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

D1.11 EGTN Reference Specifications final version

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[1] According to PLANET's Quality Assurance Process

Table of Contents

List of Figures

List of Tables

Glossary of terms and abbreviations used

Abbreviation / Term	Description
ALICE	Alliance for Logistics Innovation through Collaboration in Europe
BC	Blockchain
CCI	Corridor Connectivity Index
DSS	Decision Support System
DTLF	Digital Transport and Logistics Forum
EGTN	Green EU-Global Trade & Logistics Networks
ETS	Emission Trading System
EU	European Union
GA	Grand Agreement
IoT	Internet of Things
KPI	Key Performance Indicators
LL	Living Labs
MAMCA	Multi-Actor, Multi-Criteria Analysis
NUTS	Nomenclature of territorial units for statistics
OD	Origin-Destination
PEP	Principle Entry Points
PI	Physical Internet
RFC	Rail Freight Corridors
T&L	Transport and Logistics
TCP	Transmission Control Protocol
TEN-T	Trans-European Transport Network
TEU	Twenty-foot Equivalent Unit
UC	Use Case
WP	Work Package

1 Executive Summary

This document is the second and final version of the project deliverable reporting on the work undertaken in task 1.5 of WP1, aiming to define the reference specifications for the realisation of the Green EU-Global Trade & Logistics Network (EGTN).

In the first part of the document, the EGTN planning requirements are presented as these were identified in the first period of the project and which define the EGTN as a resilient, responsive to changes network that is optimised ready, considering for its development the view of the logistics business/industry while at the same time supports EU cohesion and strengthens European exports. In order to achieve these requirements, the integrated modelling capability of the project which has been developed through the adaptation/combination of various models for assessing the impact of the emerging new trade routes on the TEN-T, was utilised to support the planning of the EGTN. Through this capability, initially three strategic-level future scenarios have been drafted and tested for the year 2030 aiming to provide a realistic view of the future, including a baseline scenario, a scenario with the development of the rail sector as well as a scenario with a strong development of the disadvantaged regions of Europe. In addition to these scenarios, in the context of task 1.5 two more scenarios for the 2030 have been drafted and tested, one scenario for the impact of the wide implementation of PI-enabling technologies and one for the impact of the most significant upcoming policy and legislation initiatives on the future freight flows.

Based the results of these simulations, the second part of the document focuses on defining the new areas of interest for the development of infrastructure and PI-services as well the entry points for the rail flows coming from China and corridors which are expected to gain increased significance. The eastern and south-eastern regions of Europe are the main areas which are expected to serve these flows but the analysis has also showed that regions which are currently not related to the Eurasian rail flows, like the Iberian Peninsula and parts of France and Italy may become relevant due to the implementation of technology in the future. In these areas, key nodes were identified as important nodes of the EGTN together with corresponding parts of the TEN-T corridors which were prioritised for the implementation of the PI-technologies and services. Utilising also the results of the Corridor Connectivity Index calculations for corridors considered important for the EGTN, namely the Rhine-Alpine, the Baltic-Adriatic and the Rhine-Danube corridors, additional key nodes of the EGTN were identified.

In the third part of the document an assessment is performed of all the technologies that have been tested through micro-simulations and verified in the project LLs regarding their value for leveraging the PI (Physical Internet) concept. The assessment revealed that blockchain, together with the IoT supporting AI algorithms are the technologies that are most efficient toward this direction. Based on these technologies, a list of required functionalities has been drawn and was compared to the services developed I the context of the project for the open, cloud-based EGTN infrastructure, proving that these services indeed can support the realization of the EGTN concept.

Finally, in the last part of the document, drawing from the evaluation results and conclusions from the project LLs and a literature review on the governance models of goal-directed networks, a two-level governance model is proposed for the realization of EGTN. This model includes a lower (node) level collaborative governance scheme for the PI-networks of the EGTN nodes with a strong collaboration and participation of the private stakeholders and a high-level governance entity (administrative organisation) that will supervise and support the network of PI-networks. The latter will interface with the existing structure for the TEN-T governance in order to achieve synergies and alignment of activities.

2 Introduction

This document is the second and final version of the project deliverable reporting on the work undertaken in task 1.5 of WP1, aiming to define the reference specifications for the realisation of the Green EU-Global Trade & Logistics Network (EGTN). The first version of the document provided an outline of the EGTN vision based on the initial results of the project activities while the current version builds on the final results of the work undertaken in the project tasks and were tested and verified in the Living Labs. Aiming to become a compendium of the knowledge that was produced during the project, it includes the final reference specifications for all three constituting layers of the EGTN vision, namely the infrastructural, the technological and the governance layers.

2.1 Mapping PLANET Outputs

Purpose of this section is to match PLANET's Grant Agreement commitments included in the formal deliverable and task descriptions with the project's respective activities and outputs. In the following table (Table 1), the work undertaken for fulfilling the requirements emerging from the GA commitments is mapped within the document and briefly described.

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

PLANET GA Component Title	PLANET GA Component Outline	Respective Document Chapter(s)	Justification
DELIVERABLE			
D1.11 EGTN Reference Specification final version	The present deliverable in its final version will form the EGTN vision for 2030 by defining its physical, governance, and technological layer specifications. Furthermore, it will describe the 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 **Chapter 6:** EGTN Governance layer specifications	Within the respective chapters of the present document, the methodology that was followed for defining the characteristics of the EGTN vision is described. The physical network of EGTN for the 2030-time horizon is presented, in terms of new areas of interest, the development of new/of revised significance entry points and nodes and the prioritisation of corridors/areas for investments in the PI development. The minimum required technologies and services for the development of PI which are included in the Open cloud-based EGTN infrastructure are presented and assessed regarding their effectiveness. Finally, the proposed governance model for the EGTN is described.
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	**Subchapter 3.2:** Integrated macro (strategic) modelling	• Description of the TEN-T modelling process and scenarios for 2030 (baseline, Rail Freight Corridors and Disadvantaged regions scenarios).

	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.	capability of the EGTN	• Description of the methodology and scenarios input parameters established for the re-iteration of the strategic model of T1.2 including the impact of technology from T1.4 (Use Cases 1,2,3) and also the impact of Policy & legislation initiatives.
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 routes in order to ensure that the EGTN fulfils its 'geo-economics' attribute.	**Subchapter 4.1:** New areas of interest and entry points **Subchapter 4.2:** Prioritisation of PI corridors	• Analysis of all the strategic model scenarios simulation results and definition of new areas of interest, entry points. Prioritisation of corridors for PI implementation. • Description of the concept of Intelligent, PI nodal points. • Description of the Corridor Connectivity Index as a monitoring tool on the development of the nodes in the network, CCI calculation for three corridors of importance for the EGTN
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	**Subchapter 5.1:** Required technologies and functions for the EGTN **Subchapter 5.2:** EGTN technological infrastructure and services	• Identification of technologies and functionalities required for the EGTN to operate under the PI paradigm • Description and assessment of the value of services included in the Open Cloud-based EGTN as facilitators to the EGTN operationalisation under the PI paradigm.

	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.		
ST1.5.4 EGTN governance layer specifications	The present sub-task will define the specifications towards the development of a goal-directed form of 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 considering 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 6.1:** ALICE approach on the PI governance **Subchapter 6.2:** Proposed EGTN governance structure	• Based on the descriptions of the PI governance models included in the ALICE Roadmap to the Physical Internet, the main principles and rationale for the establishment of a governance structure for the EGTN is presented. • An EGTN governance structure is described in alignment to the existing TEN-T governance structure, defining stakeholders' roles and responsibilities in order for the EGTN to operate and develop under the PI paradigm.

2.2 Deliverable Overview and Report Structure

The present document is structured in a similar way as its first version (D1.10), following the structure of task 1.5 description in the GA. The first two chapters include the executive summary, the introductory section, the description of the document structure and the justification of the document alignment to the GA requirements. In the third chapter, the approach and methodology for defining the vision for 2030 is described, providing details on the linking of the two modelling dimensions of the project: the geographical and infrastructural dimension that is covered through the strategic modelling process (Task 1.2) and the technological and organisational dimension covered by the innovative technologies and concepts simulations (Task 1.4). In the following three chapters, the reference specifications for the three interacting layers comprising of the EGTN vision are described. More specifically, chapter 4 provides the specifications for the physical layer of the EGTN in terms of areas of interest for the development of nodes and entry points to the TEN-T as well as a prioritisation of corridors for the implementation of the PI-enabling technologies. In chapter 5, the specifications for the technological layer are presented with respect to the required technologies and functionalities in order for EGTN to operate as a PI network. Chapter 6 provides the specifications for the governance layer of the EGTN regarding the proposed governing structure and the roles of the EGTN members, building on the ALICE roadmap for the governance of the PI. Finally, in chapter 7 the main conclusions are presented as these emerge from the results of the work included in the document.

3 Towards the EGTN vision for 2030

As stated also in the first version of the present deliverable, 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 which will efficiently interconnect infrastructure (TEN-T, Rail-Freight Corridors) with geopolitical developments, as well as optimize the use of current & emerging transport modes and technological solutions. This needs to be achieved while ensuring equitable inclusivity of all participants, increasing the prosperity of nations, preserving the environment and enhancing citizens quality of life.

In the preceding tasks of PLANET, the main focus was on defining the impact of emerging trade routes on the TEN-T considering future scenarios related to the expected growth and infrastructure developments. This activity led to important conclusions regarding the significance of these routes and the expected changes of freight flows coming from China, allowing new areas of interest to be identified for the development of physical infrastructure. More specifically, in the context of the project's strategic simulations three emerging routes were considered; the North (Arctic) sea route, the international North-South freight corridor and the Eurasian land (rail) freight corridor. Of these routes, the analysis concluded that in the foreseeable future mainly the Eurasian land (rail) corridor is expected to have a significant impact on the TEN-T network. In addition, the impact of the Eurasian land corridor on the development of disadvantaged regions was examined. The analysis was performed by utilizing the strategic modelling capability developed within the project and the results were reported in D1.4 and D1.5.

At the same time, the project has undertaken several activities for assessing the impacts of innovative technologies and concepts on logistics operations but this time on a micro (company or local/node) level in order to conclude about the value of these technologies, implemented separately or in combinations, to the operationalisation of the EGTN. These micro-simulations included the PI concept, the IoT, the blockchain, AI algorithms and GS1 standards and the results were reported in D 1.9 and verified in the project pilots' tests.

Both simulation activities described above have helped significantly to get a picture of what the future holds. However, in order to define the EGTN vision for 2030, it is important to have a more consolidated view of the future considering how the tested PI-enabling technologies may alter the way that the globally connected TEN-T network will operate and how freight flows will be distributed to it. Toward this goal, it was foreseen in the GA that the two modelling dimensions should come together through an enhanced future scenario simulation and provide more realistic results compared to the initial modelling exercises. In addition, PLANET went one step further considering also the expected impact of the ongoing and planned policy and legislative initiatives of the EU which will formulate the environment in which EGTN will be developed and operate.

The results of this final exercise may provide also an answer to the question whether the implementation on PI-enabling technologies can produce the required efficiency gains to reduce the need for expensive and time-consuming investments on physical infrastructure.

3.1 EGTN planning requirements

Based on the D1.10 which has identified the EGTN profile in relation to its attributes, on a macro level the EGTN is a network that should be:

1. **Responsive to changes** in the sense that in the decision support for the physical infrastructure development it will be change-aware for the short- and long-term planning,
2. **Optimisation ready**, being able to support decisions related to the EGTN development by considering technological solutions and quantifying their impact for enhancing synchromodality & PI models for EGTN,
3. **Resilient** by allowing the study of the competition between corridors for categories of products in order to facilitate the balanced development of alternative modal and intermodal corridors and solutions,

4. **Facilitating exports** by having a planning capability that is aware of the connectivity and of the hinterland nodes that can support the better connection of the maritime gates to the production centres and will be able to recognise new entry points that will support exports,
5. **Supporting social cohesion and inclusivity** of disadvantaged regions by having the planning capability the can assess the policy impact of investments in these regions regarding the change of freight flows and the development of trade and economy of these regions, and
6. **Incorporating a decision support system** that can generalise and bring the impact of technology and collaboration from the **business level of supply chains to the corridor level**.

The detailed strategic profile of EGTN for 2030/2050 presented in D1.10 can be found in the Annex.

3.2 Integrated macro (strategic) modelling capability of the EGTN

3.2.1 Methodological approach

In order to achieve the planning requirements described in the previous section, the integrated modelling capability of PLANET project was developed based on the **Panteia Terminal Model**, a flexible transport model offering extensive policy and scenario evaluation options. This model is utilising input from other important Panteia models including the **Panteia NEAC Model,** a European freight flow database and a multimodal transport model designed for analysing medium to long-distance traffic flows as well as the **Panteia World Trade Model,** an input-output model of the world economy. It also utilises input from the **World Container Model** which combines a consistent description of worldwide trade flows, container flows, and transportation services on a global scale combined with a port and multimodal route choice model. Finally, the ‘disadvantaged regions’ scenario, was carried out with close support from NEWOPERA, through the application of the **Traffic Attraction Zone Model** run in 2014 with traffic projection up to 2050. The Traffic Attraction Zone model considers the nodes and their localization is the focal point of the analysis.

More details about all the models that were used to create the integrated modelling capability of the EGTN can be found in D1.4 and D1.5. The reference networks of all modes of transport that were used for setting up the model are presented in Figure 1.

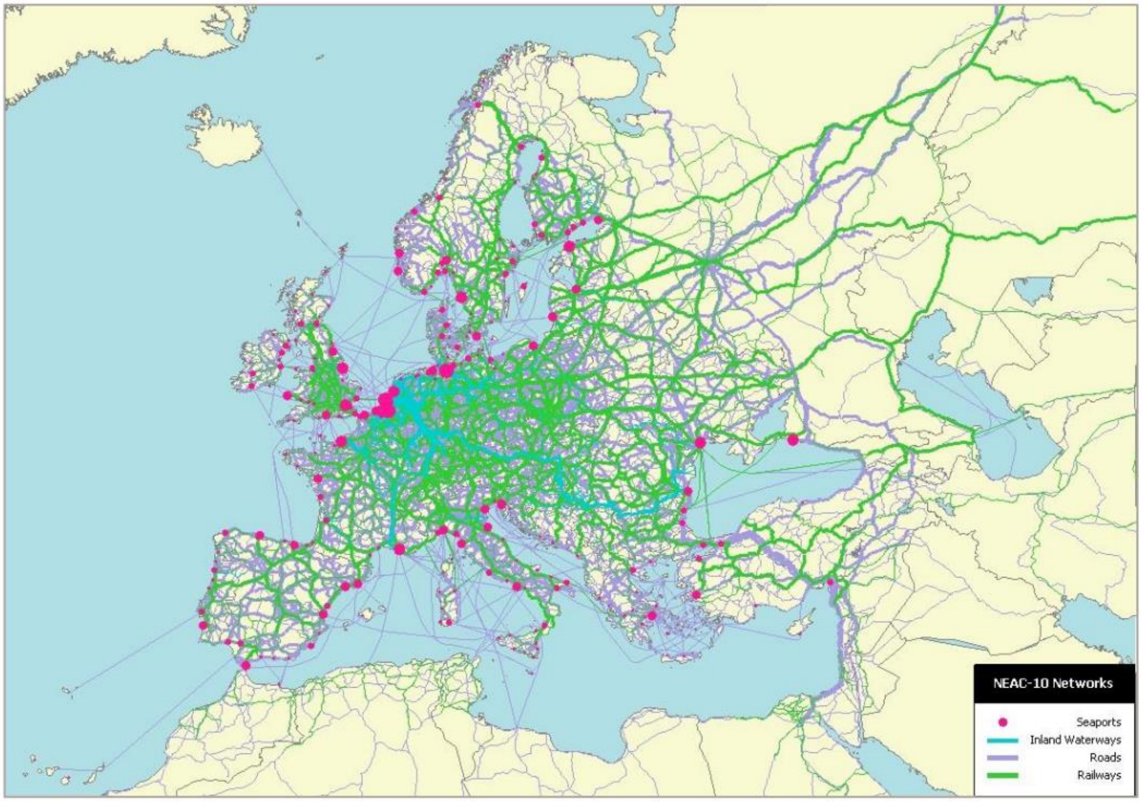

Figure 1: Multi-layered European Transport Model with reference networks of all modes of transport

These models have been updated and adapted regarding the transport supply and demand parameters and combined in order to be able to build and run plausible future scenarios that will provide a realistic view of the future freight flows. The macro level model developed under task 1.2 of the project (see also PLANET deliverables 1.4 and 1.5) contributes to gaining a more comprehensive understanding of how EGTN operates and how changes to individual components can affect the overall performance of the system. It allows us to test the implementations of micro-scale models on a larger scale by simulating the behaviour of the entire system.

In the PLANET project, various future scenarios were analysed, including the impact of new technologies and the impact of European policies on the EGTN. However, the analysis of technologies was conducted at a micro level in the PLANET living labs. To understand the impact of these technologies on a possible implementation at the European scale, the outcomes of these living labs require analysis with the macro-level model. The macro level model also provides the opportunity to analyse the impact of policies on a more detailed network level. Therefore, to better understand the impact of the PLANET results on the EGTN, this chapter analyses two scenarios, namely a "technology scenario" and a "policy scenario", using a macro-level model.

Overall, the integrated modelling and simulation capability of the project run four scenarios based on the 2030 baseline scenario, namely the “Rail Freight Corridor” and the “Disadvantaged regions” both of which are included in D1.5 and the “technology” and “Policy and Legislation” scenarios which were drafted in the context of the present deliverable.

For all scenarios the appropriate parameters have been identified that can be used to integrate the impact of the rail infrastructure development, the technology implementation, the EU Policy and legislation implementation and the development of disadvantaged regions. These parameters per mode of transport are presented in Table 2.

Table 2: Main input parameters of the strategic model

	• Costs:

• Road *• Rail* *• Inland Waterways* *• Maritime*	- **Labour costs** *(Wages incl. social costs and reimbursed expenses) for all modes* - **Capital costs** *(Costs of depreciation and interest cost of vehicle) for road* *(Lease of locomotive and wagons, reserve material) for rail* *(Costs of depreciation, interest cost of vessel) for IWW and maritime* - **Fuel costs**; *IWW and maritime* *(Including excise duties) for road* - **Traction costs** *for rail* - **Toll costs** *for Road* - **Access charges** *for rail* - **Other costs** *(Insurance, road tax, repairs and maintenance, tire costs, overhead) for road* *(Insurance, repairs and maintenance, shunting, overhead, waiting) for rail* *(Insurance, repairs and maintenance, overhead) for IWW and maritime*
	• Speed
	• Load factor
	• Reliability
	• Security
Transhipment	• Costs
	• Speed
Other parameters	• Value of time per commodity type
	• Attractiveness per terminal

With respect to the modelling steps that were followed during the project, these are presented in Figure 2 and described below.

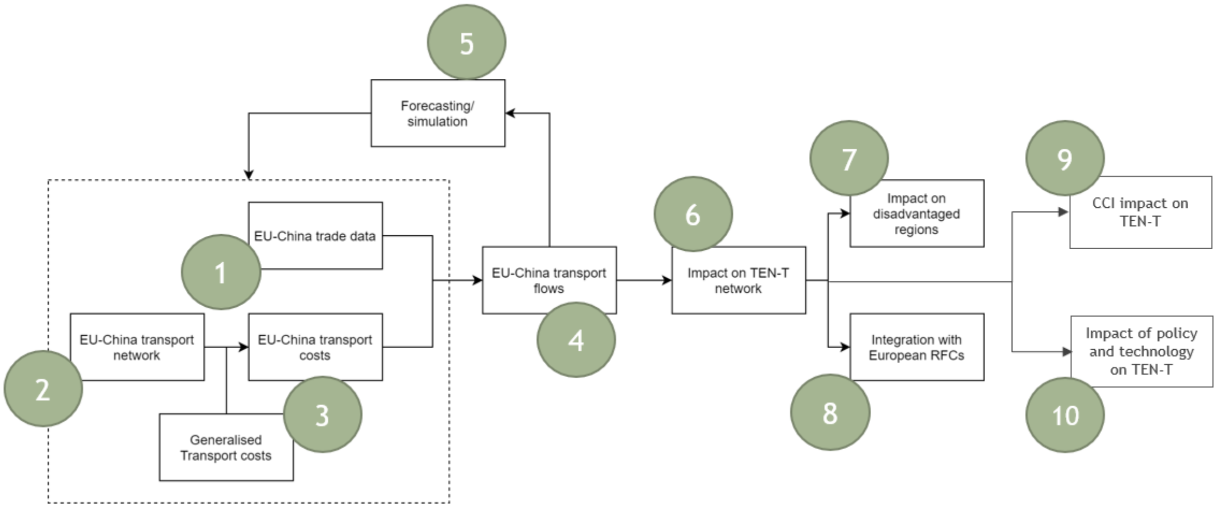

Figure 2: Modelling steps of the PLANET integrated modelling and simulation capability

The numbers in Figure 2 refer to the following modelling steps:

1. Create a matrix of origin-destination trade data between European and Chinese regions.
2. Develop a comprehensive transport network spanning Europe and China, consisting of intercontinental and continental transport services.
3. Determine the generalized transportation costs of the cargo between European and Chinese regions, including costs such as capital costs, value of time, and reliability costs. Steps 1 to 3 form the basis of the model.

4. Simulate the transport flows by sending the trade data (step 1) over the transport network (step 2) using the transport costs (step 3) and via a Dijkstra shortest path algorithm. In this step, calibration is carried out based on transhipment in European ports for intercontinental sea transport and in rail terminals for intercontinental rail transport. For each OD relationship between China and Europe, a corresponding route is searched. The sum of these routes and the corresponding trade volumes constitutes the total trade between China and Europe.
5. Step 5 includes the development of scenarios, in this case the 2030 and 2050 future scenarios, and the two specific ones (disadvantaged regions and rail freight corridors). Depending on the scenario, the data to the base model in steps 1 to 3 are adjusted and a simulation of each scenario takes place (step 4).
6. Based on the simulations of the scenarios, the analysis takes place, which focusses mainly on the impact on TEN-T.
7. A specific analysis was carried out for the impact on disadvantaged regions.
8. In addition, a specific analysis was also carried out for the impact on rail freight corridors.
9. Finally, this model is linked to several other tasks within the PLANET project. First, the output from this model is used for the Corridor Connectivity Index.
10. In addition, this model is used to better understand also the impact of technology and of the policy and legislation initiatives.

In the following sections of the document the four scenarios that were simulated for 2030 EGTN are briefly described.

3.2.2 EGTN Rail Freight Corridors and disadvantaged regions scenarios for 2030

3.2.2.1 Rail freight Corridors

In the “Rail Freight Corridors” scenario, EU rail freight transport is highly efficient and attractive. The network of international Railway Freight Corridors (RFC) which is established (Regulation No. 913/2010) for enhancing cooperation between infrastructure managers, balancing available capacity between passenger and freight transport and facilitate intermodality, is considered to have low costs due to economies of scale, an extensive rail network (Figure 3) , infrastructure investments, fast trains and efficient terminals which contribute to many shippers opting for rail freight transport instead of other modes of transport. As a result, in this scenario the Eurasian rail route will be used much more intensively for trade between Asia and Europe. With respect to the translation of these assumptions to specific parameters of the model, this scenario includes:

- Lower transport costs by rail.
- Decrease in transport time.
- Efficient border crossings.
- More efficient rail terminal operations.

More specifically, the Rail Freight Corridors scenario is derived from the 2030 scenario simulation, with the following modifications in addition to the assumptions made in the 2030 scenario:

- Due to increased investments in rail freight leading to increased efficiency of rail freight, this scenario assumes that all rail PEPs have become more attractive for shippers to use for Eurasian rail transport. This assumption is integrated into the modal by adapting the attractiveness parameter of the rail PEPs in Europe. The attractiveness parameter refers to the qualitative aspects that determine the node choice of shippers (instead of the generalized costs), such as the quality of the hinterland connections per node or shippers’ preferences. The value of this parameter was established in the base year of 2019 based on the calibration of the model, in order to correct for the differences between the observed and the calculated values by the model. For the 2030 scenario, the same values of the attractiveness parameter as for 2019 are used. In this scenario, the attractiveness of the rail PEPs is increased by 5%.

- Additionally, it is assumed that as a result of investments in rail transport along the entire BRI rail corridor, the efficiency of the corridor will increase. The assumption is made that the capital costs for using the BRI will decrease by 5% and the speed will increase by 5%.

In summary, this means that the general costs of rail transport across the entire intercontinental supply chain are expected to decrease by approximately 5%. The extent to which these investments in rail transport take place depends on several factors, including the availability of public funds to invest in the necessary rail infrastructure, as well as the degree to which technological progress makes rail transport more efficient. If the goal of doubling rail transport by 2050 is to be achieved, significant investments are required, whether through European support or other means. More details about the Rail Freight Corridor scenario can be found in D1.4 and D1.5.

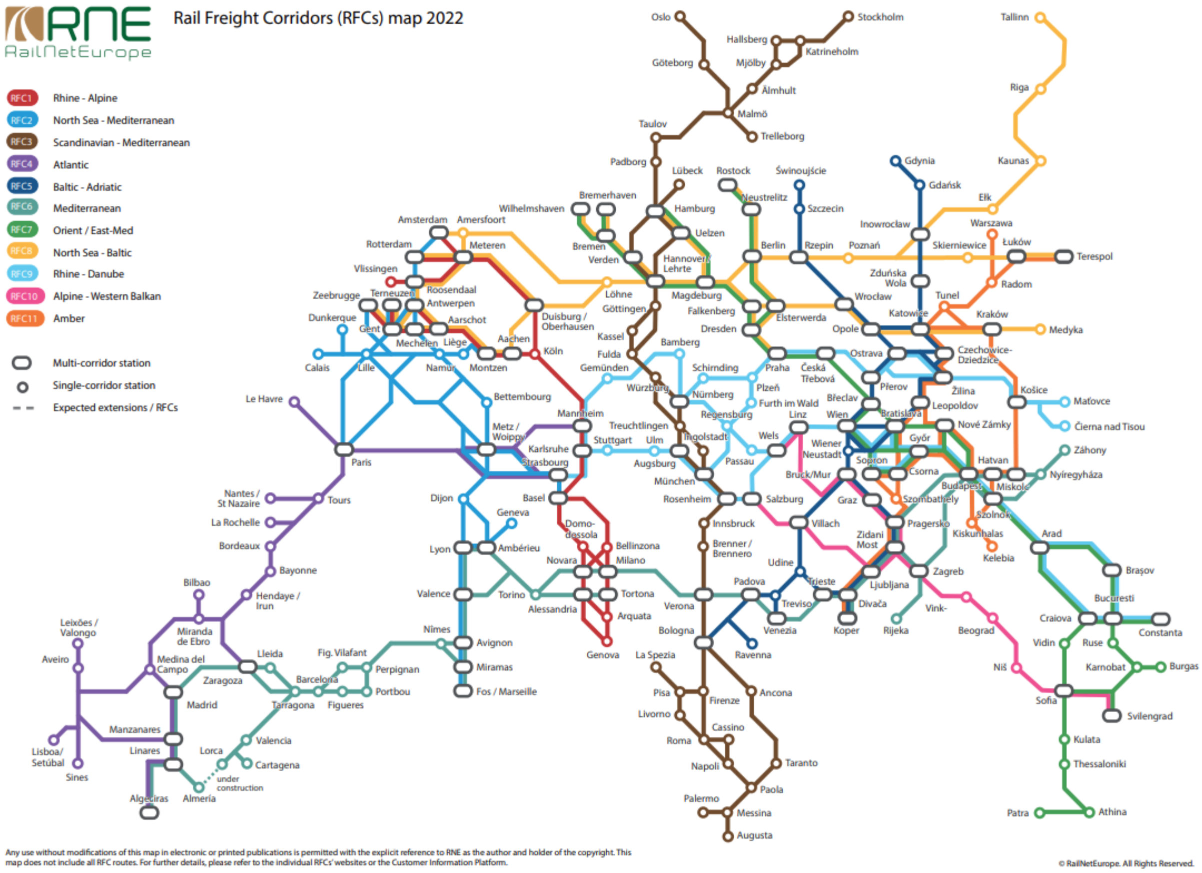

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Figure 3: Map of Rail Freight Corridors according to EU Regulation No. 913/2010

As in any case of future scenarios drafting, it is currently unclear to what extent these assumptions will become reality. The purpose of this scenario was to examine a high-growth case for rail transport, providing an answer to the question of where investments should be focused if policymakers want to facilitate future growth in rail transport.

3.2.2.2 *Disadvantaged regions*

With respect to the "Disadvantaged regions" scenario, it is considered that the disadvantaged regions will develop very strongly in the next years making Eastern Europe the gateway for rail transport to and from Asia. This involves both infrastructural and socio-economic development. From this analysis, key hubs for China Europe rail transport are identified, which can serve as a starting point to develop more centralized or local strategic management initiatives.

Disadvantaged regions in Europe refer to those areas that are facing economic, social, and territorial challenges, compared to other regions in the EU. These regions are characterized by lower levels of economic growth, higher unemployment, depopulation, and lower standards of living, among other factors.

In the context of PLANET and the EGTN concept, disadvantaged regions are defined as those that are most eligible for the support of the Cohesion Policy - EU's funding program aimed at reducing economic, social, and territorial disparities among regions in the EU (Figure 4). It is one of the main instruments for implementing the EU's regional policy and aims to create more balanced development across the EU providing funding for infrastructure, innovation, and environmental projects in the least developed regions, with the goal of promoting growth, competitiveness, and employment. The classification of regions into the categories presented in Figure 4 is based on a Eurostat calculation. For PLANET, the 'less developed regions' are classified as the disadvantaged regions, thus including eastern and south eastern Europe and also Portugal and the South parts of Italy and Spain.

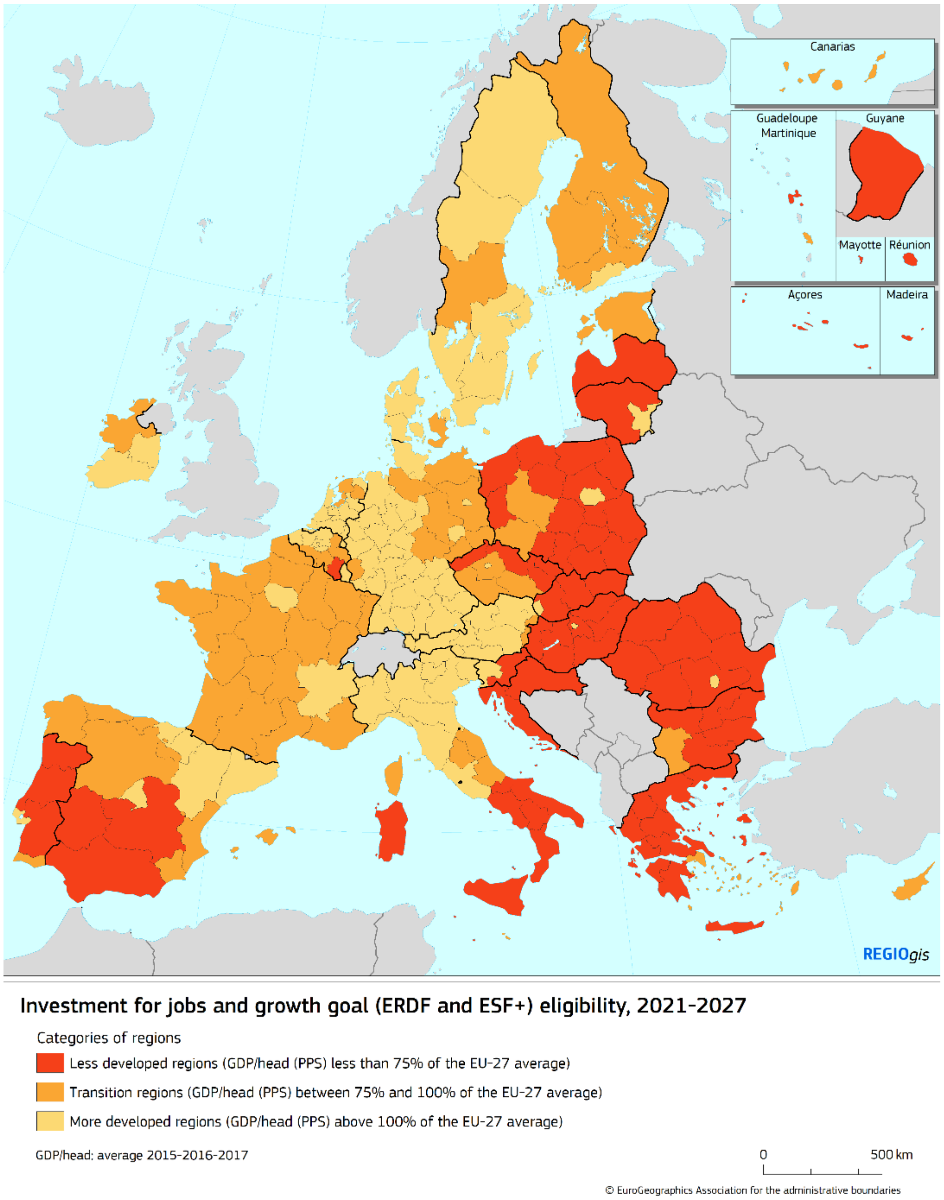


Figure 4: EU Cohesion Policy eligibility 2021-2027

The aim of the simulation was to identify the priorities of infrastructure investments in disadvantaged regions. In doing so, it helps decision-makers determine the most effective and efficient ways to invest in infrastructure in the region. The goal of this simulation is to support the EU's aim of promoting balanced regional development and reducing disparities across the EU.

This simulation is based on the 2030 scenario simulation. In addition to the assumptions in the 2030 scenario, the following adjustments have been made for this scenario:

- Due to increased economic growth leading to increased investments in infrastructure in the disadvantaged regions, this scenario assumes that the rail PEPs in the disadvantaged regions have become more attractive for shippers to use for Eurasian rail transport, compared to rail PEPs in other areas of Europe. This assumption is integrated into the modal by adapting the attractiveness parameter of the rail PEPs in the disadvantaged regions. The attractiveness parameter refers to the qualitative aspects that determine the node choice of shippers (instead of the generalized costs), such as the quality of the hinterland connections per node or shippers' preferences. The value of this parameter was established in the base year of 2019 based on the calibration of the model, in order to correct for the differences between the observed and the calculated values by the model. For 2030, the same values of the attractiveness parameter as for 2019 are used. In this scenario, the attractiveness of the rail PEPs in the disadvantaged regions is increased by 5%.

- Due to the economic growth in the disadvantaged regions assumed in this scenario, there is also more trade between the disadvantaged regions and China. Therefore, the total trade volume between China and the disadvantaged regions has increased by 5%, compared to the trade as it was in 2030.

In the disadvantaged regions scenario, an increase in trade from China is observed due to a more favourable environment for trade and investment. Several factors contribute to this, including:

- Improved access to markets due to better transportation infrastructure, such as better equipped rail PEPs and more direct shuttle services to China, and improved trade connections.
- Economic growth in the disadvantaged regions, which can increase demand for goods and services, both domestically and in China.
- Increased foreign direct investment from China in disadvantaged regions can create jobs, stimulate economic activity, and increase trade.
- Technological advancements, such as automation and digitalisation can make it easier for businesses in disadvantaged regions to participate in trade with China and increase their competitiveness.

More details about the Disadvantaged regions scenario can be found in D1.4 and D1.5.

3.2.3 PI enabled synchromodal EGTN 2030

To assess the technological impact on EGTN, a PI modelling capability has been developed in PLANET that was used for translating the technology and the input of services of the open, cloud-based EGTN infrastructure in terms of efficiency, cost and environmental footprint.

Three generalised simulation Use Cases have been developed for this purpose in order to:

1. Link the PI technologies implementation and the Open cloud-based EGTN infrastructure services to the Synchromodal model requirements of EGTN, and
2. Draft PI scenarios for the PLANET integrated modelling capability by modelling:
    a. seaports and hinterland dry ports as PI nodes rather than logistics nodes and maritime vessels as PI movers,
    b. complete collaboration, the defining characteristic of PI, between last-mile players,
    c. increasing visibility and resiliency of freight transport in intercontinental corridors using PI concepts.

The PLANET LLs are instances of the EGTN in the sense of the use (implementation) by stakeholders of the PI services which are offered from the Open cloud-based EGTN infrastructure. The testing that took place in LLs has used and produced real-life data that were utilised for checking and verifying the value of these services towards the operationalisation of EGTN under the PI paradigm.

In a parallel process, the data from the LLs were also used according to the GA requirements for developing and deploying quantitative models in order to define how enabling ICT and T&L innovations contribute to the EGTN, assess the impact of emerging concepts & technologies on freight transport corridors and hubs and position emerging technologies as contributors to the concept of the Physical Internet.

Through the PI-scenarios, the task covered the main business processes along a supply chain and the findings of the respective deliverable (D1.9) clearly highlighted the role of the Physical internet and its paradigm technologies such as Blockchain, Internet of Things, Artificial intelligence, etc. in building a seamless, flexible, and resilient system of logistics networks.

The three Use Cases that have been created in alignment to the project Living Labs, tested the implementation of innovative technologies separately and in combinations, comparing the results to the current situation (as-is) in order to conclude on their value and the optimal mix of technologies in terms of efficiency gains.

The use cases have linked the PI-technologies and services included in the Open cloud-based EGTN infrastructure to the following identified synchromodal model requirements based on the feedback received by the LLs stakeholders:

- Information on departure times and transit time distribution for all scheduled asset
- Information on unit transport cost and available capacity for all scheduled transport scheduled
- Target reliability level
- Real-time position of all containers in the network
- Deployment of the Synchromodal (adaptive) plan

The performance gains between the current status (as-is) and the optimal choice of technologies services (to-be) in the form of KPIs that were calculated were then linked and translated to input parameters of the strategic model, presented in Table 4, Table 6 and Table 8. This was the base for the third scenario simulation, the "technology scenario" which was realised through the re-iteration of the macro-model considering the implementation of the tested technologies to a wide EU scale.

It should be noted though that not all KPIs calculated in the use cases were relevant, and some parameters had overlapping effects. For example, a higher load factor could reduce capital costs. Therefore, only the lower capital costs were considered to avoid duplicating results. A brief description of the use cases and the respective outputs of the microsimulation are presented in the following sections.

3.2.3.1 Use case 1: Impact of PI services on "Gateway to hinterland" scenario in EGTN 2030

Use case 1 focused on the first PI scenario, modelling seaports and hinterland dry ports as PI nodes rather than logistics nodes and maritime vessels as PI movers, examining the hinterland rail transport of containers from China to the Madrid urban area.

More specifically, this use case simulated the PI Maritime network Asia (China) – Europe (Valencia, Madrid with respect to the optimised dynamic routing for the movement of cargo from the entry port to the hinterland distribution warehouse and the implementation of various technologies in a PI node (Distribution warehouse). Along the supply chain, Artificial Intelligence and Automated decision processes have been used for supporting the decision making at different levels. More detailed description of the UC1 testing can be found in D1.9.

Since the scope of the EGTN concept extents from the innovation implementation at operational level to the macroscopic and aggregated considerations level, the KPIs were considered at both, microscopic and macroscopic level. In the context of the UC1 the KPIs calculated are presented in Table 3.

Table 3: EGTN microscopic and macroscopic KPIs calculated for UC1

Microscopic KPIs	*Macroscopic KPIs*
• Capacity at terminals • Number of deliveries at destination • Predicted congestion at port terminals • Average time spent at sea • Distribution of total lead time	• Shipment reliability (i.e., fraction of on-time deliveries) • Modal split • Rail transport fill rate

These KPIs were calculated on the basis of the To-Be scenario which refers to the implementation of all tested technologies (PI+IoT+BC) since this scenario reports the highest values of reliability and rail modal split and least on road modal slpit. The results suggest that the highest potential of the PI concept in the maritime corridor can only be achieved if disruptive technolgies such as IoT and BC which support its implementation are established in the system.

The table below provides an overview of the UC1 KPIs and how they were integrated into the macro-level model.

Table 4: UC1 output KPIs and macro model input parameters for the technology scenario

UC1 results				*Model implementation*	
KPI	**As-Is Scenario**	**To-Be Scenario**	**Impact in 2030**	**Relevant mode**	**Impact on macro model parameter**
Rail fill rate	20%	44%	**+24%**	Rail hinterland	**120%** increase in load factor
Containers on time	78%	95%	**+17%***	Rail hinterland	**21.8%** increase in reliability
Container lead time	43	42.3	**-1.6%**	Rail hinterland	**-1.60%** reduction in travel time

**The number in question pertains to percentage points, rather than percentages. To incorporate this KPI into the model, it has been converted into percentages.*

3.2.3.2 Use case 2: Impact of PI services on "Last mile delivery" scenario in EGTN 2030

Use case 2 focused on the second PI scenario, modelling a state of complete collaboration which is the defining characteristic of PI, between last-mile players, examining the last mile delivery (LMD) process for parcel goods from depots/distribution centres located in the urban city of Madrid to end-customers located all around the Madrid city.

This Use Case provides simulation-based answers on how two main hurdles in urban deliveries, namely the risk of delay and the lack of collaboration among competing carriers, can be overcome supported by state-of-the-art T&L technology and innovations to create more efficient, reliable, and sustainable last mile delivery. These include IoT-enabled machine learning algorithms for optimising operations, a PI approach involving collaboration between carriers and also electric vehicles for emission reduction. More detailed description of the UC2 testing can be found in D1.9.

Like in the case of UC1, the KPIs were considered at both, microscopic and macroscopic level and are presented in Table 5.

Table 5: EGTN microscopic and macroscopic KPIs calculated for UC2

Microscopic KPIs	*Macroscopic KPIs*
● Average Distance travelled per vehicle. ● Total number of transport vehicles used per mode. ● Number of on-time deliveries ● Operating costs of last-mile deliveries ● CO2 emissions (Kgs/ton) ● Average delivery time (i.e., average duration of a parcel delivery from depot to final customer location)	● Parcel delivery reliability (i.e., number of parcels delivered on time) ● Parcel delivery lead time (i.e., average parcel lead time from depot to end-customer location) ● Vehicle transport fill rate (fraction of total vehicle capacity that is utilized) ● Transport cost

Use Case 2 concerns logistics efficiency within a city, but the macro model operates at a more granular level, with NUTS3 regions as the smallest unit. To account for this, the KPI is applied to all last-mile transportation within a NUTS3 region, specifically to links where the terminal and destination are both located within the same region. This approach extends the scope of the analysis beyond the use case, but it was deemed necessary to keep the model manageable and avoid major changes. The KPIs have been translated into model parameters according to the following scheme presented in Table 6.

Table 6: UC2 output KPIs and macro model input parameters for the technology scenario

UC2 results				*Model implementation*	
KPI	**As-Is Scenario**	**To-Be Scenario**	**Impact in 2030**	**Relevant mode**	**Impact on macro model parameter**
Total Distance (km)	585	180	**-69,23%**	n.a.	n.a.
Total Emissions (kg CO_2)	285	0	**-100,00%***	n.a.	n.a.
Total Cost (€)	3080	2230	**-27,60%**	Last-mile Road transport within the NUTS3 region	**27,60%** reduction in capital costs
Fill rate (%) Load Factor	20%	50%	**30%**	n.a.	n.a.
Lead Time (h)	6	5	**-16,67%**	Last-mile Road transport within the NUTS3 region	**-16,67%** reduction in Travel time

**Due to the use of electric vehicles*

3.2.3.3 Use Case 3: Impact of PI services on "New silk route" scenario in EGTN 2030

The final Use Case 3 focuses on the third PI scenario, modelling an increased visibility and resilience of freight transport in intercontinental corridors using PI concepts, examining the complete transport chain for containerized goods on the new silk route originating from mainland China and delivered to customers in Poland through rail. This use-case developed and tested simulations of implementing IoT technologies implementation for helping control resource parameters in real time and identify them while moving in the transport process as well as process innovations such as GS1 standards which help to create a digital connection between players in the transport network, enabling standardized data flow and access to information about cargoes coming from China to Poland in the whole supply chain in real time. More detailed description of the UC3 testing can be found in D1.9.

The microscopic and macroscopic level KPIs the were calculated are presented in Table 7.

Table 7: EGTN microscopic and macroscopic KPIs calculated for UC3

Microscopic KPIs	*Macroscopic KPIs*
● Number of containers delivered per month. ● Average Working Time per delivery ● CO_2 Emissions (per delivery) ● End-to-end visibility	● Container Delivery Volume ● Container Delivery Costs ● CO_2 Emissions

- Average Working time in Customs related activities.
- Total Compliance costs
- Total Operational Costs
- Reduction in Supply chain disruptions

The KPIs were translated into model parameters as follows (Table 8).

Table 8: UC3 output KPIs and macro model input parameters for the technology scenario

UC3 results				*Model implementation*	
KPI	**As-Is Scenario**	**To-Be Scenario**	**Impact in 2030**	**Relevant mode**	**Impact on macro model parameter**
Number of containers delivered (per month)	18	21	**+16,67**	Eurasian rail	**-16,67%*** cost reduction in capital costs
Average Working Time (Hours per delivery)	3,46	3,03	**-12,43%**	n.a.	n.a.
CO_2 Emissions (per delivery)	100%	83%	**-17%**	n.a.	n.a.
End-to-end visibility	0%	100%	**+100%**	n.a.	n.a.
Average Working time in Customs related activities	2,65	1,32	**-50,19%**	Eurasian rail	Since the distribution of activities is not known in the macro level model, the average of these activities is taken and subtracted from the border crossing time. Thus, the following parameter is adjusted: cross-border time in the EU reduced by **-28.06%**
Working hours for Compliance related Activities	100%	78%	**-22%**		
Working hours related to Operational Activities	100%	88%	**-12%**		
Reduction in Supply chain disruptions	0%	18%	**+18%**	Eurasian rail	**18%** improvement in reliability

**The increase in the number of containers delivered per month means in the context of this use case that more containers can be delivered with the same number of trains due to efficiency improvements. This means that more containers can be delivered at the same cost. The cost per container therefore decreases accordingly.*

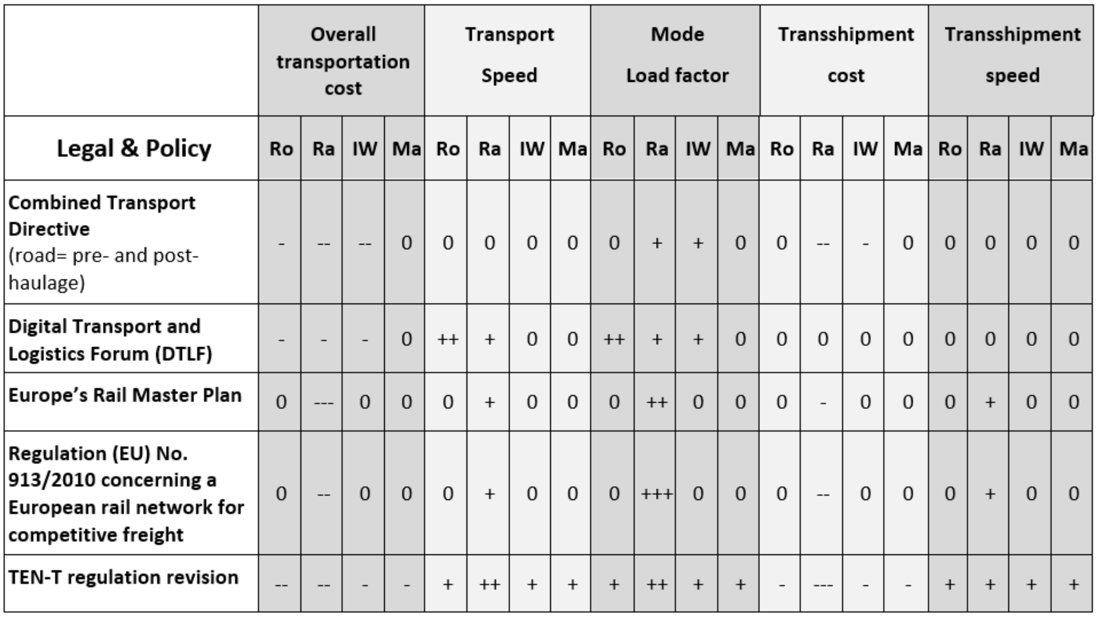
It should be noted that such a strategic model capability like the one developed in PLANET for considering the impact of technologies on the future flows and thus on the EGTN development, should be included in the Open cloud-based EGTN infrastructure as part of the offered services. The defined process and the model that emerged from integrating the impact of innovative concepts and technologies to the calculation of the future flows is an important step towards the operationalisation of EGTN under the PI paradigm, constituting a transport gravity model that can be used to assess the change in volume of freight that might result from corridor improvements as per GA requirements.

3.2.4 Policy & legislation impact considered by the strategic model for EGTN 2030

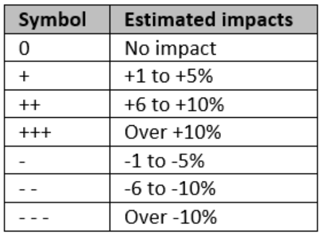
In the “Policy and Legislation” scenario, the purpose was to identify the main forthcoming policy and legislation initiatives that are expected to have a significant impact on the realisation of the EGTN and provide input to the strategic model for running an additional simulation scenario which considers their impact to the future freight flows.

Like in the case of the “technology scenario” the methodological approach included the quantification of the main impacts of selected policy and legislation initiatives in a way that can be used as parameters from the strategic model. To achieve this goal a drafting of scenarios for the 2030- and 2050-time horizons was made regarding the level of implementation per mode of transport of the selected Policy and legislation initiatives, building on the work that was undertaken in D1.6 (Table 10). In addition, in order to draft coherent and plausible scenarios, selected known existing visions and strategies per transport mode that have been developed by official institutions were also analysed and assessed, leading together with the analysis of the Policy and legislation initiatives to an initial estimation of the level of the expected impacts.

Table 9: Summary of potential impacts per prioritised policy and legal documents



	Overall transportation cost				Transport Speed				Mode Load factor				Transshipment cost				Transshipment speed			
Legal & Policy	Ro	Ra	IW	Ma	Ro	Ra	IW	Ma	Ro	Ra	IW	Ma	Ro	Ra	IW	Ma	Ro	Ra	IW	Ma
Combined Transport Directive (road= pre- and post-haulage)	-	--	--	0	0	0	0	0	0	+	+	0	0	--	-	0	0	0	0	0
Digital Transport and Logistics Forum (DTLF)	-	-	-	0	++	+	0	0	++	+	+	0	0	0	0	0	0	0	0	0
Europe’s Rail Master Plan	0	---	0	0	0	+	0	0	0	++	0	0	0	-	0	0	0	+	0	0
Regulation (EU) No. 913/2010 concerning a European rail network for competitive freight	0	--	0	0	0	+	0	0	0	+++	0	0	0	--	0	0	0	+	0	0
TEN-T regulation revision	--	--	-	-	+	++	+	+	+	++	+	+	-	---	-	-	+	+	+	+



Symbol	Estimated impacts
0	No impact
+	+1 to +5%
++	+6 to +10%
+++	Over +10%
-	-1 to -5%
- -	-6 to -10%
- - -	Over -10%

Symbol	Description
Ro	Road
Ra	Rail
IW	Inland Waterway
Ma	Maritime

Following this process, a group of experts was used in the context of a workshop to collect feedback and comments regarding the results of the work that was undertaken for prioritizing the policy and legislation initiatives.

In addition, the experts were requested to provide an estimation of the % range of change of specific parameters related to the transportation modes considering the presented policy and legislation initiatives. It was also decided to add to this assessment some new legal and policy actions such as Emission Trading System (ETS) and the Green Deal. These parameters were focused on four elements which were considered more relevant from the complete list of input parameters of the strategic model presented in Table 2: (1) Total transportation costs, (2) Load factor, (3) Reliability and transport speed.

The input from the experts was analysed and the results are presented in Table 10.

It should be noted that these parameters only concern the transport in Europe and not the intercontinental part of the logistics chain. Thus, these parameters have only been applied to the European network. Because capital cost, load factor, reliability and transport speed are included as parameters in the macro model, these parameters were directly and without translation included in the macro model.

Table 10: Estimation of main Policy and legislation initiatives impact on strategic model parameters

% value change (2030)

	Rail	**Road**	**Inland Waterways**	**Maritime**
Total transportation cost per mode	-5,00%	+4,20%	-1,50%	+2,30%
Load factor per mode	+2,90%	+2,40%	+1,70%	+0,90%
Reliability per mode	+5,50%	+2,90%	+4,20%	+1,50%
Transport speed per mode	+2,30%	+0,50%	+0,50%	0,00

As is obvious from the figures on Table 10, the values of parameters that came out from the experts' input were very moderate and thus it was not expected to have a significant impact on freight flows. This was later verified also by the simulation results which are presented in the next chapter.

There are several reasons that may have led to this outcome; most of the selected initiatives are not yet fully implemented therefore it is not easy to form a clear opinion on the level of impacts, a fact which usually leads to more moderate estimations. This was reinforced by the lack of detailed impact assessment reports for several of these initiatives. Moreover, the relative short-term horizon possibly made the participants to the experts' group to have considerations for the level of implementation that these initiatives will have by 2030 and subsequently to their impact on transportation.

However, some useful qualitative conclusions have emerged from the analysis of the results when comparing the different modes of transport. Rail appears to be the mode with the strongest prospects in relation to its development, as a result of the supportive EU policy towards the enhancement of freight rail transportation. Inland waterways also appear to have positive prospects, possibly due to the expected impact of the NAIADES III action plan which foresees significant interventions for the development of the mode. On the other hand, road transport despite increasing its efficiency, it is expected to have a significant increase in the total transportation costs, possibly due to the EU policy for charging emissions. Finally, in the case of maritime transport, the environmental initiatives such as the ETS implementation to the maritime sector is also expected to increase the transportation cost and will impose operational restrictions (e.g. speed reduction) that will not allow a significant increase of its (already high though) efficiency.

The detailed methodology and processes described above as well as the results of the analysis can be found in D1.7.

4 EGTN Physical layer specifications

The physical layer specifications aim to provide a comprehensive answer to the question of how the EGTN should be structured in terms of physical corridors and nodes in order to become a network that is better adapted to the new EU & Global geo-economic conditions, serve more efficiently future intercontinental and internal freight flows and facilitate better the development of disadvantaged regions. In this context, the present chapter consists of the description and outcome of the work undertaken in PLANET for defining the new areas of interest for infrastructure development and the new or of revised significance entry points/ nodes and corridors of the EGTN.

4.1 New areas of interest and entry points

An integral part of the globally connected EGTN is the transport nodes which play a key role in the supply chains of containers moving between Europe and Asia. In order to identify these nodes of the EGTN, PLANET has combined the outputs of the strategic model scenarios simulations, enriching them with identified TEN-T nodes of selected corridors with high connectivity which are important for linking the production locations and the maritime entry points of the network, Finally, the Living Lab locations are also considered, as identified corridors and nodes of future European significance.

This process can help identify key areas for investment and development that can improve the efficiency and cost-effectiveness of trade, support economic development, and improve competitiveness in trade with Asia.

4.1.1 New and of revised significance PEPs in 2030 EGTN (baseline scenario)

In the context of the initial strategic model simulations which are reported in D1.5, a baseline scenario was drafted as a representation of what is expected to happen in the future if current trends and policies continue without any significant changes. The purpose of this scenario was to help understand the most likely future scenario, serving also as a reference point for other scenarios to assess the potential impact of the more specific scenarios. Even though the baseline scenario was carried out for 2030 and 2050, the main focus was on mapping the developments in 2030 rather than the 2050 with the latter mainly being a further extension of the 2030 developments. The reason for this is that the assumptions and uncertainties associated with forecasting for 2050 are significantly increased thus not creating a solid base for defining the EGTN specifications. The detailed description of the baseline scenario can be found in D1.5.

The rationale behind the analysis of simulation results for the baseline scenario in terms of the new areas of interest and the new/of revised significance entry points of the EGTN was to define an initial set of important nodes for the EGTN which then can be revised or enriched with additional nodes as these may emerge from the additional scenarios.

Having said that, the baseline scenario has revealed that the expected efficiency improvements will make Eurasian rail transport more attractive for high value goods (> 15 €/kg) compared to intercontinental maritime transport for almost all regions (Figure 5). While in the baseline year of 2019 the Eurasian rail transport was competitive with intercontinental sea transport mainly in the Czech Republic, Hungary, Slovakia, Poland, and northern Romania, by 2030, the attractiveness of Eurasian rail transport is shifting westward. Eleven new rail PEPs have been added to the network with direct intercontinental shuttles to China, on top of the nine rail PEPs that were in the model in the 2019 base year and shuttle services between the PEPs have been increased.

In turn this changed the role of rail PEPs: If regions in the west of Europe become more attractive, the role of rail PEPs in those regions could become more prominent, while the role of rail PEPs in other regions could decline. However, the development could also move in the other direction. As rail PEPs in eastern Europe receive more traffic, they can benefit from economies of scale and therefore offer better services and facilities. Thus, they can offer more competition against the well-developed PEPs in western Europe.

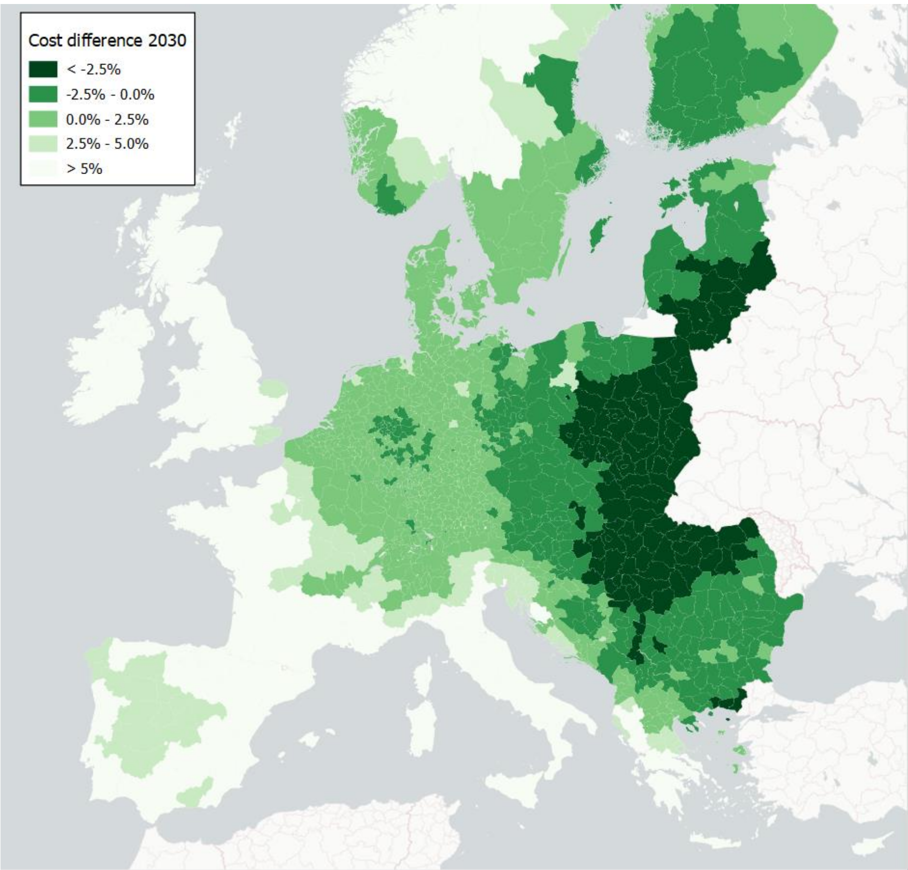


Figure 5: Cost difference of Eurasian rail transport compared to maritime transport for high value (> 15 €/KG) goods in 2030.

Based on the analysis results, a list of the most significant PEPs for the Eurasian rail transport was created including the eleven new rail PEPs, constituting a part of the nodes of new/revised significance of the globally connected EGTN. In Figure 6, these terminals are presented along with their expected transhipment flows for 2019 and 2030.

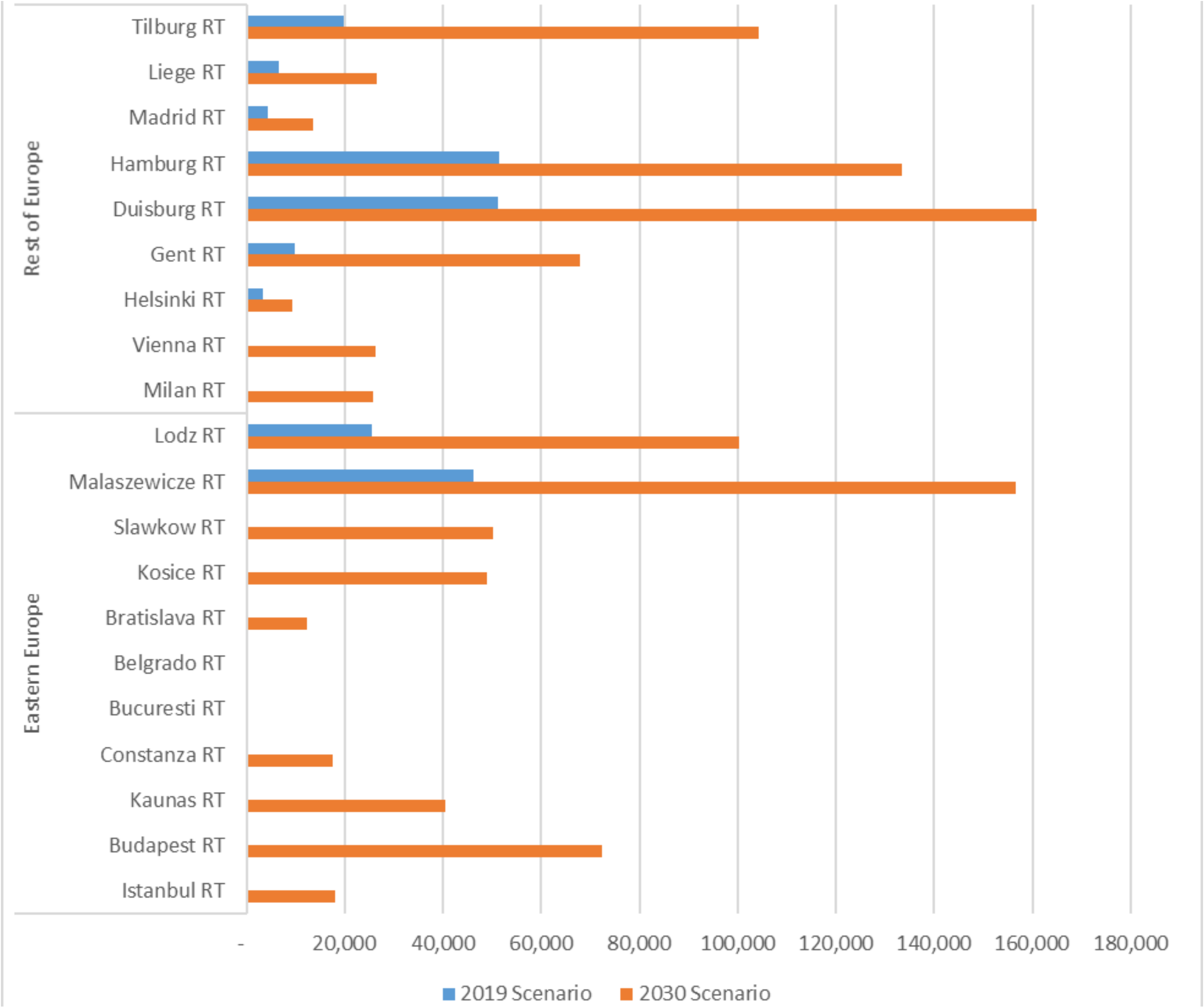
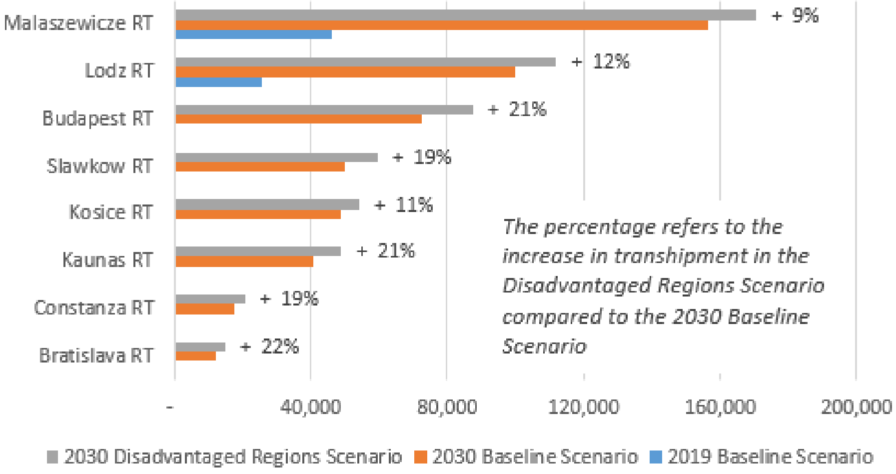


Figure 6: Modelled transhipment of most significant EGTN PEPs in 2019 and 2030.

4.1.2 EGTN 2030 nodes for supporting disadvantaged regions development

Regarding the identified nodes of the EGTN which are located in the Eastern Europe, the specific scenario analysis verified also their importance by calculating the extra transhipment which is expected at each of these terminals. Based on the results (Figure 7), the largest extra transhipment is to be expected at terminals with little competition from other terminals in their hinterland, thus having a relatively large hinterland, such as Kaunas and Budapest. In Košice, for example, the expected transhipment is lower because the hinterland is more limited and faces competition from Slawkow (which also has a connection to the broad railway gauge) and Budapest. However, if the train route through Ukraine can be used again, the expectation is that the competitiveness of the Košice terminal will greatly increase. The Kaunas terminal serves the Baltic states, parts of northern Poland, and through short sea also parts of Sweden.



The percentage refers to the increase in transhipment in the Disadvantaged Regions Scenario compared to the 2030 Baseline Scenario

Figure 7: Modelled import flows of containers from China by rail per terminal in the 2019 baseline scenario, 2030 baseline scenario and the disadvantaged regions scenario.

Based on the disadvantaged regions analysis, the conclusion is that there is not one specific terminal best positioned to serve the disadvantaged regions. There is sufficient market potential to pursue a broad development of multiple terminals in the eastern and south eastern Europe which appears to be an area of interest, attracting intercontinental rail flows. This becomes evident from looking at Figure 8.

It is therefore proposed to develop additional nodes that will be included in the list of important nodes of the EGTN in this area considering locations with a TEU factor of increase >1.25(Figure 8).

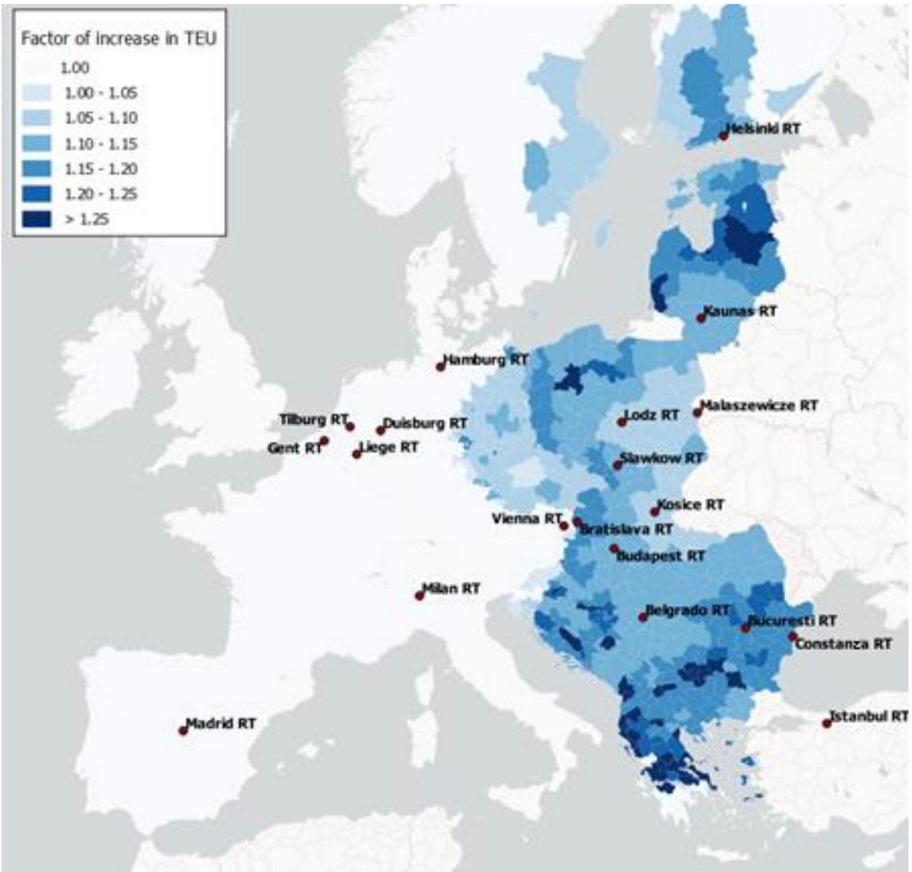


Figure 8: Factor increase of modelled import flows of containers from China by rail in the 2030 disadvantaged region scenario compared to the 2030 baseline scenario.

4.1.3 Emerging EGTN nodes as a result of the RFC development policy

The change in trade patterns described above is also the outcome of the Rail Freight Corridor scenario analysis which concluded to the area of EU where the cost difference between the maritime and rail transport becomes significantly larger thus expected to attract additional intercontinental rail flows. This is the case for a significant larger area of the EU as shown in Figure 9.

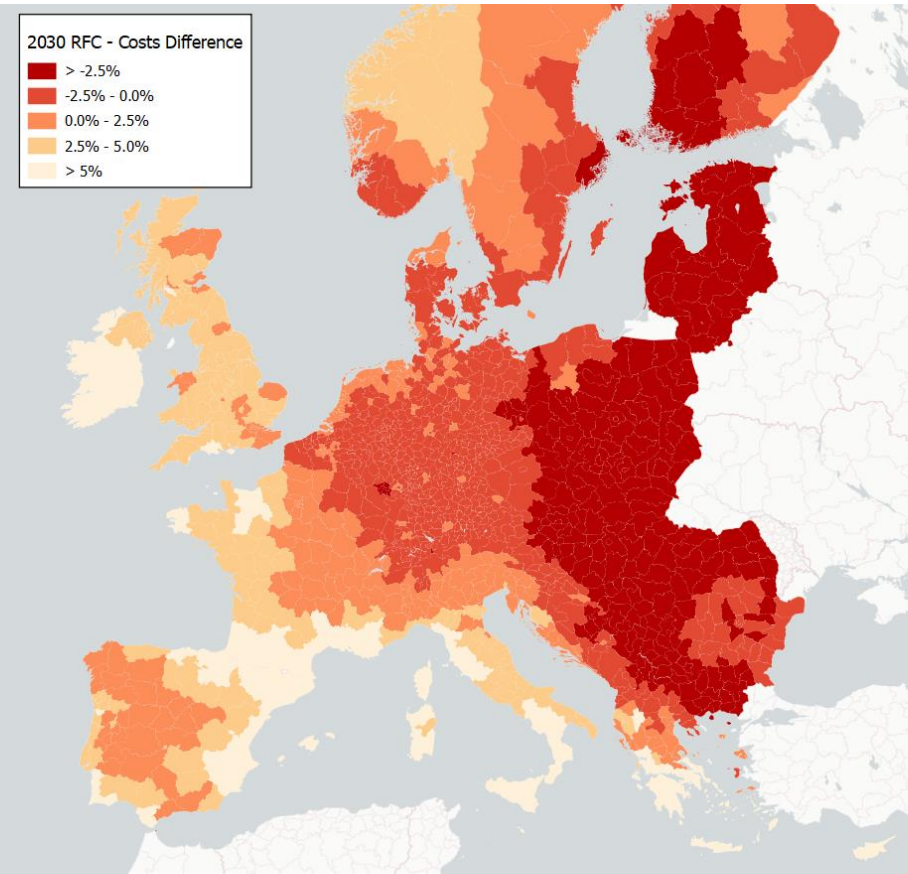


Figure 9: Cost difference of Eurasian rail transport compared to maritime transport for high value (> 15 €/KG) goods in the 2030 RFC scenario.

In the above areas of Europe multimodal nodes of EGTN need to be developed for serving additional freight transport demand.

4.1.4 Maritime is the dominant transport mode in EGTN 2030

With respect to the technology scenario, the implementation of use cases 1, 2 and 3 technologies (presented in chapter 3) in Europe and across the new silk road is considered. It is an ambitious scenario because it assumes the implementation of the technologies across the entire corridor. Nevertheless, it provides good insight into the possible impact of technologies on the balance of containerized transport flows between Eurasian rail transport and maritime transport. An overview of intercontinental transport volumes in the technology scenario compared to the baseline 2030 scenario is shown in Table 11.

Due to the new technologies, it is expected that the number of containers transported via Eurasian rail to Europe will increase by around 1.1 million TEUs, a doubling of the amount in the 2030 baseline scenario. It is also expected that the market share of Eurasian rail freight in total Eurasian goods transport will increase from 6.9% in the 2030 baseline scenario to 14.2% in the technology scenario. Thus, the implementation of new technologies is causing a significant increase in imported containers via the New Silk Road.

Table 11: Modelled import flows of containers from China, comparison between intercontinental rail and sea mode for the 2030 scenario and the 2030 technology scenario

	2030 Scenario	*2030 Technology scenario*	*Difference*
Volume (in million TEU)			
Rail	1.1	2.2	+ 1.1
Maritime	14.4	13.3	- 1.1
Share			
Rail	6.9%	14.2%	+ 7.3 pp
Maritime	93.1%	85.8%	- 7.3 pp

This increase is almost entirely attributable to one of the three use cases, namely use case 3. This use case results in a reduction of Eurasian rail transport by more than 16%. The other two use cases have hardly any impact on the balance. Use case 1 leads to cheaper hinterland transport by rail, which benefits both the seaports and the rail principal entry points. This does result in a small modal shift of hinterland transport from road to rail. Use case 3 leads to lower costs in the same region as where the principal entry node is located. This does not cause a change in balance or a modal shift, only lower costs of hinterland transport by truck.

4.1.5 Emerging EGTN nodes due to technology-enabled corridor efficiency

New technologies, especially the integration of IoT, AI, and GS1 standards in the supply chain of use case 3, make a larger area attractive for Eurasian rail transport. On the one hand, the hinterland of the rail principal entry point becomes larger at the expense of the hinterland of the port principal entry nodes. This can be seen in Figure 10. This figure shows the percentage increase in the number of TEUs that are transported by Eurasian rail to the region in the technology scenario compared to the baseline scenario. The darker the area, the larger the percentage increase. The figure shows that with the technology scenario, several regions have reached the tipping point where rail transport is an attractive option, namely parts of England, France, Spain and Italy. This only applies to higher-value goods, that is, goods with a value of more than €15 per kg. Lower-value goods - and therefore not time-sensitive goods - remain most attractive for sea transport.

However, this percentage increase in the attractiveness of Eurasian rail transport gives a distorted picture of which regions benefit the most from it. The above-mentioned regions do see a large relative increase, but the absolute increase is limited. This is because these regions are only interesting for a limited share of the Chinese market, namely the regions close to the inland terminals in China and which are far away from the seaports. The absolute increase can be seen in Figure 11. The regions with the largest absolute increase were already attractive for Eurasian rail transport from China, but lower costs of Eurasian rail transport made other regions in China appealing for this mode of transport that were not appealing before. And because these European regions already received a relatively large number of container volumes from China, percentage increases in volumes are less visible.

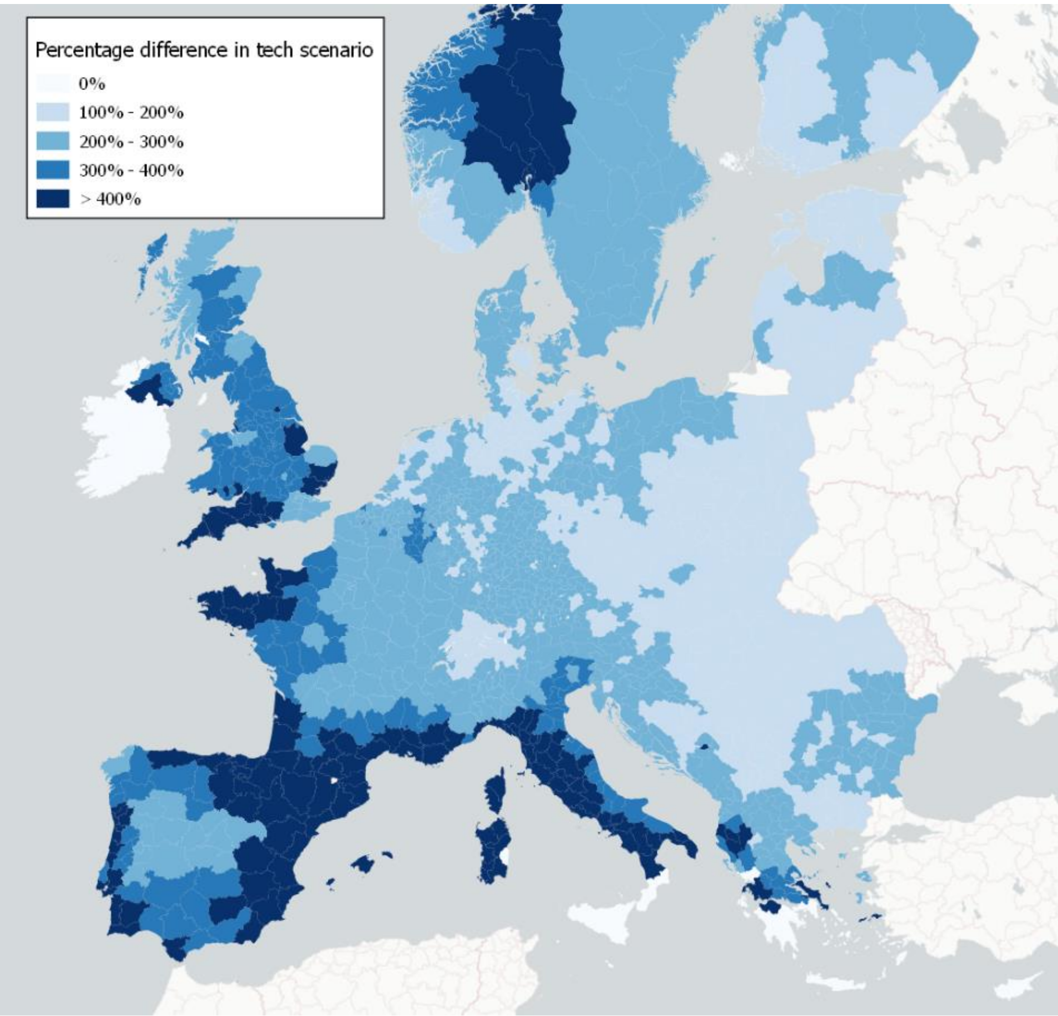


Figure 10: Percentage change in modelled import flows of containers from China by rail per NUTS3 region in the 2030 technology scenario compared to the baseline scenario.

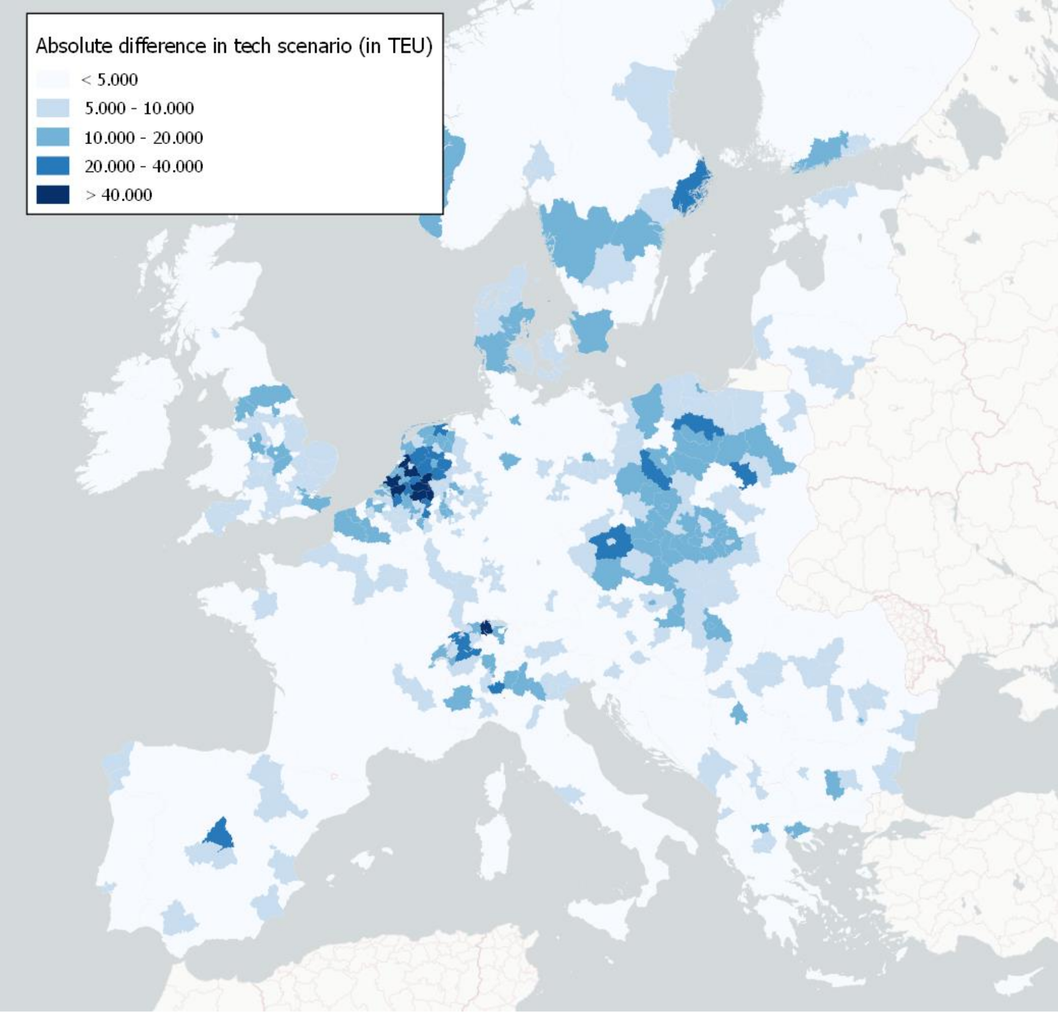


Figure 11: Additional modelled import flows of containers from China by rail per NUTS3 region in the 2030 technology scenario compared to the baseline scenario.

In sum, the technology scenario has the following impacts on Europe:

The border in Europe where Eurasian rail transportation is cheaper than sea transportation has moved westward. This means that some areas in Europe that were not suitable for Eurasian rail transportation before are now attractive for this mode of transport. Also, some areas that already used this intercontinental mode have become more appealing.

The border in China where Eurasian rail transportation is more affordable than sea transportation has moved eastward. This reflects the previous point: areas in China where Eurasian rail transportation is cost-effective will likely be used more, and this mode is now also suitable for new regions, especially in Eastern China. This has a significant effect on the estimated BRI volumes as a large number of goods come from the eastern provinces of China. Moreover, this will result in areas in Europe that are already attractive for Eurasian rail transportation receiving more cargo as new areas in China are opened.

The technology scenario analysis demonstrates that new technologies have the potential to double the number of containers transported by Eurasian rail to Europe by 2030 (compared to the baseline scenario) and boost its market share in Eurasian goods transport. This will significantly increase the imports via the New Silk Road and may cause infrastructure bottlenecks in Europe to occur sooner than expected.

The new technologies will reduce the costs of Eurasian rail freight and expand its suitability for some areas in Europe, especially parts of England, France, Spain and Italy, that were previously unsuitable for this mode of transport. Furthermore, the new technologies will enhance the affordability and suitability of Eurasian rail freight for new regions in eastern China, boosting the BRI volumes and the containers delivered to areas in Europe that currently already benefit from this mode of transport. Therefore, despite the fact that the 2030 simulations show that it is not expected a large absolute increase by 2030 in the number of containers in these regions of Portugal, Spain, France and Italy, the dynamics developing in these areas becomes apparent. Given also the fact that EGTN is a PI network and the implementation of innovative PI-enabling technologies is one of the major pillars for its development, it is expected that these areas will play a key role in the future for the global connection of the EGTN.

For this reason, it is proposed to include nodes from these areas in the list of important entry points/nodes of the EGTN, which is fully aligned also to the LL1 positioning in the Iberian Peninsula that was recognized as part of a corridor/node of future European significance for the EGTN.

4.1.6 Policy and legislation influence the EGTN development but further assessment is needed

Finally, the policy scenario focused on changes in transport costs and transport time in the European part of the logistics chains from China. The parameters in this scenario as shown in Table 11 indicate that rail transport gains the most in attractiveness, followed by inland waterway transport, whereas road transport becomes slightly more expensive. Therefore, a modal shift is expected.

Table 12: Difference in modal split in European hinterland transport of imported containers from China

	IWW	*Rail*	*Road*
2030 baseline scenario	12%	29%	59%
2030 policy scenario	11%	31%	58%
Change in pp.	**-1 pp**	**+ 2 pp**	**-1 pp**

According to the model analysis (

Table 12), a policy scenario would result in a 2-percentage point increase in the rail share of the modal split for the hinterland transport of imported containers from China. This would negatively affect both inland waterway and road transport, which would each lose 1 percentage point of the modal split. It is noteworthy that inland waterway transport would also experience a decline in its modal split share, despite being a beneficiary of the policy scenario. However, the policy and legislation initiatives considered do not account for the entire decrease.

Another explanation is the increased costs for last-mile transport or the increased costs to get the containers from the inland waterway terminal in the hinterland to the final destination. Due to the increase in last-mile costs in the policy scenario, logistic chains shift to routes with a relatively shorter last-mile distance. Although the costs of the intermodal part of the chain may increase in these alternative routes, the lower costs of a shorter last-mile distance compensate for this. There is a new optimization in the system where the last-mile costs and distance are minimized. Because rail terminals are more finely distributed over Europe (inland waterway is limited to the major rivers), rail benefits more from this, and thus we can see a shift from inland waterway transport to rail.

For maritime transport, the costs are expected to increase slightly, while a higher reliability and load factor reduces the cost increase. On balance, the costs for maritime transport increase. As a result, there is also a small shift in the balance between Eurasian rail transport and Eurasian sea transport. However, due to the small changes in costs, the shift in the balance is also expected to be minimal. Table 13 shows the modelled import flows of containers from China per intercontinental mode for the 2030 policy scenario compared to the 2030 baseline scenario. The table shows a minimal increase in the trade balance.

Table 13: Modelled import flows of containers from China, comparison between intercontinental rail and sea mode for the 2030 scenario and the 2030 policy scenario

	2030 Scenario	*2030 Policy scenario*	*Difference*
Volume (in million TEU)			
Rail	1.08	1.09	+ 0.01
Maritime	14.42	14.41	- 0.01
Share			
Rail	6.9%	7.0%	+ 0.1 pp
Maritime	93.1%	93.0%	- 0.1 pp

The policy scenario analysis shows that rail would gain 2 percentage points in the modal split of imported containers from China in the European hinterland at the expense of inland waterway and road transport, which would each lose 1 percentage point. The fact that rail transport gains in modal split share, despite inland waterway transport also benefiting in the policy scenario, can be explained by the higher costs for last-mile transport that make logistic chains prefer routes with shorter last-mile distances, which favour rail over inland waterway transport. Maritime transport costs in Europe are expected to increase minimally in this scenario, despite a higher expected reliability and load factor for this mode of transport, leading to a shift in favour of Eurasian rail transport that is negligible and therefore no additional required nodes for the EGTN are identified.

4.1.7 Emerging EGTN nodes through the Corridor Connectivity Index approach

The definition of Corridor Connectivity Index is a transport node's level of integration in the global transport network, as manifested by its position in port capacity, efficiency and ease of processes, service frequency, service quality and digital connectivity. Connectivity in our definition is a relative measure, in the sense that we do not use costs and transit time. The index has been designed to help port authorities – both seaport as well as inland port authorities – to identify and improve their position in the network, and thereby improve the network. From the literature we can derive that shippers – beneficiary cargo owners – or the freight forwarder on their behalf make the decision to select a transport mode and choose a port. There is extant research on container logistics and inland networks. The main actors in the network are deep seaports, deep sea terminals, inland terminals and hinterland transport operators. As we are interested in observing shifting trade patterns, we seek to measure the relative position of transport nodes vis-à-vis other transport nodes in the network. In this methodology we distinguish principal entry nodes from inland nodes. We deliberately choose to use the word node to emphasize the network perspective.

4.1.7.1 Methodologic approach

This methodology envisages a connectivity index which indicates the best nodes in the transport network, reflected by six components. The hypothesis is that the strongest nodes – with the highest corridor connectivity index score- are a predictor for the most favourable routes as reflected by actual shipped volumes. Ideally, a map with the corridor connectivity index of multiple seaports and inland ports will highlight the best route through the network by using the scores of each node in the network.

Corridor connectivity can be broken down in six components. For inland nodes these are: port/node capacity, efficiency and ease of processing, service frequency, service quality, digital connectivity and port liner shipping connectivity (for gateway ports only). For principal entry nodes we use the PLSCI as the additional indicator.

Within each of these components, there is a breakdown of indicators, which we will elaborate on here. These indicators are selected based on a thorough literature review. Ultimately 15 indicators were chosen, which are presented in Table 14 [1].

Table 14: Sub-components corridor connectivity index

Component	*# Sub-components*	*Sub-components*
Port capacity	3	- Port terminal area in square meters - Barge capacity in total length in metres of the quays - Rail capacity in total length in metres of train tracks
Quality of infrastructure	3	- Availability of truck transport (road) - Availability of train transport (rail) - Availability of inland waterway transport (barge)
Efficiency	2	- Efficiency and ease of process per rail - Efficiency and ease of process per barge
Service frequency	7	- # Scheduled services per week Seaport A via rail (if available) - # Scheduled services per week Seaport B via rail (if available) - # Scheduled services per week Seaport C via rail (if available) - # Scheduled services per week Seaport D via rail (if available) - # Scheduled services per week Seaport A via inland waterway (if available) - # Scheduled services per week Seaport B via inland waterway (if available) - # Scheduled services per week Seaport C via inland waterway (if available)
Service quality (centre of gravity)	4	- # Kilometres to Seaport A via rail - # Kilometres to Seaport B via rail - # Kilometres to Seaport C via rail - # Kilometres to Seaport D via rail
Digital connectivity	4	- Information of schedules online available - Ability to track and trace consignments - Possibility to book container (platform or app) - Possibility to hand over documentation (platform or app)
Green facilities	3	- Availability of an LNG refuelling station - Availability of a hydrogen refuelling station - Availability of waste reception facilities
Total:	26	

4.1.7.2 Connectivity Index input

Table 15 [1] displays the different data sources used to compile the different components of the CCI.

Table 15: Websites used for data collection of the CCI components for the Rhine Alpine corridor

Website	*Port capacity*	*Quality of infrastructure*	*Efficiency*	*Service frequency*	*Service quality*	*Digital connectivity*	*Green facilities*
Agora	x	x	x				
Inland terminal websites	x	x	x	x	x	x	x
Railscout				x	x		
Navigate				x	x		
TenTec Map							x

Antwerp intermodal planner	x
Hamburg intermodal planner	x

A database is created in excel which list every inland terminal on the specific TEN-T corridor. After gathering all the relevant data for the components and their sub-components, the base value of every terminal is calculated by determining the maximum value. Hereafter, the highest value is set as base value and made equal to 100. This refers to the following formula:

$$\text{Index}_{\text{pt}} = \frac{\text{value}_{\text{pt}}}{\text{base value}} * 100$$

Then, for each terminal, the average of the indices per component can be calculated. When one has multiple terminals in a port, the average of the terminals will result in an aggregated index value for this specific port. For example, the port of Duisburg consists of multiple terminals. Lastly, the average of all the seven index components determines the final CCI index.

The CCI is constructed from 7 components, using Principal Component Analysis (PCA). PCA is a statistical method to reduce the dimensionality of a dataset. This is done to simplify the understanding of the data which results from data collection on 26 indicators for an *x* number of inland terminals on a TEN-T corridor. To make sure the dataset does not become unmanageable, we aim to express the corridor connectivity of a node in a single indicator – the CCI – which is the weighted average of the score of the components. The weight per component in the CCI is currently equal, but perhaps after further research this will be changed to unequally divided weights.

Table Y displays the number of inland terminals per corridor. After merging the data for the inland terminals that are located in the same city, we arrive at the amount of inland ports for every corridor.

Table 16: Number of inland terminals and ports

Corridor	*Inland terminals*	*Inland ports*
Rhine - Alpine	66	35
Baltic - Adriatic	54	26
Rhine - Danube	56	33

4.1.7.3 Implementation of CCI

In the context of PLANET, the CCI has been calculated for 3 TEN-T corridors, namely the Rhine – Alpine, the Rhine – Danube and the Baltic – Adriatic. The purpose of this exercise was to test the applicability and consistency of the methodology for CCI calculation and to prove its usefulness as a tool for comparing nodes and corridors and drawing conclusions regarding their connectivity and development.

In addition, these three corridors are all important parts of the TEN-T network, linking significant production and consumption areas of EU to maritime entry points in all seas that are surrounding Europe, namely the Mediterranean, the North, the Baltic and the Black seas. For this reason, the outcome of the calculations in terms of the currently important nodes (top 10 in each corridor) is included in the list of significant nodes of the EGTN since they are expected to have a significant role in the future EU trade. Despite the fact that the calculations refer to the current state of these nodes, their significance is expected to remain for the 2030-time horizon.

Rhine-Alpine corridors

Our research presents the findings based on the Corridor Connectivity Index of 66 inland terminals in 35 ports across the Rhine Alpine corridor in Europe. We merged the inland terminals that are in the same port. Figure 1 displays the top-10 ranking for the final CCI along the Rhine Alpine corridor. The ports of Rotterdam and Antwerp are not included as port, because they are seaports.

Duisburg has the highest score, followed by Mannheim and Köln. Kehl and Ludwigshafen scored the same, followed by Neuss, Basel and Germersheim. Dietikon closes off the top 10. What is immediately evident is the fact that the top 10 are all trimodal (rail, waterway, and road) ports. In terms of port capacity, the port of Duisburg is the biggest, followed by Kehl and Ludwigshafen. The top 3 ports are known for their high scores in efficiency. The three highest scorers for service frequency are Duisburg, Basel and Mannheim – which can be explained by the fact that they are located in the centre of gravity of the corridor. Digital connectivity and green facilities are components that the ports themselves are still developing at full speed. It is therefore not surprising that there are differences within the top 10 between the different ports.

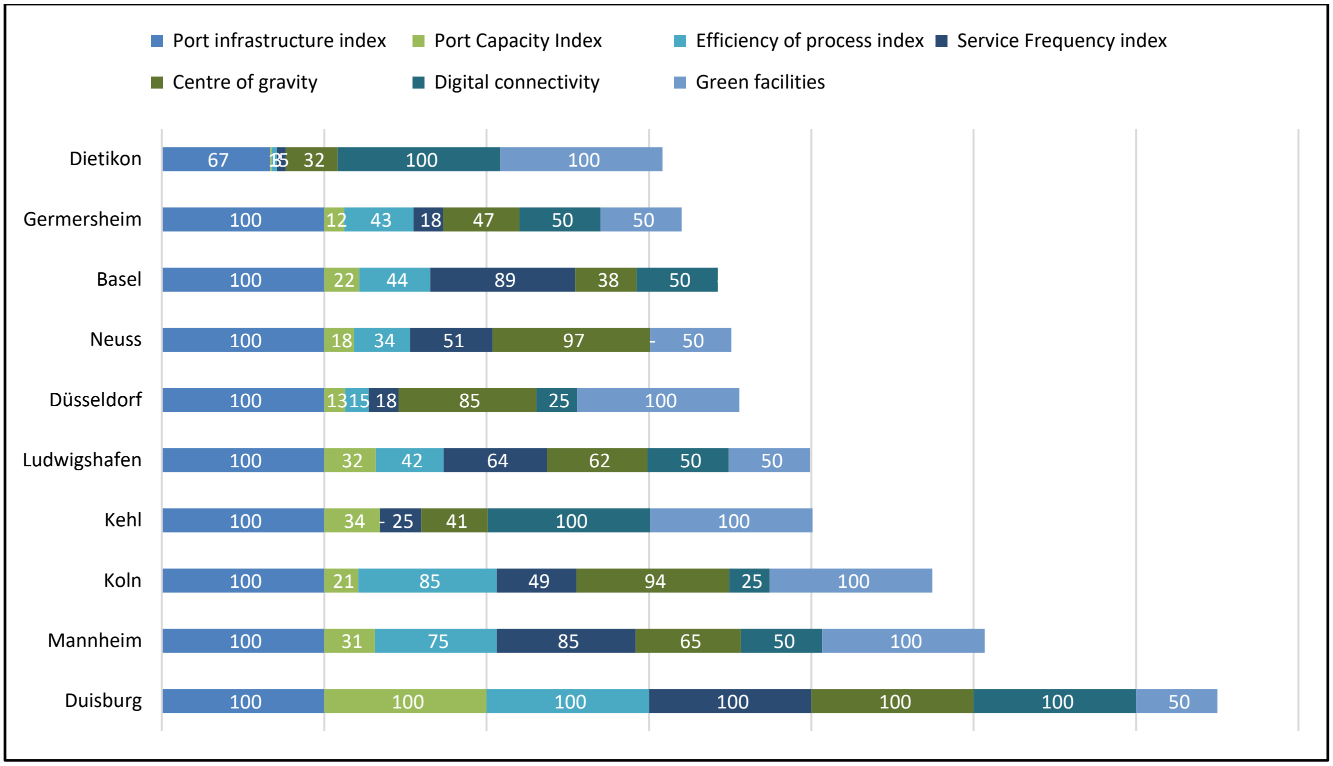


Figure 12: Final CCI Top 10 Ranking – Rhine Alpine corridor

Rhine-Danube corridor

The dataset for the Rhine Danube corridor contains 56 terminals and after merging 33 inland ports. For the Rhine Danube corridor it shows that Vienna has the best overall corridor connectivity. Vienna has both waterways and rail connections and is located in the centre of the corridor with best service frequency to Antwerp and Trieste. Budapest, also on the Danube and a major metropolis in this part of Europe ranks high on the corridor. Interesting to mention is also the position of Nurnberg, Mannheim and Prague. From the service frequency component, we can derive that Nurnberg has best performance, but mainly because of its connections to Hamburg, a seaport which is not on the Rhine Danube Corridor. Mannheim and Prague are interesting because of its high service frequency to Rotterdam, Antwerp and Hamburg, but not to Trieste. Trieste is only competing on service frequency with seaports in North-West Europe for cargo in the region of Vienna, Wels, Salzburg and Budapest. Appendix 2 contains the maps for the separate components.

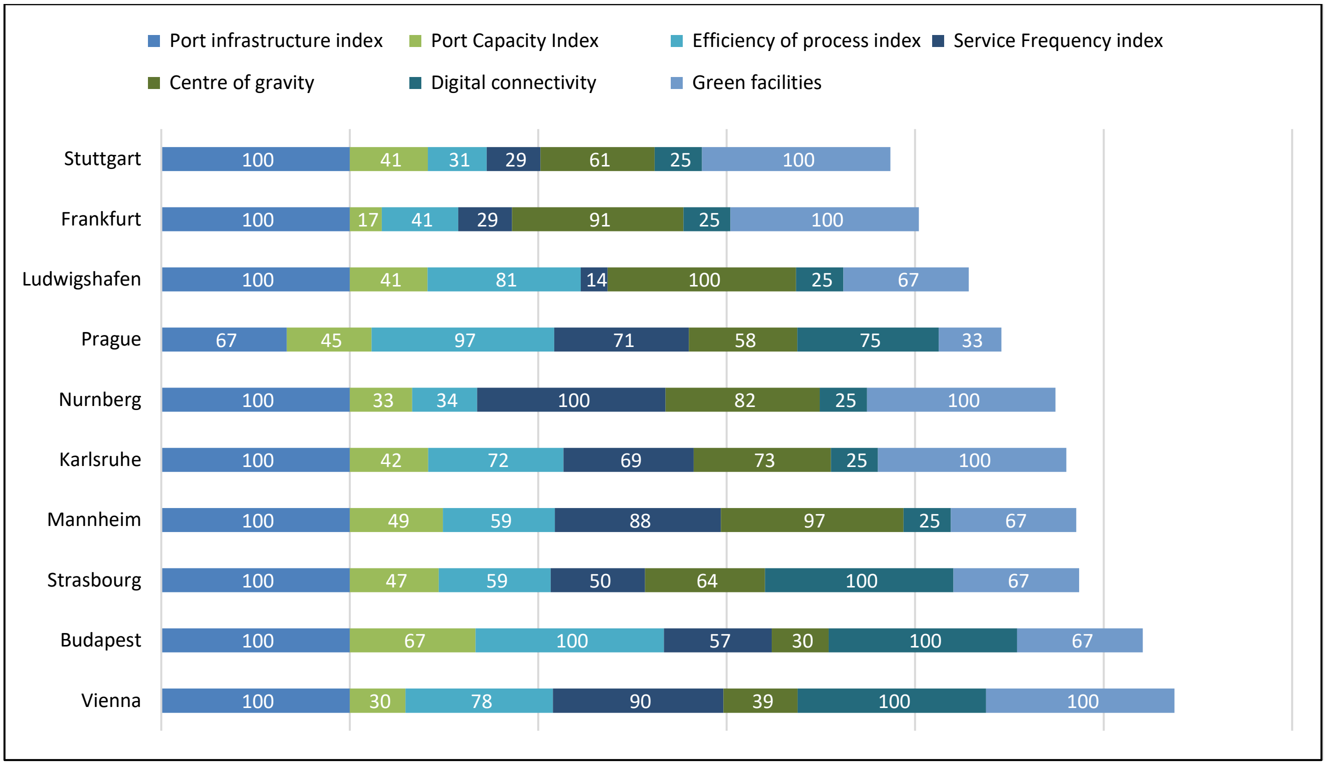


Figure 13: Final CCI Top 10 Ranking – Rhine Danube corridor

Baltic Adriatic corridor

The dataset for the Baltic Adriatic corridor contains 54 terminals and after merging 26 inland ports. For the Baltic Adriatic corridor, it shows that Vienna and Bratislava have the highest overall connectivity index, which demonstrates their position as turn tables in this corridor. It also shows the importance for trimodal inland ports for inland port connectivity. Both Vienna and Bratislava have rail and waterway connections.

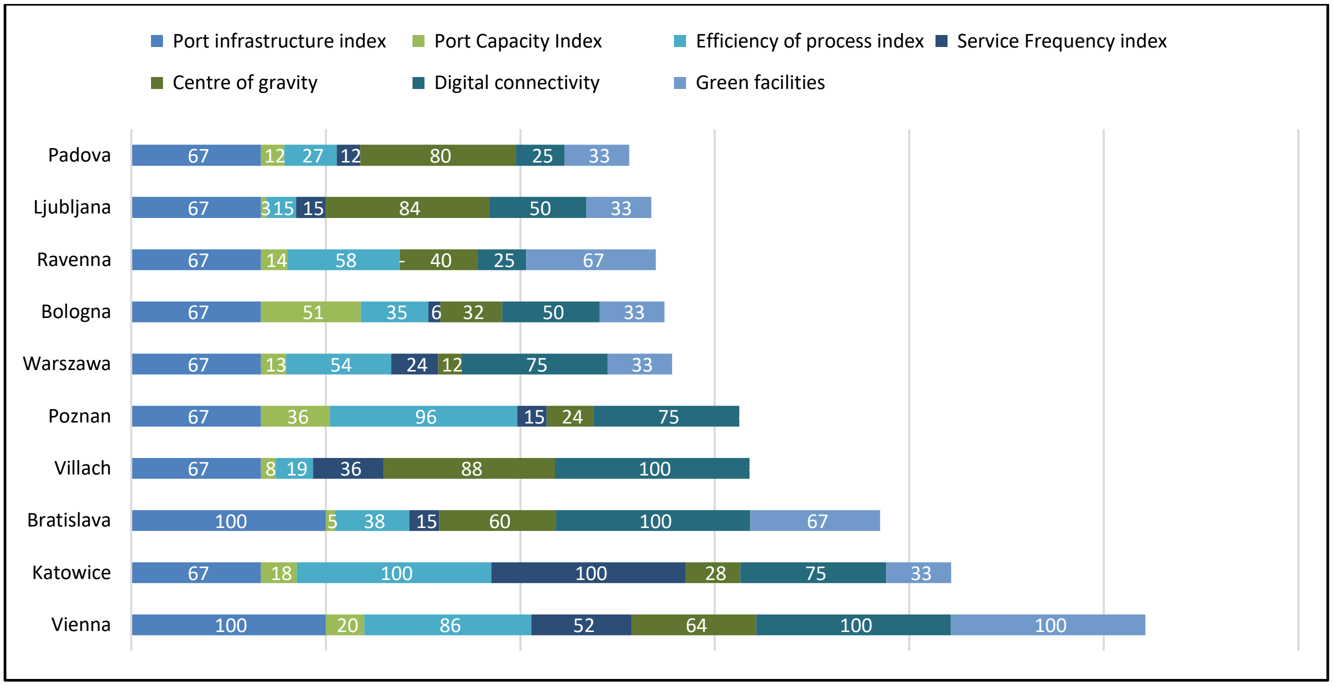


Figure 14: Final CCI Top 10 Ranking – Baltic Adriatic corridor

4.1.7.4 *Nodes and corridors comparison*

From the corridor analysis, we conclude that connectivity is skewed to specific port regions. Rhine Alpine is oriented towards Antwerp and Rotterdam. Baltic Adriatic is oriented towards Adriatic ports, whereas the Rhine Danube corridor is skewed towards the centre with Strasbourg and Vienna as pivots, located on the two main river systems of this corridor.

It is interesting to compare which inland ports can be considered the main hubs on each of the corridors. Duisburg outperforms all other inland ports on the Rhine Alpine corridor on all corridor components. Vienna is the main hub for Central Europe, as it is the pivot on both Baltic Adriatic and Rhine Danube corridors. Bratislava is a runner-up with similar differentiators.

Table 17: Corridor comparison

Corridor	*Orientation of inland ports*	*Main hub*	*Differentiator main hub*
Rhine - Alpine	Towards North Sea	Duisburg	All components
Baltic - Adriatic	Towards Adriatic Sea	Vienna	Service frequency
Rhine - Danube	Towards the centre	Strasbourg	Service frequency, Green facilities

4.1.8 Discussion on new areas of interest and entry points of EGTN 2030

The work described in the previous sections has helped PLANET to identify the new areas of interest and the network nodes of increased significance for the development of EGTN as a globally connected network. These areas include the Eastern and Southeast parts of Europe which are expected to attract the majority of Eurasian rail route freight flows but also parts of Europe located in the Iberian Peninsula and parts of France and Italy on the Mediterranean that will also emerge as attractive for these flows once the PI concept will be extensively implemented. These areas together with the traditional trade areas in Northern Europe which will retain their role in the future (as verified by the LL2) should be the focus for the development of the EGTN.

With respect to the significant nodes of the EGTN, the nodes identified through the strategic modelling simulations of the project are presented in the map in Figure 15, combined with additional important inland nodes identified through the CCI that can support the orientation of the EGTN towards supporting EU exports.

Figure 15: Map of proposed nodes and entry points of revised significance for the realisation of the EGTN

Another important conclusion from the disadvantaged regions analysis is that not specifically one terminal is best positioned to serve the disadvantaged regions and that there is sufficient market potential to pursue a broad development of multiple terminals in this region. Investing in multiple terminals in a region contributes to the resilience of the transport network by creating redundancy. If one terminal fails, the presence of additional terminals allows alternative routes to be used and maintains the flow of goods. Multiple terminals enable better distribution and localisation of goods, increasing the overall flexibility and resilience of the network.

This recommendation is fully aligned with the PLANET design proposition for the EGTN nodes regarding a new model of intelligent PI nodes which will replace the node concept as it is applied today (as individual terminal(s) in a specific geographic location, e.g., the port, the airport and the railway terminal of a city). The development of new type of nodes aims at achieving the attribute of network resilience (both in terms of capacity availability & handling unexpected operations disruptions) and also the enhanced economic, environmental & social efficiency of freight transport operations. These PI nodes/hubs include:

1. A set of transport infrastructure assets (e.g., ports, intermodal stations, warehouses, transportation links) supporting logistics operations in a specific geographical area or located along a corridor.
2. The technological infrastructure for supporting PI operations.
3. The ecosystem of stakeholders who are active and operating in this area, sharing interests and collaborating towards the increase of the node efficiency and attractiveness.

More specifically, the vision of EGTN is for the stakeholders of these ecosystems to identify their common goals and to find common ground to establish trust-based relationships and reach consensus in investment policies, leading to in-depth collaboration and the implementation of resource sharing business models in alignment to the PI concept. These ecosystems will be open systems, aiming to expand and ultimately include all actors that are operating in the node, if possible.

The value of this concept to the PI and EGTN implementation was proved in the context of LL1 where different types of actors of the supply chain in a wider region (node) and several types of infrastructure collaborated utilising the PI-services of EGTN to increase the efficiency of their node.

4.2 Prioritisation of EGTN PI corridors for PI implementation

Based on the LLs and the technologies micro-simulation testing results, implementing PI-enabling technologies in the European transport network as part of the EGTN development, is expected to have a significant impact regarding efficiency and the environment impact of logistics operations. Nevertheless, PLANET chose to have a more modest and realistic approach for the development of EGTN, in terms of the rate of development of the required PI enabling technologies implementations. The simultaneous development of the required technologies for the PI at the entire TEN-T is considered to be constrained since it requires investments, human resources and collaboration beyond the current capabilities. Therefore, taking this approach might result in dispersion of available resources and thus failure in focusing and coordinating efforts towards the long-term objective of wide market uptake of these technologies and the EGTN operation under the PI paradigm. Instead, it was decided to proceed with defining the corridors of the European network in which the implementation of such technologies should get priority for having more significant impact on the EGTN development and operation.

Technology is considered as the quick solution for increasing efficiency of infrastructure and logistics operations. PLANET has searched for an answer to the basic question about the capability of the technology development to substitute a part of the public funding for infrastructure development. A prioritisation of the PI implementation along critical links of the EGTN may provide an answer to this question. Such approach also contributes to the EGTN network resilience through the technology deployment.

4.2.1 Methodological approach

In order to define the links of EGTN that are of increased significance and therefore where the PI services should be developed/implemented by priority, it was decided to use as a main criterion the criticality assessment for resilience since it is one of the main characteristics of the EGTN profile, both in terms of the network responsiveness to disruptions and changes in demand. The results of this process were then combined with the main routes of the intercontinental rail freight transportation as these emerged from the strategic model simulations in order to cover the global connectivity and geo-economics awareness aspect of EGTN.

The methodology for the criticality assessment is briefly described below:

Initially, the road and rail networks that are used by the strategic model were extracted separately and all links were modelled as bi-directional graphs. As zones of origin and destination are considered the territorial units of Europe at NUTS 2 level and regarding the weighting factor and edges, the generalised transportation cost is used (included in the model provided). After setting up the network based on the process described above, the efficiency of the entire network is calculated considering only the paths between the origin-destination zones and not the paths between physical nodes of the network. Following this process, an iteration of the calculation of the network efficiency is performed by eliminating one link of the network each time. This is done by increasing the generalised cost for this link thus making its unattractive to use. In case an alternative path exists, the algorithm choses it and performs calculations, otherwise the efficiency calculation for this path approaches the zero value. Therefore, the results of the efficiency calculation for each link elimination can be compared to the initial network efficiency, creating a map of the most critical links of the network in the sense that these are the links that reduce significantly the overall network efficiency.

4.2.2 Analysis of the results

The results of the criticality assessment of the road and rail network are presented in Figure 16 and Figure 17. In both figures the major parts of the networks in the central part of Europe appear to be critical for the overall network resilience, despite its density mainly due to the key role it plays in relation to the major production and consumption centres located in that area.

In addition, for both networks an increased criticality is observed in parts or entire corridors which are linking Central Europe to the Principal Entry Points, including maritime (Mediterranean ports) and land (corridors from

Eastern Europe). This is a significant conclusion since the EGTN is a globally connected network and therefore the interfaces and connections with global routes need to be resilient.

Figure 16: EU road network criticality assessment results

Figure 17: EU rail network criticality assessment results

The analysis of the strategic model simulations has revealed that in each scenario the same routes are followed by the intercontinental rail flows from China, possibly due to their specific characteristics that make them more attractive compared to other routes. These flows are presented in Figure 18.

With respect to the alignment of these flows to the TEN-T network, the North Sea – Baltic corridor appears to be the most significant corridor for the flow of containers from Chinas as it was also verified by Living Lab 3 which was located on the rail route from China reaching central Europe through Poland. In addition, parts of the Baltic Sea – Adriatic Sea, the North Sea – Alpine and the Mediterranean corridors also have an important role for serving these flows towards Italy, France and Spain.

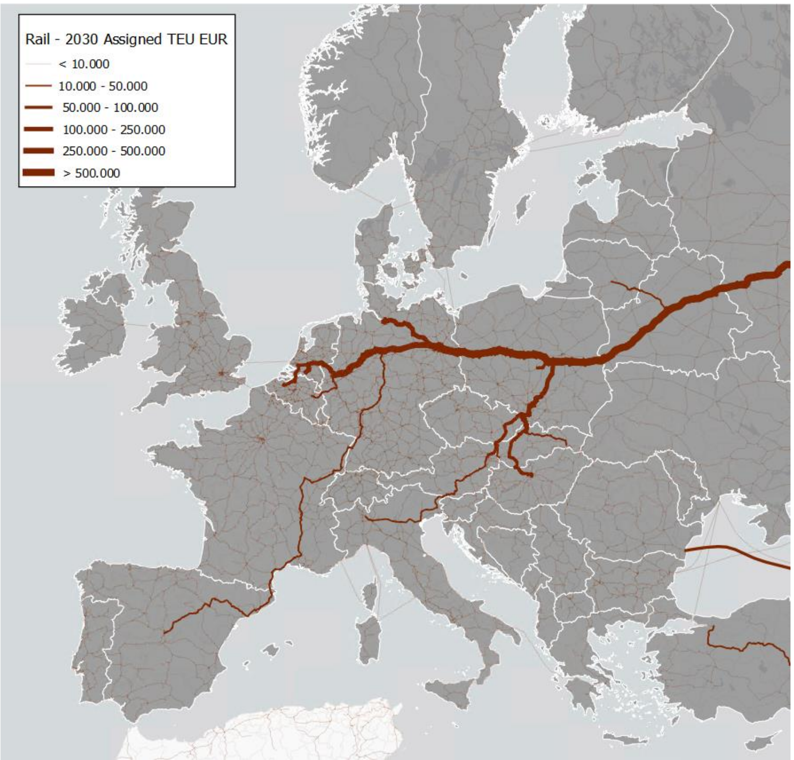


Figure 18: EU rail network Modelled transport flows of containers from China to European rail PEPs by rail in 2030

By combining the results of the criticality assessment of the road and rail networks with the expected flow patterns of the intercontinental rail freight flows, a set of sections of the TEN-T which appear to be more significant for the development of the EGTN is created and presented in Figure 19 (highlighted in grey colour). Looking at this map, it becomes obvious that the majority of the previously identified nodes and PEPs of significance for the EGTN are located on or near these sections which verifies in a way the alignment and validity of the assessment processes performed. The only exception is observed in the area of western Balkans where the need for new entry points and nodes was identified while its connection through core network corridors is not as strong as of the other areas.

This priority links mapping should be considered for guiding public and private funding to technological infrastructure and targeted ecosystems of Transport and Logistics for exploiting the services of the open, cloud-based EGTN infrastructure.

Figure 19: Prioritization proposition for the implementation of PI technologies and services on EU corridors

5 EGTN Technological layer specifications

Following the GA requirements, 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.

In the previous chapter on the physical layer of the EGTN, the specifications for the EGTN in order to be able to operate as a full-fledged or hybrid conventional (transitional) network have been described. More specifically, the drafting and simulation of the “technology” scenario through the strategic modelling capability of the project has defined the process for utilizing a gravity model for assessing the changes in the volume of freight that may result from corridor improvements such as the implementation of technology. With respect to the requirement for routing decision support models based on the CCI, the methodology for the CCI calculation has been described and is included in the Open, cloud-based EGTN infrastructure in order to be able to be connected with routing decision tools as a parameter for the attraction of nodes. Finally, the network design propositions for the nodes of the EGTN was presented in the form of the intelligent PI-node concept which is developed for supporting collaboration among stakeholders and facilitating the implementation of the PI-enabling technologies at the level of EGTN node.

In the present chapter, the focus is placed on the assessment of the innovative technologies that were tested during the project regarding their value for the enablement of the PI concept vis-à-vis the services developed for the Open, cloud-based EGTN infrastructure in the context of WP2 to support the realisation of the EGTN. The purpose is to answer one main question about which PI technologies should at minimum be applied in three distinct PI implementation contexts:

- Vertical integration of seaborn services to port clusters and their hinterland,
- Last mile delivery collaboration,
- Warehouse and PI hub resources management.

5.1 Required technologies and functions for the EGTN

5.1.1 Assessment of the PI enabling technologies

One of the major pre-requisites for the EGTN to operate under a PI principle is the collaboration between the different logistics players in the network. This collaboration could be either vertical collaboration between supply chain players or horizontal collaboration between competitors. In either case, the underlying assumption is that there is complete visibility, trust, and sharing of resources and information between the players with certain standards and protocols in place.

This section focuses on the technologies that were identified as most effective for achieving collaboration across multiple stakeholders and leveraging the PI (Physical Internet) concept in the EGTN context. The selection of these technologies was informed by the simulation capability and analysis conducted in T1.4 as outlined in D1.9.

Figure 20 offers an outline of the various technologies utilized in the three use-cases that were evaluated in D1.9.

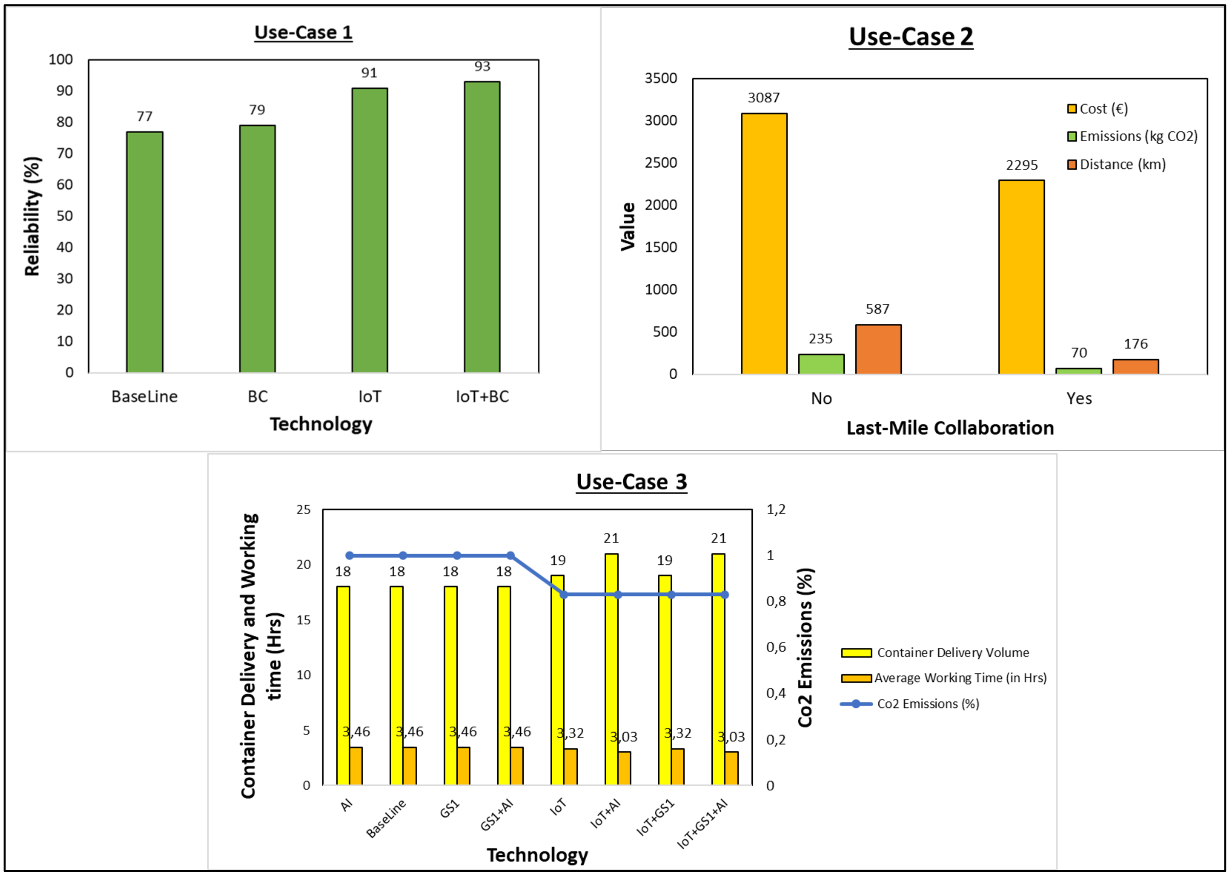


Figure 20: Overview of technologies used in micro-simulation use-cases for PI implementation

The first Use case for the vertical integration of seaborn services to port clusters and their hinterland, scrutinizes the physical internet concept by exploring the vertical cooperation among various players involved in transporting containerized cargo from China to inland Spain, such as the Ocean liner, port terminal operators, trucking companies, and rail operator (Figure 21). By leveraging IoT, each player in the network can obtain end-to-end visibility on the location and condition of the containers, enabling them to monitor weather and congestion issues faced by the cargo in each transportation leg of the maritime corridor. Meanwhile, Blockchain technology ensures secure and efficient collaboration among players, specifically in processes such as customs clearance and hinterland logistics. The combination of IoT and Blockchain technologies, as highlighted in Figure 20, can increase the reliability of containerized cargo shipment to 93%, demonstrating their complementary nature. Ultimately, the integration of these technologies, along with effective collaboration among players and the establishment of standards, has the potential to improve the transportation industry's efficiency, sustainability, and competitiveness in the future.

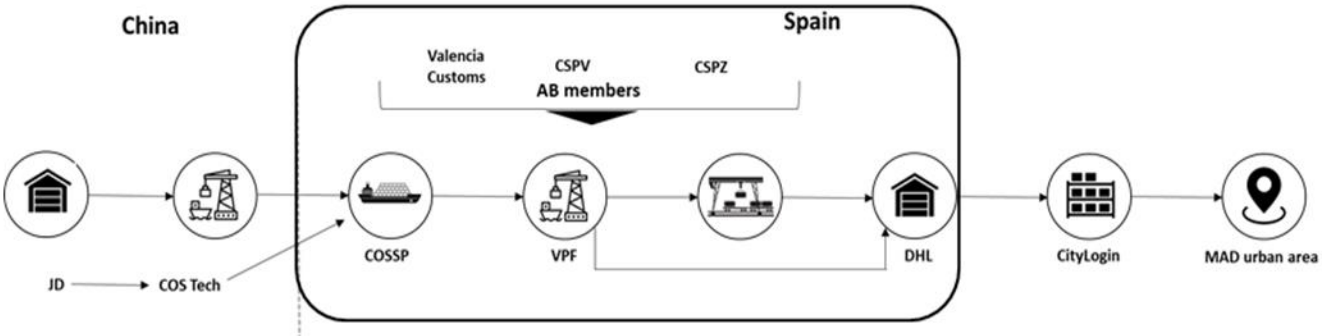


Figure 21: Use Case 1 focus, based on the LL1 supply chain scenario

In the second Use Case for the Last mile delivery collaboration, the focus is on horizontal collaboration between competing logistics players in the last-mile who work together in the Physical internet paradigm by creating urban consolidation centres and sharing resources like vehicle fleet and order information (Figure 22). The No and Yes data points in Figure 20 represent whether or not the competing players collaborate. The collaboration between the players is assumed to take place with the help of IoT and blockchain technologies with the logic of implementation similar to that of Use-case 1 where trucks enabled with GPS trackers help collect data on traffic and route conditions while containers equipped with IoT sensors help collect and analyse data on container location and condition. As seen in Figure 20, when the last-mile players collaborate with each other by establishing urban consolidation centres and share data on customer orders, vehicle fleet positions etc. through IoT and BC infrastructure, improvements in costs, distance travelled, and emissions are observed. Thus, similar to Use-case 1, IoT and BC are indispensable to implementing the PI paradigm in the last-mile as well.

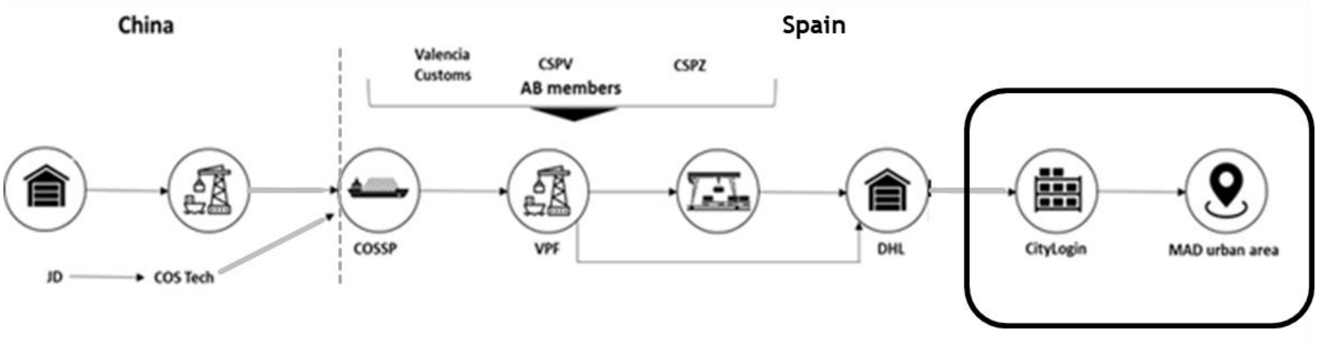


Figure 22: Use Case 2 focus, based on the LL1 supply chain scenario

Additionally, the third Use Case examines the potential of working under a PI paradigm by using standards as a proxy for collaborations among the different players in the rail-freight corridor supported by technologies such as Internet of Things and Artificial intelligence (Figure 23). As depicted in Figure 20, the combination of IoT and AI yields the best performance on the major Key Performance Indicators (KPIs) considered, akin to the performance achieved by integrating IoT, AI, and GS1 standards. The implementation of GS1 standards helps standardize the data flow and access to information about cargoes coming from China to Poland in the entire supply chain. Hence, at the very least, a combination of AI and IoT is necessary, where AI processes the data collected by IoT sensors and makes informed decisions.

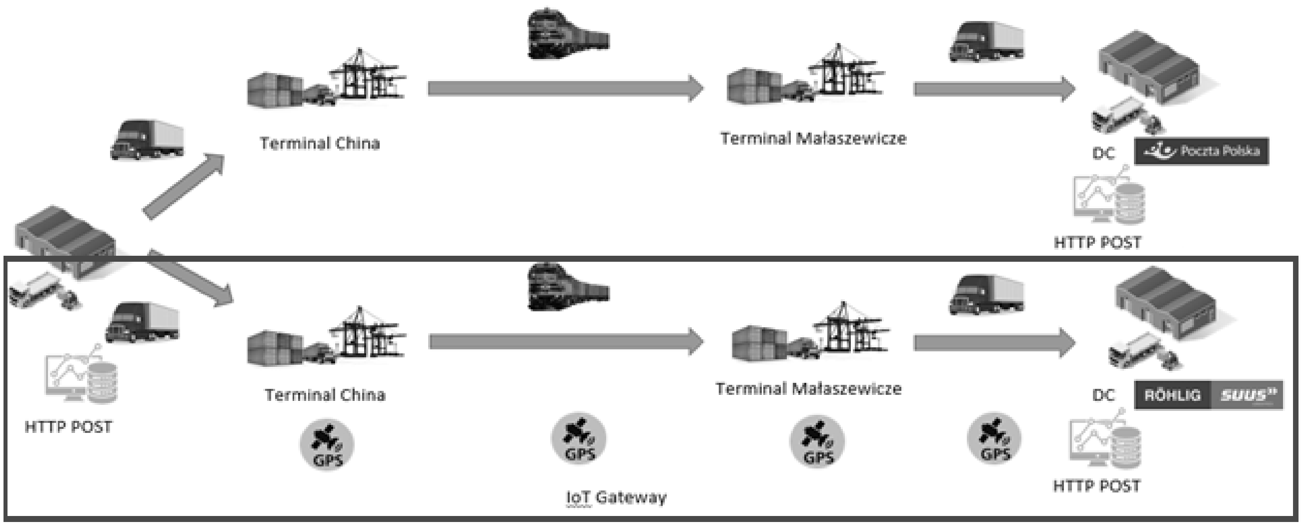


Figure 23: Use Case 2 focus, based on the LL3 supply chain scenario

Based on the analysis of the three use-cases, it can be inferred that **the successful implementation of the Physical Internet (PI) paradigm by the EGTN requires the integration of Internet of Things (IoT) and Blockchain technologies supported by AI for optimal decision-making based on the data**. Although these technologies are beneficial in their own right, their combined application amplifies the performance of the EGTN as they complement each other. The operational value of these technologies and their increased synergistic impact is also depicted in the LL testing results and the corresponding KPIs which are aligned to the results of the technological microsimulations. This fact also confirms the identified need for the platform that was developed in the context of PLANET, as a one-stop-shop for the PI services to support their combined implementation for increased impact on logistics operations. The detailed results of the three LLs can be found in D3.2, D3.4, D3.6 respectively and also in D3.9 for the generic Use Case in the port of Sines.

Considering the outcome of the technology assessment and the results of the work undertaken in the LLs, PLANET has concluded in the list of functionalities that should be included as a minimum in a PI-enabling platform that will support the EGTN operationalization, like the Open, cloud-based EGTN infrastructure. In Table 18 these functionalities, the respective technologies which they leverage and also their justifications are presented.

Table 18: Minimum set of technologies and functionalities required for supporting the PI concept

Technology	*Functional Requirements*	*Justification*
Internet of Things (AI support)	Ability to Support continuous streaming of data	Real-time status updates on containerized cargo location and conditions etc.
	Ability to run AI models and algorithms	The mass of data gathered from the IoT sensors attached to not only cargo containers but also the different modes such as a rail, ships, and trucks can help understand the traffic patterns, weather conditions and subsequent impacts etc.
	Ability to send automated notifications / alarms through emails etc.	Based on the decisions / forecasts of AI models and algorithms, appropriate notifications can be sent to affected parties or alarms can be raised for immediate attention from required players etc.
	Ability to flag data availability concerns	Also flagging events where data that is expected to be communicated by device/ player is not.
Blockchain	Data Security and privacy	Grant specific data rights to individual users as they may not want to share all information with other players
	Smart Contracts	Executing payments and contract terms is key requirement in cases where players are collaborating with each other and sharing resources such as depots and fleet. (For e.g., Use-case 2)

5.2 EGTN technological infrastructure and services

The first version of the present document (D1.10) has provided an initial estimation of the functions to be provided by the EGTN technological infrastructure in order to leverage emerging technologies, which became the requirements for the PLANET Open, Cloud-based EGTN Infrastructure.

Based on these requirements, the developed EGTN Platform provides the infrastructure, namely a secure and scalable Data Lake, software container orchestration and analytics notebooks for code development that enables the fundamentals for the development of data-driven PI services. Figure 24 shows the integrated technology architecture of the EGTN Platform that includes connectivity components for ingestion of various datasets, spanning real-time data, batch data and blockchain events, a Data Lake for data storage, analytics tools, the EGTN PI Services developed by the WP2 tasks (described in the next section) and a dashboard for a user-friendly interface to the EGTN components and data aiming at supporting the end users with real-time analytics and services.

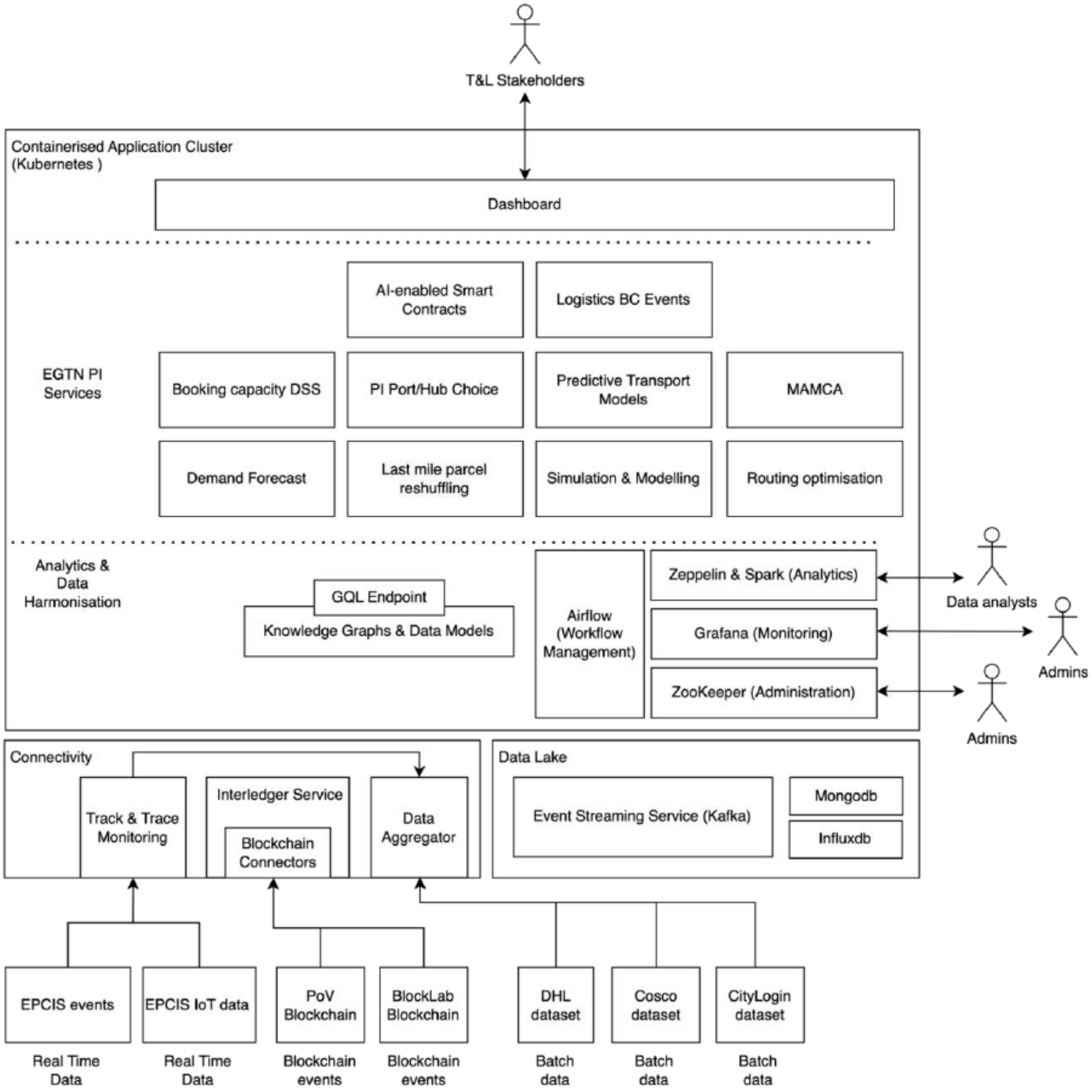


Figure 24: The EGTN platform infrastructure

5.2.1 EGTN PI logistics services

The list of the innovative technologies-enabled PI services for supporting the operationalisation of the EGTN that were developed for the Open cloud-based EGTN infrastructure are briefly described below. More details about these services can be found in D2.2:

- **Track and trace monitoring:** This service enables the real-time visibility of the shipment by proving detailed information, such as position, temperature, luminance, humidity, acceleration.
- **Demand forecast:** It forecasts the number of pallets/containers arriving in a warehouse or port, providing confidence intervals for the next 10 days. The Demand forecast service reduces hiring costs, as it enables the booking of vehicles in advance to avoid demand peaks and high prices. The output is consumed by the 4.2.15 Booking Capacity DSS service that produces recommendations for generating smart contracts based on the predictions of the Demand Forecast service.
- **Routing optimisation:** This service addresses some of the most challenging aspects in delivering freight volume within the last mile delivery (urban area). A core aspect of the service is that it scales the optimisation within a big number of delivery nodes, in the order of thousands per day. It prioritises the use of hybrid and electric vehicles to comply with carbon emission norms within the Madrid urban area.
- **Predictive transport models:** This service can make use of simulation data and machine learning-based predictive models to predict changes in freight volume across corridors. Based on the data provided, the service can generate correlation graphs between the predicted changes in volume and historical information on relevant variables such as transportation cost and lead time.
- **PI Port/Hub choice:** The PI Port/Hub Choice Service optimises terminals to be visited along a route, considering hinterland transport options and terminal congestion. Given a set of containers (and their final destinations), some candidate ports (and delays that are input by the user) and an Origin Destination (OD) matrix for one or more modes, it determines which subset of ports should the vessel visit.
- **Last mile parcel reshuffling:** The Last Mile Parcel Reshuffling Service optimises parcel reshuffling for last mile delivery, involving collaborative opportunities between vans to expedite deliveries. It determines if a van operating in proximity can be of meaningful assistance to a van running late. If yes, it redistributes the parcels, sets a meeting point, and redesigns the vehicle route.
- **Booking capacity DSS:** The Booking Capacity DSS Service determines the number of trucks that a warehouse needs to book in a time range of ten or three days ahead. It is based on time series predictions (from the Demand Forecast Service) and on a dynamic pricing strategy i.e. booking and cancellation fees. The service determines the trucking capacity that needs to be booked by the warehouse towards minimising costs.
- **Logistics events:** It increases the visibility of the supply chain by provisioning blockchain events from heterogeneous logistic stakeholders. The service implements a universal front-end to existing backend blockchain systems transparently and at the same time securely exposing logistics events i.e., container arrival at port, container pickup, container unload etc.
- **AI-enabled Smart Contracts:** It enables the automatic generation of smart contracts for warehouse management, embedding special conditions and violation measures based on risk assessment and a dynamic pricing policy. The smart contracts are generated between different blockchain communities e.g. between FF and Carrier communities and they are based on predefined contracts that increase response time significantly.

As mentioned in the introductory part of this chapter, one of the major pre-requisites for the EGTN to operate under a PI paradigm is the collaboration between the different logistics players in the network and several of the services developed in the context of the PLANET Open, cloud-based EGTN infrastructure were focused towards this direction. In addition to that, it was decided to develop and include also in the platform a tool that is not based on innovative technologies but can support the decision making on both operational and strategic level, fostering collaboration among stakeholders and facilitating the EGTN governance. A short description of the MAMCA functionality is included in the following chapter of the present document while the detailed description of MAMCA methodology together with the corresponding functionality of the Open, cloud-based EGTN infrastructure can be found in D2.12.

5.2.2 Discussion about the Open, cloud-based EGTN infrastructure

The micro-simulations undertaken for defining the impact of innovative technologies on logistics processes have helped to identify the required technologies and functionalities for supporting the realisation of a PI-enabled EGTN. Together with the LLs testing of the services which were developed following the guidelines of D1.10, they have verified that these services cover to a large extent the required functionalities by utilising the identified technologies and can support the EGTN operationalisation under the PI-paradigm.

However, these are not the only services that are needed for realising the EGTN. The Open, cloud-based EGTN infrastructure provides a great value that brings EGTN a step closer to the PI paradigm but also a solid basis for the development of more data-driven T&L collaborative logistics services and new eCommerce models. All the infrastructure software is open source, enabling an open and neutral industry platform and facilitating the engagement of smaller T&L players through the low-cost integration process. At the same time, it provides flexibility and applicability to different Cloud models, such as Public, Private or Hybrid, through its container-based architecture.

The open APIs offered by the architecture of the platform for data ingestion increase the potential for a modern Data Lake that optimises resources and data flows, improves performance and enables big data analytics on shareable data. On the other hand, the integration of the PI Services is managed by well-defined and automated processes that ensure seamless integration and visualisation through the Dashboard. The platform governance model enables a secure and private infrastructure fulfilling the privacy criteria of the business stakeholders for sharing anonymised data that are useful for the development of PI Services.

5.3 Requirements for the implementation of technologies

This section summarizes the implementation roadmap developed in D4.4 for the critical technologies of IoT, Blockchain, and AI/ML (Section 5.3.1), which were identified and assessed using the simulation capability of PLANET developed in D1.9. Their combined implementation is vital for transitioning towards EGTN in a PI paradigm.

Like D1.9 Simulation-based analysis of T&L and ICT innovation technologies, the three use-case contexts of last-mile, Maritime corridor, and hinterland corridor were considered to develop separate roadmaps underlining the most important PI-enabling technologies in each scenario and identifying the interdependencies between the technologies and sequence innovations for the PI facilitation. Apart from the technologies and their expected impact on the EGTN, each of the roadmaps developed prioritize innovations towards achieving complete PI while considering factors such as infrastructural requirements, regulations, and stakeholders involved. It should be emphasized that the insights obtained from D4.4 are in perfect agreement with the outcomes of the simulation studies conducted using PLANET's simulation capability across the three use cases.

The roadmaps have determined that achieving full PI adoption by 2050 will occur in two main stages, with the year 2030 serving as a significant milestone. Among the various PI-enabling technologies analysed, such as 5G, IoT, AI/ML, Blockchain, iMLU, UAVs, Avs, and Hyperloop, a common finding across the three roadmaps is that finalizing the coverage of 5G network in European geography and beyond, increasing IoT implementation across the T&L network, and incorporating AI/ML into planning and execution systems during the first stage (2022-2030) are crucial. These steps lay the foundation for the implementation of more advanced technologies like blockchain, iMLU, UAVs, and AVs in the 2nd stage (2030-2050) helping in a smooth transition towards a compete PI-enabled EGTN. Therefore, it can be easily concluded that prioritization-wise, these initial actions hold great significance. The developed roadmaps align with the intuitive understanding that for the successful implementation of sophisticated technologies like UAVs, Avs, blockchain, and iMLU, the T&L network must possess seamless, rapid, and reliable connectivity (5G). This connectivity always enables complete visibility across the network (IoT), while the captured data can be efficiently analysed to inform planning and execution decisions made by various T&L stakeholders. The roadmaps developed support the intuitive understanding that for the implementation of sophisticated technologies such as UAVs, Avs, Blockchain, iMLU etc. it is key that the T&L network allows for smooth, fast, and reliable connectivity (5G) such that there is complete visibility across the network at all times (IoT) and the data captured can be efficiently analysed to inform planning and execution decisions of various T&L stakeholders.

After establishing the priority of implementation for each technology, it is equally crucial to highlight the requirements for implementing 5G, IoT, AI/ML, and Blockchain. These technologies encompass the combined key enabling technologies identified in D1.9 and D4.4. In relation to 5G, crucial endeavours aimed at ensuring the successful deployment of the technology involve conducting research and performance evaluations of 5G-enabled devices to enable real-time autonomous decision-making. Additionally, addressing cross-border challenges through the promotion of homogeneity and standardization is vital. These activities are primarily led by knowledge institutes, transport and logistics companies, and policy makers. On the other hand, concerning IoT, pivotal activities revolve around implementing IoT on a large scale within organizations to establish physical intranets. Moreover, collaboration efforts to leverage IoT data across logistics networks play a crucial role in facilitating efficient resource sharing. Transport and logistics companies, warehouses, producers, and retailers primarily drive these activities. Further, for AI/ML, since this technology is already widely used to make smart decisions by various organizations, it is critical to establish service agreements (maintenance, updating, re-training etc.) by Transport and Logistics organizations with Technology companies. Regarding Blockchain, Development of regulatory policies that enable sharing transport documentation electronically between organizations and authorities to facilitate faster and cheaper intermodal operations along with development of standards and protocols for data and information sharing on BC platforms between organizations operating in the T&L domain is important with Knowledge Institutes, Technology Companies, and European and Local authorities playing a major role at orchestrating its effective adoption.

With respect to the service platforms associated with bringing these crucial PI-enabling technologies to the markets, as is clear from the above discussion, since several stakeholders are involved in the use and simultaneous exchange of data resources across the length and breadth of the EU-Global Transport and Logistics network, it is advantageous to have multiple platforms as different platforms can cater to the unique needs and requirements of diverse stakeholders, allowing for greater customization through allowing a range of specialized solutions tailored to specific industries, use cases, or user preferences.

To create a symbiotic and collaborative environment for different platforms to enable the rapid adoption of PI-enabling technologies by the market, several factors such as (i) establishing common standards and protocols across platforms, promoting data sharing between platforms to foster collaboration, (ii) establishing partnerships, consortiums, or industry associations that oversee, coordinate, and promote collaboration, knowledge sharing, and joint initiatives between the various platforms, (iii) laws and regulatory support which adopt carrot-stick mechanisms to ensure data sharing while also mitigating data privacy and security risks are required.

6 EGTN Governance layer specifications

According to the GA requirements for the governance layer of the EGTN, a goal-directed form of network governance is envisaged with the aim 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”. Based on the literature, goal-directed networks are defined as groups of three or more legally autonomous organisations that work together to achieve not only their own goals but also a collective goal [3]. In the case of EGTN, the common goal is the operationalisation of the network under the PI paradigm through the development of all required infrastructures and processes for its implementation.

It should be noted also that the EGTN governance refers to the governance of the PI network and not of the TEN-T, the current governance scheme of which is focused on the development of the corridor infrastructure and will continue to exist 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 define the prerequisites at governance level for the realization of the EGTN vision as a network operating under the PI paradigm.

6.1 ALICE approach on the PI governance

According to ALICE, the PI governance includes the developments needed to evolve the logistics nodes, logistics networks and the system of logistics networks into the Physical Internet and more specifically the rules defined by the stakeholders forming or using them as well as the trust building processes and mechanisms [2].

The first version of deliverable (D1.10) outlined the main principles of ALICE regarding the governance of PI networks. In the document it was concluded that the EGTN in order to be able to operate as a full-fledged PI network the governance should reach the maturity and the characteristics between the 4th and 5th generation of PI governance according to the ALICE PI roadmap. (Figure 25).

Based on this scale, the 4th generation will extent the governance framework to support scalable governance models in order to increase the reach of existing systems of logistics networks, thus allowing asset sharing and route planning and re-planning of shipments through logistics nodes belonging to different networks. It will also address the issue of unexclusive participation of shippers and logistics services providers to multiple logistics networks thus enabling future transition towards more open Logistics Network configurations. Regarding the 5th generation, the governance framework will be fully designed and implemented, including all required governance processes and a well-established body for defining the rules and addressing barriers for establishing shared and connected logistics networks building the Physical Internet. In addition, it will cover all relevant business and regulatory aspects that must be addressed to make Logistics Network nodes and services available to the global business community [2].

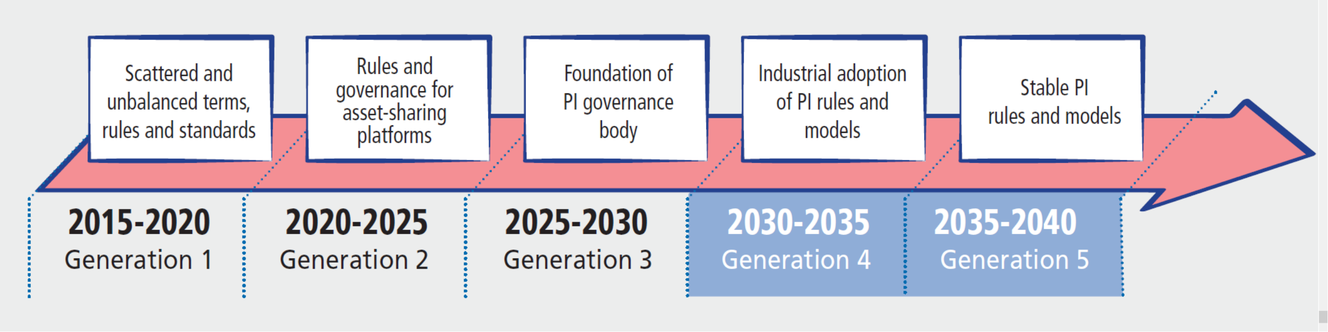


Figure 25: Overview on generations (possible development steps) for PI Governance

Moreover, EGTN as a PI network, should follow a similar approach having its governance based on the bottom-up approach considering it also as the only viable one for organic growth of the PI, as it ensures a more gradual and business-driven creation of the Logistics Network. The logistics nodes, networks and systems of logistics networks will develop their own governance mechanisms and companies and consortia will develop governance for their networks while the alignment between networks will be achieved as these models will be advancing [2].

This approach is fully aligned to the rationale of EGTN regarding its nature as a network of networks which will be developed with strong private initiative and also to its strong regional aspect of operations through the development of the intelligent PI nodes. In this new type of nodes, the need for local governance schemes to facilitate the collaboration and development and sharing of assets by engaging all actors in the area is evident, therefore the EGTN governance should have a decentralised level of local governance through which the nodes will have their self-organisation and their own voice to the higher levels of decision making.

It should be noted however that this approach could lead to the creation of islands or subsets of Physical Internets with their own standards and protocols and possibly to difficulty of access for some stakeholders. For this reason, as it is also foreseen in the roadmap document recommendations for 2030/2040, the bottom-up development should be supported and supervised by public bodies in high-level governance to Implement rules for letting the network open and ensure participation in the networks of all types of stakeholders.

6.2 Proposed EGTN governance structure

Based on the analysis above, the proposed structure for the governance of EGTN includes two levels of governance: a collaborative governance model at the local (node) PI network level engaging all stakeholders to the decision making and the setting of rules for the development of the PI network and the PI-enabled operations and on a higher level, a governance model led by an entity (agency) which will coordinate the network of PI networks, interfacing with the TEN-T governance structure to ensure that wherever possible synergies will be realised.

With respect to the governance model at the node level, the proposed as most appropriate model has emerged through the conclusions of the evaluation process that was realised for the project LLs. The EGTN impact assessment that was carried out in D3.10, demonstrated that the technological solutions developed and tested in all Living Labs and the Generic Use Case, had a significant impact on all but one KPIs that were measured before (Baseline) and after (To-Be) the implementation of the solutions. In particular, considering the average performance of the KPI categories, a positive impact was observed for all of them, ranging from 11% to 107% percentage increase when comparing the Baseline and To-Be measurements. The KPIs that were tested on a real case, such as ‘Customer satisfaction’, ‘Visibility of operations’ and ‘Volume of products’, were among those that contributed the most in the positive impact of the technological solutions on EGTN operations.

What should be noted though is that the EGTN impact assessment was only possible after an extensive data collection and stakeholder engagement for the exchange of knowledge and data. Each stakeholder involved in the project and the Living Labs, was willing to participate in this evaluation process, with effective communication and coordination of actions, achieving as a result the development of technological solutions which had a great positive impact on the operation of EGTN.

Collaboration dynamics unfold through principled engagement, shared motivation, and capacity for joint action, with each element contributing to its performance (Figure 26) [4]. Principles for effective collaboration include skilful communication, collective learning, expectation of conflict, and consensus decision-making. The interpersonal dimensions of trust, mutual understanding, legitimacy, and commitment are key to shared motivation.

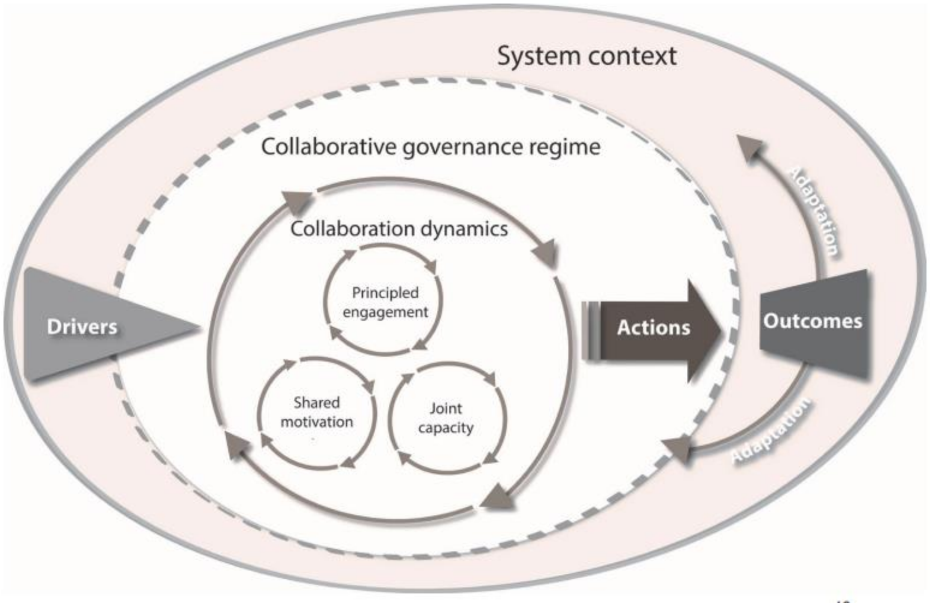


Figure 26: Framework for collaborative governance regime

Involving stakeholders in the evaluation process of operations that concern them is an important aspect of good governance. This is because effective governance requires engagement with those who are affected by decisions and actions taken by organisations or institutions. By involving stakeholders in the evaluation process, organisations ensured that their interests, concerns, and perspectives were considered, and that decisions made were more informed and equitable. The context of collaborative governance is dynamic and complex, influenced by various factors such as resource conditions, policy and legal frameworks, political dynamics, power relations, and history of conflict. Regardless of the heterogeneity of those features in the stakeholders involved in the evaluation process, the outcomes of the EGTN impact assessment were derived in a smooth and successful manner.

When stakeholders are involved in the evaluation process, they are more likely to have a sense of ownership and accountability for the outcomes. This, in turn, enhances transparency, trust, and legitimacy of the evaluation process. Stakeholders' input can help identify areas for improvement, as well as strengths and weaknesses of the solutions tested in this context. This information can be used to improve organisational performance, increase efficiency, and reduce risks. For example, the collection of data, knowledge exchange and high share in the participation to the questionnaire used for the development of EGTN impact assessment, were crucial for the success of its outcome.

Overall, the LLs testing has verified that the major pre-requisite for the EGTN to operate under a PI principle is the collaboration between the different logistics players in the network during all the stages of the logistics processes as well as their participation to its governance in order to establish a trustworthy business ecosystem.

For this reason, the collaborative model for the governance of the EGTN PI nodes PI is selected and proposed. Such a system, following also the ALICE roadmap, will be open to all types of organisations (e.g. shippers, service provides, infrastructure managers, public administration) and include stakeholders from all involved entities who will also be represented in the decision bodies for establishing/updating common rules and protocols and define service levels requirements, ensuring that on operational level the routing of cargo through the network and the service assignments are managed transparently for fair allocation of costs, risks and responsibilities among the involved providers. Moreover, these decision bodies supported by services, such as the MAMCA which is included to the Open cloud-based EGTN infrastructure, will also contribute on the development of the node on strategic level by reaching consensus for investments (private and public) on technology implementation as well as the network extensions. In addition, MAMCA can ensures even distribution of benefits across multiple stakeholders, thus promoting fair governance. In the next section, the MAMCA functionality and its potential uses are presented.

Regarding the higher level of governance of the EGTN, it should be noted that the EGTN is a goal-directed, network of networks with the common goal of facilitating the implementation of the PI concept to its operations. Based on the literature [3], goal-directed networks must be governed precisely since they aim at a collective goal and their governance can be defined as “the use of institutions and resources to coordinate and control joint action across the network as a whole”. Considering also the recommendations of the ALICE roadmap for a higher-level support and supervision to the bottom up approach development of the PI networks, the establishment of a higher-level entity for coordinating and supporting the PI-networks of nodes is proposed for the successful realisation of the EGTN.

Drawing on the research for the structure of all European regulatory networks [3], there are three identified ideal structural forms of governance for whole goal-directed networks: shared governance among all network members like the proposed model for the node level PI-networks, the governance by one of the members functioning as lead organization or the and delegation of governance to a Network Administrative Organisation (NAO) that will be created for this purpose.

The two first forms of governance are considered brokered since there is a central entity responsible for the governance of the network. In the case when there is observed low trust density and consensus, large membership and need for network-level competencies, the research concludes that a broker is far more efficient than shared governance model. In the case of the EGTN, at least at the first stages of its development these conditions are similar to the expected therefore, the brokered model appears to be more appropriate.

With respect to choosing between the two brokered forms, namely an administrative organisation or a lead organization, in the case of large number network members and the need for network-level competencies like the EGTN, the establishment of an administrative organisation appears to be the optimal choice. In addition, the EGTN as a rule setting network will probably require a less complex structure for this organisation compared to other rule-enforcing networks.

The administrative organisation will have a board structure that will include network members, addressing the strategic-level considerations for the EGTN, while the operational decisions such as the supportive rules and policies that allow collaborative and shared logistics networks to function will be taken by the organisation leader. In Figure 27, a general representation of the proposed governance scheme for the EGTN is presented.

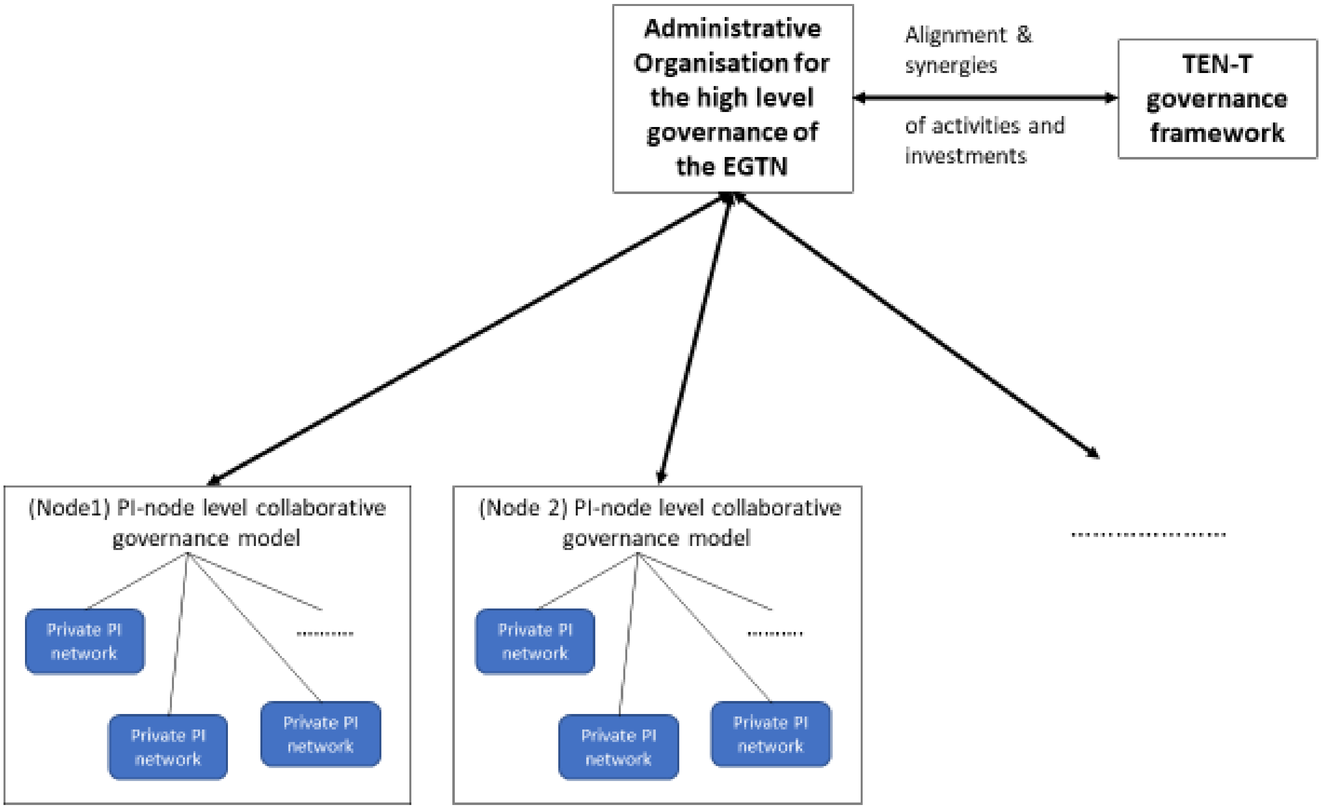


Figure 27: High level representation of the proposed governance structure for the EGTN

The proposed governance structure aspires to allow the PI-nodes to self-organise at local level with a strong participation of the private sector while at the same time supervision and support is provided from a higher-level entity that will ensure that the rules are commonly accepted and followed by all members of the network. Finally, what is important also is that through this structure the business view from the operational (node) level will be taken up to the higher level of decision making and will interact also with the TEN-T governance structure for aligning future activities and investments regarding hard and soft infrastructure. In this way, EGTN will fulfil also its purpose of bridging the logistics industry view with the EU policy and decision making for the EGTN development.

6.3 The EGTN MAMCA functionality

The EGTN Multi-Actor, Multi-Criteria Analysis (MAMCA) functionality enables the EGTN network performance evaluation models to decompose the impact of strategic network improvements per stakeholder. Recognizing that different stakeholders are associated to different stages of the supply chain, the analysis is undertaken separately for each unique supply chain context. The division classifies supply chain to intercontinental corridors, hinterland transport and last mile delivery sub-contexts as stakeholders in each sub-context are found to have significantly different and also have significantly different goals. Frequently, different legal entities in the form of subsidiary companies are assigned the operational task in each context, partially due to handling these uniquely different operational goals. For example, focusing on DHL's operations, there are three different businesses for:

- the intercontinental corridors and points of entry are handled by DHL Global Forwarding division (Air and maritime freight)
- warehouses and hinterland transport and handled by DHL Supply Chain
- while last mile delivery is handled by DHL Express.

Each context has very specific KPIs, that can be further divided into micro-KPIs and macro-KPIs. Micro-KPIs are for example when in last mile distribution the missing/wrong deliveries are considered as a critical KPI (as a single driver manages on average 60-70 deliveries per day). Obviously, for maritime or hinterland transportation such a KPI is not relevant. In maritime context, other KPIs such as waiting times at the port, total of containers/ship, etc. are more relevant. In a warehouse context, KPIs are typically related to receiving performance, put away, storage, pick & pack, etc. For hinterland transportation KPIs typically include cost/km, truck utilization (%), time windows accuracy in collections/deliveries, etc.

The analysis involves the development of weights based on the pairwise comparison through questionnaires for a specific stakeholder. Figure 28 summarizes the criteria weights for several hinterland transport stakeholders including hinterland transport providers. It is observed that delivery time weight is 0.12 for both warehouse operators and hinterland transport providers, while it is 0.16 for receivers/ customers. Transport cost weight is 0.08 for warehouse operators, 0.09 for hinterland transport providers and 0.12 for receivers/ customers. Operational throughput that is found to have limited significance for hinterland transport providers, has higher significance for warehouse operators and receivers. Information availability that was found to be significant for hinterland transport providers, is found to have limited significance for warehouse operators and receivers.

Figure 28: Criteria weights for selected hinterland transport stakeholders

Weights tables are developed for all three contexts considered in PLANET and for all significant stakeholders and criteria identified in each context. The weights tables for intercontinental corridors, warehouse and hinterland transport and last mile delivery can then be used to breakdown the analytic findings of transport studies to stakeholder preferences.

6.3.1 Applicability in Strategic Level Decision Making

The MAMCA model can be operationalized in the context of various types of network performance assessments, such as resilience, infrastructure or technology improvements. For resilience, a network component stress test can be performed, quantifying the criticality of various components in terms of various KPIs. Once the performance KPIs are quantified, then the insight from MAMCA becomes valuable by providing an analysis in terms of their impact to various stakeholders. Node or link characteristics can be altered to examine what-if scenario for investments, or disruptions. Therefore, considering the stakeholder weights and the percentile increase to the networks performance by each disruption, infrastructure or technology alteration, policy decisions can be made and a better understanding of disruption impact per stakeholder can be achieved.

6.3.2 Applicability in Operational Decision Making

Collaboration in T&L can be performed in multiple contexts ranging from warehouse and consolidation location sharing to dynamic re-routing solutions. T&L operators avoid horizontal collaboration, typically claiming fear of losing delivery volumes to competitors, poor service quality of other operators, as well as lack of brand recognition.

T&L operator collaboration leads to the identification of more efficient transport options and can significantly impact solution efficiency. PLANET's MAMCA model considers the most significant stakeholders and performance criteria for each operational context, also ranking them in terms of significance. Focusing on last mile delivery, the most significant criteria identified are: sustainability, transport cost, congestion, service quality, emissions, driver availability (human resources), delivery time and profitability. Each of those criteria is weighted uniquely by various stakeholders.

To address operational collaboration challenges the principles of MAMCA are adjusted instead of considering all relevant stakeholders to only incorporate operators. Using a standard scale for each of the criteria, a comprehensive characterization of each operator can be achieved. For example the figure below presents a mapping of five last mile operators based on synthetic data, where Operators 1, 3 and 4 are conventional van operators while operators 2 and 5 and cargo bike operators, scoring higher in emissions and sustainability performance.

Figure 29: Multi-criteria mapping of last mile operators

Maintaining a comprehensive multi-criteria performance characterization for each operator as the one illustrated above, enables, an automated collaborative filtering process to take place. Each operator can pre-define acceptable performance criteria for collaboration. For example, a mainstream operator that uses vans, may specify emissions and sustainability performance for collaboration to be at least 7, in which case only the two cargo-bike operators would qualify. Then, after respecting operators' preferences, a collaboration algorithm can be implemented to establish optimal operational conditions, considering only the last mile operators that qualify after applying the multi-criteria filtering process.

7 Conclusions

The present document reports the work undertaken to translate the results of the work of previous WPs and tasks into specifications for realising the EGTN and more specifically each of the three EGTN interacting layers, namely the infrastructural, the technological and the governance layer. In the previous chapters, the results of the future scenarios simulation for the time horizons of 2030 and 2050 provided the basis for defining new areas of focus and needs for additional corridors or entry points, utilising the strategic simulation capability developed in the project. The results of the technology micro-simulation capability of the project were used to conclude on the usefulness and impact of the innovative technologies and concepts to the T&L operations that led to defining the minimum set of technologies required for the EGTN to operate as a PI network. Finally, building on the ALICE roadmap for the PI, a governance scheme for the EGTN is proposed aiming to combine the current TEN-T governance structure with the new requirements of the EGTN development as a PI-enabled network.

Based on the project results, the technologies that were initially considered in the proposal stage for testing as potential major contributors to the realisation of the PI - enabled EGTN have proven their value with an emphasis on the demonstrated combined effect of these technologies. For this exact reason, the combined effect of technologies, it is important for users to have a one-point access to the proven technologies through a services platform. In this context, a set of corresponding functionalities exploiting these technologies have been developed as part of the Open cloud-based EGTN infrastructure in the context of WP2 in order for the EGTN users to be able to benefit from the combined use of the offered technologies/services.

Analysing the results of the strategic simulations performed in the context of PLANET for different future scenarios, it becomes clear that there is a tendency for increase in the rail flows coming from Asia (mainly China) especially for the high value category of products (approx. 15 euros/kg). For this category of products which constitute a significant part of the EU-China trade, usually time is of essence while their value does not justify the use of air transport. Despite the current decrease of rail flows which mainly approached EU through the route crossing Russia and Belarus due to the ongoing Ukraine war, it is expected that these flows will recover some time in the future and continue their growth path. This is also evident from the fact that discussions are already ongoing for the development of alternative land routes with most prominent the so-called middle corridor connecting China and Europe through the Caspian Sea, bypassing the Russian territory. Even if such an undertake would require time and significant investments, especially in the part of the route outside EU, it is a proof of the need for an efficient land connection between the two large economies.

It should be noted though, that in all initially simulated scenarios the projections of the rail future flows appear to remain low compared to maritime transport. Even in the future scenario when a significant development of the rail sector & rail infrastructure is foreseen, the volume of cargo coming from China through rail remains low in absolute terms, even though percentage-wise it shows a significant increase. This is mainly due to the fact that the development of intercontinental rail transport is not so much a matter of capacity availability (with some exceptions perhaps in specific points of the network) but more a matter of the lack of reliability and efficiency which increases the cost and time parameters of rail transport. And it is at this point where innovative technologies implementation and concepts like the PI can provide a solution by enhancing and supporting the logistics processes, optimizing the use of existing infrastructure and leading to greener and more efficient systems as has been proved through the extensive technology simulations and also the LLs testing of the project.

Having said the above, regarding the question of whether technology can reduce the need for public funding in hard infrastructure, the answer is that technology can improve processes that need to be improved (e.g., customs processes) regardless of the possible need for hard infrastructure investments (e.g., new rail lines or terminals). Through this process improvement, indeed some hard infrastructure bottlenecks will be alleviated by a better use of the existing infrastructure without the need of additional infrastructure funding but since the current capacity in most cases is capable of handling the foreseen future additional flows, the level of the possible investment reduction in hard infrastructure in the short/medium term cannot be determined with certainty.

In addition to the above, based on the simulation results of the final and enhanced future scenarios of task 1.5 in which the technological implementation together with the policy and legislation initiatives impacts has been considered for calculating future flows, it appears that technology has the potential to significantly alter the mode selection for the cargo flows originating from China. The analysis shows that for the high value products the area of the EU where rail transport costs are lower compared to maritime transport becomes significantly larger, reaching areas which are served through the sea for many years now. This fact is expected to have a major impact in the long term to the mode selection for Eurasian flows and thus for the rail network within the EU, especially when the western regions of China which are far from the shore increase their production.

Therefore, the attractiveness of rail transport for the Eurasian cargo due to the efficiency increase emerging from the technology implementation may have an opposite effect in the long term; instead of reducing the need for hard infrastructure investments, the increase of rail flows may create the need for additional funding of the already congested EU rail network in order to support the increased flows. Given also that the EU network development over the past decades has been focused on maritime transport and the port-hinterland connections by allocating significant funds in their development, the policy decisions regarding the time horizon for the intercontinental rail development should be carefully considered by the EU.

Finally, with respect to the governance of the EGTN, it is concluded from the analysis that a two-level governance structure is more appropriate to support the development and operation of EGTN towards achieving its goals. On the lower, node level, a collaborative governance scheme which will facilitate the participation of stakeholders and the establishment of a trustworthy business ecosystem is proposed while on a higher level, a governance scheme led by an administrative organization (agency) is envisaged that will supervise and coordinate the network of (local) PI networks and ensure the alignment of actions and synergies with the TEN-T governance structure.

As a concluding remark, it should be noted that the implementation of innovative technologies and the PI concept in the Transport and Logistics sector has already started, following a bottom-up approach led by the private sector as described also in the governance layer chapter of this document. PLANET has tested the impact of these technologies and their positive outcome has defined the way that the EGTN should be structured in terms of its technological infrastructure and governance. However, considering also the geo-economic aspect of transportation, the EGTN development should follow a path that will allow for a smooth uptake of these technologies by the market, leaving also time for the network to adapt to the new conditions without creating inequalities and depreciation of previous EU and private investments.

8 References

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Annex: EGTN 2030/2050 strategic profile

▪ Responsive to changes *[resp. attribute: Geo-economic awareness]*

- ➢ Consider 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.

How? 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).

- **Bridge business/industry needs for planning to EU policy and infrastructure planning *[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.

How? 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).