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

D1.3 Modelling & Simulation Capability final version

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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
PEP	Primary Entry Point
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

1 Executive Summary

This document contains the description of the PLANET simulation capability constituting from different models which have being enhanced in accordance with simulation requirements (reported in the previous version of this deliverable) and also used to evaluate strategic/macro & PI paradigm operational scenarios in the PLANET project. More specifically, the model suite presented in this deliverable contains the description of:

- A model set to evaluate long-distance multimodal transport corridors competitiveness and flows forecast to assess the impact of rail transport between Europe and Asia. It analyses the different flows from Asia through the different entry points over a transport network composed of the main European terminals and it was enhanced, through the PLANET WP1 activities, to consider also the impact of the PI technology implementation and of policies to the corridors assessment process. This capability will support decision making in relation to investment choices along the TEN-T.
- A model set to evaluate the impact of the implementation of collaborative transport enabled by Physical Internet and innovative technologies and solutions. The assessment of the impact of the application of different technologies, under the umbrella of collaborative transport, is achieved through dynamic modelling by considering alternative scenarios of technologies combinations and three main PI paradigm use cases as defined by EGTN specifications and the project LLs. Three concrete PI technology enabled use cases were analysed in this context:
    - The last step in the supply chain is the urban delivery of freight to the customer. A model is included that evaluates different collaborative urban transport alternatives.
    - A model is also included to evaluate operations within warehouses that can act as nodes in the PI network.
    - The technology impact to enable EGTN node & corridor operation.
- Technology implementation impact analysis includes analysis from business point of view and is enhanced by modelling logistics processes using IoT technology and standard protocols. The document also contains a description of questions that can be answered using these models from an economic, environmental, and operational point of view.

The requirements of the decision-making process of the Living Labs were analysed through the existing models. It has been concluded through this process an improved decision making and operations optimization due to the project innovations ,and these company or LL level results were generalized and evaluated as a strategic development scenario analysis at the level of the TENT-T with the simulation models. The models also evaluate the services of the EGTN platform and will also be able to exchange information with each other. Finally, the data used for the creation and evaluation of the models of the LL data is described. Information and indicators are collected to assess flows at micro and macro levels.

All these models are used to evaluate different scenarios including future scenarios that, through the combination of different parameters and options, may impact Intercontinental freight transport. Significant progress has been made in recent months through meetings with LL partners to customise and adjust model parameters with the validation of some of the calculation hypotheses and the results of the main indicators. In addition, a special focus has been placed on the impact that the recent war in Ukraine may have on the main continental flows of goods.

2 Introduction

Intercontinental freight transport is facing a great challenge to become more efficient and more sustainable. Analysing freight flows between continents requires complex modelling, simulation, and analysis capabilities. Supply chain and logistics professionals are using simulation more frequently than ever before. Simulation is an analytical tool that helps logistics professionals test a variety of scenarios to determine the best alternatives to move cargo between destinations.

An intermodal freight transportation operation is one that transports goods from origin to destination using at least two transportation modes and services, with mode switching occurring at an intermodal terminal. Loads are transported in one transportation vehicle or container, and they can travel using different modes of transport. Goods are moved from one mode to the next in intermodal freight transportation terminal.

The goal of this deliverable is to present the currently available models for representing freight transport processes in the intercontinental corridors, their enhancements performed during the project in relation to their key characteristics and functionalities, in order to fulfil modelling and decision-making support needs to the Living Labs' use cases.

The document contains the description of the adaptation of the simulation models by the different partners. They explain how they have adapted the functionalities of the models to evaluate the special features of each living lab. 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 to identify the business requirements affecting those models. The available data were also analysed to be able to carry out the simulation analyses.

The document describes the requirements gathered from the living labs' use cases. It includes the adaptation of the models and explains how the models have been created to evaluate the answers to the main decisions made in the use cases. Significant progress has been made in recent months through meetings with LL partners to customise and adjust model parameters with the validation of some of the calculation hypotheses and the results of the main indicators. In addition, a special focus has been placed on the impact that the recent war in Ukraine may have on the main continental flows of goods.

This document is an evolution of "D1.2 PLANET Modelling & Simulation Capability_v1" which contains the initial description of the available models. This version focuses on the adaptation to the requirements of the Living Labs and how the available data have been integrated to evaluate the scenarios foreseen in the project.

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			
D1.3 Modelling & Simulation Capability	Final Version enhanced based on LL feedback.	General content of the document	Adaptation and customisation of the models developed in the project based on the validation and feedback received from the Living Labs
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 modelling 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 3,4,5	Chapter 3 describes the customization of the models. Chapter 4 describes simulation requirements from the living labs, and Chapter 5 the integration of models with EGTN services.
ST1.1.5 Data requirements and modelling 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	Chapter 6	Chapter 6 describes data sources available for macro and micro modelling, also KPI. Integration between models.

	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.		

2.2 Overview of the Models in PLANET

The PLANET modelling & simulation capability focuses on offering:

- forecasting capacity to support long term strategic planning of infrastructure development
- short term forecasting for company's decision making on intermodal operations management and better reaction to events
- operations simulation and impact assessment of technology and of collaborative use of assets when implemented at transport corridor and/or node level
- modelling long term scenarios of technology adoption along TEN-T and supporting investments choice in infrastructure or technology.

The decision-making support offered by PLANET is based on consortium background models and simulators which were enhanced and integrated and new that have been developed during the project life cycle as part to the PLANET decision making capability & tools. The PLANET modelling and simulation capability allow for companies to perform informed decisions for their technology investments and operations improvement based on strategic knowledge about tendencies along the TEN -T and the global trade corridors and modal points. Similarly, decision making related to TEN-T corridors and nodal points development and investment choices can consider the impact of the technologies, optimization solutions & collaborative models considered under PI paradigm.

The table below is indicating the PLANET suit of models and their use in the context of the EGTN platform and the strategic modelling activity of the project.

Table 2: Models relationship with the EGTN platform	Long /medium term Planning	Medium/Short term Planning & operationalization	Governance
Geopolitical uncertainties & tendencies	• Impacts of uncertainties to operations • Impact of policy to operations & flows • Demand & flows forecasting		
Risks identification & mitigation	Impact of technology to capacities and operations of corridors	Data Analytics & detection of expected flows (AI) or anomalies *Flows optimum serving considering special conditions*	

Impacts calculation	• Costs • New corridor flows • new connectivity and attractiveness of nodes	Short term impact (including ETA, CO2 & efficiency)	*Impact information from company to the ecosystem* *Information on Capacities & alternative services availability from ecosystem to company*
Technology enabled & Services optimization driven adaptation	PI priority corridors Impact of technology to operations and of best technologies combinations to PI nodal point	Alternative routes service Optimized use of resources service Collaborative last mile service	*Support Business agreements for collaborative logistics* *Information provision through Corridor or regional observatory to plan for response*
Infrastructure driven response	Prioritization of alternative investments	Decision support for Response & business adaptation Port selection service	

2.3 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 2 contains a general introduction to the document and a specific description of how the document is adapted to the requirements of the project. In Chapter 3, customisation is described for each of the models. Different models utilised in the project are compiled and described. For each of them, the requirements, and questions to be answered, the methodology for building or adapting the models to the living labs and their status are presented. Chapter 4 describes in detail the requirements for modelling from each of the living labs, as well as the different scenarios and use cases proposed. Chapter 5 focuses on the integration of the models, both with the EGTN platform and with each other (micro-macro relationship). Chapter 6 deals with the data needed for the models and simulations. It describes requirements, general and living lab specific data sources as well as a description of KPIs. Finally, in Chapter 7, the results of the deliverable and its contribution to the project objectives are summarized.

3 Models' customizations

Companies and the authorities are faced with the challenge of making decisions considering the future evolution of transport flows between continents. It is important to have a clear vision of possible evolutions to design policies and investments efficiently. Analysing the movement of freight flows between continents is a demanding task. Many players, in different countries, multiple companies, a wide range of actors... In order to investigate the evolution of these flows, various models have been elaborated in the PLANET project. The models estimate transport flows from different perspectives. Micro models focus on more operational aspects, assessing the impact of innovations on small-scale processes. Macro models, with a broad scope, have been used, focusing on the major streams. Micro models, with a smaller scope, are also used, with a higher degree of detail in the representation of some features.

3.1 NEAC Freight Model

To assess the impact of the new trade routes, Panteia's NEAC freight model is used. This model has been used and validated in previous projects [1]. NEAC is a European freight flow database and a multimodal transport model designed for analysing medium to long-distance traffic flows under scenarios of operational & cost parameters of transport per mode and at nodal points operations.

3.1.1 Model requirements

The purpose of this model for PLANET is to identify requirements from Eurasian rail freight for TEN-T to provide recommendations for national strategies and CEF investments. The NEAC model simulates and analyses multimodal trade flows between China and Europe. Based on this, the model helps to answer the following question: What is the impact of Eurasian rail freight on the transport network in Europe and what does this mean for TEN-T?

3.1.2 Methodology

The methodology is based on a succession of different steps. A global overview of the method of the NEAC model is shown in Figure 1.

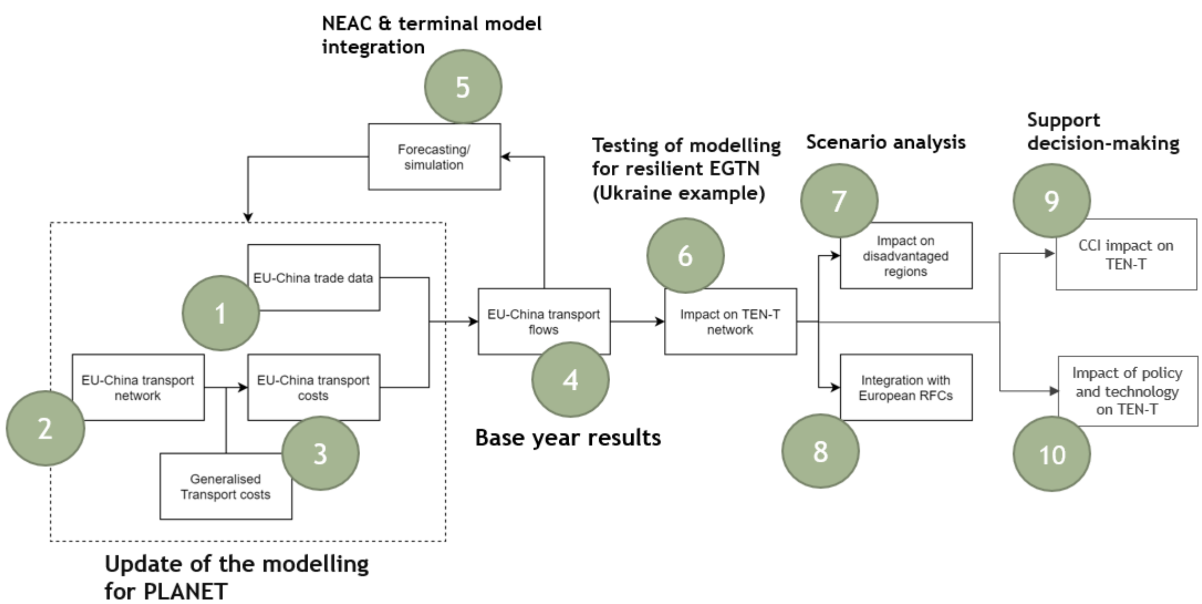

Figure 1: Overview of the method of the NEAC model for PLANET.

To meet the PLANET requirements, the model has been modified and extended in the following respects:

- A **trade dataset** of container flows between Europe and China was compiled as model input. This was done for the base year 2019, and for the future years 2030 and 2050. In the trade dataset, a breakdown by commodity group (NSTR classification) and commodity value has been made. The commodity value breakdown is crucial to simulate Eurasian rail transport. Under normal market conditions, the transport time is the most important factor why companies choose Eurasian rail transport over maritime transport.
- For the simulations, **an intercontinental transport network** has been established. This network consists of three parts, a European network, a Chinese network, and an intercontinental network connecting the European and Chinese networks. The European part of the network was already available in NEAC and has been expanded with current intermodal services. Both the Chinese and intercontinental network are newly added to the NEAC model. The intercontinental network is based on existing maritime services and existing Eurasian train services. As Principal Entry Nodes, the terminals, and seaports where these services enter are defined. Whereas the European network has a high level of detail to determine the impact on TEN-T at link level, the Chinese network has been added to the model at a more abstract level. For the 2030 and 2050 scenarios, the network has been expanded to include new Eurasian rail services and new PEPs where container train services are expected to come in from China.
- Finally, **generalised transport costs** have been defined. For Eurasian rail transport, a detailed cost model has been created consisting of various cost parameters, including most notably waiting time at borders, transit fees, wages, and track access charges. This level of detail makes it possible to simulate the influence of certain innovations that specifically affect one aspect of the transport system.

With a NEAC algorithm, the container flows are sent over the network. Due to the high level of detail in Europe, the exact routes that trade flows take can be identified. By analysing these routes, it is possible to determine the impact of the Eurasian rail freight flows on the transportation environment.

3.1.3 Current model status

The expansion of the NEAC model on the above points is completed. The NEAC model can simulate the impact of different scenarios on the European transport network.

Within task 1.2, we examine a baseline scenario for 2030 and 2050 (i.e., the most likely situation), and two alternative scenarios for 2030, namely a scenario with extra investments into rail transport, and a scenario in which the impact on disadvantaged regions is examined.

The model contains a multitude of input parameters that can be used to assess other scenarios, e.g., specific PLANET innovations. These parameters determine the capabilities and functionalities of the model. In essence, the NEAC model can be used to calculate the impact of innovations that influence either the generalised transport costs or the transport speed. Table 3 gives an overview of the generalised costs input parameters of the NEAC model which can be adjusted to calculate alternative scenarios considering impact of the technology & policy & legislation to these parameters. The technology impacts are calculated based on PI simulator.

Road
• Costs (Labour costs (driver wages incl. social costs and reimbursed expenses); Capital costs (costs of depreciation and interest cost of vehicle); Fuel costs (including excise duties); Other costs (insurance, road tax, repairs and maintenance, tire costs, overhead); Toll costs) • Speed • Load factor
Rail
• Costs (Labour costs (driver wages incl. social costs and reimbursed expenses); Capital costs (lease of locomotive and wagons, reserve material); Traction costs; Access charges; Other costs (insurance, repairs and maintenance, shunting, overhead, waiting)) • Speed • Load factor
Inland Waterway
• Costs (Labour costs (crew wages incl. social costs and reimbursed expenses); Capital costs (costs of depreciation, interest cost of vessel); Fuel costs; Other costs (insurance, repairs and maintenance, overhead) • Speed • Load factor
Sea
• Cost (Labour costs; Capital costs; Fuel costs; Other costs (insurance, repairs and maintenance, overhead)) • Ship rotations • Speed • Load factor
Transhipment
• Transhipment costs • Transhipment speed
Other Parameters
• Reliability per mode • Security per mode • Value of time per nstr1 commodity type • Attractiveness per terminal

Table 3: Generalised costs input parameters in the NEAC model

Qualitative results of the model

The NEAC freight model provides the following two key results for PLANET:

- Generalized costs information of multimodal transport chains between the origin and destination for different values of commodities
- The multimodal route that the container takes, including the transhipment points

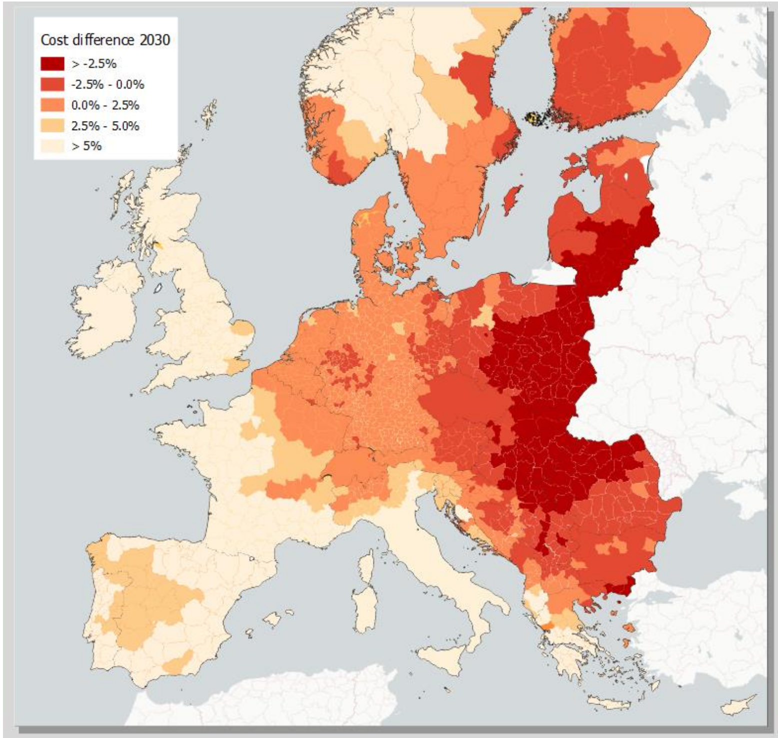

Figure 2: Example of NEAC model results.

As an example, Figure 2 represents the percentage difference in generalized costs in 2030 between rail transport and maritime transport from China to Europe for high value goods (> 15 €/KG), per nuts 3 region.

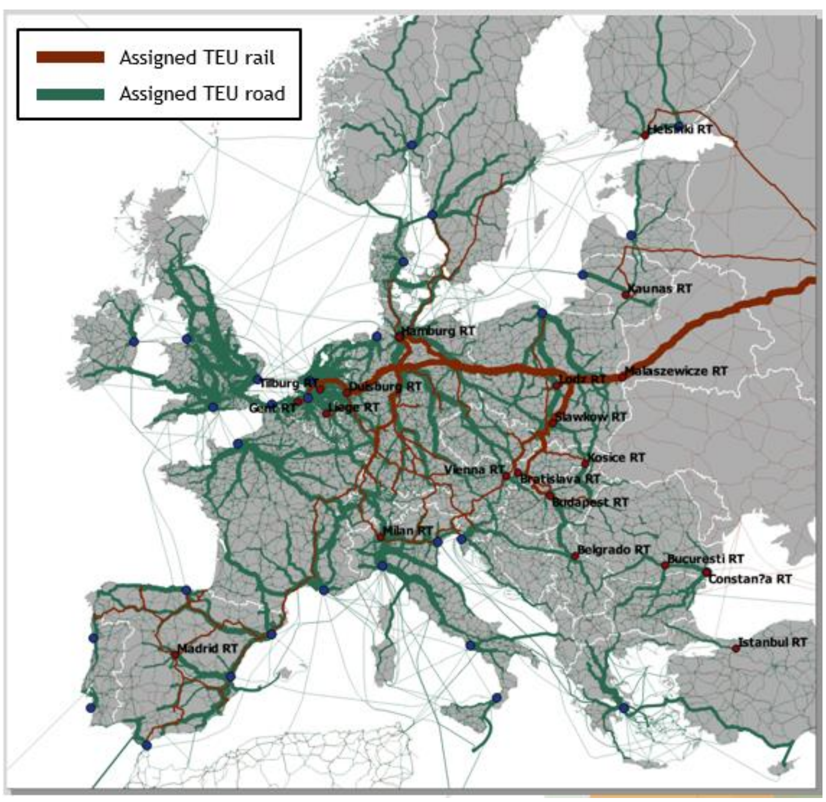

Figure 3: Example of NEAC model results: modelled network flows of containers.

In addition, the trade dataset can be adjusted as well as the transport network. For example, new intercontinental train services can be added, new routes or new PEP.

This model is used in T1.2 and in Living Lab 2. In addition, the model is used to calculate various task 1 innovations.

3.1.4 Ukraine war effect

In order to demonstrate the simulation capabilities developed under PLANET, the NEAC freight model was used to simulate the impact of the Ukraine war on rail freight between Europe and Asia.

Although Eurasian rail traffic is excluded from EU sanctions, volumes on this route dropped significantly. Estimates of the decline in volume in the months after the war started from the suspended rail services ranged from 50% to 80% year over year. Security concerns, uncertainties about insurance, blow-back from customers by using Russian rail lines and payment hurdles from sanctions were the main reasons behind the decline. As a result, congestion and delays on the New Silk Road dropped significantly due to the decreased demand for services on the main route between China and Europe.

Based on data in the NEAC model on Eurasian transport costs collected for PLANET, the economic impact of the suspension of Eurasian rail services was estimated. The economic impact was calculated by:

- The additional capital costs shippers pay due to different freight rates for sea and rail, and
- The extra costs due to the additional time it takes to ship goods from China to Europe by sea instead of rail (i.e., the value of time).

It was estimated that the transport sector collectively incurs an additional cost of € 46 million per month due to the current higher sea freight rates. In addition, the transport sector loses an estimated € 52 million a month in value of time due to the long transport time over sea compared to rail.

Based on output data from the NEAC model on network flows, it is also possible to identify the alternative routes by sea that containers are likely to take if they do not go by rail, in order to understand the resilience of the network. It was found that by far the largest share of containers is expected to transit via ports in the Hamburg - Le Havre range (67%). Some 9% pass through Mediterranean seaports and also some 9% through seaports in the Baltic Sea and Scandinavia.

In this way, the simulation capabilities developed in PLANET have proved useful for understanding the impact of a recent development, in this case, the war in Ukraine, on the European transport network.

3.2 EU Flow model

The EU flow model is a macro-level model that captures aggregate cargo movements within the European Union and considering Physical Internet Infrastructure availability. The model sets-up a single commodity network with predefined source and sink nodes and their associated supply and demand capacities respectively. Sources are then linked optimally to sink nodes considering the capacitated links available between various PI Nodes in the network. Links are associated to costs that arise form a generalized cost function.

3.2.1 Model requirements

This is a multi-modal single-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. The PI enabled nodes are represented as transhipment locations where multimodal terminals are available. The PI nodes are also associated to normalized trade inflow or outflow volumes, that represent the export and import flows 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 serviceability of the network.

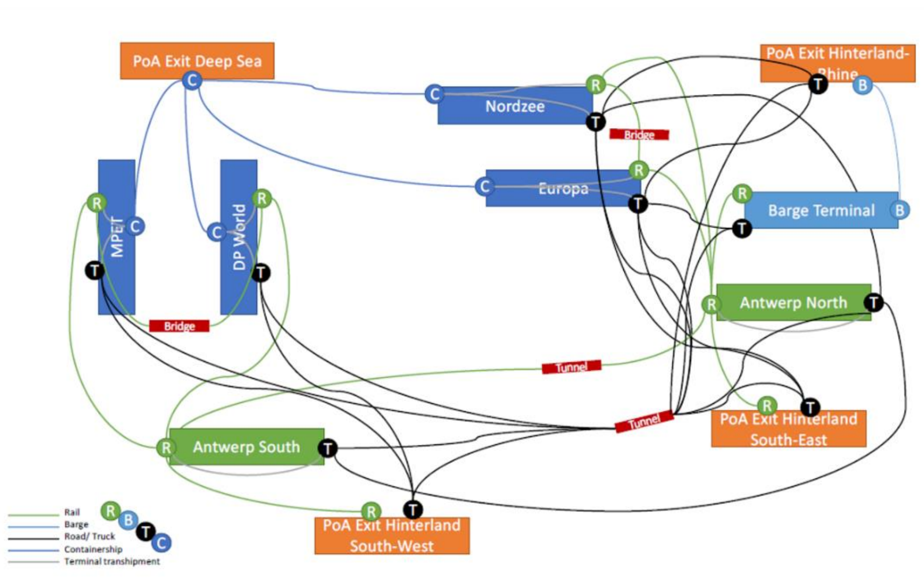

Figure 4: Example of PI Node (Mega-Hub) representation.

The figures capture the low aggregation of PI, that enables the accurate modelling of within the port cargo movement and transhipment costs, that have a significant impact on transhipment potential. The model can therefore be configured to quantify aggregate flows and how they are impacted by infrastructural and operational improvements in the network. The model can also be utilized for performing a stress test of the network and quantifying the criticality of various components. Finally, it utilizes a flow assignment algorithm able to quantify network performance in terms of various KPIs. This insight becomes valuable when analysing budgeted infrastructure investments, in terms of their impact to various stakeholders.

3.2.2 Methodology

The model assumes a transportation network of PI Nodes and capacitated multi-modal links connecting them, based on the TEN-T. Each node is associated to a positive or negative trade-balance classifying them into source or sink nodes. A flow assignment algorithm is used to quantify the total cost to satisfy demand, which is used as a proxy for network performance. The multiple KPIs considered in the generalized cost function for the model, enable the integration of Multi-Actor Multi-Criteria Analysis and the per stakeholder criteria assessment. Node or link characteristics can be altered to examine what-if scenario for investments, or disruptions. In the case of disruptions, each link is sequentially disrupted to zero throughput capacity, to quantify its overall significance to the whole network.

3.2.3 Current model status

The model is used to quantify the overall performance of the network under various operational conditions. Its flexibility to analyse both single commodity cases, or aggregated trade flows, while adapting infrastructures available for satisfying demand, enables the analysis of both budgeted investments as well as dynamic component criticality.

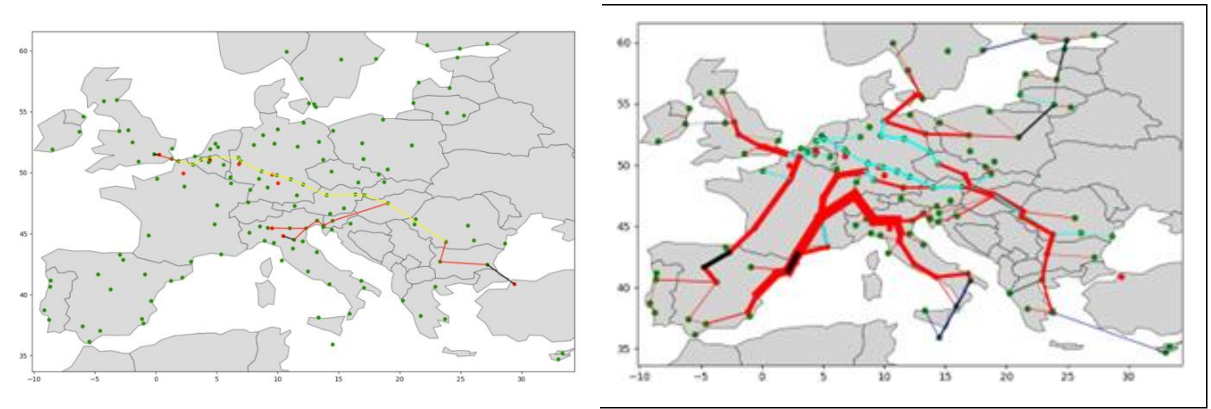

Figure 5: Example of applications on infrastructure investment, and disruption criticality.

This model is also used to identify through a critical (for EU flows serving) network analysis along the TEN-T in order to identify the priority TEN-T functional corridors along which PI technologies should be implemented to guarantee smooth operations and efficiency of the TEN -T. The output of this model will be considered by the strategic NEAC models as a technology driven scenario for the TEN -T development in time horizons 2030 & 2050.

3.3 Physical Internet Network Simulator

This model is used to evaluate the physical internet behaviour in different multimodal transport networks. In this case, it is applied to the evaluation of the PI network, including entry nodes such as ports and warehouses in the Iberian transport network.

3.3.1 Model requirements

The main requirement of this model is to evaluate how the impact of PI concepts in combination with new technologies (IoT, AI, BC) can improve the processes, operations, and efficiency of transport chains between China and the EU. In particular, the objective is to simulate and evaluate the impact that different combinations of these technologies and concepts have on containerized cargo flows between China and Spain.

The main questions answered by this model are: What's the impact of applying PI concepts in a multimodal transport network? How different technologies affect cost-effectiveness, quality of service, or environmental impact?

3.3.2 Methodology

Firstly, the current operations and processes of the transport chains between China and Spain have been studied. Based on the information provided by several logistics operators, process diagrams have been drawn up for each of the relevant elements that compose these chains (operations in maritime terminals, transport processes by road, rail, or ship).
Secondly, on the current process diagrams, the operations, or processes where the different technologies or concepts to be evaluated can generate an impact have been identified. An example is shown in Figure 6.

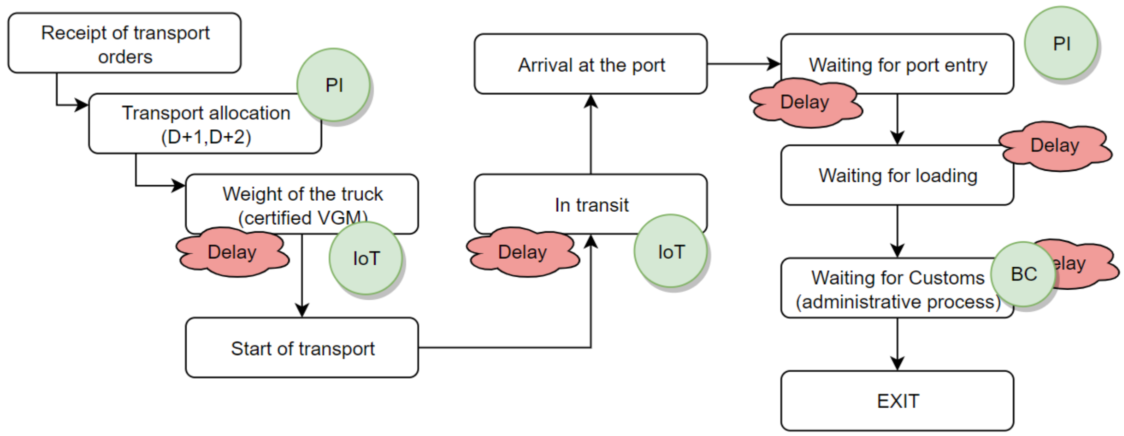

Figure 6: Process diagram of road transport.

Thirdly, the simulation model was developed using Agent Based Modelling (ABM) techniques, matching the behaviour of the agents in the simulation model to the process diagrams collected previously.

Fourth, a rules engine has been designed to modify the behaviour of each of the agents in particular and the transport chains in general, depending on the level of adoption of the new technologies and concepts.

Finally, an input and output data template has been designed so that the simulation model allows users to explore the results under different configurations or scenarios.

3.3.3 Current model status

The main view of the model is shown in Figure 7. On the left-hand part of the image is the map where the different PI nodes are located and where the different transport flows (road, railway and maritime) can be visualised. There is also a panel to dynamically activate or deactivate the effect of the different technologies and concepts through checkboxes. On the right side, the main statistics calculated by the simulation model are shown. These include the number of containers delivered on time, the lead time histogram of the containers, or the distances, emissions, and modal split of the main modes of inland transport.

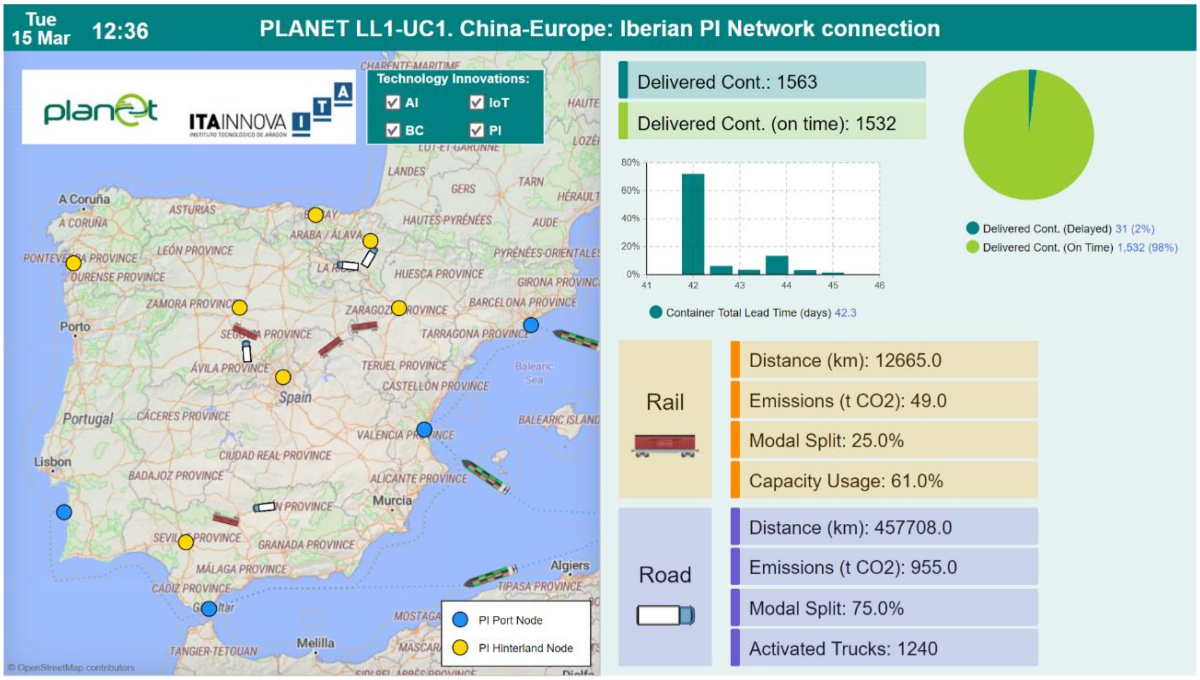

Figure 7: Main view of the PI Network Simulator.

As mentioned above, the model has been built using multi-agent simulation techniques. The main agents of the model are:

- PI Nodes: the nodes in the PI network represent the places (port terminals, warehouses...) where goods are stored, transferred or handled between movements in the network. In the model, the main nodes are maritime terminals (PI Port Node) and inland warehouses (PI Hinterland Node). The properties that define a PI Node are unique identifier, position (latitude and longitude), name and type of node (sea terminal or warehouse).
- PI Containers: the container is fundamental for the Physical Internet; it is the metaphor of the Digital Internet. By analogy with data packets, the goods are encapsulated in intelligent containers of easy-to-interconnect modular dimensions, called PI Containers, designed to flow efficiently in hyperconnected networks of logistics services. The properties that define a PI Container are unique identifier, origin node, destination node (both destination port and hinterland port), day on which the container is available at the origin node and contractual due time.
- PI Transports: transports move or handle containers within and between nodes in the PI network. In the model, the main types of transport are trucks, trains, and ships, which are defined by the following properties: unique identifier, name, speed, capacity and emissions.
- PI Services: this agent defines the transport services operating in the PI network. Each service has its own characteristics, such as the origin and destination nodes, the frequency and schedules, the type of transport that performs it or the route it follows.

These agents have their own states, can make intelligent decisions, communicate with each other, or respond to changes and parameters. An example of the state chart for a PI Transport (train type) is shown in Figure 8:

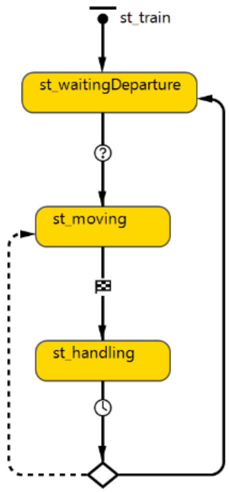

Figure 8: PI Transport agent (train type) state chart.

The agent can be in a certain state (yellow blocks) and may change its state when a transition (black arrows) is triggered. This can happen when a certain time elapses, when the agent reaches its destination, when a certain condition is met or when a message is received from another agent.
Through parameters and functions within each of the blocks and transitions, several rules have been implemented. They allow changing the behavioural logic of the agents according to the technologies or concepts whose impact is to be analysed. In particular, the following parameters can be configured:

- Artificial Intelligence (AI): AI decision system selects the best port for container unloading according to port call costs. It can take the values 0 (low) o 1 (high).
- Blockchain (BC): Blockchain technology brings greater agility in inspection operations at the port of destination and reduces the number of containers that must pass through customs, due to increased transparency and credibility in the supply chain. It can take the values 0 (low) o 1 (high).
- Internet of Things (IoT): IoT technology provides greater visibility and traceability of goods throughout the supply chain. It can take the values 0 (low) o 1 (high).
- Physical Internet (PI): when a PI strategy is adopted, each container makes autonomous decisions at each node (next destination node, next means of transport to the next node...), prioritising collaboration between agents in the supply chain and the use of more efficient and less polluting means of transport. It can take several adoption values (0%, 20%, 50%, 100%).

The model receives as input data the information of nodes, containers, transports, and services through a data template. An example of input data for PI Nodes is shown in Figure 9.

node_id	node_name	node_lat	node_lon	node_type
0	Shanghai	31,2219444	121,4894444	0
1	Valencia	39,4697500	-0,3773900	0
2	Barcelona	41,3450000	2,1416700	0
3	Zaragoza	41,6447000	-0,9720000	1
4	Madrid	40,4167061	-3,7035825	1
5	Algeciras	36,1310806	-5,4487057	0
6	Bilbao	43,2630043	-2,9349916	1
7	Sevilla	37,3886299	-5,9953403	1
8	Pamplona	42,8168700	-1,6432300	1
9	Valladolid	41,6521339	-4,7285619	1
10	Pontevedra	42,4298860	-8,6446200	1
11	Sines	37,9499962	-8,8666632	0

Figure 9: Input data template for PI Nodes.

Through the parameters and input data, different configurations or scenarios of the models can be performed and "what if" questions can be solved. In addition, an important functionality of the model is that it allows running parameter variation experiments (Figure 10), so that the isolated or combined impact of various technologies can be analysed. Finally, this model is used to evaluate different scenarios in Living Lab 1.

idSim	PI (Physical Internet)	AI (Artificial Intelligence)	IoT (Internet of Things)	BC (Blockchain)	Delivered Containers	Delivered Containers (On Time)	% Containers Delivered On Time	Container Average Lead Time (days)	Rail Distance (km)	Rail Emissions (t CO2)	Rail Modal Split (%)	Rail Capacity Usage (%)	Road Distance (km)	Road Emissions (t CO2)	Road Modal Split (%)	Road Activated Trucks	Total Distance (km x 10e6)	Total Emissions (t CO2)
0	0	0	0	0	3500	2741	78%	43,0	29850	35	9,5	20	1636058	3427	90,5	3166	1,7	3462
1	0	1	0	0	3500	2652	76%	43,6	22410	33	9,5	24	1197844	2517	90,5	3166	1,2	2550
2	0	0	0	1	3500	2744	78%	43,0	23377	34	9,5	25	1636058	3427	90,5	3166	1,7	3461
3	0	1	0	1	3500	2661	76%	43,6	18831	33	9,5	28	1197844	2517	90,5	3166	1,2	2550
4	0	0	1	0	3500	3264	93%	42,1	27159	35	9,5	22	1632775	3420	90,5	3166	1,7	3455
5	0	1	1	0	3500	3311	95%	42,0	20149	32	9,5	26	1197844	2517	90,5	3166	1,2	2549
6	0	0	1	1	3500	3266	93%	42,1	21148	34	9,5	27	1636058	3427	90,5	3166	1,7	3461
7	0	1	1	1	3500	3322	95%	42,0	16276	32	9,5	31	1197844	2517	90,5	3166	1,2	2549
8	20	0	0	0	3500	2853	82%	43,0	38670	74	19,5	32	1140166	2393	80,5	2819	1,2	2467
9	20	1	0	0	3500	2701	77%	43,7	32101	69	19,5	35	1060377	2227	80,5	2819	1,1	2296
10	20	0	0	1	3500	2852	81%	43,0	31973	74	19,5	38	1140166	2393	80,5	2819	1,2	2467
11	20	1	0	1	3500	2711	77%	43,7	29273	69	19,5	38	1060377	2227	80,5	2819	1,1	2296
12	20	0	1	0	3500	3343	96%	42,1	33620	74	19,5	36	1140166	2393	80,5	2819	1,2	2467
13	20	1	1	0	3500	3337	95%	42,1	29016	68	19,5	38	1060377	2227	80,5	2819	1,1	2295
14	20	0	1	1	3500	3341	95%	42,1	28032	74	19,5	43	1140166	2393	80,5	2819	1,2	2467
15	20	1	1	1	3500	3350	96%	42,1	25947	68	19,5	42	1060377	2227	80,5	2819	1,1	2295
16	50	0	0	0	3500	2894	83%	43,1	47174	105	27,7	37	1024948	2151	72,3	2530	1,1	2256
17	50	1	0	0	3500	2708	77%	43,8	38067	97	27,7	41	957832	2011	72,3	2530	1,0	2108
18	50	0	0	1	3500	2895	83%	43,1	39470	105	27,7	43	1024948	2151	72,3	2530	1,1	2256
19	50	1	0	1	3500	2718	78%	43,8	36646	97	27,7	43	957832	2011	72,3	2530	1,0	2108
20	50	0	1	0	3500	3357	96%	42,2	40859	105	27,7	42	1024948	2151	72,3	2530	1,1	2256
21	50	1	1	0	3500	3313	95%	42,3	35712	97	27,7	43	957832	2011	72,3	2530	1,0	2108
22	50	0	1	1	3500	3355	96%	42,2	34679	105	27,7	49	1024948	2151	72,3	2530	1,1	2256
23	50	1	1	1	3500	3329	95%	42,3	34889	97	27,7	44	957832	2011	72,3	2530	1,0	2108
24	100	0	0	0	3500	2921	83%	43,3	54506	144	37,5	44	883624	1858	62,5	2188	0,9	2002
25	100	1	0	0	3500	2699	77%	44,3	48726	132	37,5	43	825332	1737	62,5	2188	0,9	1869
26	100	0	0	1	3500	2918	83%	43,3	47052	143	37,5	50	883624	1858	62,5	2188	0,9	2001
27	100	1	0	1	3500	2712	77%	44,3	48071	132	37,5	44	825332	1737	62,5	2188	0,9	1869
28	100	0	1	0	3500	3342	95%	42,5	52289	144	37,5	46	883624	1858	62,5	2188	0,9	2002
29	100	1	1	0	3500	3280	94%	42,7	47178	132	37,5	44	825332	1737	62,5	2188	0,9	1869
30	100	0	1	1	3500	3339	95%	42,5	45802	144	37,5	51	883624	1858	62,5	2188	0,9	2002
31	100	1	1	1	3500	3293	94%	42,7	45836	132	37,5	46	825332	1737	62,5	2188	0,9	1869

Figure 10: Parameters variation experiment.

3.4 Business Process Simulation

Based on state of the art, a huge potential for the development and optimization of logistics processes within the Asian-European corridor is noted. Accordingly, Living Lab 3 set out to test solutions for technological and process innovation in collaboration with business partners - operator Rohlig Suus and postal carrier Polish Post.

Business Process Simulation in LL3 will focus on examining improvements of logistic processes in flows from China to Europe along the Silk Road Route by implementation of IoT technologies and EPCIS platform as well as other GS1 standards that facilitate transmission of data between the partners involved in the logistics operations within the e-commerce channel.

3.4.1 Model requirements

Research work is carried out with the usage of the methodology developed by the Łukasiewicz Research Network - Poznań Institute of Technology. The methodology of optimizing business processes is in accordance with BPMN 2.0. standard (Business Process Model and Notation)- currently the most popular tool for describing business and production processes. The standard is described in ISO/IEC 19510: 2013 Information technology - Object Management Group. This standard allows us to correctly map the processes taking place in the organization in order to analyse the operations performed, their duration, events, and used resources. Thanks to this, it is possible to quickly and precisely detect areas of potential improvement, and apply corrective actions, which will allow the development of a new, improved model of the process functioning. Most often, it results, in the reduction of operating costs, the elimination of bottlenecks, the improvement of work efficiency as well as the effectiveness and efficiency of the processes implemented in the organization.

It also helps to identify:

- Workflow and information flow,
- IT systems supporting processes,
- workload of employees supporting the processes,
- duration and capacity of the processes,
- activities that do not bring any added value and increase the probability of errors and mistakes,
- gaps detected in the flow of information,
- a manual work, which can be replaced or supported by the use of IT solutions, RFID Technology, GS1 Standards etc.

The process approach is about measuring performance and seeing and solving problems through continual improvement. During process modelling, the scope of duties and responsibilities are clearly mapped and allocated to the business roles that perform them. Identification, analysis, and optimization focus on factors such as resources, methods, and materials that improve key activities.

The process approach adopted in ISO 9001 is based on the fact that the requirements applied relate to the processes implemented in the organization, which defines the scope of the quality management system application - the quality system is related to both core-business processes and auxiliary processes. This allows avoiding problems with determining the area of activity of a given organization and the scope of application of the quality management system.

Living Lab set two main goals for Business Process Simulation:

1. **Examining changes in the Rohlig Suus business processes thanks to increased visibility of goods by IoT implementation along the New Silk Road**

Development of IoT solutions based on DASH7, RFID, LPWSN and sensors systems that help control resource parameters in real time and identify them while moving in the transport process, examining potential positive results in terms of broad implementation

2. **Examining changes in the Polish Post business processes thanks to implementation of the EPCIS and standardization of information flow**

Creation of a digital connection between actors in the transport network, enabling standardized data flow and access to information about cargoes coming from China to Poland in the whole supply chain in real time (EPCIS test)

3.4.2 Methodology

As part of the Living Lab preparation activities, a workshop was held with key business partners to identify all business processes related to logistics for New Silk Road operations. With a complete state-of-the-art understanding, an AS-IS map of the situation was created. In the next step, operations with potential for improvement by implementing innovative solutions were identified. In this way, TO-BE maps were created. The full methodology of the business process mapping and modelling approach is presented below.

One of the ways to verify correctness and completeness at the information flow management model is to make tests in an IT modelling environment and simulation. Modelling of processes and variety of information flow, algorithmizing of decision-making functions in processes enable multi-dimensional studies of scenarios for managing the flow of information in the supply chain along the New Silk Road.

The created model should be treated by others as a tool that allows to learn and understand a certain fragment of reality and to conduct experiments and simulations.

In specialist literature as in business practise there are a lot of different ways to show processes in supply chain for analytical purpose. Simulation methods take into account the passage of time and the variability of control parameters, therefore they seem appropriate for the presentation of the dynamics of processes. Analysing the problems of simulation in logistic processes, should be created a list of several factors which are influence on conduct of simulation. Figure 11 shows the classic design of the multiple simulation process.

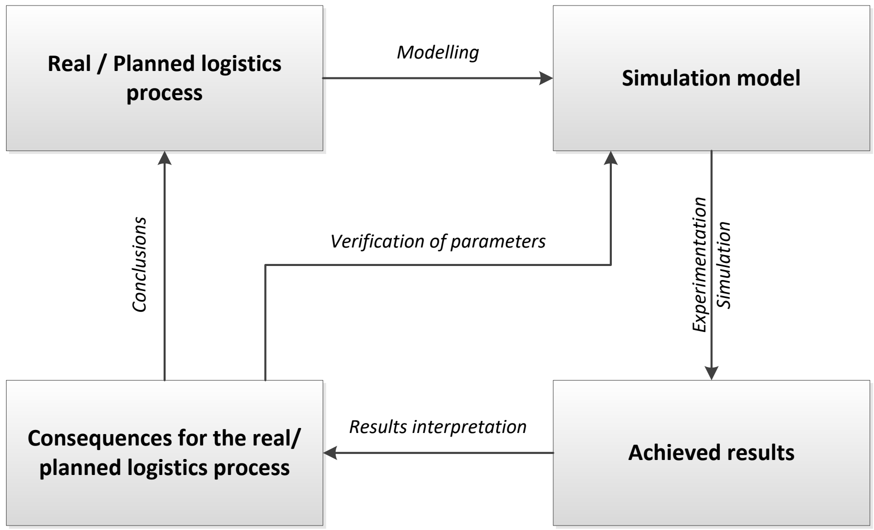

Figure 11: The classic design of the multiple simulation process.

Conducting a simulation enables the analysis of the process in terms of various variants, which are verified in a virtual way, i.e., in a way that does not affect the operation of the process in real time. However, based on well-developed control parameters, consistent with the actual state, it is high probable that the analysed process variant has a chance to be implemented in the economic reality. Each simulation requires some basic rules:

- in the case of complex processes of simulation, it is necessary to select a simulation tool and more accurately model the analysed process, define the input data and define the strategy,
- in the case of flexible processes of simulation, it is necessary to frequently change the values of the control parameters,
- when analysis is based on average values of parameters, it carries the risk of incorrect interpretations,
- the simulation must be provided at the appropriate time, to get the most benefits.

Research methodology in the field of process analysis

The process analysis is 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 chosen company in order to obtain comprehensive data that are necessary for analyse 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 – agreeing with the ordered KPIs (Key Performance Indicators), with particular emphasis on the service time of logistic processes within the New Silk Road and the percentage use of personnel resources. As a result, will be created AS IS simulation models, which will be a reference point for the target process.
4. Simulation of the models created in action 3 and then, based on the results, identification of process areas representing optimization potential, such as:
   - process bottlenecks,
   - activities that do not bring added value, that increasing the probability of errors and mistakes,
   - gaps in the information flow,
   - manual work that can be replaced or reduced by applying identification solutions.

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

1. Construction and simulation of target models for the functioning of processes, considering the recommendations developed during the implementation of the first stage and assuming the use of the proposed technological solutions – modelling of TO BE processes (in accordance with the BPMN 2.0 standard).
2. Conducting simulations of the developed process models, allowing to forecast the level of reduction of task completion time because of the implementation of new identification solutions (GS1 standards, IoT solutions), compared to the initial values.
3. Determining the values of the Key Performance Indicators (KPI) agreed with the Client for the current and target status, which will allow for a parameterized assessment of the effectiveness of the target concept.
4. Agreeing with the client about the target concept, at the management and operational level.
5. Sharing the visualization of the base and target concept. Process maps and models in the AS IS and TO BE versions, reports on process simulations as well as comments and comments collected during the process study will be available in the process repository.
6. Preparation of a proposal of the scope of information necessary to be placed on information dashboards, based on the identified needs for information flow, both from the point of view of operational employees and management staff.
7. Preparation the report considering in synthetic way the results and conclusions resulting from the project implementation.

3.4.3 Current model status

Envisioned physical flows in the Living Lab 3 from a bird's eye view are shown below (AS-IS model). The areas where the change will occur in the next steps are highlighted in yellow:

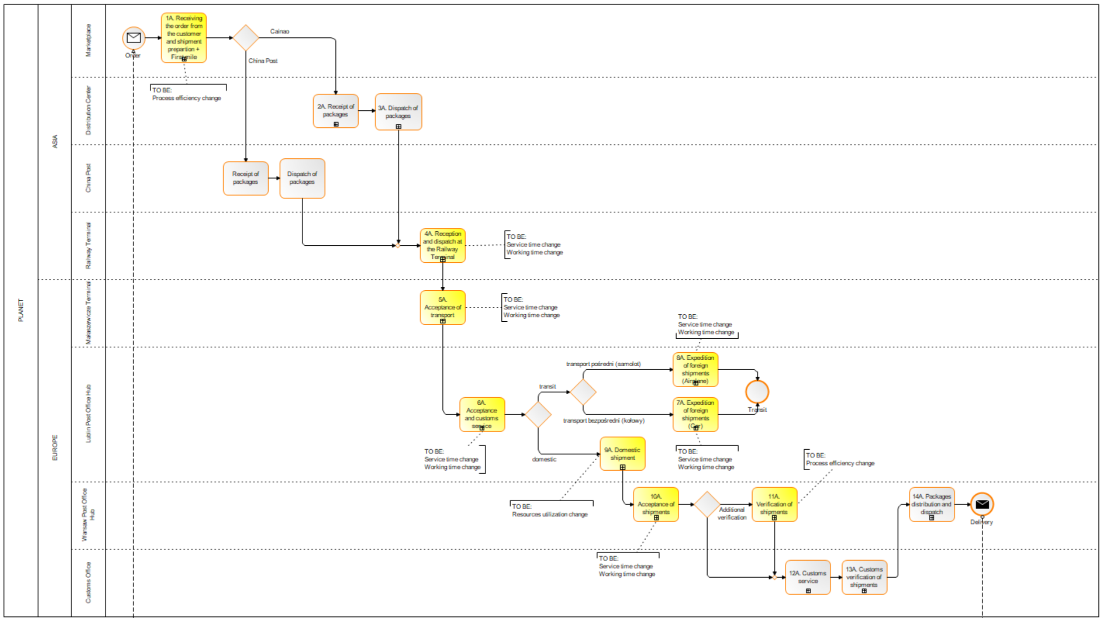

Figure 12: Polish Post Use Case.

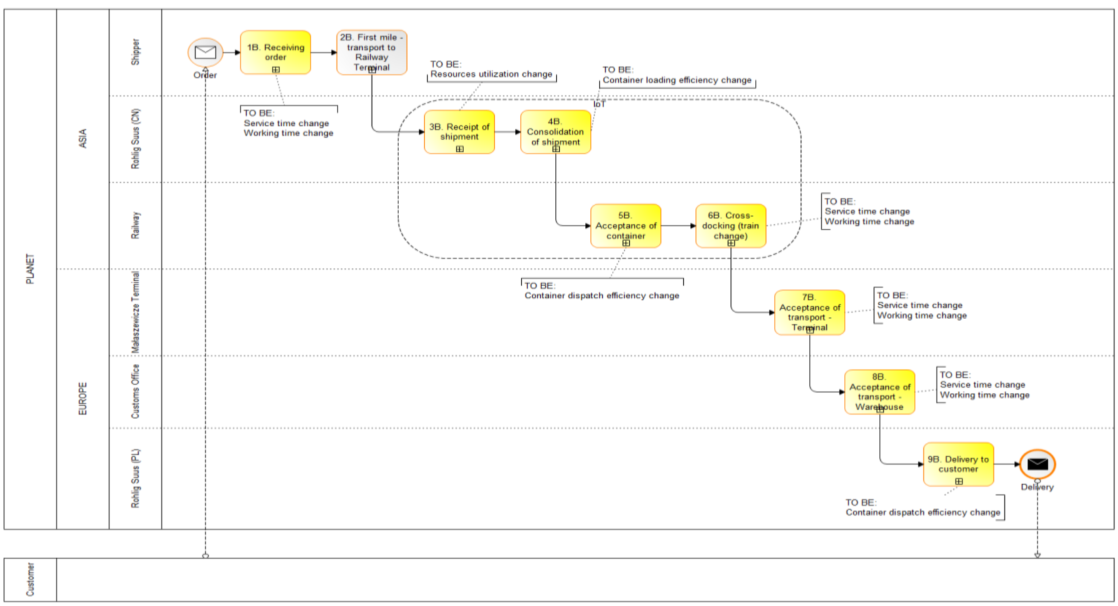

Figure 13: Rohlig Suus Use Case.

The above diagrams are the basis for creating the TO-BE model and simulating changes in KPIs, which will be presented after testing in LL3.

3.5 Last mile delivery model

The last mile delivery model is a microscopic simulation model to assess the impact of collaborative transport strategies on last mile deliveries.

3.5.1 Model requirements

The main requirement of this model is to specify and test a PI network including city-hubs, based on simulation, and using the EGTN architecture designed in WP2. It has a strategic focus on urban logistics and commitment to the Physical Internet vision, integrating the last mile to end-to-end supply chains particularly operating under PI principles.

The current state of the model allows users to make decisions based on the results of applying what-if scenarios. Some questions that the model helps to solve are the following:

- What if I adopt a Physical Internet strategy where I share my resources with another company and collaborate in the delivery of their orders? Will the fill rate of my vehicles improve?
- What if I increase the fleet of vehicles to absorb more demand? Will it be profitable?
- What if I establish a new hub in the city centre? Will I complete more orders on time?
- What if I promote the use of electric vehicles? Will I be more sustainable while maintaining or improving my current performance?

3.5.2 Methodology

First, the current operations and processes of last mile distribution have been studied, including a review of the most common available or exchanged information by logistics operators.
Secondly, based on this information, a data model has been developed on which to collect standardized information from different logistics operators. This data model includes information on orders, hubs, transports, and others.
Thirdly, the simulation model has been developed using Agent Based Modelling (ABM) techniques, matching the behaviour of the agents in the simulation model to the current last mile distribution processes.
Finally, an input and output data template has been designed, so that the simulation model allows users to explore the results under different configurations or scenarios.

3.5.3 Current model status

The main view of the simulation model is shown in Figure 14. In the picture, the orders grouped by routes and the movement of vehicles during delivery are displayed. Figure 15 shows the stats panel where the statistics collected dynamically during the simulation are gathered and displayed. It shows general statistics (distance travelled, emissions, costs), orders statistics (orders completed on time, time plot of completed orders, lead time histogram), tours statistics (average distance and time histograms) and transports statistics (fill rate, time plot of active transports).

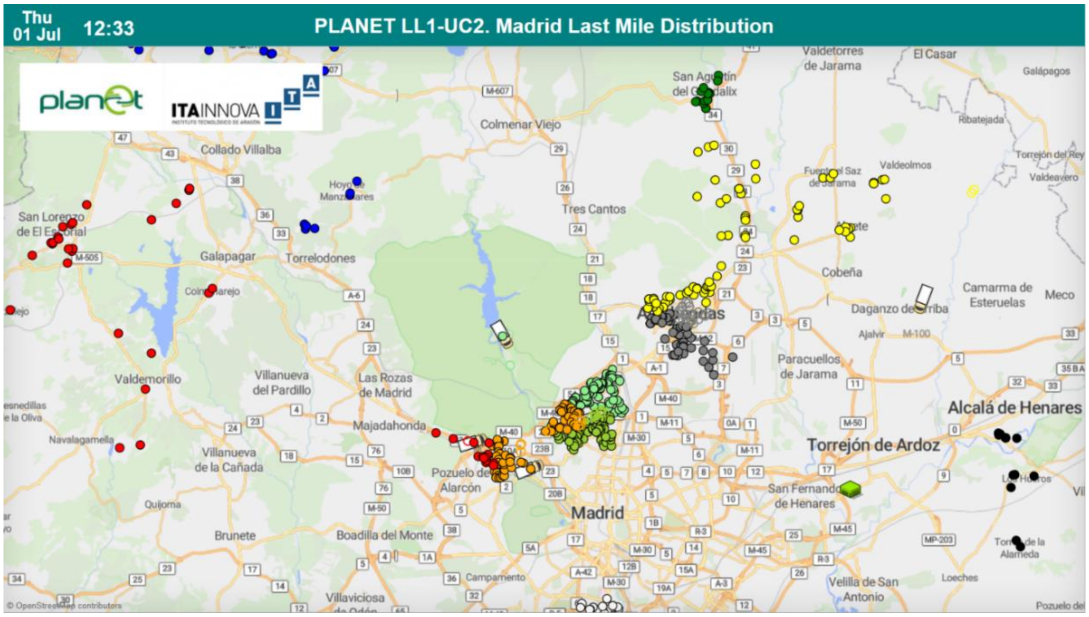

Figure 14: Main view of the last mile delivery model.

Figure 15: Stats panel of the last mile delivery model.

As mentioned above, the model has been built using multi-agent simulation techniques. The main agents in the model are:

- Hubs: hubs are the logistic nodes from where vehicles and orders depart. The properties that define a hub are its unique identifier, name, position (latitude and longitude) and time.
- Orders: orders are the customer demand. The properties that define an order are its unique identifier, position (latitude and longitude), delivery time window, number of packages, weight, departure hub and assigned tour.
- Tours: tours are the different routes that vehicles travel to complete orders. The properties that define a tour are its unique identifier, assigned vehicle and departure time.
- Transports: transports travel the routes delivering and picking up orders. The properties that define a transport are its unique identifier, capacity (weight and volume), speed, costs (activation, distance, time...) and emissions.

These agents have their own states, can make intelligent decisions, communicate with each other or respond to changes and parameters. An example of the state chart for a delivery vehicle (Transport agent) is shown in Figure 16:

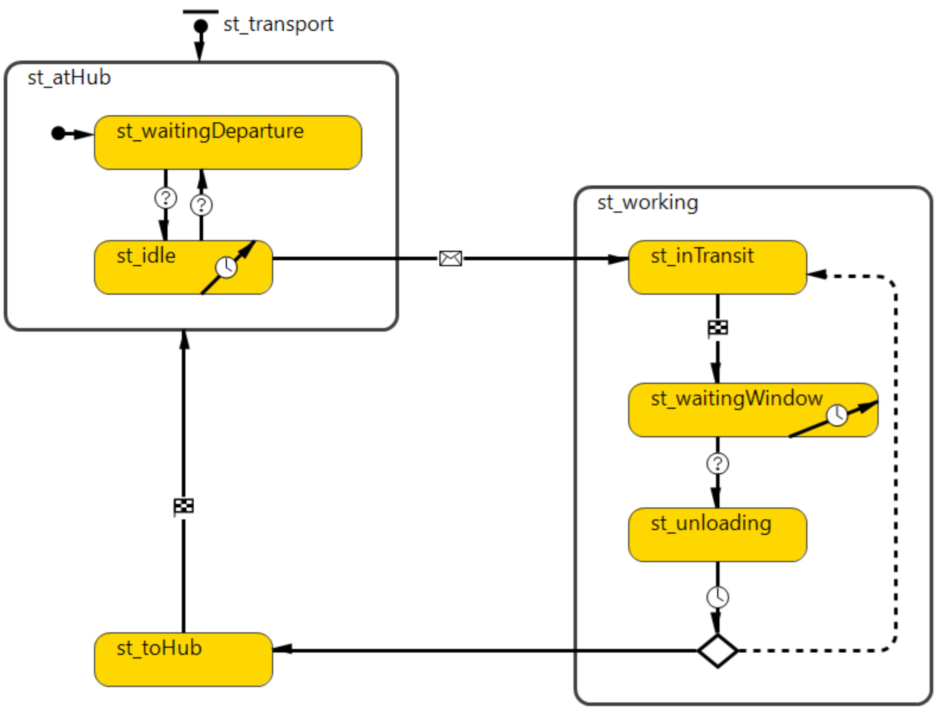

Figure 16: Transport agent state chart.

The agent can be in a certain state (yellow blocks) and change state when a transition (black arrows) is triggered. This can happen when a certain time passes, when the agent reaches its destination, when a certain condition is met or when a message is received from another agent.

The model receives as input data the information and properties of each of these agents through a data template. An example of input data for orders is shown in Figure 17.

order_id	order_mode	order_idhub	order_lat	order_lon	order_earlytime	order_latetime	order_servicetime	order_items	order_weight
0	delivery	0	40,180669	-3,709061	09:00	21:00	5	6	79,00
1	delivery	0	40,211365	-3,583947	09:00	21:00	5	5	65,00
2	delivery	0	40,210577	-3,583877	09:00	21:00	5	7	65,00
3	delivery	0	40,210577	-3,583877	09:00	21:00	5	6	60,00
4	delivery	0	40,203720	-3,582040	09:00	21:00	5	10	51,65
5	delivery	0	40,207770	-3,575340	09:00	21:00	5	4	51,00
6	delivery	0	40,210445	-3,569476	09:00	21:00	5	3	49,00
7	delivery	0	40,210445	-3,569476	09:00	21:00	5	4	48,19
8	delivery	0	40,212069	-3,574136	09:00	21:00	5	6	47,20
9	delivery	0	40,212708	-3,573695	09:00	21:00	5	7	42,58
10	delivery	0	40,213519	-3,575775	09:00	21:00	5	6	41,75

Figure 17: Input data template for orders.

In addition to being able to visualize the statistics dynamically, at the end of each run, the simulation results are exported to a results file. In this file, global and detailed statistics are collected for each order, tour and transport. An example of a results table for each of the tours is shown in Figure 18.

tour_id	tour_idtransptype	tour_start_timestamp	tour_end_timestamp	tour_distance_km	tour_drivingtime_min	tour_servicetime_min	tour_timetotal_min
0	3	2021-07-01 08:22:00	2021-07-01 11:36:26	13,09	60,44	132	192,44
1	3	2021-07-01 08:48:00	2021-07-01 10:28:57	15,11	69,76	30	99,76
2	2	2021-07-01 08:44:00	2021-07-01 13:59:31	29,06	134,12	180	314,12
3	3	2021-07-01 12:58:00	2021-07-01 14:54:51	11,23	51,85	65	116,85
4	2	2021-07-01 08:50:00	2021-07-01 16:13:28	15,3	70,59	138	208,59
5	2	2021-07-01 08:56:00	2021-07-01 14:47:38	18,51	85,41	83	168,41
6	3	2021-07-01 12:59:00	2021-07-01 14:37:18	7,87	36,31	62	98,31
7	2	2021-07-01 08:52:00	2021-07-01 13:52:27	17,07	78,78	101	179,78
8	2	2021-07-01 08:53:00	2021-07-01 14:13:48	11,48	52,98	88	140,98
9	3	2021-07-01 12:48:00	2021-07-01 15:04:23	15,56	71,81	63	134,81
10	3	2021-07-01 08:45:00	2021-07-01 13:49:29	12,17	56,18	63	119,18

Figure 18: Tours results table.

3.6 PI Warehouse model

This warehouse model allows different scenarios to be simulated in which several waves of picking orders enter the warehouse, allowing the results to be compared between a traditional warehouse and one that works as a PI node. It has a data model to synchronize orders from different companies in the traditional warehouse that in a PI-hub would work collaboratively, so that the user can obtain data on how aspects such as time, cost, energy consumption or distance travelled would improve.

3.6.1 Model requirements

The main requirement of this model is to assess how operations and processes within a warehouse are affected when PI concepts are applied in combination with new technologies such as AI. Specifically, the model makes it possible to compare the picking operation when using a normal warehouse and a collaborative warehouse.

The main question answered by this model is: What's the impact of applying PI concepts in terms of costs and energy consumption in a warehouse?

3.6.2 Methodology

A methodology has been followed in order to assess the impact of collaborative operations within a distribution centre functioning as an PI node.

First, the operations and processes that occur within a conventional warehouse were studied. In particular, the operations and data of a DHL warehouse were studied and used as the basis for the model.

Secondly, with the information obtained, a data model was proposed to be introduced into the simulation model with the picking orders to carry out, considering two scenarios, a non-collaborative warehouse and a collaborative one. It includes order information with the items to be picked.

Thirdly, the simulation model was based on both the appearance of the DHL warehouse and the data model proposed. The simulation model was developed by combining Discrete Events and Agent Based Modelling techniques.

Finally, an input and output data template has been designed, so that the simulation model allows users to explore the results under different configurations or scenarios. In the inputs, the user can enter the picking orders of his company and compare, applying or not, synchronisation of these orders, seeing the results in terms of cost, time and energy consumption. Also, the results of every picker are available.

3.6.3 Current model status

The main view of the simulation model is shown in 2D in Figure 19 and in 3D in Figure 20. In the picture, the warehouse with its shelves, forklifts and different products are displayed. The colours of the products indicate their family.

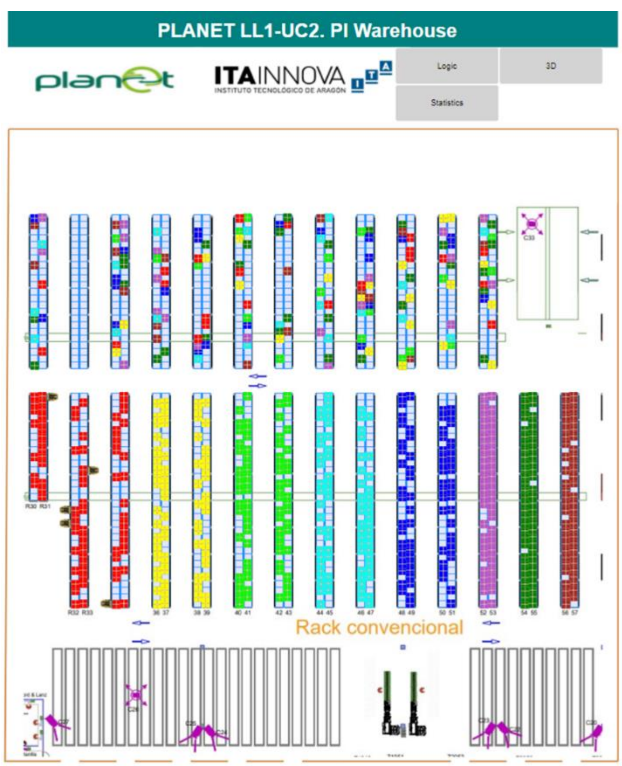

Figure 19: Main 2D view of the PI warehouse model.

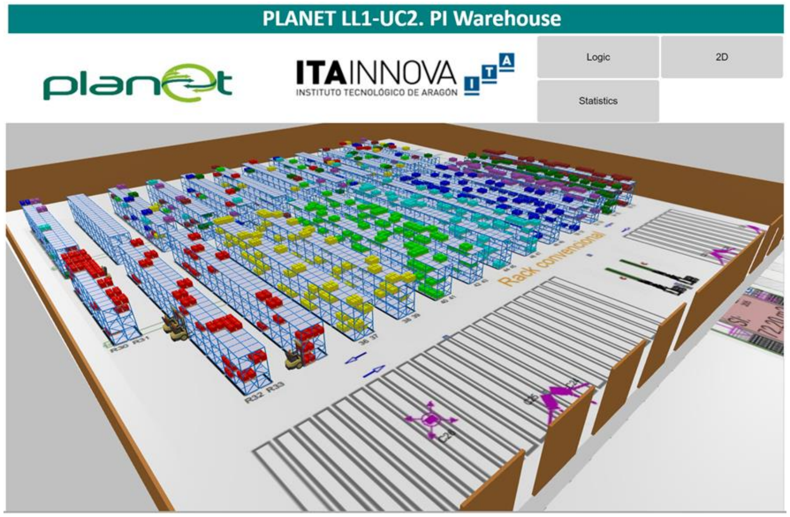

Figure 20: Main 3D view of the PI warehouse model.

Figure 21 shows the panel where the simulation statistics are dynamically collected. It shows general statistics such as occupancy, the time of each order in a histogram, the total cost, or the average available and occupied time of the picking agents.

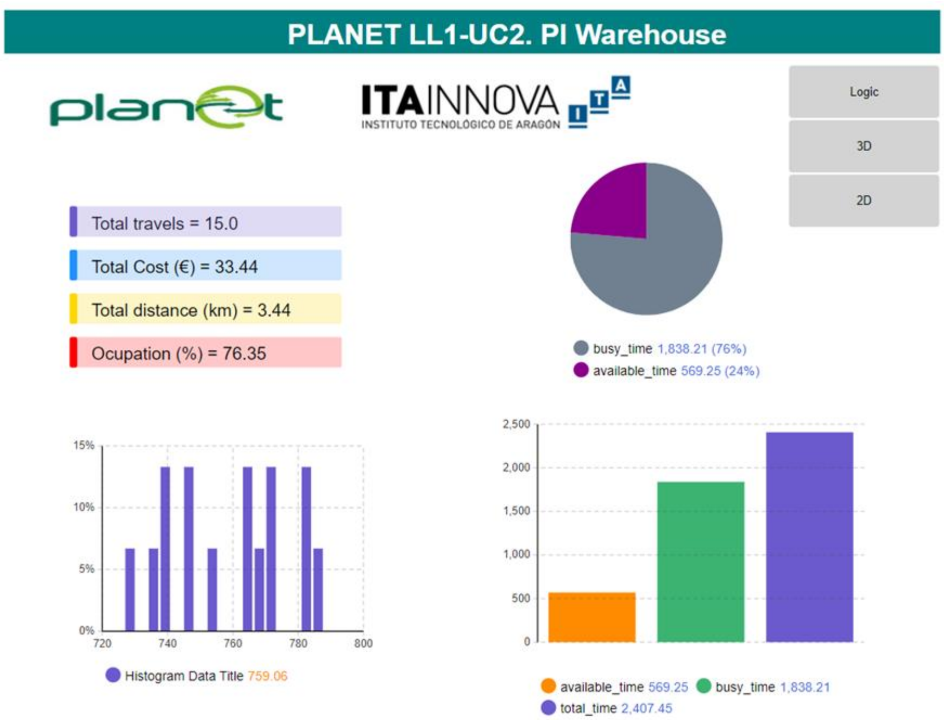

Figure 21: PI warehouse model statistics panel.

As mentioned above, the model has been developed using multi-agent simulation and discrete events and has the following agents:

- Orders: orders are the demand from customers. The properties that define an order are the unique identifier, families of items to be picked and total items to be picked.

- Items: items are the products that are stored in the warehouse. They are defined by a unique identifier and the family to which they belong. In addition, visually, the family is represented by a colour as previously mentioned.
- Forklifts: these are the agents responsible for carrying out the picking operation. The forklift is defined by the unique identifier, in addition, orders are assigned to this agent and variables have been defined to measure the distance travelled, time, cost, consumption, availability...

Figure 22 shows the flow of the forklift and order agents. These flows are modelled with discrete events. The upper flow represents the movements of a forklift when a picking order arrives, it moves to the indicated positions and picks up the material, when it has picked up all the materials it leaves them in the corresponding place and returns to its original position if there is no pending order.

The order flow assigns the pending order to an available forklift and once the order is finished, it is eliminated. There is a queue block in case no operator is available to take the order.

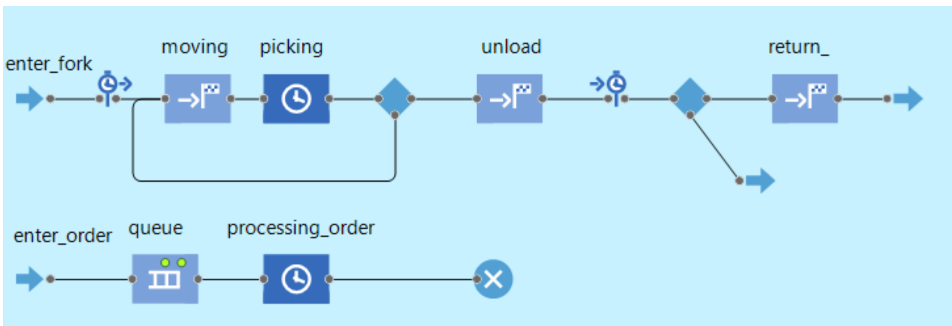

Figure 22: Forklift and order flows with discrete events.

The data model contains the information with the orders divided into different waves. This model makes it possible to synchronize these orders by simulating a collaborative warehouse.

Figure 23 contains information about the orders of different companies, including the total numbers of products to be picked and the family of each product. In Figure 24, the orders are synchronized, assuming a collaborative warehouse trying to reduce the distances travelled by the pickers. The user can introduce their own orders in the data model, synchronize it and then simulate in order to obtain the results of the comparison between the two models.

p_id	item_1	item_2	item_3	item_4	item_5	item_6	item_7	item_8	items
1	1	1	1	2	3	5	5	7	8
2	1	1	2	2	1	5	4	7	8
3	1	2	3	2	1				5
4	1	1	2	2	1	4	4	8	8
5	1	1	3	2	1	5	5	6	8
6	1	1	3	3	1	5			6
7	1	1	2	2	1	5	5	6	8
8	1	2	3	3	1				5
9	1	1	2	2	1	5	4	6	8
10	1	1	2	3	1	5			6
11	1	2	3	2	1	4	5	8	8
12	1	1	3	3	1	5	5	8	8
13	1	2	2	3	1	4	4	7	8
14	1	2	3	3	1	4			6
15	1	1	2	3	1	4	5	6	8

Figure 23: PI warehouse model orders input table.

job_order	fam_1	fam_2	fam_3	qtty_1	qtty_2	qtty_3	items
job_1	1			10			1
job_1	1			10			1
job_1	1			10			1
job_1	1			10			1
job_2	2			10			1
job_2	2			10			1
job_3	3			10			1
job_3	3			5			1
job_medium_rotation	4	5		9	1		2
job_medium_rotation	5			10			1
job_medium_rotation	4	5		3	4		2
job_low_rotation	6	7	8	4	3	3	3

Figure 24: PI warehouse model orders input table (collaborative scenario).

4 Fulfilment of simulation requirements per LLs

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.

4.1 PI and Blockchain modelling door-to-door Asia-EU corridors

The objective of Living Lab 1 model is to evaluate the impact of new solutions (IoT, AI, Blockchain) and concepts (PI) to improve process, operations, and efficiency in 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.

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 Table 4.

Table 4: LL1 Use Cases Description.

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 (i.e., 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 a collaborative warehouse.

4.1.1 Use case 1

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. Table 5 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 5: LL1 UC1 expected technology impact.

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.

Simulation scenarios in LL1 UC1

To evaluate the LL1 scenarios, we will use the Physical Internet Network Simulator model. In the base configuration (As-Is), we are going to create a scenario where several companies are shipping goods from China to Europe, independently. In the baseline scenario, we can assume that each company makes its own transport plan (no collaboration). Each company has a preferred port of destination, where it can perform the most efficient cargo unloading operations. In this configuration there is a high road modal split and a low rail modal split.

In the future scenario (To-Be), the simulation model will evaluate the use of the technological innovations developed in the project, in a collaborative scenario enabled by PI. There, companies will be able to share some of their loads with other companies to make efficient use of transport resources and containers will be delivered in a collaborative manner. The port of destination will be optimally selected according to the destination of the cargo and the congestion conditions of the ports (port choice model). Through intelligent dynamic decisions applied at each node , an increase in the modal split of rail will be pursued.

4.1.2 Use case 2

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, as shown in Table 6.

Table 6: LL1 UC2 expected technology impact.

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.

Simulation scenarios in LL1 UC2

Last mile delivery is known to be one of the largest relative cost & emission factors across a wide range of transportation systems due to limited pooling possibilities and delivery time pressure. Therefore, it is very important to establish efficient and robust last mile delivery. Last mile delivery faces two major hurdles, which we address in this use case focusing on last mile parcel delivery in urban areas.

Using the Last mile delivery model, we are going to evaluate scenarios to improve service level with sustainable planning. First, the risk of delay, which is driven by delivery vehicles being exposed to traffic conditions (e.g., congestion, construction work, or weather conditions), delivery locations being inaccurate (e.g., parking issues), and missing customer information (ambiguous handover). Delays of delivery vehicles can result in delayed parcels (limited working hours of delivery person), which either need to be delivered again the next day with a regular vehicle or need to be 'rescued' by a dedicated delivery on the same day. Both are causing additional costs and emissions. Second, last mile delivery is executed by several independent operators with a similar offering. As these carriers are competitors, no collaboration in terms of delivery pooling takes place among them, which leaves a lot of unused potential and unnecessary emissions. This use case provides simulation-based answers on how these two hurdles can be overcome supported by state-of-the-art T&L technology and innovations in order to create more efficient, reliable, and sustainable last mile delivery.

4.2 Dynamic synchromodal management for intercontinental corridor

The second living lab (LL2) focuses on dynamic and synchromodal management of TEN-T & intercontinental flows promoting rail transport and utilising the Port of Rotterdam (PoR) as the principal smart EGTN Node in the rail-focused transport chains linking China and Europe, and through Rotterdam to/from the USA and the UK, and the Rhine-Alpine Corridor destinations.

Within this living lab, three use cases are being developed. A simulation model is used in one of them, use case 3.

Use case 3 assess the implications for the ports of Rotterdam, Hamburg, Duisburg, Tilburg and (other) TEN-T infrastructure, and this will be directed at strategic corridor planning for accommodating the increasing flow from freight traffic from China. For these purposes, a dynamic simulation for the baseline year (2019) of the impact of the Belt and Road Initiative (BRI) on the RALP corridor has been carried out. The simulation takes into account both Eurasian rail freight transport entering the RALP region and the potential shift of freight flows from Northwest European seaports to Mediterranean seaports stemming from BRI and TEN-T investments. Eurasian rail freight is typically processed through Duisburg, Tilburg and a small number of alternative centres. In addition, although not part of the RALP corridor, the port of Hamburg handles considerable volumes as well.

This use case uses the model under development under task 1.2. Whereas in task 1, this model analyses the network impact at the European scale level, use case 3 focuses specifically on the RALP corridor. A first requirement complementary to the requirements in task 1.2 is therefore that the RALP network is incorporated in the model at a high level of detail. For these reasons, the intermodal services on this corridor have been updated in the model.

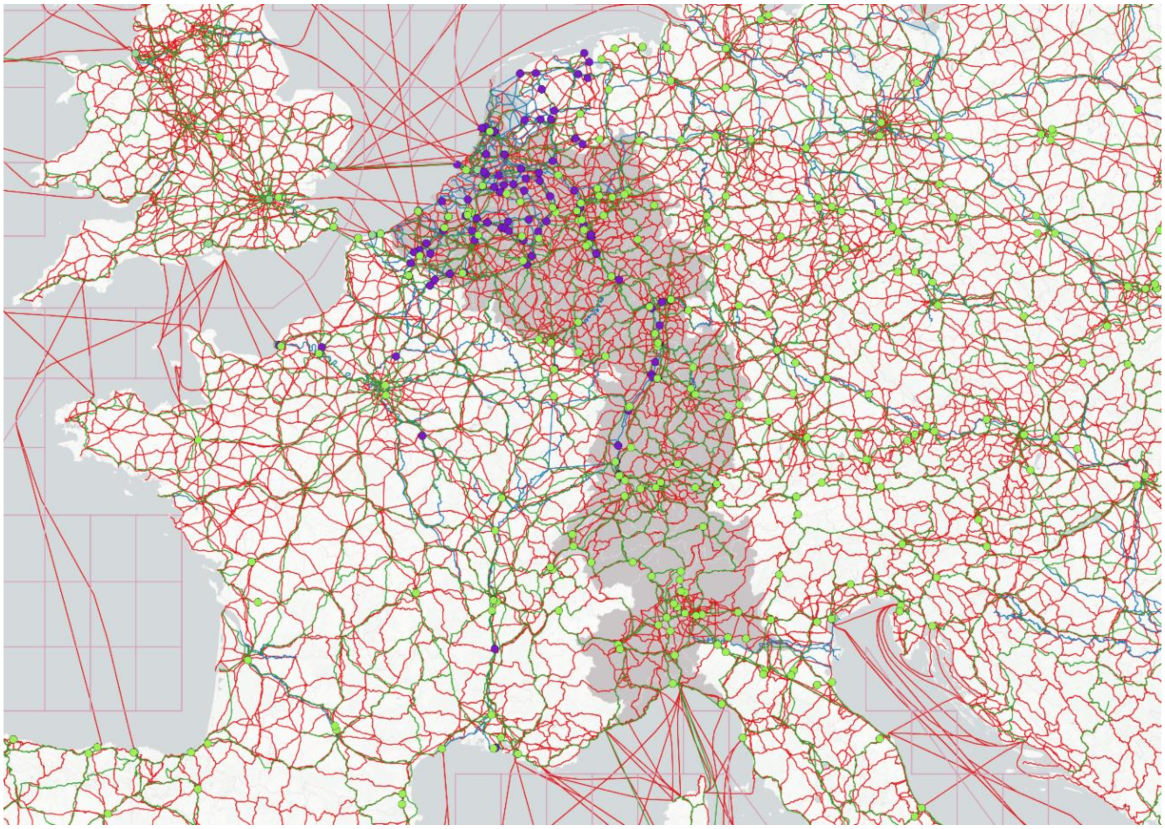

Figure 25: Snapshot of the network and transhipment points used in LL 2. ©Panteia

Simulation scenarios in LL2

Since different scenarios from the ones used in T1.2 are relevant to the RALP corridor, the scenarios have been adapted. Stakeholders from the EGTN were involved in shaping use case 3 scenarios. Based on discussions, it was decided to include a scenario in this use case analysing dynamic between the Mediterranean seaports and the North Sea port competition. By doing so, the model helps to better understand impact of dynamics between seaports on infrastructure in the RALP region. The scenarios used in use case 3 are shown in Figure 26.

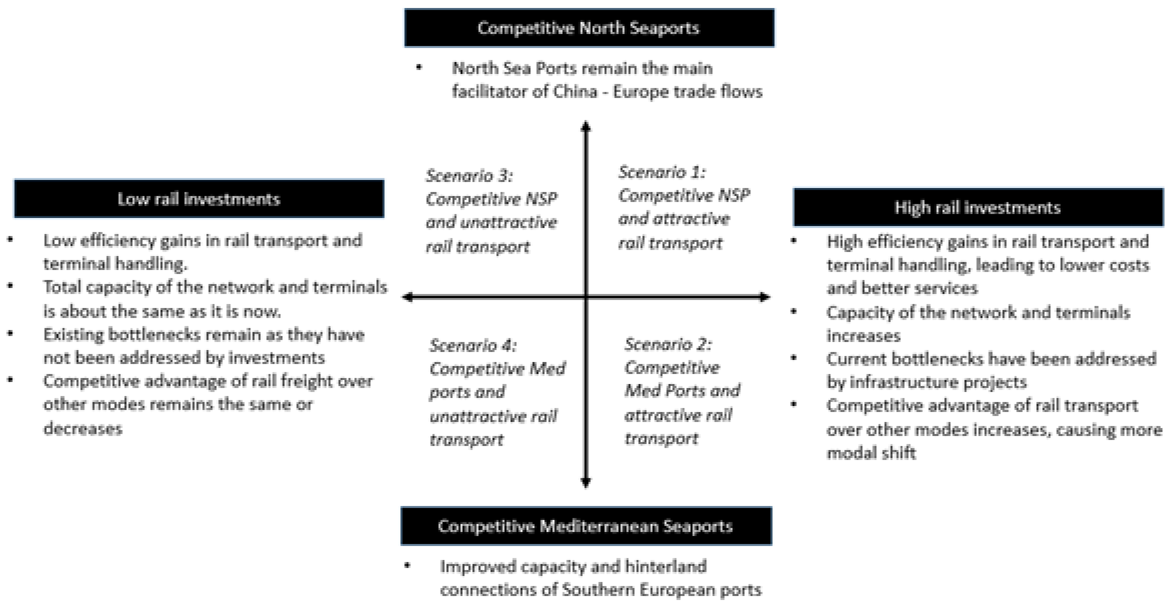

Figure 26: Four suggested Living Lab 2 use case 3 scenarios.

4.3 Silk Road Modelling and simulation

LL3 focuses on streamlining logistics processes in flows from China to Europe along the Silk Road by implementing IoT technologies (based on the EPCIS platform) and GS1 standards that facilitate data transfer between partners involved in e-commerce operations. LL3 aims to standardize the flow of information and digitize interactions between entities in the network (China Post, Poczta Polska); provide access to real-time information on cargo originating from China to Poland along the supply chain by using IoT and EPCIS to monitor supply chain events and support operational optimization. And to facilitate efficient co-modal end-to-end transportation within the EU internal rail network.

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

- container transport (with the possibility of transhipment 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 labelling 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 scopes 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.

- **Polish Post use case**

Polish Post, as a member of LL3 in the PLANET project, intends to participate in testing GS1 solutions (mainly SSCC) in servicing the supply chain from China to Europe implemented through the New Silk Road.

As part of the Living Lab, Polish Posts cooperate with several world-leading entities dealing with the issues of broadly understood logistics, supply chain optimization, and the use of IoT in the cross-border flow of goods.

Polish Post, as the designated postal operator that delivers parcels from Asia by rail, as part of the PLANET project intends to use GS1 standards and establish cooperation with business entities from China.

In this regard, PP counts on closer cooperation with GS1 China, whose local activities among partners that can use the SSCC in logistic operations, as well as the promotion of rail transport in international trade will contribute to the operational use and practical verification of benefits. Considering the growing importance of Poland on the European e-commerce map as a destination country for shipments from Asia and the growing popularity of Chinese platforms among Polish e-shoppers, we trust that choosing a partner by GS1 China will not be a problem. We are waiting for feedback from GS1 China on the above-mentioned issue.

As part of cooperation with SUUS, Polish Post expresses its hope to develop a uniform rail supply chain process using the partner's transport services for cross-border e-commerce shipments.

We identify the needs for further good communication and cooperation with all Living Lab partners, in particular at the current stage with GS1 China and GS1 Polska (choosing a business partner in China to test the designed solution), Rohlig SUUS (using rail transport services for consolidated e-commerce shipments) and ILiM (design works, process documentation, process mapping, preparation of test environments).

- **PP expected impact**

The results of the PLANET project will allow Polish Post to assess the practical use of GS1 standards in servicing the global e-commerce supply chain, its benefits and possibilities of operationalization and potential commercialization of the solution.

PP hopes to establish contacts with new business partners who have not yet cooperated with Polish Post in the implementation of e-commerce shipments from China to Europe.

PP would also like to promote modern and innovative supply chain solutions for the benefit of e-commerce entities and to improve the flow of parcels to recipients in Europe.

- **Rohlig Suus use case**

The main needs of RS dealt with by the LL3 are:

- optimization of operations, processes and efficiency of the entire supply chain of containerized cargo between China and Poland,
- improving the visibility of cargo flow throughout the supply chain by monitoring data in real time.

As part of the main objectives, activities are planned to analyse the benefits of using new IoT technologies (sensor networks).

The activities implemented under LL3 will allow the integration of partners along the New Silk Road. At present, the flow of information along the supply chain using rail transport is not continuous and has gaps in access to information lasting several days, which prevents effective planning of train arrivals and monitoring of transport statuses.

The introduction of a solution based on the use of sensor networks and the EPCIS repository can eliminate the problem. There is potential for using EPCIS in rail transport in the New Silk Road.

It was indicated that the greatest potential for the use of EPCIS exists in the real-time monitoring of rolling stock.

Thanks to this solution, it will be possible to: track loads in real time, estimate the distance travelled by the vehicle to plan preventive maintenance, as well as the control of vehicle availability. EPCIS can also be used to collect information related to the operation of rolling stock, e.g., hot axle detection, wheel shock load detection, acoustic axle bearing monitoring, and pantograph damage monitoring.

- **RS expected impact**

The results of the PLANET project will allow Rohlig Suus to assess the use of sensory networks and the EPCIS system in servicing the intermodal supply chain, its benefits and the possibility of widespread use in business conditions.

RS also hopes to establish contacts with new business partners who have so far not cooperated with RS in the implementation of rail transport from China to Poland.

As part of the LL3 PLANET project, RS plans not only to gain experience and knowledge in the use of modern technologies in the field of real-time cargo monitoring, but also to promote modern and innovative solutions in the field of digitization of the supply chain for the benefit of business partners in the field of safety and improvement of rail transport processes.

Simulation scenarios in LL3

All Living Lab partners take an active part in the creation of process maps (AS IS) - it takes place on the basis of an audit in the organization, a series of interviews with employees, and the provision of necessary information regarding the functioning of the company.

LL partners also provide data to parameterize processes and transform them into simulation models. The shared data are, for example, the duration of individual activities, business roles in the process, the number of transactions carried out within individual processes, waiting times, and the number of errors/inconsistencies in each process.

Designated representatives of partners have access to the process repository in which all developed maps and models are posted. This allows them to view the progress of work on an ongoing basis. Additionally, they have the option to leave annotations on these maps in the form of comments. The partners are also involved in the process of creating the target processes (TO BE), having a significant impact on their final shape.

The results of the simulation of individual processes and reports presenting a comparative analysis (based on agreed KPIs) - AS IS and TO BE models are also available in the process repository for viewing by partners.

Main decision addressed

- Unification of knowledge about processes at the management and operational level
- Support in making management decisions (selection of the most effective change scenario)
- Determining the level of resource involvement in the process and recommendations for their most effective use

- Support in process change management: preparation of unambiguous documentation, analysis, and assessment of the effects of implementation before the actual change

Key Performance Indicators

As part of the ongoing work, the research team defined 7 KPIs that will allow to assess the impact of implemented solutions on key areas related directly to operations and the business environment. In order to achieve a common understanding of particular KPIs, the project extended their description with a detailed definition. This approach will allow the indicators to be properly matched with the relevant processes.

- ***Reduced compliance costs (>10–) -*** Compliance costs are all expenses that a company uses up to adhere to government regulations. Compliance costs incorporate salaries of employees in compliance, time and funds spend on announcing, new system necessitated to meet retention, and so on. Compliance costs happen to be as results of local, national, or even international regulation (for instance MiFID II or GDPR applying to countries in European Union). Global firms operating all over the world with varying new regulations in each country tend to face significantly larger compliance costs than those functionating solely in one region. Given the nature of the pilot and the regulatory challenges associated with logistics operations in the New Silk Road area, the main cost to be considered will be the compliance cost of customs processes.
- ***Improved end-to-end visibility (>50–)*** - end to end supply chain visibility is transparency at all stages of supply chain management from procurement through delivery of finished goods to customers. This transparency is made possible by carefully monitoring each step of the process, capturing all related data, and organizing it in a centralized data management space, where it can be reviewed, analysed, and, in time, mined for actionable insights that improve business processes, long-term financial planning, and strategic decision making.
- ***Improved customer experience (>15–) -*** customer experience, also known as CX, is customers' holistic perception of their experience with the business or brand. Detailed areas of interest, important from the end customer's point of view, will be defined through a survey conducted among Polish Post and Rohlig Suus clients.
- ***Increased volumes (>8–)*** - in this case, volumes are defined as the quantities of products, expressed in pieces/packages/pallets, that can potentially be processed through logistics operations in the supply chain.
- ***Reduced operational costs (>10–)*** - operational costs, are the expenses which are related to the operation of a business, or to the operation of a device, component, piece of equipment or facility. They are the cost of resources used by an organization to maintain its existence. In this case, we are talking about the cost of logistics operations related to the direct handling of products. Logistics costs include the following:
    - cost of transport activities, for each mode.
    - cost of storage or warehousing activities.
    - cost of time value or investment in goods in a logistics system, including the added value of transportation.
    - cost of physical form changes required for effective and/or safe transport, storage, and handling.

- cost of marking, identifying, recording, analysis, as well as data transfer and handling.
- cost of stacking/unstacking activities.
- cost of added packaging required.
- cost of material transfer activities.
- cost of consolidation/deconsolidation activities.
- cost of information and telecommunications integration.
- cost of logistics system management.
- cost of unavailability of goods (when required).

- ***Reduced disruptions of the Supply Chain (>15–)*** - A supply chain disruption is any sudden change or crisis - be it local or global - that negatively impacts that process. It is defined as major breakdowns in the production or distribution of a supply chain, including events such as a fire, a machine breakdown, natural disasters, quality issues, and an unexpected surge in capacity. It can lead to decreased productivity, increased costs, rising customer dissatisfaction, and more. Therefore, since the solutions implemented in the pilot are not able to affect external supply chain disruptions, this KPI is defined as the reduction of the impact caused by Supply Chain disruptions.
- ***Reduction in CO2 emissions (>20%)*** – in this case CO2 emission refers to the logistics operating phase that corresponds to the use made of the means of transport, and therefore to the combustion of the energy source (fuels). From the perspective of the pilot, such an indicator can be expressed indirectly for example as a reduced number of trips due to a reduction in complaints (no need for reshipment).

Due to the need to gain insight into the business processes of individual LL actors as well as physical and documentation flows, 17 B2B and 13 B2C processes were mapped as part of the pilot preparation phase. This holistic approach will allow us to identify processes where there is potential for improvement through implementation of new technological solutions as well as changes in the organizational area. Additionally, process mapping allows us to see the connections between activities and actors and their potential impact on each other.

The KPIs presented above have been assigned to individual processes in accordance with the theme.

The processes mentioned were divided into 3 groups:

- processes in which there will be a **real implementation** of technical and organizational solutions **tested within the Living Lab,**
- processes in which there will be a **potential implementation** of technical and organizational solutions **simulated within the iGrafx platform,**
- processes that will **remain unchanged** and only reflect side operations.

All indicators of the effectiveness of the implemented processes will be important for LL partners. Of particular importance will be those allowing for the analysis and monitoring of the effects of the introduced changes, such as:

- The number of process transactions that can be carried out as part of the process, e.g., daily / monthly number of deliveries that can be handled, the daily number of accepted containers, unloaded parcels,

- Duration times (minimum, average, and maximum), e.g., time needed to handle processes, working times for individual business roles, waiting times and downtimes,
- Costs related to the involvement of individual business roles in handling the analysed processes.

5 Simulation models integration

A main goal of simulation efforts within PLANET is to define the impact of ICT and T&L innovation to EGTN as well as to assess the impact of emerging concepts & tech on freight transport corridors and hubs. This includes (1) 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 (2) 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. Moreover, (3) the simulation models should contribute additional insights for the PLANET EGTN Service platform.

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 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.

While these models are very valuable on their own, modelling and programming work is required to be able to use them in a value-adding way to contribute to the achievement of the goals (1)-(3) mentioned above. First, individual models, simulation tools & OR algorithmic solutions need to be functionally combined in order to cater the PLANET use cases. Second, interfaces between the models simulating operations at the micro level and the models capturing long-term strategic developments need to be defined and implemented. Third, these so-called modelling pipelines should be transferred into an executable program that can be integrated with the PLANET EGTN Service platform.

5.1 Model integration with EGTN services

The EGTN platform contains analytic models that address various supply chain functionalities. The models considered deal with:

- data collection and integration,
- network and cargo sensing,
- prediction of flows and performance,
- decision support algorithms, and
- automation measures.

The aim of the EGTN platform is to simultaneously provide a dynamic modelling environment as well as a real-time supply chain management tool. The cargo transported in the network as well as the network itself is continuously being monitored for performance variations, and external datasets (e.g., vessel AIS for location, weather information) are integrated to enable a wholistic management and decision support tool. This functionality is further enhanced through predictive modelling capabilities, that enable optimally preparing the network to address short-term throughput requirements. The DSS algorithms investigate decisions at a hub or vehicle level, and coordinate operations of various network components, to deliver an optimized and seamless synchro-modal operation. The automation means, enable the quick and scalable undertaking of multiple operations, beyond human capabilities as well as the immediate response to any fluctuations and alterations that arise.

5.2 Micro-scale to Macro-scale Integration

Micro-level models provide insights and learnings for specific use cases. Their focus is on a specific domain (e.g., gateway to hinterland, last mile distribution), a specific area (e.g., Iberian Peninsula, Madrid), and a short time horizon suitable for operational modelling. This constitutes a significant contribution towards several project goals including the testing of integrated scenarios within the Living Labs to evaluate quantitively the impact of new technologies on the operational characteristics of corridors. For the more strategic goals of the project, analysis beyond isolated areas, domains, and for a longer time horizon is required. In fact, the output of these scenarios should 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. As a result, interfaces between the models simulating operations at the micro level and the models capturing long-term strategic developments need to be defined and implemented.

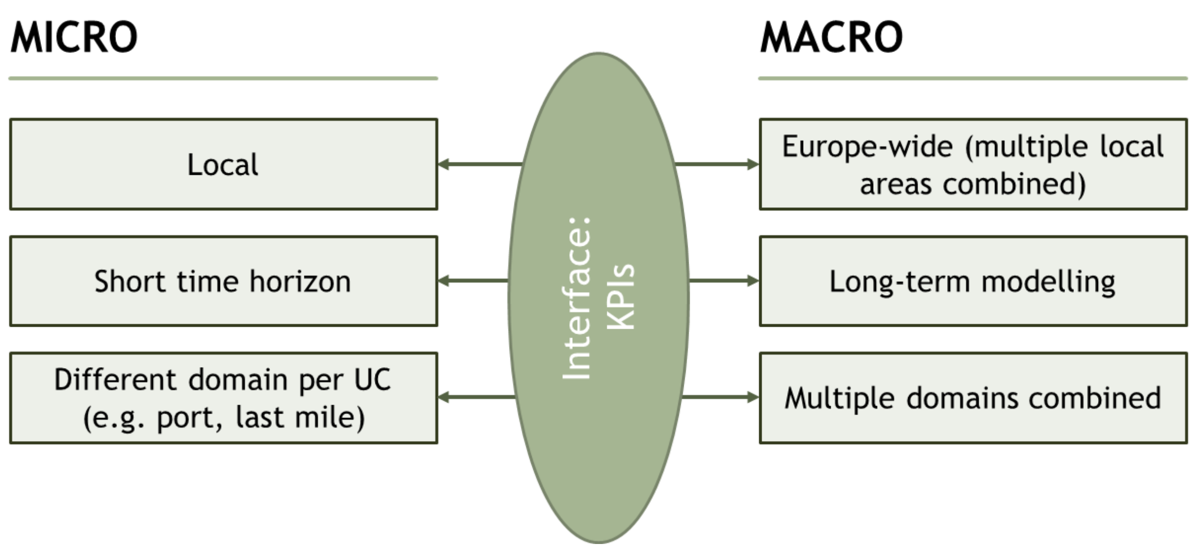

Figure 27: Alignment requirements between micro and macro level.

Figure 27 shows an overview of the matching that needs to be made between micro- and macro-models to be able to derive meaningful results. The interface is designed using KPIs. At the micro-level, models are run repeatedly to create KPIs for specific domains, areas, and levels of technology implementation (given the current level of implementation at the projected time). These KPIs are input parameters for the strategic model, which uses them to derive strategic scenarios. The results of the strategic model can be used to adjust the micro-modelling parameters and technologies based on a projected future scenario.

The interface between the different micro- and macro-models is going to be transferred into an automated modelling pipeline. A draft of this pipeline is visualized in Figure 28. This pipeline should be integrated with the PLANET EGTN Service platform to support decision making capabilities provided by the platform. The integration efforts will be further elaborated on in Deliverable 1.9.

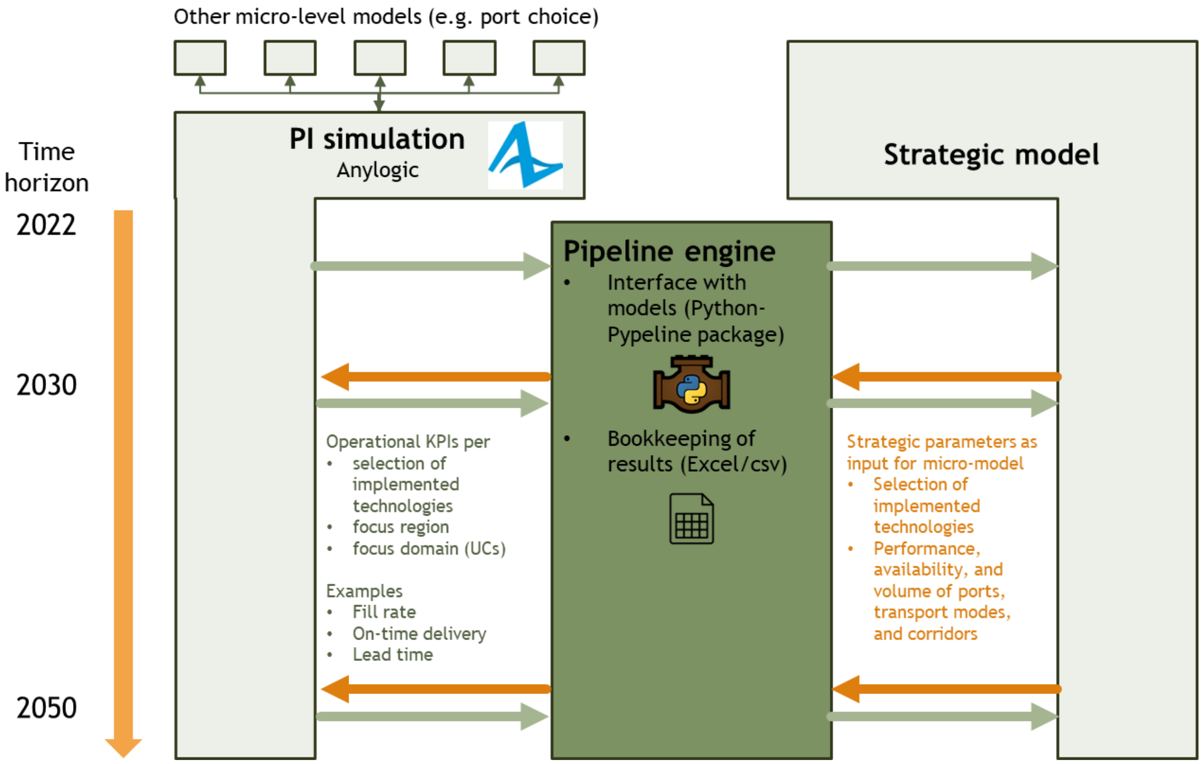

Figure 28: High-level visualization of modelling pipeline for the PLANET EGTN Service platform.

6 Data for modelling and simulation

The objective of this chapter is to identify the data sources which can be used to represent the transport flows to be evaluated with the different modelling and simulation techniques. Both global data sources at European level and local data sources will be mapped to describe the flows in each of the living labs.

The data used is grouped into different categories such as:

- Demand data. This category contains information about the movement of freight between different origins and destinations, usually using a standard unit of measurement such as tonnes or TEUs. The data used are usually obtained from historical data over a given period.
- Infrastructure data. Contains data that characterise the transport network, connectivity, capacity, or the different resources available. It may also include information on connections or corridors, between pairs of origins and destinations.
- Service data. Contains information on the transport services offered in the infrastructure for the transport of products. Its main characteristics are the origin destination, frequency, transport tariffs or emission ratios of each service.

Definitions of the detail of each of these data sources can be found in the previous version of this document D1.2 Modelling & Simulation Capability v1.

6.1 Data sources for macro modelling and strategic planning

This chapter describes the data sources that have been used to customise the models and create the scenarios for assessing the impact of the different innovations.

6.1.1 Data used for attractiveness calculation

The NEAC model produces a PEP-specific attractiveness parameter. This is because the generalized transport costs function for containers does not take into account qualitative aspects that determine node choice of shippers, such as the quality of the hinterland connections per node or shippers' preferences. The attractiveness parameter reflects these qualitative costs and is determined through model calibration. This parameter is used to explain the difference between the observed and the calculated values of the model.

Observed port throughput values are derived from the mar_go_qm dataset from Eurostat [2]. Throughput values are corrected for containers that are only transhipped in the port, so that only the throughput remains that flows to the hinterland. These port transhipment values are derived from Mueler et al. [3] and Pastori [4].

Based on observed port throughput values, the model is calibrated and node attractiveness values for each PEP are calculated.

6.1.2 Data used for connectivity calculation – CCI

The methodology for the Corridor Connectivity Index (CCI) is described in the methodology document (D1.1 EGTN Foundational Position Papers and Simulation Scenarios). The methodology describes a selection of a set components which explain the concept of connectivity in the context of transport networks. Components need to be chosen in such a way that they measure separate characteristics of an inland node. The definition of corridor connectivity can be broken down in seven components. For inland nodes these are: port capacity, efficiency and ease of processing, service frequency, service quality (measured as centre of gravity), digital connectivity, and green facilities. For principal entry nodes, i.e., seaports the PLSCI can be used as an additional indicator.

The baseline model is what needs to be established first. The initial survey engine will set up a list of Principal entry nodes and Inland Nodes. The Corridor Connectivity Index is constructed from 6 components, using Principal Component Analysis (PCA). PCA is a statistical method to reduce the dimensionality of a dataset. This is done to simplify the understanding of the data which results from data collection on (currently) 26 sub-components for *n* amount of transport nodes. To make sure the dataset doesn't become unmanageable, we aim to express the corridor connectivity of a node in a single indicator – the CCI – which is the weighted average of the score of the components. The weight per component in the CCI will be determined in consultation and based on feedback from the living labs. In case too much uncertainty is in place about the weights, the principal entry nodes and inland nodes participating in the LL's should consult their clients/shippers to justify them. The initial weighted scores per component are given in below table:

Component	Sub-components
1. Port capacity	1. Port terminal area in squared meters 2. Barge capacity in total length in metres of the quays 3. Rail capacity in total length in metres of train tracks
2. Quality of infrastructure	1. Availability of truck transport (road) 2. Availability of train transport (rail) 3. Availability of inland waterway transport (barge)
3. Efficiency	1. Efficiency and ease of process per rail 2. Efficiency and ease of process per barge
4. Service frequency	1. # Scheduled services per week Rotterdam via rail 2. # Scheduled services per week Hamburg via rail 3. # Scheduled services per week Antwerp via rail 4. # Scheduled services per week Genoa via rail 5. # Scheduled services per week Rotterdam via inland waterway 6. # Scheduled services per week Hamburg via inland waterway 7. # Scheduled services per week Antwerp via inland
4. Service quality (centre of gravity)	1. # Kilometres to Rotterdam via rail 2. # Kilometres to Antwerp via rail 3. # Kilometres to Hamburg via rail 4. # Kilometres to Genoa via rail
6. Digital connectivity	1. Information of schedules online available 2. Ability to track and trace consignments 3. Possibility to book container (either online via a platform or through an app) 4. Possibility to hand over documentation (either online via a platform or through an app)

7. Green facilities	1. Availability of an LNG refuelling station 2. Availability of a hydrogen refuelling station 3. Availability of waste reception facilities

6.2 Data collection

Given the long list of Principal entry nodes and Inland Nodes and the novelty of the index, data availability is an issue. PLANET gives an excellent opportunity to collect adequate data, validate the data and calibrate the CCI for developing and optimising the Index and making it ready for future use, also after PLANET 2020 ends. As shown from the above table there is a significant data availability gap in secondary data. Most of the indicators mentioned have been gathered in other reports, but are done on country level, not port or inland port level.

6.2.1 Considerations regarding data collection

Considerations were made on finding reliable and consistent data sources with information on all terminals in the corridor. A first aspect in our data collection is to consider what to do with data that is partially useful. In this case, we must consider minimum qualification level for an indicator to be used. In other words, what do we believe is data quality and when does it qualify to be included in the corridor connectivity index? A second consideration is when data availability is limited is to work with a classification, e.g., by determining a typology of inland ports and give the same score for similar ports.

The following steps were made in the data collection:

Step 1:	Collect data from reliable and consistent sources for the base year. Please refer to the appendix for a list of sources. Fill in the data for each (sub)component. An excel template is available.
Step 2:	Determine the base value by calculating the maximum value in the range of terminals or ports.
Step 3:	Set the highest value as the base value and make it equal to 100. You can use the following formula to do this: $Index_{pt} = \frac{Value_{pt}}{Base\ value} * 100$
Step 4:	When you have multiple subcomponents, calculate the average of the indices per subcomponent.
Step 5:	When you have multiple terminals in your port, calculate the average of the terminals that will result in an aggregated index value for your port.
Step 6:	Determine the weight of the subcomponents. Preferably each of the subcomponents should have an equal weight in the aggregated indicator. This is to prevent a bias in the index calculation.

6.2.2 Data sources

In our research so far, we have realised that data sources are not uniform, neither consistently kept for all ports and terminals. We have relied upon open access sources on the internet and assume that each port and country may have specific data sources. To get you started we have stated some useful sources in the table below, but we rely on your input as well to create a more extensive list of – preferably op–n - data sources.

The data for the different terminals on the corridor was collected at different layers:

Name	Used for	Link
TenTec Map	Green facilities component	https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html
Agora	Information on inland terminals as uploaded by the terminal operators themselves	https://www.intermodal-terminals.eu/database
Railscout	Service frequency component	https://www.railscout.nl/#!/
Navigate	Service frequency component	https://rotterdam.navigate-connections.com/network
Port of Antwerp intermodal planner	Service frequency component	https://www.portofantwerp.com/nl/connectiviteit
Port of Hamburg inland terminal	Service frequency component	https://www.hafen-hamburg.de/de/intermodal/

6.2.3 Alignment to attractiveness of strategic model

The index value that is generated as an output from the corridor connectivity index serves the purpose of monitoring the attractiveness of the node on a meso-level. It can be used for modelling purpose but cannot be simulated as such. The higher the index value of an inland node, the more likely it is that an inland node can attract cargo. Also, the maturity of an inland node’s digital capabilities or green facilities can be monitored which is an indicator for the attractiveness of the node in a network or corridor. This makes the CCI suitable in the NEAC attractiveness calculation.

During the PLANET project we assessed whether the CCI index can be used in the NEAC model. This led to the following observations:

1. The NEAC attractiveness parameter is calculated on the basis of throughput, which is an output indicator. The CCI index is calculated based on qualitative characteristics of the inland nodes.
2. The geographical scope differs, whereas the CCI index covers the RALP corridor, the NEAC attractiveness calculation covers all PEPs in Europe. Data collection on terminals in the Rhine-Danube Corridor and Baltic-Adriatic Corridor are currently underway. This will enable the usability of the CCI in the NEAC model.
3. The NEAC attractiveness calculation only considers the attractiveness of terminals used for Eurasian transport (i.e., the PEP), whereas the CCI looks at the attractiveness of a terminal for all cargo that can be routed via the inland terminal.

4. The methodology differs. The CCI index uses 26 input parameters, which is based on actual factor conditions (e.g., capacity data), whereas the NEAC attractiveness is a computed value the unit value differs. The attractiveness value is expressed modelling transport cost (€ per TEU), whereas the CCI uses a principal component analysis to compute an index value.
5. The corridor connectivity index cannot be aligned on transport costs. The question is also how the CCI can be translated in modelling transport costs, as both methods use different unit values.

In conclusion the perspective of the NEAC model, the CCI can be used for PLANET's purposes on the following aspects.

- The impact of different CCIs of terminals through the years on Eurasian container flows can be calculated. This can be done by monitoring the index value of CCI as a basis for adjusting the attractiveness value.
- It is possible to add the CCI to the NEAC model as an extra parameter for the hinterland terminals. However, this requires data for all hinterland terminals.

6.2.4 Data used for EU Flows model calculation

The EU Flows model analyses European trade based on NUTS3 regions classification. For each region the EU published data on fright transport loading and unloading are utilised. The dataset used focuses on 2020 values, disregarding more recent datasets that might be influenced by the impact of the COVID pandemic on international trade. The generalized cost information is extrapolated for various KPIs using historical information and extracting routing information through OpenStreetMap.

6.3 Data sources for micro modelling and local decision making

Simulation models are fed with data sources that represent transport movements in a way that is proportional to the movements happening in the real world.

6.3.1 Data used in Living Lab 1

The data requirements for the simulation models in LL1 are divided into three groups: demand data, infrastructure data and service data. In addition, each of the use cases has specific requirements.
In UC1, the considered demand is the flow of containers from China to the main Spanish sea ports and the distribution from these to the rest of the PI network (hinterland PI nodes). To obtain this information, the statistical reports of each of the ports considered have been studied (Valencia [5], Barcelona [6] and Algeciras [7]). With these data, and based on the calculated statistical distributions, a synthetic dataset with thousands of containers has been generated, containing the origin port, the destination port (sea terminal) and the destination (hinterland node) for each of the containers, as shown in Table 7.

Table 7: UC1 container dataset example.

Container ID	Origin Port	Destination Port	Destination Hinterland
0	Shanghai	Valencia	Madrid
1	Shanghai	Valencia	Madrid
2	Shanghai	Valencia	Madrid
3	Shanghai	Barcelona	Pamplona
4	Shanghai	Algeciras	Barcelona
5	Shanghai	Barcelona	Zaragoza
6	Shanghai	Barcelona	Pamplona
7	Shanghai	Barcelona	Zaragoza
8	Shanghai	Valencia	Madrid
9	Shanghai	Barcelona	Madrid
10	Shanghai	Algeciras	Madrid

In terms of infrastructure, Shanghai port and the most relevant PI nodes in the Iberian Peninsula, as well as the current connections between them, have been considered (Table 8).

Table 8: UC1 PI Nodes considered.

Node ID	Name	Latitude	Longitude	Type
0	Shanghai	31,221944	121,489444	Sea Port
1	Valencia	39,469750	-0,377390	Sea Port
2	Barcelona	41,345000	2,141670	Sea Port
3	Zaragoza	41,644700	-0,972000	Hinterland
4	Madrid	40,416706	-3,703583	Hinterland
5	Algeciras	36,131081	-5,448706	Sea Port
6	Bilbao	43,263004	-2,934992	Hinterland
7	Sevilla	37,388630	-5,995340	Hinterland
8	Pamplona	42,816870	-1,643230	Hinterland
9	Valladolid	41,652134	-4,728562	Hinterland

10	Pontevedra	42,429886	-8,644620	Hinterland
11	Sines	37,949996	-8,866663	Sea Port

Regarding services data available, the rail transport services have been defined according to the main corridors in Spain shown in Figure 29. In the case of road transportation, availability on demand has been considered.

Figure 29: Main rail corridors in Spain. Source: Gobierno de España. Ministerio de Fomento.

Regarding last mile distribution in UC2, files with real demand in the Madrid area corresponding to CityLogin orders have been used, studying both a normal day of operations and an atypical day with high demand (black Friday). The content of the files is aligned with the input data template designed for the simulation and contains the main information of the orders (position, time windows, number of packages, weight, volume, routes...). An example file is shown in Table 9.

Table 9: UC2 last mile distribution orders dataset.

Tipo de servicio	Identificador de la tarea	Fecha	Ruta	Secuencia	Empezar	Fin	Representante del cliente	País	Latitud	Longitud	Tiempo de servicio	ETA	Artículos	Peso	Volume
delivery	2524	16/07/2021	B06	1	09:00	21:00	2524	ESP	40,18067	-3,70906	6	09:28	1	1,37	0,02
delivery	1842	16/07/2021	B06	2	09:00	21:00	1842	Spain	40,21136	-3,58395	6	09:48	1	1,37	0,02
delivery	1823	16/07/2021	B06	3	09:00	21:00	1823	ESP	40,21058	-3,58388	6	09:54	1	1,37	0,02
delivery	2182	16/07/2021	B06	4	09:00	21:00	2182	ESP	40,21058	-3,58388	6	09:57	1	1,37	0,02
delivery	2222	16/07/2021	B06	5	09:00	21:00	2222	ESP	40,20372	-3,58204	6	10:04	1	1,37	0,02
delivery	1971	16/07/2021	B06	6	09:00	21:00	1971	ESP	40,20777	-3,57534	6	10:12	1	1,37	0,02
delivery	1664	16/07/2021	B06	7	09:00	21:00	1664	ESP	40,21045	-3,56948	6	10:20	1	1,37	0,02
delivery	2360	16/07/2021	B06	8	09:00	21:00	2360	ESP	40,21045	-3,56948	6	10:23	1	1,37	0,02
delivery	2562	16/07/2021	B06	9	09:00	21:00	2562	ESP	40,21207	-3,57414	6	10:28	1	1,37	0,02
delivery	2168	16/07/2021	B06	10	09:00	21:00	2168	ESP	40,21271	-3,57370	6	10:34	1	1,37	0,02
delivery	1551	16/07/2021	B06	11	09:00	21:00	1551	Spain	40,21352	-3,57577	6	10:41	1	1,37	0,02

6.3.2 Data used in Living Lab 2

LL2 focuses on dynamic and synchromodal management of TEN-T & intercontinental flows promoting rail transport modelling the Port of Rotterdam (PoR) as the principal smart EGTN Node in the rail-focused transport chains linking China and Europe, and through Rotterdam to/from the USA and the UK, and the Rhine-Alpine Corridor destinations.

LL2 is divided into three use cases, with each having its own data needs:

- Use case 1 focuses on Synchromodality in a Blockchain-enabled Platform involving the PoR community and customers. The focus is on the transport of foodstuff between GB and the continent, for which data for Entry In Declarant's Records (EIDR) documents are needed, used to import goods in the UK and the creation of an audit-trail on the blockchain.
- Use case 2 will focus on investigating key requirements and the growth hurdles for Eurasian rail freight expansion and identify the most appropriate organizational measures and (IT-) technologies. This is primarily done through stakeholder consultation, therefore there are no specific data requirements. Lessons learned from use case 1 will serve as input for this use case.
- For use case 3, the same model is used as in T1.2. The relevant multimodal hinterland services for the RALP region have already been updated under the model development in T1.2. However, separate scenarios relevant to the RALP region have been defined.

The output of LL2 supports PLANET's vision, in particular to:

- Assess implications of new trade routes and how best to maximize the EU's economic prospects through strategic planning.
- Examine the role of new technologies (i.e., blockchain) on intercontinental rail services promoting the EU's strategic cooperation with China and through to the UK and potentially the USA.
- Leverage Blockchain interoperability and federation for Supply Chain platforms extending the Blocklab repository knowledge hub with synchromodality models as a service with predictive and prescriptive analytics enabling corridor actors to establish the best multimodal solutions that represent the interconnection of supply chains along the TEN-T Corridors a "green" Global T&L context.

6.3.3 Data used in Living Lab 3

The data that are used in the creation of AS-IS /TO-BE models and simulations are shown for both use cases in the tables below. These are data that include information on routing, flow volumes, dates of transport, origin and destination, and type of transport, which are carried out by business partners Rohlig Suus and Polish Post as part of the New Silk Road. The data used for modelling will also be used to create predictions within the EGTN system (i.e., Volume flow forecasting, ETA prediction, Carbon Footprint prediction). The following table shows an example of the data used for the flow forecasting. The description of the rest of the data used can be found in Annex 1 of this document.

Analytics solutions	Description	Required Data	Data Sources
Volume Flow forecasting	Predicting the inflow and outflow quantities of cargo from a distribution center	Job number	RS TMS - IMP_CN_Rail_3years_v2

		Container number	RS TMS - IMP_CN_Rail_3years_v2
		Volume m3 per Job number	RS TMS - IMP_CN_Rail_3years_v2
		Weight (kg) per Job number	RS TMS - IMP_CN_Rail_3years_v2
		Unloading date	GPS/Status/ETA forcasting

6.4 Local technology impact data to strategic model

In order to use the micro-modelling use cases in a meaningful way for strategic modelling, the output variables need to be aligned with input parameters of the strategic model. Figure 30 shows an exemplary matching of KPIs between output of PI simulation (UC1, Gateway to hinterland Iberian Peninsula) and the strategic model. KPI matchings of further use cases will be elaborated on in Deliverable 1.9.

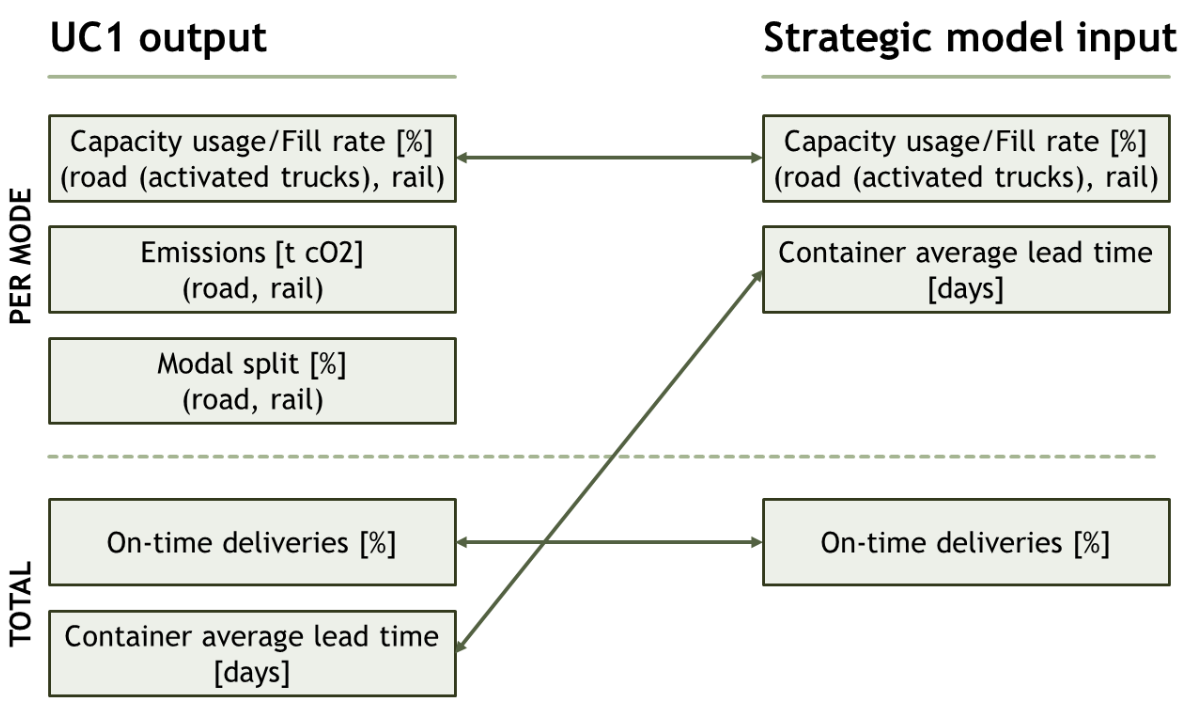

Figure 30: Exemplary matching of KPIs between PI simulation (UC1) and the strategic model.

6.5 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 10: 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 11: 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 12: 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.

7 Conclusions

This is the second (and final) version of the document describing the EGTN modelling and simulation capability developed in the project to fulfil the requirements for a comprehensive analysis of the impact of emerging trade routes and technological advancements on trans-continental and EU internal freight flows as well as on the TEN-T. Building on the work of the first version (D1.2) that mapped and detailed all the available modelling capacity of the consortium along with the initial data requirements, the current document described in more detail the harmonization and customization of the selected micro and macro-level models that constitute EGTN's modelling and simulation capability.

With respect to the micro-simulation capability and in the context of LLs, the project customized the micro-level models presented in previous chapters utilizing available operational data coming from project's industrial partners and simulated real life operations while utilizing technologies and innovative logistics concepts. In addition to the LL implementations, the customized micro-models have also been used in the context of Task 1.4 for simulating a set of Use Cases targeted to quantify the impacts of the implementation of technologies and innovative concepts (AI, IoT, Blockchain, PI) by testing them separately and in several combinations. Based on the testing results of this process both in the LLs and additional UCs, we proved the significance effect of technology in logistics operations through the calculation of KPIs depicting the positive impact on parameters such as the lead time, capacity usage/fill rate of transport means, compliance and operation costs, visibility and CO2 emissions.

The project also identified the need to bring the information produced through micro-simulation processes up to the macro (strategic) level of analysis and feed the corresponding models that simulate future scenarios and support the strategic decision making. For this reason, an interface was developed based on the calculated KPIs for supporting micro to macro integration and the generalization and alignment of their values to the input requirements of the project's macro-level models.

Moreover, the project established the capability to measure the competitiveness of nodes and corridors of the TEN-T through the development of the Corridor Connectivity Index that facilitates monitoring as well as assessment of the changes happening in the European transportation network over time while being able to be integrated to the strategic model. The CCI index utilizes data collected from various sources for calculating it's seven sub-components, including data related to the nodes' infrastructure, services, and green facilities. Considering the current level of reliability and consistency of the data sources along with data availability, the fine-tuning of CCI's parameters will continue in WP2 through the development of an observatory dashboard in the EGTN platform.

Concluding, through the macro-level modelling and simulation capability, the project has customized the strategic model so as to include the Eurasian rail routes and flows and utilize the outcomes of the technology micro-simulation processes and of the policy & legislation initiatives impact assessment. This capability will be key in the final project stage for analysing even more complex future scenarios that will introduce the impact of technology, policy, and legislation initiatives to the updated strategic model of the globally connected TEN-T and thus provide answer to the central research question related to the possibility for substituting hard infrastructure investments with targeted investments in technology implementation for serving the new flows reaching EU.

The evolution of these models is a perpetual process to adapt in the new transport circumstances in Europe due to significant geopolitical events (such as conflicts), climate change (e.g., reduced use of waterways), energy prices fluctuation or even future (restrictive) regulations

8 References

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Annex I: Living Lab 3 data description

This annex describes the data used for the modelling of living lab 3.

ROHLIG SUUS			
Analytics solutions	**Description**	**Required Data**	**Data Sources**
Volume Flow forecasting	Predicting the inflow and outflow quantities of cargo from a distribution center	Job number	RS TMS - IMP_CN_Rail_3years_v2
		Container number	RS TMS - IMP_CN_Rail_3years_v2
		Volume m3 per Job number	RS TMS - IMP_CN_Rail_3years_v2
		Weight (kg) per Job number	RS TMS - IMP_CN_Rail_3years_v2
		Unloading date	GPS/Status/ETA forcasting
Carbon Footprint Prediction	Forecasting the carbon footprint for transport routes/modes taken to deliver the goods or per package	Volume m3 per Job number	RS TMS - IMP_CN_Rail_3years_v2
		Job number	RS TMS - IMP_CN_Rail_3years_v2
		Weight kg per Job number	RS TMS - IMP_CN_Rail_3years_v2
		Transport type	Train model data (average)

		GPS historical data (average/example)	GPS tracking system (from RS partner)

ETA forecasting	Forecasting estimated time of arrival with comparison of different calculation models to determine the best accuracy. For example: • Artificial Neural Network (ANN) • Decision Tree Based Models • Recurrent Neural Network (RNN) • Support Vector Machine (SVM)	Origin & Destination	RS TMS - IMP_CN_Rail_3years_v2
		Job number	RS TMS - IMP_CN_Rail_3years_v2
		GPS data	Vayasens IoT
		Traffic density & intensity	SIRMA
		Weather conditions along route	SIRMA
		Holidays? (for ex. Chinese New Year causing delays ?)	SIRMA
		Train parameters i.e. (type, weight, speed, schedule etc.)	Train model data (average) / Schedule from RS chinese Agent
		Route information (distance, intermediate stops)	Route list - simulation of different time of arrival depending os a chosen route

POLISH POST			
Analytics solutions	**Description**	**Required Data**	**Data Sources**
Volume Flow forecasting	Predicting the inflow and outflow quantities of cargo from a distribution center	Item number (parcel)	CICU1907097-Chongqinq_Electronic Customs Declaration Form

		Container number	CICU1907097-Chongqinq_Electronic Customs Declaration Form
		- A method of converting weight to volume m3 should be worked out	CICU1907097-Chongqinq_Electronic Customs Declaration Form
		Weight (g) per Item number (parcel)	CICU1907097-Chongqinq_Electronic Customs Declaration Form
		Expected date of arrival of the cargo to Poland	by mail from China Post / GPS/Status/ETA forcasting

Carbon Footprint Prediction	Forecasting the carbon footprint for transport routes/modes taken to deliver the goods or per package	- A method of converting weight to volume m3 should be worked out	CICU1907097-Chongqinq_Electronic Customs Declaration Form
		Item number (parcel)	CICU1907097-Chongqinq_Electronic Customs Declaration Form
		Weight kg per container	CICU1907097-Chongqinq_Electronic Customs Declaration Form
		Transport type	Train model data (average)
		GPS historical data (average/example)	CHINA POST tracking system

ETA forecasting	Forecasting estimated time of arrival with comparison of different calculation models to determine the best accuracy. For example: • Artificial Neural Network (ANN) • Decision Tree Based Models • Recurrent Neural Network (RNN) • Support Vector Machine (SVM)	Origin & Destination (Malaszewicze Terminal)	CICU1907097-Chongqinq_Electronic Customs Declaration Form
		Container number	CICU1907097-Chongqinq_Electronic Customs Declaration Form
		GPS data	CHINA POST tracking system
		Traffic density & intensity	SIRMA
		Weather conditions along route	SIRMA
		Holidays? (for ex. Chinese New Year causing delays ?)	SIRMA
		Train parameters i.e. (type, weight, speed, schedule etc.)	Train model data (average)
		Route information (distance, intermediate stops)	Route list - simulation of different time of arrival depending on a chosen route