Progress towards Federated Logistics through the Integration of TEN-T into A Global Trade Network

D1.10 EGTN Reference Specification v1

Document Summary Information

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[1] According to PLANET's Quality Assurance Process

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
ALICE	Alliance for Logistics Innovation through Collaboration in Europe
DTLF	Digital Transport and Logistics Forum
DSS	Decision Support System
EGTN	Green EU-Global Trade & Logistics Networks
EU	European Union
GA	Grand Agreement
ICT	Information and Communications Technology
IDSA	International Data Spaces Association
ISP	Internet service provider
LL	Living Labs
MAMCA	Multi-Actor, Multi-Criteria Analysis
NUTS	Nomenclature of territorial units for statistics
OR	Operational Research
PI	Physical Internet
TCP	Transmission Control Protocol
TEN-T	Trans-European Transport Network
TEU	Twenty-foot Equivalent Unit
WP	Work Package

1 Executive Summary

The present deliverable builds on the results of the work undertaken in WP1 tasks in order to provide the initial specifications for defining the Green EU-Global Transport & Logistics Network (EGTN). The EGTN aims to become the realization of the EU Commission vision for Smart, Green and Integrated Transport and Logistics by efficiently interconnecting infrastructure (TEN-T, Rail-Freight Corridors) with geopolitical developments, as well as optimising the use of current & emerging transport modes and technological solutions, while ensuring equitable inclusivity of all T&L participants, increasing the prosperity of nations, preserving the environment, and enhancing Citizens quality of life.

EGTN consists of three interactive layers, the physical, the technological and the governance layer, the specifications of which are defined in the present and the last version (D1.11) of this document. The physical layer includes the physical infrastructure of the network in terms of revised/new TEN-T corridors and nodes while the technological layer includes the required digital infrastructure in order for the network to leverage innovative technologies and concepts and operate under a Physical Internet paradigm. The governance layer includes the proper governance form that will ensure that the EGTN members engage in collective and mutually supportive action, that conflict is addressed, and that network resources are used efficiently and effectively.

With respect to the physical layer of the EGTN, the initial results from the establishment of the base year scenario (2019) for the impact of the three new trade routes (Eurasian land bridge, Arctic route and International North-South corridor) on the TEN-T network showed that the intercontinental rail freight connections between China, Russia and Europe (belonging to the Belt and Road Initiative) and more specifically the corridor that runs through Kazakhstan, Russia, Belarus and Poland appears to be the most mature route and the only one that will be of significant importance in the near future. The main entry point to the EU through this route is located in Małaszewicze while the most important start and end point for trains to and from China is the inland port of Duisburg. As for the main identified bottlenecks that hinder and delay flows on this route, the Małaszewicze /Brest border crossing is identified as the most important one mainly due to time-consuming custom procedures, followed by the congestion phenomena of the European rail network. The International North-South trade corridor (INSTC) has the potential for serving significant cargo loads but its implementation time horizon is uncertain and also it will be more interesting as a European trade route if European trade can be combined on INSTC trains with Russian cargo. Finally, the freight flows through the Arctic route are not expected to increase significantly, thus keeping the impact on the European TEN-T network negligible.

Regarding the governance model of the EGTN, it appears that a bottom-up approach is the only viable strategy for a more progressive growth of the PI network. According to this approach, different stakeholders will agree among themselves to develop parts of the PI while a central body will be needed to establish common standards for the PI in order to bring these parts together. Moreover, the governance framework will need to support collaboration and asset sharing in horizontally integrated supply networks and also the removal of boundaries between vertically integrated supply chains to allow asset sharing and opportunistic routing and re-planning of shipments across PI nodes belonging to different networks. The legislative and policy initiatives which are prerequisites for the development of the EGTN, including mainly initiatives towards the achievement of interoperability, the greening of investments and the digitalisation of transportation, are also presented.

Finally, the technological layer of the EGTN will be the backbone of the network, supporting and connecting all of its aspects, namely the planning of its development, its governance and its operationalisation, through the implementation of innovative PI enabling technologies and logistics concepts. This will be achieved through the development of a cloud-based Open digital infrastructure that will include proper tools and models but also through a strategic modelling capability which however will be developed outside the Open digital infrastructure.

2 Introduction

The purpose of this deliverable is to provide a detailed description of the main components of the vision of the "Green EU-Global Trade & Logistics Networks" (EGTN). This description is based on the results of the work performed so far in the context of the WP1 tasks and includes:

a. The definition of the vision for a European Global network for 2030 time horizon and the characteristics of this network,

b. The listing of prioritised specifications for the operationalisation of the EGTN, i.e. for supporting the planning and the stakeholders in achieving the vision and safeguarding EGTN characteristics accomplishment,

c. The sum-up of capabilities of EGTN tools and technologies.

The next version of this deliverable will include:

a. Final enabling modelling tools functionality

b. Prerequisites for EGTN achievement

c. EGTN vision validation for future horizon

d. Roadmap of policies and technologies implementation for securing EGTN operationalisation.

In this (first) version of the document, the approach is made to define the EGTN specifications, considering the WP1 the analysis and bringing together the opinions and considerations of the consortium regarding the definition and components of the EGTN. These specifications will be further defined and finalized in the next (final) version of the document (D1.11), based on the final outcomes of the relevant project tasks.

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2.1 Mapping PLANET Outputs

Purpose of this section is to map PLANET's Grant Agreement commitments, both within the formal Deliverable and Task description, against the project's respective outputs and work performed.

Table 1: Adherence to PLANET's GA Deliverable & Tasks Descriptions

PLANET GA Component Title	PLANET GA Component Outline	Respective Document Chapter(s)	Justification
DELIVERABLE			
D1.10 EGTN Reference Specification v1	The EGTN vision for 2030; the EGTN physical layer, governance, and technological layer specifications. New models that will support the operationalisation of EGTN, including the corridor connectivity index and the 'transport gravity models'.	**Chapter 3:** Towards the EGTN vision for 2030 **Chapter 4:** EGTN Physical layer specifications **Chapter 5:** EGTN Technological layer specifications	In the main chapters of the current (first) version of the document, all three types of EGTN specifications (physical, technological and governance) are provided in summary with a brief analysis, building on the work undertaken in WP1 tasks. There are no details included on the new models that will support operationalization of EGTN.

		Chapter 6: EGTN Governance layer specifications **Chapter 7:** Conclusions	
TASKS			
ST1.5.1 Defining the EGTN vision for 2030	The present sub-task will link the two modelling dimensions (TEN-T & PI) developed in previous tasks (T1.2 & T1.4) in order to enrich the TEN-T modelling with the technological and organisational innovation dimension embedded in the PI modelling and the PI modelling with the geographical & infrastructural dimension provided by the TENT modelling. The results of technological innovation modelling (T.1.4) will be generalised at an EU level and will be fed into a re-iteration of TEN-T modelling undertaken in T.1.2.	**Subchapter 3.1:** Definition of the EGTN concept **Subchapter 3.2:** EGTN strategic vision/profile **Subchapter 5.3:** Generalization of technological innovation modelling	In subchapters 3.1, 3.2 & 3.3 an overview is provided of the PLANET's approach towards the definition of the EGTN, its layers, components and main characteristics. In subchapter 5.3 an overview is provided of the methodology which is being developed in order to generalise the results from micro simulation and the LLs regarding the impact of innovative technologies to logistics operations and to feed the macro (strategic) modelling.
ST1.5.2 EGTN physical layer specifications	The present sub-task will record the physical layer specifications that will be defined through the network simulation (T1.2 and ST1.5.1), in the form of new (or of revised significance) corridors & entry points and new (or of revised criticality) capacity bottlenecks on corridors & entry points, as a result of emerging trade	**Subchapter 4.1:** Introduction **Subchapter 4.2:** Integration of new trade routes to the TEN-T **Subchapter 4.3:** Strategic scenarios to be tested for 2030 and 2050	In Subchapter 4.1 an overview is provided of the parameters expected to have an impact on the physical layer structure of the EGTN and the strategic simulation process. In Subchapter 4.2 an initial assessment of the impact of the new trade routes on the TEN-T, based on the results from the base year (2019) simulation. In subchapter 4.3 an overview of the strategic scenarios methodology

	routes in order to ensure that the EGTN fulfils its 'geo-economics' attribute. Furthermore, a cross-comparison of the EGTN's physical structure with the PLANET LL corridors will be made.		for the 2030 & 2050 simulations is presented
ST1.5.3 EGTN technological layer specifications	The present sub-task will define the technological infrastructure that is required to leverage emerging technologies in order for the EGTN to operate under a PI paradigm and thus fulfil its 'innovation embedding' attribute. These specifications include: 1) a network model specifying the EGTN 'design propositions', 2) Transport gravity models which will be used to assess the change in the volume of freight and 3) Routing decision support models based on a new connectivity index. Furthermore, it will define the functions provided by this infrastructure in order to leverage emerging technologies, which will become the requirements for the PLANET Cloud-based Open EGTN Infrastructure.	**Subchapter 5.2:** Planning and decision support for infrastructure development **Subchapter 5.4:** Defining the PI subnetwork of EGTN **Subchapter 5.5:** Operationalisation of the EGTN	In Subchapter 5.2 the requirements from the technological layer are presented in order to support the planning and the decision making (governance level) of the EGTN physical infrastructure. In subchapter 5.4 a brief description of the methodology for defining the PI network model of the EGTN is provided. In subchapter 5.5 the requirements from the technological layer are presented in order to support the operationalisation of EGTN including a brief description of the routing decision support models.
ST1.5.4 EGTN governance layer specifications	The present sub-task will define the specifications towards the development of a goal-directed form of	**Subchapter 6.2:** TEN-T governance structure	In Subchapter 6.2 the current governance structure of the TEN-T is presented. In Subchapter 6.3 the possible alternative governance structures

	network governance which will ensure that the EGTN members engage in collective and mutually supportive action, that conflict is addressed, and that network resources are used efficiently and effectively, while taking into account the existing TEN-T governance structure. This will be achieved by addressing: i) the breadth of decisions to be made by the EGTN members; (ii) the competencies required to achieve the EGTN goals; (iii) the EGTN governing entity & responsibilities/tasks allocation to network members; and (iv) the EGTN evolution & expansion.	**Subchapter 6.3:** Shaping EGTN governance	for the EGTN are presented together with an initial assessment of the legislative and policy initiatives required for the EGTN development.

2.2 Deliverable Overview and Report Structure

The present document is structured in 7 chapters, providing an initial view of the reference specifications of the EGTN, building on the results of the work undertaken in WP1 tasks and was consolidated under the final WP1 task, task 1.5.

Starting from chapter 3, an initial definition of the EGTN is provided and the strategic vision for the EGTN is be described as a network that will bundle together geo-economics awareness and innovation embeddedness in order to better serve freight flows and facilitate the realisation of EU strategies regarding environmental protection, the economic development of EU, equity, human development and others. In the final version of the document, the final definition of the EGTN will be provided, together with a specific set of indicators that will be used for monitoring and assessing its performance at the strategic level. Furthermore, based on these final results of the work undertaken in the other WP1 tasks, an answer to the question about whether investments in technology can substitute infrastructure investments will be given.

In chapter 4, the results from the initial simulation of EU transportation network is presented for the base year (2019) with the integration of the main global corridors. Based on the impact on current freight flows and bottlenecks from the integration of the new trade routes, some initial considerations and conclusions regarding the possible/expected changes and problems regarding the future network setup are presented. In the final version of the document, the results from the modelling and simulations for years 2030 and 2050 will be presented, focusing on the expected new or the changes of the significance of corridors and nodes/entry points of the TEN-T as well as the expected new or of revised criticality capacity bottlenecks of corridors and entry points which will emerge from the new trade routes and the leveraging of innovative technologies and logistics concepts. This will provide an overview of the expected physical structure of the future European transportation network and will facilitate the prioritisation of nodes and corridors for developing a PI network.

In chapter 5, an initial approach is provided on the technological requirements and specifications of the EGTN in order to be able to take advantage of innovative logistics concepts and technological innovations and operate under the PI paradigm. In this context, the method for specifying the EGTN network design (in terms of PI corridors and nodes) together with the transport gravity models and routing decision support models which will be developed in the project, are briefly described. Moreover, a first approach on the requirements from the PLANET Cloud-based Open EGTN Infrastructure is provided in order for EGTN to be able to leverage emerging technologies and to support all aspects of the EGTN, namely the planning of infrastructure development, the management of operations and its governance. In the final version of the document, the specific details will be provided for the network model, the transport gravity model and the routing decision support model which will be part of the EGTN solution, supporting its operationalisation. Furthermore, the specific tools and services provided by the PLANET Cloud-based Open EGTN Infrastructure will be described based on the final results of the work of WP2.

In chapter 6 the issue of the governance specifications of the EGTN is tackled, providing information about the current TEN-T governance scheme and presenting the possible alternatives for network governance under the principals of the PI paradigm based on the ALICE roadmap to the PI. Moreover, the governance loop (planning – regulating – facilitating – monitoring – re-planning) is discussed including an initial assessment of the prerequisites at legislation/policy level for EGTN realisation. In the second version of the document, a specific model of governance will be proposed including details regarding the required competencies to achieve EGTN goals, the form of the governing entity, the responsibilities/ allocation of tasks to the EGTN members and the breadth of decisions for each member and finally the provisions for the EGTN evolution and expansion. Furthermore, specific proposals regarding the EU legislation and policy towards the realisation of EGTN will be presented.

In the final chapter of the document, the initial conclusions that emerge from the consolidation of the result from the work that has been performed so far in the context of WP1 are presented.

With respect to the linkage of this deliverable to other project outputs and deliverables, the present document is based on the outcomes of all other WP1 deliverables, consolidating their results in order to provide an initial definition of the EGTN specifications. In this context, it is closely linked to all other WP1 deliverables which are the source of the knowledge included to the current document. Moreover, the outputs of this document regarding the technological layer specification will provide guidance to WP2 tasks for defining the architecture of an open ICT infrastructure, feeding the D2.1/D.2.2 - Open EGTN Platform Architecture (v1/final version) and for the development of Transport Gravity Models and Transport Corridor and Network Data Models feeding D2.7/D2.8 - EGTN Transport Data and Knowledge Models (v1/final version). Finally, the governance layer specifications will be fed into the EGTN's business model & commercialisation strategy (task 5.3) and to the corresponding deliverable D5.6 - Business & Commercialisation plan.

3 Towards the EGTN vision for 2030

3.1 Definition of the EGTN concept

The Integrated Green EU-Global T&L Network (EGTN) can be understood as an advanced European strategy that implies the development of a Smart, Green and Integrated Transport and Logistics Network of the future to efficiently interconnecting infrastructure (TEN-T, Rail-Freight Corridors) with geopolitical developments, as well as to optimize the use of current & emerging transport modes and technological solutions, while ensuring equitable inclusivity of all T&L participants, increasing the prosperity of nations, preserving the environment, and enhancing Citizens quality of life. The strategy definition, the support to strategy implementation, the strategy possible outcomes (digital & physical infrastructures, new operational methods etc.) and the monitoring and maximization of strategy impact are functional components of the EGTN concept.

Elaborating further on the EGTN concept, it can be defined as a green, globally connected and smart network that will be aware of the global and EU geo-economic developments and take advantage of technological advancements, timely responding to changes by adapting its development and operation. It will be an optimisation ready network in terms of logistics operations, able to better respond to the industry needs through the implementation of innovative technologies under the Physical internet concept. At the same time, it will be an open network in terms of information sharing by its stakeholders, supporting their decision making at every level (operational, strategic etc) and including them to its governance scheme through a multi-level governance approach. Finally, its structure will ensure that the disadvantaged regions of EU will have the required level of connectivity.

In this context, PLANET defines the **Attributes of the future EGTN** as following:

- **Geo-economics aware:** A European T&L network that is aware of the geo-economics aspects driving the development of new trade routes and flows to/from Europe and their impact on the TEN-T;
- **Innovation:** A European T&L network that takes advantage of the potential of innovative logistics concepts (e.g. PI) and enabling technological innovations (Industry 4.0, blockchain, IoT, 3D printing, etc.) in its operation
- **Impact:** A T&L network that is more economically, environmentally and socially sustainable than the existing TEN-T
- **Integrated:** An EU T&L network integrated with the global network both in terms of hard & soft infrastructure
- **Inclusive:** Accessible to disadvantaged regions, supporting the development of workforce skills & knowledge.

This definition and attributes are aligned to the PLANET's involved stakeholders view, who by priority defined EGTN as:

- The TEN-T of the future in terms of T&L infrastructure (a revised TEN-T rail/road/maritime infrastructure, ports & terminals), connected & operationally integrated to the global corridors.
- An ecosystem of stakeholders from the logistics industry collaborating for sharing transport & logistics infrastructure
- A cloud platform offering connectivity and tools for enhancing logistics operations
- A Platform collecting data and supporting the planning for the future of TEN-T development
- The PI infrastructure and the associated innovative, disrupting technologies been implemented along selected TEN-T corridors and Gate terminals

To satisfy the above attributes PLANET goes beyond strategic transport studies and also beyond transport ICT research, by rigorously modelling, analysing and assessing T&L interactions and dynamics. The aim is to generate and exercise the most important future scenarios from a T&L perspective. The EGTN

technology workstream is not aimed at producing a 'platform' but instead focuses in a blueprint and best practices to help T&L actors to define and implement a clear digital strategy.
The technical EGTN dimension comprises of the merging of the project's two main research and development streams: 1) modelling and simulation leading to increased understanding and design of EGTN, and 2) provision of an ICT infrastructure that can be used for implementing EGTN solutions.

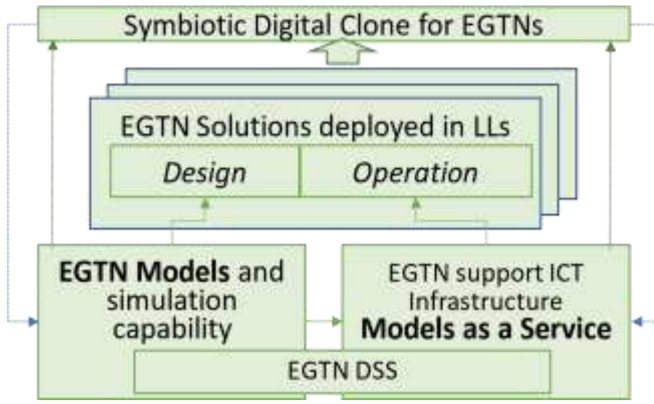

Figure 1: The technical concept of the EGTN

The EGTN network modelling capability includes models for designing of EGTN solutions and inter-organisational process models associated with synchromodality and PI, the latter also used as 'models as a service' in the ICT Infrastructure. Moreover, DSS tools are developed as part of the simulation capability but are also used as a component of the ICT infrastructure were interaction with other components is used for automated decisions. The EGTN models will be delivered as a Symbiotic Digital Clone and the developed solutions will be deployed in the LLs' EGTNs were predicted and actual performance is monitored, and feedback loops are used to constantly refine and update the models (figure 1). The digital clone will provide a collaborative planning tool for all relevant stakeholders that will facilitate: (a) Governments to create policy in advance and (b) companies to create business strategies and technology.
In order to fulfil its purpose, the EGTN concept is structured in the form of three interactive layers: the infrastructural, the technological and the governance layer. For each one of these layers their specifications need to be defined for EGTN to be realized.
The physical layer is the base of the EGTN and will include a dynamic system of terminals, rail, road, waterways and maritime networks, equipment, rolling stock, vehicles, vessels which will physically serve future freight flows and will constitute the network of corridors and nodes of the EGTN. These corridors and nodes are based on the current TEN-T network but revised to include new/of revised significance corridors and nodes, as these are expected to emerge from the integration of the TEN-T corridors to the global network and the flows coming from three emerging trade routes. Moreover, the EGTN development will consider the changes in network structure and flows because of the integration of innovative PI enabling technologies and logistics concepts in its corridors and nodes.
The governance layer deals with the establishment of a governance structure capable to respond to the geo-economic awareness as well as to the need for further integration of the EU member states thereby making sure that peripheral regions are integrated in the economic system of the EU. This also relates to the regulatory harmonization- and interoperability of existing infrastructure and future systems and standards.
Finally, the technological layer is related to the innovation embeddedness of the EGTN and includes the technological infrastructure required to support the operationalization of EGTN under the PI paradigm through providing the proper tools and services that will respond to the EU and industry needs for higher

efficiency of operations. These services will be part of a cloud-based Open EGTN infrastructure which will be developed.
Furthermore, the technological layer will include solutions to support the planning process of the EGTN and also its governance. Regarding the former, it will facilitate infrastructure development planning by providing the strategic modelling and simulation capability for calculating the future freight flows which however will not be included as a service in the Open EGTN infrastructure. As for the EGTN governance, it will provide the tools to foster communication among stakeholders and to support the decision-making processes. Moreover, it will provide the tools for monitoring and calculating all the KPIs which will be used for assessing the EGTN development in operational but also on strategic level.

3.2 EGTN strategic vision/profile

One major objective that PLANET approaches is to assess the impact of emerging trade corridors on the TEN-T network and ensure effective connectivity and sustainability of the European Global Network.
The international competitive position of ports and industries along TEN-T corridors is influenced by development in global value chains. The formulation of the EGTN vision builds on the awareness of geo-economic dynamics expressed in strategies of state-owned and multinational enterprises. Furthermore, inland terminal operators are adopting pro-active strategies in developing new routes, supported with innovative technologies (e.g. equipment, software, network infrastructure).
The EGTN is not a goal in itself, but is a holistic perspective on the international transport system which is embedded in a geo-economic context that makes use of physical and digital infrastructure, aims at enabling operational excellence for customers and external stakeholders, made possible by disruptive transport and logistics concepts and technologies.
What makes the EGTN so different from the TEN-T network? The TEN-T network was intended to address the implementation and development of a pan-European network of railways, roads, inland waterways, maritime shipping routes, ports, airports and railroad terminals. TEN-T policy evolved into supporting the application of new technologies and digital solutions to all modes of transport with the aim to reduce environmental impact and enhance energy efficiency and safety.
The EGTN vision goes a step further in its ambition to be **more economically, environmentally and socially sustainable**. Whereas the TEN-T network had a focus on the main arteries of the pan-European transport network, the **EGTN takes a broader perspective and wants the network to be inclusive by design**. Demographic developments have a significant impact on economic development of European societies, especially in rural and remote regions. There is a growing polarization between the regions in the core and those in the periphery both between member states as well as within EU member states. Overall, especially young people tend to move to where there are jobs and good career opportunities, although the quality of life also plays a role in urban settlement. A recent report on demographic trends in EU regions (European Commission, 2019) it was concluded that depopulation may lead to a vicious circle of decline with rural inhabitants being excluded from education, work, social well-being. Then, there is the 'middle-income trap' phenomenon that has been described in the State of European Cities report. This report concludes that although cities and urban areas are generally considered to be centres of economic growth, this is not necessarily true for secondary cities who cannot benefit from agglomeration effects of capital cities, are internationally less well-connected and may not be as attractive to live in. The urbanization trend across Europe and within European regions are a growing concern with complex social challenges relating to social exclusion, poverty and high unemployment on the countryside. At the same time, urban areas especially those in coastal regions are suffering from high exposure to air and (waste) water pollution, nuisance to noise and congestion (among others), altogether resulting in health issues for millions of people.

The European social cohesion policy will need to go hand in hand with promoting sustainable rural development. In the European Parliament Resolution (2018/2279(INI) it emphasized a territorial dimension and the necessity to support rural areas in their "diversity and encourage investments for better transport connectivity, accessibility and very high-speed broadband".

In this context the EGTN will be a network with an increased focus on **regional logistics** through the development of infrastructure and services that will enhance operations at regional level as an approach that will increase inclusiveness of the disadvantaged regions and support their development.

Taking into account the uncertainties related to the scenarios of EGTN (D1.1: EGTN Foundational Position Papers and Simulation Scenarios), regional actor governance and the ability of supporting and planning of new and enhanced operation for better use of infrastructure capabilities and technologies to better serve the demand generated or attracted in a region would be a major specification/characteristic of EGTN.

The PLANET Living Labs are examples of the **EGTN regional ecosystems specification**. In the LLs, local and global actors are collaborating for implementing technological solutions which meet ecosystem needs for optimised logistics operations. These ecosystems will be enriched and PLANET tools will contribute to regional PI hubs infrastructure planning and further logistics operation enhancement in the view of the 2030 time horizon.

Furthermore, the EGTN aspires to be a network with i**ncreased resilience** compared to the TEN-T**.** It will be a network set up to ensure seamless logistics operations and the smoothness of freight flows under situations that would cause significant problems today. More specifically, the EGTN will be able to:

1. deal with infrastructure capacity shortages at certain regions/periods and to avoid or mitigate bottlenecks within the EU network, due to climate change or other impacts,
2. deal with uncertainties that can cause serious disturbances to freight flows. These uncertainties include situations with a low level of predictability and also developments that can be predicted to an extend through the use of scenarios simulation. The first category includes situations such as natural disasters, accidents (e.g. the Suez Canal incident on March 2021 which resulted in the blocking of the passage for 6 days) or political issues in non-EU countries located on global corridors. The second category includes developments such as the impact of climate change on the transportation networks and possible changes in the global production model (shift from globalisation to the regionalisation of production),
3. limit the dominance of a single country, a region or even a company over freight flows by providing viable multiple alternative routes to freight flows.

With respect to the logistics operations, the EGTN will be a network with an increased **development of collaborative logistics** as a backbone of the PI concept implementation. The PI concept not only makes use of (smaller) standardized load units (pi-containers), but also builds on the availability of open and integrated networks that connect freight transport origins and destinations. In this context, the PI is based on the physical and digital collaboration between different actors in the supply chain along the corridors, through sharing information and resources such as transport capacities or storage areas. EGTN will be an **optimisation ready network** that will have the public and private infrastructure (hard and soft) available together with the willingness of stakeholders to share infrastructure and data (shared capacity models and collaborative logistics) in order to gain benefits in terms of process optimisation and the establishment of intelligent and efficient hubs.

However, EGTN has a realistic approach toward the PI concept implementation, acknowledging that it is not feasible to implement the PI concept to the entire network by 2030. For this reason, EGTN will be a network that has **prioritised corridors and nodes for PI development.** Based on current and forecasted flows, it will define a subnetwork of corridors and nodes that will benefit the most from the PI in order to establish policies and to provide incentives for the development of PI infrastructure and services.

Finally, the successful implementation of the PI concept requires also close cooperation/coordination between the public and private sector actors on infrastructure investments and the network development. For this reason, the EGTN will have a **multi-level governance system** that will include all relevant stakeholders to the decision making, bridging business/industry needs to the EU policy/investments and reaching consensus among stakeholders for the development of EGTN. This governance structure aims also facilitate the EU strategy on economic development through the **EGTN orientation towards the achievement of EU import/export trade balance with China.** The current network configuration is mainly focused on efficiently handling import flows from China, especially with regard to the port system. The EGTN governance structure will take into account the industry requirement for facilitating also export flows and thus support EU strategy for trade balance with China.
The first release of the EGTN profile including the ways of achievement are summarised in the following table.

Table 2: EGTN 2030/2050 Strategic profile

▪ **Responsive to changes** ***[resp. attribute: Geo-economic awareness]***	
	➢ Take into account in its physical infrastructure development (planning process and impact assessment) the three new trade routes, the innovative technology & concepts implementation to logistics operations and identified future uncertainties (through scenarios creation).
	How? By modelling all these and defining the physical network based on the outcome of the model's simulations.
	➔ Related to the **Physical layer** (Physical network of Corridors and Nodes, the TEN-T of the future), to the **technological layer** (Strategic modelling capability – developed outside of the platform, methodology for connecting micro to macro simulation for feeding the latter with innovation modelling results) and the **governance layer** (Decision support system for public & private physical infrastructure investments, stakeholders participation to the physical network development decisions, monitoring the development of the network through observatory/KPIs).
▪ **Optimisation ready** ***[resp. attributes: Innovation, Impact]***	
	➢ Increased efficiency of operations (cost, environment, time etc.) under a PI paradigm by implementing new technologies (blockchain, IoT, AI, drones, Hyperloop, 3D printing etc.) & concepts (collaborative logistics, shared capacity models, synchromodality, multimodality, intelligent hubs etc.).
	How? By creating the technological infrastructure (cloud-based Open EGTN infrastructure) to support the implementation of these technologies (tools & models as a service, operational & investments decision support systems) and also taking a realistic approach and dynamically defining a prioritised network for PI implementation (it is not feasible to happen in the entire EU network at the same time).
	➔ Related to the **Technological layer** (Open EGTN infrastructure, PI prioritised network definition, monitoring operations through KPIs) & to the **Governance layer** (Governance of the ecosystems at regional/cluster level and stakeholder participation to decision making for the development of collaborative logistics and capacity sharing).

▪ **Resilient** ***[resp. attributes: Impact, Inclusive]***	
	➢ EGTN will be able to: 1) deal with regional/periodical infrastructure capacity shortages, 2) deal with uncertainties with low predictability (accidents, natural disasters, political instability) and partially predictable through scenarios simulation (climate change impact, international foreign relationships, geo-economic changes) and 3) limit dominance over freight flows of a single country/region/company.
	How? Through the development of regional logistics & clustering (infrastructure & regional platforms), collaborative logistics development & implementation of shared capacity models. Support impact assessment of these PI enabled solutions and enhanced planning of infrastructure and technology investments. Secure provisions to regional ecosystems stakeholders for common knowledge and conditions understanding and efficiently improve their collaboration.
	➔ Related to the **Physical layer** (Required infrastructure at regional level, multiple entry points/network of nodes etc, interoperability of physical infrastructure), to the **technological layer** (development of regional logistics platforms, interoperability of digital infrastructure) and to the **Governance layer** (Governance of the ecosystems at regional/cluster level and stakeholder participation to decision making for the development of collaborative logistics).
▪ **Oriented towards facilitating EU exports** ***[resp. attributes: Geo-economic awareness, Integrated]***	
	➢ In addition to facilitating import flows (mainly from China) which is the dominant orientation of the EU network today (especially to the port sector) the EGTN setup & services will also be oriented towards efficiency in serving the exports of the EU industry from multiple EU regions and thus align to the EU economic strategy for achieving trade balance with China and support regionalisation as counterpart of the globalisation of economy.
	How? By assessing the development of the inland network of multimodal nodes and prioritising technological solution for shifting the infrastructure development from the port-hinterland perspective which mainly facilitates import flows, to the inland network perspective which facilitates the identified trend for regionalisation of production.
	➔ Related to the **Physical layer** (possibly more or of revised significance inland nodes, development of better links connecting them), to the **technological layer** (simulating the scenario for regionalization of production at the strategic level in order to guide the development of the EGTN physical network, development of tools & services in the Open EGTN infrastructure to serve the increased internal flows/exports that will emerge from the regionalization of production).
▪ **Supporting social cohesion & inclusiveness** ***[resp. attribute: inclusive]***	
	➢ It is a network that is intended to be inclusive by design, ensuring accessibility to disadvantaged regions and their development, in alignment to the European social cohesion policy.

	<u>How?</u> By enhancing the regional dimension of logistics (which also contributes to the network resilience) through the development of the corresponding infrastructure and services which will increase the attractiveness of these regions. By defining and enhanced entry point.
	➔ Related to the **Physical layer** (Required infrastructure at regional level), to the **technological layer** (development of regional logistics platforms) and to the **Governance layer** (Governance of the ecosystems at regional level and stakeholder participation to decision making for the development of regional logistics).
▪ **<u>Bridge business/industry needs for planning to EU policy and infrastructure planning</u>** ***[resp. attributes: Impact, Innovation]***	
	➢ EGTN will be a network that takes advantage of the unique knowledge which businesses/industry have regarding real logistics operations in order to achieve consensus among stakeholders and to support decision making for (hard and soft) infrastructure investments. At the same time, it will feed this knowledge at a higher (strategic) level in order to create awareness of the industry needs and thus align EU policy and infrastructure planning to these needs to the extent possible.
	<u>How?</u> By collecting disaggregated data from the LLs, the micro simulation processes developed within PLANET and also from real logistics operations. This data is added to a data lake for analysis and production of aggregated figures and KPIs in order to assess the impact of technologies on logistics operations and also to feed the strategic models.
	➔ Related to the **technological layer** (IoT for data collection, technology simulation processes/models & scenarios, data lake and data analytics tools, process for generalising technological innovation modelling, Decision Support Systems) and **governance layer** (Governance of the ecosystems at regional/cluster level and coordination/collaboration for private physical infrastructure investments, stakeholders' participation to the physical network development decisions).

3.3 EGTN components

The EGTN is composed by two integrated components. These are:

1. The **EGTN** [Integrated Smart Green EU-Global T&L Network] **Dynamic Reference Modelling Framework** and associated 2030 and 2050 EGTN Target Models based on a EGTN roadmap and detailed KPIs for the 2030 and 2050 transitions.
2. An **EGTN Data Space** and simulation and AI tools [**Symbiotic Digital Clone**] supporting:
   a. refinements for the Reference/ Target Models
   b. design and investment decisions in development of EGTN network nodes
   c. EGTN Operational Optimisation.

The EGTN Dynamic Reference Modelling Framework supports the interdisciplinary representation of an evolving EU-Global T&L Network driven by geo-economics and emerging technologies and concepts enabling progress towards a smart and green transport network. It facilitates the specification of Target Models based on an EGTN roadmap and detailed KPIs for the 2030 and 2050 transitions. The framework assumes the use of existing modelling and simulation tools to determine the characteristics/status of an existing network and to investigate the impact of geopolitical developments (e.g., future New Silk Road and emerging trade routes) and impact of adopting innovative technologies and concepts (e.g., autonomous vehicles, warehousing automation, hyperloop, ICT, PI).

The EGTN Data Space and simulation and AI tools Symbiotic Digital Clone [SDC] enables:

a. refinements for the Reference/ Framework and Target Models
b. investment decisions in development of EGTN Nodes
c. Operational optimisation of network performance

SDC will provide a virtual representation of EU-Global T&L Network or sub-Network utilising the EGTN models and providing data driven simulation and AI based decision support to stakeholder groups involved in a, b, c above. For this an EGTN Dataspace is constructed supporting an ecosystem of actors that interact through the sharing of data in assessing the status of EGTN and contributing to its developments.

4 EGTN Physical layer specifications

4.1 Introduction

The physical layer specifications aim to provide a comprehensive answer to the question: How should the EGTN be structured in terms of physical corridors and nodes? The objective is to have a network that is better adapted to the new EU & Global geo-economic conditions, serve more efficiently future freight flows and facilitate better the development of disadvantaged regions in comparison to the current TEN-T structure. In this context, the infrastructural layer of **EGTN is defined as the TEN-T of the future in terms of T&L infrastructure** consisting of revised and enriched existing rail/road/maritime TEN-T infrastructure (nodes & corridors). These required network changes are mainly the result of:

- **the new emerging global trade routes (Eurasian rail land bridge, Arctic route, International North-South corridor) and the connection and operational integration of TEN-T corridors to these global corridors**. This development will alter the significance of existing infrastructure and the criticality of current capacity bottlenecks, causing also the emerge of new important entry points, nodes, corridors and bottlenecks. Each TEN-T corridor will be associated with selected continental/global corridors and connected to them through new entry points leading from TEN-T to GTEN-T (Global TEN-T).
- **the identified trend for regionalization of production in the project's Position Papers** which has the potential to shift the balance between import/export flows through deep sea ports and the import /export through intercontinental rail routes and the intra-European flows. This in turn may shift emphasis of infrastructure development from hinterland networks to inland networks, requiring an enriched network of inland nodes.
- **the expected/foreseen implementation of innovative technologies on Transport & Logistics operations** which will enable the Physical Internet concept and change the operational characteristics of the network components. In addition to the impact of the aforementioned geo-economic developments on the network structure, the implementation of the PI and the enabling innovative technologies (e.g. blockchain, IoT) and concepts (e.g. multimodality, synchromodality) has the potential to alter the operational characteristics of nodes and corridors (capacities, environmental footprint of operations etc.) and thus change the competitiveness and attractiveness of network components.
- **the enhancement of the regional dimension of infrastructure** in order to facilitate the development of disadvantaged regions and also meet the **need for network resilience**. The EGTN infrastructure development will support the development of regional clusters of nodes and of collaborative logistics/shared capacity models, leading to a network with multiple entry points and alternative routes for the flows arriving/leaving EU from/to global corridors.
- **the potential impact of climate change on the EU and global transportation networks.** The climate change may lead to phenomena such as the melting of polar ice and prolonged periods of draught which are closely related to the capacity and operability of modes of transport (e.g. inland waterways) and routes (e.g. Arctic route).

In order for EGTN to take into account all the parameters described above into its infrastructure planning and design, PLANET is developing a strategic modelling capability to forecast future freight flows for years 2030 and 2050 which will lead to defining the final form of the physical network needed to be able to efficiently serve these flows.

More specifically, the strategic modelling capability of the project will assess together:

- the impact of the three emerging trade routes (Eurasian rail land bridge, Arctic route, International North-South corridor) on the TEN-T network regarding freight flows and the corresponding infrastructure needs that will emerge from the new flows. In the next paragraph (4.2) of the present document, an initial assessment of the expected impact on current flows by the integration of the new trade routes to the TEN-T is presented for the base year (2019) including some considerations for the current network structure. Moreover, an initial assessment of the impact of the new trade routes to the EU disadvantaged regions is performed.

- the alternative plausible future scenarios, developed in the project's Position Papers, which are based on the most important uncertainties and their variations and are expected to affect future freight flows and network structure. In this context, the identified uncertainties of the trend for regionalization of production, the climate change leading to possible exploitability of the Arctic route but also may cause problems to the European Inland Water Ways and the level of implementation and EU support to the PI concept will be consider during the strategic simulations.
- the impact of leveraging emerging technologies which are enablers for the operation of the EGTN under the PI paradigm, on the network structure. In order to be able to do so, the capability to simulate the impact of various new technologies, individually or in combinations, at micro level and then generalise the results and translate them in a form that can be imported in the strategic model is being developed within PLANET. The methodology for achieving this interface between the micro and macro levels of modelling is described in paragraph 6.2.1 of the present document.

The new hierarchy and significance of entry points, nodes and corridors of the EGTN that will result from the strategic simulation process will be continuously monitored and assessed through the technological infrastructure of the EGTN since may dynamically change through time. In this sense, EGTN will be an intelligent network regarding its infrastructure development, being continuously aware of the geo-economic developments on EU & Global level and of the technological advancements.

The planning and design process of the physical layer of the EGTN as described above requires a strong technological support which will be provided by the Cloud-based Open EGTN infrastructure developed as part of the EGTN technological layer. More details on the functions and services required from the technological infrastructure of the EGTN will be provided on the relevant chapter of this document.

4.2 Integration of new trade routes to the TEN-T

Further advancing the EU's leadership in global transport flows and logistics starts with establishing a sound and fundamental understanding of the impact on the TEN-T network of global transport and geo-economic trends. In order to achieve this, Task 1.2 performs a strategic analysis of the most relevant emerging trade routes which are expected to gradually change global transport patterns, and a simulation of their potential impacts on the TEN-T. This relates to the intercontinental rail freight connections between China, Russia and Europe (Belt and Road Initiative), the maritime connection between China, Russia and Europe through the Arctic (Arctic route) and the connection between Middle East and Northeast Europe (International North-South Corridor).

The findings of Task 1.2 are published in two deliverables: D1.4 (available at the time of writing of the present document) and D1.5. The initial report establishes the baseline scenario (year 2019) for the three new trade routes considered for the EGTN network. The second report will explore the 2030 and 2050 simulations and link the usage of the corridors to changes in the disadvantaged regions (e.g. accessibility, economic growth, population).

4.2.1 Flows analysis and Physical corridors definition

With respect to flows reaching Europe through the aforementioned trade routes, regarding the Eurasian rail freight transport, rail services coming from China and arriving at the European border in 2019 overwhelmingly used Małaszewicze as principle entry point (PEP). The 200.000 TEU per year coming from China translated into some 55 trains per week. About 12% of this flow branched off towards Lodz. Some 23% went to Hamburg and some 44% went on to Duisburg. Smaller flows went to Liege, Ghent, Tilburg and Madrid. Export flows also travel in the opposite direction, but to a lesser extent.

For the International North-South Corridor, we see a current potential of over 86.000 TEU, which could increase to 125.000 TEU in 2030 and 206.000 TEU in 2050. It remains to be seen how long it will take for these volumes to be realised if the route is completed. Only a fraction of the cargo is related to Europe.

This concerns 8.500 TEU if the route would be opened right now, which could increase to 13.500 TEU in 2030 and 24.000 TEU in 2050. The corridor is therefore most interesting as a European trade route if European trade can be combined on INSTC trains with Russian cargo.

Regarding the Arctic Route, we have found that its greatest potential lies in the transport of raw materials that come from this region, especially energy-related raw materials. In 2019, approximately 6 ships per week arrived in Europe from this region. Russia has plans to more than triple the amount of raw materials extracted by 2030. However, Russia also plans facilities to be able to process the raw materials on its own soil, so that transport to Europe will no longer be necessary. It is therefore not expected these commodity flows to increase, thus keeping the impact on the European TEN-T network negligible.

As set forth already, by far the most important railway corridor between Western Europe and China, now and in the foreseeable future, runs through Poland, Belarus, Russia and Kazakhstan. Trains typically carry up to 41 high-cube containers of 40 ft., making up for trains of approximately 565m. As a rule, the trains do not exceed the total number of 41 containers, of any type or size, due to Chinese government subsidy regulations in conjunction with infrastructure capacity in the EU. However, for the long haul through the Eurasian Economic Union (EAEU) countries – in effect Belarus, Russia and Kazakhstan – where freight trains often exceed 1.000m, combining trains is common use.

Under normal circumstances, lead times from terminals in inland China to Duisburg stand at 15 to 16 days or slightly less, which would allow for a time saving of some 14 days compared to ocean for the overall transport. However, currently experienced delays are seen to increase lead times to 18 to 19 days or even more. These partially capacity-related issues are a driver towards considering and testing possibilities for using alternative stretches. In the next sections, this is examined in more detail.

From the Polish-Belarusian border, two routes are available. The first proceeds to Moscow and from there to Yekaterinburg, where the corridor is split up with the most important leg transiting Kazakhstan towards the Chinese border, and an alternative leg transiting Siberia and reaching China either via Mongolia or via the Russo-Chinese border. The second route diverts at Minsk, transits Southern Russia and then crosses into Western Kazakhstan, from where it also proceeds to the Chinese border. Over two thirds of rail freight between China and Europe is forwarded via the Russia-Kazakhstan route, with only small portions via alternative routes.

Break of gauge takes place on the Polish-Belarusian border (Małaszewicze/Brest or alternative EU-EAEU border crossings) and on the Kazakh-Chinese border (Dostyk/Alashankou; Khorgos) or, for the Trans-Siberian route, the Russo-Chinese (Zabaykalsk/Manzhouli) or Mongolian-Chinese border (Erenhot). Customs procedures also take place on these border crossings, with Russia, Belarus and Kazakhstan being members of the Eurasian Economic Union (EAEU) customs area and Mongolia being aligned to it.

The essential milestones (both westbound and eastbound) are thus:

- Assembly/arrival of the goods at European rail terminals, such as Duisburg, Hamburg or Tilburg;
- Brake of gauge, transhipment and customs procedures at Małaszewicze/Brest;
- Brake of gauge, transhipment and customs procedures at Dostyk/Alashankou or Khorgos;
- Arrival/assembly of the transports at Chinese rail terminals, such as Chongqing, Chengdu, Wuhan, Xi’an or Yiwu.

Figure 2: The main Europe-China railway corridor. ©Panteia

4.2.2 European sections, terminals and transhipment points

The most important start and end point for trains to and from China is the inland port of Duisburg, which at the time of writing handles some 120 trains per month in either direction, and in the same area the inland port of Neuss. Other important departure and arrival points include the port of Hamburg, Railport Brabant (Tilburg) and, in Central Europe, Łódź (Łódź Special Economic Zone) and Budapest. Apart from the logistic rationale, not all European rail terminals are able to handle trains to and from China due to the capability requirement of communicating with information control systems used by the Chinese intermodal operators who organise the transport process. A number of Western European destinations are serviced through Duisburg rather than directly.

The trains reach the Polish-Belarus border at Małaszewicze/Brest, where break-of-gauge transhipment and customs procedures take place. Traditionally, westbound trains were transhipped in Małaszewicze, whereas eastbound trains were transhipped at Brest. However, nowadays operators can decide on which side of the border the transhipment takes place.

The Małaszewicze/Brest border crossing is identified by all stakeholders as the first and foremost bottleneck, notably for westbound transport. Ideally, transhipment and customs procedures would take some 18 hours for an entire train (this is the official aim of the Belarus Railways), but in practice this may last for 2 to 3 days or even longer. This, combined with the notorious difficulties of the busy European railway network, causes many trains to arrive with serious delay at their Western European destinations and leads to rescheduling issues and congestion at the most important arrival terminals.

Estimations of current infrastructure capacity at the border crossing (e.g. availability of cranes and tracks at the terminals) stand at some 10 trains per day (loaded with 80 TEU). Also, current regulations between Poland and Belarus allow for a maximum of 12 border crossings per day. Thus, in terms of infrastructure, the border crossing may already be operating at its maximum capacity. [1]

Border procedures are generally very time-consuming. Also, the time needed for border procedures can deviate due to logistics processes of operators (choice of terminal, trucking operations between terminals, loading and unloading in addition to transhipment, storages, train composition) or incorrect documents. It therefore seems fair to conclude that infrastructure limitations coincide with suboptimal administrative procedures and organisation.

Poland intends to invest some 55 million euros in the facilities on the Polish side of the border over the coming years, aiming to increase capacity and enable the use of 750m trains and higher axle loads. Another 40 million of investment is depending on the construction of a third railway bridge (broad gauge only) and additional tracks across the border jointly with Belarus. Terminals on the Polish side are privately owned, whereas Belarusian facilities belong to Belarusian Railway. Ideally, infrastructure investments would be accompanied by optimisation of procedural management and communication between parties on both sides of the border, initiatives for which are being started as well. Options for improvement are being considered by multiple stakeholders, but, as we will see, partially depend on customs regulations. One possible option could be a limitation of loading and unloading operations at the border terminals, in order to focus on essential border handling (transhipment and legal procedures). Also, optimising shunting procedures of empty wagons in the border area is considered.

Obviously, another option might be bypassing Małaszewicze/Brest altogether, possibilities for which are being examined by a number of market parties. One such possible option would run from Poland through Lithuania, entering the broad-gauge system at Šeštokai, and rejoin the main corridor at Minsk. Infrastructure capacity on this route is relatively limited, however, thus rendering it unsuitable for large numbers of trains in the foreseeable future. Currently, the Polish and Belarus governments are also considering a second border crossing north of Małaszewicze (Czeremcha/Vysokolitovsk) for border crossing. Another potential bypass transits Ukraine, possibly departing from Budapest or Bratislava and changing to broad gauge at Dobrá/Chop. Recently a plan was conceived by the Austrian, Slovak and Russian railways to construct a broad-gauge freight railway line from nearby Košice to Vienna. According to the plan, construction would start in 2024 with operational status to be reached in 2033. [2]

4.3 The strategic scenarios to be tested for EGTN 2030 and 2050

The strategic planning capability of the EGTN will consider future scenarios which combine the main uncertainties expected to impact future freight flows towards Europe and within TEN-T and the network. In the context of D1.1 (EGTN Foundational Position Papers and Simulation Scenarios) the four Foundational Position Papers defined the main uncertainties and formulated scenarios related to each covered field (Geo-economic developments, interconnection issues of railway transport corridors, transition towards PI). Following this process, two consolidated scenarios were drafted, combining plausible variations of all the identified uncertainties in the PPs. The detailed analysis of the parameters and the narratives of the consolidated scenarios can also be found in D1.1.

The structure which was used for drawing the consolidated EGTN scenarios (figure 3) includes the combination of variations of the main parameters that are expected to affect the future demand and supply for transportation, leading to the definition of the narrative of each scenario. The assessment of the results from the simulation of the two scenarios will be made through the implementation of proper Key Performance Indicators.

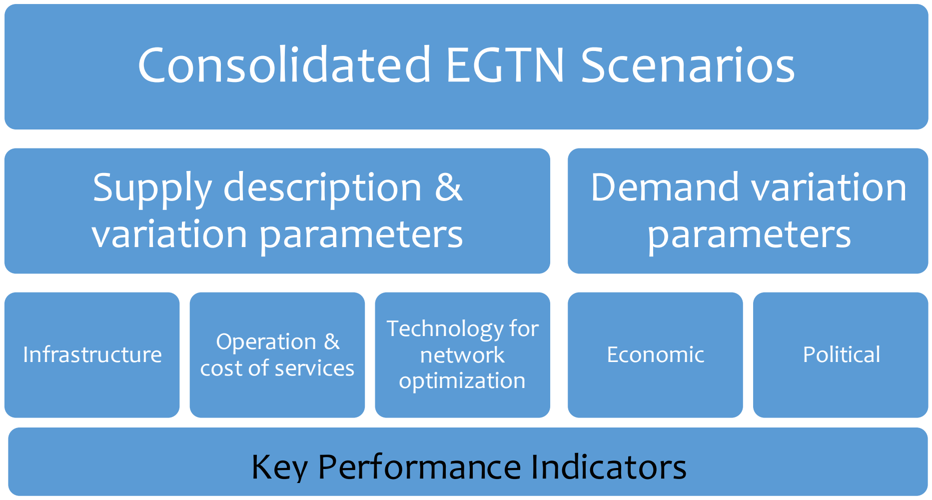

Figure 3: Consolidated scenarios structure

Definition of demand

The demand for freight transportation is expected to be mainly affected by parameters related to economic and political development. According to the uncertainties used in the PP scenarios these parameters include:

- Economic parameters:
  - Economic and population growth (EU, China, World).
  - Location of production (Regionalization vs Globalization).
- Political parameters:
  - Funding schemes (subsidies) from China supporting rail transportation.
  - Tariff regimes.
  - Restriction on the rail transportation of dangerous goods from China.
  - Commercial agreements with China.

Definition of Supply

The supply regarding freight transportation includes the available hard infrastructure, the services and the technological infrastructure for serving the flows but also the environmental parameters affecting capacity and decisions made regarding the use of the available infrastructure. According to the uncertainties used in the PP scenarios these parameters include:

- Investments in transport and logistics infrastructure (concerning all modes of transport with special focus on investments in rail infrastructure to increase efficiency and attractiveness of rail corridors).
- Interoperability of rail infrastructure along the Eurasian corridor.
- Development of new nodes.
- Level of PI adoption and implementation of the enabling innovative, disruptive technologies.
- Harmonization of documents (commercial & customs) along the rail corridors.
- Impact of global warming (on IWW in Europe & on the Arctic route).

Translating consolidated scenarios implications for strategic modelling

The implications of the two consolidated scenarios, need to be translated to specific input parameters in order to be able to be inserted into the strategic model. The following input parameters will be used to quantify the foreseen implications of the future scenarios:

- Average speeds of transport modes.
- Generalized transport cost of transport modes, including all types of costs (labour, capital, fuel costs, tariffs etc.), transport time etc.
- The "Attractiveness" cost of nodes.

In the following table (table 3), an initial approach to quantify the implications of the two consolidated scenarios on the transportation system is presented (for year 2030), by changing the values of the aforementioned parameters in relation to their value in the base year (2019).

Table 3: Translation of scenarios implications to modelling parameters

Parameter	**Implications & relevant strategic model parameters**	
	Consolidated Scenario 1	**Consolidated Scenario 2**
Infrastructure	• Lower average speeds to IWW (because of reduced capacity). • Lower average speeds to road network (because of road congestion). • The average speed of rail increases (because of investments to infrastructure and increased interoperability).	• The average speed of rail increases (because of investments to infrastructure and increased interoperability). • The average speed of IWW and road does not change.
Barge Tariffs	Structural increase factor (because of reduced capacity).	No structural factor applied, remains equal.
Road tariffs	Structural increase factor because of increase of demand for road transportation (due to lost capacity of IWW).	Structural factor >1 per t.km (because of carbon pricing).
Rail tariffs	Structural increase factor because of increase of demand for road transportation (due to lost capacity of IWW).	Structural factor <1 per t.km (in order to make rail more competitive).
Modal split	• Decrease of generalized transport cost of rail (increased share). • Increase of generalised transport cost of barges (significantly decreased share). • Small increase of generalised transport cost of road (small increase of share).	• Significant increase of generalised transport cost of road (significant decrease of share). • Significant decrease of generalized transport cost of rail and barges because of high efficiency due to high PI & DTLF adoption (increased share)
Continental divide ratio	• Increase of attractiveness cost of Northern seaports because of IWW	• Decrease of attractiveness cost of nodes of the Eurasian land bridge

	connectivity problems (reduction/small increase in the throughput of Northern seaports). • Small decrease of attractiveness cost of Southern seaports (Globalisation of production remains predominant). • Decrease of attractiveness cost of Eurasian land bridge (increased intercontinental rail transportation).	(due to regionalisation of production).
Transport Efficiency	• Reduction of transport time for all modes to certain corridors with PI implementation, referring to up to 30% of freight flows.	• Reduction of transport time for all modes to corridors referring to 60% of freight flows (due to extended PI implementation).
Transport Cost	• Reduction of generalised transport costs for all modes in the corridors with PI implementation (referring to up to 30% of flows) due to the reduction in the use of assets & transport time.	• Reduction of generalised transport costs for all modes in the corridors with PI implementation (referring to 60% of flows) due to the reduction in the use of assets & transport time.

5 EGTN Technological layer specifications

5.1 Introduction

The main objective of the EGTN technological layer is to ensure that the EGTN fulfils its 'innovation embedding' attribute in the sense that it takes full advantage of the potential of innovative logistics concepts and enabling technological innovations in its operation, ultimately aiming to become a network operating under a PI paradigm. Towards achieving this goal, a Cloud-based Open EGTN infrastructure is being developed in the context of WP2 to support accordingly the main aspects of the EGTN concept, namely:

- the planning and the decision support (on governance level) for the development of EGTN infrastructure and
- the operationalisation of the EGTN.

In the following paragraphs, the required functionalities for supporting each of the above aspects are described, leading to the definition of the EGTN technological requirements and specifications.

5.2 Planning and decision support for infrastructure development

The successful planning of the Physical components (entry points, nodes, corridors) and structure of the EGTN requires awareness of the future freight flows. In order to acquire awareness, PLANET is developing a strategic TEN-T modelling capability which is described in chapter 4 and will be used to calculate the changes in flows at the macro level compared to a base year (2019) by integrating the emerging global corridors and simulating plausible future scenarios based on possible geo-economic, environmental, technological and other developments.

The strategic modelling and simulation capability which will allow EGTN to be aware of the geo-economic developments and other factors affecting flows and to timely respond to these changes, is part of the technological layer of the EGTN. However, the development and update of the model as well as the running of the simulation process whenever deemed necessary for providing new/updated information for the network planning, will be performed outside the cloud-based Open EGTN infrastructure and will not be included in its services.

Nevertheless, despite belonging in a parallel stream, the strategic TEN-T model will be connected to the Open EGTN infrastructure for two main reasons:

1. Regarding the potential impact of innovative technologies to future freight flows and thus to the development of the EGTN physical infrastructure, the strategic model will need to take into account during its simulations of parameters that quantify the impact of technology implementation to the logistics operations. For this reason, the Open EGTN infrastructure is developing a tool that will simulate various PI and Synchromodality implementation scenarios and also validate these scenarios in terms of cost/benefit, feasibility, possible time horizon of implementation etc. The results from these simulations which will be produced in the LLs at the micro level will be transformed through proper methods in order to provide aggregated figures on modelling parameters to the macro strategic TEN-T model. In addition to this process, these parameters can be also be provided through the analytics of data which will be collected by the monitoring of real operations and will be stored in a data lake developed as part of the Open EGTN infrastructure.

2. With respect to the strategic simulation results, the TEN-T model will need to provide Open EGTN Infrastructure with forecasts of the future freight flows and detailed KPIs related to the future network performance in order to support the decision making of the relevant stakeholders at the operational level.

The implementation of the PI concept and the operation of the EGTN under a PI paradigm is the PLANET approach towards achieving the "Green" attribute of the EGTN and align to the EU taxonomy for sustainable activities. The latter aims to direct investments towards sustainable projects/activities in order to meet the EU's climate and energy targets for 2030 and reach the objectives of the European Green Deal. According to the "Roadmap to physical internet" published by ALICE, in a scenario in which all Physical Internet potential efficiencies are achieved the forecasted 300% increase in transport demand could be achieved with only 50% increase in assets. The potential emissions reduction from a better use of resources through applying Physical-Internet concepts can help significantly towards achieving the goal of temperature reduction (Paris Agreement).

PLANET recognizes that the PI not only makes use of (smaller) standardized load units (pi-containers), but also builds on the availability of open and integrated networks that connect freight transport origins and destinations. However, the implementation of the PI concept simultaneously to the entire EU transportation network until 2030 is not realistic nor feasible in terms of the time and of resource allocation (cost, experts, etc.) In this context, in addition to facilitating the definition of the physical layer of the EGTN, <u>the Open EGTN infrastructure will also define a subset of TEN-T corridors for prioritized development of Physical Internet concept (EGTN PI corridors)</u>. Along these corridors, the PI hard infrastructure will by priority be implemented and incentives and policy packages may apply for the development of the corresponding PI digital infrastructure & services (Multimodal & Synchromodal services) that are also part of the technological layer of EGTN. The selection/definition of the PI corridors (in order to guide companies & public investment) will be based on strategic PI scenarios creation and validation based on aggregated parameters resulting from Synchromodality, OR based Modelling and PI simulation. These strategic PI corridors will be dynamically updated.

Finally, the planning of the infrastructure development of the EGTN as being also part of the EGTN Governance process requires the wide participation of stakeholders and their support through the development of a Decision Support System (DSS). Multi-Actor Multi-Criteria Analysis (MAMCA) is a decision-making method to enable the simultaneous evaluation of alternative policy measures, scenarios, technologies, etc. while explicitly including different stakeholders' opinions at an early stage of the decision-making process and during the whole decision-making process. It is extremely well suited to complex decision-making processes such as those involved in mobility policies and the transport sector where many stakeholders from several areas and with different background are involved. It renders the decision-making processes more efficient and contributes strongly to critical debates by offering to approach these with a democratic dimension [10]. In this context, PLANET will develop a MAMCA DSS to consider the opinions of various stakeholders regarding public and private investment scenarios related to the development of EGTN and the corresponding economic impacts. Through this method, stakeholder groups will identify a specific set of criteria and allocate weights to each distinct criterion leading to decisions that are better informed and of wider acceptance. The PLANET DSS may be focused on different levels of stakeholder governance (regional ecosystem stakeholders, EGTN corridor stakeholders or at the whole EGTN level).

Crucial for the success of MAMCA method is the provision to all participating stakeholders of sufficient information in order to be able to assess the investment scenarios and reach unbiased decisions. This will be facilitated through establishing of a process for continuously monitoring EGTN infrastructure development and operations and calculate proper Indices and KPIs that will be provided to stakeholders in order to be aware of the operation and status of the network.

Summarising from the above, in order for the Open EGTN infrastructure to provide the functionalities described above, it will develop and integrate:

- an interface with the dedicated strategic TEN-T model (enabling modelling of scenarios for the EGTN infrastructure development), in order to:
    - provide to the strategic model aggregated figures on parameters needed for the strategic modelling (resulted from the synchromodality modelling & PI simulation or from operations monitoring data stored in the data lake) and

  - receive from the strategic model, data & results (KPIs) for enabling Decision Support.

- visualisation tool of the EGTN infrastructure and decision theatre for providing comprehensive network visualization and monitoring (KPIs per corridor and/or node, standards, interoperability of procedures etc.).
- a method for defining & validating PI scenarios (cost benefit /feasibility etc.) in the micro level and transforming the results in order to provide aggregated figures to the macro (strategic) model. Moreover, the efficiency performance gains that will be defined by the technology implementation through this method, will be also used to provide an answer to the question: Can technology investments substitute costly investments in hard infrastructure? In paragraph 6.2.1 (Generalisation of technological innovation modelling) an initial approach on developing this process is presented which aspires to generalise the results from the technological innovation modelling and to bridge micro-simulations and macro (strategic) model.
- a method for defining and dynamically update the prioritised set of nodes and corridors of the EGTN in order to develop the required infrastructure and services for PI implementation. The initial approach on defining the EGTN network model is presented in paragraph 6.2.2 (EGTN Network model).
- an observatory to support the calculation and ensure the access to relevant stakeholders to the following EGTN indices:

  a) the PLANET new global connectivity index of nodes and regions which was developed in the context of the Position Paper 1,
  b) operational efficiency indices and
  c) the PLANET Reliability index of corridors (considering the performance of the corridor at the level of infrastructure, trade, political, financial and cultural).

- a MAMCA tool for facilitating the participation of the stakeholders to the infrastructure planning process.

5.3 Generalization of technological innovation modelling

By technological innovation modelling, we refer to the abstract procedure that aims at providing a representation (a model) of the impact of novel and not-yet established technologies and concepts (i.e., innovations) on the EGTN. This capability meets the EGTN vision for efficiently undertaking the business operations view to public policy and planning process. In this section, we present a generalization of the first prototyped model developed as part of Task T1.4. The model developed there was built around a single case (inspired from LL1) and now we highlight the modelling process that led to that development.

The first step was the definition of a modelling use case, by following the template in Table 4. By **modelling use case** we refer to a specific situation in which a model could potentially be used. For our purposes, it provides main user (stakeholder interested in the analysis), context of application (logistic setting of interest) and evaluation scenarios of interest. Table 4 provides both the list of features and an explanation for each of them. It is important to note that the template provided defines both the modelling efforts and the project partners involved in the definition of the modelling use case and of a pipeline.

Table 4: Modelling use case template

Feature	*Explanation*
Modelling use case title:	A title for the modelling use case
Narrative presentation:	Explain what is are the problems being modelled and how this is being done.
PLANET partners involved:	List of partners name involved in the modelling use case

Model stakeholders:	List the main stakeholders considered in the model
Involved models (reference to D1.2):	List the models involved (as defined in D1.2 or additional ones)
Focal technologies and innovation:	List the technologies considered in the modelling use case
Modelling scenarios:	Describe the scenarios at a high-level

Once the first definition of the modelling use case is completed, it is then linked to a specific pipeline. By **pipeline**, we mean a sequence of models executed in sequence in such a way that the output of one will be the input of another. For our use here, a pipeline should substantiate a modelling use case. In other words, for each modelling use case, we devise a pipeline. A pipeline is written in a certain programming language. The definition of a pipeline follows the map given in Figure 4: Technological innovation modelling map

Starting from a simple instance, multiple scenarios (two in the case depicted) are formalized in such a way to be used by a combination of various models. The combination of the models is driven by the modelling use case, which defines the main goal of the modelling use case, but also by the specific capabilities of the models considered. Moreover, the combination of the models needs to be constructed in such a way to allow for a transfer of information from the microscopic and operational setting where a set of technologies is deployed to the macroscopic level of interest for the EGTN. The output of the evaluation of the models is then post-processed leading to two (or more) alternative parameter settings which then fit a macroscopic model. The combination of various models is the central and pivotal step of the whole technological innovation modelling as it requires a way to bridge the results (the output) of a microscopic model with the requirements (input) of a macroscopic model.

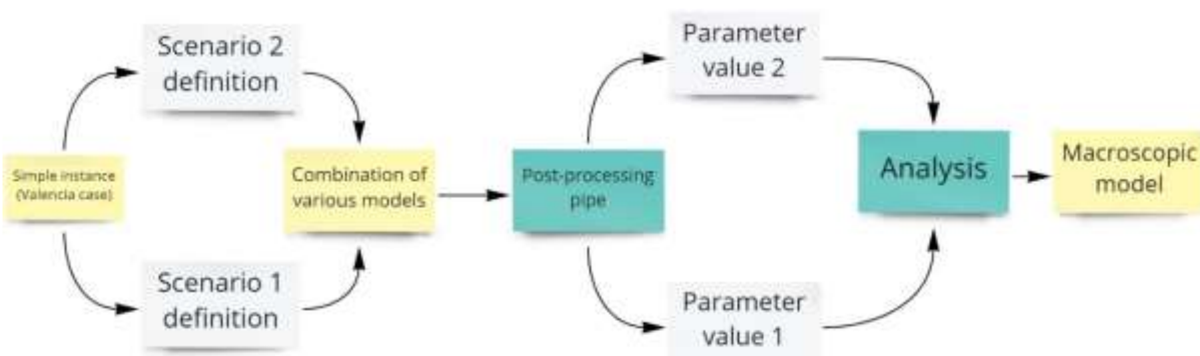

Figure 4: Technological innovation modelling map

This combination is the main modelling contribution that can be extracted from the prototype model developed in T1.4. In order to evaluate the impact of innovative technologies at the EGTN level, i.e., at the macroscopic level, we found most effective a method that, first, models the impact of technology at the microscopic level and second,

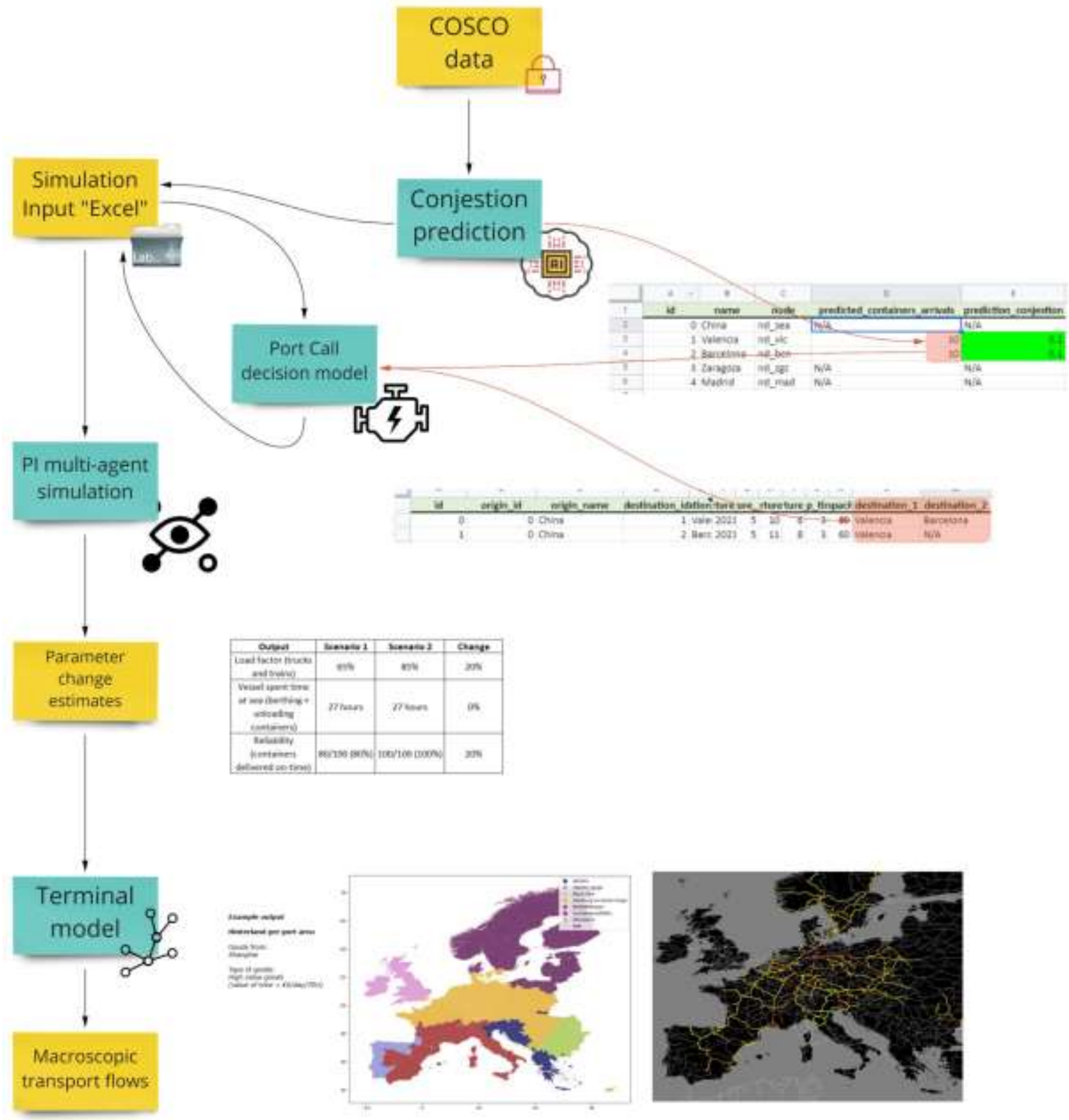

Figure 5: Bridging the micro-macro modelling gap - example from T1.4

estimates the aggregated impact for these parameters that are input to a macroscopic model. Figure 5 shows, by means of an example, the steps followed. This Figure shows three models (turquoise boxes) representing different technologies (Congestion Prediction, Port Call decision model and PI multi-agent simulation) whose output leads to the parameter changes estimate then input to the Terminal model (a macroscopic model leading to the plots on the left where port attractions are calculated at the EU-level). The parameter changes estimations where related to a selection of parameters input to the macroscopic model. The fact that we estimated changes and not the parameters required by the model is due to the fact that the microscopic models could not reproduce the baseline parameters of the macroscopic model. This constitutes the approach to close the gap between microscopic and macroscopic level.

5.4 Defining the PI subnetwork of EGTN

5.4.1 Approach

The main objective of the long-term EGTN network design is to find the best nodes of a PI network based on the TEN-T corridors in order to guide the PI infrastructure and secure its development. PLANET will deliver as part of the EGTN 2030 & 2050 infrastructure the PI subnetwork of EGTN using strategic PI impact assessment models as part of the strategic modelling infrastructure. In addition, it is necessary to investigate the balance between costs and CO_2 emissions when designing such a PI network.

5.4.2 PI strategic modelling

The project WP1 activities will focus on defining this PI priority corridors of EGTN. The methodology to be applied and embedded in the PLANET platform is described below.
The transport network may adopt different configurations. As a starting point there are some models as described in the ICONET project [11].

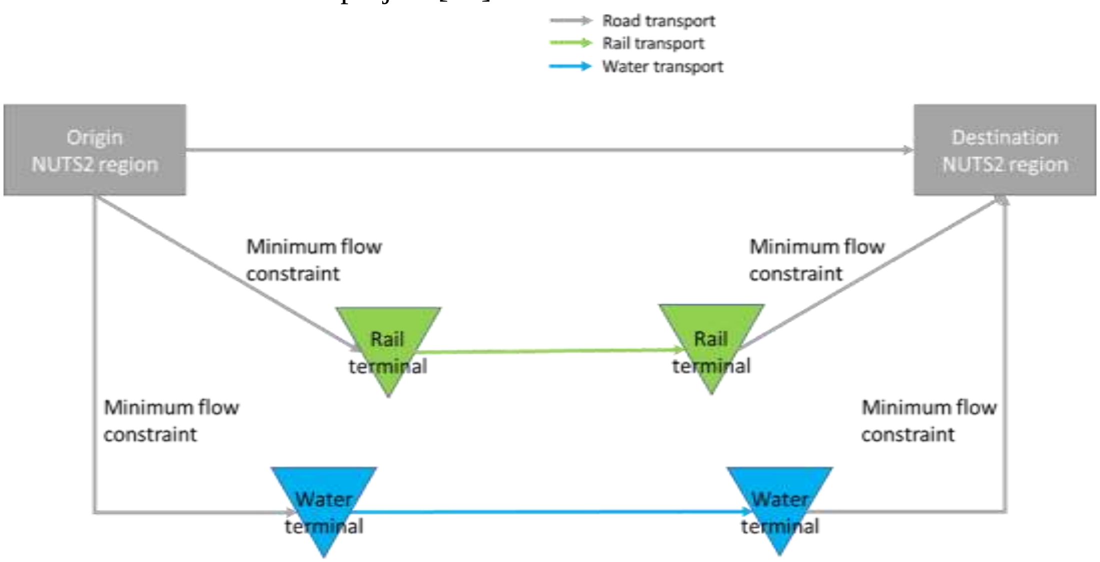

Figure 6: Network model structure for the TEN-T based PI network [11]

As shown in Figure 6, TEUs are transported from one NUTS2 region to another and this can be done by road, rail or water, depending on the available infrastructure. To replicate the current situation in the TEN-T network, flow restrictions on road transport to and from rail and water terminals are set according to how many containers are currently transported by rail and water to and from each region. The resulting network flows for rail and water are shown in Figure 7.

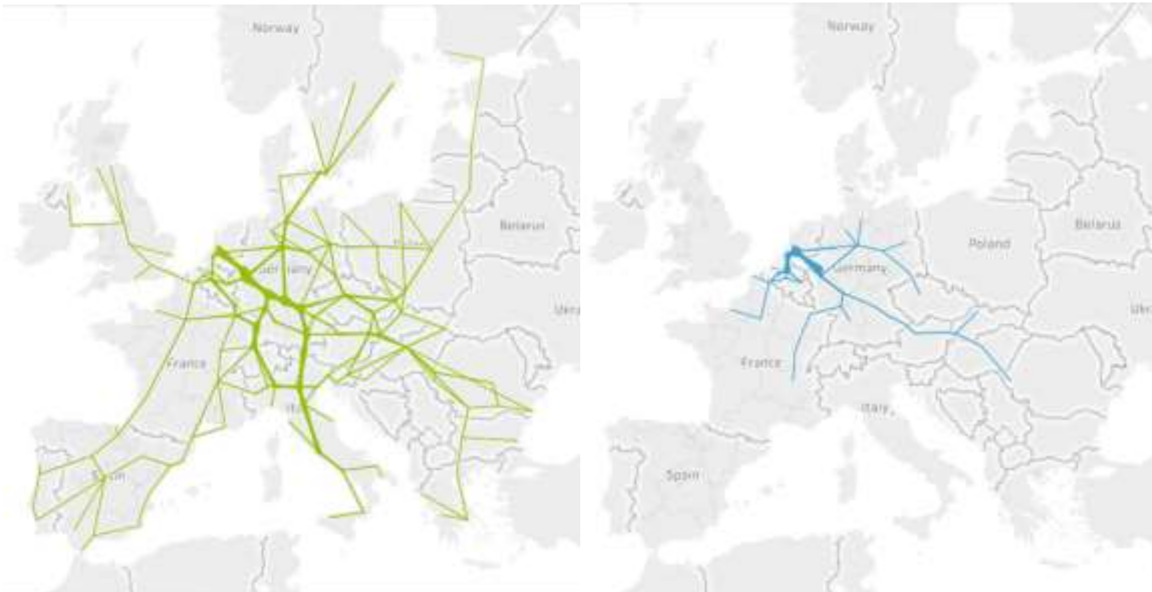

Figure 7: Rail and water transport networks of the PI network based on TEN-T [11]

In the case of rail and water terminals, we can define the role of a PI node in the network according to the type of flows passing through that node. If only flows to and from other terminals pass through the node, it is defined as a PI transit. If flows to and from the originating or destination NUTS2 regions pass through the node, it is defined as a PI gateway. This is shown in Figure 8 for rail terminals and water terminals, respectively.

Figure 8: Railway and water terminals [11]

The scope of a network is defined as the set of NUTS2 regions that are within a given distance from the nearest PI gateway. Containers are transported from rail or water terminals to NUTS2 regions. According to results published in ICONET [11], to cover at least 90% of the containers transported by TEN-T, the network must incorporate some 110 terminals. To cover 95% of the containers transported, the network needs to incorporate about 10 more terminals. The remaining 5% will be too far away from a PI gateway to be realistically and cost-effectively covered by the PI.

5.4.3 PI hubs analysis for assessing the impact of logistics innovation

Within the network, goods may reach their destination by various routes depending on how overloaded the network is, which may seek different alternatives and thus avoid delivery delays or congestion at network connections. The transportation of goods is modelled by links that represent transport infrastructure and services. However, to account for multimodal transport, different levels of network representation detail require to be considered. In the context of examining PI hubs [12], whose role in the PI network goes beyond transhipment and short-term storage functionality to include the complex interactions between the multiple terminals and services operating in close proximity, it is required that the network representation of the model considers:

- Multiple terminals with modal shift capability
- Multiple links between the hub's terminals
- Multiple terminal operations, that can be further broken down to mandatory such as customs or non-mandatory such as short-term storage, and
- Multiple bottlenecks, that inflict capacity and operational limit constraints on both transport and operational PI Hub link components.

Therefore, two different aggregation levels are used as a more detailed representation of the PI Hub assets is required. Within the PI Hub, specific terminals, routes, and bottlenecks are considered as illustrated in Figure 9. Such detail is critical for the representation of routing decisions within the Hub, while for the hinterland, aggregation is limited to the generic functionality of PI Hubs' as transshipment locations.

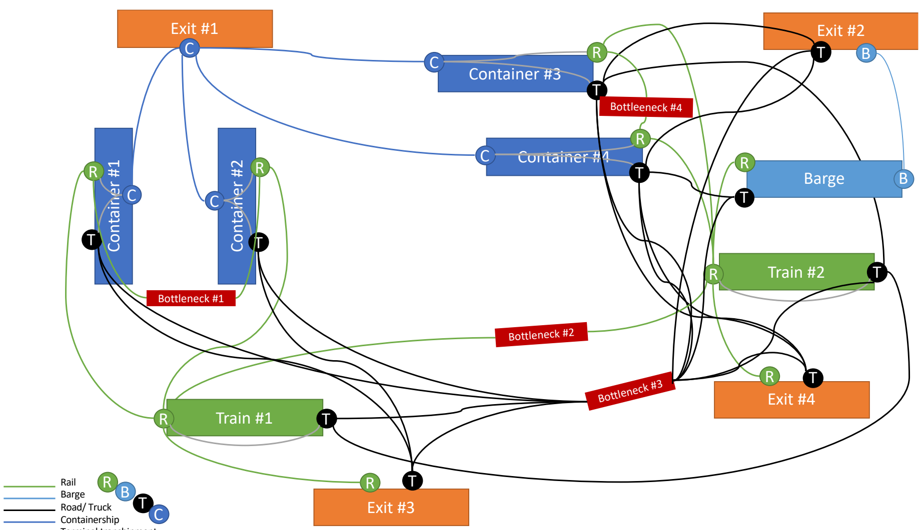

Figure 9: Port of Antwerp representation as a PI Hub [12]

The PI Hub network representation is composed of terminal nodes with transshipment capability between various modes. Rail and barge terminals are also considered for transhipments to rail wagons and to river barges respectively. For each of the terminals, the modal shift services offered are associated to performance properties that can impact the routing decision in terms of travel time and cost. Each of the PI Hub links, is associated to specific distance, travel time, cost and capacity. The capacity feature is also used for the representation of the port's bottleneck locations. Capacity limitations also apply on the transshipment capability of the PI Hub terminals. Transhipments are also associated to cost and duration. The queueing that occurs for transshipment operations is therefore reflected in a dynamic way.
PI Hub entry and exit locations are captured through fictional nodes, that facilitate the boundary between the disaggregate representation of a PI Hub and the aggregate representation of the PI Hub's hinterland.

For the aggregate hinterland representation, the TEN-T PI hubs are represented as nodes, with short-term storage and transshipment for each connection between two PI hubs, the great circle distance, the road distance and travel time are obtained by using the Google Maps API. For calculating the distances of the rail and inland waterways network, the GIS information were used.[2] For calculating the sea distances, an online tool [3] was used. For the calculation of travel times, river and sea services were assumed to operate at 7 and 15 knots respectively. Traffic congestion as provided by Google Maps API at a morning peak hour was measured in minutes.

By adopting this detailed disaggregate representation of PI Hubs enhanced visibility in operations status within the hub is achieved, which can drive a significant increase in operational efficiency. By recording information on queues and travel times for transhipments at different terminals of the PI Hub, more efficient and less congested hubs are promoted. This enables routing cargo by considering both the hinterland transport and the transshipment legs cost components. Depending on the status of each terminal, the travel time information is dynamically updated, enabling logistics providers (and the PI Shipping Service) to continuously track and compare the performance of their route of choice, against other potentially more efficient routes. This dynamic approach provides fair criteria for all logistics providers, and mode operators, as it can encourage modal shift and deviations against disruptions considering both the level of terminal operations congestion and transport mode (including hinterland) efficiency criteria.

Despite analysing the performance of an established network, the above modelling approach can also be utilized from an infrastructure investment perspective. Transport investments are not only expected to introduce new physical links or nodes in the network, but instead to enhance the operational efficiency of the existing ones. Through the disaggregate representation of PI hubs, it is possible to represent the impact of technological improvements into the efficient operation of intra-terminal or transshipment (between two terminals of a hub) operations. Other technological advances might have an impact on capacity levels or consolidation rates, that can again be represented as an impact into the capacity feature of a specific link or node of the network.

In the context of the above, PLANET infrastructure for planning and operationalisation of EGTN will provide major capability and results for realisation PI network development and paradigm shift support. This is especially import since in order to reach a Europe-wide version of PI requires a massive change in the contemporary logistics industry. According to the ALICE roadmap [6], PI should be a reality by 2040-2050. Climate agreements within and between EU Member States will play a key role. When transport becomes more expensive due to emission charges there will be a greater incentive for suppliers and users to make transport more efficient, which can be a strong driver for the PI network.

The PI-based transport model transforms the fragmented industries of freight transport, logistics and distribution into a hyper-connected logistics-based industry. The article [2] indicates that when applied to urban environments, PI enables the emergence of Hyperconnected City Logistics (HCL), a rich conceptual framework for designing much more efficient and sustainable urban logistics and transport systems.

5.5 Operationalisation of the EGTN

The Open EGTN infrastructure will provide tools and services that will support stakeholder for operational decision making and will improve procedures towards achieving the **“operational excellence”** attribute of EGTN in the context of implementing the PI concept. EGTN will be an **optimisation ready network** in order to be able to respond to the operational needs of the industry. In this context, the public and private infrastructure (hard and soft) will be available together with the

[2] The GIS maps for road, rail and river TEN-T network were provided by EC DG Move.

[3] Online tool for calculating sea distances: https://sea-distances.org

willingness of stakeholders to share infrastructure and data (shared capacity models and collaborative logistics) in order to gain benefits in terms of process optimisation and the establishment of intelligent and efficient hubs.

For EGTN to operate under the principals described in the previous paragraph it requires the technological developments to enable a gradual improvement of the current intermodal freight network. More specifically, the main identified prerequisites include the following:

- The different technologies that could help to **promote standardisation and collaboration between companies** in order to make transport options more accessible and sustainable for all participants in the supply chain. A key factor for collaboration is standardisation. Standardisation regulations allow companies to reduce costs by facilitating the physical and information exchange with other actors in the supply chain. **Standards such as GS1 help to create interoperable communication protocols between different companies**, combined with the use of standard containers, at different levels, facilitates an intermodal flow of goods between different modes of transport and handling.
- **Information exchange platforms** contribute to the cooperation of distribution networks that are currently disconnected. For the integration of these networks, **the concept of a federated network of platforms** has been promoted by the **Digitalisation of Transport and Logistics Forum (DTLF)**. This is an expert group established by the European Commission with the mission to assist the Commission in implementing EU activities and programmes aimed at fostering a more efficient exchange of electronic information in transport and logistics. In addition, there are different **platforms such as Fiware, IDSA (International Data Spaces Association) and initiatives such as GAIA-x** that promote the creation of a European space that **facilitates the exchange of data between the different companies on the continent**.
- **Blockchain technology** assists in building trust between companies in a fast and distributed way. On the one hand, it enables the generation of an immutable audit trail in the recording of supply chain transaction information, and on the other hand, it helps to reduce and automate administrative tasks by facilitating the creation of smart contracts and regulatory activities.
- Finally, in order to monitor the execution of transport plans, it is important to be aware of the status of the network and the position of the freight at any time. **Sensors and IoT devices help to capture the position and status information of the cargo in real time**. With this information, **efficient exception management, contingency planning and monitoring services can be developed** to analyse the overall status of the system.
- All these technologies should support the development of new services that foster collaboration between companies. A **key service is the routing service**, which should help to coordinate the different agents and align them with current and future transport demand needs. This service should **apply optimisation criteria** to coordinate, in the most efficient way possible, **handling and transport assets** in a manner that minimises the cost and environmental impact of executing all transport activities on the network of transport corridors.

Based on these prerequisites, the Open EGTN infrastructure will develop and integrate:

- Visibility services, exploiting the available technologies (low cost satellite, IoT sensors, drones etc.) for monitoring assets (tracking and tracing of the location and status) and processes of companies which will be accessible through ubiquitous technologies such as mobile devices together with an appropriate visualization (dashboard) of EGTN parameters of operations to provide visibility of the supply chain and to support the management decisions at corridor/node level, including the main KPIs of nodes and corridors, the implemented standards, the interoperability procedures etc.
- A data lake and tools for data analytics & aggregation of data resulting from PI services, leading to 'Big data' utilization for the creation of advanced transport and logistics services such as route optimisation, warehousing as a service and supplier collaboration and also for feeding Indices calculation for supporting public & industry decision making.

- Connectivity tools to digital infrastructure available at corridors and nodes (inside & outside EU) and to federated public and private platforms at EU for providing open access to data & services & for creating neutral Data availability to enable visibility, collaborative planning among stakeholders & optimization of supply chains "using" the network and "consuming" its capacities.
- Tools and services for planning of regional logistics in order to enhance operations at a regional level through achieving collaborative logistics & shared capacity models' implementation by the ecosystems in a geographical area or along a corridor.
- Tools to support cross organizational, cross country and cross system workflows with the use of interoperable distributed ledger ('blockchain') and 'smart contract' technologies.
- Synchromodality modelling & PI simulation capability for supporting Industry decision making.
- Models to support optimum network setup and routing optimisation. In the next paragraphs, the characteristics and functionalities of the **routing decision support models** and the **transport gravity models** which are being developed in PLANET are briefly described. (models as a service)

5.5.1 Routing decision support models

Routing decisions in logistics vary considerably with the context of application. PLANETs Living Labs offer wide applicability in that sense with routing decisions ranging from intercontinental to urban. The use cases that arise from the Living Labs, offer an excellent opportunity to understand the operational requirements for addressing and operationalizing them in an EGTN context. Multiple use cases are examined, one focusing on long-haul intercontinental sea routes while the another one on challenges associated to urban distribution. Despite similar incentives for operational efficiency, cost reduction and environmental sustainability, the context of each decision is different, and produces unique industrial requirements.

5.5.1.1 Urban distribution

A challenge proposed by Living Lab 1 partner, CITYlogin, was that of dynamically redesigning urban delivery rounds, to alleviate delivery delays. This challenge is highly relevant to the concept of EGTN as it utilises the benefits associated to dynamic tracking of parcel deliveries and vehicle fleet. The proposed operational problem focuses on delivery rounds that are typically fully designed prior to initiating their implementation every day (for CITYlogin this is 9am local time). The design of delivery rounds takes into account, the fleet (i.e. the number and capacity of delivery vehicles available) and local accessibility constraints such as Low Emissions Zones (LEZs) or Zero Emissions Zones. LEZs that are increasingly popular in European cities [13] as they are one of the most effective measures towns and cities can take to improve air pollution. Low emission zones reduce emissions of fine particles, nitrogen dioxide and (indirectly) ozone. LEZs are areas where the most polluting vehicles are regulated. In practice this means that vehicles with higher emissions cannot enter the area.

As delivery rounds commence, uncertainty in traffic conditions, limited parking availability, handover conditions uncertainty and the lack of accurate information may incur significant delays. It is often the case that the original planning and design of the rounds requires to be updated. This is because delivery operational constraints, such as delivery time windows and driver shift hours, are not met anymore and at the same time they cannot be violated. In such cases, a fleet operator tries to identify delivery rounds that might finish early and dispatch them for helping the round running late. The process of identifying van availability, van suitability and then redesigning the delivery rounds, that involves identifying which parcels will be moved from the original van to the helping van, and where the two should meet for the parcel exchange will take place. This process, which is currently performed manually can be automated and integrated into the EGTN platform and operationalized to enable the identification of considerably more efficient solutions through improved consolidation.

The EGTN should therefore be able to accommodate the dynamic information on the routing of vehicles, make fair decisions and efficient decision on collaboration opportunities, and be optimization-ready for undertaking fleet management type decisions and communicating them to the operators.

5.5.1.2 Containerships routing

In the context of liner shipping, containership schedules rarely change with minor deviations typically arising due to queues for calling a port or for breakdowns. However, the increasing size and capacity of vessels makes them a significant asset for serving the supply chain, that also incurs significant economic and environmental costs for less-than-optimal operation. It is becoming increasingly significant to coordinate oceanic operations with hinterland operations with port operations and determine if ports in a vessels route can be omitted. The decision is associated to the dynamic conditions that dictate port operators and their serviceability, as well as the hinterland infrastructure and its ability to handle additional shipments. As ports are increasingly being operated by logistics providers (UNCTAD, Review of Maritime Transport, 2020), there is limited ability to dynamically adjust and prioritise cargoes or vessels, which has become an inherent decision of the port operator. Therefore, vessels calling at ports where a different logistics provider is operating the port, might face additional delays. Such delays can be avoided by omitting a port, and instead visiting a nearby one, where the hinterland can accommodate the additional cargo load. EGTN should therefore consider the formation of port clusters and provide the queueing information to vessel operators, to determine dynamically which port they should optimally call. Vessel operators, who have the information on the final destination of all the cargoes on a vessel can then make an informed decision on which port to call from a cluster of nearby ports, or whether to completely omit a port along a route, and choose a different container discharge point.

5.5.1.3 Node operations and warehousing

In a warehouse context, multiple processes are facilitated between shipment arrival and departure, that are all constrained by space and workforce capacity, and represents a major component of the operational cost. The inefficient assignment of staff to workstations is identified as a major bottleneck for warehouse operational efficiency and increase of service level. The key operational objectives of a warehouse include:

- Customer satisfaction via effective resource utilization.
- The shipment of the right product in good condition and within the target shipment time.
- In effect, warehouses address the differences in time and space between suppliers and customers, while adapting to the fluctuating market conditions. The processes facilitated in warehouses include:
- Temporary storage
- Protecting goods
- Service support in customer order fulfilment
- Goods packaging
- After sales service support
- Quality inspections
- Testing
- Assembly
- Repairs

The accurate manning of all operational stations in any warehouse poses, an operational efficiency decision, until the actual shift takes places, and it becomes an operational capacity constraint on cargo throughput. Optimal staffing, or allocation of workers to tasks, is key to tackling the challenges of high demand fluctuations on a daily basis. In the warehouse, this problem is dependent on workers qualifications, i.e., skill sets, which are very specific to each employee. The utilisation of rich historical information and dynamically updated routing statuses of cargo, offer a unique opportunity to integrate predictive capability into an EGTN platform, that will then enable the more efficient station staffing of warehouses by its operators.

6 EGTN Governance layer specifications

6.1 Introduction

The EGTN governance goal is to ensure that the EGTN members engage in collective and mutually supportive action, that conflict is addressed and that network resources are used efficiently and effectively. EGTN governance refers to the PI network and not of the TEN-T, the current governance scheme of which is presented below and will continue to exist in parallel and interface with the EGTN governance model whenever possible and needed. The purpose of the present chapter is to define the specifications of the EGTN governing scheme in order to achieve the aforementioned goals, building on the work undertaken in the PI roadmap of ALICE and defining the prerequisites at governance level for the realization of the EGTN vision as a network operating under the PI paradigm.

The governance of a transport network can be considered as a loop including the following stages: The planning of its development, establishing the required rules and procedures (regulating) for all its aspects, facilitating the implementation of plans and finally monitoring of the development progress and level of achievement of its objectives in order to adapt/correct initial plans (re-planning). In this context, the proposed governing scheme for the EGTN should be able to support all the above-mentioned stages of network governance. Starting from the planning and re-planning process, it should be able to include all relevant stakeholders in the decision-making using the proper tools and processes and to ensure that they have the required access to information to come to their decisions. With regard to the establishing of rules and procedures for the development and operation of the EGTN, priority should be given to policy and legislative initiatives which will support PI in terms of technology implementation and infrastructure development (e.g. rail interoperability, green investments). Facilitating the EGTN realization will require a competent governing entity at each level (e.g. regional level) which will ensure that collaborative logistics and the shared capacity model which are the backbone of PI can be achieved, by bringing onboard all relevant stakeholders. Finally, a framework for collecting and sharing data (KPIs etc.) related to the development and the efficiency of EGTN should be established to support decision making. All the above-mentioned functions of the EGTN governance are closely connected to and will have the strong support from the functions provided by the PLANET technological solutions which will be part of the technological layer of the EGTN.

6.2 TEN-T governance structure

6.2.1 The corridor approach

The Trans-European Transportation Network (TEN-T) is a recent multimodal transport initiative, having a clear corridor approach and focusing particularly on the most strategic parts, i.e. the Core Network Corridors (CNC). For implementing the CNC, a governance structure is established, including a **European coordinator**, a **secretariat** supporting the coordinator and a **corridor forum** for each corridor. As described in the regulation documents, the coordinator has an important role in facilitating the CNCs implementation by ensuring that a work plan is established and by identifying appropriate measures, foremost the infrastructure investments in the corridor. The work plan is approved by the **concerned states** assigned to each CNC. Corridor forums are a new tool aiming to bring key stakeholders for each corridor respectively together for consultative purposes and in addition working groups can be connected to the Corridor forums.

The Corridor forum has according to the regulation a consultative role and is set up in agreement with the concerned states. The composition of representatives in the Corridor forum can be agreed between concerned states and the European coordinator, and can comprise stakeholders including local and regional authorities or operators. In addition, working groups on specified topics can be arranged. Coordinators have also been used in developing the TEN-T priority projects preceding the corridor approach, achieving good results.

The corridor approach has been a part of the earlier deployed initiative of Rail freight corridors. Since these rail corridors to a large extent overlap with the Core network corridors, adequate coordination between the initiatives is considered to be important and representation from the Rail freight corridors is expected in the Corridor forums.
The corridor approach aims to bring all concerned stakeholders together and enhance a coordinated infrastructure planning and thereby strengthen the connection between infrastructure planning in different levels of society. [3]

Table 5: Current TEN-T governance structure

Governance structure components	***Role***
European Coordinator:	Facilitate the implementation
	Ensure that a workplan is established
	Identify appropriate measures (e.g. infrastructure investments in the corridor)
Secretariat:	Provide support to the Coordinator
Corridor forums:	Bring the stakeholders together for consultative purposes
	Exchange of information and multi-level interaction between stakeholders
	Reach common overarching objectives
Concerned states:	Approve the workplan
Additional working groups (on specific topics):	Several actors with similar interests can come together and form one voice

6.3 Shaping EGTN governance

6.3.1 Governance of the Digital Internet

Governance can be defined as the development and implementation by public governments, the private sector and civil society, in their respective roles, of shared principles, norms, rules, decision-making procedures and programmes to shape developments and their use.
Governance of the Physical Internet is like governance of the digital internet. Digital Internet governance is defined as "the development and implementation by governments, the private sector and civil society, in their respective roles, of shared principles, norms, rules, decision-making procedures and programmes that shape the evolution and use of the Internet" [4]. The digital Internet consists of thousands of interconnected networks run by service providers, individual companies, universities, governments, and others. The Digital Internet is a complex communications system that connects billions of devices around the world and allows each device to communicate with every other device using a common protocol. Internet users can be governmental, commercial, or private entities.
Internet services are operated by several Internet Service Providers (ISPs), which ensure a smooth flow of all kinds of digital information. These providers assign a unique number to each device called IP and it will be unique throughout the network.
The standards or protocols of the digital internet are called TCP, which indicate how information is sent over the internet. The information is sent by dividing all the information into small packets of information that travel through the network and when they arrive, they are joined together again. How they are sent and how they are joined together is determined by the TCP protocol. **The Internet is decentralised,** there are many ways to reach the same destination through the network. [5]

6.3.2 Governance of the Physical Internet

In projects such as Sense [6] and ALICE work groups, various levels of governance have been proposed depending on how the physical internet will be implemented over the next few years, as shown in Figure 8.

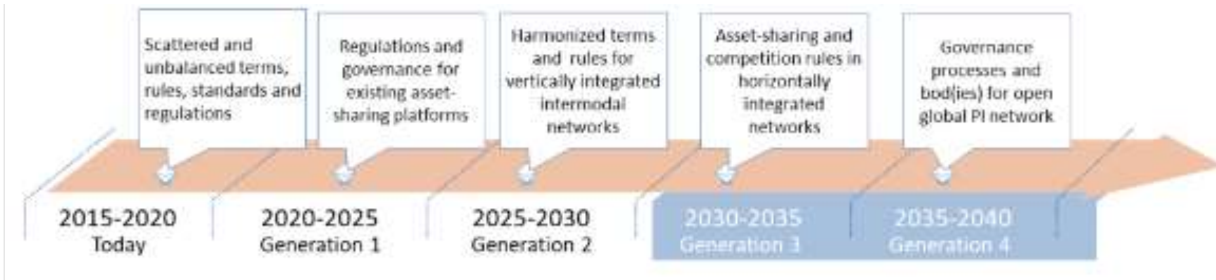

Figure 10: Levels of physical internet governance [6]

The main characteristics of each of these levels are described below from the simplest current levels to the most advanced levels.

Level 0

At the grassroots level, the governance of supply network collaboration and coordination is currently a scattered and unbalanced set of terms, rules, norms and regulations. There is no governance framework that facilitates and supports horizontal collaboration and vertical coordination between different supply networks. Governance of horizontal collaboration has mostly been based on individual cooperation agreements between individual shippers, designed on an ad hoc basis and studied by law firms and consulting teams.

A list of different examples of existing collaborative transport and how they are operated:

- **Pallet networks.** They represent a growing segment in the logistics sector, which bases its business model on the distribution of pallets through continental networks by sharing capacity between different shippers. Its governance is based on a membership programme in which members are accepted if they meet certain requirements, collaborate through a shared technology platform and can participate in an informal forum where they could share their business ideas and participate in the development of the network in general. Palletways [7] would be an example of this.
- **Clustered networks.** These are networks of independent local or international transport companies connected to one or more strategic hubs through which transport services to various destinations can be organised by optimising the capacity of the member companies. Governance is usually carried out through a board of representatives of the parties involved: the member carriers, the hubs and representatives of the authorities. Cargoline [8] is an example of this.
- **Open warehouse networks.** These are networks of warehouses where capacity is shared between individual users, which can be different companies or manufacturers. This simplifies the supply chain and reduces costs by sharing warehouse capacity. The warehouse network manager is typically a non-asset-based company, operating through an ICT infrastructure, which is responsible for the governance of the warehouse network through a 'platform' business model. We can find an example of this in [9].

Level 1

It is a first step towards a shared governance framework for Physical Internet networks, which will emerge from existing asset sharing platforms under development. These first steps will be explored and used to constitute the first concrete example of common terms of reference for sharing logistics assets and services in different supply networks. They will be addressed through specific regulations at EU level. It will require mapping and analysis of existing asset sharing networks, their forms and business models and reaching consensus on basic rules for the treatment of individual platforms.

Level 2

It will focus on the vertical integration of different supply chains in physical Internet networks. This will require the establishment of a governance framework with harmonised conditions and rules for vertically integrated intermodal networks. This will require the ratification of the Rotterdam rules that will facilitate the adoption of collaborative management of intermodal transports and the definition of the next generation of Incoterms.

Level 3

The governance framework will be extended to support collaboration and asset sharing in horizontally integrated supply networks. In addition, the boundaries between vertically integrated supply chains will be removed as different agreements are made between key logistics players. This will allow asset sharing and opportunistic routing and re-planning of shipments across PI nodes belonging to different networks. Organisational models and rules for asset sharing in horizontal networks, defining a governance framework and defining the business model for the flow of PI data will be necessary.

Level 4

At this last level the governance framework will already be fully defined and implemented, including everything necessary for a free and global physical Internet network. The governance framework for Generation 4 PI will cover all relevant business and regulatory aspects that need to be addressed in order to make the nodes and services of the PI network available to the community. Governance processes will be needed for the different layers/areas comprising both centralised and federated governance models and apply standards to leave the network open, involving high-level public bodies following the example of 4G and 5G.

6.3.3 Alternative approaches and proposed governance form for the EGTN

In terms of the governance of the EGTN network, it could be said that it is an adaptation of PI governance applied to the different corridors. Two approaches can be envisaged for the origin of the construction:

- **Bottom Up:** It would be an ascending approach in which the different stakeholders would agree among themselves to develop parts of the network as independent supply networks built on the PI model, thus forming different "islands" with their own rules. The key point would be that in order to bring these "islands" together, the help of a central body would be needed to establish common standards for the PI.
- **Top down:** this approach would be less ideal and would consist of a central body planning and organising the creation of a global PI network. It would require strong public sector action, supported by massive investment, to enforce standards and ensure that market competition rules are applied.

The bottom-up strategy would be the one on which the above-mentioned tiers would be based and would be the only viable strategy for a more progressive growth of the network.

An acceptable estimate for the EGTN network would be to reach the PI governance level 3 mentioned above, as this would be the first of the levels at which the physical Internet network as such is developed. To reach this level would require [6]:

- Conduct an analysis of existing asset exchange networks at the European level.
- This would require reaching a consensus on the basic rules for the treatment of individual platforms, reaching a consensus on how and by whom these platforms would be managed, in which directions they could be expanded, and always ensuring security and non-monopoly, imitating the classic Internet model.
- Define new International Trade Terms more focused on collaborative transport and the new EGTN network.
- Clearly define what data exchange is needed between the different stakeholders to create value.

- Define a European level governance architecture where some aspects of major importance can be managed by global organisations while others can be controlled by the network itself.

6.3.4 Required legislation and policy initiatives to facilitate EGTN development

Based on the results from the D1.6: Legislation and EU policy to impact EGTN, which has created an inventory of the ongoing and forthcoming legislative and policy initiatives that might impact the design and realisation of the EGTN, the following elements are considered critical for all three dimensions of the EGTN (infrastructure, technological and governance):

- **Revision of TEN-T guidelines:** The revision of the TEN-T Guidelines Regulation offers an ideal opportunity for the European legislator to enact the changes needed on the European Union level and to integrate more elements regarding intermodality compliance. The fulfilment of the envisioned modal shift to achieve the decarbonisation objectives of the EU transport sector requires the following changes to the TEN-T Guidelines Regulation: (1) clarification of the TEN-T technical parameters for the railway infrastructure, (2) review of the railway line codification for the 4-meter loading gauge, (3) introduction of parameters to guide the upgrading of transhipment terminals and (4) Introduction of the "freight preferred railway line" category.
- **Revision of the RFC Regulation:** the planned revision should include additional requirements regarding shortfalls like transparency (reporting, one-stop-shop websites, clear and univocal KPIs), enhanced organisation and governance structures (role of corridor managing directors, composition of the RAGs and TAGs, public meetings) and improved tasks and competences (adequate capacities, quick win projects, traffic management).
- **Single European Railway Area:** a Single European Railway Area means that, in principle, any European railway undertaking may operate services on any rail network in any country of the European Union. In recent years, the EU has adopted four railway packages which aim to open the railway market to competition, increase the interoperability of national railway systems and define the framework for a Single European Railway Area. The EGTN will only be demonstrated its benefits with the full realisation of a harmonised European infrastructure network (for example parameters such as train length, axel load, speed…).
- **CT Directive:** Combined Transport provides the most efficient link between road and the other sustainable modes of surface transport like electric rail and the waterborne solutions. While the demand to transport conventional cargo is decreasing, the unabated growth of the surface freight transport market is fuelled by processed goods typically carried in trucks. The European Union must reverse the trend under these circumstances and double, even triple the tonne-kilometre performance of non-road modes. The intermodal system of freight transport will need to play a very substantial role in this transformation, which is only possible if transport policymakers ensure that the rail infrastructure is adjusted to the needs to intermodality and its capacity adequately extended. The new proposal is expected to be drafted by the Commission in the course of the fourth quarter of 2021.
- **Full digitalisation of transport-related documents and creation of adequate document exchange platform:** legislative initiatives such as CIM, SMGS and TIR clearly support the aim to digitalise land transport modes such as road and rail by proposing digital measures within and outside the European Union. The realisation of EGTN will be successful under the condition that all these initiatives are somehow coordinated, enhanced and aligned.
- **Digital transport and Logistic Forum:** the policy initiatives emerging from the DTFL aim to achieve paperless freight transport for all transport modes and the establishment of a federated network of platforms, both of which are related to the digitalisation of the transport sector and thus are crucial for the implementation of the PI concept.

- **The sustainable finance policy:** it has the objective of involving the private sector in the funding of sustainable activities and infrastructure in order to complement public funding in the effort to reach the objectives emerging from the Green Deal. In this context, it is expected to have a significant impact on the private funding of PI infrastructure and technologies which needs to be developed on the EGTN prioritised PI network.

7 Conclusions

In this first version of the deliverable, an initial attempt is made to define the characteristics of EGTN based on the work undertaken in WP1 tasks leading to the first set of specifications for the network, broken down to each of the three identified constituting layers. It is an effort towards the establishment of a green, intelligent, resilient and inclusive network which on the one hand will be significantly more efficient compared to the existing TEN-T (environment, cost, speed) while on the other hand it will have the safeguards to secure its operations under constantly changing global conditions mainly in terms of the geo-economic developments, climate change and international politics.

With respect to the physical layer of the EGTN, the initial results from the assessment of the impact of the three new trade routes on the TEN-T network is that the intercontinental rail freight connections between China, Russia and Europe (belonging to the Belt and Road Initiative) and more specifically the corridor that runs through Kazakhstan, Russia, Belarus and Poland appears to be the most mature route and the only one that will be of significant importance in the near future. The main entry point to the EU through this route is located in Małaszewicze while the most important start and end point for trains to and from China is the inland port of Duisburg. As for the main identified bottlenecks that hinder and delay flows on this route, the Małaszewicze /Brest border crossing is identified as the most important one mainly due to time-consuming custom procedures, followed by the congestion phenomena of the European rail network. The International North-South trade corridor (INSTC) has the potential for serving significant cargo loads but its implementation time horizon is uncertain and also it will be more interesting as a European trade route if European trade can be combined on INSTC trains with Russian cargo. Finally, the freight flows through the Arctic route are not expected to increase significantly, thus keeping the impact on the European TEN-T network negligible.

Regarding the governance model of the EGTN, it appears that a bottom-up approach is the only viable strategy for a more progressive growth of the PI network. According to this approach, different stakeholders will agree among themselves to develop parts of the PI while a central body will be needed to establish common standards for the PI in order to bring these parts together. Moreover, the governance framework will need to support collaboration and asset sharing in horizontally integrated supply networks and also the removal of boundaries between vertically integrated supply chains to allow asset sharing and opportunistic routing and re-planning of shipments across PI nodes belonging to different networks. Legislative and policy initiatives are also required to support the development of the EGTN, including mainly initiatives towards the achievement of interoperability, the greening of investments and the digitalisation of transportation.

The technological layer of the EGTN will be the backbone of the network, supporting and connecting all of its aspects, namely the planning of its development, its governance and operationalisation, through the implementation of innovative technologies and logistics concepts. This will be achieved through the development of a cloud-based Open digital infrastructure that will include tools and models but also through a strategic modelling capability that will be developed outside of it.

In addition to the above, one general conclusion that is inferred from this document is that in order for the EGTN to be able to acquire the desired attributes, the three layers must be developed as a whole and in alignment to each other since the EGTN is intended to provide solutions to complex problems. For example, a possible part of the solution to the request for network resilience includes the development of clusters of nodes e.g. in the land entry points to the European network, which will help distribute the risk regarding the continuity of operations and deal with fluctuations of freight flows that can cause capacity problems. However, this physical layer characteristic of the network, while critical, is not sufficient by itself. It needs to be supported by the technological layer which will provide the proper digital infrastructure (e.g. regional logistics platforms) to facilitate the operation of the cluster and the development of collaborative logistics and shared capacity models. Moreover, the governance layer will need to provide the proper structure in order to bring all relevant stakeholders together and jointly reach decisions, collaborate and develop joint business models while at the same time it will monitor the results of the implemented solution and plan changes deemed necessary. In this simplified case, each EGTN layer has a special role to play but they need to be combined together in order to achieve the objective of resilience and this is something that needs to be considered in their development.

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