The current release has considered different collaborative strategies between existing logistics networks in relation to the PI. New detailed modelling option for GPICS components were also included. For the GPICS evolution new node sophistication levels, with different detail levels for generic components were defined. Finally, new references were included to describe the interconnection between the physical and the digital network.

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. Every GPICS specification ensures a comprehensive PI case study from the initial to the final version.

GPICS specification version 2 represents an evolution and a more complex case study with regard to the initial version but also addresses the needs and expectations of the Supply chain industry operators. Main difference between the initial and the current versions is their scope in terms of more extensive in terms of geographic area, detail of the data, and complexity of base configuration rules and scenarios capabilities. KPIs will also be more detailed.

Generic PI Case Study definition and its associated PI Hubs Plan version 2 propose locations and scope of PI Hubs that are assumed to form the core of the future PI network. As PI is going to be evolutionary, in our approach, these hubs are located at places where there is already significant transport/logistics activity and intermodal terminals. It must be clarified that the above defined PI locations are not the only suitable candidate locations for hosting PI nodes, but one of several possible alternatives, and were chosen based on their existing logistics capabilities and proximity to transport corridors. The assumption is that some of these terminals will develop in the future, PI capabilities and become PI Hubs. Subsequently, smaller logistics nodes (Level 2/ Tier 2) connect to their nearest PI Hubs to join the PI network. Our approach was focused on France, Portugal, Spain, Luxemburg, Belgium, Netherlands, Germany and Italy, to keep aligned with the needs, the evolution and the work done under the umbrella of the project's Living Labs. However, the methodology for determining PI hub locations can also be applied to wider geographical regions. In addition, by considering statistical transport data we extrapolated the size of transport flows that future PI hubs are likely to handle.

The increased complexity of this second release of the GPICS specifications, documented in chapter 11, also drove a more complex and ambitious PI Hubs Plan. The number of Tier-1 Hubs has been more than doubled and Tier-2 Hubs have reached 116.

GPICS specification final version and its associated PI Hubs Plan is going to be based on an iteration of the current version extending the scope of the GPICS Framework's dimensions through: a wider geographic area covering most of the EU state members; more detailed master data associated to the extended geographic area; more complex PI Network configuration on the basis of advanced parameterization of the configuration rules; additional simulations scenarios, using simulation scenarios capabilities not included in the current GPICS specifications and complete coverage of all KPIs.

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