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

D1.9 Simulation-based analysis of T&L and ICT innovation technologies final version

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Responsible Author	Lavanya Meherishi (EUR-RSM)		
Contributions from	Camill Harter EUR-RSM <harter@rsm.nl>; David Cipres ITA <dcipres@itainnova.es>; José Luis López ITA < jlopez@itainnova.es>; Witold Statkiewicz PIT< witold.statkiewicz@pit.lukasiewicz.gov.pl >; Kostas Zavitsas VLTN <k.zavitsas@vltn.be>; Georgia Ayfantopoulou CERTH <gea@certh.gr>; Orestis Tsolakis CERTH <ortsolakis@imetb.gr>;		

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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
BC	Blockchain
BPMN	Business Process Model and Notation
B2B	Business-to-Business
B2C	Business-to-Consumer
EGTN	EU-Global T&L Network
EPCIS	Electronic Product Code Information Service
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
ICT	Information and Communication
IoT	Internet of Things
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LL	Living Lab
LMD	Last-mile Delivery
ML	Machine Learning
NSTR	Uniform Nomenclature of Goods for Transport Statistics
NUTS	Nomenclature of Territorial Units for Statistics
PI	Physical Internet
SSCC	Serial Shipping Container Code
T&L	Transport and Logistics
TEN-T	Trans-European Transport Network
UC	Use Case
UNCTAD	United Nations Conference on Trade and Development
WP	Work Package

1 Executive Summary

While the interim deliverable document, D1.8, specified the creation of the prototype 'PLANET integrated modelling capability', the current version of the document i.e., D1.9 not only recapitulates the creation process but also details the extension of the integrated modelling capability to different modelling use-cases along with the results obtained. More specifically, D1.8 developed the prototype PLANET integrated modelling capability by combining the various models mentioned in other deliverables. On the other hand, D1.9 tests this modelling capability through its application in various contextual scenarios based on the viewpoints of various modelling partners and foundational position papers.

In a nutshell, the integrated modelling capability is a pipeline of multiple quantitative models successfully combined and run sequentially. Through the extension and refinement of this integrated modelling capability, the goal of D1.9 is to support the *innovation, impact, and integrated* attributes of the EGTN concept by achieving the set of following <u>*research objectives*</u> in T1.4,

(i) define the impact of different ICT and T&L innovations on the development of the EGTN.
(ii) assess the impact of emerging concepts and technologies on the performance of freight transport corridors and hubs.
(iii) position the emerging technologies as contributors to the Physical Internet.

While successful ICT and T&L innovation adoptions can result in macroscopic changes in the performances of transportation networks and supply chains, these adoptions are also moderated by several factors such as geography/ context of adoption, leading to a different degree of implementation and, as a result, changed performances. Thus, to assess how the context of application of the different ICT and T&L innovations considered within the integrated modelling capability impact their performances, **three** geographical contexts based on Living Labs 1 and 3 are used as a backdrop. Moreover, this deliverable sheds light on how the outcomes of the micro-modelling efforts carried out using the integrated modelling capability can be generalized and utilized as inputs for the macro-modelling efforts developed within the PLANET project. It is pertinent to note that the PLANET integrated modelling capability developed to suit the contextual settings of the three-modelling use-cases is the main contribution of this deliverable.

In sum, this deliverable demonstrates the concept of '*whole is greater than the sum of its parts'* by highlighting the enhanced effect of integrating the features and potential of individual models developed across the PLANET project to model a range of operational contexts, emerging technologies, and future scenario logics.

2 Introduction

The EGTN concept can be understood as an advanced European strategy vision that implies the development of the Smart, Green and Integrated Transport and Logistics Network of the future. Its purpose is to efficiently interconnect infrastructure (TEN-T, Rail-Freight Corridors, etc.) with geopolitical developments, as well as to optimize the use of current & emerging transport modes and technological solutions. As efficiency and geo-economic developments do not necessarily lead to inclusivity and enhanced quality of life, the EGTN concept should be provided with the instruments to ensure equitable inclusivity of all T&L participants, increasing the prosperity of nations, preserving the environment, and enhancing Citizens' quality of life.

PLANET defines the following *attributes* for the EGTN concept, where an attribute is a feature that the EGTN, as a strategic vision, should manifest:

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

As described below, this deliverable considers **innovation**, **impact,** and **integrated** attributes, both, individually, as distinct features and collectively as a whole in the modelling to create an understanding of the EGTN concept:

- **innovation** is considered by modelling advanced ICT (AI, BC, IoT) and innovative T&L concepts (e.g., PI).
- **impact** is considered by focusing on KPIs at the different levels of aggregation and as seen by different stakeholders.
- **integration** is considered by building models based on integrated transport corridors and integrated operations.

By systematically modelling, analyzing, and evaluating T&L interactions and dynamics, PLANET goes beyond strategic transport studies and beyond transport ICT research to achieve the aforementioned criteria. From a T&L standpoint, the goal is to generate and test the most significant future scenarios. Rather than providing a 'platform', this deliverable focuses on providing a blueprint and a set of best practices to assist T&L actors in defining and implementing a clear digital strategy.

Modelling and simulation is one of the main research and development streams of the PLANET project as it can lead to an improved understanding and design of EGTN, and is thus, the focus of the research pursued in this deliverable. This focus has led to the development of the integrated modelling capability.

While the interim deliverable D1.8 focused on introducing and testing a prototype of the integrated modelling capability for only one modelling use-case scenario, this deliverable not only improves the prototype modelling capability and tests it on real data, but also extends the capability to two other modelling use-cases to examine its true potential.

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			
D1.9 Simulation-based analysis of T&L and ICT innovation technologies	Application of modelling approaches in support of LLS and Roadmap toward PI for EGTN.	Chapter 3,4,5	The respective chapters bring forward PLANET's integrated modelling capability to model, simulate, analyze, and compare the impact of the various ICT and T&L innovations to aid the transition from TEN-T to EGTN and PI paradigm.
TASKS			
ST1.4.1 Preparatory activities for the simulation	Preparatory activities for the simulation will build upon the scenarios formulated in T1.1 to detail the research questions for applying the ICT and T&L innovations model. More specifically, the scenario analyses of emerging technologies will be translated into concise plans for modelling and simulation. The results of the analysis of forthcoming legislative & policy initiatives (T1.3) will be integrated in the simulation plans to the extent that are expected to have an impact on the ICT and T&L innovations. Furthermore, the required data sets will be prepared which will contain information about corridor flows, node capacities, services, and actors	Chapter 3	Chapter 3 defines the scenarios within which the different ICT and T&L innovations will be evaluated. Section 3.4 lists the concise plans for modelling and simulating the impact of these technologies.
ST1.4.2 Impact assessment of	Impact assessment of T&L and ICT innovation technologies will apply the	Chapter 4, 5	Chapter 4 assesses the impact of the T&L and ICT innovations by using PLANET's integrated modelling capability within

T&L and ICT innovation technologies	quantitative models to EGTN simulation scenarios to establish a comparative evaluation of potential benefits from innovations considered (Autonomous vehicles, warehousing automation, advances in Sensors, IoT, Blockchain, 3D printing for some product types, hyperloop) and to define the factors affecting their selection in EGTN corridors. This will connect with some of the findings of T1.5. It will also provide input to WP4, T4.3.		each modelling use case. Chapter 5 presents the results obtained from the comparative evaluation of potential benefits from innovations considered.
ST1.4.3 Enhanced synchromodality and PI models for EGTN	Enhanced synchromodality and PI models for EGTN: This subtask will research and develop synchromodality and PI models for EGTN, extending the simulation scenarios of ST1.1.2 if necessary, to gauge the impact of PI and the role of the enabling technologies and innovations therein. These models will support WP2 components and modelling applications for the roadmaps.	Section 3.3.3 Chapter 4	The listed sections identify the PI models used as well as the requirements that should be fulfilled by models that enable synchromodality. Chapter 4 gauges the extent to which the modelling pipelines constructed within each use-case scenario meet the modelling requirements identified in Section 3.3.3 to enable synchromodality and full PI concepts for EGTN.

2.2 Deliverable Overview and Report Structure

This section provides a description of the Deliverable's structure, outlining the respective chapters and their content. The chapters 3, 4, and 5 are aligned to the research objectives of Task 1.4 as defined in Chapter 1. The contents of each chapter are further outlined below.

- **Chapter 3** considers the first research objective of the deliverable (as mentioned in Chapter 1).
  - To define and run the PLANET integrated modelling capability to successfully transition from a TEN-T network to an EGTN, firstly, this chapter provides the context of this deliverable by elaborating on the relevant use cases borrowed from the Living Labs within PLANET project.

- Secondly, this chapter provides a first-hand discussion of the technologies and innovation considered within the scope of each use case and their potential impacts within the scenarios they are deployed in.
- Furthermore, this chapter develops a methodological framework highlighting PLANET's integrated modelling capability which will be used to evaluate and quantify the effect of different technologies on the EGTN concept.
- **Chapter 4** considers the second objective of the deliverable.
- Specifically, this chapter evaluates the disruptive innovations identified in Chapter 3 and determines the extent to which the context of their deployment affects their impact.
- **Chapter 5** focuses on the third objective of the deliverable**.**
- This chapter establishes a comparative evaluation of the potential benefits emerging from the different ICT and T&L innovations within each relevant use case considered.
- **Chapter 6** synthesizes the results of the deliverable and summarizes the contributions to the project objectives.

3 Defining impact of ICT and T&L innovations on EGTN

This section provides a brief overview of the three different geographical settings used as modelling use-cases/scenarios, as well as the associated Transport and Logistics actors, stakeholders, technologies, and processes considered within each scenario. Although the PLANET project houses three living labs (LL 1, LL 2, and LL 3), with the aim of seeking relevant use cases, the current deliverable (i.e., D1.9) considers geographical settings, actors, stakeholders, and T&L processes that are aligned with the Living labs 1 and 3 only. By focusing on a Living Lab instead of devising an artificial case, we consider technologies that are currently being evaluated and found relevant by the stakeholders within the LLs. Thus, as Living Lab 2 does not evaluate any technology per se, it has not been used as an inspiration for a modelling use-case within this deliverable.

3.1 Use-Case 1 (LL1): Gateway to hinterland

3.1.1 Geography, Actors & Stakeholders, and T&L innovations:

Figure 1 shows the complete transport chain for containerized goods originating from mainland China and delivered to customers in the Madrid urban area. The highlighted box shows the operational context modelled within the PLANET integrated capability as the *first modelling use case*. We consider maritime container transport, terminal operations at ports and inland transport by means of rail or truck. The transport operations modelled are (i) port selection for the ocean liner to enter the European territory, (ii) inland movements of containers by scheduled rail service or by truck and (iii) transshipment across different modes (maritime to road or rail). Further details are provided in Section 4.1.

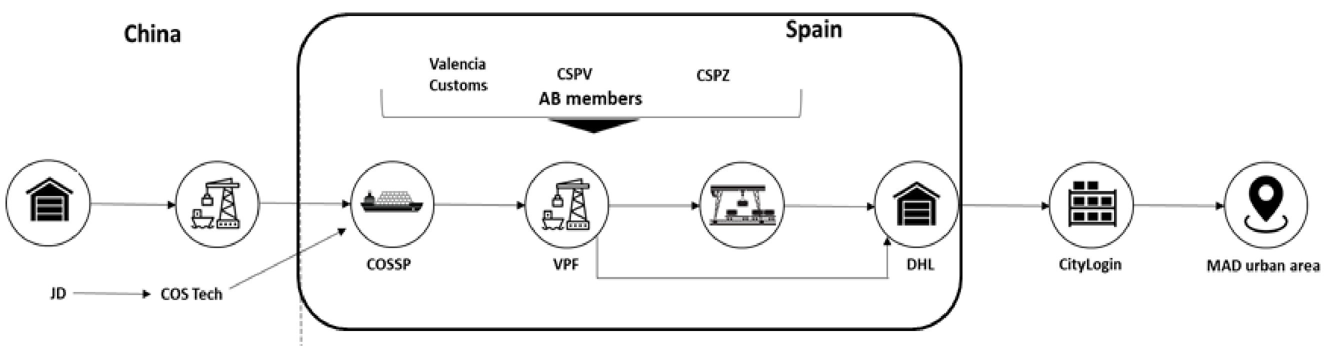

Figure 1 Transport chain described in LL1 and the modelling focus of Use-Case 1.

It is important to observe that the stakeholders and processes considered in this use case cover the EGTN scope at the *maritime corridor level*. Also, it is pertinent to note that the inclusion of intercontinental flow is novel and extends the current view of a corridor within a TEN-T network – which is limited to intra-European transport. The port selection problem plays an important role as it represents the decision-making problem of a stakeholder, the ocean liner, who needs to evaluate the advantages and disadvantages of *multiple points* of entry into the European territory. It can be observed that such a framework is a clear step forward towards a geo-economically aware EGTN.

3.1.2 Type of decision-making problem modelled:

Table 2 summarizes the focal decision-making problems considered in the container transport process described above. Furthermore, Table 2 compares the aim of LL1 and how this has been considered in defining the PLANET modelling approach. Overall, the specific goals of the Living lab are generalized and translated into an appropriate model.

Table 2 Type of decision-making problem considered in the PLANET integrated modelling capability for UC1 (LL1)

LL1 / UC1 aim	Consideration within the PLANET modelling approach
Real-time decision-making approach ● Implement PI and AI for inland transport optimization based on customer instruction. ● Give intelligence to terminals for dynamic routing considering network capacity, transport mode, service level and costs. ● Changing maritime routes & container inland transport re-routing	● *PI multi-agent simulation:* As such the multi-agent simulation models different stakeholders and processes as independent agents that follow a pre-specified logic and interact to each other. ● *Port Call decision model:* This optimization model captures the operational decision of an ocean liner regarding which ports to call at to enter the European territory.
Import from Shanghai to Barcelona ports. ● AI to take decision on changing POD and evaluate new alternatives. ● Alternative analysis in terms of economic costs and times: ● Vessel waits at the port until the slot is released. ● Change port rotation.	● *AI (forecasting model)*: This is integrated with the Port Call decision model to guide container vessels in the simulation. This is a data analytics model used to estimate the congestion at ports and thus, the value of AI deployment in the operations.

3.1.3 EGTN KPIs Considered:

Since the scope of the EGTN concept spans from innovation (that is deployed at the operational level) to geo-economical awareness (that requires macroscopic and aggregated considerations), we consider KPIs both at microscopic and macroscopic level. Thus, to evaluate the potential of the integrated modelling pipeline in the first modelling use-case, the KPIs considered are listed in Table 3:

Table 3 EGTN KPIs for first modelling use-case

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

It is pertinent to note that the choice of the micro and macro level KPIs is motivated by both the current stage of the modelling capability (in particular, what is being represented) and the need to interact with the Terminal model (c.f., Section 4.1.6) which provides insights at the aggregated level.

3.1.4 T&L and ICT innovations considered:

This section briefly presents the technologies and innovations considered in the PLANET integrated modelling capability developed for the contextual setting of Figure 1 and which are familiar within PLANET (e.g., Blockchain, Physical Internet, AI, Optimization).

While Table 4 provides an overview of the technologies/innovations considered along with their associated features that have been successfully modelled, Table 5 summarizes the expected impact of each of the considered technology/innovation in the contextual setting highlighted in Figure 1. Table 5 also compares the expected impact modelled in the PLANET integrated modelling capability with the impact as expected from stakeholders of LL1. Indeed, the concepts reported have a larger scope and higher degree of complexity than what decided to model in the definition of the integrated model.

Table 4 Technologies and innovations considered in the integrated PLANET modelling capability for UC1(LL1)

Technology /Innovation	Characteristics considered in the PLANET integrated modelling capability	Technology Description
Blockchain	The impact of has been modelled, rather than the precise operations the technology facilitates.	Blockchain, as a distributed ledger technology, is considered secure by design and is an example of a distributed database system with high fault tolerance. As such it has been employed to facilitate custom clearance transactions where security and reliability of information is key (Okazaki, 2018)
Physical Internet	• Integrated transport planning. • Full visibility in the transport chain.	Physical Internet (PI) aims to integrate logistics networks into an open and interconnected global system through standard containers and routing protocols (Ballot et al., 2014). PI is a global logistics system in which products are transported in standardized, modular containers as efficiently and effortlessly between continents as in the case of Digital Internet transferring information between servers. Physical Internet is an open framework also from the point of view of the use of the resources (Ballot et al., 2014; Montreuil, 2011).
Artificial Intelligence	• Predictive models • Neural networks	AI, or Artificial Intelligence, is a set of algorithms and machine implementations addressing a large class of problems that have been seen – until now – as solvable by human intelligence only. Out of the metaphor, Artificial Intelligence is used here for prediction of a certain quantity of interest given noisy historical data (Nilsson, 2014).
Optimization for decision making	Linear programming model	Under the umbrella term of optimization, which collects a set of quantitative methodologies to support decision making, we focus on one of the most studied and successful ones: Linear Programming. This is a method that, after constructing a mathematical model allows to find optimal solutions quickly (Dantzig, 2002).

Table 5 Impact of technology on T&L processes modelled in UC1 (LL1)

Technology	Impact on the business processes as from LL1 description	Modelled impact
Blockchain	• Time reduction in administrative processes • Secure business-to-business data exchange • Facilitate collaboration	• Time reduction on custom declaration processing.
Physical Internet	• Autonomous decision per container at each node. • Open logistics environment to share capacity data to improve the use of assets.	• Open logistics system: all available asset is fully visible and can be used without boundaries of ownership
Artificial Intelligence	• Selection of the best means of transport according to timetable, capacity.	• Forecasted congestion at a port used in combination with the Port call optimization model.
Optimization for decision making	• Port call decision. If there is congestion in a port (wait for port to clear) or go to other port.	• The same as the expected from LL1 description.

3.2 Use-case 2 (LL1): Last-mile Delivery

3.2.1 Geography, Actors & Stakeholders, and T&L innovations:

While the complete transport chain shown in Figure 2 is similar to that shown in Figure 1, the operational context modelled within the PLANET integrated capability as the *second modelling use case* (as shown in the highlighted box) is different. Specifically, the second modelling use-case moves beyond containerized cargo operations and focuses on the complete last mile delivery (LMD) process for parcel goods from depots/ distribution centers located in the urban city of Madrid to end-customers located all around the Madrid city. The urban LMD of parcel goods by means of trucks is considered. The LMD operations modelled are (i) identification of vehicle tours to complete customer orders given time window constraints, (ii) identification and matching of delayed and non-delayed vehicles and reshuffling parcels with minimal detours to respect time window constraints. Further details are provided in Section 4.2

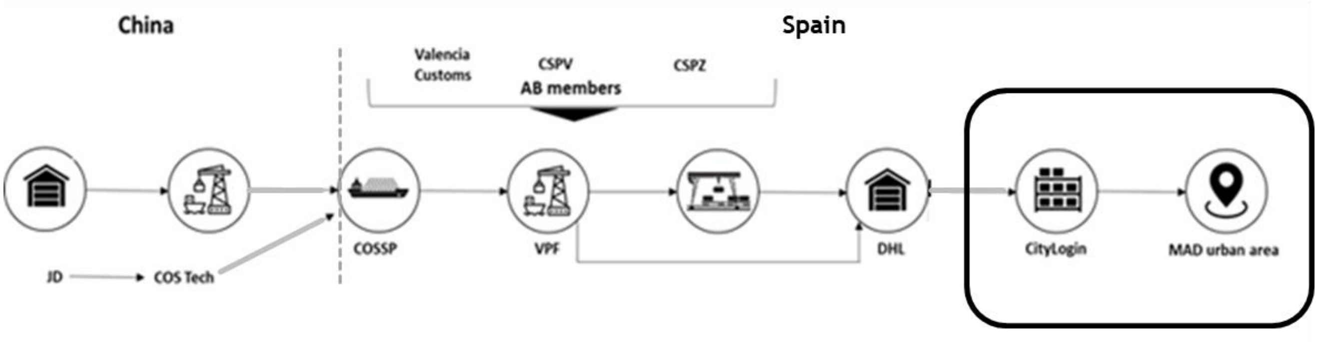

Figure 2 Transport chain described in LL1 and the modelling focus of Use-Case 2.

It is important to note that the stakeholders and processes considered within the context of the second use-case cover the EGTN scope at the *inland corridor level*. The congested urban environment and the multiple different functionalities it accommodates, impose significant uncertainty in last mile delivery operations. Uncertainty is observed in travel times due to road congestion, parking availability in proximity to the delivery location, information accuracy associated with package drop off location, as well as when applicable uncertainty about the presence of the recipient at the time and location of the drop-off. Last mile operators frequently assume a unilateral travel speed and drop-off duration in their planning process. Depending on the conditions encountered during the delivery round, last mile operators frequently need to dynamically redesign urban delivery rounds, to alleviate delivery delays. This challenge is highly relevant to the concept of the Physical Internet and EGTN as it utilizes the benefits associated with real-time tracking of parcel deliveries and vehicle fleet to dynamically reshuffle parcels and re-route vehicles on the fly. The problem focuses on decision-making at an operational level.

3.2.2 Type of decision-making problem modelled:

Table 6 summarizes the focal decision-making problems considered in the parcel distribution process described in Figure 2. Table 6 also compares the aim of Use case 2 within Living Lab 1 and how this has been considered in defining the PLANET modelling approach. Overall, the specific goals of the Living lab are generalized and translated into an appropriate model.

Table 6 Types of decision-making problem considered in the PLANET integrated modelling capability for UC2 (LL1)

LL1 / UC2 aim	Consideration within the PLANET modelling approach
Real-time decision-making approach • Implement PI to assist collaboration between last-mile logistics operators to hedge against urban uncertainty • Dynamic truck route optimization for parcel deliveries	• *PI multi-agent simulation:* Different stakeholders (i.e., logistics operators in the last-mile) and last-mile delivery processes are modelled as independent agents that follow a pre-specified logic and interact with each other. • *Parcel reshuffling model:* Matches pairs of non-delayed and delayed vehicles performing last-mile delivery rounds in the face of urban uncertainty.

3.2.3 EGTN KPIs Considered:

Since the scope of the EGTN concept spans from innovation (that is deployed at the operational level) to geo-economical awareness (that requires macroscopic and aggregated considerations), KPIs are considered at both the microscopic and macroscopic level. Thus, to evaluate the potential of the integrated modelling pipeline in the second modelling use-case the KPIs considered are listed in Table 7:

Table 7 EGTN KPIs for second modelling use-case

Microscopic KPI	Macroscopic KPI
• Average Distance travelled per vehicle. • Total number of transport vehicles used per mode. • Number of on-time deliveries • Operating costs of last-mile deliveries • CO_2 emissions (Kgs/ton) • Average delivery time (i.e., average duration of a parcel delivery from depot to final customer location)	• Parcel delivery reliability (i.e., number of parcels delivered on time) • Parcel delivery lead time (i.e., average parcel lead time from depot to end-customer location) • Vehicle transport fill rate (fraction of total vehicle capacity that is utilized) • Transport cost

3.2.4 T&L and ICT innovations considered:

This section briefly presents the technologies and innovations considered in the PLANET integrated modelling capability developed for the contextual setting of Figure 2 and which are familiar within PLANET (e.g., Physical Internet, AI, Optimization).

While Table 8 provides an overview of the technologies/innovations considered along with their associated features that have been successfully modelled, Table 9 summarizes the expected impact of each of the considered technology/innovation in the contextual setting highlighted in Figure 2. Table 9 also compares the expected impact modelled in the PLANET integrated modelling capability with the impact as expected from stakeholders involved in UC2 of LL1. Indeed, the concepts reported have a larger scope and higher degree of complexity than what decided to model in the definition of the integrated model.

Table 8 Technologies and innovations considered in the integrated modelling capability for UC2 (LL1)

Technology /Innovation	Characteristics considered in the PLANET integrated modelling capability	Technology Description
Physical Internet	Integrated transport planning through	The Physical Internet (PI) is the visionary paradigm supplying an integrated approach to address logistics

	collaboration to share resources without boundaries.	integration and collaboration issues, and to pave the road forward to deploying efficient supply chains (Ballot et al., 2014). Physical Internet is an open framework from the point of view of the use of the resources. The use of open warehouses and transport networks looks for a systemic load consolidation and optimization in which the capacity in the logistics sites and transport networks could be more available for the use of stakeholders in a more optimized way: reducing energy consumption, environmental emissions, and economic cost (Ballot et al., 2020)
Internet of Things (IoT)	End-to-end visibility in the transport chain	The Internet of Things (IoT) describes the network of physical objects that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet (Oracle, 2022). IoT applications guide businesses for making decisions by providing actionable intelligence from real-time and old (pseudo or non-real time) data mashup (Pundir et al., 2019)
Optimization for decision making	Linear programming model	Same as Table 4. The term optimization encompasses a collection of quantitative methodologies to support decision making. Linear Programming is one of the most studied and successful methods.
Green Logistics	Use of alternate sustainable modes of transportation for LMD	Green Logistics is the study of practices that aim to reduce the environmental externalities, mainly related to greenhouse gas emissions, noise and accidents, of logistics operations and therefore develop a sustainable balance between economic, environmental, and social objectives (Dekker et al., 2012)

Table 9 Impact of technology om T&L processes for UC2 (Ll1)

Technology	Impact on the business processes as from LL1 description	Modelled impact
IoT	• End-to-end visibility over different operators and means of transport	• The same as expected from the LL1 description. GPS trackers installed in vehicles and parcel barcodes can help in live tracing and tracking of vehicle and goods locations in the last mile.

Physical Internet	• Open logistics environment to share asset (viz. trucks, depots) capacity, routes, and customer order data to improve the last-mile delivery performance.	• Open logistics system: Collaboration between all last-mile logistics operators with complete visibility of all available assets (depot space, vehicle capacity, live vehicle locations) which can be utilized without boundaries of ownership. Also, complete visibility and sharing of customer order information between competing carriers.
Optimization for decision making	• Vehicle routing Problem: Optimal routing of parcel deliveries in the last mile • Dynamic matching of delayed and non-delayed vehicles	• The same as the expected from LL1 description. Because of urban uncertainty caused by traffic conditions, inaccurate delivery locations etc., to serve customers within the promised time-windows, it is important to dynamically match delayed and non-delayed vehicles considering driver working hours, detour times and costs.
Green logistics	• Replacing the conventional diesel trucks with more sustainable vehicle options to carry out the last-mile deliveries	• The same as the expected from LL1 description.

3.3 Use-Case 3 (LL3): New Silk Route

3.3.1 Geography, Actors & Stakeholders, and T&L innovations:

Figure 3 shows the complete transport chain for containerized goods on the new silk route originating from mainland China and delivered to customers in Poland. The highlighted box shows the operational context modelled within the PLANET integrated capability as the *third modelling use cas*e.

The purpose of this use-case is to explore the possibility of expanding Physical Internet along the New Silk route by assessing the impact of the implementation of IoT on shipments transported by rail from China to Europe. The deployment implies standardizing the transmitted information along the entire supply chain (for e.g., implementing GS1 standards) and linking it to a platform using Artificial Intelligence for the purpose of optimizing logistics processes. Thus, this use-case focuses on the intercontinental long-haul rail transportation of containers as well as the terminal operations. The operations modelled are (i) information flow between stakeholders in the Eurasian corridor, and (ii) physical flow of goods by scheduled rail services. Further details are provided in Section 4.3.

It is important to observe that the stakeholders and processes considered in this use case cover the EGTN scope at the *intercontinental rail freight corridor level*. Also, it is pertinent to note that the inclusion of intercontinental flow extends the current view of a corridor within a TEN-T network – which is limited to intra-European transport.

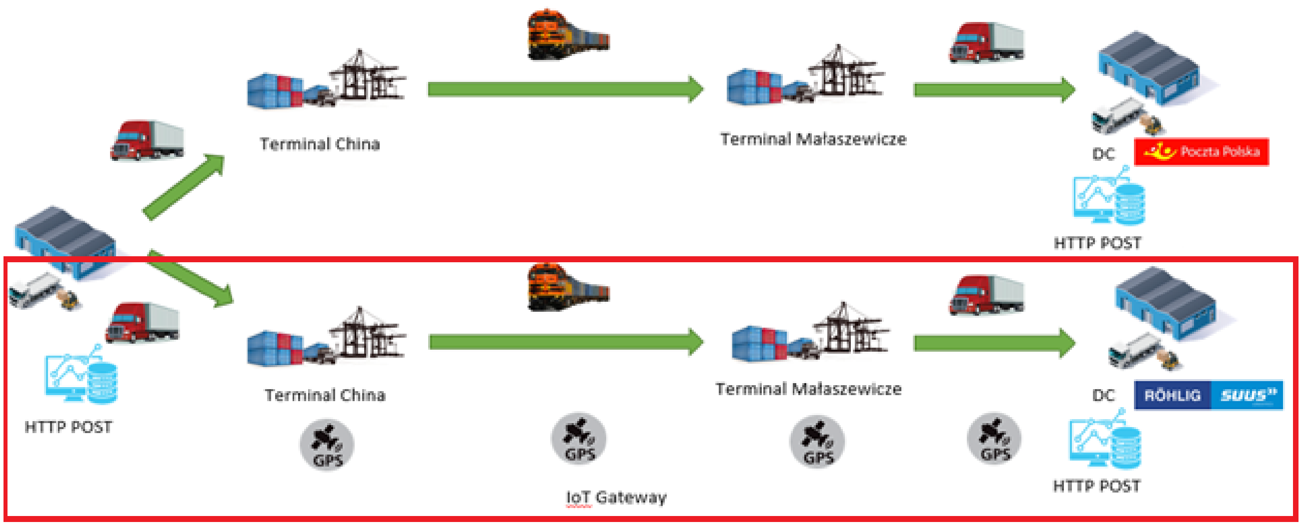

Figure 3 Transport chain described in LL3 and the modelling focus of Use-Case 3.

3.3.2 Type of decision-making problem modelled:

Table 10 summarizes the focal decision-making problems considered in the container transport process described in Figure 3. Table 10 also compares the aim of Use case 3 within Living Lab 3 and how this has been considered in defining the PLANET modelling approach. Overall, the specific goals of the Living lab are generalized and translated into an appropriate model.

Table 10 Types of decision-making problem considered in the PLANET integrated modelling capability for UC3 (LL3)

LL3 / UC3 aim	Consideration within the PLANET modelling approach
Real-time decision-making approach • Implement IoT along the New silk road rail corridor for increased visibility of physical flow of goods. • Implementation of GS1 standards in the logistics processes of the new silk road • Implementation of AI for forecasting events (arrival of goods etc.) in the rail corridor.	• *Business Process Modelling:* Process maps comprising of all business processes related to logistics for New Silk Road operations are developed. Operations with potential for improvement by implementing innovative solutions are identified and tested through experiments and simulations. • *AI (forecasting model)*: This is appended with Business Process Model. This is a data analytics model used to estimate the arrival of containers at the main entry point in Europe: Malaszewicze rail terminal and accordingly issue alerts and recommendations to stakeholders along the corridor.

3.3.3 EGTN KPIs Considered:

Since the scope of the EGTN concept spans from innovation (that is deployed at the operational level) to geo-economical awareness (that requires macroscopic and aggregated considerations), KPIs are considered at both, a microscopic and macroscopic level. In the context of the third modelling use-case, the KPIs considered are listed in Table 11:

Table 11 EGTN KPIs for third modelling use-case

Microscopic KPI	Macroscopic KPI
• Number of containers delivered per month. • Average Working Time per delivery • Co2 Emissions (per delivery) • End-to-end visibility • Average Working time in Customs related activities. • Total Compliance costs • Total Operational Costs • Reduction in Supply chain disruptions	• Container Delivery Volume • Container Delivery Costs • Co2 Emissions

3.3.4 T&L and ICT innovations considered:

This section briefly presents the technologies and innovations considered in the PLANET integrated modelling capability developed for the contextual setting of Figure 3and which are familiar within PLANET (e.g., Physical Internet, Block Chain, Internet of Things, Optimization).

Table 12 Technologies and innovations considered in the integrated modelling capability for UC3 (LL3)

Technology /Innovation	Characteristics considered in the PLANET integrated modelling capability	Technology /Innovation Description
GS1 standards	Standardization of information flow for ease of interoperability	GS1 standards create a common foundation for business by uniquely identifying, accurately capturing, and automatically sharing vital information about products, locations, assets and more. Businesses can also combine different GS1 standards to streamline business processes such as traceability (GS1, 2023).
Internet of Things (IoT)	End-to-end visibility in the transport chain which helps providing information on the	Same as Table 8. The term, IoT, collectively refers to a network of connected devices and the technology that facilitates communication between devices and the cloud, as well as between the devices themselves.

	status and location of goods in real time.	
Artificial Intelligence	Forecast information to enable different services such as a corridor route optimization analytics and transport models' services to build decision support systems.	Same as Table 4. At its simplest form, artificial intelligence is a field, which combines computer science and robust datasets, to enable problem-solving. In the given context, it is used to ingest data collected by IoT devices and predict the estimated time of arrival of rail freight at the Malaszewicze terminal.

While Table 12 provides an overview of the technologies/innovations considered along with their associated features that have been successfully modelled, Table 13 summarizes the expected impact of each of the considered technology/innovation in the contextual setting highlighted in Figure 3. Table 13 also compares the expected impact modelled within the boundaries of UC3 with the impact as expected from stakeholders involved in UC3 of LL3. Indeed, the concepts reported have a larger scope and higher degree of complexity than what has been decided to be modelled within the scope of UC3.

Table 13 Impact of technology on T&L processes for UC3 (LL3)

Technology	Impact on the business processes as from LL3 description	Modelled impact
IoT	End-to-end visibility over different operators and means of transport. 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.	The same as expected from the LL3 description i.e., complete end-to-end visibility over the rolling stock and its components along the new-silk route.
GS1 standards	• SSCC mandatory on the Transport Label and in the 2D barcode • Improved first and last mile processes through the capture of essential information relating to the transport task from the barcode on the transport label. • Visibility of transport task requirements even if the remote IT systems are unavailable for look-up. • Improved efficiency and interoperability across industry through a standard label across the entire supply chain	A critical component to implement PI (such as collaboration and sharing resources) is standardization of data to ensure interoperability. Thus, GS1 standards can be viewed as a proxy for collaboration through PI between business partners along the new silk route. The modelled impact is the same as the expected from LL 3 description.

Artificial Intelligence	Forecasting estimated time of arrival of containers in Europe for further route optimization in inland corridors.	The same as the expected from LL3 description i.e., AI algorithms are run on the real-time data provided by the IoT sensors connected to the rolling stock components to predict the time of arrivals of the freight and alert customers accordingly.

3.4 Methodological Framework for simulation:

3.4.1 PLANET integrated modelling pipeline and Modelling Use-cases:

This section presents a brief discussion on the architecture of the integrated modelling pipeline. Further, a formal description of the associated modelling use-cases is provided which would be examined in greater detail in Section 4 and which are based on the three scenarios described in the previous sections.

By definition, a **modelling use case** is a specific situation in which a model could potentially be used. For our purposes, it provides main user (stakeholder interested in the analysis), context of application (logistic setting of interest), and evaluation scenarios of interest.

Every modelling use case is related to a specific pipeline. Here, **pipeline** implies a sequence of models run in sequence in such a way that the output of one will be the input of another. For our use here, a pipeline should substantiate a modelling use case. In other words, for each modelling use case, a pipeline is devised which is executed in a certain programming language.

Figure 4 provides the template of the integrated modelling pipeline developed and used for each of the three-modelling use-cases identified. It shows how, starting from the given problem and contextual setting of each use case, two separate **modelling scenarios** viz. the *as-is scenario* and the *To-be scenario* are considered for modelling. On the two scenarios a combination of quantitative models run in a sequential manner is executed outputting values related to the KPIs defined in Sections 3.1.3, 3.2.3, and 3.3.3. This output is then processed and presented to a macroscopic model. The post-processing pipe step is required to transform the output of the model executed at an operational/ microscopic level into a valid, and meaningful input for the strategic/macroscopic models.

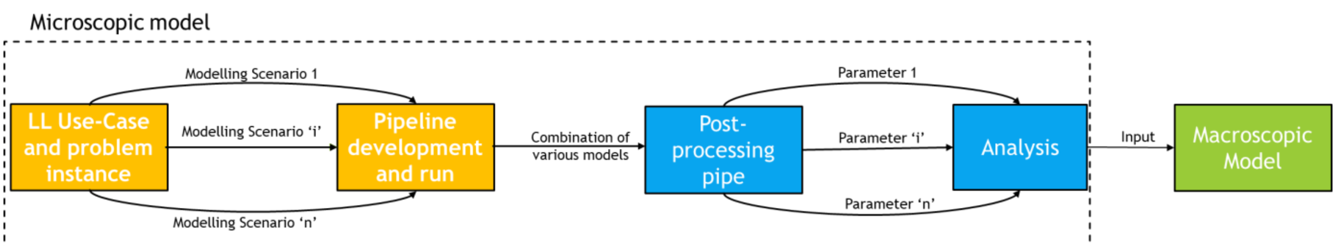

Figure 4 Pipeline high-level definition

It is important to note that the term 'modelling scenario' is different from the term 'modelling use-case'. Modelling scenarios refers to settings which the modeler finds to be of primal interest (among the many alternatives present to him) when devising a quantitative model for a modelling use-case. In other words, a modelling scenario is a specific situation that is represented in abstract terms by the model.

By means of a summary,

1. Each scenario implies a selection of technologies to consider that is motivated by the associated LL.
2. The scenarios also define the freight transport corridors and hubs to consider.
3. The to-be scenarios position some technologies as contributors to the concept of PI.

Table 14 formalizes a template for a generic modelling use case which is composed of several features that are explained in the Table itself.

Table 14 Modelling Use Case template and information for PLANET integrated modeling capability

Feature	Explanation
Modelling use case title:	A title for the modelling use case
Narrative presentation:	Detailed overview of what problems are being modelled and how they are being modelled.
PLANET partners involved:	List of partners name involved in the modelling use case
Model stakeholders:	List the main stakeholders considered in the model
Involved mathematical and simulation models	List the models involved (as defined in D1.2, D1.3)
Focal technologies and innovations:	List the technologies considered in the modelling use case
Modelling scenarios:	Describe the scenarios at a high-level

3.4.2 EGTN Synchromodality Requirements:

Since one of the goals of T1.4 is to research the synchromodality models for EGTN, to define the possibility of deploying the concept of synchromodality, Table 15 presents the business requirements of synchromodality identified through several discussions held with various LL stakeholders. In Section 4, Table 15 will further be used as a guide to examine if the integrated modelling pipelines developed for each of the three scenarios have the potential to be adapted towards enhanced synchromodality in the EGTN.

Table 15 Synchromodal model requirements for EGTN

Synchromodal model requirement	Requirement for EGTN stakeholders and key actors	Explanation
Information on departure times and transit time distribution for all scheduled asset	**Exact schedule information for near-future departing transport services is shared.** **The transit time of each transport mean is tracked and historical data on transport lead time is shared**	The synchromodal model provides decision support assuming exact and reliable information on departure times. This information is often not available by practitioners.
Information on unit transport cost and available capacity for all scheduled transport scheduled	**Cost and capacity information for the near future is exact and shared.**	Cost and capacity are sensible information. Key to the meaningful devise of any transport plan. This information should be reliably defined and made available in real-time.
Target reliability level	**Visibility of end-customer agreed reliability**	Synchromodal transport requires a certain reliability target being set jointly by customer and network operator. While the customer might aim for the highest possible value, it is the network operator who can define a meaningful value.
Real-time position of all containers in the network	**Real-time visibility of all containers** **Sharing of real-time information on containers position**	To being able to adapt transport plans, visibility on the asset and capacity to change and adjust plans is required. In many real cases this is simply not possible, thus leading to little room for the deployment of synchromodality.
Deployment of the Synchromodal (adaptive) plan	**Real-time adjustment of transport decisions for each container at each node of the network.**	Being able to adjust a transport plan is a pre-requisite of synchromodality. This is often not possible, especially for inter-continental flows where different technologies are used.

4 Assessing the impact of emerging concepts & technologies on freight transport Corridors and hubs

4.1 Modelling Use Case 1:

In 2021, around 40% of total containerized trade was on the main East-West routes – between Asia, Europe and the United States (UNCTAD, 2022). The large volume and high value of cargo transported by containerships has driven significant attention towards methods for improving the efficiency of fleet and port operators.

Container routing problems typically assume a set of pre-defined routes, and a decision requires to be made for the optimal allocation of slots to maximise profit, considering the expected time for maritime transportation, transhipment at the port, and hinterland transport. Since maritime transport constitutes the longest part of the journey of a container, decisions must be taken a long time before they become effective. In contrast, port operations and hinterland transport are relatively short, but they contribute chiefly to the disruption and delay risk. As a result, the decisions taken prior to the journey might not be optimal any more by the time the vessel approaches a port in Europe. Efficiency of port and hinterland operations could be improved if the decision on port calls and corresponding hinterland routes were postponed as much as possible. Congestion could be balanced across different ports and hinterland routes could be optimized.

However, there are barriers to enabling such an optimized decision making. Real-time data needs to be available; it needs to be shared by stakeholders who might be competitors, and there needs to be a capability to take optimized decisions from a system perspective in an automated fashion. These barriers can be overcome through novel technologies such as IoT, AI, and Blockchain, which pave the way towards a Physical Internet transportation system.

In this use-case, modelling and simulation techniques are used to evaluate from a Physical Internet point of view how collaborative logistics can be improved in the corridor from China to the Iberian Network. Special focus on how Planet paradigm technologies such as AI, BC, etc. helps to improve collaboration in these processes.

4.1.1 Modelling Scenarios for Use Case 1:

For our purpose in this deliverable, the modelling scenarios developed for the focal processes given in Figure 1 have been sourced from D1.2 (PLANET, 2021)and D1.3 (PLANET, 2022a) and adapted to the context of Use-Case 1 considered in this deliverable. Table 16 provides a summary of these scenarios modelled using the integrated modelling capability.

Table 16 Modelling scenarios for the PLANET integrated modelling capability.

Simulation	Scenarios	Description
PI Maritime Network Asia (China) – Europe (Valencia, Madrid)	**AS IS (current)**	Ocean Liner'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.

		Terminals provide optimized dynamic routing of containers through the network (Intelligent algorithms based on AI).
PI Node (Distribution warehouse)	**AS IS (current)**	Container from Valencia Port arrives at Warehouse, container is unloaded, and then deliver pallet/parcels to destination with standard truck/van. Manual operation in warehouse with fixed rules (i.e. static allocation of products to zones in the warehouse).
	TO BE (PI network)	Containers arrives at automated warehouse, where pallet units are defined. Modelling the warehouse human resources, based on inflow/ outflow predictions. Pallets are then sent to Madrid city hubs where parcels are created for final customers in Madrid city. Track & trace delivery using Sustainable vehicles. Automated operations in the warehouse (AGVs). Smart Decision Making: Adapting the flows of goods to the situation in the warehouse (digital clones).
Artificial Intelligence	**AS IS (current)**	Little to no forecasting for quantities of interest into current decision making that is chiefly guided by expert knowledge and simple expressions.
	TO BE (AI adoption)	Deployment of Artificial Intelligence methods for supervised learning tailored to the specific quantity of interest. Estimation and Forecasting are adopted in multiple aspects of a single decision-making procedure.
Automated decision making	**AS IS (current)**	Decisions are made without support from mathematical models. Decisions are not *optimized*, but status-quo and current practice prevails without support from quantitative models and methods.
	TO BE (Optimization Adoption)	Optimization models are used to support (and drive) decision making in complex problems. Various decisions at different levels are supported for automated decision-making models.

4.1.2 Modelling Pipeline:

Table 17 maps the features of the first modelling use case defined in Section 3.1 and detailed in Section 4.1 to the generalized modelling use case template provided in Table 14. This has further been translated into the pipeline depicted in Figure 5. Each component of the pipeline is described in a separate section (cf. Sections 4.1.3, 4.1.4, 4.1.5, 4.1.6), in what follows we describe the pipeline by explaining how the models interact and show the relation with the EGTN concept.

Table 17 Description of Modelling Use-Case 1 features for PLANET integrated modelling capability

Feature	Development of Modelling Pipeline for UC1 (LL1)
Modelling use case title:	PLANET integrated modelling capability for Gateway to Hinterland corridor
Narrative presentation:	Containerized cargo from China to inland Spain can enter the Mediterranean coasts of Spain via several ports. Congestion at the ports impact the decision of the ocean liner shipping company which results in different hinterland connections being used. In this setting, several technologies impact decision-making. Utilizing the multi-agent simulation as a base, AI and Optimization models are integrated to evaluate the impact of emerging technologies on T&L processes. Finally, a macroscopic model analyses long-term changes in flows resulting from the operational analysis.
PLANET partners involved:	EUR, IBM, ITANNOVA, VLTN
Model stakeholders:	Ocean liner, port authorities, port terminal operators, trucking companies, rail operator, hub operators.
Involved models	PI simulation, Forecasting model, Port call decision model
Focal technologies and innovations:	Physical Internet, Artificial Intelligence, Optimization, Blockchain
Modelling scenarios:	As is situation vs To-be situation (deployment of PI and paradigm technologies of AI, BC, Optimization)

Figure 5 depicts a visual representation of the different models run in a sequence to form the pipeline for the modelling use-case under consideration. As can be observed, the pipeline consists of yellow boxes representing data and azure boxes representing models that are connected by several arrows. Starting from COSCO data, the Congestion prediction model, based on AI, forecasts the number of containers predicted at each port. After the calculation of the congestion at the ports based on an estimated port capacity level, the congestion level is provided to the Simulation Input “Excel” spreadsheet. This document contains all specifications of transport means, technologies and demand information required to execute the multi-agent simulation. Before the simulation is executed, the Port Call decision model (cf. Section 4.1.3) is called, which, using the predicted congestion, computes the optimal port of call for the ocean liners. The decision is then stored back in the Simulation Input “Excel” and serves as input for the PI multi-agent simulation. (cf. Section 4.1.2) This model generates an instance of the network described in Section 3.1.1 (cf. Figure 1) and executes a multi-agent simulation where the a prespecified scenario is executed by simulating all transport and transshipment operations. As a result of this simulation, the KPIs defined in Table 3 are computed. By comparing two scenarios run, the parameter changes relevant for the Terminal model (cf. Section 4.1.6) are computed. Finally, an execution of the Terminal model allows for an estimation of the macroscopic effect of technology.

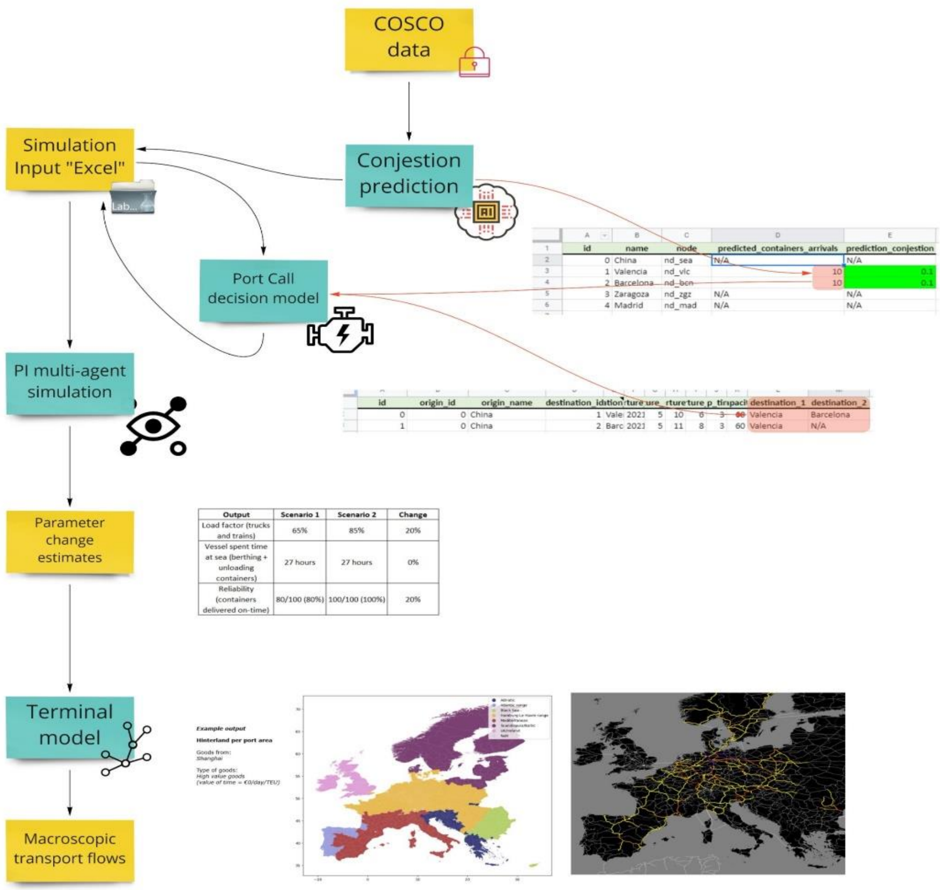

Figure 5 The pipeline - The PLANET integrated modelling capability for UC1

We now highlight the relationship between the developed pipeline and the EGTN concept and attributes selected in Section 2 (i.e., Innovation, Impact and Integrated). First, the containerized cargo flow that is considered crosses the EU boarder with a decision on which points of entry to use. This is a fundamental feature to qualify this modelling effort for the EGTN concept within PLANET. Indeed, this allows for an understanding of the impact of planetary/global decisions at the local level. Second, several emerging technologies are considered in a concerted deployment and their effect at the macroscopic level is computed. This relates to the Innovation and Impact attributes of the EGTN concept as it allows to evaluate the impact of innovation at the EGTN level.

Although the interim deliverable D1.8 described the different models considered in the pipeline developed in Figure 5, they are described again in Sections 4.1.3, 4.1.4, 4.1.5, 4.1.6 for the sake of completeness of this document.

4.1.3 PI multi-agent simulation

The PI multi-agent simulation is a part of the Physical Internet network simulator model developed by ITANNOVA and described in D1.3 (PLANET, 2022a). More information on the model can be found there.

Figure 6 presents the overview of the PI multi-agent simulation. The model is composed of two types of nodes: The sea ports (i.e., the PI port nodes such as Valencia, Barcelona, etc.) and the dry ports (i.e., the PI hinterland nodes such as Zaragoza, Madrid, etc.) The blue nodes correspond to seaports of Barcelona and Valencia, and the yellow nodes correspond to dry ports of Zaragoza and Madrid.

At a given time, vessels which are carrying containers are faced with two decision time points (viz. day -2, day -1) as they approach the seaports, and can choose which one of the seaports (e.g., Valencia and/or Barcelona) to call at. Once the containers arrive at the port, they are unloaded from the vessels. At the landside, there is a fleet of transport vehicles (trucks and trains) that run circular routes with a given schedule. When these transport vehicles arrive at one of the seaports, they load containers and transport them to their destination (dry port).

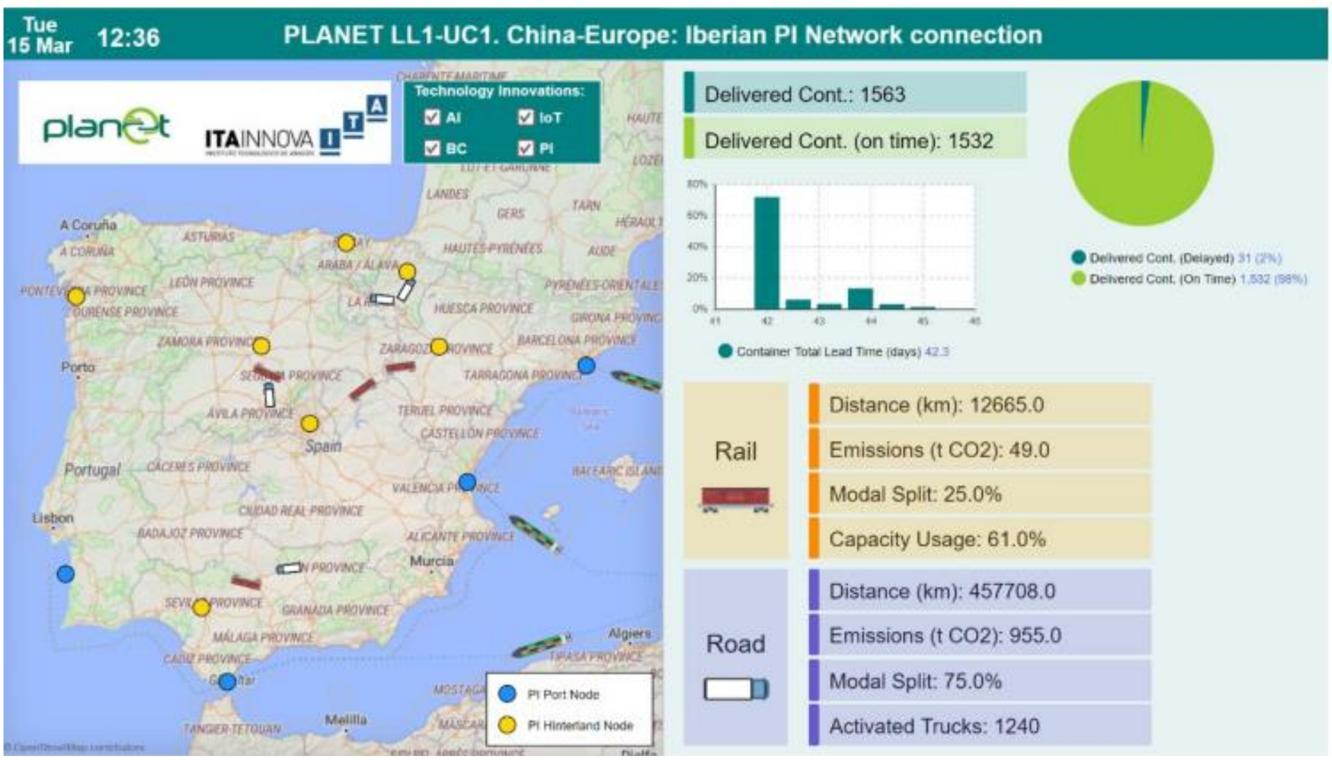

Figure 6 Multi-Agent Simulation overview in the PI Network Simulator

Each agent in the model (nodes, vessels, transport vehicles, containers) is modelled by state charts that capture the actual process sequence of that agent. Communication between agents is done by messages, which allows

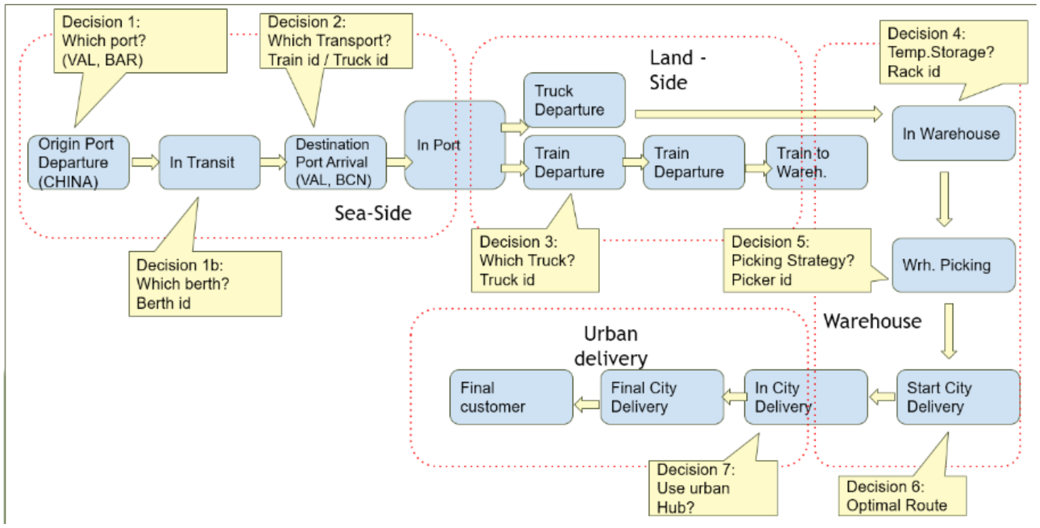

Figure 7 Detailed process flow modelled by the multi-agent simulation.

triggering transitions that make an agent take a decision or move from one state to another.

During the simulation, the model allows the collection of statistics (numerical indicators, graphs, histograms, etc.) such as the number of containers delivered, number of containers delivered on time, the containers lead time, the fill rate of the transports or the modal split, among others. In addition, the model allows different scenarios to be parameterized, for e.g., evaluating the impact of applying or not applying technologies such as blockchain in certain processes or considering the adoption of PI.

The model and process just described are related to part of the Sea and Land-side operations depicted in Figure 7. This relation between the LL's operations, previously described in in Section 3.1.1, and the multi-Agent simulation shows the practical relevancy of the PLANET integrated modelling capability.

4.1.4 Port call decision model

The description of the Port Call decision model from D2.14 (PLANET, 2022b) is reported here to make this deliverable complete. Further information on the model can be found there.

For a giver liner shipping route, which is a sequence of port calls for a containership, the aim of the proposed program is to decide whether to call or not at all ports within a subset of the route ports. As hinterland transport can forward some to the containers to their hinterland destinations, the program minimizes the cost of the maritime and hinterland transport as well as port handling costs and accounting for delays. In the Living Lab context, the question concerns *COSCO's aem1* route that is designed to call at both Valencia and Barcelona ports. As depicted in Figure 8, the decision between two alternatives must be taken considering both port and hinterland congestion on the route to the customer. The decision variables capture if a specific cargo shipment (container) is discharged in Valencia or Barcelona. For example, x_{PC} where P denotes the port of discharge and C denotes the container identification, is further tied to a specific destination. Therefore, for any container C, $x_{BC} + x_{VC} = 1$. Then a binary variable indicating whether a port $'P'$will be called can be defined as y_P, that will be equal to 1 if at least one container is discharged there. The point of having a y parameter is to allow for port handling and vessel queueing costs of calling an additional port to be represented.

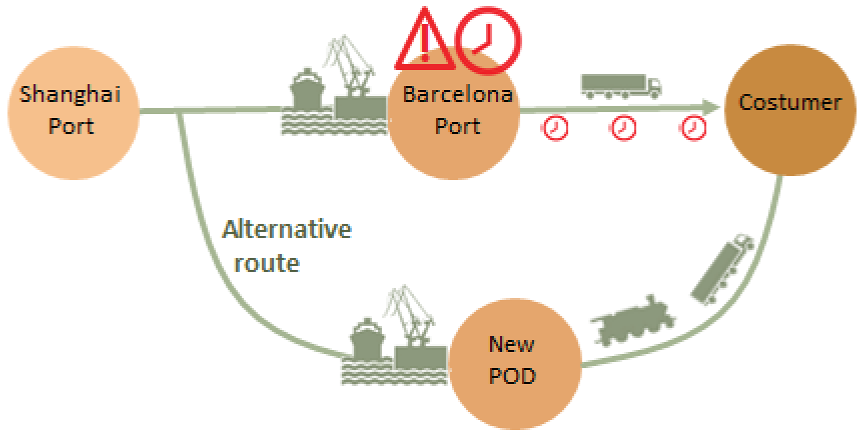

Figure 8 The real case motivating the port call decision model.

In Figure 9, a simple implementation of the port call decision model is illustrated. The left column (light green) names the destination of each container. The y variable (first line below the colored section) reflects the main decision variable of the model, which captures which of the two ports the vessel should call. When equal to 1 the port is called, and when equal to zero the port is not called. The two-colored columns on the top right capture the x decision variable, which indicates where each container is discharged (1 resembles the discharge location). The figure below captures how the solution of the program changes for different port call costs. On the left, the port call cost is low for both Barcelona and Valencia, and the algorithm decides to call both, also indicating where to discharge each container. In the instance in the middle, the call cost increases substantially, representing a large queue for both ports. In this instance the algorithm chooses to call only at the port of Valencia, as the hinterland connections are closer. The third instance (right) illustrated that the decision changes if the level of congestion at the two ports is not even, and a longer queue is observed at Valencia. The program then, decides to only visit the port of Barcelona.

	discharge port, x	
final destination	Barcelona	Valencia
Zaragoza	1	0
Madrid	0	1
Albacete	0	1
Zaragoza	1	0
Zaragoza	1	0
Madrid	0	1
Madrid	0	1
Valencia	0	1
Murcia	0	1
Barcelona	1	0
Call port, y	1	1
Call, LHS	100	100
Call, RHS	4	6
M	100	100
Call cost	0	0

	discharge port, x	
final destination	Barcelona	Valencia
Zaragoza	0	1
Madrid	0	1
Albacete	0	1
Zaragoza	0	1
Zaragoza	0	1
Madrid	0	1
Madrid	0	1
Valencia	0	1
Murcia	0	1
Barcelona	0	1
Call port, y	0	1
Call, LHS	0	100
Call, RHS	0	10
M	100	100
Call cost	2000	2000

	discharge port, x	
final destination	Barcelona	Valencia
Zaragoza	1	0
Madrid	1	0
Albacete	1	0
Zaragoza	1	0
Zaragoza	1	0
Madrid	1	0
Madrid	1	0
Valencia	1	0
Murcia	1	0
Barcelona	1	0
Call port, y	1	0
Call, LHS	100	0
Call, RHS	10	0
M	100	100
Call cost	100	5000

Figure 9 Port Call decision model - Comparison of different parameter settings

4.1.5 Congestion prediction

The congestion prediction model forecasts 24 hrs. in advance the number of containers arriving the next day at Valencia Port. Currently this model is trained on historical data based on estimated arrival times and so can be improved further if historical data on actual arrival times is available. The graph in shows results of our model when tested on 100 days, the root mean squared error is 2.11 which means prediction is off from the actual value by approximately 2 containers on average. A comparison between the actual and the predicted arrivals against the day of arrival in shown in Figure 10.

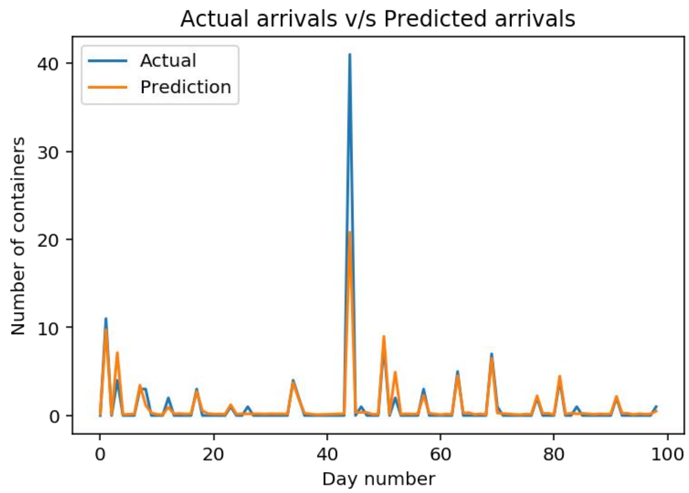

Figure 10 Congestion prediction model results

4.1.6 Terminal model

We report here the description of the Terminal model from D1.2 (PLANET, 2021), to make this deliverable complete. Further information on the model can be found there.

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

The terminal model requires the following inputs:

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

Figure 11 shows an example output from the Terminal model. On the left, the hinterland region per port for a specific commodity type. On the right, the utilization of rail infrastructure for a certain import flow.

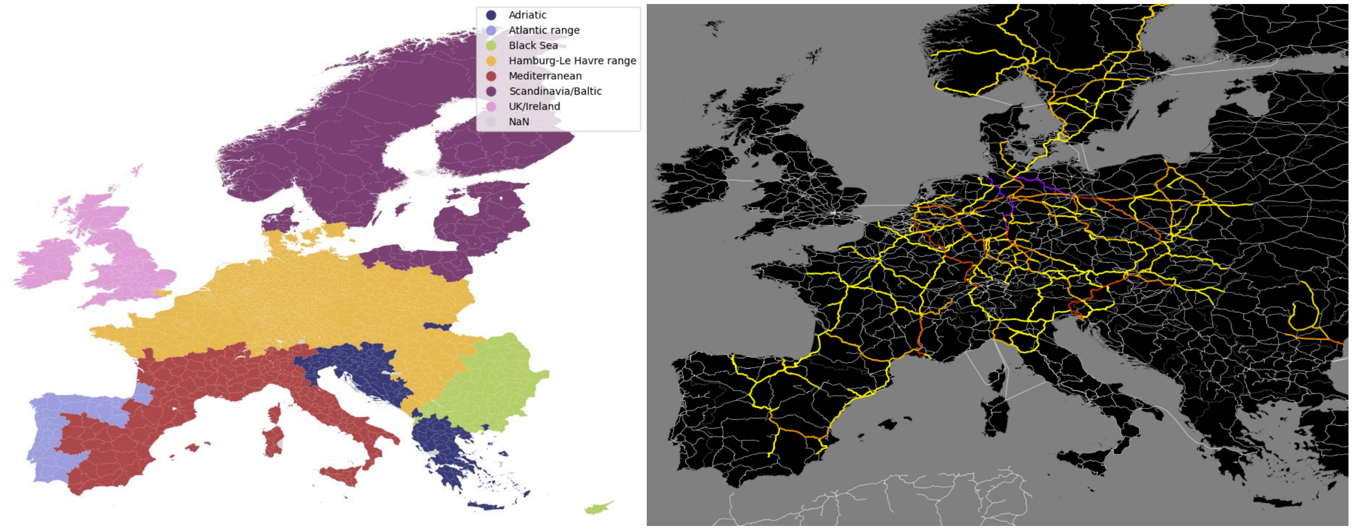

Figure 11 Illustrative output from the Terminal Model.

4.1.7 Results from Integrated Pipeline model execution:

This section presents the results obtained from the execution of the integrated modelling capability i.e., the pipeline developed for the first modelling use-case.

The pipeline developed as a characterization of the integrated modelling capability is executed by initiating the provision of input given by COSCO following which all models described in Figure 5 are run in the predefined sequence. Table 18 reports the results obtained from output as obtained from the software responsible for the execution of the Pipeline. Scenario 1 is the baseline scenario, also referred to as the As-Is situation described in Table 16 where no technology or T&L innovation is implemented. On the other hand, Scenario 2 represents the other end of the spectrum, namely the To-Be situation, which considers the deployment of all technologies listed in Table 4. The 'Change' column in Table 18 highlights the extent of the potential benefits that can be obtained from adopting the said technologies and T&L innovation concepts (mainly, PI). It can be observed that Scenario 2 presents an improved performance for all KPIs. Furthermore, the 'Change' column also serves as an input to the Terminal model described in Section 4.1.6 for the purpose of macroscopic modelling.

Table 18 PLANET integrated modelling capability results for Modelling Use-Case 1 (LL1)

KPI	Scenario 1: As-Is	Scenario 2: To-Be	Change
Load factor (Rail fill rate (%))	20%	44%	**+24%**
Reliability (Containers On-time in (%))	78%	95%	**+17%**
Container Lead time (days)	43	42.3	**-1.6%**

The results of Table 14 prove that an integrated modelling capability can be developed to provide a quantitative answer to the examination of the benefits provided by technology within the EGTN. Further, by considering additional technologies and scenarios, the results obtained from the comparison of benefits obtained from implementing different technologies in Section 5.

4.1.8 Mapping integrated modelling pipeline for UC1 to Synchromodal Model Requirements:

Based on the features and capabilities of the integrated modelling pipeline developed for the contextual setting of UC1, Table 19 examines if the pipeline model in Figure 5 has the potential to be adapted towards enhanced synchromodality in the EGTN. As can be observed, the synchromodal model requirements identified by several LL stakeholders in Table 15 are more or less satisfied with the ICT and T&L innovations deployed in the modelling pipeline. Also, the sequence of the models run in the pipeline ensure that the right information is shared with the right players at the right time.

Table 19 Mapping UC1 modelling capability to Synchromodal model requirements for EGTN

Synchromodal model requirement	Features ICT and T&L innovations and the integrated modelling pipeline for UC1
Information on departure times and transit time distribution for all scheduled asset	Use of Blockchain technology and PI concept ensures that reliable information on cargo vessel departure times, deep-sea port conditions (such as congestion), inland schedule of trucks and rail is completely shared and visible to all parties involved in the supply chain.
Information on unit transport cost and available capacity for all scheduled transport scheduled	Use of Blockchain technology and PI concept ensures that Cost and capacity information for the near future is reliable and shared.
Target reliability level	The integrated modelling capability developed measures the maximum % change that can be brought about in the container delivery reliability. Based on these potential levels that can be achieved, customer and network operator can jointly define a target reliability level.
Real-time position of all containers in the network	The deployment of Block chain in the model requires the collection of data on not only asset capacities but also the location of the containers in the supply chain using sophisticated sensors.
Deployment of the Synchromodal (adaptive) plan	The congestion predictions made by the *AI* algorithms which are run in tandem with the optimization model in the pipeline allow for real-time adjustment of cargo vessel terminal visit plans as well as the inland logistics plans to ensure that the target reliability levels are maintained.

4.2 Modelling Use Case 2:

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(Ranieri et al., 2018). 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.

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 cause 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 to create more efficient, reliable, and sustainable last mile delivery.

First, a low-emission solution for delay handling involving dynamic re-allocation of parcels between delayed and undelayed vehicles is assessed. This includes the identification of vehicle pairs, parcels to be transferred from delayed to undelayed vehicle, and a suitable meeting point. We derive the impact of IoT-enabled machine learning algorithms to dynamically match vehicles over manual matching. Second, a PI approach involving collaboration between carriers in delayed vehicle management is assessed. While currently parcels of delayed vehicles can only be re-allocated to vehicles of the same carrier, the PI solution offers automated matching between delayed and undelayed vehicles of arbitrary carriers. This is particularly promising as the vehicle routes of competing carriers can be more overlapping than vehicle routes of the same carrier (different areas), which leads to a reduction of detours. The role of different and potentially conflicting interests emerging through the presence of various stakeholders in the PI setup (e.g., low emissions vs. low cost) is addressed by a multi-user/multi-criteria analysis.

4.2.1 Modelling Scenarios for Use Case 2:

For our purpose in this deliverable, the modelling scenarios developed for the focal processes given in Figure 2 have been sourced from D1.2 (PLANET, 2021)and D1.3 (PLANET, 2022a) and adapted to the context of Use-Case 2 considered in this deliverable. Table 20 provides a summary of these scenarios modelled using the integrated modelling capability.

Table 20 Modelling scenarios for the PLANET integrated modelling capability

Simulation	Scenarios	Description
PI Node (City Hubs/	**AS IS (current)**	Delivery of parcels to final customer destinations with standard truck/van.

distribution centres)		No collaboration between competing carriers. Specifically, no order and asset sharing between independent logistics operators.
	TO BE (PI network)	Collaboration between independent logistics operators in the last-mile through creation of urban consolidation centers and complete customer order-sharing. Track & trace delivery using Sustainable vehicles.
IoT	**AS IS (current)**	Discrete event monitoring of parcels in the last mile.
	TO BE (IoT adoption)	Real time monitoring through deployment of IoT technology for end-to-end visibility in the last-mile delivery process for track and trace of parcels.
Automated decision making	**AS IS (current)**	Decisions are made without support from mathematical models. Decisions are not *optimized*, but status-quo and current practice prevails without support from quantitative models and methods.
	TO BE (Optimization Adoption)	Optimization models are used to support (and drive) decision making in complex problems. Various decisions at different levels are supported for automated decision-making models.

4.2.2 Modelling Pipeline:

Table 21 maps the features of the second modelling use case defined in Section 3.2 and detailed in Section 4.2 to the generalized modelling use case template provided in Table 14. This has further been translated into the pipeline depicted in Figure 12. Each component of the pipeline is described in a separate section (cf. Sections 4.2.3, 4.2.4), in what follows we describe the pipeline by explaining how the models interact and show the relation with the EGTN concept.

Table 21 Description of Modelling Use-Case 2 features for PLANET integrated modelling capability

Feature	Development of Modelling Pipeline for UC2 (LL1)
Modelling use case title:	PLANET integrated modelling capability for Urban Last-mile Delivery in Madrid

Narrative presentation:	Urban LMD is typically associated with not only high uncertainty due to the busy city environment but also high operational costs. 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 causing additional costs and emissions. Also, existence of competition and hence, no collaboration between several independent carriers offering similar logistics services leaves a lot of unused potential and unnecessary emissions. In this setting state-of-the-art T&L technology and innovations can impact decision-making to create more efficient, reliable, and sustainable last mile delivery. Utilizing the multi-agent simulation as a base, IoT and Optimization models are integrated to evaluate the impact of emerging technologies on T&L processes. Finally, a macroscopic model analyses long-term changes in flows resulting from the operational analysis.
PLANET partners involved:	EUR, ITANNOVA, VLTN
Model stakeholders:	City hub/ depot operators, trucking companies, end-customers
Involved models	PI simulation (collaboration between multiple operators), Delayed delivery matching and relocation
Focal technologies and innovations:	Physical Internet, IoT, Optimization,
Modelling scenarios:	As is situation vs To-be situation (deployment of PI and paradigm technologies of IoT with Optimization)

Figure 12 depicts a visual representation of the different models run in a sequence to form the pipeline for the modelling use-case under consideration. As can be observed, the pipeline consists of yellow boxes representing data and azure boxes representing models that are connected by several arrows. An arrow from a data box to a model box means that data is used an input by the model, while an arrow from a model box to a data box means that output from the model is stored in a dataset. Snapshots of data and red arrows show precisely where each model interacts.

Having presented the elements of the pipeline in Figure 12, we now describe the flow of information. Starting from data provided by City Login, which is artificially split to create a multi-company dataset (Three companies in our case), the 'Excel' spreadsheet consisting of synthetically generated hub and customer locations, time-windows requirements of each customer along with order information that are to be delivered during a single day of operation is provided to the PI based last-mile delivery model (c.f. 4.2.3). This model generates an instance of the network described in Section 3.2.1 (i.e., Figure 2) and executes multi-agent simulations where the a prespecified scenario is executed by simulating and computing all delivery routes from the depots to the end-consumers. As a result of this simulation, the KPIs defined in Section 3.2.3 (i.e., Table 7) are computed. Further, three simulation scenarios are run and compared (as delineated below):

- ***Scenario 1. As-is.***

  In the baseline scenario, the three companies operate in the center of the city in the traditional, non-collaborative manner. Each company has a fleet of three conventional delivery vehicles, which start their routes from their company's hub located on the outskirts of the city, as shown in Figure 13 (left). The distribution of demand among the companies, represented by the different colors are also shown in Figure 13 (right).

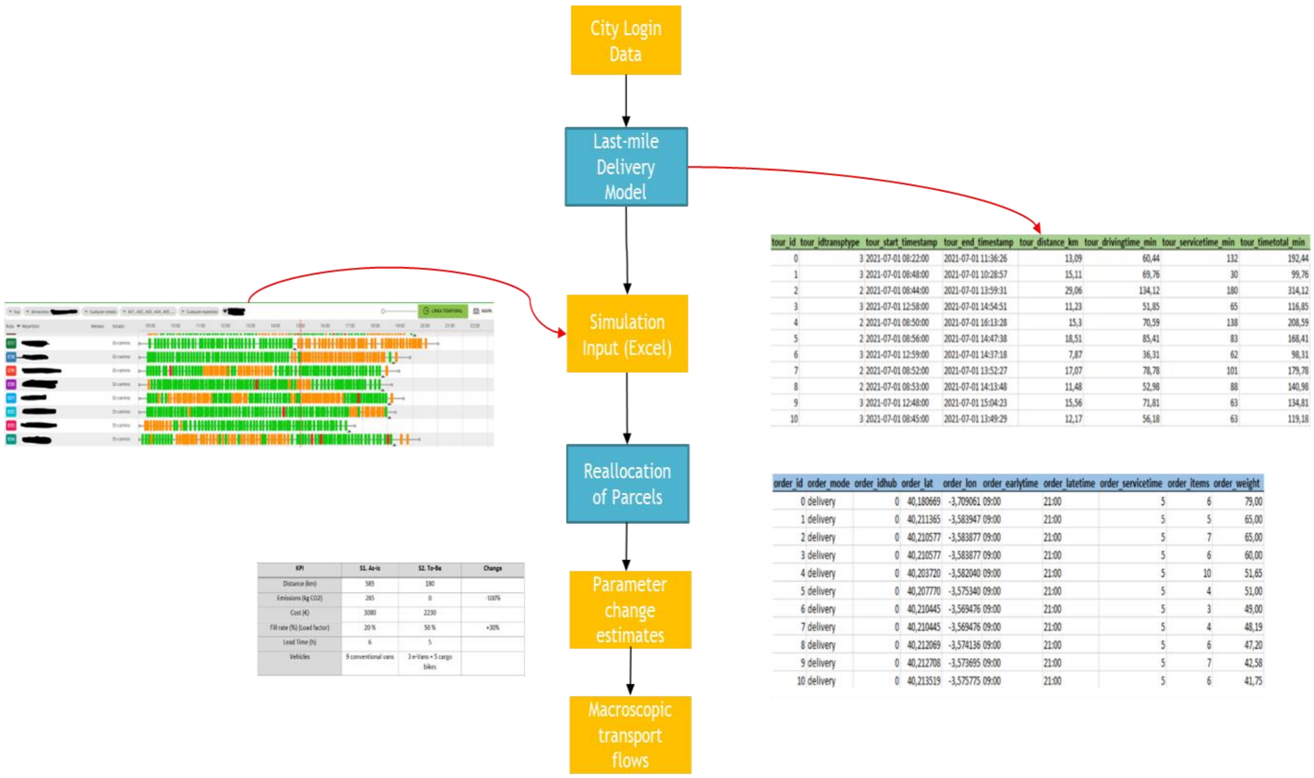

Figure 12 The pipeline - The PLANET integrated modelling capability for UC2

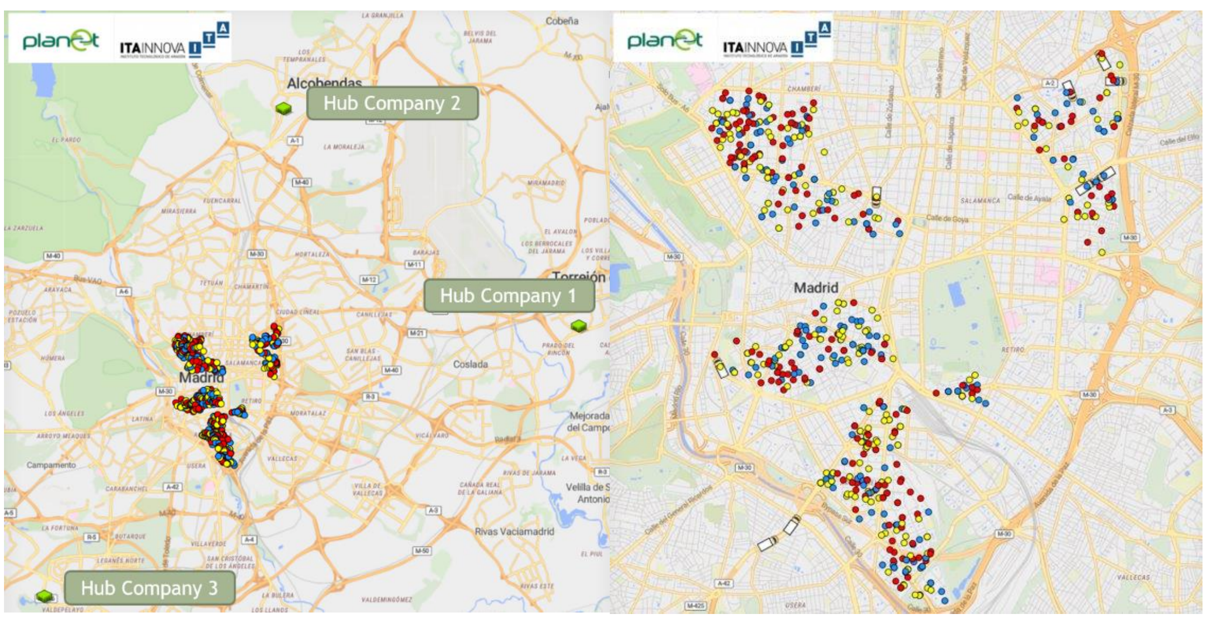

Figure 13 Companies' hub location and demand distribution

- ***Scenario 2. Collaborative urban hubs***
  In this scenario, collaborative urban consolidation hubs are implemented to facilitate collaborative cargo distribution using the Physical Internet approach. These centers act as hubs for receiving and sorting parcels from the three companies, standardizing the cargo containers and transportation modes, and redistributing them to their respective destinations. By centralizing the distribution process in this way, the system aims to reduce traffic congestion and emissions, as well as increase the efficiency of delivery operations. The simulation tracks the flow of goods through the centers and measure the impact on logistics and transportation in the area. Additionally, it also considers the cost-effectiveness and sustainability of the consolidated distribution model and how it aligns with the Physical Internet concept.

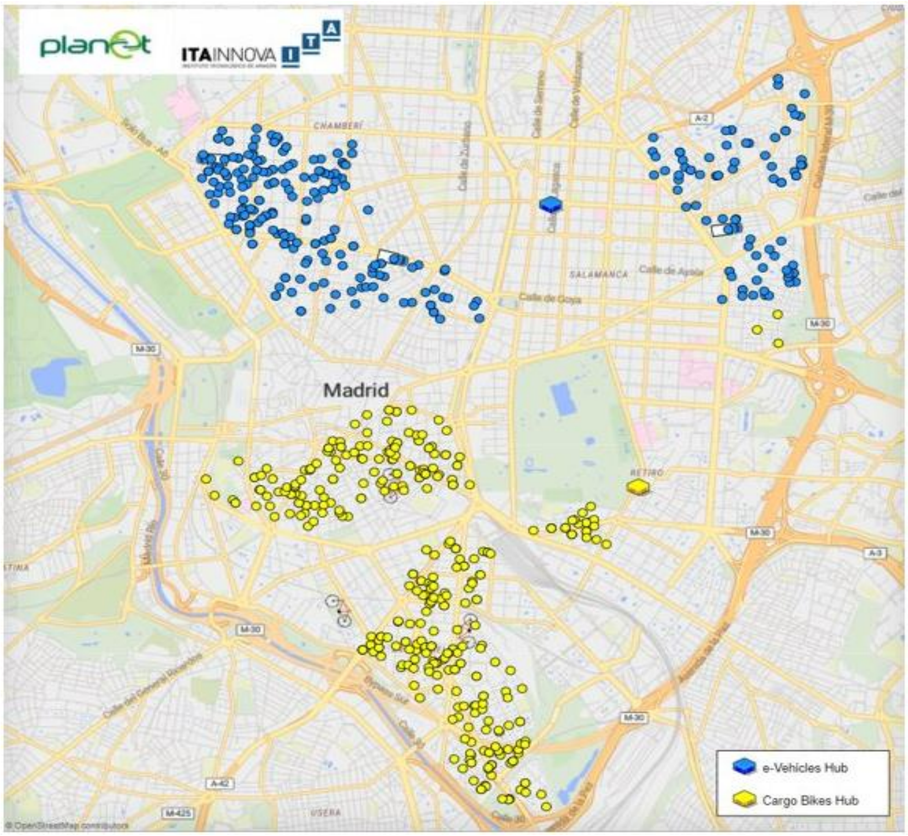

Figure 14 Collaborative urban hubs location and order-hub assignment

- ***Scenario 3. Collaborative urban hubs + e-vehicles***
  This scenario aims to show the potential for using electric vehicles and cargo bikes in collaborative cargo distribution networks and the benefits it can bring in terms of sustainability and urban logistics. The urban consolidation centers established in the previous scenario are still being used to facilitate collaborative cargo distribution using the Physical Internet approach. However, in this scenario, traditional delivery vehicles are replaced with electric vehicles (EVs) and cargo bikes, as shown in Figure 14. This change in transportation mode is aimed at reducing the environmental impact of cargo distribution and increasing the sustainability of the logistics and supply chain network. The simulation measures the impact of using cargo bikes in urban areas, such as the reduced traffic congestion and improved accessibility in densely populated areas.

By comparing the KPI values obtained in the three scenario runs, the parameter changes relevant for the macroscopic flows are computed.

We now highlight the relationship between the developed pipeline and the EGTN concept and attributes selected in Section 2 (i.e., Innovation, Impact and Integrated). Last mile delivery of goods to final customers is a critical component of any inland corridor as it is known to be one of the largest relative cost and emission factors across a wide range of transportation systems due to limited pooling possibilities and delivery time pressure. Within the current use-case, several emerging technologies are considered in a concerted deployment to study the effect of collaboration between competing stakeholders and their effect at the macroscopic level is computed. This relates to the Innovation attribute of the EGTN concept as it allows to evaluate the impact of innovation at the EGTN level. Further, the consideration of use of vehicles based on electric propulsion relates to the Impact attribute of the EGTN concept as it allows for the evaluation of the impact of more sustainable options on the existing TEN-T network. Also, the integration of different processes and the integration of different technologies with these processes clearly relates to the Integration Attribute of the EGTN. Hence, it can be observed that the several Attributes of the EGTN concept interact with each other, and that it is pertinent to examine them.

Following the development of the pipeline in Figure 12, Sections 4.2.3, 4.2.4 provide detailed descriptions of each of the models implemented in the pipeline.

4.2.3 Last-mile Delivery Model:

We report here the description of the Last-mile Delivery model from D1.3 (PLANET, 2022a) for the sake of completeness of the report. Further information on the model can be found there.

The last mile delivery model is a microscopic simulation model to assess the impact of collaborative transport strategies on last mile deliveries. 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 model allows users to make decisions based on the results of applying what-if scenarios such as:

- What if a Physical Internet strategy is adopted where competing organizations collaborate in the delivery of their orders and share their resources?
- What if the fleet-size of vehicles is increased?
- What if a new hub in the city center is established?
- What if electric vehicles are used for last-mile deliveries?

The main view of the simulation model is shown in Figure 15. In the picture, the orders grouped by routes and the movement of vehicles during delivery are displayed. Figure 16 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).

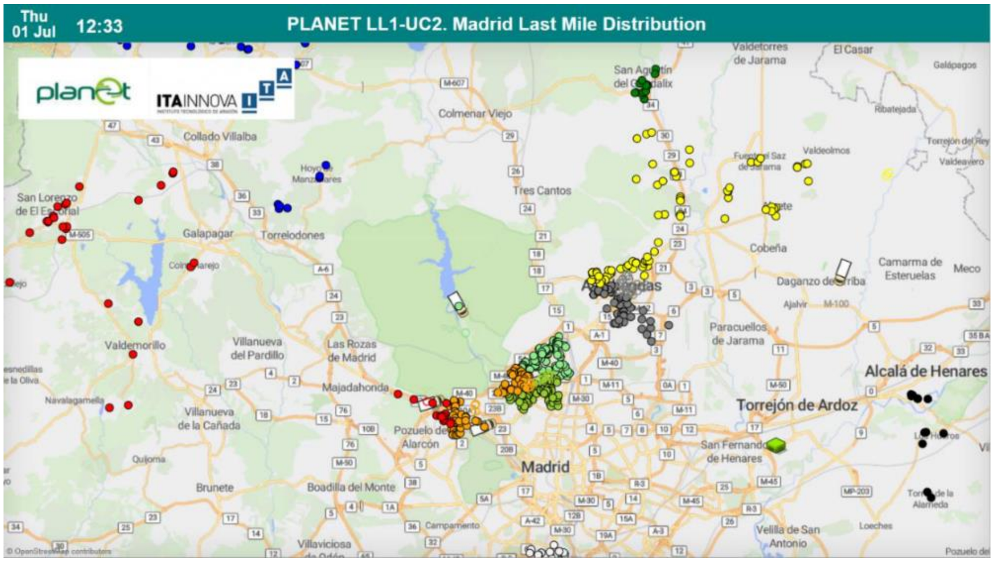

Figure 15 . Main view of the last mile delivery model.

Figure 16 Stats panel of the last mile delivery model.

Each agent in the model (hubs, orders, tours, transports) is modelled by state charts that capture the actual process of that agent. Each of these agents has 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 17:

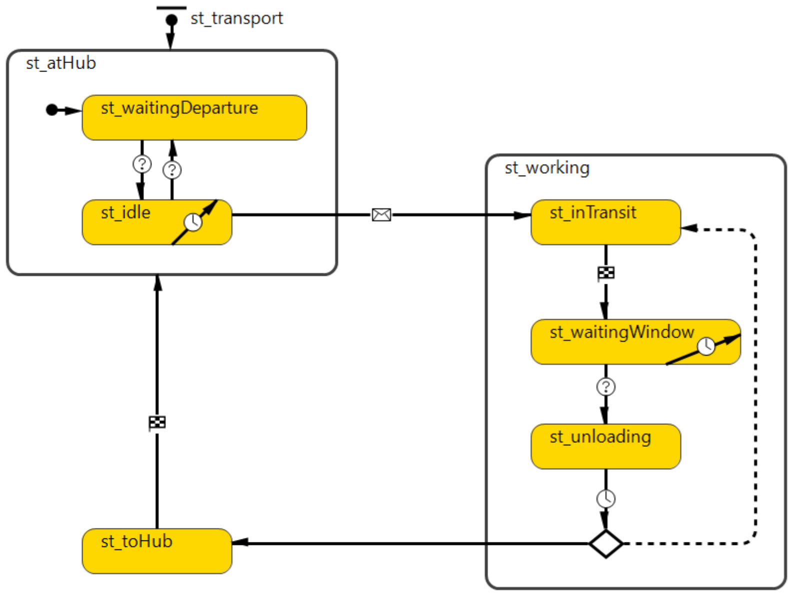

Figure 17 Transport agent state chart

Communication between agents is done by messages, which allows triggering transitions that lead an agent to decide or move from one state to another.

The simulation model has been developed using Agent Based Modelling (ABM) techniques, matching the behavior of the agents in the simulation model to the current last mile distribution processes. During the simulation, the model allows the collection of detailed statistics for each hub, order, tour and transport along with the visualization of the statistics dynamically, at the end of each run. The simulation model allows users to explore the results under different configurations or scenarios.

4.2.4 Parcel reshuffling Model:

We report here the description of the Parcel Reshuffling model from D2.14 (PLANET, 2022b) for the sake of completeness of the report. Further information on the model can be found there.

Delivery rounds, that are typically fully designed prior to initiating their implementation every day, consider the delivery locations, fleet availability (i.e., the number and capacity of delivery vehicles available) and local accessibility constraints such as Low Emissions Zones (LEZs) or Zero Emissions Zones. When delays arise, in order to expedite a late delivery round completion time, operators send assistance vehicles, that share the delivery load. Visualization of the delivery rounds enables the manual tracking of delivery progress, and the identification of severe delays, when a delivery round is considerably behind schedule. The red vertical line at 3pm in Figure 18, captures the current time, and enables progress inspection. For example, route C17 (first row) seems to be roughly on-time, while round C24 (last row) seems to be running slightly late.

Figure 18 Example of delivery rounds monitoring dashboard

When an alert for a late running delivery is raised, the automated parcel reshuffling model is initiated to assess possible options for assisting the van that is running late and optimize the process (i.e., Delayed delivery management). As shown in Figure 19, the process is designed to run in two stages, with the first stage identifying the nearest available help rounds (i.e., matching delayed vehicles with vehicles capable to help), and the second stage dealing with the redistribution of parcels (i.e., identifying Meeting points of matched vehicles) and updating of the delivery routes.

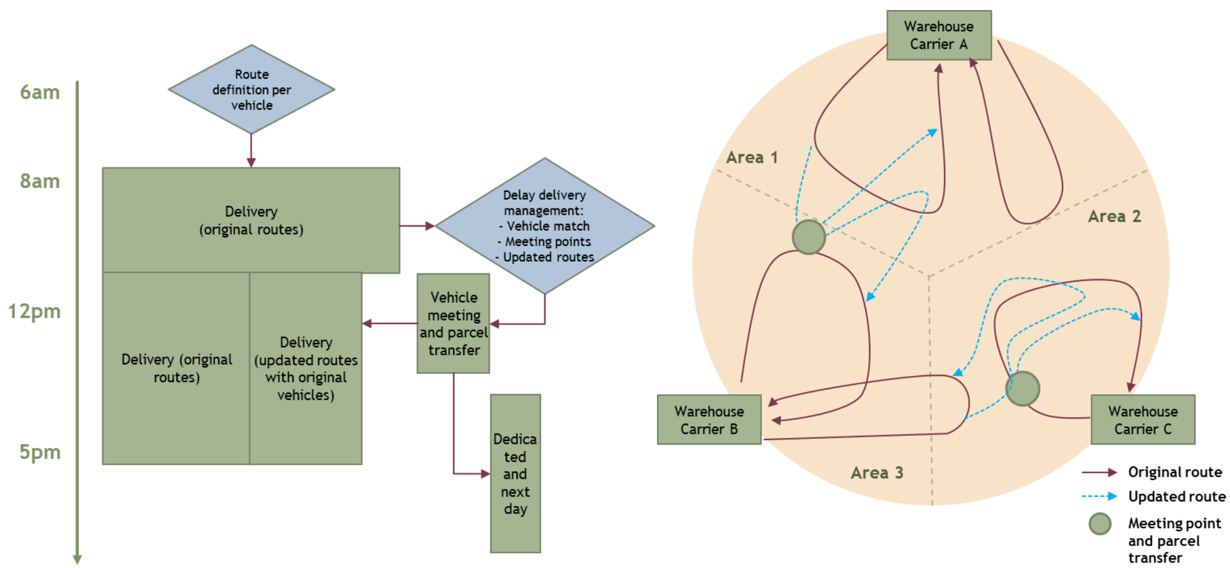

Figure 19 Sequence of events and logic of decisions to be made in UC2

As highlighted in Figure 19, to identify which helping round should assist and share the load of the late running round, a K-Means clustering approach for parcel reshuffling, and routing based on city grid distances and travel times based on Open Street Maps API is used. Visualization of the delivery rounds enables the manual tracking of delivery progress, and the identification of severe delays, when a delivery round is considerably behind schedule. The red vertical line at 3pm in Figure 18, captures the current time, and enables progress inspection. For example, route C17 (first row) seems to be roughly on-time, while round C24 (last row) seems to be running slightly late. The algorithm developed consists of a multi-company feature to assess how performance changes when operators choose to collaborate or not. Due to the lack of availability of a multi-company dataset that is required for analyzing the scenarios described above, a copy of the City Login's dataset was used to create a multi-company dataset. Figure 20 shows an example output of the multi-company parcel reshuffling model.

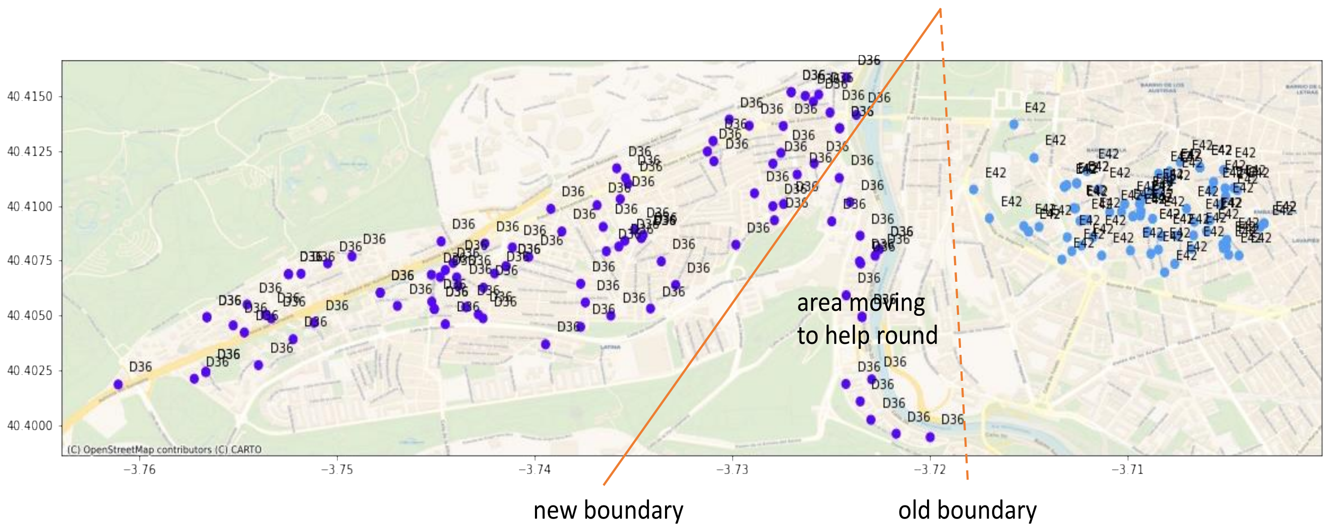

Figure 20 Parcel reshuffling algorithm output based on Black Friday dataset

4.2.5 Results from Integrated Pipeline model execution:

This section presents the results obtained from the execution of the integrated modelling capability i.e., the pipeline developed for the second modelling use-case.

The pipeline developed as a characterization of the integrated modelling capability is executed by initiating the provision of input given by COSCO following which all models described in Figure 12 are run in the predefined sequence. Table 22 reports the results obtained from output as obtained from the software responsible for the execution of the Pipeline. Scenario 1 is the baseline scenario, also referred to as the As-Is situation described in Table 20 where no technology or T&L innovation is implemented. On the other hand, Scenario 2 represents the other end of the spectrum, namely the To-Be situation, which considers the deployment of all technologies listed in Table 8. More specifically, for UC2, the To-Be situation represents the case where 100% collaboration takes place between the competing organizations in the last-mile along with use of alternate green vehicles such as Cargo bikes and E-vans. The 'Change' column in Table 22 highlights the extent of the potential benefits that can be obtained from adopting the said technologies and T&L innovation concepts (mainly, PI and green logistics). It can be observed that Scenario 2 presents an improved performance for all KPIs. Furthermore, the 'Change' column also serves as an input for the purpose of macroscopic modelling.

Table 22 PLANET integrated modelling capability results for Modelling Use-Case 2 (LL1)

KPI	S1. As-is	S2. To-Be	Change
Distance (km)	585	180	-69%
Emissions (kg CO2)	285	0	-100%
Cost (€)	3080	2230	-28%
Fill rate (%) (Load factor)	20 %	50 %	+30%
Lead Time (h)	6	5	-17%
Number and type of Vehicles	9 conventional vans	3 e-Vans + 5 cargo bikes	

The results of Table 22 prove that an integrated modelling capability can be developed to provide a quantitative answer to the examination of the **benefits** provided by technology within the EGTN. Further, by considering additional technologies and scenarios, the results obtained from the comparison of benefits obtained from implementing different technologies in Section 5.

4.2.6 Mapping integrated modelling pipeline for UC2 to Synchromodal Model Requirements:

Based on the features and capabilities of the integrated modelling pipeline developed for the contextual setting of UC2, Table 23 examines if the pipeline model in Figure 12 has the potential to be adapted towards enhanced synchromodality in the EGTN. As can be observed, the synchromodal model requirements identified by several LL stakeholders in Table 15 are more or less satisfied with the ICT and T&L innovations deployed in the modelling pipeline. Also, the sequence of the models run in the pipeline ensure that the right information is shared with the right players at the right time.

Table 23 Mapping UC2 modelling capability to Synchromodal model requirements for EGTN

Synchromodal model requirement	Features ICT and T&L innovations and the integrated modelling pipeline for UC2
Information on departure times and transit time distribution for all scheduled asset	IoT enabled Collaboration (based on the PI concept) between all parties involved in the last-mile delivery system ensures that reliable information on customer order locations, order attributes, schedule of vehicles departing from different city hubs is completely shared and visible to all parties involved.
Information on unit transport cost and available capacity for all scheduled transport scheduled	IoT enabled Collaboration based on the PI concept ensures that Cost and capacity information for the near future is reliable and shared.
Target reliability level	The integrated modelling capability developed measures the maximum % change that can be brought about in the parcel delivery reliability. Based on these potential levels that can be achieved, customer and last-mile delivery operator can jointly define a target reliability level.
Real-time position of parcels in the network	The feature of dynamic reallocation and readjustment of parcels in a delayed vehicle round to a non-delayed vehicle round in the parcel reshuffling model ensures that real-time location the parcels and vehicles is visible to all network players.

Deployment of the Synchromodal (adaptive) plan	The feature of dynamic reallocation and readjustment of parcels in a delayed vehicle round to a non-delayed vehicle round through combining optimization models and the use of e-vans and cargo bikes displays the ability to deploy synchromodal / adaptive logistics plans.

4.3 Modelling Use Case 3:

The international trade and transport corridors resulting from the 'One Belt, One Road' initiative announced by China are often referred to as the "New Silk Roads" (or "New Silk Routes") in Europe (Transport Logistic, 2023). The New Silk route initiative brings great opportunities for the European transport system such as shorter transport times due to new land corridors used to transport goods by rail accompanied by lower transport costs since freight can be transported by train both faster and cheaper than by sea or plane (Cosentino et al., 2018). However, several challenges also exist along the development of the New silk route namely, (i) subsidies for regular container transportation along the New silk route amount to about 40-50% of the total cost without which, the total cost of rail freight would be much higher than sea freight, (ii) the depleting capacity of the corridor caused, among others, by the lack of transshipment terminals and train stoppages at the terminal in Małaszewicze, (iii) the development of intercontinental transit via the Trans-Siberian corridor is hampered by the required train length which leads to accumulation of containers on loading fronts of terminals, which in turn results in longer delivery times and higher costs, (iv) breakdowns are quite common and difficult to fix if the train is in a remote location.

This use case provides simulation-based answers on how these hurdles can be overcome supported by state-of-the-art T&L technology and innovations to create more efficient, reliable, and sustainable intercontinental rail freight transportation along the new silk route.

This use-case develops and tests simulations for

- *technological solutions* such as implementing IoT technologies that help control resource parameters in real time and identify them while moving in the transport process and
- *process innovations* such as GS1 standards to help create a digital connection between players in the transport network, enabling standardized data flow and access to information about cargoes coming from China to Poland in the whole supply chain in real time.

An important aspect for the successful implementation of the concept of Physical Internet is the collaboration between multiple stakeholders to ensure the flow of commercial information in the safest, quickest, and most cost-effective way. Based on this description, it is easy to observe that in the current use-case, the collaboration between the various partners across the transport network to implement and use GS1 standards for information sharing on cargo containers for ease of tracking is a step towards developing PI in the corridor. Thus, in this use-case, GS1 standards can be perceived as a proxy for collaboration through PI.

4.3.1 Modelling Scenarios for Use-Case 3:

For our purpose in this deliverable, the modelling scenarios developed for the focal processes given in Figure 3 have been sourced from D1.3 (PLANET, 2022a) and D3.5 (PLANET, 2022c). Table 24 provides a summary of these scenarios modelled.

Table 24 Modelling scenarios for the business process modelling in UC3

Simulation	Scenarios	Description
IoT	**AS IS (current)**	Discrete event monitoring of containers along the new silk route through phone calls, emails etc.
	TO BE (IoT adoption)	Real time monitoring through deployment of IoT technology for end-to-end visibility. It is required to track the current position of train itself, but also its wagons and containers being transported. The selected technology must ensure on-line communication with supply chain actors and monitor the location and environmental conditions of the transport on an ongoing basis.
GS1 Standards	**AS IS (current)**	Little to no standardization of information shared between various stakeholders in the concerned transport network. Each party involved follow own data structure and standards.
	TO BE (GS1 adoption)	Marking and recording of goods and loads according to the global GS1 standard that facilitate transmission of data between the partners involved in the logistics operations
Artificial Intelligence	**AS IS (current)**	Little to no forecasting for quantities of interest into current decision making that is chiefly guided by expert knowledge and simple expressions.
	TO BE (AI Adoption)	Deployment of Artificial Intelligence methods for supervised learning tailored to the specific quantity of interest. Estimation and Forecasting are adopted in multiple aspects of a single decision-making procedure.

4.3.2 Modelling Pipeline:

Table 25 maps the features of the third modelling use case defined in Section 3.3 and detailed in Section 4.3 to the generalized modelling use case template provided in Table 14.

It is critical to note that transportation, due to limited real-time information on resource availability, generates significant economic, social, and environmental costs. Hence, UC3 focuses on streamlining logistic 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 transmission of data between the partners. For studying the improvements made in the physical and information flow in the China-EU corridor, *business process modelling* (c.f. 4.3.3) is used to simulate the processes with the help of a specialized software *iGrafx*.

Section 3.4.1 defined a pipeline to be a sequence of models run in such a way that the output of one will be the input of another and that every modelling use-case is associated with a pipeline which demonstrates the PLANET integrated modelling capability. However, in this use-case, a single business process simulation model that is run on the operational data provided by the business partner, Rohlig SuuS, stands alone to demonstrate the integrated modelling capability. The Business process simulation model ingests data received from Rohlig SuuS, helps create the process maps highlighting the potential improvements emerging from implementation of IoT, GS1 standards, and AI algorithms for improved ETA forecasting, and finally provides the results of the KPIs. Thus, the pipeline consists of only one model run on a sophisticated platform which serves the final purpose of UC3, eliminating the need to use multiple models. Another way to look at it is that the pipeline can be seen from the standpoint of examining processes that are performed in a sequence as opposed to models that are run in a sequence. Section 4.3.3 further provides a detailed description of the Business process simulation model and methodology adopted.

Table 25 Description of Modelling Use-Case 3 features for PLANET integrated modelling capability

Feature	Development of Modelling Pipeline for UC3 (LL3)
Modelling use case title:	PLANET integrated modelling capability for New Silk Route-Full IoT Corridor
Narrative presentation:	The promotion of interoperability in logistics services is dictated by the inefficiency and instability of the current organization of the logistics system. Transportation, due to incomplete utilization of cargo space and limited real-time information on resource availability, generates significant economic, social, and environmental costs. The use-case focuses on analyzing operational performance indicators, which clearly demonstrate the impact of the implementation of state-of-the-art T&L technology and innovations both on the operational activities of a single enterprise, improvements throughout the supply chain, and ultimately on the development of the idea of the Physical Internet. Various experiments and simulations of business processes compliant with the BPMN 2.0 standard to assess the improvements in the physical and information flows of the transport network under consideration.
PLANET partners involved:	EUR, ILIM, Rohlig Suus, GS1 Poland, GS1 China
Model stakeholders:	Terminal Operator, Customs, Intermodal Operator, Road and Railway Carrier, Freight Forwarder.

Involved models	Business Process Models
Focal technologies and innovations:	IoT, GS1, AI
Modelling scenarios:	As is situation vs To-be situation (deployment of IoT, AI, and GS1 standards)

4.3.3 Business Process Modelling:

A business process is a set or sequences of linked tasks and activities that result in a specific goal or outcome. A business process model is a mechanism used to test and analyze both current business processes and those that have not yet been implemented. Within the framework of the PLANET project, Use-Case 3 employs a defined methodology based on the following steps to conduct the process analysis (as described in D3.5 (PLANET, 2022c) and D1.2 (PLANET, 2021)):

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

1. Conducting a local vision in a chosen company to obtain comprehensive data that is necessary for analysing the designated processes.
2. Analysis of the current situation of the processes that are going to be identified and verified during the local vision, including the following elements:
    - assigning business roles to individual participants of the processes covered by the analysis,
    - mapping processes using activities and events as well as decision points using an innovative methodology compliant with the BPMN 2.0 standard, regulated by ISO / IEC / 19510: 2013 Information technology - Object Management Group Business Process Model and Notation,
    - agreeing on the management and operational level maps of currently functioning processes, compliant with the BPMN 2.0 standard,
3. Construction of AS IS simulation models, their parameterization and calibration - 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, AS-IS simulation models will be created, which will be a reference point for the target processes.
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, taking into account the recommendations developed during the implementation of the first stage and assuming the use of the proposed technological solutions - modeling of TO BE processes (in accordance with the BPMN 2.0 standard).

2. Conducting simulations of the developed process models, allowing to forecast the level of reduction of task completion time as a result 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 of the report synthesizing the results and conclusions resulting from the project implementation.

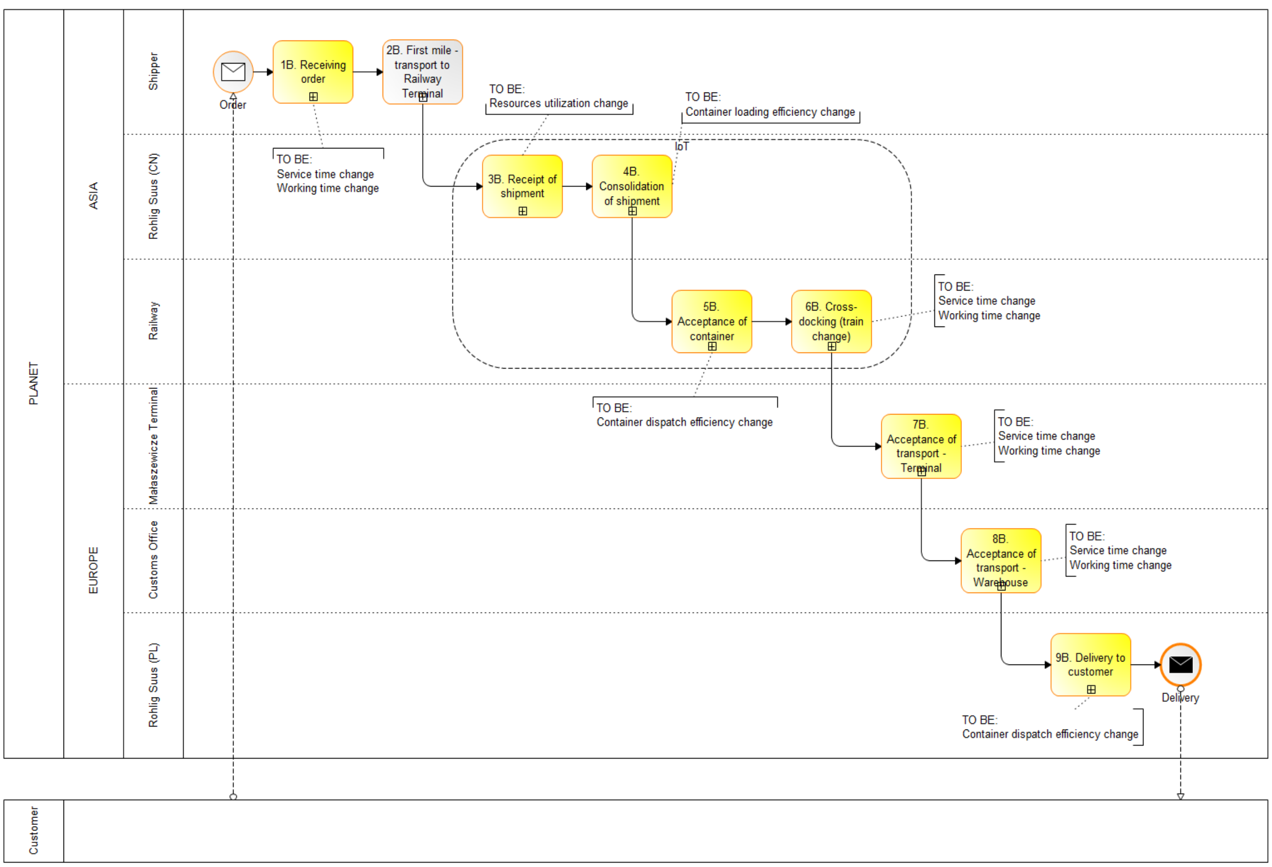

Figure 21 Process map for intercontinental long-haul container transport from China to Poland (UC3)

Expected results:

• process maps, compliant with the BPMN 2.0 standard. described in ISO / IEC 19510: 2013, showing the functioning of the base processes (currently functioning in the supply chain - AS IS) and target processes after the implementation of the concept developed as part of the service (TO BE),

• simulation models of the processes covered by the analysis (AS IS and TO BE),

• final report providing recommendations and results of a comparative KPI analysis before and after the potential implementation of the recommended changes.

Figure 21 shows the envisioned physical flows in the operational context considered from a bird's eye view. 17 business processes in the B2B context have been mapped. The areas where the change will occur are highlighted in yellow. The business process modelling is undertaken using the sophisticated iGrafx platform. Figure 22 summarizes the methodology adopted for the third modelling use-case.

Figure 22 Logic of action to assess UC3 KPIs

Each process is a sequence of sequentially connected activities which transform input elements into other output elements. A prerequisite for good process management is appropriate diagnosis of the initial situation and its description (AS IS) by means of graphic representation of the process course. The next step will be the analysis of the existing situation, which has been described, including the determination of the time structure of activities, bottlenecks and critical points connected with the process. As a result of such analysis, it will be possible to plan an improved course of the process (TO BE) transforming process maps into models - collecting parameters (duration, resource commitment, work schedules, number of transports/parcels, etc.); designing new processes which will include GS1 standards, IoT, and other solutions. It will result in defining the metrics by which the improved process will be monitored when it enters the operational phase. Simulation of the models created based on the results and identification of process areas representing optimization potential will include:

• processes bottlenecks,

• activities that do not bring added value, but increase the probability of occurrences of errors and mistakes,

• gaps in the information flow,

• manual work that can be replaced or reduced by applying innovative solutions.

• preparation of a proposal of the scope of information relevant for the dashboards, based on the identified needs for information

4.3.4 Results from the pipeline execution:

Table 26 reports the results obtained from output as obtained from the software responsible for the execution of the Business process simulation. Scenario 1 is the baseline scenario, also referred to as the As-Is situation described in Table 24 where no technology or T&L innovation is implemented. On the other hand, Scenario 2 represents the other end of the spectrum, namely the To-Be situation, which considers the deployment of all technologies listed in Table 12. More specifically, for UC3, the To-Be situation represents the case where complete end-to-end visibility exists along the Eurasian rail corridor with complete information sharing between stakeholders in a standardized manner. The 'Change' column in Table 26 highlights the extent of the potential benefits that can be obtained from adopting the said technologies and T&L innovation concepts (mainly, IoT, GS1, and AI). It can be observed that Scenario 2 presents an improved performance for all KPIs. Furthermore, the 'Change' column also serves as an input for the purpose of macroscopic modelling.

Table 26 PLANET integrated modelling capability results for Modelling Use-Case 3 (LL3)

KPIs	S1. (As-Is)	S2. (To-Be)	Change
Number of containers delivered per month	18	21	**+16,67**
Average Working Time per delivery (in Hrs)	3,46	3,03	**-12,43**
Co2 Emissions (per delivery)	100%	83%	**-17%**
End-to-end visibility	0%	100%	**+100%**
Average Working time in Customs related activities per delivery (in Hrs)	2,65	1,32	**-50,19**
Total Compliance costs (per delivery)	100%	78%	**-22%**
Total Operational Costs	100%	88%	**-12%**
Reduction in Supply chain disruptions (per delivery)	0%	18%	**+18%**

The results of Table 26 prove that a modelling capability can be developed to provide a quantitative answer to the examination of the **benefits** provided by technology within the EGTN. Further, by considering additional technologies and scenarios, the results obtained from the comparison of benefits obtained from implementing different technologies in Section 5.

4.3.5 Mapping UC3 modelling capability to Synchromodal Model Requirements:

Based on the features and capabilities of the integrated modelling pipeline developed for the contextual setting of UC3, Table 27 examines if the simulation model described in Section 4.3.3 has the potential to be adapted towards enhanced synchromodality in the EGTN. As can be observed, the synchromodal model requirements identified by several LL stakeholders in Table 15 are more or less satisfied with the ICT and T&L innovations deployed in the modelling pipeline.

Table 27 Mapping UC3 modelling capability to Synchromodal model requirements for EGTN

Synchromodal model requirement	Features of ICT and T&L innovations and the simulation model for UC3
Information on departure times and transit time distribution for all scheduled asset	IoT sensors deployed on rolling stock components such as wagons, locomotives ensure that reliable information on container locations, rail time-table order, rolling stock conditions etc. are visible end-to-end.

Information on unit transport cost and available capacity for all scheduled transport scheduled	Collaboration between stakeholders along the New silk route through implementation of GS1 standards ensures that Cost and capacity information for the near future is reliable and shared.
Target reliability level	The simulation model developed measures the maximum % change that can be brought about in the number of containers delivered on time. Based on these potential levels that can be achieved, customer and network operator can jointly define a target reliability level.
Real-time position of containers in the network	Adoption of IoT and GS1 standards ensure that real-time location the parcels and vehicles is visible to all network players.
Deployment of the Synchromodal (adaptive) plan	While this feature has not been considered as such along the intercontinental long-haul rail freight corridor, it has scope to be considered once the containers arrive in Europe i.e., at the Malaszewicze terminal. In the current scope of the model, AI algorithms predict the ETA of containers using the data received from IoT sensors in the New silk route. To extend this model, this information can further be used to dynamically plan and optimize logistics in the *inland corridors* by booking transport capacity (rail/ road) to the customers' container delivery locations.

5 Positioning emerging technologies as contributor to PI

Understanding whether developing technologies should receive additional development and adoption support is important from the standpoint of policymakers. Because of the long-term vision of a Physical Internet, the supporting choice is (partially) driven by an understanding of which technologies (or combinations of technologies) best contributes to the development of the Physical Internet.

5.1 Comparative evaluation of potential benefits from ICT and T&L innovations:

The pipeline has been developed in such a way to enable a testing of various technologies on the same transport setting. By doing so, it is possible to compare the potential benefits from innovation.

5.1.1 Modelling Use-Case 1:

Figure 23 highlights and compares the impact of different ICT and T&L innovations, namely, PI, IoT, and BC on the fraction of containers delivered on time. To test the impact of the innovations, the same instance setting is assumed where 3500 containers are delivered from China to Europe through the intercontinental maritime corridor. The simulation experiments are also tested for different adoption levels of the PI concept (viz. 0%, 20%, 50% and 100%) where 0%-20% PI adoption level corresponds to the current status of PI in Europe and 100% corresponds to the vision in PI vision for 2050. As can be observed from Figure 23, higher adoption levels of all the ICT and T&L innovations i.e., PI, IoT, and BC lead to an improved fraction of containers delivered on time to the European continent, hence increasing the reliability of operations. However, the improvement resulting from the complete adoption of IoT alone (where 0 represents low adoption and 1 represents high implementation levels of IoT) is the greatest. This result suggests the importance of IoT for an improved performance of the maritime corridor.

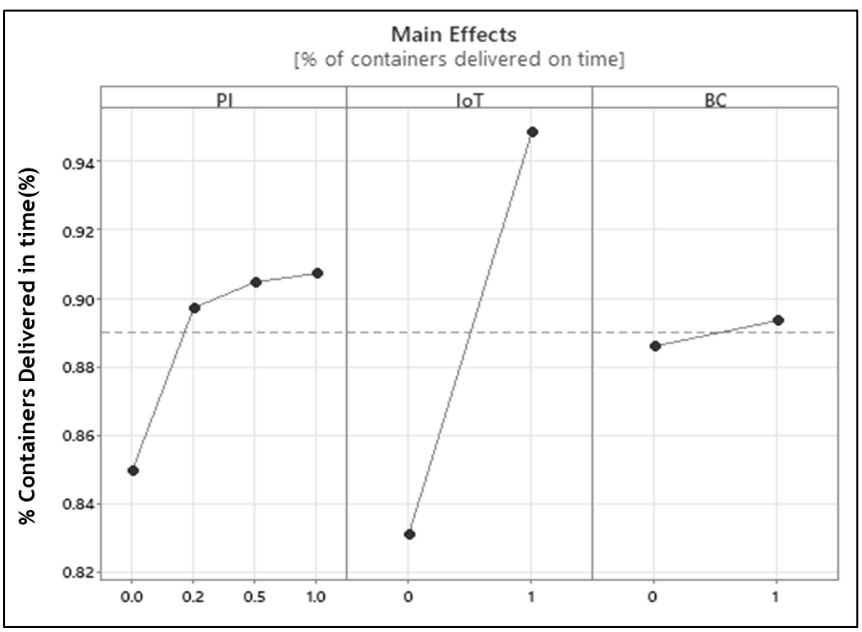

Figure 23 Comparison of impact of individual ICT and T&L innovations on Container Delivery Reliability

Further, while Figure 23 highlights the individual impacts of the various logistics and technological innovations considered in UC1, Figure 24 also evaluates the combined impacts of these innovations on the three macrscopic KPIs (reliability, rail and road modal split). The Y-axis in igure 24 represents the different technology/innovation scenarios with the results related to the baseline case (i.e., the As-Is scenario) where no innovation is considered are reported first. In the various scenarios, technologies and innovations considered can be deployed either individually or jointly (note the "+" sign). It is important to note that the impact of different technologies are evaluated on the same EGTN instance where 3500 containers are delivered. It is easy to observe that the BaseLine (As-Is) scenario performs the worst on all the three KPIs considered while the To-Be scenario (PI+IoT+BC) performs the best as it reports the highest values of reliability and rail modal split and least on road modal slpit. These results suggest that the highest potential of the PI concept in the maritime corridor can only be achieved if disruptive technolgies such as IoT and BC which support its implementation are also established in the system.

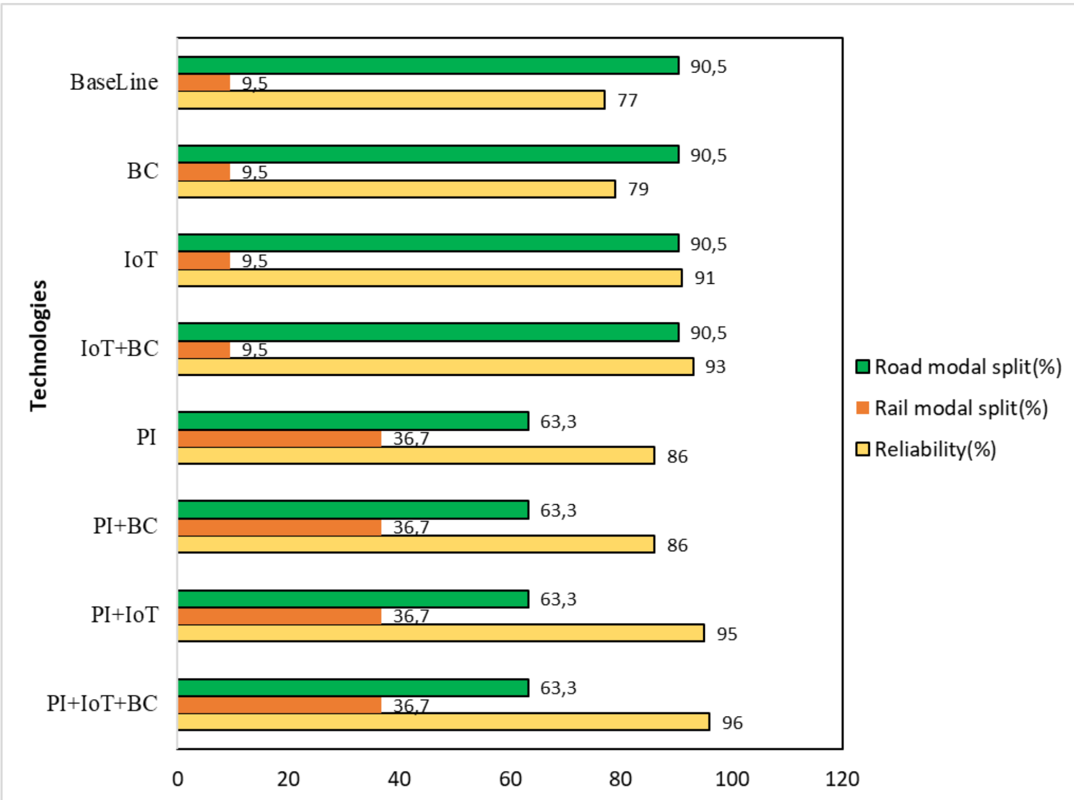

Figure 24 Comparative analysis of potential benefits emerging from T&L innovations in UC1

5.1.2 Modelling Use-Case 2:

With respect to UC2, Figure 25 details the impact of different levels of adoption of the PI concept on the operational costs along with the route distance travelled for cases when only conventional vehicles are used for last-mile delivery vs. when greener alternatives such as cargo bikes and e-vans are used. It is pertinent to note that in UC2 throughout, by PI adoption, we specifically mean collaboration/sharing between competing organizations in terms of customer orders received as well as asset capacities used in the last-mile. Two major observations can be made:

- Firstly, for all levels of PI adoption (i.e., 25%, 75%, and 100%), greener vehicle alternatives contribute to lower last-mile delivery costs. This result can be partly attributed to the shorter routes that are traversed by cargo bikes and e-bikes (as seen in Figure 25).

- Secondly, as the PI adoption levels increase, irrespective of the type of vehicle used for making the last-mile deliveries, not only does the distance travelled by vehicles (Secondary Y-axis) reduce, but also the associated operational costs reduce (Primary Y-axis).

Thus, we can conclude that, individually, implementing PI (i.e., collaboration) and using greener delivery vehicle alternatives in the last-mile result in lower travel distances and operational costs. The reduction in distances travelled combined with the use of greener delivery vehicle alternatives ultimately reduces the negative environmental impact (as shown in Figure 27). However, combining the two T&L innovations leads to the least distance travelled and least amounts of costs incurred.

A similar set of observations can be made for Figure 26 where the Primary Y-axis represents the time taken to complete delivery routes along with the distances covered (Secondary Y-axis) in the last mile for different PI adoption levels.

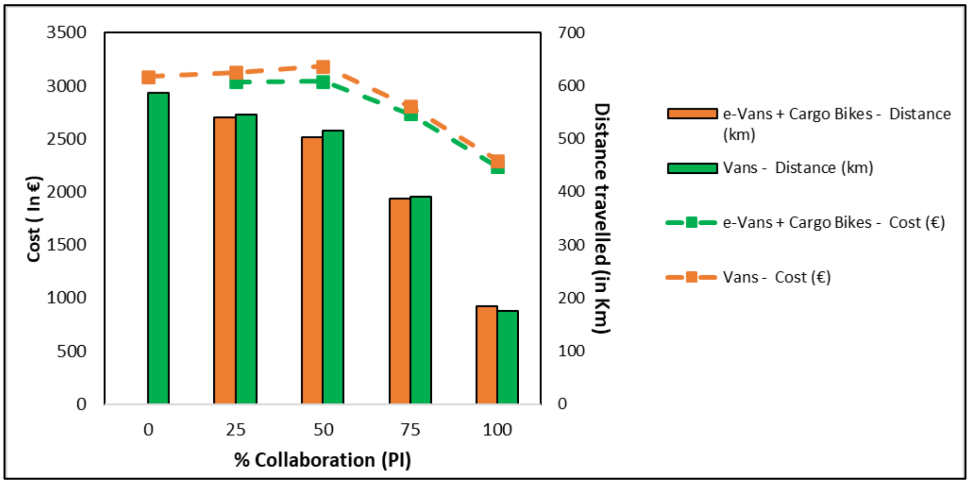

Figure 25 Impact of different collaboration levels between companies in the last mile on operational costs

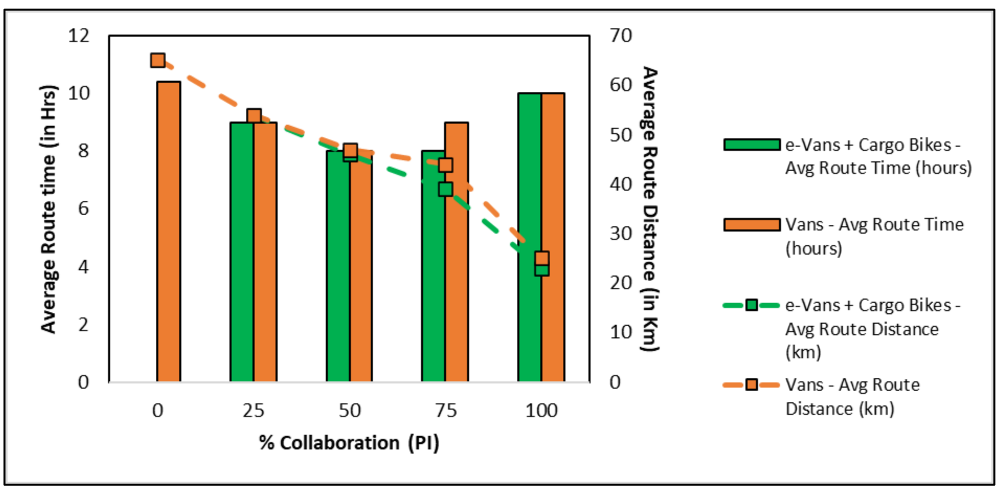

Figure 26 Impact of different collaboration levels between companies in the last mile on route time

Further, Figure 27 highlights the impact of different levels of adoption of the PI concept on the average vehicle fill rate and CO2 emissions for cases when only conventional vehicles are used for last-mile delivery vs. when greener alternatives such as cargo bikes and e-vans are used. Similar to Figure 25 and 26, two major observations can be made:

- Firstly, for all levels of PI adoption (i.e., 25%, 75%, and 100%), the use of greener vehicle alternatives are associated with higher average vehicle fill rate in comparison to the use of conventional vehicles. Also, they contribute to lower emission levels, which supports our intuitive understanding.
- Secondly, as the PI adoption levels increase, irrespective of the type of vehicle used for making the last-mile deliveries, the emissions generated drastically reduce due to greater efficiency brought about in the system through collaborations (Secondary Y-axis). Also, in general, the average fill rate of the vehicles (Primary Y-axis) increases.

In sum, we can conclude that potentially high economic and environmental benefits in the last-mile delivery system can be achieved by establishing collaborations between players in the last-mile while also encouraging the use of sustainable delivery options.

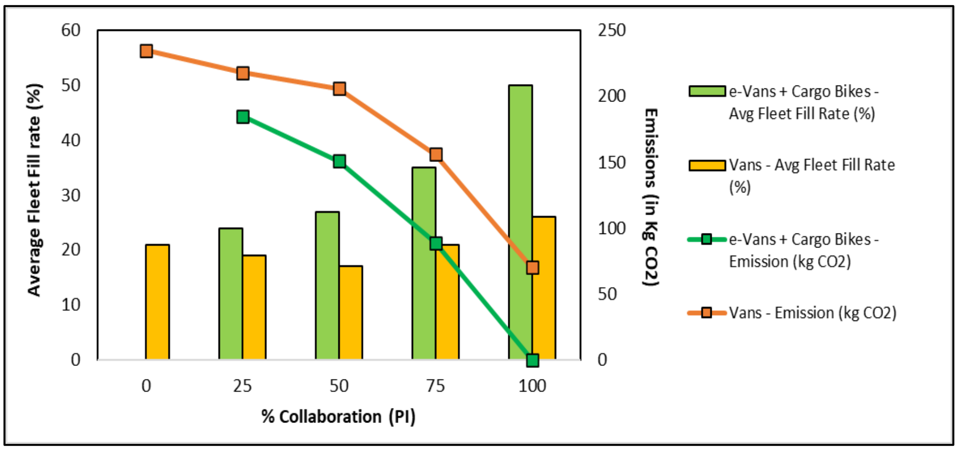

Figure 27 Impact of different collaboration levels between companies in the last mile on vehicle fill rate

Finally, Figure 28 provides a snapshot of key microscopic (such as route time and distance) and macroscopic (such as vehicle fill-rate, emissions) KPIs across all the three scenarios considered within UC2. Clearly, the scenario *'Collaboration + Green vehicles'* wherein complete collaboration takes place along with deliveries undertaken using greener logistics alternatives performs the best for all KPIs while the *As-Is* case performs the worst. Therefore, it can be concluded that it is beneficial to develop an urban last-mile delivery system where competing organizations can come together and efficiently collaborate on (i) sharing customer orders via establishing urban consolidation centers, (ii) sharing vehicle capacities in order to dynamically reallocate delayed parcels in real-time to other vehicles, thereby ensuring on-time deliveries, and also (iii) utilizing sustainable logistics alternatives for delivering the parcels to final customers.

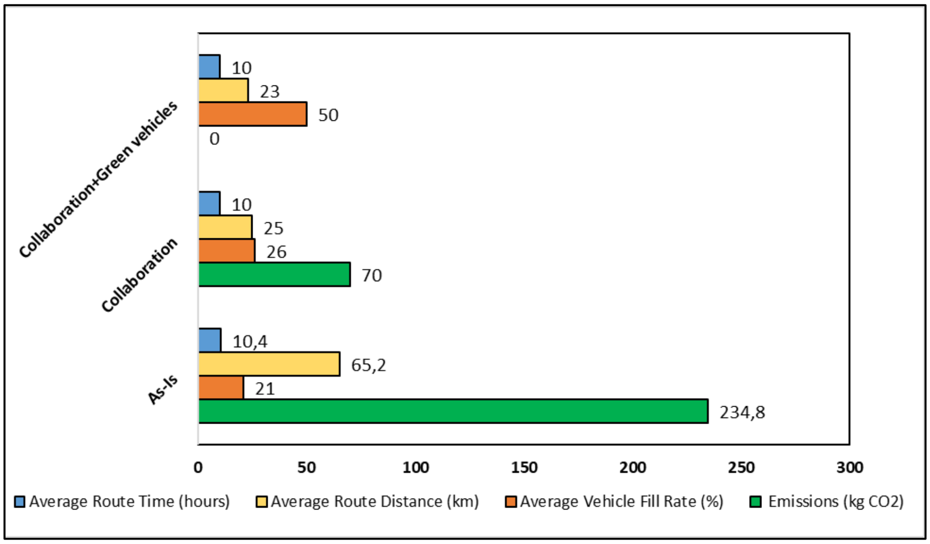

Figure 28 Comparison of operational and environmental indicators across the three scenarios

5.1.3 Modelling Use-Case 3:

With respect to UC3, Figure 29 details the impact of implementing different ICT and T&L innovations on the key operational (i.e., container delivery volume), economic (i.e., operational and compliance costs), and environmental indicators (i.e., CO2 emissions) to assess their performance in the intercontinental long-haul rail freight corridor. The Baseline case represents the AS-IS case as highlighted in Section 4.3. In other words, the Baseline scenario represents the case where none of the ICT and T&L technology and innovations considered in the context of UC3 are applied. On the other end of the spectrum, we have the 'IoT+GS1+AI' scenario which represents the final 'TO-BE' situation described in Section 4.3.

It is worth noting that in Figure 29, the values of the KPIs indicated across all scenarios are percentage changes with respect to the values in the Baseline scenario. Thus, the 0% value indicated for 'container delivery volume' for scenarios 'AI', 'GS1', 'GS1+AI' indicate no change in the number of containers delivered per month (18 containers per month) compared to the Baseline situation. The major observations that can be made from Figure 29 are delineated below:

- Implementation of only AI (where it is majorly used for forecasting ETA of goods in Poland to plan availability of logistics in the hinterland), without implementing IoT to collect real-time data on parameters such as wagon and container locations, container temperature and humidity, condition of rolling stock components such as wheels, axle etc. does not lead to any significant improvement compared to the Baseline situation in the corridor. Also, implementing AI without implementing GS1 to standardize the data shared across the stakeholders in the Eurasian corridor does not result in any improvements.
- Implementation of GS1 standards helps reduce only compliance costs (~22% compared to Baseline) as GS1 standards such as GTIN, GPC, GDSN, SSCC help reduce time of preparing declarations by both importer and exporter as well as verification by customs agency and office through standardization and automation of these processes. Also, additional benefits such as improved accuracy, quality, and consistency of data are realized.

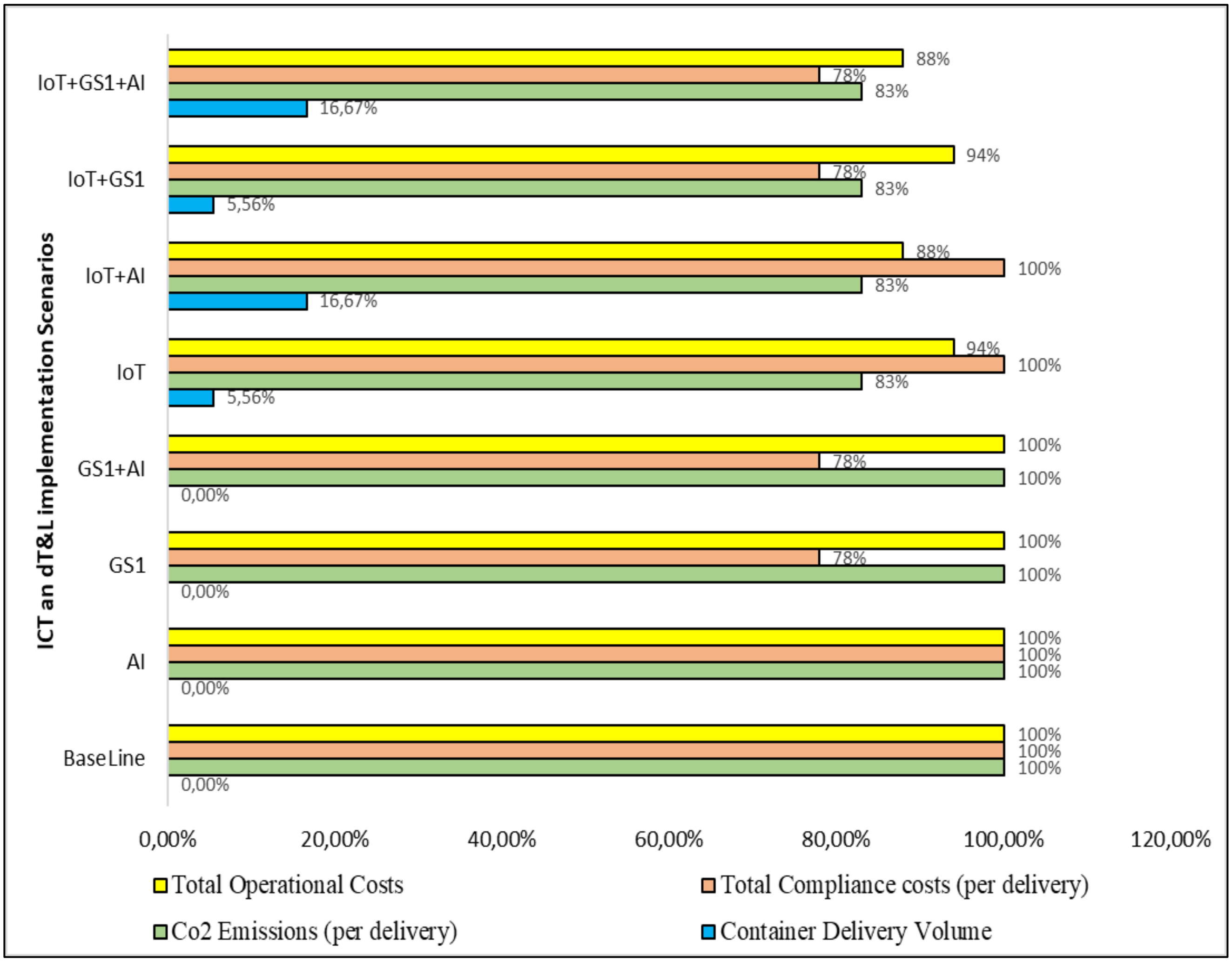

Figure 29 Comparison of operational, economic, and environmental indicators across different ICT and T&L implementation scenarios in UC3

- Implementation of IoT sensors which provide real-time monitoring of the individual components of the rolling stock such as wagons and locomotives helps not only reduce the operational costs and Co2 emissions generated but also help increase the container delivery volumes in the corridor. This is because real-time data helps increase the accuracy of knowledge about the location of the train. This further helps in the planning process by enabling the booking of fixed carriers to drop off containers, instead of seeking transportation on the exchange. It also enables optimal replanning of a container to alternative routes in terms of distance from the customer and cost of operations, i.e., more time for replanning while also allowing the reduction of time due to manually tracking location of containers and freight by telephone call and e-mails, and associated delays caused by waiting for replies.

Finally, from Figure 29, it can be concluded that the combined implementation of GS1 standards, IoT, and AI results in significant changes across all the KPIs considered. Thus, is important to consider the possible potential benefits that each of these ICT and T&L technologies and innovations can help achieve in intercontinental rail freight corridors to enable the existing TEN-T network to transform to an EGTN.

6 Conclusions

The deliverable presents an approach to evaluate the impact of ICT and T&L technologies and innovations at the microscopic and macroscopic levels by defining, developing, and running the PLANET integrated modelling capability. The modelling capability developed is tested in three different contextual settings to represent the operational flow of containerized cargo in (i) maritime networks, (ii) intercontinental rail-freight networks, and extending the operational flow beyond containerized cargo to model (iii) last-mile delivery operations in urban cities. Moreover, the deliverable also maps the integrated modelling pipelines used in the different geographical contexts to the synchromodal planning features identified by stakeholders to gauge whether such pipelines can be adopted to develop enhanced synchromodality and PI models for EGTN.

The key and novel aspect of our approach is the modelling of technologies and innovations at the microscopic level and the estimation of the resulting macroscopic effects which helps further WP1's understanding and development of the EGTN concept -which is central to PLANET. This micro to macro modelling approach is viable and depends on the estimation of aggregated KPI changes due to the deployment of certain technologies. For e.g., the estimated modal shift resulting from the joint deployment of PI, Blockchain and Artificial Intelligence in the first modelling use-case is then fed into a macroscopic model to compute the change in entry point for certain commodity types. In summary, the main results of this deliverable are the integrated modelling pipelines constructed which are a sequence of different models deployed in a joint manner to achieve the research objectives explicitly laid down in T1.4 and summarized below:

(i) define the impact of different ICT and T&L innovations on the development of the EGTN.

(ii) assess the impact of emerging concepts and technologies on the performance of freight transport corridors and hubs.

(iii) position the emerging technologies as contributors to the Physical Internet.

The findings of this deliverable clearly highlight the role of the Physical internet and its paradigm technologies such as Blockchain, Internet of Things, Artificial intelligence, etc. in building a seamless, flexible, and resilient system of logistics networks. In particular, the net benefits of the Physical internet on people, planet, and profit, are outlined through the modelling of

- seaports and hinterland dry ports as PI nodes rather than logistics nodes and maritime vessels as PI movers in UC 1,
- complete collaboration, the defining characteristic of PI, between last-mile players in UC2,
- increasing visibility and resiliency of freight transport in intercontinental corridors using PI concepts

It is essential to note that each of the pipelines devised and tested are linked to the geographical setting, players involved, and the ICT and T&L innovations deployed. Thus, to reproduce the results found through simulations in real-life practice, it is crucial to take note of a few key points in each Use-case. In the case of UC1, the port optimization model used in the integrated modelling pipeline is applicable if multiple entry points (at least 2) to the European hinterland exist in proximity and the incoming deep-sea vessels are presented with a choice on selecting their preferred port of call. However, although not in scope of this deliverable, it is possible to examine the effect of different technologies through microsimulation regardless of the use of port optimization. Similarly, the integrated modelling pipeline developed for UC2 is applicable to a situation where competing organizations come together to share sensitive information on customer orders, delivery locations and resources such as depot/hub capacity, vehicle capacity etc. Further, it is to be noted that each vehicle in this context needs to be equipped with technology such as GPS to have complete visibility of vehicle locations and dynamically plan the assignment of parcels in delayed vehicles to non-delayed vehicles. In the case of UC3, it is key to note that IoT sensors need to be deployed on every wagon and the locomotive of the rolling stock. Further sensors need to be deployed on each container to obtain data on container conditions such as temperature and humidity inside the container.

While this study majorly adopts a simulation environment to achieve the goals outlined at the onset of the deliverable, the pipelines in each of the modelling use-cases can be extended in the future to capture and study greater shifts emerging from concerted deployment of sophisticated technologies and concepts such as hyperloop, autonomous vehicles and maritime vessels etc. Also, while UC3 does not consider the construction of a pipeline per se (due to the use of sophisticated and all-purpose modelling and simulation platform), it can be further extended to simulate inland corridor optimization upon the rail fright arrives in Europe (such as advance booking of trucks and rail capacity), forecasting availability of assets such labor, space etc. at different customer warehouses and distribution centers to optimize routing of containers inland, etc.

7 References

Ballot, E., Barbarino, S., van Bree, B., Liesa, F., Rod Franklin, J., Nettsträter, A., Paganelli, P., & Tavasszy, L. A. (2020). *Roadmap to the Physical Internet*.

Ballot, E., Montreuil, B., & Meller, R. (2014). (2014). *The Physical Internet.*

Cosentino, S. D. G. B., Dunmore, D., Ellis, S., Preti, A., Ranghetti, D., & Routaboul, C. (2018). *Research for TRAN Committee: The new Silk Route - opportunities and challenges for EU transport*.

Dantzig, G. B. (2002). Linear Programming. *Operations Research*, *50*(1).

Dekker, R., Bloemhof, J., & Mallidis, I. (2012). Operations Research for green logistics–An overview of aspects, issues, contributions and challenges. *European Journal of Operational Research*, *219*(3), 671–679.

GS1. (2023). *How GS1 standards work*.

Montreuil, B. (2011). Toward a Physical Internet: meeting the global logistics sustainability grand challenge. *Logistics Research*, *3*(2–3), 71–87.

Nilsson, N. J. (2014). *Principles of Artificial Intelligence*.

Okazaki, Y. (2018). *Unveiling the Potential of Blockchain for Customs.*

Oracle. (2022). *What is IoT?* https://www.oracle.com/internet-of-things/what-is-iot/

PLANET. (2021). *D1.2- Modelling & Simulation Capability*.

PLANET. (2022a). *D1.3-Modelling & Simulation Capability*.

PLANET. (2022b). *D2.14- Intelligent PI Nodes and PI Network services*.

PLANET. (2022c). *D3.5-LL3 Specifications and Baseline measurements*.

Pundir, A. K., Ganapathy, L., & Jagannath, J. D. (2019). IMPROVING SUPPLY CHAIN VISIBILITY USING IoT-INTERNET OF THINGS. *IEEE Annual Computing and Communication Workshop and Conference*.

Ranieri, L., Digiesi, S., Silvestri, B., & Roccotelli, M. (2018). A Review of Last Mile Logistics Innovations in an Externalities Cost Reduction Vision. *Sustainability*, *10*(3). https://doi.org/10.3390/su10030782

Transport Logistic. (2023). *New Silk Road & Europe: opportunity for European companies?*

UNCTAD. (2022). *UNCTAD's Review of Maritime Transport 2022: Facts and Figures on Asia and the Pacific*.