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

D1.2 Modelling & Simulation Capability

Document Summary Information

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1 According to PLANET's Quality Assurance Process

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
AI	Artificial Intelligence
API	Application Programming Interface
B2B	Business-to-Business
B2C	Business-to-Consumer
BPMN	Business Process Model and Notation
EGTN	EU-Global T&L Network
ETA	Estimated Time of Arrival
EU	European Union
GA	Grant Agreement
GDSN	Global Product Data Synchronization Network
GPC	Global Product Classification
GTIN	Global Trade Item Number
GSIN	Global Shipment Identification Number
IoT	Internet of Things
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LL	Living Lab
LMD	Last Mile Delivery
NSTR	Uniform Nomenclature of Goods for Transport Statistics
NUTS	Nomenclature of Territorial Units for Statistics
PI	Physical Internet
SKU	Stock Keeping Unit
SSCC	Serial Shipping Container Code
TENT-T	Trans-European Transport Network
UC	Use Case
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
WP	Work Package
WTMS	Wayside Train Monitoring Systems

1 Executive Summary

Objective of this document is to provide a detailed description of the available models for representing the freight transport processes in the intercontinental corridors examined in PLANET. It addresses the characteristics of those models along with their main functionalities, exploring complementarity and analyzing the data necessary to assess the use cases as realized in the project's living labs.

The report also covers the main models used to simulate and analyze transport operations on intercontinental corridors along with an overview of ten specific models developed by seven project partners.

The information requirements of all models have been thoroughly analyzed in order to achieve harmonization of the required data. Various categories of input data, parameters and results have been specified as they will be used across all models along with the main data sources needed to build the living lab models. The deliverable also addresses the initial description of the analysis requirements and the principal scenarios currently evaluated in the living labs.

Finally, this report specifies the first steps towards the integration of the various models enabling analysis at different levels (both micro and macro) considering interaction both as regards with input as well as output data level. Follow-up work (under T1.4) will define in further detail the integration of those models.

2 Introduction

This deliverable's goal is to detail currently available models for representing freight transport processes in the intercontinental corridors, addressing their key characteristics and functionalities, evaluating in parallel their overlap as well as their data needs as those are framed with the Living Labs' use cases.

This document has been prepared in collaboration with several project partners, following a multi-stage evolutionary process. As a first step, all available information on models from the different modelling partners has been compiled, including their descriptions of their main features. This was done in close cooperation with Living Labs users in order to identify the business requirements affecting those models. The available data were also analyzed in order to be able to carry out the simulation analyses.

In order to coordinate all available information from models, two modelling workshops were conducted. The first one focused on the evaluation of models to identify overlaps and synergies between them. Also, the input and output information of the different models was evaluated. Based on the results of the first workshop, two weeks later, another workshop was organized to complete the information from the first workshop and to evaluate the possible connection between micro and macro models. The development of these workshops and the subsequent discussions have been of great interest for the drafting of this document D1.2 and document D1.1 and subsequent documents such as D1.4.

2.1 Mapping PLANET Outputs

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

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

PLANET GA Component Title	PLANET GA Component Outline	Respective Document Chapter(s)	Justification
DELIVERABLE			
D1.2 Modelling & Simulation Capability	Simulation models extensions and **customisations requirements**, including potential **data sources** and **data harmonization processes** (Report) and **enriched simulation models** and framework for integrated simulation V1 M12. Final Version enhanced based on LL feedback M26.	Chapter 4 simulation models, Chapter 7 data harmonization.	The document contains the description of the simulation models and the main data sources used.

TASKS			
ST1.1.3 Customisation requirements of existing models:	This subtask will review the **existing models** of the project partners (e.g. Panteia's NEAC, ICONET's PI, etc.) and will perform a **gap analysis** with a view to fulfil the simulation scenarios needs. This subtask will define any necessary requirements to extend and customise the existing models in order to provide coverage to the project simulation tasks, i.e. physical flows (T1.2), and new technologies (T1.4).	Chapter 2,3,4,6	Chapter 2,3 concepts and description of the process followed. Chapter 4 Description of available simulation modelling and customizations. Chapter 6 Simulation model integration.
ST1.1.5 Data requirements and harmonisation process	This subtask will define key data requirements (e.g. configuration or parametrization data, entry data, etc.) for the defined simulation scenarios supported by the implemented enriched models. This task will propose a potential set of data sources and a harmonization process (data filtering, data fusion, etc.) to be performed as part of each of the two-project simulation task and the integrated simulation task.	Chapter 5,6,7	Chapter 5 Simulation requirements and scenarios. Chapter 6 Simulation model integration. Chapter 7 Data harmonization.

2.2 Deliverable Overview and Report Structure

In this section, a description of the Deliverable's Structure is provided, outlining the respective Chapters and their content.

Chapter 3 defines the terminology used and key concepts related to simulation models and tools.

Chapter 4 describes the current state of the available simulation models. It reviews the technology on which they are built and summarizes the main characteristics of each of them, as well as their objectives, inputs and outputs. In the case of service models, their objective functions, solution method and expected results are also described.

Chapter 5 describes the main requirements and details the scopes of each Living Labs. On one hand, the expected results of the application of technological solutions in logistics processes are mentioned and those technologies whose impact can be validated by the simulation models are proposed. On the other hand, for each Use Case, the current scenario (AS IS) and the desired scenario (TO BE) after applying the above mentioned are presented.

In **Chapter 6**, Description of interaction between different simulation models. Initial steps towards integrated Planet modeling capacity.

In **Chapter 7**, first, a potential data harmonization is proposed as an input to the simulation models. In particular, data related to demand, infrastructure or services are defined. Secondly, some of the outputs of the models are listed. Thirdly, the available data sources to be used for each of the living labs are described. At the end of the chapter, the main indicators are described in three categories: cost, operational and environmental.

Finally, in **Chapter 8**, the results of the deliverable and its contribution to the project objectives are summarized.

3 Key Concept Definitions

PLANET's key goal is to investigate the potential for cost savings along with reduction of the environmental impact if there is collaborative planning at a tactical and operational level between the different companies that distribute products along the intercontinental corridors, through frameworks such as Physical Internet.

In supply chain, decisions taken are classified as strategic, tactical, or operational:

- Strategic decisions are related to the company's strategy and are long term (usually 2-5 years) with involvement of the most partners in the supply chain.
- Tactical decisions are mid-term (a month to 1 year).
- Operational decisions are short term, which are related to the day-to-day activities.

Tactical and operational decisions are taken usually affecting an individual area of the supply chain (e.g., plant and warehouse) and deal with issues related with demand, procurement, production, warehousing and distribution.

Definition of the terminology about models and simulation tools.

PLANET's "modeling syntaxis" will help us decide how and in which deliverable project's modeling capacity will be presented:

A **MODEL** is a representation of the structure and operation of a system of interest. It is similar to, but simpler than, the system it represents, and its purpose is to enable the analyst to predict the effect of changes to the system. A model should be a close approximation to the real system and incorporate most of its key features while at the same time it should be simple enough to understand and experiment with it[2].

A **SIMULATION** is the operation of a model of an existing or proposed system to evaluate its performance under different configurations and over extended periods of real time. It is used before an existing system is altered or a new system is built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources, and to optimize system performance[2].

An **ALGORITHM** is a set of rules for solving a problem in a finite number of steps. In computing, an algorithm is an ordered set of instructions recursively applied to transform data input into processed data output[3].

The **MICRO LEVEL** models are data intensive, providing a fully disaggregated approach to the analysis of transportation networks and/or systems and are usually applied for the detailed analysis of limited segments of transportations systems, e.g., within limited geographic areas or for specific corridors.[4].

The **MACRO LEVEL** models are based on highly aggregated data and have been developed to support decision making for large transportation networks and/or systems. Despite not having the functionality to include the detailed aspects of transport, they are often the most appropriate choice in largescale

[2] Anu Maria. (1997). Introduction to modeling and simulation. In Proceedings of the 29th conference on Winter simulation (WSC '97). IEEE Computer Society, USA, 7–13.
[3] https://www.dictionary.com/browse/algorithm
[4] Barcelo, Jaume & García, David & Perarnau, J. (2005). Methodological notes on combining Macro, Meso and Micro models for transportation analysis

modeling because of the need of micro-level models for large amounts of processing power and input data in order to include all entities for studying large transport systems.[5]

The **MESO LEVEL** models fall between the aggregated and disaggregated approaches of macro and micro level models respectively. They require more data than macro models thus providing greater precision of results while can be applied to larger transportation networks and/or systems than micro level models[4].

[5] Johan Holmgren, Linda Ramstedt, Paul Davidsson, Henrik Edwards, Jan A. Persson, Combining Macro-level and Agent-based Modeling for Improved Freight Transport Analysis, Procedia Computer Science, Volume 32, 2014, Pages 380-387, ISSN 1877-0509

4 Description of available simulation modeling and customizations

This section covers the description of different models used for the analysis of the living lab scenarios. In the project's lifetime, various types of simulations and optimization models will be developed and further evolved. The characteristics of each of those models are described in detail in the following sections. At the of this Chapter a table summarizes all discussed models.

Each model is defined by its main features and functionalities. Each section also includes information of the necessary input data and the expected results along with potential customizations driven by the Living labs' specific requirements.

4.1 Physical Internet Network Simulator

The **Physical Internet Network Simulator** is a tool that helps companies to visualize how the movement of products over a PI network can be, including flows from other companies.

Table 2: Physical Internet Network Simulator

Model 1	Physical Internet Network Simulator (ITAINNOVA)
Objective	Evaluate the dynamics of services in PI networks: Comparison scenarios AS-IS (actual corridors behaviour), TO-BE (with PI, technology...) for a certain group of orders (containers) with different PI strategies.
Main Features	Dynamic simulation of PI effects in the PLANET corridors, Intermodal transport (ship, truck, train...) Cloud simulation model.
Input	• Network nodes (latitude, longitude) • Links (connection between nodes) • Transport (type, route, frequency) • Orders (group of containers moved)
Output	• Operational (Fill rate, delays, stockouts) • Economical (handling, transport) • Environmental (C02 emission)

This simulation model has been created based on multi-agent simulation technology. Agents can represent diverse things: vehicles, units of equipment, projects, products, people in distinct roles, etc. The agents are the main components of the simulation model. The agent is a component of the design of the model design that can have behaviour, memory (history), timing, contacts, etc. The agent internal state and behaviour of the agent can be implemented in several ways. The state of the agent can be represented by a series of variables, by the status of the state graph, etc. The behaviour can be, roughly speaking, passive (e.g., there are agents that only react to the arrival of messages), or active, when the agent´s internal dynamics (waiting times or system dynamics processes) causes it to act.

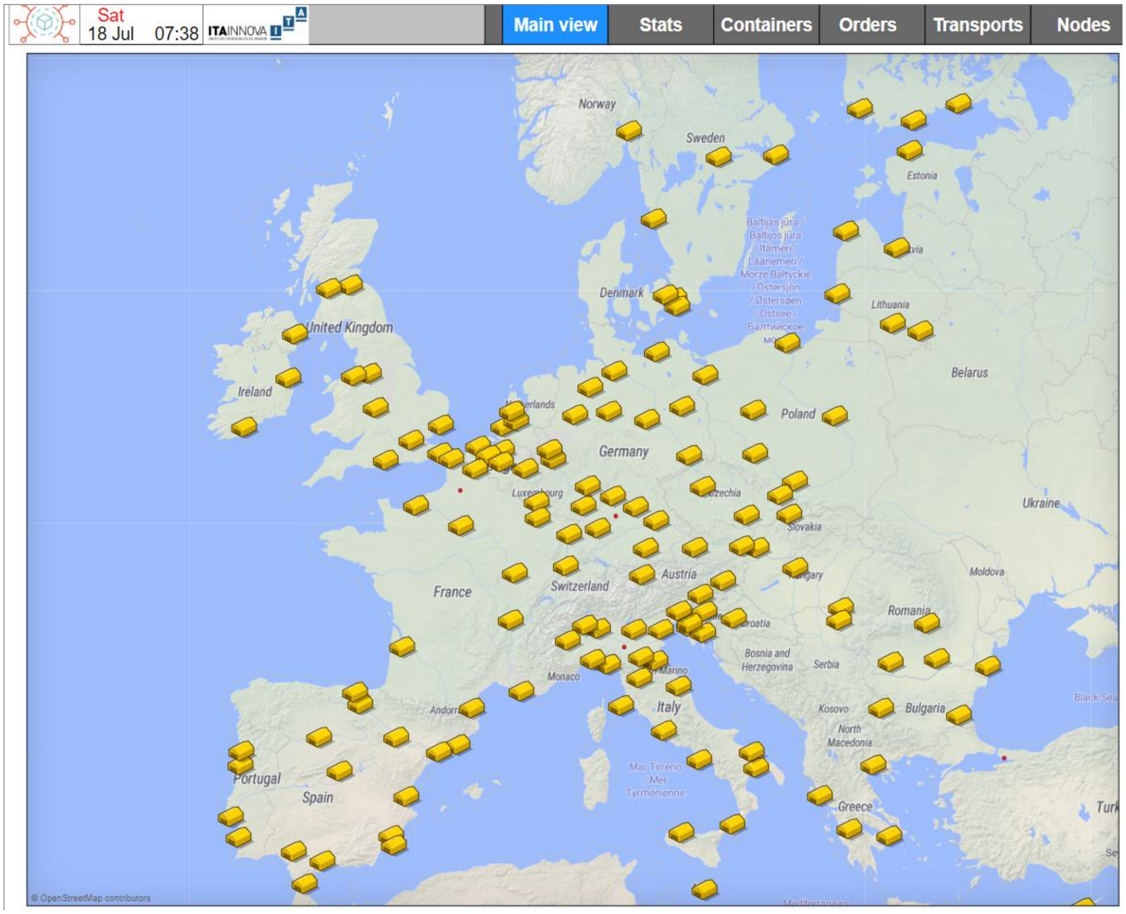

Figure 1: PI Network simulation overview

The basic elements of this model correspond to the fundamental elements of the physical internet: containers, orders, nodes, connections, and transports. In summary, the orders contain information about the origins and destinations of the containers that are moving through the network. They can contain additional information, such as ETA constraints. Each container has an origin node and a destination node. During the container's trip, at each node, decisions are made about the next leg of the network, selecting the best transport. The nodes are connected by links. The transports travel through the links.

The data needed to set up a simulation model are associated with the physical internet elements. For example, information on node position (location, capacity), transport (speed, type of transport, capacity), connections (road status, congestion level) and orders (origin, destination, number of containers, estimated ETA). The model is prepared to use data from local tables (excel type) or connect to services that offer this data via API. The scope of the model is limited, computation time can increase exponentially with model complexity (i.e. preferable use 100 nodes, not thousands). For living lab simulation model some scale hypotheses are needed. (i.e., test with the 10% of the network and extrapolate the results).

Model results: The simulation is a powerful tool to visualize how the movement of products over a PI network can be, including flows from other companies. The models are used to quantify the impact of the different services, economic (transport and handling costs), operational (reducing lead time) and environmental (CO_2 emissions) indicators have been obtained. Results obtained with data from the living lab companies.

Model customization:

In previous projects, such as ICONET, this model has been developed on land transport models (European corridors, urban eCommerce, and port terminal activities). This project includes specific intercontinental transport processes with a greater weight of maritime and rail transport. The present project has to also consider greater interaction with IoT, Blockchain and Artificial Intelligence technologies in the living labs' use cases.

4.2 NEAC freight model

Significant efforts have been made to model the inter-relationships between economic development, trade, and transport. Normally transport models focus upon analysing detailed patterns of road traffic flows within limited regional scope; and this may extend to national transport models or cross-border "corridor" models. However, the main differentiating features of NEAC are that it addresses:

- Multimodal transport
- Regional to European scale.

Table 3: NEAC freight model

Model 2	NEAC freight model (PANTEIA)
Objective	Analyse traffic flows from medium to long distances: Simulation of transport flows (current and future) on the European transport network
Main Features	European freight flow database and a multimodal transport model, combining inputs and experience from a long series of European transport studies. Classical European transport model with mode chain builder and highly versatile.
Input	• Origin & destination (nuts3) • Volume (tonnes or TEU), transport links • Transport costs
Output	• Network flows • Transport costs • Emissions

Therefore, it is a suitable system for analysing medium to long-distance traffic flows, for analysing macro-economic impacts, global trade patterns, and for measuring wider-scale impacts such as greenhouse gas emissions. The system covers all of Europe and neighbouring countries and provides the link between traffic and economic development across European regions. Applications typically focus upon forecasting, transport policy, transport infrastructure, port competition, containerisation, and environmental impacts of transport. The basic units within the system are NUTS3 regions, and a multimodal transport network. Goods are traded between regions depending on their socio-economic needs and routed from origin to destination via the transport network. The volumes being traded, and the route/mode choices used determine the system's cost, measured as user (internal) and non-user (external) cost. Through a combination of exogenous and endogenous effects, the system can be modelled over time to produce forecasts.

Levels of economic development are linked to their levels of trade, which is constrained by transport costs, which increase over longer distances, resulting in the familiar pattern in which shorter distance traffics tend to dominate. The major trade routes connect urban centres, but flows are dispersed across thousands of links. Such a polycentric/dispersed pattern makes it difficult to develop new markets for transport systems such as rail and inland shipping which rely on scale economies. The development of European multimodal corridors is a way to focus the major flows onto priority routes which can be adapted in an efficient way to provide multimodal capacity and impact-amelioration methods in order to minimise internal and external costs.

The complexity of the spatial patterns of traffic flows are illustrated below in Figure 2. NEAC uses the extended networks developed by the WORLDNET project connecting to neighbouring regions in the Middle East, North Africa and Central Asia. Ports have a special role within the system as the primary gateways for intercontinental traffic. Sea transport is included within the multimodal network structures in NEAC. Naturally, sea transport which offers high capacity and relatively low greenhouse gas emissions and low transport costs per tonne kilometre is a key element in NEAC. Port choice also has a major bearing upon inland patterns of goods distribution.

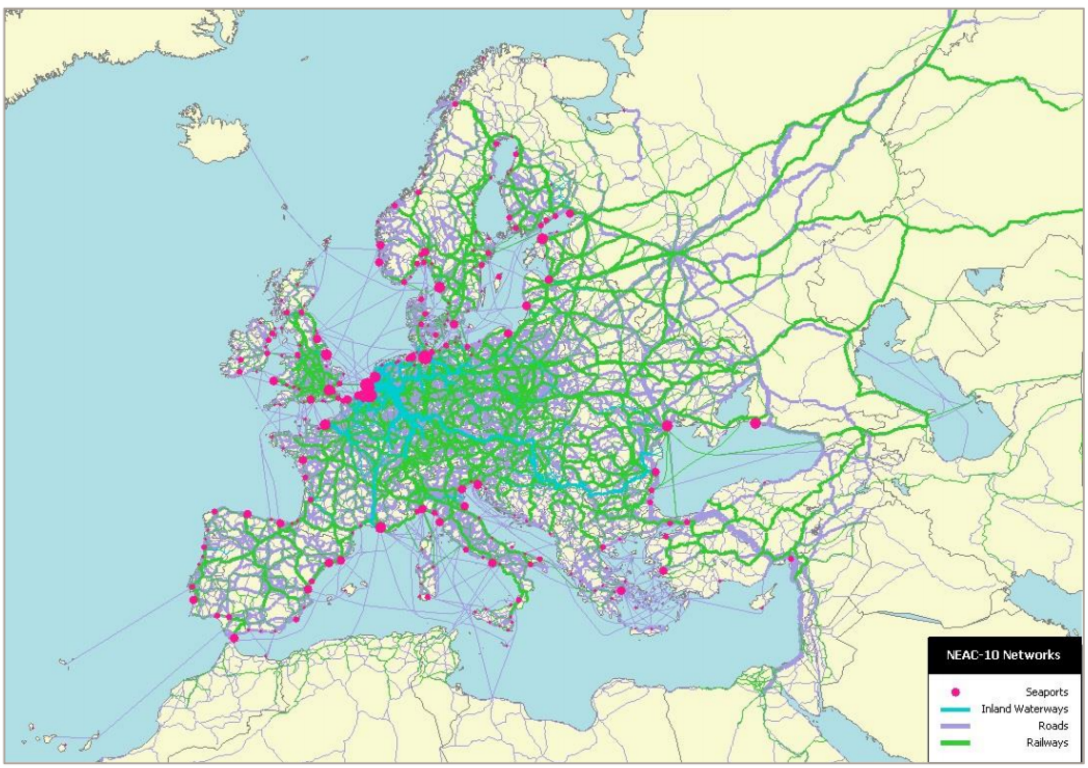

Figure 2: NEAC-10, Multi-layered European Transport Model

The NEAC model offers the following level of detail:

- The system applies a common regional structure (EZ2006-Level3), based on NUTS3, as developed for the ETISplus project Excluding the Russian Federation, there are 1585 regions defined in Europe. There are 2321 Level-3 regions worldwide.
- A core European area including all EU Member States, Norway, Switzerland, and neighboring countries including Serbia, Bosnia, Albania, Montenegro, North Macedonia, Moldova, Ukraine, Belarus and Turkey.
- Worldwide flows to and from the core European area detailed by 52 product types (NSTR 2 Digit).

- Cross-border and domestic flows within the European core area detailed by 52 product types (NSTR 2 Digit).
- Five transport modes for freight; road, rail, inland waterway, sea and others.
- 250 Seaports.
- 10,231 Railway links.
- 58,639 Road links.
- 2,005 Waterway links.

Within PLANET, the NEAC model shall be used for Task 1.2 to model transport flows on the European network.

4.3 Business Process Simulation

A business process is a set or sequences of linked tasks and activities that result in a specific goal or outcome. A business process simulation is a mechanism used to test and analyze both current business processes and those that have not yet been implemented.

Table 4: Business Process Simulation

Model 3	Business Process Simulation (L-ILIM)
Objective	Testing and analysing of business processes: Dynamic analysis (discrete event simulation) to foresee the results of changes (due to implementation GS1 standards, IoT, EPCIS and other solutions). Visualizing animation of simulation steps to identify bottlenecks and delays.
Main Features	Processes related to information exchange and transport (railway) of goods between China and Europe, with emphasis on the transport of e-commerce parcels and containerized cargo.
Input	• Process transaction generators • Resources executing the process • Duration of individual process activities • Work schedule
Output	• Process cycle time, Working time • Bottleneck's level, Average resources usage • Maximum process capacity

A simulation enables to test real-life situations and processes without implementing those situations and processes. Since they help to identify where improvements can be made before processes are put in place, working with simulations can save valuable time and resources. The following features are distinguished:

- improvement of work effectiveness through process standardization
- improvement of process quality
- reduction of process execution time
- identification of errors and bottlenecks in processes

- estimation capabilities of costs of business processes
- estimation of the decreasing costs of reporting actions
- estimation of the decreasing costs of documentation distribution

In the PLANET project the process analysis will be conducted using a standardized methodology based on the following steps:

Stage I: Study of the current processes (AS IS analysis):

1. Conducting a local vision in a selected company to obtain comprehensive data that are necessary for analysing the designated processes.
2. Analysis of the current situation of the processes that are going to be identified and verified during the local vision, including the following elements:
    - assigning business roles to individual participants of the processes covered by the analysis,
    - mapping processes using activities and events as well as decision points using an innovative methodology compliant with the BPMN 2.0 standard, regulated by ISO / IEC / 19510: 2013 Information technology - Object Management Group Business Process Model and Notation,
    - agreeing on the management and operational level maps of currently functioning processes, compliant with the BPMN 2.0 standard,
3. Construction of AS IS simulation models, their parameterization and calibration towards the relevant KPIs (Key Performance Indicators), with particular emphasis on the service time of logistic processes held within the New Silk Road and the percentage utilization of personnel resources. As a result, AS IS simulation models will be presented, that will become a reference for the target processes.
4. Simulation of the models created in step 3 and then, based on the results, identification of process areas representing potential for further optimization, including:
    - processes bottlenecks,
    - activities that do not bring added value, but increase the probability of occurrences of errors and mistakes,
    - gaps in the information flow,
    - manual work that can be replaced or reduced by applying innovative solutions.

Stage II. Development of target logistics process models (TO BE analysis):

1. Construction and simulation of target models for the functioning of processes, taking into account the recommendations developed during the implementation of the first stage and assuming the use of the proposed technological solutions - modeling of TO BE processes (in accordance with the BPMN 2.0 standard).
2. Conducting of simulations of the developed process models, enabling to forecast the level of reduction of task execution time resulting from the implementation of new solutions (in our case new identification solutions enabled by GS1 standards and IoT), compared to the initial values.
3. Determining the values of the Key Performance Indicators (KPI) agreed with the company for the current and target status, which will allow for a parameterized assessment of the effectiveness of the target concept.
4. Agreeing with the company on the targets, at the managerial and operational level.
5. Visualization and comparison of the base and target concept.
6. Collection of the process maps and models in the AS IS and TO BE versions, reports on process simulations as well as comments collected during the study in the process repository.
7. Preparation of a proposal of the scope of information relevant for the dashboards, based on the identified needs for information.

8. Preparation of a report summarizing the results and conclusions resulting from the project implementation.

Expected results:

- process maps, compliant with the BPMN 2.0 standard. described in ISO / IEC 19510: 2013, showing the functioning of the base processes (currently functioning in the supply chain - AS IS) and target processes after the implementation of the concept developed as part of the service (TO BE),
- simulation models of the processes covered by the analysis (AS IS and TO BE),
- final report providing recommendations and results of a comparative KPI analysis before and after the potential implementation of the recommended changes.

Within PLANET, the Business Process Simulation model will be used in the execution of Living Lab 3 to analyze transport and logistics processes along the Silk Road Route.

Each process is a sequence of sequentially connected activities which transform input elements into other output elements. A prerequisite for good process management is appropriate diagnosis of the initial situation and its description (AS IS) by means of graphic representation of the process course. The maps for all processes that are part of Living Lab 3 (transport order from China to Poland), including possible scenarios of its course will be created. For the description of the processes also other documents will be considered: Schedule Order, Wagon Order , Railroad waybill, International waybill SMGS, International waybill CIM and etc. Next, the graphic representation of the process will be presented using a methodology compliant with the BPMN 2.0 standard, regulated by ISO / IEC / 19510: 2013 Information technology - Object Management Group Business Process Model and Notation. The next step will be the analysis of the existing situation, which has been described, including the determination of the time structure of activities, bottlenecks and critical points connected with the process. As a result of such analysis it will be possible to plan an improved course of the process (TO BE) transforming process maps into models - collecting parameters (duration, resource commitment, work schedules, number of transports/parcels, etc.); designing new processes (with other LL members) which will include GS1 standards, IoT, EPCIS, and other solutions. It will result in defining the metrics by which the improved process will be monitored when it enters the operational phase. Simulation of the models created based on the results and identification of process areas representing optimization potential will include:

- processes bottlenecks,
- activities that do not bring added value, but increase the probability of occurrences of errors and mistakes,
- gaps in the information flow,
- manual work that can be replaced or reduced by applying innovative solutions.
- preparation of a proposal of the scope of information relevant for the dashboards, based on the identified needs for information.

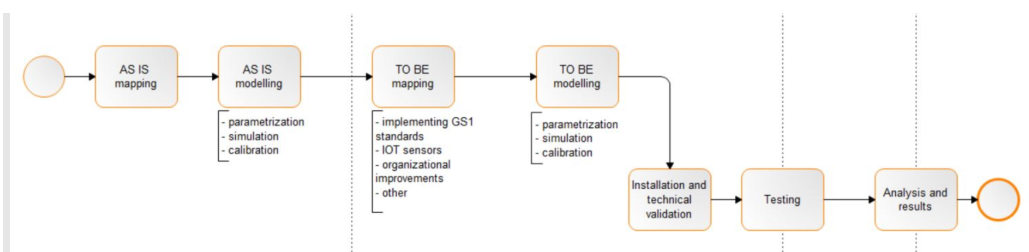

Figure 3: Business Process Simulation

Regarding model customization, the same methodology of process analysis is used in common consulting projects, differentiating scope of analyzed processes and the innovation of simulated solutions in terms of TO-BE analysis.

4.4 Terminal model

The Terminal Model is a flexible transport model offering extensive policy and scenario evaluation options. In its core, the terminal model calculates transport costs and time between regions for various modes of transport and different commodities. It uses a complex network (road and intermodal, including transhipment points) including associated transport cost to establish transport costs from a particular location within the study area (municipality level) to any other area within Europe (NUTS-3 level) or outside Europe.

Table 5: Terminal model

Model 4	Terminal model (PANTEIA)
Objective	Calculate transport costs and time between regions for various modes of transport and different commodities.
Main Features	Simulation of transport flows (current and future) between Asia and Europe. It uses a complex network (road and intermodal, including transhipment points).
Input	• Origin & destination volume (tonnes or TEU) • Transport links • Transport costs • Transport mode
Output	• Network flows • Transport costs • Emissions

The terminal model requires the following inputs:

- Detailed regional structure based on NUTS2006, including the neighboring countries Norway, Switzerland, Serbia, Bosnia, Albania, Montenegro, and North Macedonia. All other countries are included on the country level. For PLANET, China has been included on the province level.
- Trade data from various sources depending on the application of the model, including Statistics Netherlands for trade related to the Netherlands; ETISplus for inter-EU trade; Eurostat COMEXT for EU-extra EU trade and UNCTAD for extra-EU – extra EU trade (non-EU trade).
- Rail network & internal and external transport costs.
- Road network & internal and external transport costs.
- Sea network & internal and external transport costs.

The terminal model follows a classical macro modelling approach. Using generalized transport costs and random utility theory, transport flows are modeled across the network. Transport is modelled as multimodal chains describing the transport of a commodity from its region of production, via transshipment locations to the region of consumption.

4.5 EU Flow model

This is a multi-modal multi-commodity flow model, which is based on a PI enabled TEN-T network. The model considers links connecting European cities for road, rail, sea and river modes.

Table 6: EU Flow model

Model 5	EU Flow model (VTLN)
Objective	Simulation of impacts of infrastructure's changes in the operation and serviceability of the network. Calculates the optimal routes based on distance, travel time, etc.
Main Features	Multi-modal and multi-commodity flow model, that is based on a PI enabled TEN-T network (terminals and **links**). Standard capacitated flow model.
Input	• One or multiple origins and destination volumes of a commodity
Output	• Links and nodes utilised for optimally connecting sources and sinks

The PI enabled nodes are represented as transshipment locations where multimodal terminals are available. To run, the model requires the export and import flows for single or multiple commodities between at least two network nodes. It then calculates the optimal routes based on distance, travel time, or other parameters, while considering the throughput capacity for each node and link. It allows for the representation of the PI Hubs at a different aggregation level that accounts for terminals and other PI Hub functionalities. Network data can be amended to investigate the impact of new network components, infrastructure and services in the operation and service ability of the network.

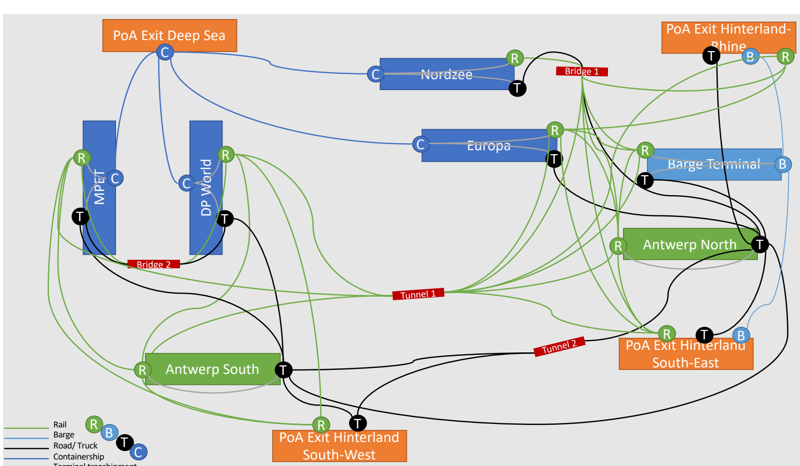

Figure 4: Example of flow diagram

The figures below capture the high aggregation representation of the TEN-T network (up) for multi-modal and multiple OD pair flows. Below, the low aggregation of PI Hubs is illustrated, that enables the accurate appreciation of within the port operations and costs, that have a significant impact on transshipment potential.

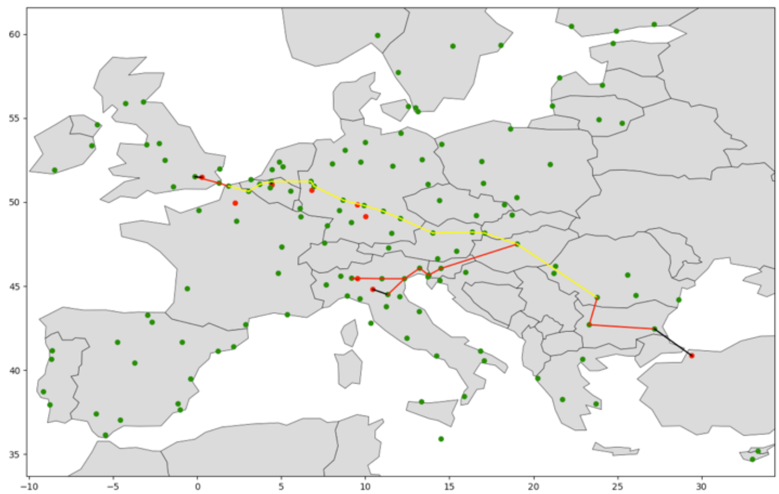

Figure 5: TEN-T Network representation

4.6 Simulation Team

Regional transport patterns are the result of microscopic interactions and daily operational decision making. While the effect policies and infrastructure have on transport planning has already been studied, we focus on the moderating effect technology has on high-level aggregated transport performance measures. Furthermore, this model studies the effect alternative geo-political settings have on the technology-driven effect. This leads to the development of a range of scenarios to test the model.

Table 7: Simulation Team

Model 6	Simulation Team (EUR)
Objective	Testing impact of new technologies on trade-routes. Modelling of the operational impact of new technologies.
Main Features	Data-driven as well as theory-driven modelling of logistic operations. Combinatorial optimization. Machine learning. Prescriptive analytics. Adaptive planning modelling.
Input	• Transport times • Nodes • Routes
Output	• Transport Cost

	• Compliance with capacity and reliability constraints

This model is personalized per each project. The model will be enhanced as part of Task 1.4 where the micro-to-macroscopic interface will be addressed.

4.7 Services and other models

This chapter includes the description of models related to optimization issues in different areas related to freight transport in the corridors.

4.7.1 e-Commerce flexible order preparation

To incorporate urban eCommerce delivery into the concept of the Physical Internet it is required to associate each shopping list type order with an optimal fulfilment store or warehouse. This is because nearest stores and warehouses often cannot fulfil an entire order due to the lack of sufficient stock, causing stock-outs and poor customer satisfaction. In a PI context this challenge can be overcome, by incorporating a fulfilment store identification tool. The tool addresses the stockout challenge, by adopting a more dynamic process for identifying which store should fulfil each order.

Table 8: e-Commerce flexible order preparation

Model 7.1	e-Commerce flexible order preparation (VTLN)
Expected results	Identifies the optimal store to prepare each order to minimise stockouts and transport cost.
Objective Function	Transport cost minimisation, sales profit maximisation.
Input	• locations and the stock level for products at the stores • locations and the products requested by customers
Output	• Pairing of orders to preparation stores
Solution method	A binary linear optimization algorithm that identifies the optimal store for fulfilling each order with respect to the stock level available at each store/ warehouse.

This process builds on the stock information available that are maintained in the Network Layer for each store/ warehouse at the time an order is placed. Then an optimization algorithm is deployed that identifies the optimal store for fulfilling each order with respect to the stock level available at each store/ warehouse.

The aim of the tool is to optimally associate orders with a preparation store. This is handled through a binary linear optimization model that seeks to minimize the total distance for satisfying all orders. Assuming that the distance d_{ij} between every customer location j and every fulfilment store i is known, and that an additional integer variable s_{ik} captures the stock of products available at each fulfillment store i per product k. And an additional integer variable o_{jk} captures the number of products k ordered in order j. A binary decision variable x_{ij} is equal to 1 if fulfillment store i is chosen to satisfy customer order j, and is 0 otherwise. Then, a cost minimization problem can be formulated as follows:

Objective function:

$$\min_{x_{ij}} \sum x_{ij} d_{ij}$$

Subject to constraints:

$$\sum_i x_{ij} \geq 1 \quad \forall j, k$$

$$\sum_j x_{ij} * o_{jk} \leq s_{ik} \quad \forall i, k$$

$$x_{ij} \in \{0,1\}$$

The first constraint ensures that all orders are satisfied. The second constraint ensures that the store capacity for each SKU is not exceeded, while the last constraint defines the binary decision variables.

A case study undertaken for SONAE supermarkets in Portugal as part of ICONET project, illustrated that a dynamic distribution approach overperforms the nearest store/ warehouse fulfillment approach. In the dynamic fulfilment approach, stores are assigned both based on whether they have sufficient stock to prepare an order and how far this order is.

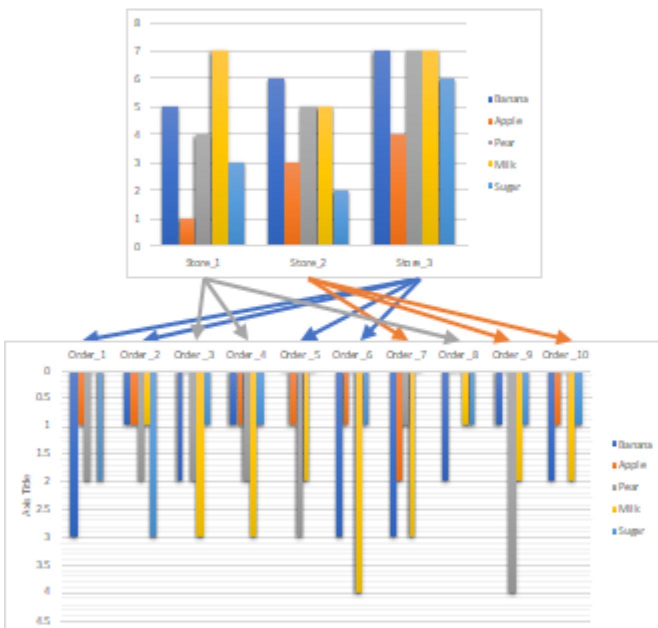

Figure 6: Representation of solution strategies

A case study undertaken for SONAE supermarkets in Portugal as part of ICONET project, illustrated that a dynamic distribution approach considerably overperforms the nearest store/ warehouse fulfillment approach. In the dynamic fulfilment approach, stores are assigned both based on whether they have sufficient stock to prepare an order and how far this order is as illustrated by the links in image (Figure 6). The Figure capture the solution for a simplified network of ten orders and inventory of five SKUs. In the simplified network, the nearest store to all orders is store 3, the second nearest is store 2 and the third store 1. The formulation considers a cost proportional to the distance between every order and every store. Therefore, it chooses the nearest store as long as there is sufficient capacity available.

The objective function and constraints of this model will be adapted to the operational needs of Planet Living Labs.

4.7.2 Loading Optimisation Model

The 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.

Table 9: Loading Optimisation Model

Model 7.2	Loading Optimisation Model (IBM)
Expected results	Optimise the loading of PI containers to Train Wagons in both 2-Dimensional and 3-Dimensional space
Objective Function	Minimize occupied cargo space

Input	• JSON definitions for Wagons and PI Containers.
	  ○ Wagons have dimensions (2D, 3D) and maximum weight capacity.
	  ○ PI containers have dimensions (2D, 3D) and weight.

Output	• Transport Capacity Efficiency • Transport Costs • CO2 Emissions
Solution method	Real-time Optimisation. Easily adapted to Optimising any 2D/3D space

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 7 shows an example of the stackable PI Container concept[i].

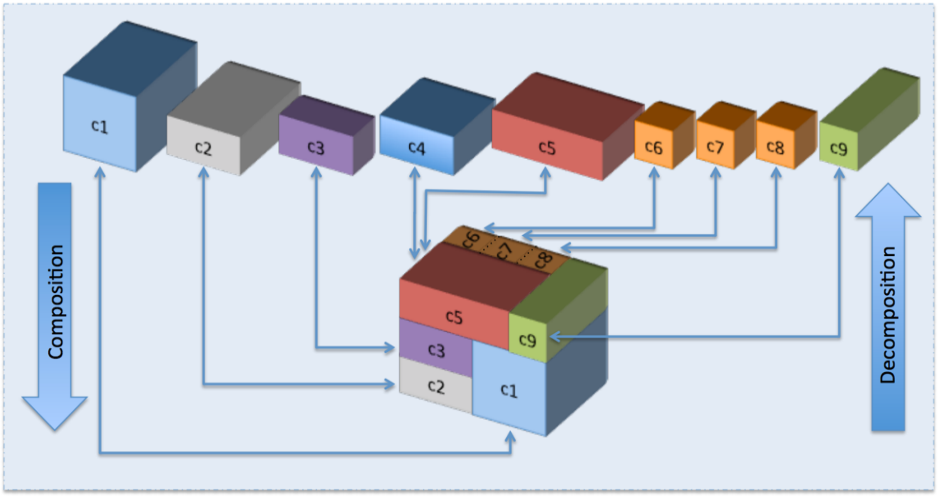

Figure 7: Illustration of PI Container composition concept

The ICONET Train Loading Optimisation service 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 in rail 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. This service could be modified in PLANET to devise a loading plan for trucks.

4.7.3 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.

Table 10: PI Route Optimization Model

Model 7.3	PI Route Optimization Model
Expected results	Optimise the route taken by a PI Means within a PI Network
Objective Function	Minimize PI Mean cost, carbon footprint, delivery time and delivery distance
Input	• PI Network definition • Start PI Node and Destination PI Node • Departure schedule
Output	• Routing Efficiency • Cost • CO_2 Emissions • Time Efficiency
Solution method	Routes through the PI Network from the source to the destination are analysed using a deep learning model and the optimal route is selected automatically.

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. This service could be further built up on in PLANET to take into account along with required input some external factors such as weather and traffic congestion to calculate the optimal routes.

4.7.4 Enhanced synchromodality model

The goal of the enhanced synchromodality model is to capture dynamic routing and committed capacity booking to evaluate the benefits of synchromodality in trade flows. While synchromodality was developed in the context of hinterland transport, trade-lanes are characterized by long-duration transits with little flexibility. As such, dynamic mode or route changes are not possible during the long-haul and might hinder the benefit of adaptive routing. This, challenges the predominant approach of synchromodal planning and requires revisiting and improving current ideas.

Table 11: Enhanced synchromodality model

Model 7.4	Enhanced synchromodality model (EUR)
Expected results	Adaptive routing of cargo flow with a-priori booking of transport capacity.
Objective Function	Minimize total capacity booking costs while guaranteeing an expected amount of flow is delivered before deadline
Input	• Capacited freight network with departure times and arrival times distributions for each arc. • Origin and destinations of cargo. • Target reliability level for the overall shipment.
Output	• Capacity booking and adaptive routing strategy for the cargo. • An adaptive strategy prescribes which routes to take depending on the arrival time and the status of the whole network as well as the overall cargo position in the network itself.
Solution method	Synchromodal planning model exploring the trade-off between adaptive cargo routing and capacity booking

In spite of the different operational context, freight forwarders' transport demand is elastic to reliability and costs as in the case of hinterland transport operators. Indeed, shippers make transport purchase choices based on their perception of transport reliability: how often communicated transport lead time are met affects their supply chain operations and, thus, increases their costs.

Moreover, various technologies as blockchain aim at simplifying international trade and speed-up several administrative procedures while improving visibility. This creates new opportunities that will be evaluated with this model and will be represented by different operational regimes (parameter settings).

The following figure shows that a higher reliability target implies larger amount of booked capacity. This is the main trade-off that will be investigated in the setting of trade-lane transport.

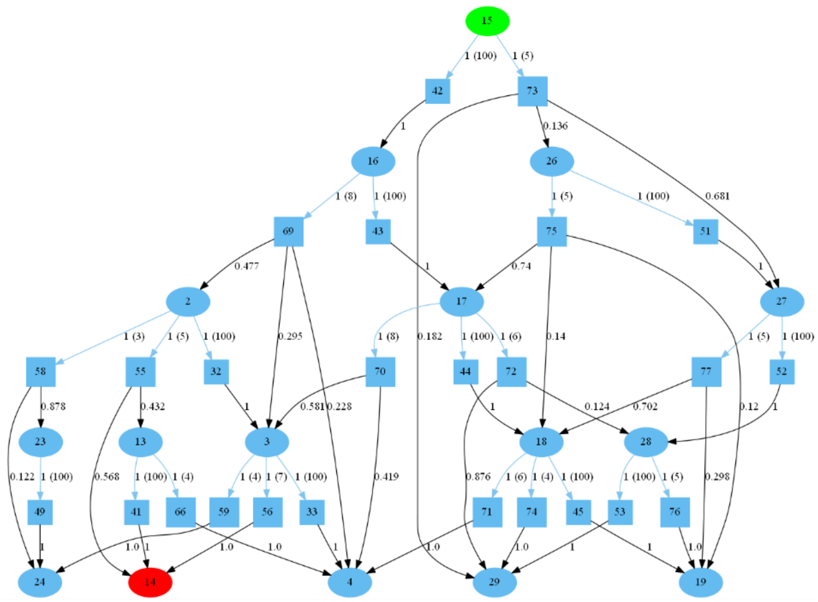

Figure 8 Time-expanded network representation for a simple network.

Flow has to be shipped from node 15 (green) to node 14 (red) using diverse services represented by square nodes. Each service has multiple outgoing arcs representing stochastic transit. A detailed explanation is provided in the text.

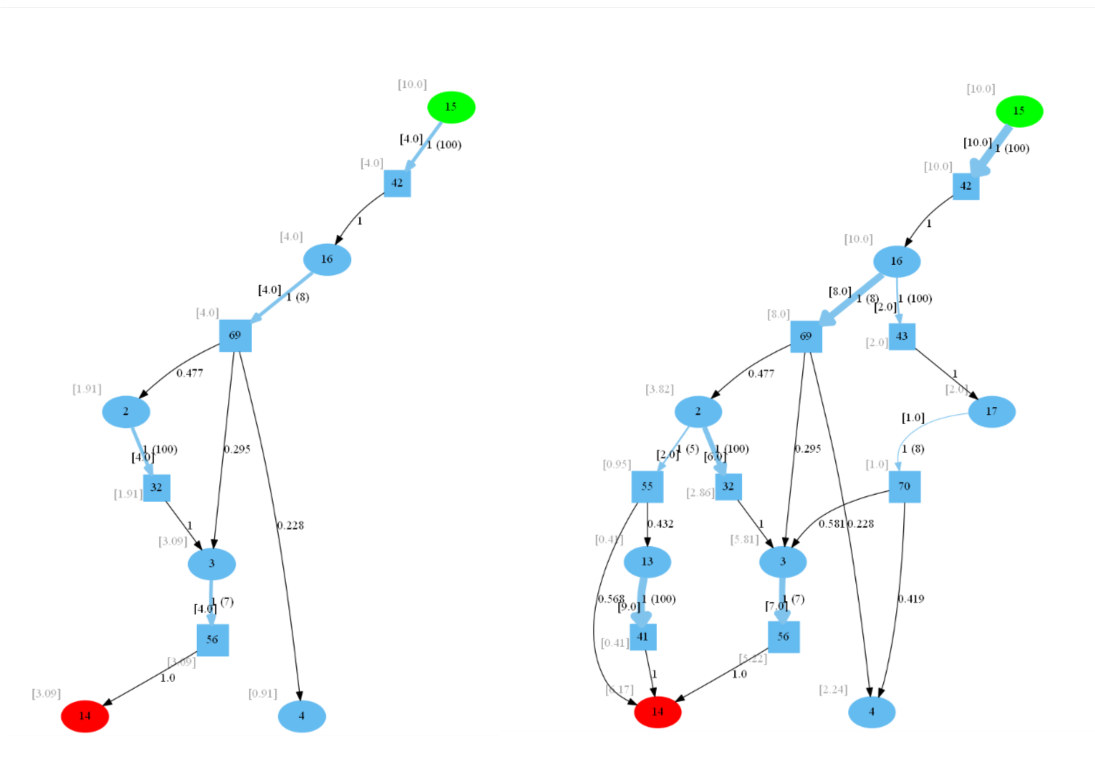

Figure 9: Representation of solution strategies

In this context, our model studies the reliability-costs trade-off on a capacitated network featuring stochastic transit times and typical trade-lane hindrances (e.g., cross-border and customs delays, restricted flexibility, and visibility, etc.) with the moderating presence of different technologies. The central question addressed by our model is therefore:

1. Can synchromodality benefit trade-lane transport? Theoretically, synchromodal planning should improve current planning but limited alternatives might reduce the benefit.
2. What is the effect of novel technologies on synchromodal planning in the context of trade-lane transport? It is assumed such technologies will simplify cross-border activities, but it is not understood to what extent this will benefit current planning.

In what follows, we highlight the major features of the basic model.

Table 12: Basic synchromodality model

Input	Data representation [preliminary]
Directed graph	Adjacency matrix
For each arc: • Departure times • Transit time distribution • Transport capacity • Unit transport cost	Csv
Time horizon length	Integer
Transport demand • OD pair • Number of containers	Nodes in graph; integer number
Target reliability level $\boldsymbol{\beta}$	Real number in [0,1]

Model objective: minimization of total booking costs for a feasible adaptive strategy of reliability at least β.

Model output: capacity booking for all arcs [vector], adaptive routing strategy [policy – represented as a multidimensional matrix (state x action) space].

Solution method: MIP model solved either with heuristics or general-purpose MIP solvers.

Expected result: for each network configuration, we expect to study the pareto-frontier of the reliability-cost trade-off for different network configurations. Different scenarios will allow to evaluate the impact of different technologies on the same trade-off.

Model customization:

Starting from LL requirements, the following customizations for the enhanced Synchromodality Model can be implemented.

1. Multi-source and multi-destination flow. As a transport operator executes transport from multiple sources to multiple destinations, it is required to capture multiplicity of Origin/Destination-pairs in the model as well.
2. Economies of scale in transport costs. Unit transport costs might decrease as more capacity is booked. When booking transport capacity on large transport means such as trains or sea-going

vessels, economies of scale can be achieved by consolidating freight on the same transport mean.

3. Uncertain transport demand availability. Often, it is uncertain when transport demand will become available for transport. For instance, containers from China to Europe might be announced well ahead of their actual delivery at a 3PL provider.

4.8 Models Summary

The table below provides an overview of all available project models, their main features and objective.

Table 13: Summary table of models

Models	Type	Level	Technology	Objective
MOD 1 **Physical Internet Network Simulator – (ITAINNOVA)**	Simulation	Micro	Multi agent simulation. Cloud simulation Java	Evaluate the dynamics of services and movement of products in PI networks.
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 optimization and identification of bottlenecks.
MOD 4 **Terminal model (PANTEIA)**	Simulation	Macro	Python	Transport calculation: cost time, emissions.
MOD 5 **EU Flow model (VTLN)**	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 (VTLN)**	Optimization	e-Commerce orders	Python	Pairing of orders to preparation stores, to minimize stockouts and transport cost.

MOD 7.2 **Loading Optimisation Model (IBM)**	Optimization	Micro (hourly, daily evolution)	Python	Optimise the loading of PI containers to Train Wagons
MOD 7.3 **PI Route Optimization Model (IBM)**	Optimization	Micro (hourly, daily evolution)	Python	Optimise the route taken by a PI Means within a PI Network
MOD 7.4 **Enhanced synchromodality model (EUR)**	Optimization	Operational level. Micro level for time dimension	Python	Capture dynamic routing and committed capacity booking to evaluate the benefits of synchromodality in trade flows

5 Simulation Requirements as per Living Labs' Use Cases

This chapter describes the main requirements, from a simulation and modelling point of view, that are necessary to assess the impact of the application of proposed technological alternatives in the various Living Lab Use Cases. The following sections outline those use cases, their main requirements, and the prospect scenarios to be considered and evaluated in each case.

5.1 LL1: PI and Blockchain for optimised door-to-door Asia-EU corridors

LL1 aims at testing new solutions (IoT, AI, Blockchain) and concepts (PI) to improve process, operations, and efficiency along D2D transport chains linking China with Spain.

Two use cases will be developed:

1. Use case 1 on improving container cargo operations between China and Spanish hinterland.
2. Use case 2 on optimizing warehouse operations and automation and last mile deliver efficiency and sustainability.

5.1.1 Simulation requirements LL1

This use case examines the operations from China ports to Madrid, involving two maritime routes from China to Valencia served by COSCO's oceanic service lines, and then pre-defined inland movements to Madrid's dry port by rail and finally to customer destination by truck. Additional route from China ports to Spain, involving maritime routes from Chinese ports to Valencia port served by COSCO's service line with final delivery to end customer destination by truck. The following image (Figure 10) shows a representation of the main processes in this route. The image shows the main transport processes and the decisions that can be made at different points in the process, such as the choice of destination port in case of congestion, the selection of the best means of land transport (truck or train) or even the best delivery strategy for urban goods.

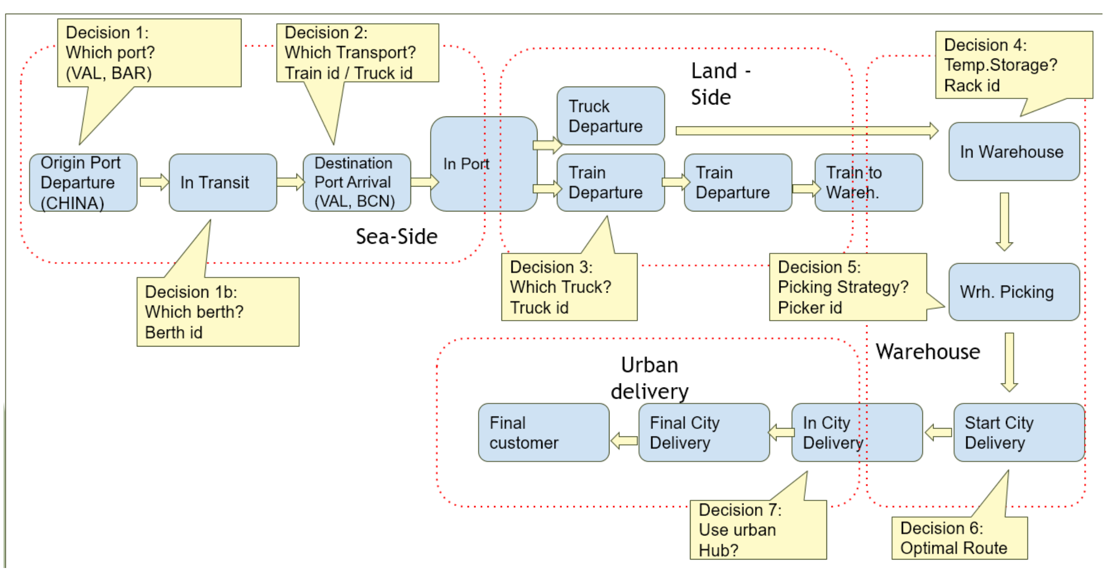

Figure 10: Diagram LL1 process description

The first use case of this living lab is about modelling the impact that different EGTN technologies can have on a complete corridor, from maritime section, port handling, transport to hinterland node and final urban distribution.

The following table shows the results expected from the application of different technologies in the transport process. The impact of these technologies will have to be assessed by modelling to validate and characterize the impact of the application of EGTN in the corridor.

Table 14: Use Case 1 in LL1

TECHNOLOGY	LL1. UC1. IMPACT
Blockchain	• Time reduction in administrative processes • Secure business-to-business data exchange
IoT	• Control of the location of the cargo • Reduction of waiting times in the loading/unloading process (lorry, ship, train). Improved synchronization of processes.
AI	• Selection of the best means of transport according to timetable, capacity... • Vessel planer decision. If there is congestion in a port (wait to port clear) or go to other port.
Physical Internet	• Autonomous decision per container at each node. • Open logistics environment to share capacity data to improve the use of assets.

The second use case of LL1 refers to the last leg of the transport, from the last distribution warehouse to the final customer. In this last stage, different EGTN technologies could help to improve the efficiency of the operations and the environmental impact of the processes.

Table 15: Use Case 2 in LL1

TECHNOLOGY	LL1. UC2 IMPACT
Blockchain	• Facilitate collaboration with other companies. • Greater use of green vehicles • Help with conflict resolution.
IoT	• Anticipated arrival of container at short range • Location of a package during delivery
AI	• Cargo demand forecast • Route optimization • Standardization of information (addresses, opening hours...)
Physical Internet	• Collaboration with other companies • Standardization of containers for last-mile delivery.

5.1.2 Simulation Scenarios LL1

The simulation in this Living Lab is based on the comparison of scenarios, using the “what if” technique, to assess the impact that different EGTN technologies may have on the performance of the transport processes. The actual current transport process is considered as the baseline (AS-IS) scenario. The scenarios enhanced by PLANET EGTN solutions are considered the future (TO-BE) scenarios, integrating a selection of technological alternatives. A summary of the scenarios compiled for this living lab is shown in the table below.

Table 16: Simulation scenarios LL1

Simulation	Scenarios	Description
UC 1: **PI Maritime Network Asia (China) – Europe (Valencia, Madrid)**	AS IS (current)	COSCO’s Oceanic routes from China to Spain. Pre-defined container movements by truck & rail to customer warehouses.
	TO BE (PI network)	Containers arrive at VLC port, intelligent real-time decision for movements to warehouse (DHL). Terminals provide optimized dynamic routing of containers through the network (Intelligent algorithms based on AI).
UC 2a: **PI Urban Network in Spain**	AS IS (current)	Container from Valencia Port arrives at Warehouse (DHL), container is unloaded, and then deliver pallet/parcels to destination with standard truck/van.
	TO BE (PI network)	Containers arrives at DHL automated warehouse, where pallet units are defined. Modelling the warehouse human resources, based on inflow/ outflow predictions. Pallets are then sent to CityLogin hubs where parcels are created for final customers in MAD city. Track & trace delivery using CityLogin APP/Sustainable vehicles.
UC 2b: **PI Node (Distribution warehouse**	AS-IS (current)	Manual operation in warehouse with fixed rules (ie. static allocation of products to zones in the warehouse).
	TO-BE (PI Node)	Automated operations in the warehouse (AGVs...). Smart Decision Making: Adapting the flows of goods to the situation in the warehouse (digital clones).

5.2 LL2: China–Rotterdam/USA focusing on rail transport

Within the PLANET project, Living Lab 2 specifically addresses improvements in the handling of rail freight between China-USA with the port of Rotterdam as transshipment and modality shift point. This living lab has two use cases.

- Use case 1 focuses on Synchromodality in a Blockchain-enabled Platform involving the PoR community and customers. In this use case, Blocklab will develop a blockchain demonstrator to deal with post-Brexit customs processes between the Netherlands (PoR) and the UK.
- Use Case 2 of LL2 will focus on investigating the potential of a Eurasian rail freight expansion. Depending on the identified key requirements of the relevant stakeholders and on the growth hurdles, the most appropriate organizational measures and (IT-) technologies will be identified and selected.

5.2.1 Simulation requirements LL2

The following tables show a summary of the main requirements of the use cases raised in this Living Lab.

Table 17: Use Case 1 in LL2

LL2 Use Case 1:	**Synchromodality in a Blockchain-enabled Platform**
Objective:	Within use case 1, Blocklab will develop a blockchain demonstrator to deal with post-Brexit customs processes between the Netherlands (PoR) and the UK. The functional specifications of this demonstrator will also be used as an initial step for use case 2. With the information gathering of functional requirements now on the way, use case 2 stakeholders, including HUPAC and VTG are now able to reflect on initial requirements.
Critical points:	Implementation will be carried out through a phased approach, ending with a demonstrator of the solution. In phase 1 we will work with anonymized but realistic shipping data from previous pilots within the fresh produce supply chain. The deliverable of phase 1 will be used for demo purposes, to gather further user input and as a starting point for real-life pilots. In phase 2 the vital customs certificates will be directly made available from origin (the Dutch Chambers of Commerce and the Dutch Food and Consumer Goods Authority (NVWA)), instead of obtaining those indirectly from the shipper. Furthermore, return flow from the UK to the Netherlands will be captured. We will also start a pilot with actual customers and real live data. The scope of phase 3 will take into consideration that the overall aim of the LL is to improve rail freight between China-USA with the port of Rotterdam as transhipment and modality shift point, there's considerable potential to further built on the lessons learned and the digital infrastructure created in phases 1 and 2 for them to be relevant for the LL. Final implementation of the demonstrator will be carried out.

Possible Technology Solutions:	Blockchain enabled platform.

Table 18: Use Case 2 in LL2

LL2 Use Case 2:	**Investigating the potential of Eurasian rail freight expansion**
Objective:	The Use Case 2 of LL2 will focus on investigating the potential of an Eurasian rail freight expansion. Depending on the identified key requirements of the relevant stakeholders and on the growth hurdles, the most appropriate organizational measures and (IT-) technologies will be identified and selected. The insights, experiences and early demonstrators of innovative solutions such as blockchain will be given sound analysis if a use for rail freight transport between China and Europe (on TEN-corridors) is likely to be successful.
Critical points:	LL2 use case 2 members are focusing on a strategy to identify a combination of underdeveloped areas and innovative services to achieve the highest possible leverage of the demonstrator(s) of the LL2. The ultimate proof of the LL2 use case next to its future economic viability is its utilization and adoption rate. Early measures on stakeholder involvement and participation need to be devised and implemented to achieve stakeholder buy-in and adoption. The implementation, adoption assistance and sign-off of the demonstrator by the project partner and potentially additional stakeholders are the key result. Possible demonstrator scenarios are facilitated customs processes, harmonized wagon types, infrastructures or common booking processes or digitalized documents and processes.
Possible Technology Solutions:	The implementation will include the solution design, testing and adoption management. Specific plans will be developed once the chosen measures and scoping are finalized. The impact is assessed based on the results of the demonstrator, its wider adoption strategy, and transferability to other routes. The degree of digital transformation achievable and the capability improvement towards synchromodality will be addressed based on the findings of the demonstrator. This will be the basis for a fact-grounded proposal of future measures.

5.2.2 Simulation scenarios LL2

The following table shows the possible scenarios to be considered to assess the impact of the technologies in the two proposed scenarios.

Table 19: Simulation scenarios LL2

Simulation	Scenarios	Description
LL2: UC1 **Synchromodality in a Blockchain-enabled Platform**	AS IS	Current transport conditions between the China and USA with manual process for customs.
	TO BE	New scenario using blockchain to deal with customs processes taking into consideration that the overall aim of the LL is to improve rail freight between China-USA with the port of Rotterdam as transhipment and modality shift point.
LL2: UC2 **Investigating the potential of Eurasian rail freight expansion**	AS IS	Current transport conditions between the China and EUROPE (on TEN-corridors)
	TO BE	New scenario between China and Europe considering facilitated customs processes, harmonized wagon types, infrastructures or common booking processes or digitalized documents and processes.

5.3 LL3 Silk Road Modeling and simulation

The modelling of logistics processes in LL3, addressed the implementation of activities along the New Silk Road, in two main aspects:

- execution of logistic processes within the parcel service in e-commerce channel based on rail transport from China to Poland (called conventionally in the project as modeling of B2C processes),
- execution of logistic processes embracing the handling of containers in rail transport from China to Poland (conventionally referred to in the project as modeling of B2B processes).

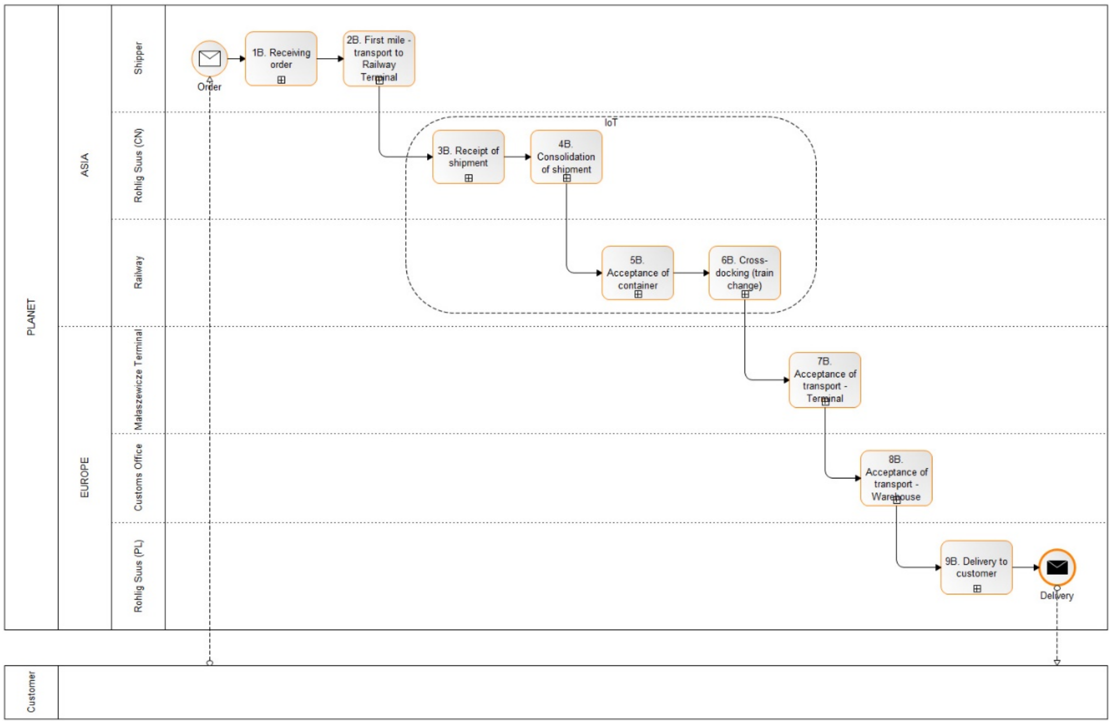

Figure 11: End to end overview - B2B

Due to the nature of LL3 and the composition of business partners carrying out project tasks in LL3, the substantive scope of implementation has been divided into two main aspects:

- application of GS1 standards and EPCIS in parcel flow processes (for B2C processes),
- application of IoT solutions using sensory network and EPCIS (for B2B processes).

The following table shows the critical points to evaluate and the possible technological solutions to apply within this living lab.

Table 20: LL3 Description

Living Lab 3:	**IoT for Silk Road Route**
Objective:	Optimization of logistics processes using monitoring and tracking capabilities along the New Silk Road route, using GS1 standards and IoT solutions.
Critical points:	Problems in obtaining a consolidator and/or manufacturer to mark parcels bound for the EU with an SSCC number, Limitations of access to actual data related to e-commerce parcels delivery by rail transport to Malaszewicze terminal, Reduced flows of e-commerce parcels from China to Poland, Unpredictable effects of the entering of Low Value Consignment Directive from July 1st, 2021, on e-commerce flows to UE,

	Lack of assurance about the correct tagging of the container with sensors by the Chinese business partners (the necessity to manually perform tagging operations on the container), Risk of lack of interest in applying GS1 standards by companies in rail transport.
Possible Technology Solutions:	IoT sensors: • real-time tracking of loads locations, • monitoring of several parameters such as temperature, humidity, accelerations (beats) • estimating the distance travelled by the vehicle in order to plan preventive maintenance, • container availability planning, EPCIS (GS1) event data base: • collection of huge volumes of events and its repository GS1 standards: • GTIN - Global Trade Item Number, that is recommended for the identification of goods, • SSCC - Serial Shipping Container Code, that is designed to identify loads

The changes made in the planned work for LL3 must consider the division of processes into two aspects, so two diagrams are shown.

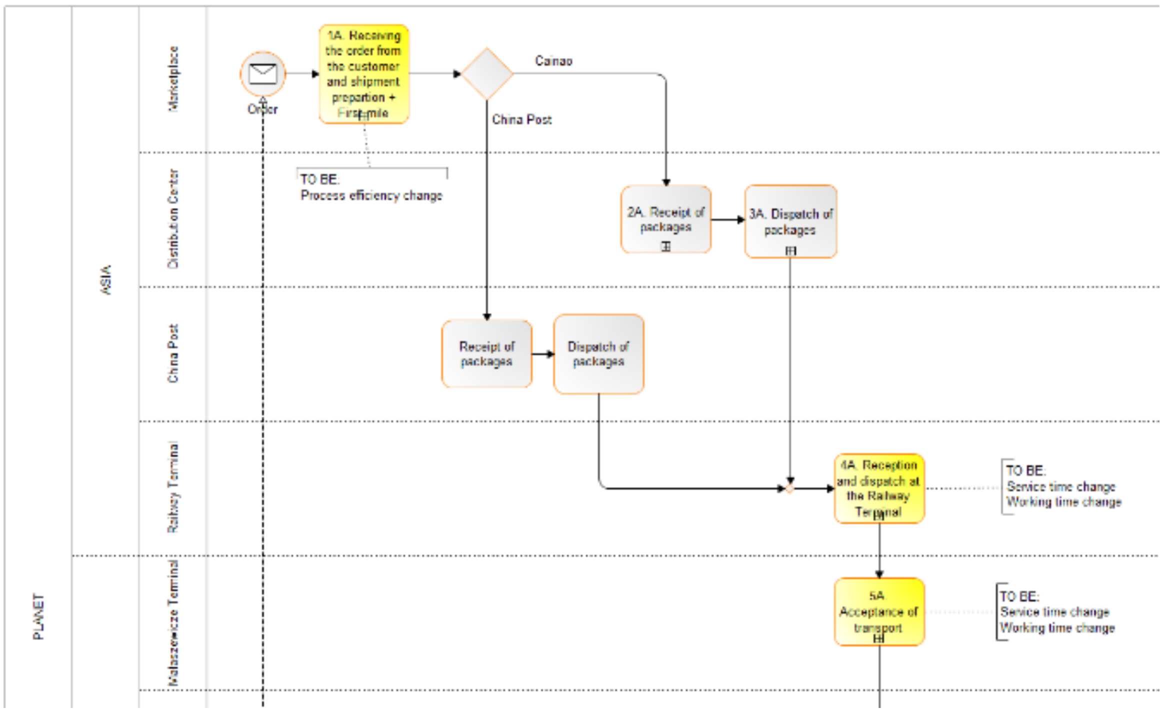

Figure 12: Example of end to end overview in TO BE perspective - B2C

The yellow color indicates process locations where performance improvements are expected. It should be remembered, however, that the ongoing parameterization and calibration of processes may generate additional new process areas that will change favorably after implementation of the proposed solutions.

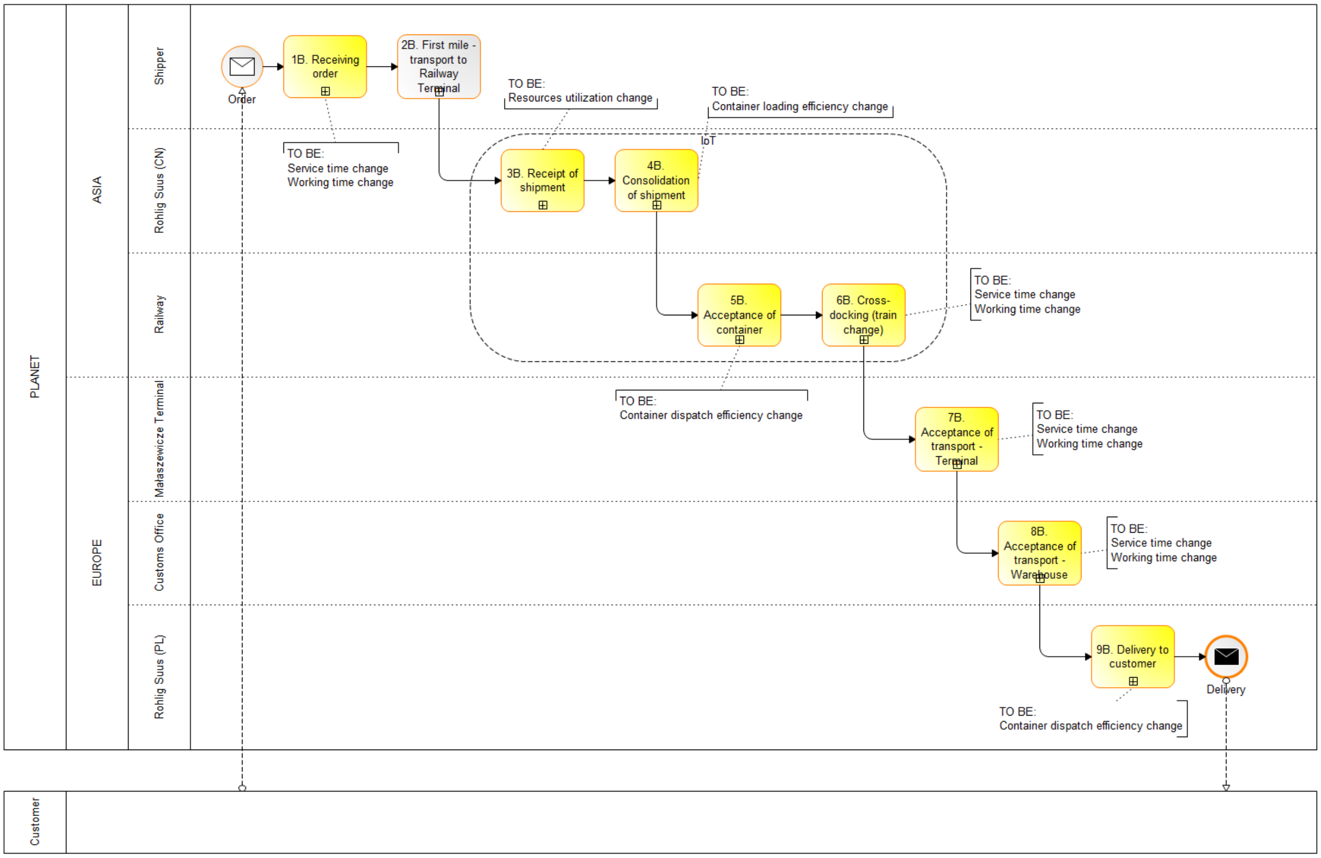

Figure 13: Example of end to end overview in TO BE perspective - B2B

5.3.1 Simulation requirements LL3

As modelling and simulation requirements in this living lab, the main processes considered and the expected impact on each of them are described. The following table shows the relationship between the requirements and the indicators to evaluate the expected impact.

Table 21: Simulation requirements LL3

Transportation Process	Expected impact
Container filling	• % Loading container occupancy
Loading structure	• qty of single (scannable) loading units in containers • qty of partners involved. • % Shipments with delivery time guarantee required
Transport information accuracy	• % of transports notified for pickup accordingly • % of containers consistent with detailed notification
Logistics service effectiveness	• % of containers hold for information completing • Allowance time for container (customs service preparation)

	• Average daily loading units handled in distribution centre (project perspective)
Customs service effectiveness	• % of containers hold for additional customs data completing • Time from presenting the shipments for customs purposes until procedure finish. • % of shipments hold for control / inspection
Shipments' safety	• % of containers consistent with detailed notification • qty of damage protocols (transport unit)

5.3.2 Simulation scenarios LL3

As part of the project activities in LL3, two process divisions were identified that were subject to modeling and will be simulated:

- container transport (with the possibility of transshipment during transport from China to Poland), conventionally named as B2B processes.
- e-commerce parcel distribution (which includes the full supply chain, from the loading and labeling of the parcel in China to the distribution of the parcel to the end customer), conventionally referred to as B2C processes.

This division is also conditioned by the division of the scope of activities of the business partners in LL3: Polish Post and Rohlig Suus. The developed business scenarios are aimed at verification of efficiency of application of the proposed solutions within LL3.

Table 22: Simulation scenarios LL3

Simulation	*Scenarios*	*Description*
SIM 1: Process of e-commerce parcel delivery from China to Poland (B2C processes)	*AS IS (current)*	*Analysis of the current process including order processing on the Chinese side, order consolidation, container and train loading, parcel rail transportation, customs handling, parcel distribution.*
	TO BE (SSCC implementation)	*Analysis of the process of considering potential changes resulting from the application of the SSCC number on shipments, simulation of the process, identification of benefits.*
SIM 2: Container transport process from China to Poland (B2B processes)	*AS IS (current)*	*Analysis of current process including container loading, planning and transportation of containers from China to Poland.*
	TO BE (sensors network implementation)	*Process analysis considering potential changes due to IoT (sensor network) application in containers, process simulation, identification of benefits.*

5.4 Gaps in simulation & requirements for integrated modelling capability

Modelling gaps and requirements have been identified at the level of LLs. However, more generalized approach has been followed in order to define the first list of modelling requirements for securing micro to macro models' interface, since this is the predominant need to be fulfilled when developing the PLANET integrated simulation capability introduced in Chapter 4.

At the level of the LLs important gaps are related to data access needed for modeling & simulation. When considering T&L operations along global corridors the completeness and the validity of data are not at the same level along the corridor and for all operations. This is particular the case in LL3 for the data of the activities performed on the Chinese side. This gap indicates the risk of lack of data for reliable simulation of processes in the scope of LL. Although solutions within LLs for improving data availability may occur, in such cases models & simulators should rely on generic representations of data. It can therefore be concluded, as a requirement of the PLANET modeling capacity, <u>the definition/selection</u> <u>& use by the models of a limited/minimum set of data at the desired level of quality and completeness for models input & output.</u>

The COVID-19 pandemic highlighted another important gap that affects the simulation of processes. As flows have been redistributed and considerably decreased (for example lack of current deliveries to the Malaszewicze terminal of LL3) <u>modeling & simulation process should be able to make use of historical data</u> with which should be made available for at least 2 years period.

Another important gap in the simulation assumptions is the lack of standards among companies in information exchange and data structure especially when these data are captured or generated by technology. This might have a significant impact on the <u>multiple assumptions for designing, simulating and assessing the TO BE scenario processes.</u>

In the context of the above a generalized <u>requirement for interface development between micro (mainly) simulation models and the macro (mainly) flows forecasting models</u> is concluded. The requirements for this interface in the sense of the structural properties and of the input/output variables of this interface have been discussed in the context of an expert workshop and the main conclusions are summarized in the following paragraphs of this chapter. Detailed specifications of this interface will be produced in activity 1.4.1 & delivered in Del 1.8.

<u>G1: Single vs multiple stakeholder view</u>. The micro models are on a small-scale level having one or only few clients while macro models are considering multiple clients/users. There is a need for supporting multi-stakeholders & overall assessment by aggregating the impact achieved through the execution of multiple micro simulation instances and measuring the impact. In the same context, there is a requirement for proper aggregation of the results coming from LLs micro simulation regarding the impact of technology in order to be used as impact to the macro models. Additionally in task "ST2.4.1 Multi-Actor Multi-Criteria Analysis (MAMCA) DSS" a Multi-Criteria Analysis (MCA) will be used to enhance policy analysis by explicitly considering the opinions of various stakeholders regarding investment scenarios that maximize for economic impacts from new corridors and routes.

<u>G2: Different perception of Information Technology role and impact to operations</u>. The micro and macro level models differentiate in the way in which IT is conceived and assessed by these types of models. <u>A large set of nodes using the digital network next to the physical one is describing the basic analogy</u>. At macro level, we do not yet have a notion of digital connectivity in modelling which means that the impact of IT at macro level will only be included by enhanced performance as it results from the micro level simulator or tool. This requires the connection of the impact of specific IT solutions through micro-simulation to more 'general' parameters which can be the input for macro models (for example if a specific solution reduces the transport costs by 10%, this connection/parameter that macro models can use). This process can also consider the creation of IF-THEN matrices of operational parameters from macro models which relate emerging impact to conditions of technology or operation results coming from the micro-level modeling in LLs.

Another dimension which needs to be considered in the case of the PI and the blockchain technology is the effect on the value of parameters due to the existence of both public and private PI/blockchain networks at the same time along with the effect of the rate of adoption of these technologies. The same applies to the effect of interconnectivity of supply chain stakeholder's IT systems in decision making which can be taken into account by applying the decision making in different interconnectivity scenarios and comparing the different outputs.

G3: Coherent micro and macro scenarios descriptions. The PLANET modelling capacity must have the ability to describe scenarios in a way compatible to both micro and macro level models, using common parameters. The scenario implications (and the table with parameters) allows for a bridge between micro and macro. The scenario narratives allow for a more qualitative description of certain choices in the model and how they translate into transport flows (given a future reality/scenario).

G4: Macro to micro models' input. The micro models need also to be able to take into account the reverse effect from the macro model outcomes in terms of changes in the values of the initially calculated parameters due to phenomena related to flow sizes (e.g., economies of scale because of increase of flows).

Finally, micro level models have a limited scope in terms of geographical area, time frame (weekly/monthly) and number of resources when compared to the macro models which refer to longer periods of time and wider geographical areas. The alignment of the micro and macro models at this level will be further examined using the Use Cases from the Living Labs in order to conclude to the micro models' scope and their alignment with macro models.

The evolution required for those models to meet the specific needs of Living Labs is an iterative process. In the coming months, a number of workshops are already scheduled in conjunction with T1.2 and T1.4, purposed to advance both the specifications as well as the actual implementation of the EGTN, in close collaboration with the living lab users.

6 Simulation models integration

In order to coordinate all available information from models, two modelling workshops were conducted. The first one focused on the evaluation of models to identify overlaps and synergies between them. Also, the input and output information of the different models was evaluated. On the basis of the results of the first workshop, two weeks later, another workshop was organised to complete the information from the first workshop and to evaluate the possible connection between micro and macro models. In the following image, the result with the models and the mains input and output is presented in the following image (Figure 14 Figure 14). The image represents the main models used in the project with the information about the input and output of each model. The yellow boxes represent the models, and the green and blue boxes represent the inputs and outputs of these models, respectively. The data required by each model and the expected outputs provide the basis for the data harmonization described in Chapter 7.

In addition, this diagram is of great value in identifying possible synergies between models, as it allows to visualise which outputs of a given model can be considered inputs for another.

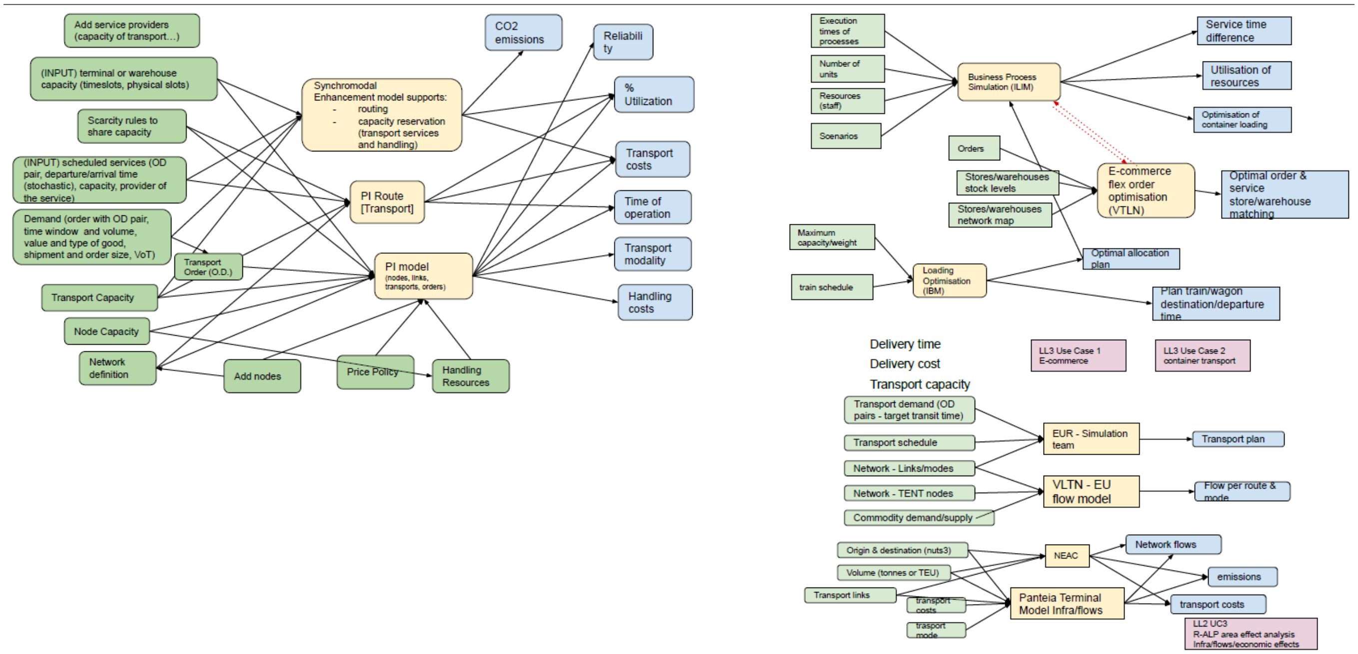

Figure 14: Models Input – Output workshop schema

6.1 Towards integrated PLANET modeling capacity

As it can be concluded from the models presented in the previous paragraphs, within the PLANET consortium there are several modelling & simulation tools available which will be used into the project LLs for supporting demand forecasting, optimization and performance assessment at network, corridor or T&L operations level. These models & tools have different focus and are able to answer a variety of "what-if" questions in the tested at the LLs scenarios and therefore provide support to different types of decisions, including decisions related to operations execution and planning or Policy and infrastructure or technology adoption. In broad terms they can be segmented in (i) predictive models supporting Planning for Policy & industry stakeholders (macro level models), simulation models supporting industry decisions through impact assessment of technological mainly solutions at operational level (operational micro models) and OR-based models supporting industry decisions related to distribution network design or to capacity optimization.

Additionally, these models cover different time horizons of decisions making, with strategic models supporting longer term decisions (over years), tactical models supporting decisions for a medium time period while operational models may guide short term decision making. Finally, depending on the input data they use and their computational capacity the available models can perform either dynamic or static simulations.

In the context of the PLANET project, there is a requirement to test integrated scenarios within the Living Labs in order to evaluate quantitively the impact of new technologies on the operational characteristics of corridors while at the same time the output of these scenarios must serve as an input for drawing and evaluating different strategic scenarios regarding the future competitiveness of the European transport corridors and guide decisions regarding infrastructure & technology investments in T&L.

For this to be achieved, a functional combination of available forecasting models, simulation tools & Operations research algorithmic solutions is needed, in order to be taken into account for the development of the PLANET Decision Support Platform, enable efficient support to the Living Lab operations and allow for strategic global & European corridors development scenarios.

In the context of the above the PLANET Integrated modeling capacity refers to the delivery of a modelling framework which on the basis of decisions categories and of stakeholder related to the decisions (policy or industry stakeholders) it defines roles of the different models/tools to the decision making process, specifies i/o interfaces among the models, harmonizes assessment approaches and guides the final user through options (scenarios) assessment for the corridor or the T&L network development & optimization. It will enable an integrated approach by using all the available simulation capability to assess the impact of emerging trade routes, national strategies and technological concepts to the TEN-T corridors leading to 'design propositions and blueprints for an integrated green EU-Global T&L Network based on market data and technology projections.

The integrated PLANET modeling capacity will support policy recommendations, scenario testing for the development of EGTN. In this context typology of scenarios to be tested at operational (LL level) and strategic (corridor or EU level) are important input for further defining it.

In developing the integrated modeling capability existing models need to be enhanced. The activities reported in this deliverable focus on defining current model's extension requirements in terms of:

- Initial mapping of the models' roles
- Needs for implementing Integrated modeling use cases at Living Labs for supporting decisions and
- Models' alignment requirements in terms of data categories used as input and output, data significance and harmonization of data collection or KPIs calculation methods.
- Identification of gaps and interfaces needed among models for securing functional models interoperation.

Elaboration on models interfaces is performed in the context of Task 1.4.1 and will be reported in Deliverable 1.8. The relations between the available models will be defined leading to the development of transportation models based on relationships between Principal Entry Nodes (PEN) and TEN-T corridor Intermediate Nodes and Urban Nodes.

The following figure (Figure 15) provides an overarching architecture of the integrated modeling capability by mapping categories of models and requirements of interoperations based on the LLs Use Cases. Categorization includes three main groups of models; the first group consist of micro level models which are oriented towards the enhancement of the operational characteristics of corridors under the PI paradigm, the second group also includes micro-level models which however are oriented towards the business perspective of operations and finally the third group which includes the macro-level models and is oriented towards policy making and strategic decisions.

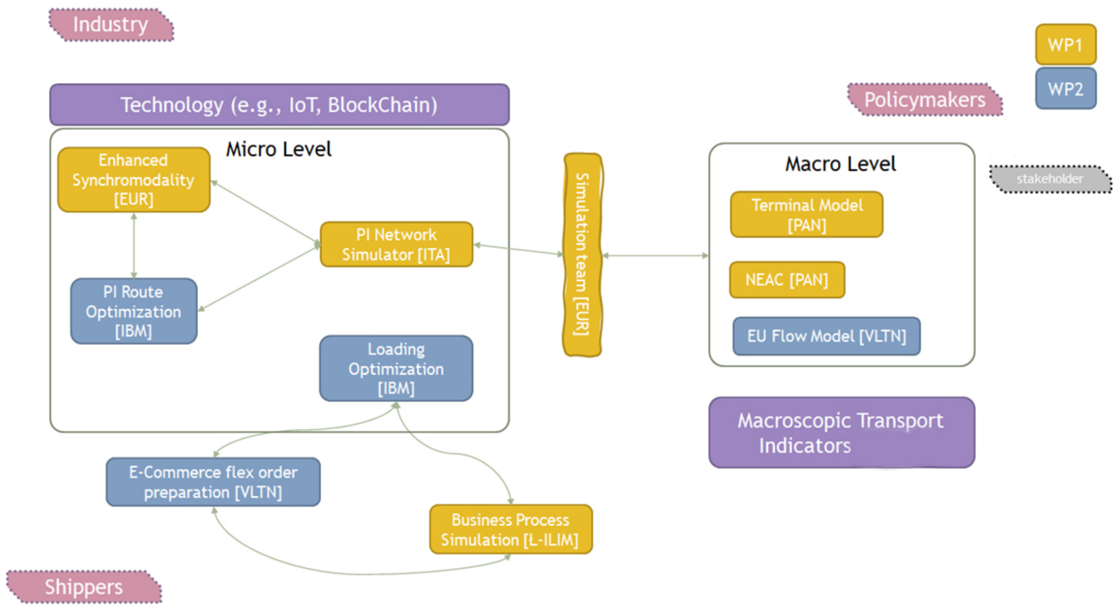

Figure 15: The mapping of modeling categories under the overarching architecture

Analysis of requirements for model's data exchange harmonization was performed by testing through two experts' workshop on the overarching architecture needs for data exchange between the groups of micro and macro models. The results of these activities are reported in next chapter. The overarching architecture of the PLANET integrated modeling capability has been validated by modeling experts, LL partners and industry representatives and was the basis for exploring possible connections between all the available models and for mapping input and outputs requirements. The exercise provided an initial view of the final model's combination which needs to be enabled.

The definition of interface between micro & macro models is central in the integrated modeling framework, since the main challenge to face is to enrich strategic scenarios assessment (performed by macro models) by efficiently taking into account results (provided by micro models) on operational variations of T&L enabled by technology implementations and/or operations optimization.

The identification of gaps and the associated broad requirements for existing models' enhancement is reported in previous chapters of this report. However, detailed specifications for the functional missing link connecting microscopic to macroscopic models will be elaborated & reported in Deliverable 1.8: "Simulation-based analysis of T&L and ICT innovation technologies v1". At this stage, our goal was to describe the conceptual gap between micro to macro modelling and the required interface between those two levels and enrich the Input/Output map (Figure 14) with new potential modelling perspectives.

On the basis of these initial requirements, together with Tasks 1.2 (physical flows simulation), and 1.4 (new technologies simulation), several interactive workshops will be held to define in great detail the integration of those models (scenarios and pipelines definition) and their adaptation to the requirements of the Living Labs.

7 Data harmonization

Data harmonization is the procedure of bringing together data from diverse sources and files, transforming them into a cohesive data set. UNCEFACT [6] defines data harmonization as an iterative process of capturing, defining, analysing and reconciling government information requirements, and data standardization as the mapping of this simplified data to international standards.

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

Aim of this chapter is therefore to initiate this iterative process with the review of the main inputs and outputs required by the simulation models, as well as describe the available data sources to be used for each of the living labs.

7.1 Data sources for modeling and simulation

The main datasets used as inputs in the configuration of the models and scenarios are described below. These datasets can be grouped in the following categories: demand data, infrastructure data, services data and parameters. For each category, a description of the fields that compose the dataset is summarized in a table.

7.1.1 Demand data

This category contains all the data that describe the demand, such as: origin and destination, product quantity or unitization. Generally, orders are expected to be filled within time windows and containers may consist of one or more SKUs.

Table 23: Demand data

DEMAND DATA	
Origin - Destination	*Pair of origin and final destination data of the shipment. For the harmonisation of origin and destination data, the NUTS classification shall be used, where possible.*
Product quantity	*Number of containers that compose the order.*
Unitization	*Type of container (box, pallet, 20ft container...).*
Size	*Container dimensions (length by width by height).*
Volume	*Container volume.*
Type of good	*One or more SKUs that compose the container.*

[6] https://tfig.unece.org/contents/data-harmonization.htm

Time window	*Time windows interval in which the order is expected to be delivered.*

For the characterization of demand, it is necessary to identify geographically the region to which the data is referring. Regions can be grouped at different levels, from macro levels, such as country or continent, to micro levels, such as city or postcode. In Europe, the NUTS classification is used. The NUTS classification (Nomenclature of territorial units for statistics) is a hierarchical system for dividing up the economic territory of the EU and the UK for the purpose of the collection, development and harmonization of European regional statistics. There are three levels:

- NUTS 1: major socio-economic regions.
- NUTS 2: basic regions for the application of regional policies.
- NUTS 3: small regions for specific diagnoses.

According to Eurostat from 1 January 2021, lists 104 regions at NUTS 1, 283 regions at NUTS 2 and 1345 regions at NUTS 3 level. An example of the representation of these levels can be found in the following figure (Figure 16).

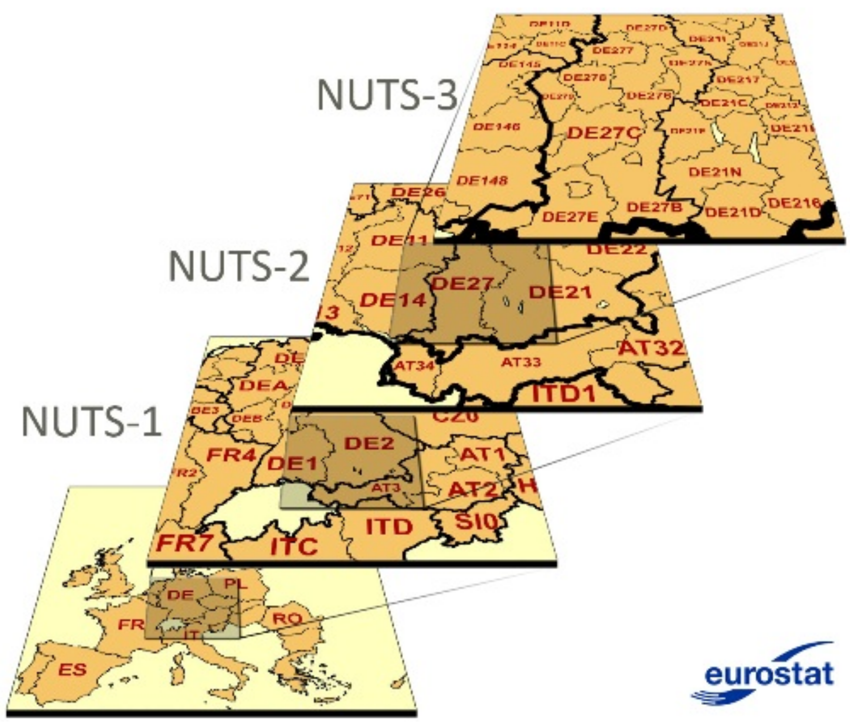

Figure 16: Example of nomenclature of territorial units for statistics (NUTS) [7]

In order to implement the specific types of simulation analysis, it is necessary to use data from various time intervals. A categorization of time intervals is shown in the following table.

[7] https://ec.europa.eu/eurostat/web/nuts/background

Table 24: Categorization 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*

7.1.2 Infrastructure data

Infrastructure data refer to the nodes and links that form the transport network as well as the transports operating on the network.

A node can represent a warehouse, a port terminal or a client. The following table lists the data that make it possible to characterize it, such as its identification code, name or geolocation. This category includes data which characterize the different elements of the transport network. For example, the stock level of its products must be known, the available spaces or the characteristic handling and storage times.

Table 25: Infrastructure data

NODE PARAMETERS	
ID	*Unique numeric node identifier.*
Name	*Name of the node.*
Geolocation	*Latitude and longitude.*
Capacity (Physical slots)	*Capacity of different spaces or resources (docks, berths, cranes...).*
Resources available	*Human and material resources available.*
Stock level	*Quantity of product available per SKU.*
Time slots	*Periods of time in which the node is open.*
Process cycle time	*Regarding material handling and warehousing.*
CCI (Connectivity Index)	*Level and quality of network connections.*

A link is the connection between two network nodes. For the correct definition of the links, the data listed in the following table are required: pair origin-destination, mode, capacity and status. For example, congested links can result in longer transit times, or a link between two barge terminals may be closed if the water level is not sufficient to ensure navigability.

Furthermore, the group of links used by a transport to go through several nodes are called the corridor. Some properties from the links, like the capacity or the status, could be applied to the corridors.

Table 26: Links/Corridor

LINKs / CORRIDOR	
Node Origin - Node Destination	*Pair of origin and destination node defining the link.*
Mode	*Types of transport that can travel along the link (road, rail, barge...).*
Capacity	*Link capacity in terms of transports per hour or volume per hour.*
Status	*Possible statuses in which the link can be found (open, closed, congested...).*
Corridor ID	*Identifier of the corridor(s) this link belongs to*

To characterize a transport, the data in the following table need to be known. For example, the type of transport (van, truck, train, barge...), its capacity, or the frequency of the route between its origin and destination. While in transit, its estimated time of arrival at destination may be known.

Table 27: Transport characteristic

TRANSPORT	
Origin - Destination	*Pair of origin and destination node.*
Frequency	*Number of departures per unit of time.*
Departure - Arrival time	*Departure time from origin node and arrival time at destination node.*
Estimated Time of Arrival	*Estimated remaining time until arrival at destination.*
Capacity	*TEU or Number of containers that fit in the shipment.*
Type	*Main transport types considered:* • *Maritime: vessel* • *Land: Train, Truck, Van (urban delivery)*
Transport Mode	*Type of link travelled over:* • *Sea* • *Rail*

	• *Road (streets in urban delivery)*
Transit time distribution	*Distribution of times to go through a link.*
Time at node	*Average services completion time at nodes.*

7.1.3 Services data

In addition to demand and infrastructure data services, information from different types of corridor services can be used. Transport services can be used to arrange for the movement of goods between two points. The results of some of the optimisation models described in section 4.7 "Services and other models" can also be considered as services; these services base their solution on demand data and infrastructure data. Regarding the transport service, it is expected to know the unique identifier of the service provider, the capacity of its transport fleet and the routes it can cover (origin-destination, frequency, costs...).

Table 28: Transport services

TRANSPORT SERVICES	
ID	*Unique transport services provider identifier.*
Capacity	*Fleet size of transport services provider.*
Origin - Destination	*Pairs of origin and destination nodes realisable by the services provider.*
Frequency	*Number of departures per unit of time realisable by the services provider.*
Transport Costs Tariff	*Transport rates used to calculate the transport cost of a freight.*

From a generic point of view, the results of the different optimisation models can be considered as services, and the following table shows an example of the possible optimisation services available.

Table 29: Optimization services

OPTIMIZATION SERVICES	
Smart Route Service	*Optimise the route taken by a PI Means within a PI Network.*
Loading Optimization Service	*Optimise the loading of PI containers to Train Wagons in both 2-Dimensional and 3-Dimensional space.*
eCommerce order optimization	*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.*

7.1.4 Data standards

As a guiding principle, wherever possible, data should be transformed in a standardised form. It is therefore recommended to employ standards, such as GS1, for capturing information. The GS1 Global Data Model helps to identify content across multiple channels, increasing operational efficiency for brand owners and retailers and improving data accuracy and completeness for consumers. As a result it advisable to use GS1 codes such as GTIN. Global Trade Item Number (GTIN) can be used by a company to uniquely identify all its trade items. Many of these formats are currently evaluated and utilized under PLANET's Living Lab 3.

EPCIS in logistics processes

Electronic Product Code Information Services (EPCIS) is a global GS1 Standard for creating and sharing visibility event data, both within and across enterprises, to enable users to gain a shared view of physical or digital objects within a relevant business context. There is a significant potential of EPCIS to observe rolling stock.

The EPCIS database assumes that an RFID system will send location and other information in certain situations, but at the same time it should not dictate how that information is created and captured. The EPCIS database has an influence on RFID implementations because it specifies what information should be collected. It is expected that with the increased interest in the use of RFID in rolling stock, there will be a growing number of applications of information connected to the monitoring of wagons and locomotives. This is a strong foundation for the use of EPCIS in rail transportation.

For asset monitoring, it is typically based on Level 1 of the transport mode (wagon, locomotive), tracking the location and status of each rolling stock during transportation. Potential applications of EPCIS can be identified as:

- real-time cargo tracking,
- estimation of the distance covered by the vehicle in order to plan preventive services,
- vehicle availability scheduling.

Alternatively, EPCIS can be used to obtain data on rolling stock (cars, locomotives) as well as rolling stock components to facilitate preventive conservation.

WTMS (Wayside Train Monitoring Systems), as it is referred to, is an integrated system of measuring devices that could monitor the conditions of rolling stock in time of moving on railroad tracks. These systems have been used for many years and are becoming increasingly common as a way of reducing accidents by enabling preventative maintenance and by improving the reliability of the rail system.

GS1 standards in the logistics processes

Data standardisation is very important for the exchange of information in business-to-business transactions. GS1 standards are the most widely used system of standards for unique identification of products, logistics units, locations, assets, documents, and relationships across the supply chain. GS1 uses two basic capture technologies – based on barcode and RFID. The standardization problem of identification system in cross-border trade concerns four aspects:

- identification of goods and logistic units (shipments) using GS1 standards for the needs of the supply chain,

- GPC system, which classifies products by grouping them into categories based on their essential properties as well as their relationships to other products,
- customs classification and identification of goods according to CN using tariffs for customs and fiscal processing of trade transactions,
- identification of shipments and cargoes according to UPU industry standards for the purposes of their recording, tracking and planning.

A special attention was paid to the ability to universalize and standardize applied identifiers, and to the cooperation of applied IT systems.

It is recommended to use primarily two basic identifiers to handle the import of goods from China, which are include:

- GTIN - Global Trade Item Number, that is recommended for the identification of goods,
- SSCC - Serial Shipping Container Code, that is designed to identify logistic units (parcels),
- GSIN – Global Shipment Identification Number, to identify online transactions.

Implementation of the developed GS1 standards is intended to streamline logistics operations throughout the supply chain by applying unique and uniform data recorded by all GS1 system participants.

GPC system

Global Product Classification (GPC) - is the GS1 global system that allows standardized grouping and product classification. The GS1 GPC gives buyers and sellers a common language for grouping products in the same way, everywhere in the world. The GPC system is used in the Global Product Data Synchronization Network (GDSN) catalogs.

The GPC classification data structure matches the logistical needs of commercial transactions between suppliers and customers. The basic data included in the catalog consists of at least: product name, brand name, product specification / characteristics, product identifier (GTIN – Global Trade Item Number), information on dimensions and weight, types of packaging, local and international classifications, etc.

7.1.5 Data harmonisation mechanism

Simulation models use a wide range of information, normally stored in the tables of the management software of the different companies or in public repositories (as is the case of the aggregated data for the corridors). To achieve meaningful and comparable conclusions from the analyses, a common data repository will be created on the EGTN platform, with the main data collected. In this way the data can be consumed more efficiently by the different models.

In this chapter, the initial structure of the information to be collected has been defined. This data structure will evolve according to the analysis requirements identified in the process of verification and validation of the models and the information available in the different living labs.

7.2 Model and simulation parameters

Simulation models can generate different types of results by the modification of different parameters. The main types of parameters that can be obtained through the available models are grouped below. Demand parameters may include the number of orders to be fulfilled in a certain period or the number of shipments per unit of time.

Table 30: Demand parameters

DEMAND PARAMETERS	
Contract volume	*Number of entities involved.*
	Total volume for the contract.
	Number of containers per day.
	Number of shipments per time unit.

At the transport network level, the possible parameters to be obtained are shown in the following table. The quantity of cargo entering and leaving a distribution centre are examples of network parameters.

Table 31: Network parameters

NETWORK PARAMETERS	
Network results	*Quantity of cargo entering the distribution center in each time unit in relation to a specific contract.*
	Quantity of cargo leaving the distribution center in each time unit with reference to a specific contract.
	Average daily number of cargo units processed at the distribution center for a specific contract.

Transport parameters may refer to their capacity, their loading and unloading times, or the maximum distance transports are allowed to travel.

Table 32: Transport parameters

TRANSPORT PARAMETERS	
Transport time/cost	*Number of pallet units.*
	Number of entities involved.
	Number of transhipments.
	Number of kilometres travelled.
	Number of SSCC scans.
	Number of incorrect shipments from shipper/manufacturer to warehouse in China.

	Container fill rate.
Container transport	*Total volume (cbm) / weight (kg) of cargo in one container.*
	T1 issue time.
	Waiting time for container collection
	Waiting time for unloading container
	Planned ETA, Actual ETA (ATA).
	Planned ETD (Estimated Time of Departure), Actual ETD (ATD).
	Container unloading time (PL).
	Customs clearance time (PL).
	% of container filling.

Certain simulation models can take as handling parameters the average container handling time or the percentage of containers to be examined.

Table 33: Operational parameters

OPERATIONAL	
Capacity reservation	*Physical spaces reserved in warehouses for notified arriving containers.*
Transport plan	*Travel itinerary for transports (origin, destination, and departure/arrival times).*
Reliability	*Level of reliability with which cargo can be transported from one node to another.*
Attractiveness of nodes	*How prone a node is to have transports passing through it to go to their destinations.*
CCI (Connectivity Index)	*Level and quality of network connections.*
Flow per route and mode	*Transport flows for each link in the network over time.*
Time of operation	*Time required to complete an operation (storing cargo, transporting a container between nodes, etc.).*
Transport loading plan	*Allocation of containers to the available train wagons.*

Resource's availability in nodes	*Node capacity forecasting (availability of storage space, stock level, labour...).*
Stakeholder satisfaction	*Level of stakeholder satisfaction (contract compliance, on-time delivery of orders, transport network performance...).*
Shipment's safety	*Number of alarms related to possible cargo damage.*
Optimal preparation store	*Optimal store to prepare an order.*
Logistics performance	*Time from the arrival of the transport to the collection of the containers.*
	Time of completion of a single container clearance.
	Time from presentation of consignments for customs control to completion of customs procedures.
Efficiency of customs handling	*Lead time for a single container clearance.*
	Time from presentation of consignments for customs control to completion of customs procedures.
	% of consignments detained for control / examination.

7.3 Data sources from living labs

To perform the modelling and simulation of the different scenarios from the Living Labs, it is necessary to include information on the movements describing the flows in the main corridors under analysis.

In general, for each of the corridors analysed in the living labs, it is necessary 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 and are usually applied for 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 needs information to support decision making for large transportation networks.

Having revised the categories of data types defined in chapter 7.1, the following table provides an overview of the main characteristics of the sources that are necessary to perform an analysis of living lab flows.

Table 34: Data sources from living labs

	Demand	Infrastructure	Services
Micro Level	Movement data on the transport network at warehouse, postcode or city level. Origin/destination	Detailed data of the nodes (e.g., ports, rail terminal, warehouses): capacity, available resources, available time slots, handling cycle times, IT infrastructure in place	Information on the services offered by T&LSP related to transport: type of

	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.	(WMS (Warehouse Management System), etc). Connections available between nodes, with capacity data, congestion statistics...	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).

Over the coming months, following the detailed assessment of the needs of each of the scenarios to be evaluated, the necessary information will be compiled, according to the guidelines described above, to carry out representative analyses with the available models.

7.4 KPI Description

A KPI (Key Performance Indicator) is a performance measurement of a process, which in turn assesses how close or far it is from achieving a goal. In this section, the main KPIs used as model outputs are described in three categories: economic, operational, and environmental.

Economic indicators measure the costs of transport, handling, and storage of containers, as well as penalty costs for delayed delivery. Total delivery costs may include costs for priority cargo handling or customs fees, among others.

Table 35: Economic KPI

ECONOMIC	
Transport costs	*Costs of transporting containers through the network (labour, fuel...) considering fix and variable costs.* • *Fix: € Per Journey (activation cost per transport per day)* • *Variable: Per Km, per ton-km, or full-km, empty-km*
Handling costs	*Costs of handling containers in warehouses and terminals. It is the result of applying an entry and exit fee to each container that has been handled (€/container-in and €/container-out).*

Inventory holding costs.	*Costs of storing containers in warehouses and terminals. It is calculated based on a storage rate expressed in € per container per day/week/month/year.*
Penalty costs	*Costs of not delivering orders on time. Each order not delivered on time is subject to a fixed penalty cost and a variable cost depending on the delay time (€ per hour/day of delay).*
Delivery costs	*Total costs of delivering an order. It is the sum of all the above costs and is expressed in terms of absolute cost (€), cost per order (€/order) or cost per container (€/container).*

Operational indicators evaluate the delivery of orders (delivery time, on-time deliveries, quality of service...). In addition, they evaluate transport efficiency (fleet utilization, fill rate, delays, etc.). Finally, they also consider the impact that shipments have on the transport network (links usage or modal split).

Table 36: Operational KPI

OPERATIONAL	
Delivery time	*Time to fulfil an order.*
On time delivery	*Number of orders delivered on time.*
Service quality	*Damages or alerts during the journey.*
Delays at nodes	*Transport delay in relation to the scheduled departure time from the node.*
Utilization	*Utilization of the transport fleet (number of activated transports).*
Fill rate	*Used capacity over total transport capacity available.*
Stockouts	*Times a warehouse runs out of products and quantity of these products.*
Link usage	*Link usage per transport mode (transports or volume per time unit).*
Modal split	*Percentage of shipped orders using a particular mode of transport (road, rail, barge...).*
Accuracy transport time	*Accuracy of estimated transport time, the expected effect is in-crease of the accuracy of estimated transport time.*
Transparency of rail transport	*Information about the status of the freight in train transport.*

Environmental indicators not only measure emissions of harmful gases such as CO2 or NOx and check compliance with continental or global emissions reduction targets but also evaluate the environmental impact in terms of congestion of transport network nodes and links.

Table 377: Environmental KPI

ENVIRONMENTAL	
Emissions	*Quantity of harmful gases released into the environment (CO2, SO2, NOx...). Transport emissions are calculated based on an emission rate expressed in g/ton-km.*
Congestion	*Congestion level at nodes and links, expressed in transports/h or TEU/h.*
Corridor environmental index	*Environmental impact index of each network link.*

8 Conclusions

For the Planet project, several diverse types of models have been evaluated, to allow assess multiple dimensions of transport in large intercontinental corridors. This report contains a description of the simulation and optimization models that can be used to evaluate the different scenarios presented in the living labs as well as more generic type of use cases. Those models do investigate distinct aspects of the supply chain and transport. The complementarities and overlaps of the models have been explored to achieve a complete analysis of the several aspects that influence intercontinental transport. Two levels of analysis, micro (narrow geographic scope) and macro (broad geographic scope) have been identified and various dimensions are evaluated to exchange relevant information between both levels. A structure is proposed to connect both levels.

An initial data requirements analysis of the models has been carried out and a set of potential data has been identified that can be used to describe the movements of transport freight in the corridors through the connected use of various models. The requirements of the use cases of the living labs have been evaluated. In particular, the parameters and technologies to be evaluated in each use case were analyzed. Finally, scenarios have been defined so that they can be evaluated under different simulation and optimization models.

Furthermore, it expected that both data harmonization and model integration will evolve during the project lifetime to meet Living Lab's specific needs. Joint workshops with the collaboration of T1.2 and T1.4 have already been planned to formalize the EGTN systems scope and ensure complete alignment with the Living Lab users' aspirations.

Using as basis the identified available models, complimented by the relevant datasets as described in this report, the project will be enabled to perform scientific analysis and a quantifiable assessment of the EGTN solutions' effect in the diverse Living Labs' Use Cases.

Annex I: Model Descriptions

id	Simulation Name	Owner	Description	Inputs	Outputs
1	ITAINNOVA PI NETWORK SIMULATOR	ITAINNOVA	Simulation toolkit to evaluate the dynamics of services in Physical Internet Networks.	Network nodes (latitude, longitude), Links (connection between nodes), Transport (type, route, frequency), Orders (group of containers moved)	Operational (Fill rate, delays, stockouts) Economical (handling, transport) Environmental (C02 emission)
2	BUSINESS PROCESS SIMULATION	L-ILIM	Business process simulation allows dynamic analysis (discrete event simulation) to foresee the results of changes. Visualize animation of simulation steps to identify bottlenecks and delays. View side-by-side comparison of the As-Is and To-Be. Easily design full factorial experiments, risk-free. Improve accuracy of simulation results through statistical fitting of real-world data.	Process transaction generators, Resources executing the process, Duration of individual process activities, Work schedule	Process cycle time, Working time, Bottlenecks level, Average resources usage, Maximum process capacity etc.
3	NEAC	Panteia	NEAC is a European freight flow database and a multimodal transport model, all in one package, designed for analysing medium to long-distance traffic flows. It was developed in-house by Panteia, combining inputs and experience from a long series of European transport studies. As a highly detailed and flexible system, it has extensive policy and scenario assessment capabilities.	Origin & destination (nuts3), volume (tonnes or TEU), transport links, transport costs	Network flows, transport costs, emissions

4	Terminal model	Pantiea	The Terminal Model is a flexible transport model offering extensive policy and scenario evaluation options. In its core, the terminal modal calculates transport costs and time between regions for various modes of transport and different commodities. It uses a complex network (road and intermodal, including transhipment points) including associated transport cost to establish transport costs from a particular location within the study area (municipality level) to any other area within Europe (NUTS-3 level) or outside Europe.	Origin & destination volume (tonnes or TEU), transport links, transport costs, transport mode	Network flows, transport costs, emissions
5	EU Flow model	VLTN	A capacitated freight flow routing model based on the multimodal infrastructure of EUs TEN-T network (terminals and links)	One or multiple origins and destination volumes of a commodity	Links and nodes utilised for optimally connecting sources and sinks
6	e-Commerce flexible order preparation	VLTN	A model that identifies the optimal store to prepare an e-commerce order (prior to solving VRP (Vehicle Routing Problem)). Can be solved either as a transport cost minimisation problem, or as a profit maximisation if sales profit is available. It is extended to identify optimal additional order preparation stores (facility location).	The optimiser considers the locations and the stock level for various products at the stores, and the locations and the products requested by customers.	It identifies which store should prepare each order to minimise stockouts and transport cost

7	Loading Optimisation Model	IBM	The Train Loading Optimisation model looks to optimise the loading of PI containers to Train Wagons in both 2 Dimensional and 3 Dimensional space. The model accepts the list of available Train Wagons and the list of PI Containers to be loaded in JSON format and creates an optimised loading plan in real-time. If there are PI Containers unassigned after the initial Wagons are filled, the loading plan will include additional Wagons (same spec as original) that could carry the remaining PI Containers. This information could be used to make decisions on whether to asign more Train Wagons or hold PI Containers over to a subsequent shipment. This model was created as a Train Loading service for ICONET but could be used to optimise PI Containers in any 2D or 3D space (ships, trucks, vans etc.)	JSON definitions for Wagons and PI Containers. Wagons have dimensions (2D, 3D) and maximum weight capacity. PI containers have dimensions (2D, 3D) and weight.	Transport Capacity Efficiency, Transport Costs, CO2 Emissions
8	PI Route Optimisation Model	IBM	The PI Routing Service model looks to optimise the route taken by a PI Means within a PI Network. Routes through the PI Network from the source to the detination are analysed using a deep learning model and the optimal route is selected automatically.	PI Network definition, Start PI Node and Destination PI Node, departure schedule	Routing Efficiency, Cost, CO2 Emissions, Time Efficiency
9	Simulation Team	EUR	We can develop additional logic that captures adaptive/advanced decision making. This logic can be developed into widgets extending pre-exhisting simulation software. We work on on both theory-based as well as data-driven problems. For smaller problems, a simulation solution can be built ex-novo. Related to task T1.4.	Open for discussion.	Open for discussion

10	Enhanced synchromodality model	EUR	Synchromodal planning model exploring the trade-off between adaptive cargo routing and capacity booking. The model aims at minimizing total capacity booking costs while guaranteeing a an expected amount of flow is delivered before deadline. Related to task ST1.4.3	Capacited freight network with departure times and arrival times distributions for each arc. Origin and destinations of cargo. Target reliability level for the overall shipment.	Capacity booking and adaptive routing strategy for the cargo. An adaptive strategy prescribes which routes to take depending on the arrival time and the status of the whole network as well as the overall cargo position in the network itself.

Additional table columns:

id	Simulation Name	Owner	Main Features	Expected Results	Level	Calculation Technology
1	ITAINNOVA PI NETWORK SIMULATOR	ITAINNOVA	Dynamic simulation of PI effects in the PLANET corridors. Intermodal transport (ship, truck, train, van..) Cloud simulation model.	Comparison scenarios AS-IS (actual corridors behaviour), TO-BE (with PI, technology...) for a certain group of orders (containers) with different PI strategies.	Micro (hourly, daily evolution)	Multi agent simulation, Cloud simulation, API integration with external services.
2	BUSINESS PROCESS SIMULATION	Ł-ILIM	Processes related to information exchange and transport (railway) of goods between China and Europe, with particular emphasis on the e-commerce sector.	AS-IS and TO BE comparative analysis - helps to estimate the effects before the actual implementation (GS1 standards, IOT, EPCIS and other solutions)	Micro (each process analysis - hourly, daily, monthly, yearly)	pseudo-random number generator, direct values or distributions generated according to the function, based on the exchange of data with statistical tools (minitab, jmp) and the construction of simulation projects based on the sheets of the above-mentioned statistical tools
3	NEAC	Panteia	Classical European transport model with mode chain	Simulation of transport flows (current and future) on the	Macro, yearly	C++ and Java

			builder and highly versatile	European transport network		
4	Terminal model	Pantiea	Classical transport model and highly versatile	Simulation of transport flows (current and future) between Asia and Europe	Macro, yearly	Python-based
5	EU Flow model	VLTN	Standard capacitated flow model	Simulation of impacts of changes in infrastructure	Aggregated flows	Python
6	e-Commerce flexible order preparation	VLTN	Mixed integer linear program that solves reasonably quickly for a network of up to 100 nodes. Facility location extension. Relevant to last mile logistics.	Pairing of orders to preparation stores	e-Commerce orders.	Python
7	Loading Optimisation Model	IBM	Real-time Optimisation, Easily adapted to Optimising any 2D/3D space	AS-IS and TO-BE comparative analysis - LLs with Cargo and PI Means data could compare actual transport capacity usage with optimised usage. Could be used to Optimise PI Means before routing, saving costs, emissions.	Micro (hourly, daily evolution)	Python-based
8	PI Route Optimisation Model	IBM	Originally focused on Inland Routing, Easily adapted to other transport	AS-IS and TO-BE comparative analysis - LLs with Cargo and PI Corridor Route data could compare actual transport routes with optimised routing. Could be used to Optimise PI Corridor Routing, saving costs, emissions.	Micro (hourly, daily evolution)	Python-based
9	Simulation Team	EUR	Data-driven as well as theory-driven modelling of logistic operations. Combinatorial optimization. Machine learning. Prescriptive analytics. Adaptive planning modelling.	Testing impact of new technologies on trade-routes. Modelling of the operational impact of new technologies.	Micro (hourly, daily evolution). Macro level is open for discussion.	Python

10	Enhanced synchromodality model	EUR	Adaptive routing of cargo flow with a-priori booking of transport capacity.	Comparison between current transport planning and adaptive one. Model adjustments to possible field application.	Operational level. Micro level for time dimension.	Python