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

D2.1 Open EGTN Platform Architecture v1

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1 According to PLANET's Quality Assurance Process

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
AI	Artificial Intelligence
DSS	Decision Support System
EGTN	EU-Global T&L Network
EPCIS	Electronic Product Code Information Services
EU	European Union
GDPR	General Data Protection Regulation
GS1	Global Standards 1
GPU	Graphics Processing Unit
HMI	Human Machine Interface
ICONET	New ICT infrastructure and reference architecture to support Operations in future PI Logistics NETworks, https://www.iconetproject.eu/
ICT	Information and Communications Technology
KPI	Key Performance Indicator
LMD	Last Mile Delivery
ML	Machine Learning
PI	Physical Internet
SELIS	Shared European Logistics Intelligent Information Space
SKU	Stock-Keeping Unit
TEN-T	Trans-European Transport Network
WMS	Warehouse Management System

1 Executive Summary

The Cloud-based Open EGTN Infrastructure Architecture deliverable reports on the creation of an open-source blueprint that aims to empower organisations to build upon and implement T&L design tools, collaborative logistics and new eCommerce models underpinned by data-driven supply chain insights. The deliverable aims to inform any stakeholder or consortium of stakeholders involved or interested in the design of innovative, cross-organisational EU-Global T&L networks.

The deliverable includes a detailed specification of the platform based on stakeholder needs analysis and it is inspired by other logistics collaboration platforms from previous Horizon 2020 projects (e.g. SELIS and ICONET). The design and architecture of the platform are presented in a separate chapter aiming to point out the state-of-the-art technical solutions behind the blueprint.

The EGTN Platform endeavours to become a powerful platform due to the unique combination of technologies and models it entails. Data Ingestion is handled by versatile mechanisms responsible for importing heterogeneous data from various external sources in batch and/or in real time in a secure manner. A Decision Support System (DSS) allows the users to make important T&L and PI decisions, such as corridor route optimisations, warehouse time reductions etc. The DSS provides data intelligence and is based on different Machine Learning (ML) models, as well as simulation mechanisms. The results of these models and simulations are the basis for the decision-making process. Intelligent forecasting is used with the ultimate purpose of achieving the PI roadmap, while the use of smart contracts facilitates automated and paperless negotiations. Blockchain interoperability aims to overcome the silos of the different Blockchain systems/partners, and, finally, user-accessible dashboards within the Human Machine Interface offer a visual frontend to all stakeholders. Most of the underlying technical solutions used throughout the implementation of the EGTN Platform are industry standard, production proven and open source.

The combination of these technical advancements plays an instrumental role in uniquely positioning the EGTN Platform in terms of technical enablement of the Physical Internet (PI) paradigm. In that context, the EGTN Platform empowers T&L stakeholders by offering them a means to access tools and PI services for routing, node optimisation, shipping, and encapsulation, and so on, as well to collaborate with other T&L actors across borders and organisations in a self-determined and secure way.

Based on the requirements set out from the partners in Work Package 1, as well as the workshops organised by the Living Labs and by WP2, this document provides an architectural blueprint for a cloud-based platform, which is versatile enough to accommodate different sizes of T&L/PI actors. Detailed deployment strategies and cloud provider considerations are also covered, aiming to ensure that the platform can be easily adopted by any interested T&L party. Finally, the platform was developed in such a way that it can ensure secure, and seamless integration of logistics services, and it is based on an explicit governance model for onboarding of users, data, and services.

2 Introduction

2.1 Mapping PLANET Outputs

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

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

PLANET GA Component Title	PLANET GA Component Outline	Respective Document Chapter(s)	Justification
DELIVERABLE			
D2.1 Open EGTN Platform Architecture v1	Open EGTN Platform Architecture expanding the principles outlined in section 3 and complying to requirements from T1.5, and addressing governance, cybersecurity and privacy design decisions.	Chapters 3-7	3.1-3.4 Requirements of the project 3.5, 4.5, 7.1 Cover aspects of governance and security
TASKS			
T2.1 Cloud-based Open EGTN ICT Infrastructure Architecture	The objective of this task is to specify, design and prototype an open Cloud-based platform that will provide stakeholders with a low entry cost (open) collaboration platform for sustainable integrated multimodal freight transport.	Chapter 3-5, 7	Specifications 3 Design 4 Prototype 5 Open standards and support 7.1,7.2
	The task will create an open-source blueprint that enables organisations to build upon and to implement T&L design tools, collaborative logistics and new eCommerce models underpinned by Big Data driven Supply Chain insights.	5.2, 6.1	This deliverable and all associated software assets will be open. The specific subsections provide blueprints for deploying the system and integrating components.
ST2.1.1 Specification of a Cloud Platform for sustainable integrated	Specification of a Cloud Platform for sustainable integrated multimodal freight transport: Based on stakeholder needs analysis (Task 1.5) and	3.1-3.4	Covers requirements, reusable components from other projects and the specifications of the PLANET infrastructure.

multimodal freight transport	experience gained from other logistics collaboration platforms from other Horizon 2020 projects (SELIS & Aeolix), this task will provide an architectural blueprint for a Cloud based platform.		
	To maximize acceptance and applicability, different Cloud models such as Public, Private, Hybrid and federated will be considered and supported.	3.5.2 and 5.1	Cover deployment strategies and cloud provider considerations
ST2.1.2 Design for service integration, governance, privacy and cybersecurity	The platform will be implemented from the ground up to be secure, provide seamless integration of logistics services, and be based on an explicit governance model for onboarding of users, data & services, and providing a customized environment for specifying privacy policies.	3.4.4, 4.4-4.5,7	Covers aspects of security and governance of the platform.
	Key assets from SELIS, CHARIOT, ICONET AND FENIX will help accelerate implementation.	3.3	Reusable assets
ST2.1.3 Platform Implementation and Deployment	This subtask will prototype the Platform and make it available for integration of data and services developed by other WP2 tasks, and deployment across PLANET's Living Labs.	5, 7.1	

2.2 Deliverable Overview and Report Structure

The deliverable is organised in separate chapters as follows:

- **Chapter 3** provides a detailed overview of the functional and non-functional requirements of the EGTN Platform. D1.10 has played an instrumental role in shaping these requirements, as it ensured that the EGTN fulfils its 'innovation embedding' attribute, in the sense that it is expected to take full advantage of the potential of innovative logistics concepts and enabling technological innovations in its technical operation. In addition to this, D1.2 helped define the modelling and simulation capabilities of the

Platform. The chapter also discusses hardware considerations for the platform and deployment strategies. Assets from other European projects that are used in PLANET are also presented briefly.

- The focal point of **Chapter 4** is the overall design and architecture of the EGTN Platform. This chapter includes a detailed overview of the platform design from different perspectives, an account of all the involved components, but also the expected features of the Platform Frontend, i.e., the HMI, in accordance with the functional and non-functional requirements.
- **Chapter 5** sets out the deployment process of the EGTN Platform, including deployment scripts, so that other interested parties may access and make use of the platform.
- **Chapter 6** focuses on how data from various heterogeneous sources as well as the different components can be integrated into the EGTN Platform.
- **Chapter 7** recounts the state of the art in modern T&L networks and illustrates how the EGTN innovations take a step beyond the current state of the art.
- **Chapter 8** offers a governance and support plan for all parties involved in the EGTN Platform - either as users or as developers.
- Finally, **Chapter 9** summarises the deliverable and highlights its key outputs.

3 EGTN Platform Requirements

This chapter describes in detail the EGTN Platform requirements in terms of:

- Modelling and Simulation needs
- EGTN reference specifications as these were defined in WP1
- Functional and non-functional requirements using a Usage-Actors-Requirements approach.
- Hardware and Deployment strategies

A section on reusable assets from other EU Horizon 2020 projects is also included in this chapter.

3.1 EGTN Reference Specification

This section synthesises the initial outcomes of the WP1 activities that aimed to define the first level specifications of the Integrated Green EU-Global T&L Network (EGTN). At this stage the document defines the content of each EGTN interactive layer (see more details in 3.1.1) and discusses requirements for planning, implementation & monitoring/managing of each layer.

3.1.1 EGTN definition

PLANET formalizes a set of guidelines (a roadmap) to facilitate the EGTN realization and signify the development of the Smart, Green and Integrated Transport and Logistics Network of the future to efficiently interconnect infrastructure (TEN-T, Rail-Freight Corridors) with geopolitical developments, as well as to optimise the use of current and emerging transport modes and technological solutions. At the same time, it is required to ensure equitable inclusivity of all T&L participants, increase the prosperity of nations, preserve the environment, and enhance citizen's quality of life.

The functional requirements of the EGTN consist of the strategy definition, the support to strategy implementation, the possible outcomes (digital and physical infrastructure, new operational methods etc.), as well as monitoring and maximisation of the strategy impact.

In this context PLANET defines the **attributes of the future EGTN** as:

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

Aiming to satisfy the above attributes, PLANET goes beyond strategic transport studies and beyond transport ICT research, by rigorously modelling, analysing, and assessing T&L interactions and dynamics. Its purpose is to generate and exercise the most important future scenarios from a T&L perspective. The EGTN technology workstream is not just aimed at producing a “platform”. Instead, it focuses on delivering a blueprint accompanied with best practices to help T&L actors define and implement a clear digital strategy.

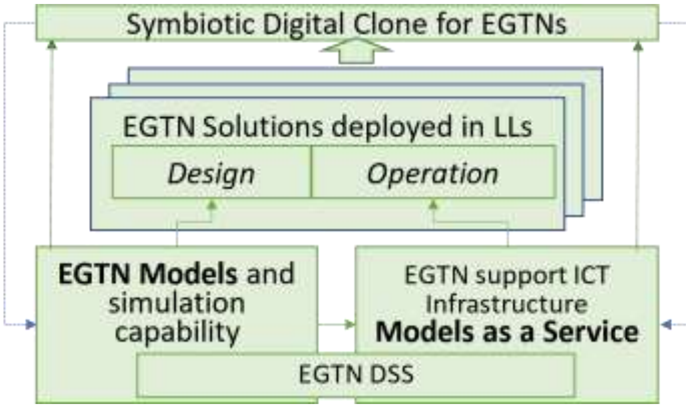

Figure 1: The technical EGTN Concept

The technical EGTN dimension comprises of the merging of the project's two main research and development streams: 1) modelling and simulation leading to increased understanding and design of the EGTN, and 2) provision of an ICT infrastructure that can be used for the implementation of the EGTN solutions.

The EGTN concept is structured in the form of three interactive layers: the infrastructural, the technological and the governance layer. The detailed specifications of each layer need to be clearly defined for the EGTN to be successfully realised.

From the perspective of the PLANET partners the future EGTN definition can be defined as:

- The TEN-T of the future in terms of T&L infrastructure (Revised TEN-T rail/road/maritime infrastructure, ports and terminals), connected and operationally integrated into the global corridors.
- An ecosystem of stakeholders from the logistics industry who collaborate to share transport & logistics infrastructure.
- A cloud platform offering connectivity and tools that enhance logistics operations.
- A platform that collects data and supports the planning for the future TEN-T development.
- The PI infrastructure and the associated innovative, potentially disrupting technologies currently implemented along the selected TEN-T corridors and Gate terminals.

3.1.2 Physical layer of EGTN

The Physical layer addresses the question of how the EGTN should be structured in terms of physical corridors and nodes and is described in the following sections.

3.1.2.1 Physical layer Specifications/Definition

The infrastructural layer of EGTN is defined as **the TEN-T of the future in terms of T&L infrastructure**. It consists of the revised and enriched existing rail/road/maritime TEN-T infrastructure (nodes and corridors) and is the result of the new emerging routes which alter the significance of existing infrastructure and the criticality of current capacity bottlenecks, causing also the emerge of new important nodes/corridors. The EGTN **is connected and operationally integrated into the new global corridors while at the same time the regional dimension of infrastructure is enhanced looking to facilitate the development of disadvantaged regions.**

Within the future EGTN network it is expected that:

- Each TEN-T corridor will be associated with selected continental/global corridors and connected to them through new entry points (from TEN-T to GTEN-T).
- The Physical Network of TEN-T will be enriched by inland nodes (new as well as existing nodes upgraded in capacities and technological infrastructure) as a result of the trend for regionalisation of production. The latter combined with the lower volumes of maritime container flows to Europe are expected to alter the flows on the TEN-T and shift emphasis of infrastructure development from hinterland networks to inland networks.

- There will be a new hierarchy and significance of the corridors, nodes and entry points of the global trade corridors which need to be continuously assessed, as they might change dynamically over time.
- Capacity management solutions and/or capacity sharing models shall be needed to solve bottlenecks and flows rerouting. This is crucial for future network efficiency and resilience.
- Multimodal and synchromodal infrastructure and services would be required along selected corridors. Regional Logistics platforms will be developed dynamically as collaborative, technology-enabled new generation "nodes" of the Intelligent T&L corridors of EGTN.
- Interoperability of Infrastructure, process, and services along rail corridors of EGTN will continue to be critical and should be enabled by symbiotic development of physical - and digital - infrastructure.
- A new TEN-T strategic development methodology shall be developed securing new criteria for the TEN-T definition (nodes and links selection) and investment prioritisation to achieve network development in accordance with the EU green & digitisation strategies but also to avoid single country/region dominance.
- In the EGTN network the connectivity of the regions and nodal points as well as the corridors' competitiveness and reliability will be continuously monitored based on three categories of KPIS: a) the PLANET new global connectivity index of nodes and regions, b) the operations efficiency, and c) the PLANET Reliability index of corridors (considering the performance of the corridor in terms of infrastructure, trade, political, financial, and cultural level).

PLANET recognises that the PI not only makes use of (smaller) standardised load units (PI containers), but also builds on the availability of open and integrated networks that connect freight transport origins and destinations. In this context and considering the above-mentioned, the infrastructure layer of the EGTN shall also include a subset of TEN-T corridors for prioritised development of the Physical Internet concept (EGTN PI corridors). The PI hard infrastructure will be implemented with high priority and incentivised policy packages may apply for the development of the corresponding PI digital infrastructure and services that are part of the technological layer of the EGTN. Selection/definition of the PI corridors (to guide companies and public investment) shall be based on the creation of strategic PI scenarios and validation shall be based on aggregated parameters which will be the outcomes of Synchromodality OR Modelling and PI based simulation. The strategic PI corridors could be dynamically updated.

The implementation of the PI concept within the PLANET approach aims to achieve the "Green" attribute of the EGTN and aligns with the EU taxonomy for sustainable activities, which in turn aims to direct investments towards sustainable projects and activities with goal to meet the EU's climate and energy targets for 2030 and reach the objectives of the European Green Deal. According to the "Roadmap to Physical Internet", published by ALICE, in a scenario in which all Physical Internet potential efficiencies are achieved the forecasted 300% increase in transport demand could be achieved with only 50% increase in assets[2]. Furthermore, according to the ETP on Logistics ALICE[3] the potential emission reductions stemming from a better use of resources and the application of Physical-Internet concepts can help significantly towards fulfilling the goal of temperature reduction (Paris Agreement).

There are many parameters influencing the EGTN development (climate strategy success, political influence, external countries investment and applied policy, economic growth etc.) hence different variations i.e., scenarios of EGTN infrastructure should be elaborated and validated in terms of impact and strategic outcome.

[2] Roadmap to the Physical Internet, ALICE, http://www.etp-logistics.eu/wp-content/uploads/2020/11/Roadmap-to-Physical-Intenet-Executive-Version_Final.pdf

[3] Roadmap Towards Zero Emissions Logistics 2050, ALICE, http://www.etp-logistics.eu/wp-content/uploads/2019/12/Alice-Zero-Emissions-Logistics-2050-Roadmap-WEB.pdf

3.1.2.2 Requirements for the PLANET EGTN platform

The PLANET EGTN Platform is the ICT infrastructure that shall support planning of the EGTN physical infrastructure, decision making and monitoring impact of the EGTN infrastructure development. In this context, the following can be identified as initial platform requirements coming from the EGTN physical infrastructure planning and decision making:

- Interface with dedicated strategic models (enabling modelling of scenarios for the EGTN infrastructure development) that will not be integrated to the platform so that the platform can:
    - provide the strategic models with aggregated figures on parameters needed for the strategic modelling (resulted from the synchromodality modelling & PI simulation or from operations monitoring data stored in a data lake) and
    - receive from models, data and results (KPIs) to support decision making.
- EGTN infrastructure visualisation and *EGTN decision theatre*
    - The platform could provide comprehensive network visualization and monitoring (KPIs per corridor and/or node, standards, interoperability of procedures etc.)
    - Scenarios Choice support.
- EGTN scenario management capability
- Development and validation of strategic PI scenarios (cost benefit /feasibility etc.).
- Support the calculation of EGTN infrastructure indices:
    - a) the PLANET new global connectivity index of nodes and regions, b) the operations efficiency, and c) the PLANET Reliability index of corridors (considering the performance of the corridor at the level of infrastructure, trade, political, financial and cultural).
    - EGTN corridor attractiveness/competitiveness analysis.

3.1.3 Technological layer of EGTN

3.1.3.1 Technological layer specification

The technological layer consists of the digital infrastructure of EGTN which aims to realise the innovation attribute of EGTN by leveraging emerging technologies and supporting its operation under the PI paradigm. With that in mind, an open, cloud based EGTN infrastructure is under development in the form of an online platform to support the planning of EGTN, meet its management requirements and facilitate its governance.

The Technological layer of EGTN platform comprises of:

- Technologies that monitor assets & processes of companies (IoT etc.) along with the physical EGTN infrastructure.
- Connectivity to digital infrastructure available at corridors and nodes (inside and outside the EU) and to federated public and private platforms within the EU that providing open access to data & services and create neutral data availability for visibility, collaborative planning among stakeholders, and optimisation of supply chains “using” the network and “consuming” its capacities.
- EGTN solutions that manage the physical & digital infrastructure of the network aiming at:
    - supporting optimum network setup
    - guiding optimised management of T&L
    - stimulating the PI paradigm shift, and
    - achieving collaborative logistics and shared capacity models implementation within ecosystems in a geographical area or along a corridor.

- Data analytics and data aggregation from PI services that feed the indices calculation to support public and industry decision making.
- Synchromodality modelling and PI simulation to support industry decision making.

3.1.3.2 The PLANET EGTN platform required functionality

As far as the planning of the EGTN is concerned, the platform needs to visualise forecasts for the future of supply chain flows by considering not only the integration of global corridors but also the possible integration of innovative, disruptive technologies which have the potential to alter the operational characteristics of corridors and facilitate the operations under the PI paradigm. The estimation of future flows which will allow to define the EGTN infrastructure layer is currently considered to be performed outside the platform while the platform includes the PI priority network definition. Consequently, the platform needs to develop interfaces for strategic modelling capability (see more in section 3.2) which will calculate the changes in flows at a macro level compared to a base year (2019) by integrating the emerging global corridors and simulating plausible future scenarios based on possible geo-economic, environmental, technological, and other developments.

Most importantly with regards to the technological developments, the platform should allow the development and simulation of various PI implementation scenarios and validate these scenarios in terms of cost/benefit, feasibility, possible time horizon of implementation etc. The results from these simulations, which will be produced in the LLs at the micro level, will be transformed through proper methods to provide strategic modelling parameters to the macro strategic TEN-T model. The interface between micro and macro models will be developed under an overarching architecture under the name “EGTN integrated modelling and simulation capability”.

In terms of meeting the EGTN management requirements the platform needs to provide services that shall support stakeholders in operational decision making and improve operational procedures towards achieving the “operational excellence” attribute of EGTN.

For that reason, there is a need for the platform to provide visibility of the supply chain through an appropriate visualisation (dashboard) of the EGTN parameters of operations required to support the management decisions at corridor/node level, including the main KPIs of nodes and corridors, the implemented standards, the interoperability procedures and so on.

A toolbox/marketplace of PI services to EGTN stakeholders to support the operation of digital hubs and PI corridors is being built as part of the EGTN solutions available by the platform. These services shall also focus on the facilitation of network and routing optimisation, on increasing network resilience and on stimulating collaborative logistics and shared capacity models.

The planning of regional logistics should also be included in the support services provided by the EGTN platform to enhance operations at a regional level and, thus, facilitate the development of disadvantaged regions.

In terms of facilitating the EGTN governance, the role of the platform is to ensure the transparency and equity to all stakeholders of EGTN and to provide them with the required information to make decisions related to EGTN governance.

In this context, the platform should have an active role in the data exchange between EGTN stakeholders by incorporating and managing a neutral data lake/repository, thus, ensuring security and equal access to information to all relevant stakeholders.

Furthermore, the platform should capture the corridors/nodes attractiveness/competitiveness by incorporating the Corridor Connectivity Index but also monitor its corresponding changes to provide insight to stakeholders regarding potential changes in the network. This information together with the collection of relevant data regarding the status of the network (e.g. KPIs of corridors) must also be used as feedback to enhance and adapt the planning of EGTN through a perpetual process.

Finally, the platform should have the ability to monitor the physical and digital EGTN infrastructure and support their symbiotic development and the coordination of works on the EGTN. The idea behind is that it should provide an overview of the network status and assess the differences between national and EU priorities.

3.1.4 Governance Layer of EGTN

The governance layer consists of the processes and mechanisms that govern the interaction and collaboration between all stakeholders with the ultimate purpose of developing and sharing T&L infrastructure and participating in the EGTN decision making process.

It also includes the corridor governing schemes which will be developed within EU or between EU and non-EU countries as well as a possible overarching governance scheme similar to the concept of Single European Sky (SES) which delegated competences in air traffic management (ATM) to the EU and the decision-making process has moved away from an intergovernmental practice to the EU framework. The objective was to reform ATM in Europe to cope with sustained air traffic growth and operations under the safest, most cost-effective, flight-efficient and environmentally friendly conditions. These EGTN governance schemes will consider the existing TEN-T governance structure to ensure that wherever possible, synergies will be realized and propose changes for the efficient EGTN development & management.

Furthermore, the governance layer includes the new TEN-T regulation which will be required for EGTN to be developed and operate efficiently (standardization of infrastructures & processes, criteria for nodal point inclusion in the TEN-T, etc.).

Finally, the governance layer includes the monitoring of the performance of corridors and nodes of the EGTN as well as the evolution and expansion of the EGTN with the development of symbiotic infrastructure to ensure the resilience of the network and to avoid single country/region dominance.

3.2 Modelling and Simulation Capabilities

From a modelling point of view, different models will be used to represent the freight transport processes in the intercontinental corridors examined in PLANET. Models require information and services from the platform. A detailed description of the information needed to run these models is given in D1.2 Modelling & Simulation Capability. Various categories of input data, parameters and results have been specified (see section below), as they will be used across all models along with the main data sources needed to build the models for the Living Labs.

In the project's lifetime, various types of simulations and optimisation models shall be developed and further evolved. The table below provides an overview of all available project models, their main features and objective.

Table 2: Summary table of models

Models	Type	Level	Technology	Objective
MOD 1 Physical Internet Network	Simulation	Micro	Multi agent simulation. Cloud simulation	Evaluate the dynamics of services and movement of products in PI networks.

Simulator – (ITAINNOVA)			Java	
MOD 2 NEAC (PANTEIA)	Simulation	Macro	C ++ Java	Model transport flows on the European network.
MOD 3 Business Process Simulation (L-ILIM)	Simulation	Micro	BPMN	Process analysis for its optimisation and identification of bottlenecks.
MOD 4 Terminal model (PANTEIA)	Simulation	Macro	Python	Transport calculation: cost time, emissions.
MOD 5 EU Flow model (VLTN)	Simulation	Macro	Python	Simulation of impacts of changes in multimodal infrastructure.
MOD 6 Simulation Team (EUR)	Simulation	Micro	Python	Testing impact of new technologies on trade-routes.
MOD 7.1 e-Commerce flexible order preparation (VLTN)	Optimisation	e-Commerce orders	Python	Pairing of orders to preparation stores, to minimise stockouts and transport cost.
MOD 7.2 Loading Optimisation Model (IBM)	Optimisation	Micro (hourly, daily evolution)	Python	Optimise the loading of PI containers to Train Wagons
MOD 7.3 PI Route Optimization Model (IBM)	Optimisation	Micro (hourly, daily evolution)	Python	Optimise the route taken by a PI Means within a PI Network
MOD 7.4 Enhanced synchromodality model (EUR)	Optimisation	Operational level. Micro level for time dimension	Python	Capture dynamic routing and committed capacity booking to evaluate the benefits of synchromodality in trade flows

Given that these models need to represent accurately the transport processes in the corridors, it is necessary for the platform to have information regarding demand, infrastructure and available services.

In the context of this project, data harmonisation will be employed to bring together the information requirements of the different models used for simulation and analysis. A harmonised dataset will enable the combination of information provided by the various use cases and facilitate the usage of different models.

3.2.1 Data requirements for modelling

3.2.1.1 Demand data

This category contains all the data that describe the demand, such as origin and destination, product quantity or unitisation. Overall, orders are expected to be filled within time windows and containers may consist of one or more SKUs. Data from various time intervals are used to implement the specific types of simulation analysis. A categorisation of time intervals is shown in the following table.

Table 3: Categorisation of time intervals

DEMAND TIME HORIZON	
Historic data	Dataset of orders from previous months or years.
Real Time	Orders for the current month or year (Living Labs).
Future demand	Short- and long-term demand forecasting: • Short term: days, "Nowcasting" • Long term: 10 years

3.2.1.2 Infrastructure data

Infrastructure data refer to the nodes and links that form the transport network, as well as the means of transport operating on the network. Examples of the required data types are:

- Node parameters (Geolocation, Capacity (Physical slots), Resources available)
- LINKs / CORRIDOR (Node Origin - Node, Destination, Mode, Capacity, Status)
- Transport (Origin - Destination, Frequency, Departure - Arrival time, Estimated Time of Arrival)

3.2.1.3 Services data

As a rile, the results from the different optimisation models can be considered as services. The following table shows an example of the available optimisation services.

Table 4: Optimisation services

OPTIMISATION SERVICES	
Smart Route Service	Optimise the route taken by a PI Means within a PI Network.
Loading Optimisation Service	Optimise the loading of PI containers to Train Wagons in both 2-Dimensional and 3-Dimensional space.
eCommerce order optimisation	Identifies the optimal store to prepare each order to minimise stockouts and transport cost.
Synchromodality planning	Adaptive routing of cargo flow with a-priori booking of transport capacity.

3.2.1.4 Data sources from Living Labs

It is necessary to include information regarding the movements that describe the flows in the main corridors under analysis, to perform the modelling and simulation of the different scenarios from the Living Labs.
Overall, for each of the corridors analysed in the Living Labs, it is important to consider the information at two levels of detail, depending on the models used for the analysis. **The micro-level** models are data intensive, providing a fully disaggregated approach to the analysis of transportation networks and/or systems. They are

usually applied to the detailed analysis of limited segments of transportations systems, e.g., within limited geographic areas or for specific corridors. **The macro-level** models are based on highly aggregated data and require information to support decision making for large transportation networks.

Table 5: Data sources from Living Labs

	Demand	Infrastructure	Services
Micro Level	Movement data on the transport network at warehouse, postcode or city level. Origin/destination matrix for observed flow movements, with type of loading unit (pallet, parcel, container, etc.). Demand availability and deadline information. Time scope: hourly or daily data, over a week or a month.	Detailed data of the nodes (e.g., ports, rail terminal, warehouses): capacity, available resources, available time slots, handling cycle times, IT infrastructure in place (WMS (Warehouse Management System), etc). Connections available between nodes, with capacity data, congestion statistics...	Information on the services offered by T&LSP related to transport, e.g., type of services, capacity, frequencies. Operational cost tariff data for comparison of scenarios: transport fee, handling cost fee… Environmental information of the transport and handling operations.
Macro Level	Movement data on the network at Country level, NUTS (1,2) or corridor level. Time scope: weekly or monthly data, over one or more years. Also, long term forecast (10 years)	Data at aggregated level per network node, e.g. (maximum number of ships per day in a port, average number of loaded trains per week...).	Generic costs of services in the corridor (cost per goods movement, port usage fee, rail usage fee).

3.3 Reusable Assets

3.3.1 The open IoT environment of ICONET

The findings from the ICONET project have served as the foundation of NGS's contribution to PLANET. The first input derives from ICONET D1.6, which includes stakeholder analysis, business and technical requirements – as summarised in PLANET D2.3, as well as the on-premises architecture, which enables automatic encapsulation detection and its generalisation on the cloud, as depicted in Figure 2. The architecture foresees an open environment, in which different IoT service providers cooperate at different layers enabling decentralised "logical consolidation" operations that represent fully the physical encapsulation of goods, containers and means. This encompasses the foundation on top of which the generalised as a service architecture that will be presented in PLANET's D2.3 was designed and built.

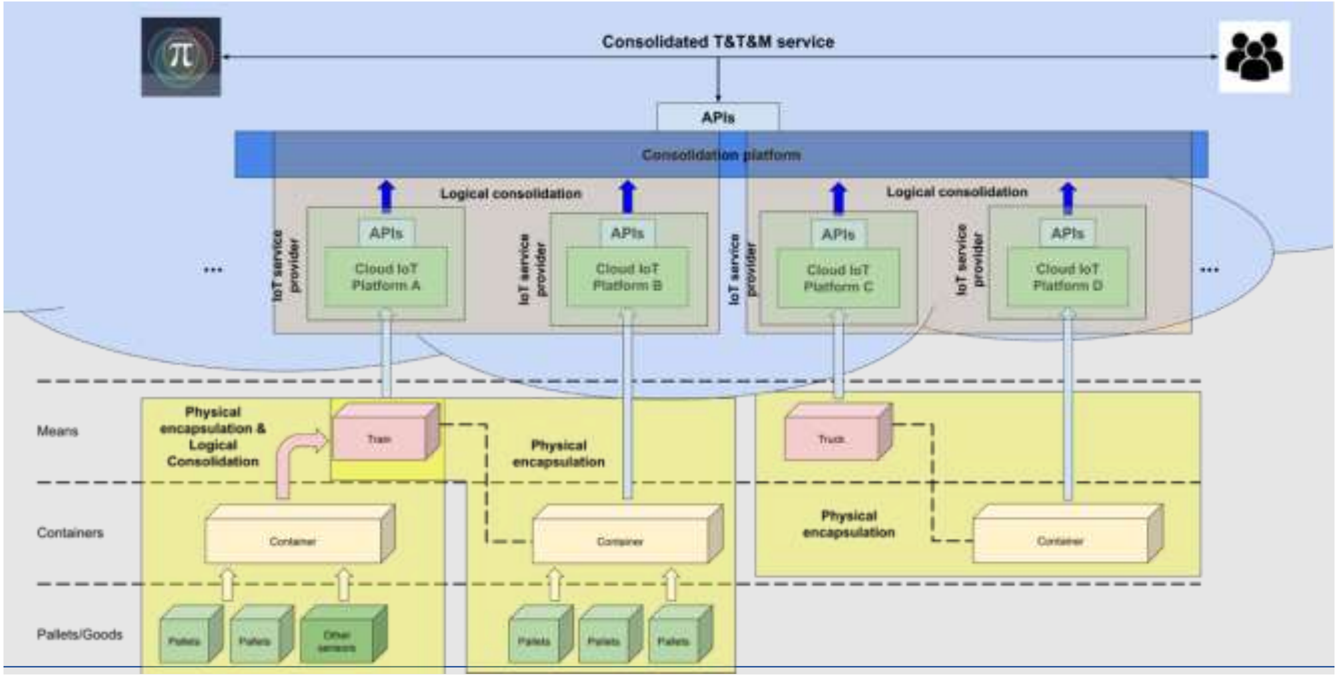

Figure 2: Generalised IoT Architecture from the ICONET project

The implementation within PLANET's Living Lab 1 shall be based upon this premise, exploiting and improving the components developed in the ICONET project, most notably:

1. The Smart Router in charge of T&L containers/means and offering IoT connectivity to enhance the system with pervasive monitoring functionalities.
2. The Cloud IoT Platform in charge of ingesting information gathered in the field, storing, processing and sharing it (i.e., GUI and APIs).

3.3.2 The PI Models of ICONET

3.3.2.1 Loading Optimisation Model

The ICONET Train Loading Optimisation service models PI Containers, PI Means (in the form of train wagons) and rail Shunting/Marshalling Yards. The service contains APIs that facilitate the optimised loading of PI Containers to PI Means and the optimised formation of trains in Shunting/Marshalling Yards. The PI paradigm proposes introducing an expanded set of standardised shipping containers to convey cargo. It is expected that along with existing monolithic containers, such as the 40-foot and 20-foot shipping containers, a range of smaller, modular containers will be introduced. These modular containers could be stackable or un-stackable. Stackable containers could be composed into larger units for transport.

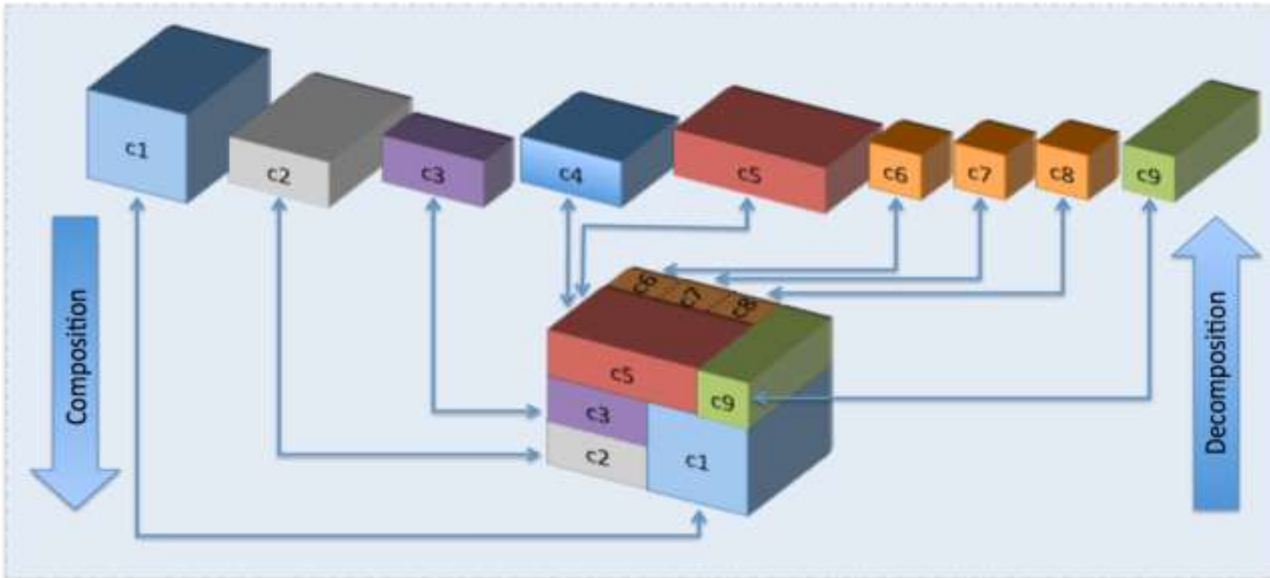

Figure 3: The ICONET Train Loading Optimisation service

The ICONET Train Loading Optimisation service (see Figure 3) models PI Containers in a simple JSON data format containing dimension and weight properties. Similarly, train wagons are modelled in a JSON format with maximum dimensions and weight capacity. There are APIs to allocate the input PI Containers to the available train wagons. This can be done in two-dimensional (2D) or three-dimensional (3D) space. The APIs produce a JSON data format loading plan. The loading plan lists the train wagons with their allocated PI Containers and gives exact placement coordinates for each container. The Train Loading Optimisation service also provides a data generator API that produces randomly generated sets of PI Container objects and train wagons to be loaded. As the modular PI Container concept is still a proposal, no real data for these containers exists. This data generator API is a convenience feature for simulation and can be configured to produce representative synthetic data while real-world data is still emerging.

The ICONET Train Loading Optimisation service also provides an API to optimise the formation of trains from incoming train wagons inrail Shunting/Marshalling Yards. Rail Shunting/Marshalling Yards are a series of parallel rail tracks used to sort train wagons by destination to form outgoing trains. Shunting/Marshalling Yards are found in PI Hubs such as ports and rail terminals. The service models the Shunting/Marshalling Yard as a JSON data format containing the number of parallel rail lines and the max train wagon capacity for each line. Train wagons are modelled in a JSON data format with destination and capacity properties. The optimisation API for sorting the incoming train wagons across the available rail lines accepts a JSON data format arrival schedule that lists the times at which train wagons arrive. The optimisation API outputs an optimised allocation plan, in JSON data format, that specifies the rail line each train wagon should be directed to and when to despatch formed trains. The ICONET Train Loading Optimisation service aims to assist the automation of rail operations like loading containers to train wagons and sorting wagons across Shunting/Marshalling Yards. This kind of automation is needed to achieve the goals of the PI paradigm in seamless transport networks. The efficiency improvements that result from these optimisation efforts can reduce costs, such as reduced energy consumption and lower carbon footprint, associated with operating rail infrastructure.

In the context of PLANET the train loading optimisation service can be used in conjunction with the predictive services to plan the transport capacity required to book in advance, and in this way help make planning more efficient and cost effective.

3.3.2.2 PI Route Optimization Model

The ICONET PI Routing service models Last-mile Delivery (LMD) routing operations for centralized and decentralized delivery of goods. For centralized delivery, the ICONET PI Routing service designates a distribution centre for a set of orders to be fulfilled, allocates the orders across an available set of PI Means and calculates the optimal route for each PI Mean to service the required delivery destinations.

For the decentralized delivery of goods, multiple distribution centres can be designated where orders can be collected from in addition to delivery to final destination for existing orders. The PI Routing service can consider delivery time-windows for delivery destinations when calculating the optimal route for PI Means to fulfil orders. The APIs use JSON data formats for both inputs and outputs, with inputs being the distribution centres, order details and available PI Means. The output is the optimised delivery route for each destination.

The ICONET PI Routing service can optimise specific attributes when determining optimal routes. PI Mean cost, carbon footprint, delivery time and delivery distance can be emphasised as the parameter to be optimised. The routing optimisation provided by the ICONET PI Routing service can be beneficial to LMD operations by improving efficiency while maintaining customer satisfaction with delivery assurance. The PI paradigm goal of achieving the seamless transport of goods requires the efficient orchestration of cargo being conveyed and the PI Means required to transport it. The ICONET PI Routing service contributes to this goal through the automation of the orchestration process.

PLANET aims to build upon this PI routing service with ultimate goal to solve the dynamic vehicle routing problem by taking into account real-time data from IoT sensors among other factors to further improve real-time routing use cases.

3.4 Functional and Non-Functional requirements

In this section a Usage-Actors-Requirements approach is used to define the functional and non-functional requirements for the PLANET EGTN Platform. Figure 4 shows the relationship between each usage scenario of the platform that will involve some actor and have some functional requirements. These usage scenarios and the general environment in which the platform runs will, in turn, generate further requirements that the system needs to adhere to. These are the so-called non-functional requirements - e.g., none of the usage scenarios explicitly require GDPR compliance, however given the euro-centric deployment and users, the platform must comply with GDPR. Each functional requirement is then classified as per the Must-Should-Could-Won't key (as outlined in Table 6).

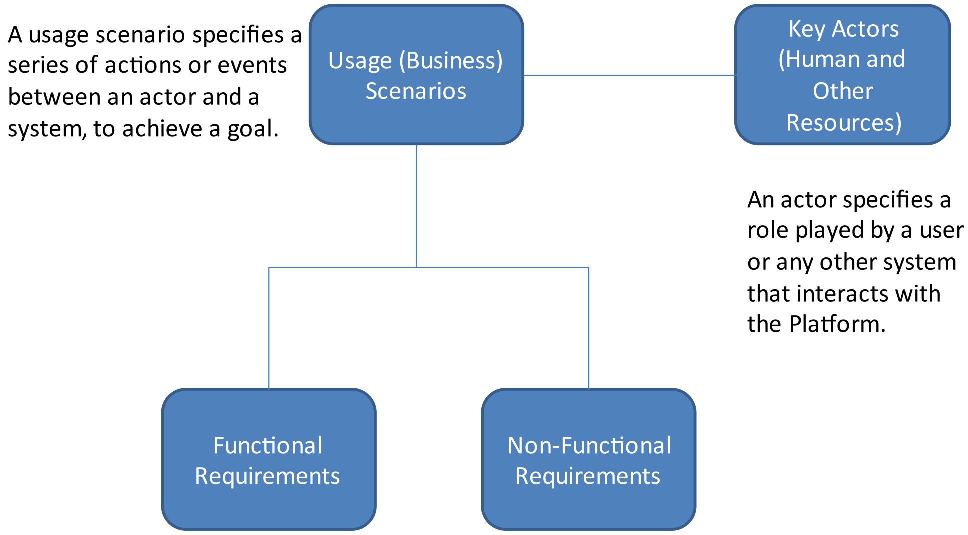

Figure 4: Usage-Actors-Requirements Approach

Key	Description
M	MUST: Describes a requirement that must be satisfied in the final platform for the platform to be considered a success.
S	SHOULD: Represents a high-priority item that should be included in the platform if it is possible. This is often a critical requirement but one which can be satisfied in other ways if strictly necessary.
C	COULD: Describes a requirement which is considered desirable but not necessary. This will be included if time and resources permit.
W	WON'T: Represents a requirement that stakeholders have agreed will not be implemented in the current project but may be considered for the future).

Table 6: Must-Should-Could-Wont Key Legend

3.4.1 Usage Scenarios

Table 7 defines at high-level the usage scenarios of the platform. These scenarios govern the design principles of the underlying system.

Usage Scenario	Description
A. Add/Remove data from the platform	The activities involved in adding or removing data sources from the platform
B. Pre-processing data ready for analysis	The activities involved in preparing datasets for analysis (cleansing, normalising, extracting, merging, transforming, loading)
C. Visualising and analysing data	The activities involved in visualisation and analysis using statistical, modelling, and AI-based analytics tools and code
D. Building algorithms and analytical workflows	The activities involved in creating algorithms and workflows (using application packages or by programming) to transform raw data into statistical results
E. Automation of analytical workflows	The activities involved in establishing continuous analytical operation and providing real-time insights.
F. Curating and archiving data	The activities involved in the lifecycle of a trial from the initial brief or experimental design to the release of data from the trial as complete and final

Table 7: PLANET EGTN Platform Usage Scenarios

3.4.2 Actors and Assets

Table 8 and Table 9 define and describe the each of the human actors that interact with the PLANET EGTN Platform and each of the assets and tools that communicate with/or are used by the platform during the execution or realization of a use case.

Actor	Id	Description
1. Data Owner	DO	The person responsible for data curation (including classification according to General Data Protection Regulation and Commercial Sensitivity)
2. Modeller	MO	The person responsible for constructing or programming analytical models
3. Analyst	AN	The person responsible for designing and running analytical experiments (incl. requesting model construction)
4. System administrator	SA	The person responsible for operational availability of the platform
5. User Administration	UA	The person responsible for on-boarding and off-boarding users

Table 8: PLANET EGTN Platform Actors

Assets	Id	Description
1. WAN	WA	The wide area network that the Platform is connected to
2. LAN	LA	The local area network associated with the Platform
3. Data pipeline	DP	Data transport and storage mechanisms used by the Platform
4. Packaged application	PA	Application software used (e.g., R)
5. Custom software	CS	Scripts and applications specifically written for use on the platform
6. External system	ES	Systems external to the platform such as Weather APIs

Table 9: PLANET EGTN Platform Assets

3.4.3 Functional Requirements

In the context of the usage scenarios and defined actors (outlined above), Table 10 through Table 15 define the relevant functional requirements along with a compliance key.

Business Scenario	ID	Functional Requirement	Key Actors Involved	Assets	Category
A. Add / Remove data from the platform	A.1	Add data in any agreed format to the platform	DO, MO, AN, SA	DP	M
	A.2	Provide metadata for every file and storage (e.g., sensitivity, keyword and tags, short description, owner and uploader)	DO		S
	A.3	Provide volumetric information for validation purposes (see B)	DO		S
	A.4	Securely add data following the security and data encryption requirements on a case-by-case basis (most stringent applies, min. AES128)		DP	M
	A.5	Support continuous streaming data	DO, SA	DP	M

Table 10: Usage Scenario A: Add / Remove data from the platform

Business Scenario	ID	Functional Requirement	Key Actors Involved	Assets	Category
B. Pre-processing data ready for analysis	B.1	Ability to extract, transform and load from a wide variety of file and stream formats	AN, MO	DP	M
	B.2	Ability to automate the pre-processing of the data from multiple, varied sources (structured)	MO		M
	B.3	Ability to automate the pre-processing of the data from multiple, varied sources (structured)	MO		C
	B.4	Ability to respect data sensitivity attached to data sources and to label transformed outputs appropriately (see D3.1)		DP, PA, CS, ES	M
	B.5	Maintain metadata for pre-processing and log and report associated pre-processing activity		DP	S
	B.6	Ability to validate data files (and report exceptions) based on metadata and volumetric information provided in scenario A		DP	S
	B.7	Securely clean-up all workspaces, VM's and mount points	SA	PA, CS,	M

Table 11: Usage Scenario B: Pre-processing data ready for analysis

Business Scenario	ID	Functional Requirement	Key Actors Involved	Assets	Category
C. Visualise and analyse data	C.1	Ability to run supervised and semi-supervised analytics and models	MO, AN		M
	C.2	Ability to run unsupervised / unattended analytics and models	MO, AN		M
	C.3	Export reports in a range of formats (e.g. ,pdfs, images, Office) from unattended models	AN		M
	C.4	Run classical statistics and models based on many, varied sources (unstructured and unstructured)	MO, AN		M
	C.5	Ability to fully integrate with off-site training facilities for model creation (e.g., EC2)	MO, AN		S
	C.6	Ability to run all analytics server side or via EC2		DP, WA, LA	M
	C.7	Ability to perform a wide range of statistical analysis techniques on T&L data and business outcome data	MO, AN		M
	C.8	Ability to use any open-source visualisation library (subject to license), and to create new, custom visualisations	MO	CS	M
	C.9	Ability to create and run agent-based models	MO		C

Table 12: Usage Scenario C: Visualise and analyse data

Business Scenario	ID	Functional Requirement	Key Actors Involved	Assets	Category
D. Building algorithms and analytical workflows	D.1	Develop the algorithms and workflows in-situ on the Platform	MO		S
	D.2	Collaborative development of algorithms, workflows and code	MO		S
	D.3	Code management for source and executable management	MO		C
	D.4	Respect a deny list (i.e., data objects that a) the user has no permission to see and b) should not be combined for legal, commercial or analytical reasons)		DP, PA, CS	S
	D.6	Version control the algorithms and workflows	MO, AN		C
	D.7	Ability to automate the algorithms and workflows so they can run unattended	MO, AN		M
	D.8	Ability to integrate Bluemix and EC2 into workflows	MO	CS, DP, WA	M
	D.9	Ability for workflows to respect data sensitivity attached to data sources and outputs		CS	S
	D.10	Develop workflows and algorithms using multiple tools on the same platform	MO	CS	S

Table 13: Usage Scenario D: Building algorithms and analytical workflows

Business Scenario	ID	Functional Requirement	Key Actors Involved	Assets	Category
E. Automation of analytical workflows	E.1	Constructed pipelines should continuously operate under predefined performance criteria	MO, AN, SA	DP	M
	E.2	Algorithmic performance issues/timing should be raised	MO, SA		S
	E.3	Data availability issues should be raised	AN, DO	DP	S
	E.4	Cost-constrained Scale up	SA, MO		M

Table 14: Usage Scenario E: Automation of analytical workflows

Business Scenario	ID	Functional Requirement	Key Actors Involved	Assets	Category
F. Curating and archiving data	F.1	Retain all for the duration of the project	DO		S
	F.2	Flag datasets as out of service (e.g., superseded, defective etc)	DO		S
	F.3	Version control datasets	DO		C
	F.4	Provide daily snapshot backups	SA		C
	F.5	Ability to back-up entire platform at regular intervals to tape	SA		W
	F.6	Maintain encryption during archiving (min. AES128)	SA		C
	F.7	Ability to extract training sets in a controlled manner	DO, MO, AN		M
	F.8	Off-site archiving	SA		W

Table 15: Usage Scenario F: Curating and archiving data

3.4.4 Non-Functional Requirements

The following subsections define all the non-functional specifications that have been identified as possible requirements of the PLANET EGTN Platform, along with a compliance key, corresponding to the project aspirations.

3.4.4.1 USABILITY

Type	ID	Description of the non-functional requirements	Category
USABILITY	US.1	Custom information screens (e.g., for adding metadata) should be designed to make user tasks and workflows intuitive and efficient	S
USABILITY	US.2	Save analysis and visualisation outputs to local drives	M
USABILITY	US.3	Record and retain metadata and volumetrics information associated with a dataset	M
USABILITY	US.4	It should be possible to access the platform remotely	M
USABILITY	US.5	The platform must be accessible to all project team members	M

3.4.4.2 SECURITY

Type	ID	Description of the non-functional requirements	Category
SECURITY	SE.1	Physical security to Tier 1 minimum	M
SECURITY	SE.2	Secure access control to the platform	M
SECURITY	SE.3	Unified user management for the platform with IP restrictions, and permission delegation options	S
SECURITY	SE.4	Single sign-on	W
SECURITY	SE.5	Access to platform must be supported in writing from institutional PIs (and all other PIs will be informed)	M
SECURITY	SE.6	Connection to Durham intranet will use SSH	M
SECURITY	SE.7	Hold all data in an encrypted vault (AES128 min.)	M
SECURITY	SE.8	Offer an encrypted mail drop for the most sensitive information	S

3.4.4.3 INFORMATION MANAGEMENT

Type	ID	Description of the non-functional requirements	Category
INFORMATION MGMT	IM.1	All analysis outputs should be checked back into the platform (even if saved locally)	M
INFORMATION MGMT	IM.2	Outputs are automatically classified based on a matrix (see below). Status may be changed based on Data Governance meeting.	S

INFORMATION MGMT	IM.3	Support for distributed code repositories	C

3.4.4.4 INFRASTRUCTURE

Type	ID	Description of the non-functional requirements	Category
INFRASTRUCTURE	IN.1	Platform must be protected against unauthorised intrusion and viruses	M
INFRASTRUCTURE	IN.2	Use gigabit or greater networking between platform hardware components	M
INFRASTRUCTURE	IN.3	Aggregate distributed physical resources into one, shared compute and data resource platform	S
INFRASTRUCTURE	IN.4	Support low latency, parallel processing	S
INFRASTRUCTURE	IN.5	Support long-running services	C
INFRASTRUCTURE	IN.6	The platform should support multiple Infrastructure models - bare metal, private cloud, public / hybrid cloud	S

3.4.4.5 INTEGRATION

Type	ID	Description of the non-functional requirements	Category
INTEGRATION	IT.1	Platform is a single platform as far as user is concerned	M
INTEGRATION	IT.2	Cloud and non-cloud components need to be fully integrated	W
INTEGRATION	IT.3	An air gap is permissible between the cloud and non-cloud components during the project	M
INTEGRATION	IT4	The platform should provide integrated application support with rich API layer	C

3.4.4.6 COMPLIANCE

Type	ID	Description of the non-functional requirements	Category
COMPLIANCE	CO.1	The platform must comply with accessibility standards such as the Web Accessibility Directive (Directive (EU) 2016/2102 and the W3C Content Accessibility Guidelines	S
COMPLIANCE	CO.2	Personal Information storage must comply with the General Data Protection Regulation 2016/679	M
COMPLIANCE	CO.3	Compliance to Freedom of Information Requests	C

3.4.4.7 OPERATIONS

Type	ID	Description of the non-functional requirements	Category
OPERATIONS	OP.1	Available during EET/GR working hours	M
OPERATIONS	OP.2	Inlecom service levels apply (see Section 8.2)	M

3.5 Other Considerations

3.5.1 Hardware Considerations

As per function requirements C.5 and D.8, the PLANET Platform needs to integrate and provide support for:

- GPU and/or AI co-Processors: While initial model training will take place off the EGTN platform on researcher machines, GPUs will be required on the platform to enable model training using the larger datasets. Cost and compliance requirements limit the ability to keep the GPU systems permanently integrated and switched on. Therefore, a mechanism to deploy/activate GPU-enabled processing servers on-demand is required. Due to the competitive quotation process and the budgetary constraints, the GPU server will be provisioned within the resources of a secondary cloud provider. Further details on procurement can be found in Section 5.1.

- Blockchain Ledger: As part of activities of Task 2.5 the PLANET EGTN Platform must also support integration with Blockchain technologies. Given the diversity of products that already exist within the PLANET LLs, the EGTN infrastructure will not deploy its own Blockchain ledger but enable APIs to interact with the backend blockchain systems of the PLANET end-users.

Additionally, partner SIRMA AI, will co-locate the deployment of a version of their AI, Graph and streaming data processing platform. This platform is containerised and requires Kubernetes and Helm for optimal deployment. The largest container requires 64GB of RAM.

3.5.2 Deployment Strategies

Ensuring modularity and elasticity, as described in the non-functional requirements (section 3.4.4), of the PLANET EGTN Platform is of utmost importance, therefore a containerised approach has been used to deploy the various components (described in Section 4.2). Containerisation enables the EGTN platform to be easily migrated between cloud providers and in a scenario where LLs wish to deploy their own mini ecosystem, the platforms shall be reusable.

Budgetary (described in Section 5.1) and GDPR constraints prevented the project from leveraging managed containerised services such as Google Kubernetes Cloud, Amazon EKS, AWS Fargate, etc. Instead, the project opted to rent dedicated Virtual Machines within an EU-based cloud provider. Partner ILS, manage the underlying container management system and other machine-related components. Kubernetes, an open-source container management system has been deployed across the various virtual machines. Partners (e.g., SIR) can then leverage the Kubernetes API to deploy their own containers.

4 Design & Architecture

4.1 Architecture

This chapter outlines the platform architecture that aims to address the development of:

- a technology architecture capable of ingesting and transforming heterogeneous data in preparation for analysis
- a data model suitable for analysing structured and unstructured information at the same time
- configured analytical engines that facilitate model development

This chapter further outlines the architecture, the underlying systems, the network layout and configurations for the PLANET EGTN Platform and its associated systems. The designed architecture is in accordance with the Archimate 3.1 Open Standard[4] and is "layered" as shown in Figure 5.

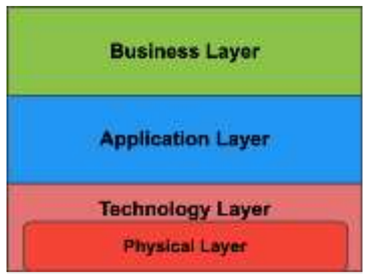

Figure 5: Archimate 3.1 Standard Layers

4.1.1 High-Level Architecture

This section presents the high-level architecture of the EGTN Platform along with a description of each of the individual components, as illustrated in Figure 6. The purpose of the architecture is to provide all PLANET partners a platform to facilitate data sharing, collaboration and decision making, by enabling different AI models to be easily implemented and analytics questions to be answered in real time with a plethora of data stemming from heterogeneous sources. The PLANET EGTN Platform is built on top of notable collaboration platforms from previous EU Horizon 2020 projects.
The PLANET architecture imports data in real time and in batches from various sources, such as IoT network and devices, using publish and subscribe mechanisms inspired from the PubSub engine developed for the SELIS project. SELIS developed a platform for greener, interconnected, pan-European logistics applications. The different data sources are presented in more detail in Section 6.2.

The data aggregation engine is responsible for the provision of all the data to the entire PLANET infrastructure and to all EGTN actors through open APIs. The data flow is configured based on business relationships and data sharing agreements - in the form of a Knowledge Graph containing the contact semantics for data sharing, data usage and data access. The internal components of the aggregation engine are explained in detail in Section 4.2.

On top of the data aggregator is the analytics cognitive decision support system that consists of predictive and prescriptive models and whose goal is to decide upon the best transportation options. In this context, Intelligent PI nodes perform intelligent forecasting built upon the models of the **ICONET** project. ICONET developed novel ICT infrastructure and reference architecture to support operations in PI logistics networks.

The analytics engine aims to empower all EGTN actors with better decision-making tools, so that they can in turn optimise planning and pre-planning, considering a plethora of goals and limitations, such as lowest-cost route,

[4] https://publications.opengroup.org/standards/archimate/c197

fastest route, low-carbon route and so on. Following the decision-making process, contract negotiation and execution shall take place, using smart contracts.

Smart contracts are enabled through Blockchain technology, that commission a decentralised network of transactions – in the form of audit logs - in a transparent, immutable, trusted, and efficient manner. The integration of the Blockchain networks within the EGTN are presented in Section 4.4.2.2. The final component of the PLANET architecture is the unified interface with custom dashboards that shall empower all partners to manage all TEN-T corridors as well as the PI workflows in real time through a Human Machine Interface. More details on the HMI regarding its scope and implementation plan can be found in Section 4.4.1.

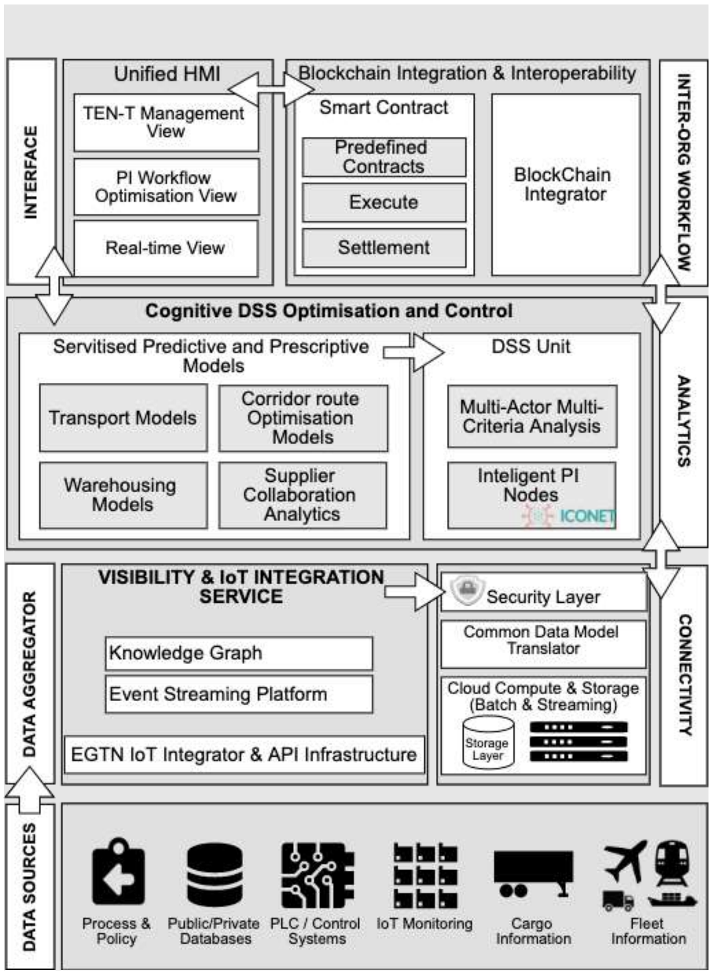

Figure 6: PLANET High-Level Architecture

4.1.2 Business Layer

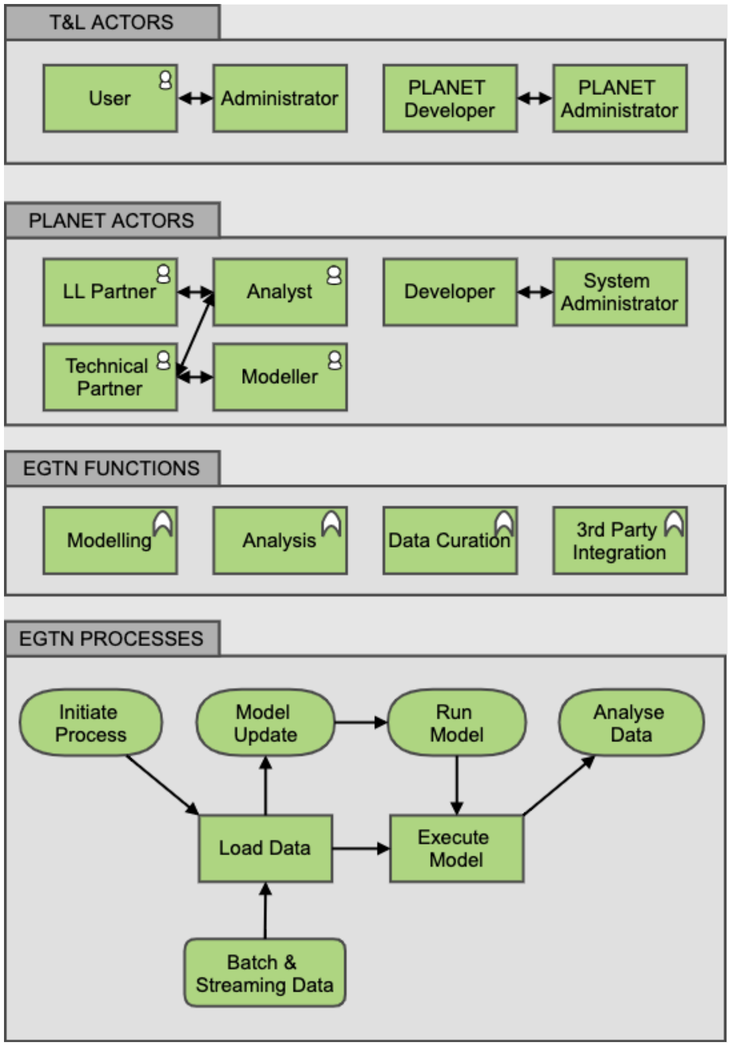

Figure 7: EGTN Business Layer

Within the business layer, the operational organisation of the PLANET EGTN Platform is displayed independent of technology (Figure 7), highlighting all the partners involved (i.e., actors), the main functions applied on top of the Platform (i.e., internal behaviours based on required business resources, skills etc.), as well as the process flow (i.e., flow of activities needed to obtain a service) as defined by the Archimate 3.1 Open Standard. At the top of the diagram lies an access scenario that highlights how any T&L actor shall be able to access and expand the EGTN Platform.

4.1.3 Application Layer

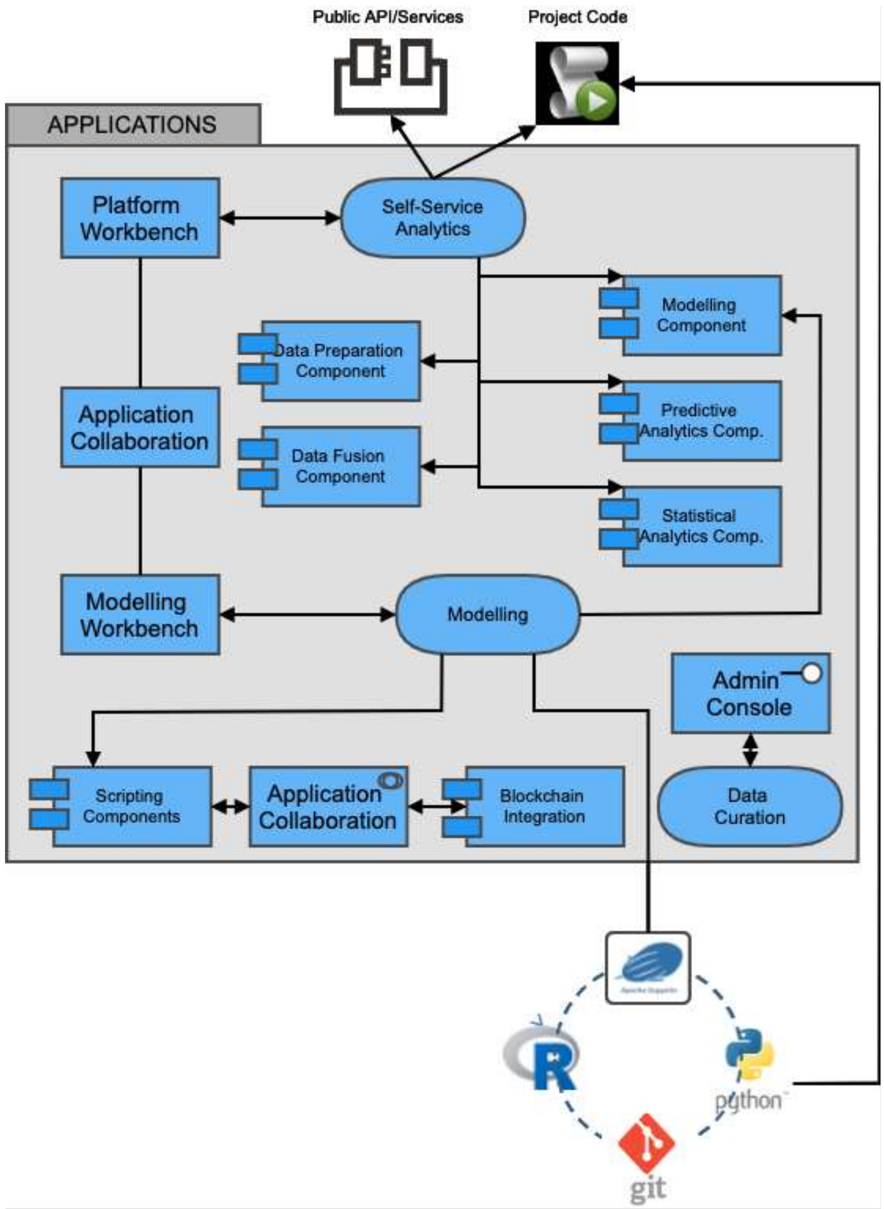

Figure 8: EGTN Application Layer

The EGTN application layer displays the structure, behaviour, and interaction of the different application components within the EGTN Platform (Figure 8). The modelling application consists of the different predictive and prescriptive AI models, but also collaborates with the Blockchain integration to execute smart contracts. From a technology perspective, the modellers develop their AI models in R and Python programming languages through Apache Zeppelin notebooks and use git to track changes in their code. This is described in detail in section 4.2. The analysts use the self-service analytics service through the platform workbench to make AI-driven decisions based on the modelling application components. Finally, the administration console is used to curate the data.

4.1.4 Technology Layer

The EGTN platform was designed in a modular manner that can scale horizontally as needed in accordance with the requirements of the EGTN partners. As such, the usage of certain frameworks was preferred to set a standardised technology foundation. The corresponding technology structure can be seen in Figure 9. Three main nodes communicate over a local network and provide the infrastructure for the deployment of containerised applications, the real-time data ingestion and the blockchain interoperability. The event streaming platform provides a great level of flexibility regarding the data ingestion patterns, while the blockchain interoperability node is dedicated to the deployment of software that handle the communication between a certain set of blockchain network types. Finally, all other software needed by the involved Living Labs and partners are deployed as containers in a container orchestration platform providing the well-known advantages related to management, availability, and monitoring of the applications.

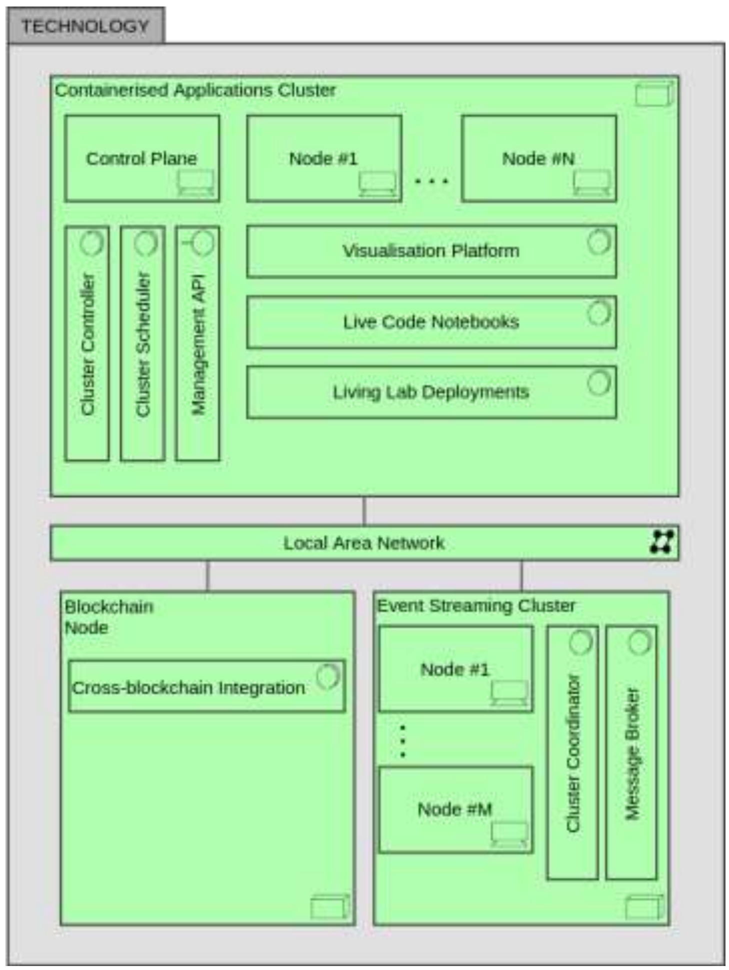

Figure 9: EGTN Technology Layer

4.2 Component Description

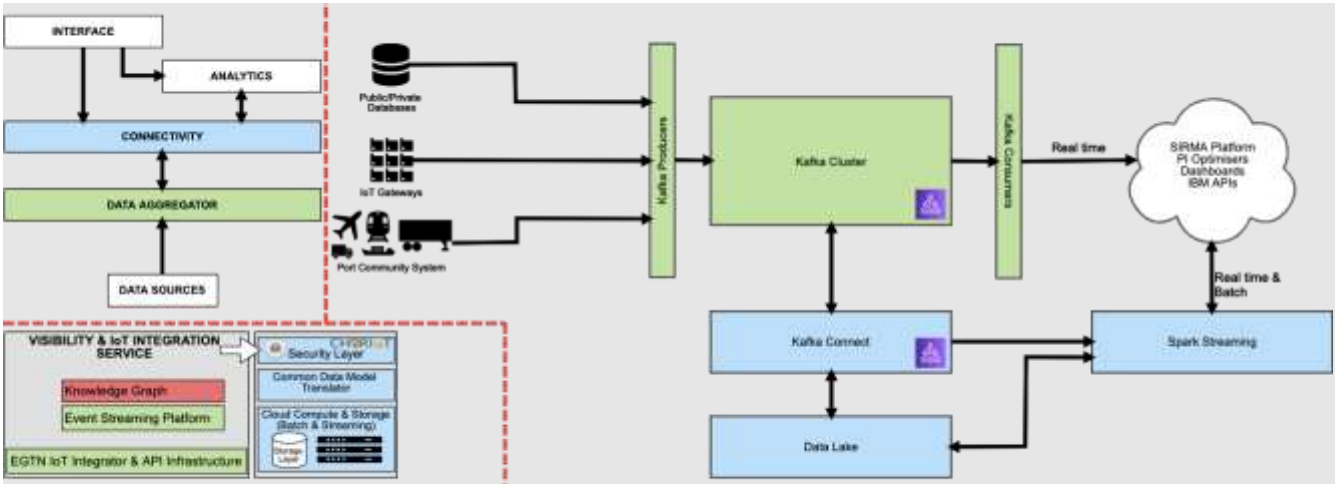

Figure 10: High Level View of EGTN Components

This section provides a description of all the components involved in the PLANET Open EGTN Platform as well as the underlying technologies used in the implementation process. As Figure 10 illustrates, the main data sources include IoT sensors, databases and other systems provided by the partners. Data from these sources is ingested into the platform using a distributed event streaming mechanism. The chosen technology is Apache Kafka, a well-established open-source platform that is often preferred for such applications. The data are stored in Kafka topics and can be distributed to other platforms through Kafka Connect in a scalable and reliable manner based on the needs of the project's partners. Kafka Connect imports data from any external source – called Source connector – and exports data to any external system – called Sink connector- offering the flexibility of changing data source/export system at any time in the future without changing the stream processing code. The Kafka cluster is administered by a Zookeeper; this service keeps track of the cluster's metadata, such as the nodes, topics, partitions and so on. Moreover, a Kubernetes cluster manages the deployment of containerised platforms providing significant flexibility. Notably, the current stack of containerised applications consists of the Ontotext Platform developed by Sirma AI (more details can be found in D2.5 "EGTN Connectivity infrastructure v1"). Apache Zeppelin Notebooks are used for data exploration and processing and provide an interface to the Apache Spark cluster-computing to the interested actors. Lastly, Grafana dashboards provide monitoring for the Kafka and Kubernetes infrastructure as well as visualisations of quantitative outputs of the Spark jobs.

4.3 Component Interactions

This section describes the interactions between the different EGTN components with the hope to efficiently describe the EGTN platform and its potential. To that end, the interactions are showcased through a Use Case taken from a Living Lab.

As shown in Figure 10, data from the IoT network is imported into the platform though the EPCIS event-oriented database. A Kafka connector is responsible to retrieve the data (EPCIS v1.2 XML format) from the database and populate the Kafka topic with a predefined naming convention and format. Following that, Sirma AI use their Ontotext platform to read directly from the Kafka topics in real time. Their platform is deployed on the Kubernetes cluster and combines GraphDB and Elasticsearch to generate Knowledge Graphs using the functionality of their Semantic Search Service, which is exposed through a GraphQL API.

Since the data is ingested using Kafka topics, extensive flexibility is provided. Managing data access with ACL rights, moving data via Kafka Connect to other systems - such as a timeseries database - or even consuming the data directly from the topics are all viable options for any interested party. In the latter case, Apache Zeppelin notebooks can be used with Python or R in conjunction with Apache Spark (PySpark, SparkR) to enable further data processing.

4.4 Interfaces

A dedicated section on the internal and external API design considerations and their specifications shall be included in the second version of this report.

4.4.1 HMIs

This section refers to task T2.6 ‘Unified interface to EGTN Data and support Services’ and describes the objectives, requirements, architecture considerations as well as initial design mock-ups of the EGTN Dashboard.

4.4.1.1 Scope and Objectives

The objective of T2.6 is to produce a unified interface to communicate with all of PLANET’s Cloud-based Open EGTN Infrastructure components via suitable interfaces, including mobile devices and Human Machine Interface (HMI) touch panels. Moreover, the unified interface will be adaptable to the users’ needs with different access roles and customizable dashboards (using pre-defined templates) will support value-driven insights and analytics for Management of the EGTN corridors and real-time state-of-the-system.

The deliverable D2.19 'Unified HMIs implementation and technical documentation v1' will be submitted by M18 - November 2021 and will address in detail all relevant workings and developments of the Task.

4.4.1.2 Implementation Plan

To satisfy the above objectives a stepped approach has been adopted for the design to identify and register the user needs, roles, the kind of data to be visualized as well as the mapping of the requirements to the HMI functionalities.

The implementation plan is shown below:

- Stage 1 - Scope and objective
  Ongoing discussions involve the scope of the work to be undertaken and alignment with the objectives of the specific project task and requirements. Also, identification of interdependencies and work from other Work Packages as well as WP2 own tasks’ outputs.
- Stage 2 -Business Functions and Target groups
  The Business areas and the user groups to be involved in the HMI have been identified by reaching out to the Living Labs (LLs) of PLANET to ensure relevance of the HMI communication and preferences of the users. For this purpose, a questionnaire has been prepared and circulated amongst the LLs. The questionnaire results will be presented in Deliverable D2.19 which is to be submitted in November 2021. This information will define the number of dashboards and overall structure of the interface aiding the representation of business segments as identified by the user. A thorough examination of the EGTN framework and WP1 activities, as these are laid out in Section 3.2 above, proved to be necessary to streamline the HMI design considerations with the strategic direction and objectives of WP1.
- Stage 3 - User Requirements (Functional, non-functional, performance)
  The primary functionality of the HMI and dashboards is the visualization of information by the users therefore the specific needs in terms of functional, non-functional and performance aspects become critical to the design of the interfaces and therefore, in similar fashion to stage 2, these requirements were also collected from the LLs in line always with the scope of the project.
- Stage 4 - Data specifications, Integration needs and Connectivity

The type of data and the software systems that need to communicate to enable a free seamless flow of information to the dashboards is important to ensure the quality and robustness of the interface. This is also information investigated and registered from partners both in WP3 and WP2.

- Stage 5 - Dashboard functionalities and Requirement mapping
  Given that the task requires the mapping of the functionalities to the user needs, this shall be verified through a detailed analysis and investigation of the actual elements and components covering the visualisation preferences as these were registered in earlier processes.
- Stage 6 – Security
  Like in all modules the data security and privacy considerations are a pivotal factor to safeguard a smooth operation of the interface and adherence to current legislation on data protection.
- Stage 7 – Mock-ups, Implementation (testing, refinement, validation)
  An Agile approach is to be adopted where an iterative process of redesign, development testing and repeat till acceptance will guarantee satisfaction of requirements by the users and within project framework
- Stage 8 – Finalization and Acceptance
  Final validation of the design and functionality of the interfaces will be completed.

4.4.1.3 Concepts and Features

The web-based, front-end dashboards provide an efficient management tool to assess interactive interfaces, business metrics, trends and other analytics quickly and accurately through any browser via interconnecting to other software systems, databases or applications.

The main features of the dashboards which are the backbone of the design, are:

a. Configurable, well-organised and meaningful presentation of needed data across devices and operating systems, devices, browsers and time frames
b. Filtering capability to ensure relevance of results
c. Simplicity and ease of use by the user
d. Ability to create multiple, simultaneous, and configurable dashboards per user based on roles and rights
e. Use of widgets to focus on required data by combining different information and data points
f. Offer schematic representations of data which can be easily customized for an informed decision-making process(es)

4.4.1.4 Initial Design Mock-ups

The dashboard would make use of widgets, interface components combining interrelated data to provide an analysis on certain specified data categories in a manner and context chosen by the user. It would also provide statistics and data relationships in the form of graphs either bar charts, histograms, pie charts, gauge meters or other form of schematic representation easily managed and administered by the user. Examples in Figure 11 below:

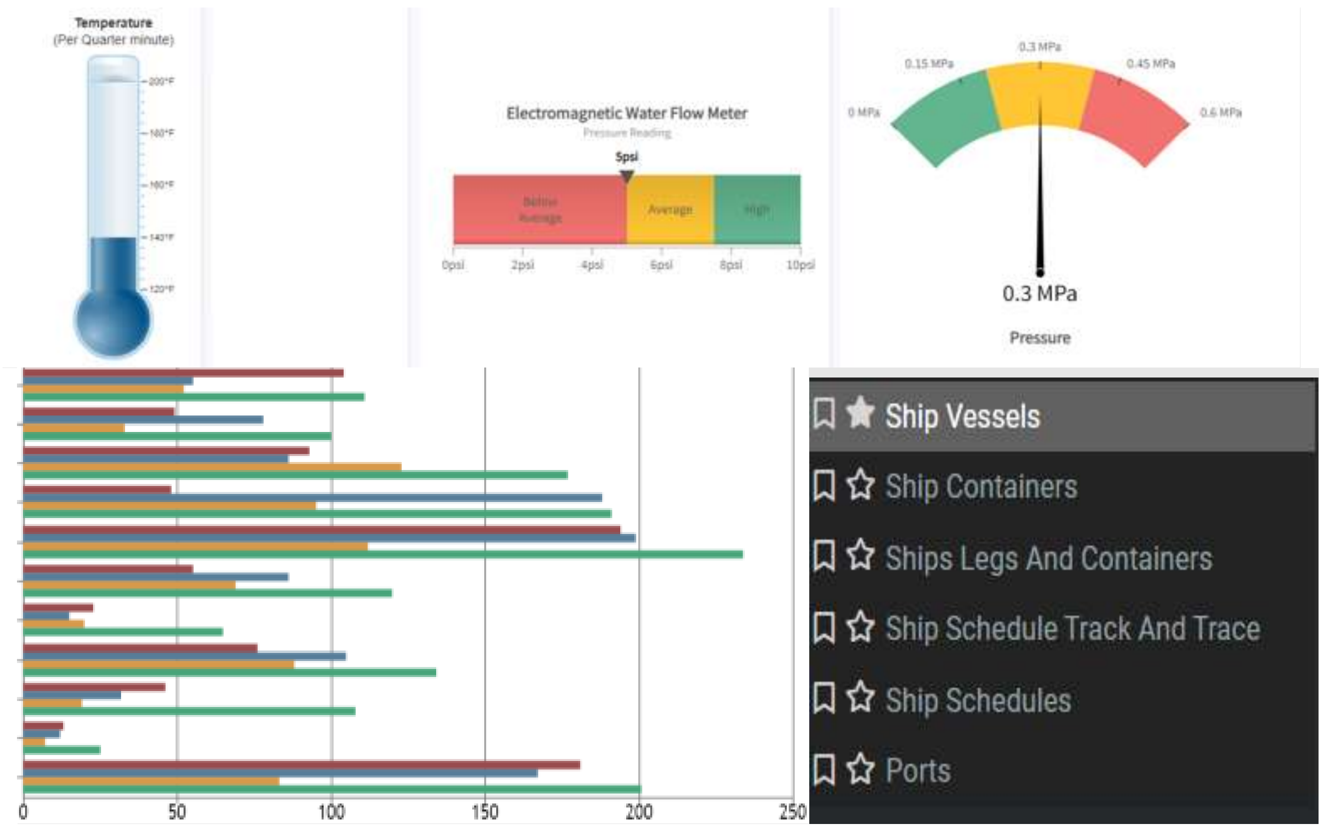

Figure 11: Examples of schematic representation of data analytics and widgets in dashboard

4.4.1.5 Requirements and Functionalities

Following a survey of the LLs user needs and preferences for the dashboards, as outlined in the sections above, measurable requirements and user groups were identified. The deliverable report D2.19 which will be submitted in November 2021 will include a full analysis and discussion of the requirements.

The requirements of the LLs, similarly to the requirements presented in Chapter 3, were divided into functional, and non-functional, hoping to address different aspects of the user preferences. More specifically, they addressed questions such as which are the business functions where visualisation is needed and what kind of analysis and interaction with the dashboards is desired by the user.

As per the task's objectives the usability requirements measured in the LLs and the mapping of the requirements with the technology/ functionality of the interface remain the key elements in the design configuration of the dashboards. Similarly, the identification of the users in each LL and the expected access rights also form part of the visualisation solution aiming towards the formulation of different access roles.

4.4.1.6 Design and Architectural considerations

As illustrated in other parts of this document and shown in Figure 6 the interface, as any front-end application, relies heavily on the connectivity to the information at the back end. Therefore, the focus for these systems is monitoring API calls the application makes to other systems to ensure success. Understanding the data coming through connections and proper data ingestion from remote locations such as those presented by the use cases scenarios in the various Living Labs via databases and IoT devices is fundamental to the design of the interface.

Well defined communication and interoperability between the services being developed in WP2 will help ensure success in this regard.
Within the Project scope:

> 'Interfaces will leverage REST APIs to enable software developers to define API calls with a high granularity, which simplifies the logic required to provision complex services, thus providing interoperability between online software systems. By using stateless protocols, such as HTTP/HTTPS and standard operations, the REST-based APIs will enable fast performance, reliability, and the ability to scale, by re-using components that can be managed and updated without affecting the system as a whole, even in its runtime mode'.

As inspired by work in the SELIS project and the Pub-Sub engine, a data transportation system based on a publish/ subscribe mechanism is to be considered. The Publish-Subscribe component delivers messages to interested subscribers. Participants publish messages as key value pairs. Participants define subscriptions indicating what subset of messages they are interested in and receive matching messages.

At this point in time (this deliverable is finalised in August 2021) the work is focused on defining the external components, outputs, and data exchanges that will be required in the process of achieving the targets. More work is planned to fine tune the architectural building blocks to be deployed and thus the interface requirements of the HMI structure to enable the correct connectivity.

4.4.2 Integrations

Several data sources and systems are integrated into the EGTN platform. Different data streams, such as IoT or EPCIS data are ingested into the platform through the Apache Kafka event streaming platform. The available data are then consumed by any deployed services and models. The platform offers Zeppelin notebooks that can be used for the development of models which will run using the EGTN data as input. The notebooks have access to the EGTN data either through the Kafka topics or from the filesystem itself with volume mounts on the notebook pods. Models are deployed on the platform as separate services in the Kubernetes cluster that consume data from the available data sources. Finally, data from other sources, such as Warehouse Management Systems (WMS), can be integrated into the EGTN platform using a shared API or database endpoint.

4.4.2.1 IoT Infrastructure

IoT data is ingested into the platform through the dedicated Apache Kafka topics. Topics are defined by the Living Lab they refer to and the type of the received data. Data are consumed from the partners either in real time from the dedicated producer processes or in a periodic fashion via cron jobs. Once the data is integrated into the EGTN platform, other running services in the Kubernetes cluster can process and use them e.g. the SIRMA AI software consumes IoT data and enriches them with metadata to produce a global view of the entire participant corridor network. The messages stored in the topics can be of any type, with JSON objects being the most common type. Other well-established standards such as the XML formatted EPCIS v1 are also a viable option. All necessary meta-information of static character accompanying the IoT data, such as port terminal and depot names codes and location, are stored in a SQL database.

4.4.2.2 Blockchain

The EGTN platform will integrate a blockchain component that will interconnect multiple backend blockchain systems to support critical interorganizational trade workflows and provide a frontend for other services to interact with. The detailed architecture of the blockchain component is a work in progress at the time of writing this deliverable (August 2021) and will be further described in D2.15 and D2.17.

From a high-level point of view, the component will act as a multi-directional intermediate component between the different ledgers and will use transaction events to read payloads and forward data from one end to the other. The backend blockchain systems that have been identified, up to now, to connect with the EGTN platform are the Port of Valencia and the DHL warehouse in LL1 and the Port of Rotterdam in LL2. The blockchain technology used by the first two is Hyperledger Fabric while the latter is using Ethereum, which adds complexity in achieving interoperability between them. Specific smart contracts will be deployed in the partners' blockchain networks so that they will listen for events in one of the ledgers and act on the others accordingly.
Moreover, the Blockchain component will connect with the IoT infrastructure through the Kafka topics that are created for each LL to consume data that will guide the decisions of the smart contracts. The IoT sensors will provide geolocation, environmental and other monitoring data and events that will either trigger the automatic execution of a smart contract or will be used for the verification of an SLA between T&L actors.

4.5 Security and Encryption

Security and Encryption lie at the heart of the EGTN Platform. It is of critical importance to secure the connection and transfer of sensitive information between the user and the platform, therefore all domains related to the EGTN platform use X.509 certificates for the Transport Layer Security encryption and are accessible through the HTTPS protocol. Furthermore, the Apache Zeppelin notebooks interface is secured with Apache Shiro[5], which handles authentication, authorisation, session management and cryptography among others. Apache Shiro is an open-source software security framework developed by the Apache Software Foundation.

[5] https://shiro.apache.org/

5 Deployment

This chapter describes in detail the deployment process of the EGTN Platform. The entire cloud-based infrastructure is depicted in Figure 12. The figure illustrates the different nodes that were set up in the context of the PLANET project, along with the technical solutions that were deployed on each of them. A Kafka cluster consisting of three nodes along with an Apache Zookeeper were set up to offer scalable and reliable performance to the system.

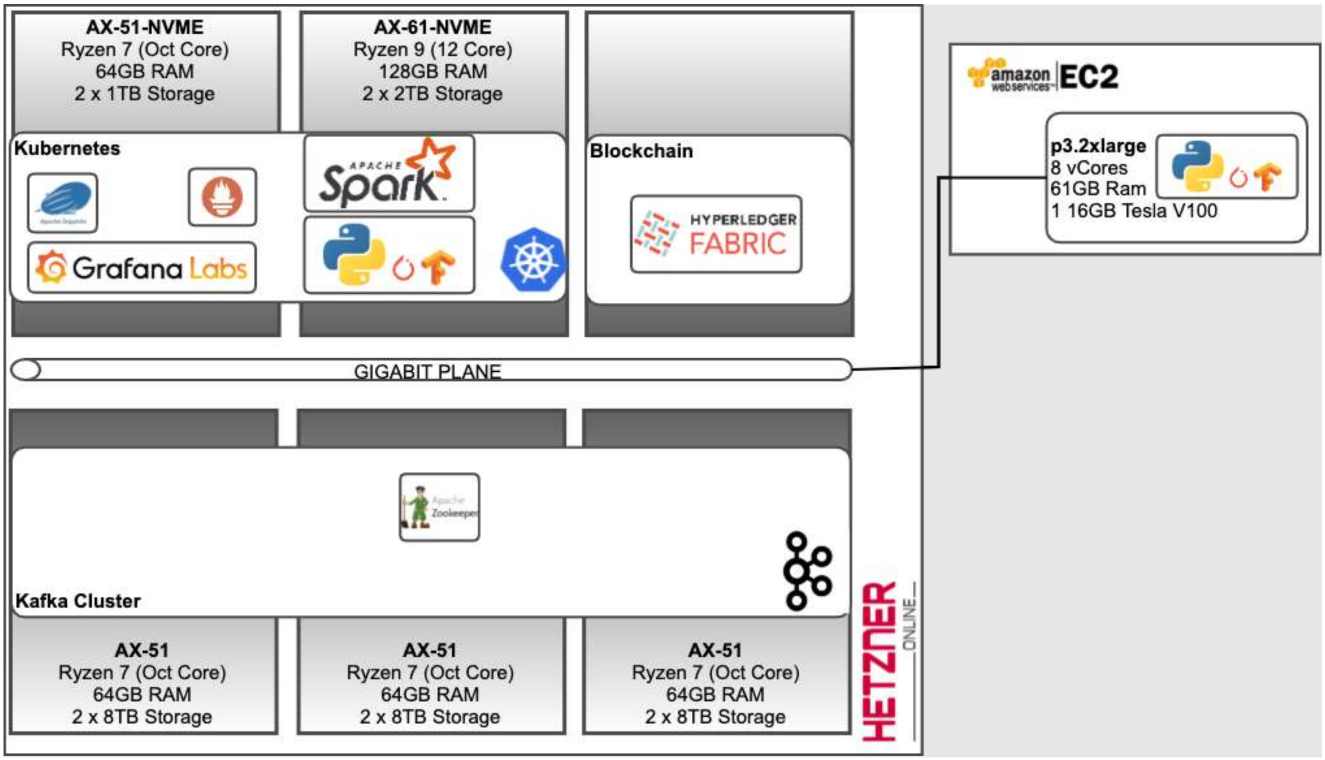

Figure 12: EGTN Deployment on Cloud Provider

5.1 Cloud Provider Selection

The process of selecting the cloud infrastructure provider of the EGTN was lengthy and required a comprehensive study of the requirements of the EGTN infrastructure and a thorough investigation of the available choices in terms of cloud infrastructure providers. As described in Section 3.1, a requirements analysis was carried out to identify the technical requirements of the partners for processing and storage, knowledge graphs, IoT data, analytics and blockchain in the EGTN cloud infrastructure. The table below, summarises the requirements for the cloud infrastructure extracted during discussions with all the LLs and the WP2 partners:

EGTN functionality	Cloud Infrastructure Requirements
Processing and Storage	Support for ingestion of multiple streams of data and batch uploads Fast access to large sets of historic data Easy access to 'live' data Simple data ingestion extensibility

	Support for parallel execution of code Support for containerised components
Knowledge Graph/IoT Data	Support for containerised component deployment Kubernetes with Helm support for orchestration Container information: 64GB RAM 300GB of Storage
Analytics Requirements	Periodic access to GPU's required Most training will take place offline, but some training (using larger datasets) will be done on the platform Unified shared environment for analytics tool development required Easy visualisation environment required General Computational Requirement: 8GB RAM 2.7+ Quad Core CPU 8-10 GB storage
Blockchain Requirements	Hyperledger Fabric support Latest features of Fabric codebase supported Easy access to interfaces and support for easy integration with local instances

As one may infer, the T&L stakeholders' needs imply a rather sophisticated set-up given that its implementation in a single cloud infrastructure provider can be challenging. Access to GPU resources can be very costly and difficult to source due to the lack of hardware chips as a result of the pandemic. The next step was to shortlist the available providers and select the most appropriate one considering costs, hardware availability, stability of the infrastructure and previous experience.

Since the deployment of the set-up within a single provider was not possible, due to mainly increased cost of GPU access, several infrastructure designs were made involving different vendors to both support the entire requirements list and stay within the project's budget (27k). The Hetzner[6] cloud provider was chosen to host the infrastructure for the EGTN platform except for the services involving access to GPU. The competitive rates offered by the Hetzner provider, combined with its reliability according to the previous experience of the involved partners (Inlecom and EBOS) led to this decision. In terms of access to the GPU, the Amazon Web Services (AWS)[7] cloud platform was chosen, taking advantage of the pay-as-you-go feature which provides the option to pay only for a specific number of months according to the project's needs for training AI models. Finally, the blockchain expertise of the consortium allows for the manual installation of the blockchain software, avoiding payment for a blockchain-as-a-service and, in this way, saving budget. This is accomplished by simply renting another Hetzner Linux server and deploying all the blockchain-related software on that server.

5.2 Deployment Scripts

The deployment set-up procedure consists of the following parts:

- Setting up the Kafka nodes
- The initialisation of the Kubernetes control-plane node and the rest of the nodes
- The set-up of the GPU node

[6] Hetzner Online GmbH https://www.hetzner.com/

[7] Amazon Web Services https://aws.amazon.com/

- The set-up of the Hyperledger Fabric network

The first step of the process involves the Kafka nodes, which are configured using the most recent version of Apache Kafka (2.7) with Scala version 2.12. The operating system of the machines is Ubuntu 20.04. A single script is responsible for installing the platform to all the nodes accepting as input the targets' IP addresses. The script will then initialise the node by setting a dedicated user, installing the Kafka prerequisites, and downloading the Kafka service at the aforementioned version. It then proceeds by modifying the broker's properties such as the unique broker ID, the listener and Zookeeper IP addresses and more. Subsequently, the script creates Systemd unit files for both Kafka and Zookeeper setting a dependency of the Kafka service towards the Zookeeper. It empowers the service, so that it runs upon system start-up and then starts the Kafka service. Finally, as an added measure of precaution, the administrative rights of the Kafka user that were created initially are removed and the password of the user locked. No further topic configuration is set, as such decisions are taken in coordination with the project partners. This script is fully automated and can easily be used as a blueprint for other deployments.

A second script is tasked with the Kubernetes installation. The IP addresses of the nodes are again given as input with the first in the sequence being considered as the control-plane node. The preparation stage of the nodes is identical for all nodes and consists of networking modifications, disabling of the swap partition and the installation of the kubeadm, kubelet and kubectl tools and their prerequisites. The script moves then to the control-plane node where it initialises the cluster with kubeadm and continues with the installation of:

- the Calico Kubernetes Pod network[8]
- the Helm Kubernetes package manager[9]
- the Kubernetes dashboard[10]

Following that, the script loops through the rest of the nodes and uses kubeadm so that they join the Kubernetes network. The above procedure serves as a blueprint and any other platform can then be deployed through Helm or kubectl. Such a procedure is purposely not incorporated in the script since it is dependent on various and changing factors.

The GPU node is provided through Amazon's EC2 platform and uses a VM which is optimised for model training. The node is already configured with package and environment management tools (pipenv, conda) that facilitate the developer workflow. The node is spawned upon demand and is used exclusively for the training of the models.

Finally, the inter-ledger software is deployed on a separate machine. The initialisation script handles the prerequisites and the installation procedure. Subsequently, the network and connection details of the concerned blockchains need to be provided to the software as JSON configuration files by an administrator, while the necessary contracts need to be installed on the blockchains. The service is then initiated with said configuration files as input parameters and starts listening to events from the blockchains.

5.3 System Performance

Monitoring the performance of the system is an important aspect that was included as a basic component of the EGTN platform. System performance may refer to the network capacity, data ingestion capacity, I/O throughput,

[8] Project Calico, https://www.tigera.io/project-calico/
[9] Helm – Package Manager for Kubernetes, https://helm.sh/
[10] Kubernetes Dashboard, https://github.com/kubernetes/dashboard

availability, and more. Monitoring these aspects of the platform provides useful insights on critical topics such as the message broker set-up or the need for a cache layer among others.

Network traffic can be observed through the online dashboards of the Hetzner cloud provider (Figure 13) which offer further insight regarding the need for more nodes in the cluster. Furthermore, the Grafana visualisation platform contains several dashboards that are used to monitor a variety of systems such as databases I/O or the Apache Kafka message broker (Figure 14).
As the platform is still at an early development stage, further enhancements in the domain of the platform monitoring will be added along with a more detailed quantitative analysis of the overall system's performance will be presented in the second version of this deliverable.

Figure 13: Traffic Usage

Figure 14: Grafana Dashboard

6 Data and Component Integration

6.1 Data and Component Integration Guidelines

The EGTN platform provides a variety of services related to the ingestion and processing of data, which is used to help in the decision-making process of the T&L stakeholders. A set of standards need to be put in place so that the platform can function efficiently and meet the requirements of the platform's users.

As such, the various data sources that connect to the platform need a clearly defined manner of how to send data to the platform. Real-time data is ingested into the platform via Kafka topics. There is a great deal of flexibility regarding the data format provided that an understanding exists between the interested parties. The data should nevertheless be in standardised formats that would facilitate parsing from any interested partner. The ingestion services can be executed either periodically (through a cron job) or continuously. Data of static nature can be stored in different and more suitable structures. In this context, the EGTN platform offers both document-based and relational databases - MongoDB and PostgreSQL respectively.

Additional data processing may be required to extract insight for the relevant business scenarios. The EGTN platform offers Zeppelin notebooks so that developers can implement and test their solutions directly on the platform. Valuable analytics can then be continuously calculated through dedicated services on the Kubernetes cluster. As previously mentioned, multiple solutions are offered by the platform for the storage of the generated analytics. It is encouraged that naming conventions are to be followed for the tables, collections, or topics and should contain information regarding the concerned LL, the data source, and the data consumer.

Finally, the EGTN platform's modular design offers the potential to integrate external systems, such as Warehouse Management Systems (WMS) and more, provided they offer an API for the platform to interact with. In this case, such requests can be sent on demand, periodically or continuously through a dedicated service, while the retrieved data can be stored ephemerally or permanently in the available data services following naming conventions.

6.2 Data Integration & IoT Infrastructure

A foundational requirement for successful IoT applications is the usage of standards for achieving syntactic interoperability in the data formats, such as the Electronic Product Code Information Services (EPCIS), a GS1 standard that enables stakeholders to share information about the movement and the status of products, travelling throughout the supply chain. As explained in 4.4.2.1, the IoT infrastructure is integrated through Apache Kafka topics where heterogeneous data, including but not limited to environmental measurements, assets' geolocation data and transaction events, are shared with the interested parties according to the associated agreements. The different data providers, as well as the data consumers of the EGTN Platform are listed in Table 16.

More specifically, the EGTN infrastructure captures EPCIS events related to assets such as pallets or crates together with sensor data such as temperature, shock, or humidity relative to the asset at a given moment in time. Then, those data streams are shared with the connectivity layer and consumed by the SIRMA AI software where they are enriched with metadata to produce a global view of the entire participant corridor network.
As a use case example, EPCIS v1 XML-based data from ILIM are periodically retrieved from their EPCIS server through a Cron Job process and stored in a dedicated topic defined by the Living Lab and the data type. SIRMA processes are consuming data from this topic and handle the transformation of the XML EPCIS v1 data to JSON

EPCIS v2. Finally, the documents are stored in a MongoDB database from where they are used by the rest of the SIRMA services for their semantic search platform.

Similarly, order data is ingested into the system as JSON objects in partnership with DHL, while COSCO provides shipping containers' data in both JSON and EDI formats. Following the guidelines, the EGTN platform accepts real time data, such as orders or trading communications (for DHL and COSCO respectively), through dedicated Apache Kafka topics while static information such as depots, port terminals and train services that concern mostly COSCO's use cases are captured and stored in data structures that facilitate their usage and further processing such as a document-based database.

Table 16: EGTN Data Sources

Data Provider	Ingestion Platform	Data Type	Consumer	Consumption Platform	Data Type
ILIM	Apache Kafka	EPCIS v1 XML	SIRMA	Mongo DB	EPCIS v2 JSON
DHL	Apache Kakfa	JSON	IBM	Apache Kafka, Influx DB	JSON
COSCO	Apache Kafka, Mongo DB	JSON, EDI	IBM	Apache Kafka, Mongo DB, Influx DB	JSON
CityLogin	Apache Kafka	.xlsx	VLTN, IBM	Apache Kafka	.xlsx

7 An Open-Source Blueprint for the EGTN network

7.1 The state of the art

Modern Transport & Logistics networks have been seeking to resolve several challenges – such as the complexity of trade and customs processes, traceability of shipments, transparency, trust, and confidentiality between different stakeholders – using disruptive technology. The emergence of IoT, Big Data, Machine Learning, and Blockchain technologies have created a fruitful ecosystem where the combination of these technologies has helped T&L networks overcome major issues and, in the meantime, innovate. Notably, blockchain has the potential to redesign informational and financial flows, both of which supplement physical flows in a supply chain [1]. Most importantly, the adoption of these different technologies in T&L networks laid the groundwork for innovative cross-organisational, collaborative, data sharing platforms.

During the past five years several initiatives have taken place in that regard, predominantly commercial platforms. In the airline sector, BRUCloud [4] is a winning open data sharing platform used by the cargo community at the Brussels airport to digitise communication and share data between all actors involved. In the shipping industry, IBM and Maersk joined forces to develop TradeLens [5]; a blockchain-based global trade platform for sharing shipping events, messages, and documents across all the actors and systems in the supply chain ecosystem. The platform provides shared visibility and shared state for container shipments. DL Freight [6], developed by DLT Labs, uses private blockchains as a backstory to bring trust between T&L stakeholders while acknowledging that different parties should take on different roles in terms of data access. Deutsche Bahn, in collaboration with US logistics technology company uShip, have developed their own platform, Drive4Schenker [7], that matches shippers and carriers and offers end-to-end transport monitoring.

Several solutions have been introduced aiming at the digitisation of the supply chain process. For example, Tilkal [8] combines private Blockchain networks and Big Data to bring end-to-end, real-time traceability and, in turn, transparency within the supply chain. In the same domain, Transparency-One [9] enables different stakeholders to have a complete, end-to-end view of the supply chain by offering real-time monitoring and analytics. The collaboration between Chainyard and Trust Your Supplier [10] resulted in the development of a supply chain solution that puts trust and security at the forefront using Blockchain, IoT and Machine Learning. On top of that, Machine Vision and Predictive Analytics are put into action for product verification during customs control. NxtPort [11] puts data sharing among port stakeholders at the forefront by producing a platform that offers transparency in the entire shipping process. IBM have also developed a solution tailored to the food industry. IBM Food Trust [12] is a set of modules that offer traceability to improve transparency and efficiency across the food supply chain. Blockchain is used to create a trusted connection with shared value for all stakeholders, including end consumers.

Similarly, Accenture developed the True Supplier Marketplace platform as a blockchain-based solution for supplier onboarding and management. Notably, projects are in development in other business areas, such as automotive (e.g., blockchain-based platform for transparency in the supply chain by Mercedes-Benz [13]) and pharmaceutics. For instance, PharmaLedger [14] is a project currently in development that aims to create a blockchain-based platform for the healthcare sector, while BRUINchain [15] is a last-mile blockchain application designed to help deliver medicine to patients.

It should be highlighted that this is not an exhaustive list of all the software solutions that are currently available, but rather an indicative showcase of the most prominent ones in the world now. All the aforementioned solutions highlight the value that new emerging technologies, such as IoT, Blockchain and Machine Learning can bring to T&L solutions. These solutions and their technologies provided the basic design and technological principles on top of which the EGTN Platform was developed.

7.2 EGTN innovations beyond the current state-of-the-art

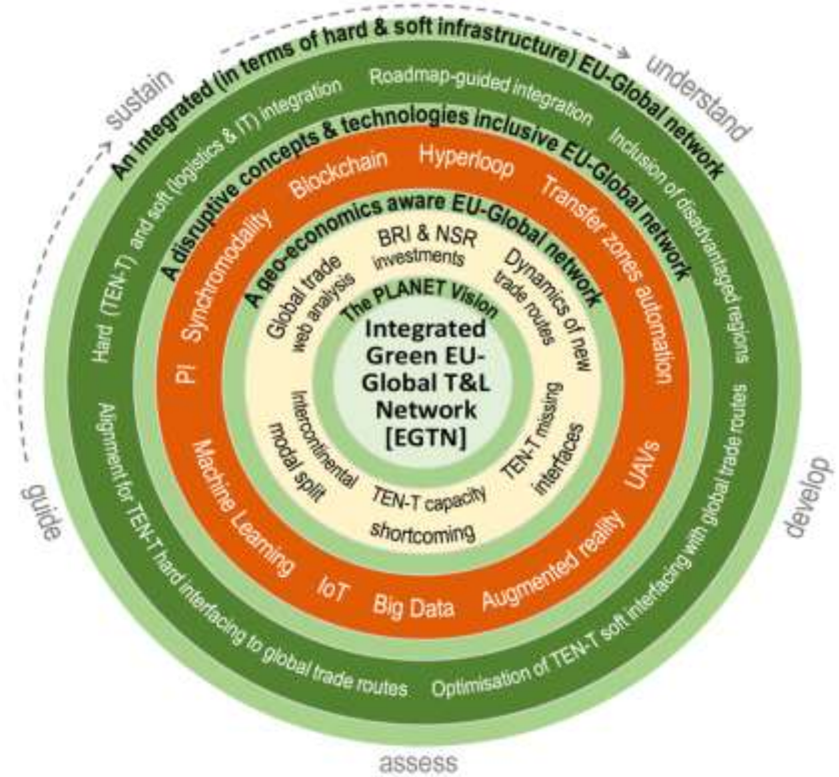

Figure 15: The PLANET Concept

The vision of the PLANET project consists of two key R&D pillars: a Geo-economics approach that models the dynamics of new trade routes and their impact on T&L infrastructure and operations with a particular focus on TEN-T, and an EU-Global network enablement through disruptive technologies and concepts. To that end, the project focuses on understanding and exploiting the EU-Global network by leveraging advancements linked to the federation of Blockchain networks, which in turn lead to federated logistics (Figure 15). As stated in the Project Proposal, this can be regarded as a step prior to the accomplishment of the Physical Internet.

The EGTN Platform is in alignment with the project pillars - especially with the second one - and aims to address the PLANET technical requirements, as defined in the outputs of WP1. The open cloud-based infrastructure described in Chapter 4 is the cornerstone of the PLANET project, as it offers the foundation on top of which the EGTN Platform is developed.

The EGTN Platform is a powerful platform due to the unique combination of technologies and models it includes:

- A real-time data ingestion pipeline, which consumes streaming and batch data from a plethora of data sources, ranging from IoT sensors to weather and traffic data. In this way, information such as waiting times, order status, or even delays in vessel journeys can be fed into the platform. This feature empowers the platform with real-time, automated decisions, such as dynamic contract activation.
- The platform is developed based on the requirements defined in WP1. More specifically, it considers the simulation analysis of T&L and ICT innovations that position emerging technologies (e.g., Blockchain and IoT) as contributors to the Physical Internet. In addition to this, simulation models developed in WP1 can

be executed in the cloud-based infrastructure of EGTN. The EGTN functionalities, as defined in WP1, are addressed in detail in the following section (section 7.3).

- A Decision Support System is built within the EGTN Platform that aims to empower partners to make data-driven decisions, especially related to synchromodality, based on optimisation models and predictive analytics. More precisely, the models include corridor route optimisation, forecasting services for warehouses and ports and supplier collaboration analytics. In addition to these models, multi-Criteria Analysis will consider stakeholder opinions regarding investment decisions on the development of new corridors and routes.
- The use of Blockchain technologies for paperless, dynamic contract generation and management. As described at the beginning of the section, Blockchain is an effective solution for T&L networks and in the context of PLANET it offers a unique set of features, such as:
  - Improve customs control through the digitisation of the process
  - Increase traceability of events and respective partners
  - Increase trust but also confidentiality between different partners
  - Ensure the authenticity and veracity of the data shared between partners
- A technical innovation of the PLANET project is that it introduces Blockchain interoperability into a complex T&L network: the TEN-T network. Interoperability is the capacity of computer systems to exchange and use data, but also the capacity to transfer an asset between different systems while keeping the state and uniqueness of the asset consistent. In that regard, Blockchain interoperability enables knowledge sharing without sending copies of data and provides fairness in the ordering of transactions and accessibility to data and codification of and adherence to common rules (Hewett and al, 2020). Over the past year, it has become an emerging hot topic in both academia [3] and the industry [16], [17], [18], as new commercial products have been initiated and are currently under development. In the context of PLANET, interoperability addresses the issue of exchanging assets – such as the Bill of Lading - between several blockchain networks of different partners and Living Labs. To the best of our knowledge, none of the industry platforms described in the previous section address the issue of interoperability between different blockchain systems.
- A trending topic PLANET addresses is the incorporation of the EGTN platform on the PI roadmap. Using intelligent forecasting and planning the project tackles important PI questions, such as predicting the use of resources in a PI node and rerouting cargo in the case of congestion in one of the corridor ports. The models developed require the data ingested from the different sources of the EGTN Platform, but also the outputs of the predictive models as input.
- Blockchain features, and functionalities have the potential to meet PI implementation requirements as well as overcoming key PI barriers and deficiencies [2]. Moreover, the combination of Blockchain and PI has the potential to achieve triple bottom line sustainability; that is social, economic, and more importantly environmental gains [1]. This is quite a milestone for a T&L network, as the existing TEN-T network is not linked to the EU's green strategy and does not consider innovations.
- On top of all these technological layers is a powerful Human Machine Interface, which will contain different customisable dashboards and will support data-driven analytics stemming from the EGTN platform's backend with the ultimate purpose to manage the TEN-T corridors.
- Finally, the EGTN Platform, and especially the Human Machine Interface, are available to <u>all</u> partners of PLANET. This sets a new standard for a more open and inclusive ecosystem where logistics partners share infrastructure and data and, in this way, overcome the silos of existing T&L systems and organisations.

The beyond-the-state-of-the-art innovation of the EGTN Platform is that all these different technologies are brought together in the service of a leading-edge European T&L project that aims to take one step closer to realisation of the Physical Internet. Through this lens, the EGTN Platform does not aim to develop a new "platform". Instead, its ambition is to develop an <u>original blueprint</u> accompanied with <u>best practices</u> with ultimate goal of helping T&L actors define and implement clear digital strategies to support their physical operations.

Figure 16, "EGTN Platform Design Influences", captures "at a glance" the inputs and influences that guide the EGTN platform architecture and design specifications. These inputs drive the technological innovations in Work Package 2 and will continue to do so until the end of the project. They support the platform design to go beyond the state-of-the-art by positioning it as solution inspired by key EGTN factors related to the Physical, Governance and Technology insights being surfaced in Work Package 1. These inputs also help to uniquely position the EGTN platform in terms of technical enablement of the Physical Internet (PI) paradigm. In that regard, empowering T&L stakeholders by offering them a means to access tools and PI services for routing, node optimisation, shipping and encapsulation etc. and to collaborate with other T&L actors in a self-determined and secure way.

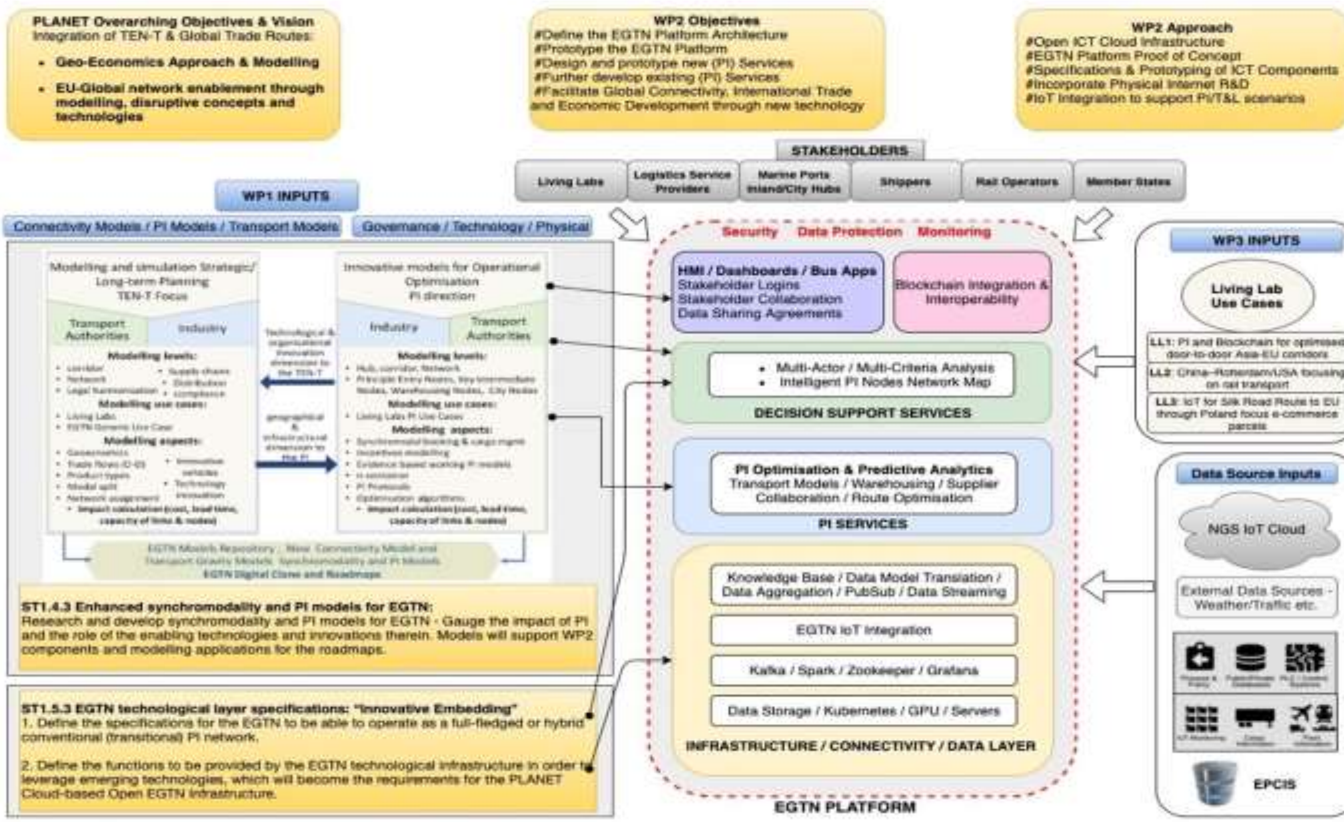

Figure 16: EGTN Platform Design Influences

Figure 16 illustrates the interrelationship between WP1, WP2 and WP3 and how these influence the design specifications and architectural blueprint of the EGTN platform which is described in this Deliverable. The diagram starts by highlighting the overarching objectives of PLANET and then focuses on the WP2 objectives and the approach taken to achieve these. WP1 is a major source of inspiration for the technical direction taken in WP2 and it is based on extensive modelling and simulation research being conducted in that Work Package with regards to TEN-T Strategic planning and innovative models for optimisation of PI nodes, hubs and corridors. The Living Lab Use Cases also played an instrumental role as input to both WP1 and WP2 platform architecture. WP2 set up a series of productive workshops with the Living Labs of WP3 to evolve the use case storyboards, which in turn further serves to inform the technical componentry and configuration of the platform. This combined effort of the Work Packages highlights and helps define what is probably the most important aspect of the platform design; that is the stakeholders. Who will use the platform? How will they use it? And what factors need to be considered to encourage widespread adoption of the platform and the associated EGTN and PI protocols and standards? In addition to this, Figure 17, "Key Platform Design Considerations" provides an overview of the important design aspects which were under consideration and highlights some potential barriers to adoption, which are important to know so that they can be mitigated in the planning and design phases.

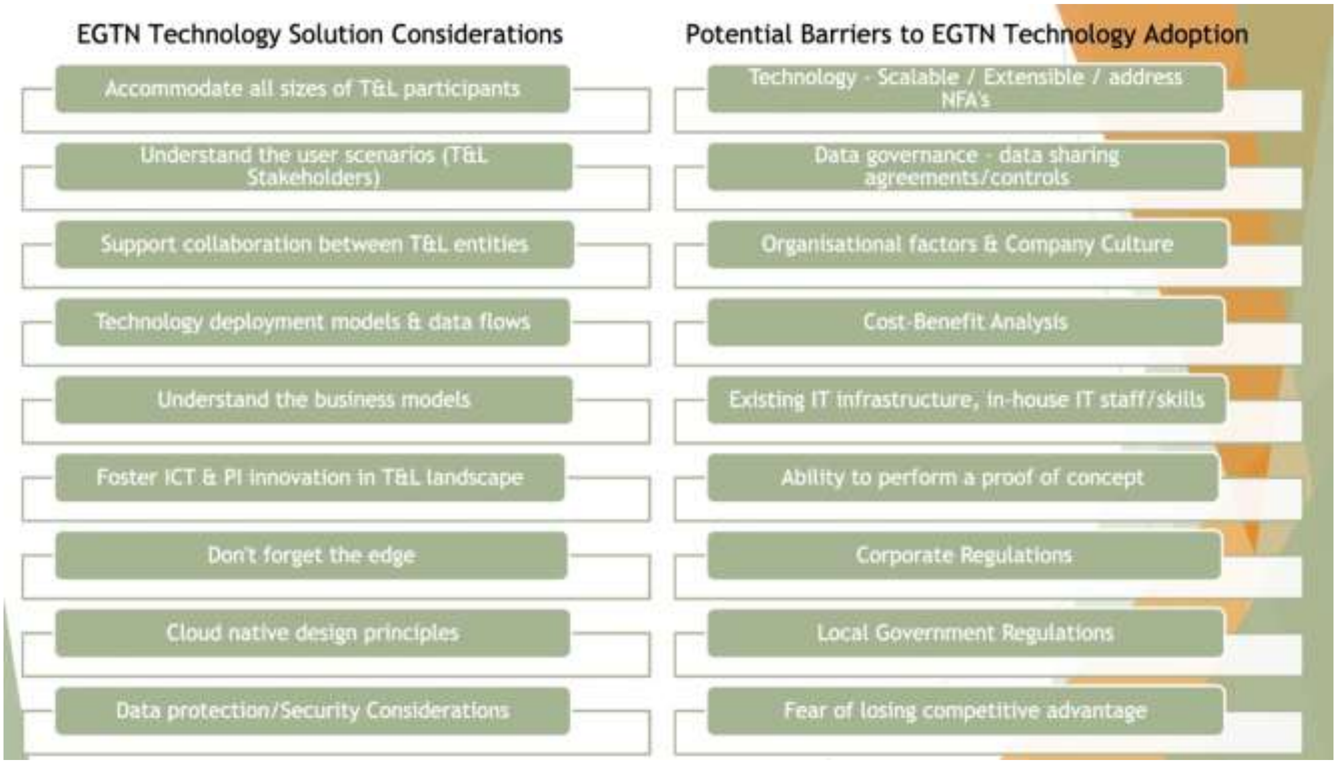

Figure 17: Key Platform Design Considerations

The EGTN platform must be versatile enough to accommodate different sizes of T&L/PI actors, not just large enterprises with expensive IT budgets. As mentioned earlier, understanding the stakeholders, their business models and how they need to collaborate with each other is of fundamental importance. The ICT innovations supporting the combined EGTN/PI landscapes need to be fostered and encouraged as much as possible by allowing stakeholders to develop and adapt them to their own requirements and scenarios. Adhering to cloud native design principles will "future proof" the platform architecture and allow for diverse deployment recipes as needed by a plethora of stakeholders in different scenarios. For example, by allowing integration with service meshes and/or SDN to support cross-geo service-chaining, or by supporting the introduction of federated or distributed learning in an edge or FOG networking context. The edge is an important consideration in view of the ever-increasing trend of analysing data on the edge rather than moving large amounts of data to the cloud. The platform needs to support the FOG networking model and whenever necessary, ingest pre-processed or aggregated data from different points on the Cloud-to-Thing hierarchy. The potential barriers to adoption that are in the forefront of the design methodology, with a view to mitigate them, include the non-functional attributes, such as scalability and elasticity of resources, data protection and data sharing in a controlled manner. Other potential barriers are considered in WP1 such as the ones related to governance and regulatory aspects, and these were also considered in WP2 when designing the platform solution to enable the EGTN/PI.

7.3 The EGTN Platform Functionalities

7.3.1 Collaboration with Partners

Throughout the course of this project, inputs from different partners involved in Work Packages 1, 2, and 3 have determined the direction of this deliverable. Several meetings have taken place that shaped the requirements of the EGTN Platform, such as:

- Consortium Workshop between WP1 and WP2 (June 2021)
- WP3 Living Lab 1 Regular Meetings by ZLC
- WP2 Bi-weekly Meetings by IBM
- WP2 EGTN Platform Requirements Calls by Inlecom

It is worth noting that apart from the Consortium Workshop the regular meetings organised by the partners of the PLANET project offered the most fruitful setting for interactions and exchange of ideas. For instance, the meetings have helped define the various data sources that feed data into the Platform, as well as the different users of the Platform, as these are defined in Chapter 4. In addition to this, meetings with WP3 partners enabled WP2 partners to identify the relevant use cases and define their respective requirements, which in turn informed the decisions regarding the design of the platform and its interfaces. Finally, feedback from WP1 on the required specifications of the EGTN technological layer influenced the design and development of each EGTN component and service, as it is shown in the following section.

7.3.2 The EGTN Platform Functionalities

This section identifies how the EGTN platform addresses the required functionality as defined in Sections 3.1.2.2 and 3.1.3.2. More specifically, Table 17: EGTN Functionalities provides a mapping between each EGTN component and the respective functionality it fulfills.

Table 17: EGTN Functionalities

Functionality	Description	EGTN Component
EGTN infrastructure visualisation and decision theatre	Provide visibility of the supply chain through an appropriate visualization of EGTN parameters of operations required to support the management decisions at corridor/node level. Include the main KPIs of nodes and corridors, the implemented standards and the interoperability procedures.	Kafka component, Blockchain component, EGTN Dashboard
Visualise the forecast for the future of flows	Develop interface to strategic modelling capability which will calculate the changes in flows at the macro level compared to a base year (2019) by integrating the emerging global corridors and simulating plausible future scenarios based on possible geo-economic,	Analytics (Predictive & Prescriptive Models and DSS Tool) component, EGTN Dashboard

	environmental, technological and other developments.	
Development & validation of PI scenarios	Validate PI scenarios in terms of cost/benefit, feasibility, and possible implementation timeframe	Analytics (DSS Tool) component
Support the calculation of EGTN infrastructure indices	Capture the corridors/nodes attractiveness/competitiveness by incorporating the Corridor Connectivity Index	Analytics (Predictive & Prescriptive Models) component, Open Data Repository, Kafka component
Planning of regional logistics	Enhance operations at a regional level and thus facilitate the development of disadvantaged regions.	Blockchain component, IoT and Connectivity component
Facilitate EGTN governance	Ensure transparency and equity to all EGTN stakeholders	Blockchain component, IoT and Connectivity component, Open Data Repository
Monitor the physical and digital EGTN infrastructure and support their symbiotic development	Provide an overview of the network status and assess the differences between national and EU priorities	EGTN Dashboard, IoT Connectivity component, Open Data Repository

8 Governance and Support Plan

8.1 Open EGTN Platform Governance

Platform Governance can be defined as who makes what decisions about a platform. In that regard, a critical challenge is that a platform owner must retain sufficient control to ensure the integrity of the platform while giving away enough control to encourage innovation by the platform's module developers [19].

In this context, the EGTN Platform shares some of the characteristics of businesses such as Airbnb or Uber, which are part of a new economic revolution known as the platform economy. As Uber disrupted the taxi business and brought closer taxi drivers with taxi riders, PLANET changes the way that T&L actors interact, share information, optimise their performance and increase their revenue by connecting them through an online platform. These platforms require open, accurate governance frameworks that define the rules, practices, and design decisions put in place to influence how content is filtered and presented and to monitor the behavior of a community to ensure cooperation and prevent abuse amongst users [20].

Regarding the onboarding of the users, even in these early days of the EGTN Platform, there are policies in place that were designed to keep user identity and data safe, since a relationship built upon trust with all users is a top priority of the PLANET project. User interfaces, such as Grafana and Zeppelin are strictly secured, and accounts are given on-demand with strong password restrictions. There are mechanisms to allow single sign-on on the different interfaces to reduce user confusion. Personal Identification Information (PII) are not stored within the EGTN Platform's databases, while any data stored are encrypted using strong cryptographic algorithms (AES-256) to enhance the accountability of the platform. This gives users full control over their data even through there is a central governance framework. Last and most importantly, there are ACL protection rules to access data topics on Kafka.

A further analysis of the EGTN platform governance will be presented in the final version of this deliverable.

8.2 Support during Project

8.2.1 Improvements and Maintenance

Wherever possible the PLANET EGTN Platform incorporates open-source tools, applications and programs. Therefore, the platform itself is built using a disparate set of components, each with its own system requirements, installation procedures, and interoperability settings. Each tool has its own independent update cycle that includes not only bug fixes and new or improved features, but also security updates. Once established most of the maintenance activities will focus on ensuring continued security, interoperability and performance (in that order).

To ensure reproducibility of the platform, all component installations have been automated and scripted. These scripts are kept version controlled and form part of a Continuous Integration and Continuous Deployment pipeline (CI/CD). This pipeline will monitor the code repositories of the various components and any changes will trigger re-testing and operator instructed redeployment of the platform.

In terms of system functionality, the next phase of the platform development will focus on ingesting more data sources and integrating with the higher layers of the architecture, e.g., Dashboard, Blockchain, Analytics. As more data is integrated into the system and more analysis is performed the requirements and expectations of the underlying system will evolve. This task will adopt an agile approach in dealing with change requests.

Users and developers will be able to create tickets on slack that the development team will flesh out with the requester. Based on the load these changes will be handled based on priority first then first come first served. If many change requests come together, then the team will perform sprints to ensure all changes maintain compatibility. This reduces the interoperability challenge down the line. Requests are prioritised based on (but not limited to) the following orders of factors: Security (system or data), stability, restriction in existing functionality, support for new data, support for new functionality.

8.2.2 Support Definitions

Support is defined as the technical assistance provided to the end users and developers of the PLANET EGTN Platform. This assistance can be as severe as fixing service disruptions or less business critical as making modifications to processing chains or component interactions etc. Subsequent subsections outline the severity of service disruptions/support needs, the various types of support levels available, when each level should be used, and the expected turnaround times.

Statuary Holidays not only include the approved Greek holidays but also some days around the prescribed day. This is due to lack of access to premises during extended periods of holidays. Email and Slack notifications of these periods and the level of cover provided will be circulated closer to the dates.

Scheduled Downtimes may be required periodically for maintenance of PLANET systems. Up to 3 business days notification will be provided.

The project Principal Points of Contact may be unavailable to respond to a critical disruption. Under those circumstances there is a secondary team of technical support that can restore the platform from an Unscheduled downtime. All members of the team are employees of Inlecom and as such are covered by the relevant GA. and CA.

Disruptions to 3rd Party Service: As the Hetzner Cloud, IBM Fabric, and Amazon's EC2 services are externally supplied resources any disruption at those end points will be handled based on their respective SLA's. This shall apply to other 3rd party services that have not yet been identified.

8.2.2.1 Service Levels

Categories of Service Disruptions

Level	Description	Examples
Severity 1	Critical Impact/System Down: Business critical software component is inoperable; Virtual Machine has stopped working or critical interface has failed.	Disruption in public cloud provider services. Bad or disruptive updated causes system failure leading to reinstallation.
Severity 2	Significant impact: A software or VM component is severely restricted in its use or a deadline may be missed.	Network issues causing API calls to EC2 to activate GPU node to fail, preventing use of some analytics or training features.
Severity 3	Minimum impact: A software component is malfunctioning, a non-trivial change in model logic is required	An existing data consumer needs to be modified to incorporate a new format/field in incoming data.

Categories of Support Needs

Level	Description	Conditions
Level 1	Use of Urgent Phone contact number	9am to 5pm EET support available outside statutory holidays

Level 2	Email/Slack or UK office hours phone contact.	Standard method to resolve issues
Level 3	Use of special mailing list to contact non-project based critical technical help.	To be used when System Administrator is not available

Turn Around Times

Severity Level	Impact	Support Level	Response Goal
Severity 1	Critical Impact	Level 1 / Level 3	Same day (except statuary holidays)
Severity 2	Significant Impact	Level 2	Within 2 business days
Severity 3	Minimum Impact	Level 2	Within 10 business days

8.2.2.2 Route to Escalation

Multiple routes to escalation are available, which correspond to the three levels of support described in the previous section.
Critical Phone Contact: In the event of a Severity 1 disruption on any day outside statutory periods urgent phone contact can be made. The number for this is provided to key members of the PLANET Development team.
Critical Support Mailing List: In the event the secondary support team needs to be contacted (level 3) for a critical disruption the email planet-support@inlecomsystems.com can be used.
Email, Slack, and/or Telephone contact for Level 2 can be made to the project System Administrator. These details will be circulated to the main project mailing list. It is also included in registration emails send by the system. A file of these details is also made available within the project Teamwork folder.

8.3 Sustainability

The PLANET project will conform to the principles set out by the 'Karlskrona Manifesto for Sustainable Design'[11] in all aspects of development, including infrastructure and architecture. These principles are:

- Sustainability is systemic;
- Sustainability has multiple dimensions;
- Sustainability transcends multiple disciplines;
- Sustainability is a concern independent of the purpose of the system;
- Sustainability applies to both a system and its wider contexts;
- Sustainability requires action on multiple levels;
- System visibility is a necessary precondition and enabler for sustainability design;
- Sustainability requires long-term thinking.

[11] Becker, C., Chitchyan, R., Duboc, L., Easterbrook, S., Mahaux, M., Penzenstadler, B., Rodriguez-Navas, G., Salinesi, C., Seyff, N., Venters, C. and Calero, C., 2014. The Karlskrona manifesto for sustainability design. *arXiv preprint arXiv:1410.6968*.

In practice these principles are being applied as follows:

- All design is user driven with functionality and workflow matching the end user needs – to ensure maximum adoption;
- All components are modular preventing technology lock;
- Components are based on open-source software and agreed standards to enable migration;
- Plans are already being developed for post-PLANET adoption of the platform.

The specific sustainability plan for the architecture, software assets, and platform will be presented in the final version of the Open EGTN Platform Architecture deliverable (D2.2).

9 Conclusion

The purpose of this deliverable was to present the open cloud-based architecture of the EGTN Platform. The technical outcome described is a low-entry cost (open) collaboration platform for sustainable integrated multimodal freight transport. The corresponding task aimed to create an open-source blueprint that shall enable any relevant organisation to build upon and to implement T&L design tools, collaborative logistics and new e-commerce models underpinned by data-driven supply chain insights.

More specifically, the EGTN Platform brings together data from heterogeneous sources in real time and in batch, which are then used in the predictive and prescriptive models which are part of the Decision Support System. On top of this, PI optimisations take place to develop an interconnected network and improve the efficient use of resources. The use of automated, smart contracts shared through the different Blockchain systems of the partners alleviates the problems related to interoperability and cross-organisational collaboration. Finally, critical data shall be presented to the end users through the dashboards developed in the frontend of the EGTN Platform. All these different components are brought together through the EGTN Platform and deliver an innovative solution that aims to achieve the overall goals of the PLANET project. It should be noted that the PLANET ambition is to interconnect infrastructure (TEN-T, rail-freight corridors) with geopolitical developments in an efficient manner, as well as to optimise the use of current and emerging transport modes and technological solutions, while ensuring the equitable inclusivity of all participants, increasing the prosperity of nations, preserving the environment and enhance citizens quality of life. The innovative architectural blueprint enables different sizes of T&L/PI communities to deploy cloud-based platforms and improve their efficiency through collaboration, openness and secure access to advanced services.

The final version of this deliverable shall include further additions to the Platform, such as new components that are in the implementation pipeline, data sets stemming from the Living Lab partners as well as public datasets that have not yet been integrated into the system. The integration of the new datasets in the platform will boost the EGTN platform’s potential by bringing more value to the developed analytics and blockchain services. Moreover, the final version will provide detailed information regarding system performance as well as any other learnings that the project partners will obtain in this project task in the meantime.

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