Flexible, multi-mOdal and Robust FREIGHt Transport

D3.1 Trial planning and experimentation methodology

Document Summary Information

Grant Agreement No	101069731	Acronym	FOR-FREIGHT
Full Title	Flexible, multi-mOdal and Robust FREIGHt Transport		
Start Date	01.09.2022	Duration	40 months
Project URL	https://www.for-freight.eu/		
Deliverable	D3.1 Trial planning and experimentation methodology		
Work Package	WP3 - Field Trials & Validation		
Contractual due date	30.06.2024	Actual submission date	28.06.2024
Nature	R – Document, report	Dissemination Level	PU - Public
Lead Beneficiary	WINGS		
Responsible Author	Orestis Manos, Sokratis Barmpounakis		
Contributions from	Katerina Batzou (CERTH), Sofoklis Dais (CERTH), Luis Fonseca (ABS), Pavel Muresan (BEIA), Maria Ramirez Gutierrez (DHL), Andreas Gavrielides (IMEC), Ana Isabel Mayor (CSLS), Chiara Iorfida (CSLS), Jorge Feliu (FVP), Giota Lilli (EBOS), Philippos Philippou (EBOS), Sokratis Barmpounakis (WINGS), Panagiotis Zagas (AIA), Andreas Togias (GOLD), Athina Ridaki (COEL), Diana Baciu (INLS), Andra Marcu (ATG)		

Funded by the European Union

Funded by the European Union under Grant Agreement no. 101069731. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

Revision history (including peer reviewing & quality control)

Version	Issue Date	% Complete	Changes	Contributor(s)
V0.0	04.03.2024	10	ToC-Initial contributions of Chapter 3	WINGS (Orestis Manos)
V0.1	11.03.2024	10	Quality Assurance Review of V0.0	EBOS (Giota Lilli)
V0.2	15.04.2024	50	Chapter 3	WINGS (Orestis Manos), BEIA (Pavel Muresan), FVP (Jorge Feliu), IMEC (Andreas Gavrielides), CERTH (Katerina Batzou), ABS (Luis Fonseca), COEL (Athina Ridaki), AIA (Panagiotis Zagas), GOLD (Andreas Togias), DHL (Maria Ramirez Gutierrez), CSLS (Ana Isabel Mayor), CSLS (Chiara Iorfida), Andra Marcu (ATG)
V0.3	12.05.2024	70	Chapters 1, 2, 3, 5 (Partly)	WINGS (Orestis Manos), BEIA (Pavel Muresan), FVP (Jorge Feliu), IMEC (Andreas Gavrielides), CERTH (Katerina Batzou), CERTH (Sofoklis Dais), ABS (Luis Fonseca)
V0.4	19.05.2024	70	Quality Assurance Review of V0.3	EBOS (Giota Lilli), EBOS (Philippos Philippou)
V0.5	19.06.2024	95	All chapters	WINGS (Orestis Manos), BEIA (Pavel Muresan), FVP (Jorge Feliu), IMEC (Andreas Gavrielides), CERTH (Katerina Batzou), CERTH (Sofoklis Dais), ABS (Luis Fonseca)
V0.6	21.06.2024	100	Quality Assurance and Peer Review of V0.5	WINGS (Sokratis Barmpounakis), WINGS (Orestis Manos), EBOS (Giota Lilli), CERTH (Katerina Batzou), CERTH (Sofoklis Dais), INLS (Diana Baciu), Panagiotis Zagas (AIA)

Disclaimer

Copyright message

[1] According to FOR-FREIGHT's Quality Assurance Process for reports:
4 months before Deliverable's Due Date: Table of Contents ready to be reviewed by WP leader/ Technical Manager/ Quality Manager
3 months before Deliverable's Due Date: 50% should be complete. Review by the Quality Manager (& Technical Manager for software).
2 months before Deliverable's Due Date: 80% should be complete. Review by the Quality Manager. (& Technical Manager for software).
1 month before Deliverable's Due Date:100% should be complete. Review by the Quality Manager and Peer Reviewers.
M: Sent to PC for Submission to the EC after addressing all comments by Quality Manager and Peer Reviewers

Table of Contents

List of Figures

List of Tables

Glossary of terms and abbreviations

Abbreviation / Term	Description
ABS	ALLBESMART LDA
AI	Artificial Intelligence
AIA	ATHENS INTERNATIONAL AIRPORT S.A.
API	Application Programming Interface
ATG	ASOCIATIA TEHNOPOL – GALATI
BEIA	BEIA CONSULT INTERNATIONAL SRL
CERTH	CENTRE FOR RESEARCH & TECHNOLOGY HELLAS
C-ITS	Cooperative Intelligent Transport Systems
CO2	Carbon dioxide
COARRI	Container discharge/loading report message
COEL	COSCO SHIPPING Lines Greece
COPRAR	Container discharge/loading order message
CSLS	COSCO SHIPPING Lines Spain
DHL	DHL EXEL SUPPLY CHAIN SPAIN SL
DSS	Decision Support System
DT	Digital Twin
E2E	End-to-End
ES	Spanish
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FR	Functional Requirement
FTP	File Transfer Protocol

FVP	FUNDACIÓN DE LA COMUNIDAD VALENCIANA PARA LA INVESTIGACION, PROMOCIÓN Y ESTUDIOS COMERCIALES DE VALENCIAPORT
GA	Grant Agreement
GHG	Greenhouse Gases
GOLD	GOLD EXYPIRETISEIS EDAFOUS ANONIMI ETAIREIA
GR	Greek
GUI	Graphical User Interface
HTTP	Hypertext Transfer Protocol
HW	Hardware
IMEC	INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM
IoT	Internet of Things
INLS	Inland Shipping
KPI	Key Performance Indicator
MDM	Metro De Madrid
ML	Machine Learning
MVP	Minimum Viable Product
OBU	On-board Unit
RBAC	Role-Based Access Comtrol
RO	Romanian
SCADA	Supervisory Control And ata Acquisition
sotA	State of the Art
SW	Software
TBD	To Be Decised
TcCFR	TELECOMUNICATII CFR SA
TRL	Technology Readiness Level
T&L	Transport and Logistics
UC	Use Case
WINGS	WINGS ICT SOLUTIONS INFORMATION & COMMUNICATION TECHNOLOGIES IKE
WMS	Warehouse Management System
WP	Work Package

1 Executive Summary

D3.1 "Trial planning and experimentation methodology" is responsible for the **trial planning of the UCs** and specifying **the validation methodology** to be followed. For trial planning, the task involves analysing facility layout and experimentation methodology. The objective is to ensure the integrity of the technical components to meet the described targets and to provide **clear directions for achieving KPI satisfaction, fulfilling functional requirements, data collection and analysis, trial tools involved, and execution phases.** The trial validation methodology will adopt a holistic approach covering both business and technical standpoints, focusing on the satisfaction of KPIs against specific metrics, baseline values, and predetermined targets, and ensuring the proper functionality of the involved modules.

This comprehensive approach begins with a thorough assessment of the facility layout, considering factors such as equipment placement, workflow optimisation, and potential interaction effects between different system components. The experimentation methodology is meticulously crafted to simulate real-world conditions, ensuring that the trials accurately reflect operational scenarios. By doing so, the trial planning process not only tests the technical viability but also validates the operational readiness of each UC.

Furthermore, the validation methodology incorporates a robust framework for data collection and analysis. This includes deploying advanced data acquisition tools and techniques to capture high-fidelity performance metrics. The collected data undergoes rigorous analysis using statistical and computational methods to derive meaningful insights and validate the KPIs. The process also involves setting up a detailed execution phase plan, outlining the sequence of activities, resource allocation, and timeline management to ensure that the trials are conducted smoothly and efficiently.

In addition to the technical evaluation, the methodology also emphasises the business implications of the trial outcomes. It assesses aligning the technical results with the strategic business objectives, ensuring that the trials contribute to overall business value. This dual focus on technical and business aspects ensures a balanced approach to KPI validation, providing stakeholders with a comprehensive understanding of both the capabilities and the potential impacts of the UCs.

Through continuous monitoring and iterative adjustments, the trial validation methodology aims to achieve and sustain the stipulated performance criteria. This iterative process allows for the identification and rectification of any deviations from expected outcomes, thereby enhancing the reliability and accuracy of the validation results. Ultimately, this methodical and thorough approach ensures that the UCs are technically sound and aligned with the overarching business goals, paving the way for successful implementation and operational excellence.

2 Introduction

The purpose of D3.1 is to provide comprehensive and detailed information on the trial planning for each facility, including the tools employed and the **experimentation methodology** to be adhered to FOR-FREIGHT experimenters. This document will also encompass an experimenter's manual, which serves as a crucial resource for ensuring consistency and precision across all trial activities. D3.1 is responsible for establishing stringent rules and guidelines for experimentation at each site, defining the various trial cycles—such as setup and configuration, testing, trialling, results analysis and feedback, updates, and more—and systematically collecting data to inform and improve future trials. This data will be gathered through detailed observation, sensor outputs, automated data collection systems, and participant feedback, all of which will be analysed to inform and improve future trials. By using these methods, we will ensure that the information collected is comprehensive and precise, allowing for continuous enhancement of our trial processes and methodologies.

This deliverable also addresses Implementation objectives 2 and 3. **Objective 2** aims to build and deliver three state-of-the-art T&L experimentation facilities based on real operational multi-stakeholder environments that support multimodal and transshipment ITU logistics. This involves recapitalizing on, expanding, and upgrading existing infrastructure and legacy systems from consortium partners and ongoing and previous EU-funded projects [1] H2020-ICT-17-2018 5G-EVE project, https://www.5g-eve.eu/, [2] H2020-ICT-18-2018 5G-CARMEN project, https://5gcarmen.eu/about/[3] H2020-ICT-18-2018 5G-MOBIX project, https://www.5g-mobix.com/[4] H2020-ICT-53-2020 5G-ROUTES project, https://www.5g-routes.eu/[5] H2020-ICT-41-2020 VITAL-5G project, [6] H2020-ICT-52-2020 DEDICAT 6G project, [7] H2020-ICT-52-2020 Hexa-X project, to support collaborative and cooperative logistics operations with a high degree of automation. **Objective 3** focuses on validating the FOR-FREIGHT solutions in real-life multimodal/multi-stakeholder environments using real end-user data. This will be based on carefully designed UCs that showcase the maturity and business-readiness of the solutions (TRL≥7), demonstrating superior performance in terms of capacity, resource efficiency, sustainability [8] Silva et al., "Sustainable Urban Last-Mile Logistics: A Systematic Literature Review", Sustainability 2023, 15(3), 2285; https://doi.org/10.3390/su15032285, reduced emissions, and cost compared to current fragmented logistics operations.

To meet Objective 2, D3.1 will provide information on the integration of various T&L legacy systems and existing solutions, detailing the methodology within a concrete validation framework. Integration plans for the legacy systems will be presented in detail, highlighting the business flows that show how the various legacy systems exchange information with the solvers and how the entities are orchestrated to enhance the system's capabilities. D3.1 also significantly contributes to Objective 3 by presenting three high TRL (TRL≥7) UCs that achieve specific KPIs, advancing the current T&L scheme by reducing transport times and costs [9] Handbook on the external cost of transport, Version 2019, https://op.europa.eu/en/publication-detail/-/publication/e021854b-a451-11e9-9d01-01aa75ed71a1/language-en, lowering GHG emissions, and optimizing warehouse resource allocation.

By integrating these detailed methodologies and structured approaches, D3.1 aims to provide a holistic and rigorous framework for trial planning and execution. This ensures that the trials are not only methodologically sound but also strategically aligned with both technical and business objectives, thereby paving the way for successful implementation and operational excellence.

2.1 Mapping FOR-FREIGHT Outputs

This section presents the FOR-FREIGHT 's GA commitments, as extracted from the formal deliverable and task description, in respect to their outputs and work to be performed. The purpose is to aid the reviewer in finding the specific sections of the document where the respective tasks' requirements are addressed but also to guide the author through and serve as a check list to address everything that is needed to be addressed.

Table 2-1. Adherence to FOR-FREIGHT's GA Deliverable & Tasks Descriptions.

FOR-FREIGHT GA Component Title	FOR-FREIGHT GA Component Outline	Respective Document Chapter(s)	Justification
DELIVERABLE			
D3.1 "Trial planning and experimentation methodology"	"This deliverable will provide details on the trial planning of each facility, the used tools and the experimentation methodology to be followed by the FOR-FREIGHT experimenters, as well as the experimenter's manual. It is the output of Tasks 3.1 and 3.5."	Chapter 2	Brief outline of the interdependences between the several T3.x tasks
		Chapter 3	Description of each pilot site's trial planning contains information about the facilities layout and infrastructure and the experimentation methodology.
		Chapter 4	Description of the risks such as technical failures, data inaccuracies, timeline delays, and resource limitations with their mitigation strategies.
		Chapter 5	This chapter analyses the trial validation methodology which is going to be followed in a holistic approach using three pillars: 1. The association of Business scenarios with the described KPIs and the proposed solutions. 2. The quantification of the KPIs using baselines, metrics, and targeted values. 3. The evaluation of the functionality of the solvers and the system components.

		Chapter 6	This chapter concludes the main outcomes of this deliverable.
TASKS			
T3.1 - Planning, setup of field trials and operational management	"The general guidelines and trial preparation methodology to be followed by all FOR-FREIGHT trials will be defined in this task to ensure a comprehensive and detailed trial approach and the delivery of homogeneous and detailed results for T3.5 and WP4 for KPI and business validation. The trialling methodology will at least include a) a stepwise approach for the completion of a test run from set-up, to configuration, to calibration, to testing and finally to trial and results collection per trial site;, b) a time plan per trial site for the testing, trialling and validation periods (cycles) expected by experimenters and c) the tools to be used per trial for (meta)data and KPI collection, the aligned storage data formatting respective data storing facilities. This task will platform. Output: D3.1."	Chapter 5	This chapter elaborates on the methodology for satisfying each trial's functional requirements/KPIs. It outlines the tools planned to be used for the specific functional requirements/KPIs, along with any related metrics and target values. The logical sequence to meet each functional requirement/KPI is also detailed. Additionally, a clear timeline for the development of each component per trial site is presented.
T3.2 - Sea port - last-mile trials	"This task will be responsible for the experimentation in the ES trial site, including the definition of the trial cycles (set-up/configuration, testing, trialling, results analysis & feedback, updates, etc.), the collection of data, and their communication to T3.5. The trialling activities performed in this task are tightly coupled to T2.2, as constant feedback from this task will allow for the upgrade, reconfiguration and optimisation of the observed performance in WP2, as well as	Chapter 5, section 5.2.1	This chapter outlines the path to achieving KPI satisfaction, detailing specific metrics. It also provides a detailed plan for satisfying the functional requirements. Testing tools and methods are presented, emphasising the hardware and software components to be deployed and developed,

	T3.5, WP4 and WP5 where the results of the trials will be evaluated, the performance and resulting impact assessed, and the outcomes and insights from the ES trials will be shared. Output: D3.2, D3.3.”		respectively. Each step of this methodology is clearly defined within a timeline.
T3.3 - River port - Rail trials	“This task will be responsible for the experimentation in the RO trial site, including the definition of the trial cycles (set-up/configuration, testing, trialing, results analysis & feedback, updates, etc.), the collection of data, and their communication to T3.5. The trialing activities performed in this task are tightly coupled to T2.3, as constant feedback from this task will allow for the upgrade, reconfiguration and optimisation of the observed performance in WP2, as well as T3.5, WP4 and WP5 where the results of the trials will be evaluated, the performance and resulting impact assessed, and the outcomes and insights from the RO trials will be shared. Output: D3.2, D3.3.”	Chapter 5, section 5.2.3	The outlined task focuses on managing the RO trial site's experimentation through structured trial cycles, including setup, testing, analysis, and updates. It emphasises systematic data collection and communication with T3.5, ensuring real-time feedback to T2.3 for continuous improvement. The trial results are integrated with T3.5, WP4, and WP5 for comprehensive performance evaluation and impact assessment, aligning the trials with broader project goals and facilitating cross-functional collaboration. Each step of this methodology is clearly defined within a timeline.
T3.4 - Airport - Sea port trials	“This task will drive the experimentation in the GR trial site and will be responsible for setting up the rules and guidelines of experimentation for that site as well as the definition of the trial cycles (set-up/configuration, testing, trialling, results analysis & feedback, updates, etc.), the collection of data, and their communication to T3.5. The	Chapter 5, section 5.2.2	This chapter outlines the pathway to achieving KPI satisfaction, detailing specific metrics. Additionally, it provides a detailed plan for satisfying the functional requirements. The trial tools and methods are presented, with

	trialling activities performed in this task are tightly coupled to T2.4, as constant feedback from this task will allow for the upgrade, reconfiguration and optimisation of the observed performance in WP2, as well as T3.5, WP4 and WP5 where the results of the trials will be evaluated, the performance and resulting impact assessed, and the outcomes and insights from the GR trials will be shared. Output: D3.2, D3.3."		emphasis on the hardware and software components to be deployed and developed, respectively. Each step of this methodology is clearly defined within a timeline
T3.5 - Evaluation, lessons learned and best practices	"The task is responsible for the analysis and evaluation of the trial results performed in T3.2-3.4 based on obtained metrics and KPIs. A holistic evaluation framework will be developed (with T1.2-1.3), defining and validating results with corresponding KPIs (before-after) and generating insights per testing case and utilized multimodal solution. The framework will build upon FENIX's Common Evaluation Framework, a modification of FESTA and SCOR methodologies (FENIX-CEF 2018), a six-step approach measuring the impact of digital services implementation in the performance of T&L operations, encompassing impact definition, baseline and trial KPI measurements, and analysis for overall impact determination (with T4.3). It will comprise technical (e.g., interoperability maturity), operational (e.g., efficiency), readiness, adaptation and transferability analyses, and best practices benchmarking. As a shared decision-making tool, an evaluation platform will obtain disaggregated assessment metrics, which will be all further	Chapter 3, Chapter 5	Chapter 3 describes the experimentation methodology of the trial sites for the satisfaction of their KPIs. For each broader KPI, the subKPIs are listed and the exact experimentation methodology, baseline, related solutions, and metrics are analysed. The specific tools (HW and SW components) that will be used for the execution of the trials, data collection methods, technical aspects and timeline of the trial phases are described for each trial site. Chapter 5 describes the validation methodology of the modules and the solvers developed. A component functionality assessment for performance compliance is conducted for each trial site, evaluating

	combined into an integrated index. Timelines and technical aspects about data collection, use and storage will be outlined (with T3.1). Evaluation will feed solution design (T1.4) in an iterative process (M22, M36) to enable refinements, improvements and optimisation aspects. It will also provide insights for commercialization (WP4) through knowledge exchange workshop (M36) between trial participants and other stakeholders, presenting lessons learned, highlighting best practices and co-designing future application trajectories."		the functionality of individual system components.

2.2 Linkage to other project outputs

This section gives details of the interdependencies of the respective deliverable with other WPs, project outputs, etc., as provided on the table below.

Table 2-2.Links to other Project Outputs/ Work.

WP Number	Task Number	Deliverable Number related	Content
WP1	T1.2 T1.3 T1.4	D1.2 D1.3 D1.4	The marked tasks and deliverables define the technical and non-technical requirements, associating them with specific UC scenarios. The appropriate technologies and a necessary validation methodology are also identified to ensure these requirements are met. Furthermore, the design of the FOR-FREIGHT end-to-end system architecture for the central platform is analysed, incorporating a comprehensive risk analysis methodology.
WP2	T2.2 T2.3 T2.4	D2.1 D2.2 D2.3	The tasks and deliverables are focused on creating the first demonstration plan, covering development through the integration stage. Additionally, they highlight the impact of the proposed solutions. Furthermore, various implementation activities are analysed for ES_UC, GR_UC, and RO_UC. This analysis includes the deployment and development of both hardware and software, as well as a detailed description of the current status of solution

			development, functional requirements of each solver, timeline, and expected demonstration output. Simultaneously, each component of the central platform architecture is examined individually, with particular emphasis on demonstrating E2E solutions.
WP3	T3.2 T3.3 T3.4 T3.5	D3.2 D3.3	The tasks and the deliverables are responsible for conducting experiments at the ES, GR, and RO trial sites, which includes defining trial cycles (set-up/configuration, testing, trialling, results analysis & feedback, updates, etc.), collecting data, and communicating them to T3.5. As a next step the analysis and evaluation of the trial results will be performed based on the obtained metrics and KPIs.
WP4	T4.1 T4.2 T4.3 T4.4	D4.1 D4.2 D4.3 D4.4 D4.5	The current tasks and deliverables are dedicated to performing market analysis, developing a business plan, and ensuring sustainability. Additionally, these tasks will include activities related to innovation, intellectual property rights (IPR), and the examination of socio-economic and environmental friendliness aspects.

2.3 Deliverable Overview and Report Structure

D3.1 provides an overview of the trial planning and validation methodology for each pilot within the FOR-FREIGHT project, following a structured approach.

Chapter 2 outlines the mapping of FOR-FREIGHT's output and its linkage to other project outputs, highlighting the connections and relationships between them.

Chapter 3 delves into specific aspects of the trial planning process. **Chapter 3.1** offers a detailed overview of the trial planning for each pilot site, including comprehensive information on the specific facilities that constitute each UC and the business scenarios to be enacted. This section ensures that each trial is tailored to the unique characteristics and operational requirements of the individual pilot sites, optimising the relevance and applicability of the trial outcomes. **Chapter 3.2** presents the experimentation methodology, a critical framework designed to ensure the satisfaction of functional requirements and KPIs for each trial. It details the trial tools and methods (including hardware and software components) necessary for the execution of the trials, as well as the data collection and analysis methodology. Advanced techniques for data capturing and rigorous analytical methods for deriving actionable insights are covered. The trial execution phases and timeline are also outlined, providing a clear roadmap for the sequential steps and timeframes involved in conducting the trials.

Chapter 4 focuses on the challenges inherent in trial planning and execution, considering potential risks and specifying mitigation strategies to ensure the success of each trial. The primary risks identified include technical failures, data inaccuracies, timeline delays, and resource limitations. To address these risks, D3.1 includes various strategies aimed at proactively identifying, managing, and resolving potential issues.

Chapter 5 introduces a robust trial methodology built upon three foundational pillars. The first pillar emphasises the association of business scenarios with the described KPIs and the proposed solutions, ensuring that each trial is directly aligned with strategic business objectives. The second pillar focuses on quantifying KPIs through baselines, metrics, and targeted values, providing a clear and measurable framework for assessing performance. The third pillar involves the evaluation of the functionality of the solvers and the system components, ensuring that the technical solutions are not only effective but also seamlessly integrated into the overall system architecture.

Chapter 6 concludes the document by summarizing the key findings and conclusions of this deliverable.

3 Trial planning for each pilot site

The objectives of Chapter 3 are to provide a comprehensive framework for trial planning and execution, ensuring that each pilot site trial is tailored to its specific characteristics and operational requirements, and to present a robust experimentation methodology that guarantees the satisfaction of functional requirements and KPIs. By detailing the tools and methods used, and outlining the phases and timeline of trial execution, Chapter 3 aims to optimise the relevance and applicability of trial outcomes and ensure that the trials are methodologically sound and strategically aligned with both technical and business objectives.

3.1 Facilities layout and infrastructure

Section 3.1 provides a detailed analysis of the facilities layout and infrastructure of three distinct UCs: the ES_UC, the GR_UC, and the RO_UC. Each UC represents a crucial node in their respective regional logistics networks, contributing significantly to international trade and transportation efficiency. In the Spanish UC, emphasis is placed on the port of Valencia, the DHL warehouse, and the Metro de Madrid, showcasing their roles in maritime trade, logistics, and urban transit. Operational procedures are detailed to highlight safety, efficiency, and environmental considerations. Moving to the Greek UC, the report explores the facilities of the Port of Piraeus and the GOLD warehouse. Operational procedures are outlined to underscore optimised logistical workflows. Lastly, the Romanian UC focuses on the Port of Galati and the surrounding railway infrastructure. Detailed operational procedures ensure reliable and scalable transportation solutions across the region.

3.1.1 Spanish UC

Scenario 1: Valencia

In scenario 1, the Port of Valencia will be the starting point from which the logistics transport process defined in the Spanish use case begins. The operations in this scenario will be carried out within the Port of Valencia and its hinterland, to where the container will be transported by truck or a combination of rail and truck. The following Figure 3-1 shows the facilities of the port of Valencia.

Figure 3-1. Aerial view of the port of Valencia.

- **Container yard:** A place where containers will be stored until they require to be loaded into a truck/train;

- **Truck loading areas**: Dedicated zones within the port where trucks are loaded with containers for transportation to a warehouse/dry port;
- **Railway facilities**: Railway facilities within the port facilitates the transfer of containers onto trains for long-distance transportation;
- **Logistic node**: In this scenario, work is being carried out with the logistics node of the dry port of Coslada (Madrid). The freight coming from the port of Valencia that has been transported by rail will arrive at this logistics node and will later be transported by lorry to the warehouse.

Scenario 2: Madrid

In scenario 2, logistics operations will take place between DHL warehouses located in Illescas and Ontígola, the MDM subway depots, trains, and the lockers across the different stations for last-mile distribution. The facilities and infrastructure involved include:

- **DHL Warehouses**: Two DHL warehouses will serve as storage and distribution centres for goods awaiting transportation to the Metro de Madrid subway depot. These facilities will store the goods, load them into roller cages and distribute them via their vans or trucks to the MDM depot destination. These facilities will count on designated zones where goods are classified, packed into roller cages, and prepared for transportation. These roller cages will be loaded onto vans or body trucks for transit to their correspondent Metro de Madrid subway depot.
    1) **Illescas** (Toledo), from where all IKEA and Zalando parcels currently depart.
    2) **Ontígola** (Toledo), working with Amazon and Tienda Animal.

- **Metro de Madrid Subway Depots**: Goods transported from DHL warehouses are unloaded from trucks and loaded onto subway trains for distribution across the subway network. The depot is equipped with loading platforms, and systems for efficiently handling roller cages in the trains.
  Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε. localizes the different MDM depots and the lines associated with each of them:

Table 3-1. MDM Depots.

MDM Depots	Line	Coordinates
Depot Hortaleza	Línea 1, Línea 4	40.46521494666425, -3.653888646478099
Depot Cuatro Caminos	Línea 2	40.4459384441738, -3.703701475313683
Depot Villaverde	Línea 3	40.329071679778174, -3.716739014391368
Depot Canillejas	Línea 5, Línea 7	40.444325832948934, -3.6081474739088053
Depot Laguna	Línea 6	40.403241265937396, -3.7357002661899577
Depot Fuencarral	Línea 10	40.50459323315727, -3.6912631041479664

- **Metro de Madrid stations**: Goods transported via subway trains are delivered to designated lockers at Metro de Madrid stations, where they will be picked up by final clients. Different stations will be selected along the line depending on the feasibility of having lockers.
- **Metro**: For the Madrid scenario, the metro will be used to take advantage of the empty journey it makes early in the morning without passengers. It will be loaded with roller cages that will be unloaded along the line at the various stations (if necessary and where lockers are available). The metro model will depend on the selected line.

- **Roller cages**: In order to transport the individual parcels, roller cages will be used, initially loaded with the parcels at the DHL warehouse and unloaded at the corresponding locker. These lockers will be loaded onto the DHL trucks/vans and transported to the depot, where they will be put into the train wagons and taken out at the relevant station for unloading.
- **Lockers**: Some designated stations along the selected line(s) are equipped with locker systems where the goods will be placed. For the pilot trial site, MDM has lockers (Figure 3-2) to deliver spare parts are expected to be used for this test. The trial site lockers have space for 18 packages (5 big packages, 5 medium packages, 8 small packages). For simulations, the lockers to be considered will have a maximum capacity of 80 parcels.

Figure 3-2. MDM trial site locker.

3.1.2 Greek UC

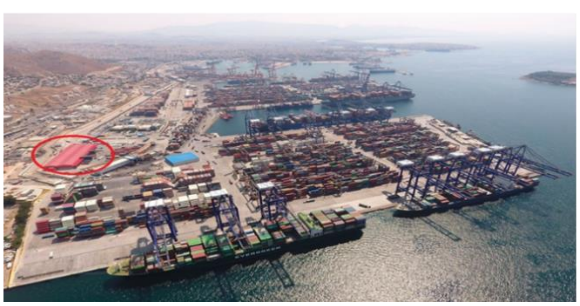


Figure 3-3. View of the port of Piraeus (left images) and the GOLD (right images).

The T&L line of the GR_UC encompasses two critical entities: the Port of Piraeus (PCT – Piraeus Container Terminal) and the GOLD warehouse situated within the AIA area. The primary objective is to establish a seamless connection between these two endpoints, achieving a high degree of interoperability. This includes the digitalisation and automation of logistic processes and significant optimisation of resource planning. The integration aims to streamline operations, reduce transit times, and enhance overall efficiency within the supply chain.

The main scenario illustrating the logistics workflow between these points is the following: Firstly, freight arrives at the Port of Piraeus, where customs clearance process takes place after freight has been discharged from the vessel. Once cleared, the freight destined for the GOLD warehouse is loaded onto trucks. These trucks then transport the freight to the GOLD warehouse in the AIA area. Upon arrival, the cargo undergoes unloading and inspection. In the final stage, the freight is either stored in the warehouse for future flights or directly loaded onto a specific flight bound for its international destination. The facilities that support this procedure include several key components:

Port part

The facilities supporting this procedure include several key components. The container yard is designated for storing containers until they need to be transported to the PCDC warehouse (Piraeus Consolidation and Distribution Center) for unstuffing, cargo storage and customs inspection. The warehouse serves as a storage facility for handling and customs inspection on the cargo level (PCT—handling on the container level).

GOLD part (Airport warehouse)

GOLD's warehouse functions as a temporary storage and distribution centre for freight destined for various international locations. GOLD operates its own cargo terminal on a 24-hour basis, servicing all types of PAX and CAO aircraft. The 6,000 m^2 terminal is strategically located to ensure fast and seamless handling of all types of freight and mail. It includes a bonded warehouse, a Dangerous Goods (DGR) acceptance area, and storage facilities for valuable (VAL), human remains (HUM), and perishable (RRY) goods according to international standards. Additionally, the terminal features cooler and freezer rooms with ample storage capacity, as well as specialised storage areas for dangerous goods.

3.1.3 Romanian UC

The Romanian Use Case follows the T&L lines that interconnect fluvial and railway transport. The pilot site serving as the multimodal point is the port of Galati. However, to properly define meaningful trials, the activities will span across multiple cities. The flow of goods, which we will focus on within the use case, can be summarised as follows: loading the goods onto a ship in the port of Reni or Izmail, transporting them via the Danube to the port of Galati, unloading the goods directly into wagons, and then transporting them to the final destination via railway. To ensure a comprehensive understanding, we will break down the layout and infrastructure of each section of the T&L line:

- **Reni&Izmail:** Both are Ukrainian cities with ports that have access to the Danube, which acts as the border with Romania. Each can serve as the starting point of the transport process we follow, but we are not focused on the exact port infrastructure and the established procedures for bringing the containers to the port and loading them onto the ship. We track activities once the ship is prepared to leave the port and move towards Galati. In Fig. 3-4, we can see both cities highlighted.

Figure 3-4. Map of the port of Galati region.

- **Galati:** The port of Galati can serve as a multimodal point for inland waterway transport and truck or railway transport. Within our use case, no container storage is defined. Once the ship has docked, the containers are unloaded directly onto wagons that are on train tracks parallel to the water. The unloading is done with cranes that run on fossil fuels. Once the containers have been unloaded, the wagons are manoeuvred out of the port areas, connected to a train, and start moving to the final destination. In Fig. 3-5 (left), we can see images showing the cranes near the waterline, and in Fig. 3-5 (right), we can see the local train track infrastructure of the port area.

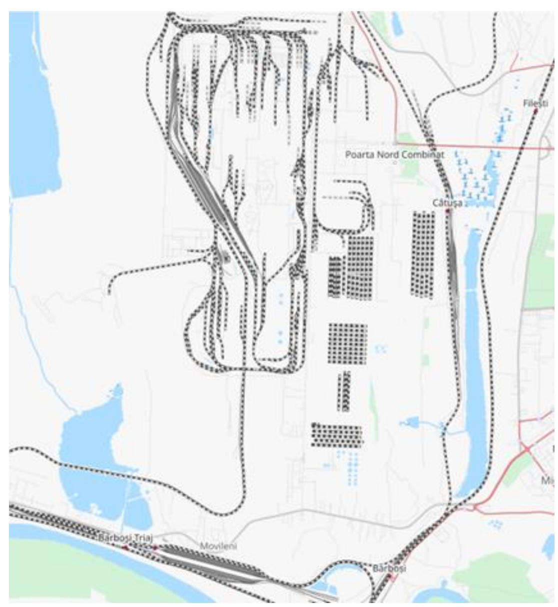


Figure 3-5. Panoramic view of the cranes in port of Galati (left). Sketch of the local train track infrastructure (right).

- **Final destination:** The final destination of the containers depends on the type of shipment and typically represents a train depot where the goods are unloaded from wagons. At this point, we consider the goods to have reached the customer, and the scope of the use case ends. To maintain flexibility while keeping a realistic scope within experimentations, we have defined an area around the city of Galati that includes several major cities such as Constanta, Brasov, and Bucharest. Only the railway infrastructure within this area will be considered. The railway infrastructure in the area can be seen in Figure 3-6.

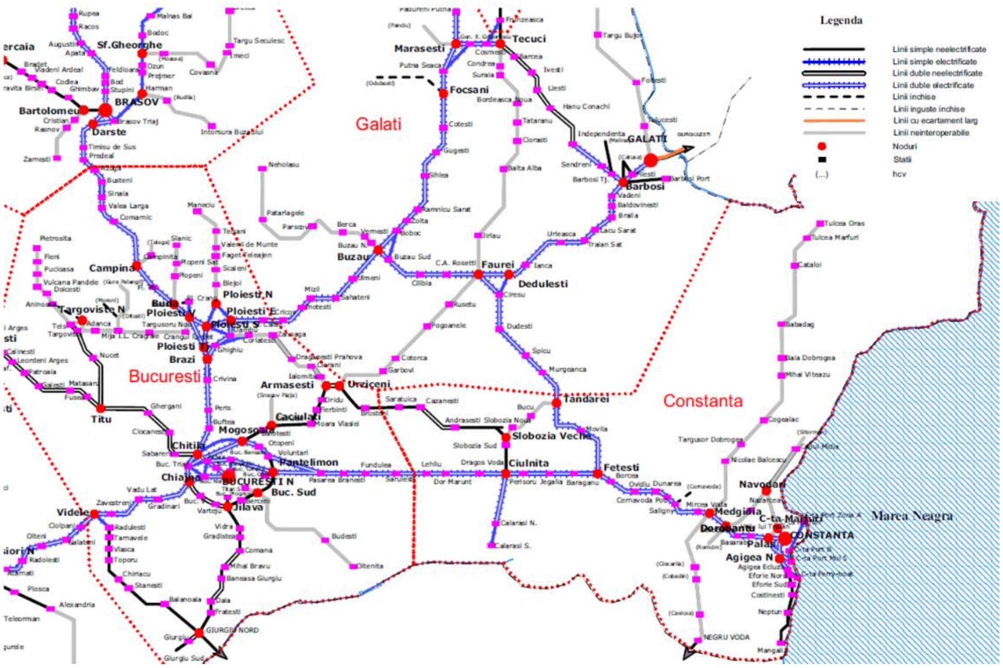


Figure 3-6. The railway infrastructure of the area around Galati port.

3.2 Experimentation methodology

In this chapter we present the methodology for the satisfaction of the FRs/KPIs per each trial. The tools planned to be used for the specific FRs/ KPIs the related metrics (if any) and target values (if any). The logical sequence is to satisfy each FR/KPI.

3.2.1 Spanish UC

3.2.1.1 Route of the KPI satisfaction

The successful achievement of KPIs is dependent on a methodically designed route that evaluates the different specific KPIs comprising the Spanish UC. This initial route will examine the connectivity between these metrics and the participating solutions, linking each sub-KPI with their general KPI group. The resulting outputs of the solutions and the methodologies employed will be analysed, establishing a clear picture of the whole KPIs route until its completion. In order to provide the best possible performance of the route and methodologies to be followed for the measurement of the KPIs, it may be adjusted retrospectively to reflect a more accurate measurement in the Spanish UC.

The KPI completion will be achieved by examining the KPI and, if it is composed of the different sub-KPIs that comprehensively address and form the main KPI. Each sub-KPI will be weighted according to its relative importance to the overall objective. By analysing the performance of each sub-KPI and applying the assigned weightings, it creates a holistic picture that reveals the factors influencing the satisfaction of the main KPI. This approach allows optimisations and analysis at the sub-KPI level, leading to the achievement of the KPI.

For the measurement of KPIs composed of different sub-KPIs, weights will be assigned according to the relevance of each sub-KPI, based on the evaluation that will be provided and assigned by the end-users of each solver.

$$KPI = \sum_{i=1}^{n} w_i \times subKPI_i$$

Here, $subKPI_i$ (where *i* = 1, 2, ..., n) represents each sub-KPI value that conforms to the main KPI, and w_i its corresponding weight. The formula iterates over each parameter, multiplying it by its weight and then summing up all these products to compute the overall KPI value.

KPI Improve forecast planning by >15%

To measure the "improve forecast planning" KPI based on the provided information and its sub-KPIs, we can construct a formula that considers the improvement in each of the sub-KPIs and aggregates them into an overall metric. The different sub-KPIs that make up the improved forecast planning are the following:

Table 3-2. Summary of the components for the satisfaction of the “improve forecast KPI”.

subKPI	Acronym	Baseline	Solutions Related	Metrics	Methodology
Current on-time delivery ranges	OTDR	~60% of shipments	ES_01 ES_02 ES_06 ES_07 Digital Twin	Dates of cargo unloading in port Truck ETA and updates on the ETA Digital Twins are used to simulate the optimal scenario for container on-time delivery.	ETA predictors will provide information about the estimated time of arrival of vessels and trucks or trains; comparison of ETA updates prediction will support the measurement of on-time deliveries. The DT will be used to simulate the optimal scenarios for container on-time delivery.
Errors, accidents	EA	18% as ratio of disputes	ES_14 ES_17	Availability of cargo status and location in real time and registered events to be visible from a blockchain solution with different access profiles depending on the agent.	Solver ES_14 will provide tracking of the container (potentially based on events). Through solver ES_17, cargo status and location will be visible.
Time to set-up an end-to-end multimodal freight transport with multiple stakeholders	TSUT	2 days	ES_02 ES_06 ES_07 Digital Twin	Measuring time since we receive the transport request from the customer, and we arrange the transport to be carried out (incl. Optimal decision between truck/train)	Solver ES_02 will support the process of setting up E2E multimodal freight transport. Solvers ES_06 and ES_07 aim to achieve better decision-making, improving the time since the transport request arrives up to arrange the truck/train to carry the container to the transloading point/DHL warehouse.

Delivery lead time in inland transport	DLT	~4 days	ES_01 ES_02 ES_06 ES_07 ES_12 ES_13 Digital Twin	Measuring time since we receive the transport request from the customer to arrival at the final destination, also includes the transit time (incl. Optimal decision between truck/train)	Solver ES_06 and ES_07 will support to choose the optimal decision between truck or train, while solvers ES_12 and ES_13 will assist on providing the transit time from port to transloading point/DHL warehouse.

$$\textbf{Improve forecast planning}_{\boldsymbol{baseline}} = w_1 \times OTDR_{baseline} + w_2 \times EA_{baseline} + w_3 \times TSUT_{baseline} + w_4 \times DLT_{baseline}$$

$$\textbf{Improve forecast planning}_{\boldsymbol{objective}} = w_1 \times OTDR_{current} + w_2 \times EA_{current} + w_3 \times TSUT_{current} + w_4 \times DLT_{current}$$

This overall KPI would not have a specific unit but would represent a composite measure of the various sub-KPI metrics related to improving forecast planning. It would be a weighted average or composite score reflecting the performance across these different dimensions. The route satisfaction of this solver will be accomplished by satisfying:

$$\frac{\textbf{Improve forecast planning}_{\boldsymbol{objective}} - \textbf{Improve forecast planning}_{\boldsymbol{baseline}}}{\textbf{Improve forecast planning}_{\boldsymbol{baseline}}} \geq \mathbf{0.15}$$

<u>KPI Reduce container staying at the port by >15%</u>

To measure the reduction of containers staying at the port KPI based on the provided information and its sub-KPIs, we can construct a formula that considers the improvement in each sub-KPI and aggregates them into an overall metric. The different sub-KPIs that will be part of this KPI route are the following:

Table 3-3. Summary of the components for the satisfaction of the "Reduce container staying at the port by 15% KPI".

subKPI	Acronym	Baseline	Solutions Related	Metrics	Methodology
Trucks' waiting time at the Terminals	TWT	~ 2 hours	ES_02	Tracking the waiting time trucks spend at the terminals between terminal entry and exit. DT used for simulation to reduce truck dwell time.	ETA predictors and resource allocation will reduce trucks' waiting time at the terminals. Digital twin will be used for simulation on reducing truck dwell time. To measure the time, the waiting time of trucks at terminals between entry and exit will be tracked.

Loading time in the terminals	LT	~ 1-2 hours	ES_02 ES_03 ES_06 ES_07	Measuring/ tracking the waiting time since truck arrives at the terminal to the load of the container on it DT use for simulation on reducing truck dwell time.	ETA predictors and resource allocation will reduce loading time in terminals. DT will be used for simulation on reducing truck dwell time. To measure the time, the waiting time of trucks at terminals between entry and exit will be tracked.
ITU/container dwell time in port	CDT	9,6 days full container	ES_01 ES_02 ES_03 ES_06 ES_07	Measuring time between discharge of the container (COARRI) and the terminal gate's exit (CODECO) DT use for simulation on optimal planning, selecting optimal transport mode (truck/ train).	ETA predictors and resource allocation will decrease container idle time. Digital twin will be used for simulation on optimal planning, selecting optimal transport mode (truck / train)

$$\textbf{Container staying at the port}_{\boldsymbol{baseline}} = w_1 \times TWT_{baseline} + w_2 \times LT_{baseline} + w_3 \times CDT_{baseline}$$

$$\textbf{Container staying at the port}_{\boldsymbol{objective}} = w_1 \times TWT_{current} + w_2 \times LT_{current} + w_3 \times CDT_{current}$$

This overall KPI would not have a specific unit but would represent a composite measure of the times offered by the sub-KPI related to reducing the time that the container will stay at the port. It would be a weighted average or composite score reflecting the performance across these different dimensions. The route satisfaction of this solver will be accomplished by satisfying:

$$\frac{\textbf{Container staying at the port}_{\boldsymbol{objective}} - \textbf{Container staying at the port}_{\boldsymbol{baseline}}}{\textbf{Container staying at the port}_{\boldsymbol{baseline}}} \geq \mathbf{0.15}$$

<u>KPI Reduce GHG emissions by >15%</u>

To measure the reduction of GHG emissions KPI, the predictions related to GHG emissions associated with a given trip that offers the group of solvers ES_05, ES_12 and ES_13 regarding scenario 1 routes. To achieve it, the following methodology will be followed:

Table 3-4. Summary of the components for the satisfaction of the "Reduce GHG emissions by >15%" KPI.

KPI	Acronym	Baseline	Solutions Related	Metrics	Methodology
Reduce GHG emissions	GHG	0,3 t CO_2e 9 In addition to this initial baseline, a comparison and adjustment will also be made with the value presented by a route with the same cargo weight, in order to make the results obtained comparable.	ES_05 ES_12 ES_13	Measurements of the tracking distance travelled in terms of emissions produced on the trip from the port to the DHL warehouse.	Measurement of GHG emissions produced on a trip from Valencia Port to DHL warehouse by truck or by the combination of train and truck. Compare the GHG emission emitted on both alternatives.

The GHG baseline will be based on the measurements provided by CSLS of one route port of Valencia – Madrid using truck. This KPI will highlight the use of this combination of train and truck to showcase how this multimodal option will be able to achieve less GHG emissions than using a truck. Using the GHG emissions predictor that offers the route planning group of solvers, the estimated CO_2e emissions of a given trip will be obtained and later be used for this KPI comparison. The route satisfaction of this solver will be accomplished by satisfying:

$$\frac{\mathbf{GHG}_{\boldsymbol{objective}} - \mathbf{GHG}_{\boldsymbol{baseline}}}{\mathbf{GHG}_{\boldsymbol{baseline}}} \geq \mathbf{0.15}$$

KPI Increase Transport orders digitalisation by 20%

To measure the "increase transport order digitalisation" KPI, the platform developed to share documents and verify the integrity of the transactions of the digitalized transport orders. This platform will be supported by the functionalities that ES_16 and ES_17 offer. To achieve it, the following methodology will be followed:

Table 3-5. Summary of the components for the satisfaction of the “Increase Transport orders digitalisation by 20%” KPI.

KPI	Acronym	Baseline	Solutions Related	Metrics	Methodology
Transport Orders digitalisation	TOD	0	ES_16 ES_17	Transport orders fulfilled using the blockchain-based system.	Using blockchain technology, documents will be accessed and visualised through the platform, and the transport event registration between the port and stakeholders in the logistics community will be carried out. This technology will reduce delays in original documentation/paper-based documents. Also, all the actors of the supply chain working through blockchain will reduce redundant data transactions between them.

By comparing the current number of orders fulfilled using blockchain to the baseline, we can determine the percentage increase in transport order digitalisation. This KPI reflects the progress made in transitioning from traditional paper-based documentation into digitalized documents verified on a blockchain-based system that will be used to manage transport orders. Given that the current digitalisation is absent, according to the baseline, once the platform functionality is be able to properly manage and visualise the transport orders, verifying their integrity through the blockchain-enabled functionality, the KPI will be satisfied. The theorical approach for the route satisfaction of this solver will be accomplished by satisfying:

$$\frac{\mathbf{TOD}_{objective} - \mathbf{TOD}_{baseline}}{\mathbf{TOD}_{baseline}} \geq \mathbf{0.20}$$

KPI Reduction of Operational Costs by >12%

To measure the "reduction of operational costs" KPI based on the provided information and its sub-KPIs, we can construct a formula that considers the improvement in each of the sub-KPIs and aggregates them into an overall metric. This KPI will cover this reduction of operational costs in the Madrid scenario. The different sub-KPIs that make up the reduction of operational costs are the following:

Table 3-6. Summary of the components for the satisfaction of the "Reduction of Operational Costs by >12%" KPI.

subKPI	Acronym	Baseline	Solutions Related	Metrics	Methodology
Current operational cost	OC	2.25€/ parcel	ES_04 ES_09 ES_12 ES_13	Measuring the operational cost AS-IS (courier) vs TO-BE (MDM) of the full process from DHL warehouse to end destination for an average parcel.	The following areas will be measured: distance travelled, congestion cost, etc. Through the solvers ES_04, ES_12, and ES_13, the cost associated with a given trip between the DHL warehouse and MDM lockers will be obtained. ES_09 will obtain the man-hour cost associated with the operations on MDM facilities.
Missed deliveries	MD	~ 10%	ES_08 ES_15 ES_17	Comparison of the average missed deliveries AS-IS (Warehouse + last mile courier) vs TO-BE (warehouse + MDM last mile distribution).	With ES_15, information will be transmitted through 5G. Parcels (units) will be assigned an individual code upon arrival at DHL warehouse depending on the final destination (MDM final station). Parcels will be grouped in rolling cages according to their code. For tracking missed deliveries the process will be: 1) scanning individual parcel codes before loading into the rolling cages; 2) tracking of rolling cages, with assigned parcel codes, from DHL warehouse to MDM Depot to MDM final destination; 3) final scanning of the individual parcels at MDM final station before placing it in the assigned lockers.
Number of vehicles required for last-mile delivery with average loading	VLM	~ 75 units/ van	ES_08 Digital Twin	Comparison of the AS-IS vs TO-BE: number of vehicles needed in circulation to deliver the same number of parcels (AS-IS) delivered by MDM in the TO-BE scenario.	Measurement of 1) the average number of parcels per rolling cage, 2) the number of rolling cages loaded per van, and 3) the number of vehicles in circulation carrying those roller cages to MDM depot (units/vehicle).

$$\textbf{Reduction of Operational Costs}_{\textbf{baseline}} = w_1 \times OC_{baseline} + w_2 \times MD_{baseline} + w_3 \times VLM_{baseline}$$

$$\textbf{Reduction of Operational Costs}_{\textbf{objective}} = w_1 \times OC_{current} + w_2 \times MD_{current} + w_3 \times VLM_{current}$$

This overall KPI would not have a specific unit but would represent a composite measure of the various sub-KPI metrics related to operational costs, the percentage of missing deliveries, and the number of vehicles required for last-mile delivery. A weighted average or composite score would reflect the performance across these dimensions. The route satisfaction of this solver will be accomplished by satisfying:

$$\frac{\textbf{Reduction of Operational Costs}_{\textbf{objective}} - \textbf{Reduction of Operational Costs}_{\textbf{baseline}}}{\textbf{Reduction of Operational Costs}_{\textbf{baseline}}} \geq \mathbf{0.12}$$

KPI Reduction of External Costs (environmental + social cost) by >80%

To measure the "reduction of external costs" KPI, the predictions related to GHG emissions associated with a given trip that offers the group of solvers ES_05, ES_12 and ES_13 at the Madrid scenario. This KPI will help to see how the shift from last-mile delivery to using the metro to transport parcels instead of the usual delivery vans/trucks, is a more sustainable alternative and able to affect factors such as reduced congestion. To achieve it, the following methodology will be followed:

Table 3-7. Summary of the components for the satisfaction of the "Reduction of External Costs (environmental + social cost) by >80%" KPI.

KPI	Acronym	Baseline	Solutions Related	Metrics	Methodology
Reduce GHG emissions	GHG	~ 0.88 Kgs/ stop (75 units/ van, 10 stops/ hour, 50 stops/ route)	ES_05 ES_12 ES_13	Comparison of the average GHG emissions with the AS-IS situation (courier stopping 6 times per hour with an average load of 75 units per van; using van/ truck alternative to last-mile delivery), with the TO-BE situation (MDM last-mile delivery to station lockers). Also, compare GHG emissions predicted for the AS-IS situation (DHL warehouse to locker, using just van/truck) with the TO-BE situation (MDM last mile delivery to station lockers).	The following areas will be measured supported with solvers ES_05, ES_12, and ES_13: GHG of MDM emissions, DHL van/truck from warehouse to MDM Depot emissions, the average load of parcels per roller cage and roller cages per van/truck. Compare the GHG emission emitted by both alternatives.

The GHG baseline will be based on the measurements provided by DHL of the GHG emissions generated on the last-mile delivery using vans. This KPI is aimed to support the benefits of shifting to a last-mile delivery model using the subway metros, achieving less GHG emissions than the common last-mile process using vans and trucks. Using the GHG emissions predictor that offers the route planning group of solvers, the estimated CO_2e emissions of a given trip will be obtained and later would be used for this KPI comparison. The group of solvers will also assist in generating potential baseline values for specific routes that can be covered using the two alternative modes in order to provide more accurate comparisons representing concrete and defined routes. The route satisfaction of this solver will be accomplished by satisfying:

$$\frac{\mathbf{GHG}_{\boldsymbol{objective}} - \mathbf{GHG}_{\boldsymbol{baseline}}}{\mathbf{GHG}_{\boldsymbol{baseline}}} \geq \mathbf{0.80}$$

KPI Reduction of transport times from DHL warehouse to final destination by >10%

To measure the "reduction of transport times from DHL warehouse to final destination" KPI based on the provided information and its sub-KPIs, we can construct a formula that considers the improvement in each sub-KPI and aggregates them into an overall metric. This KPI will cover this reduction of times related to the parcel's load/unload operations, the number of packages delivered or the average delivery times in the Madrid scenario. The different sub-KPIs that make up the reduction of transport times are the following:

Table 3-8. Summary of the components for the satisfaction of the "Reduction of transport times from DHL warehouse to final destination by >10%" KPI.

subKPI	Acronym	Baseline	Solutions Related	Metrics	Methodology
Average loading/ unloading time per parcel	LUT	~ 96 seconds/ parcel (considering 75 parcels/ van requires 2 hours to be loaded)	ES_08 ES_09 ES_12 ES_13 Digital Twin	Comparison of the AS-IS (last mile courier) vs TO-BE (MDM last mile).	The following areas will be measured: 1) time to complete the loading of a roller cage with the assigned parcels and 2) time to load vans/ trucks with the roller cages. Supported with solvers ES_12, and ES_13, information regarding time estimations will be available. That data might be adjusted according to the number of parcels, that could be estimated using the solver ES_08, as well as the staff required using the solver ES_09.
Average urban delivery times for the average number of units in 1 vehicle	UDT	5 hours circulation/ route for 75 units/van/ route	ES_12 ES_13 Digital Twin	Comparison of the time required in the AS-IS (courier with 10 stops per hour and 6 min per stop) with TO-BE (MDM last mile distribution) for a given number of parcels.	Comparison of the time required in the AS-IS (courier with 10 stops per hour and 6 min per stop) with TO-BE (MDM last mile distribution) for a given number of parcels.
Average number of stops per route carried out by 1 vehicle (van) to deliver an average of 75 parcels	S	~ 50 stops/ route	ES_12 ES_13 Digital Twin	Comparison of the number of stops, for a comparable number of parcels, for the AS-IS (last mile courier) scenario and the TO-BE scenario (MDM last mile).	Comparison of the number of stops, for a comparable number of parcels, for the AS-IS (last mile courier) scenario and the TO-BE scenario (MDM last mile) where no vehicle is circulating on the road.

Average delivery loading per van	DL	~ 75 units	ES_12 ES_13 ES_15 Digital Twin	Comparison of the AS-IS vs TO-BE: number of vehicles needed in circulation to deliver the same number of parcels (AS-IS) that in the TO-BE scenario are delivered by MDM.	Measurement of 1) the average number of parcels per rolling cage and 2) the number of rolling cages loaded per van/ truck.

$$\boldsymbol{Transport\ times\ DHL\ to\ final\ destination}_{\boldsymbol{baseline}} = w_1 \times LUT_{baseline} + w_2 \times UDT_{baseline} + w_3 \times S_{baseline} + w_4 \times DL_{baseline}$$

$$\boldsymbol{Transport\ times\ DHL\ to\ final\ destination}_{\boldsymbol{objective}} = w_1 \times LUT_{current} + w_2 \times UDT_{current} + w_3 \times S_{current} + w_4 \times DL_{current}$$

This overall KPI would not have a specific unit but would represent a composite measure of the various sub-KPI metrics related with the different times, average number of parcels and stops realised during last mile delivery. It would be a weighted average or composite score reflecting the performance across these different dimensions.The route satisfaction of this solver will be accomplished by satisfying:

$$\frac{\boldsymbol{Transport\ times\ DHL\ to\ final\ destination}_{\boldsymbol{objective}} - \boldsymbol{Transport\ times\ DHL\ to\ final\ destination}_{\boldsymbol{baseline}}}{\boldsymbol{Transport\ times\ DHL\ to\ final\ destinations}_{\boldsymbol{baseline}}} \geq \mathbf{0.10}$$

3.2.1.2 Route for the Functional Requirement Satisfaction

To showcase the route for the FR satisfaction, the following tables show how the FR of the Spanish UC connects to the current system capabilities, the possible solutions, applicable metrics, and the expected targets. This is a structured approach to check how the FR meet the project goals and objectives, considering the current system's limitations and relating them with the different solvers that will support the FR.

Table 3-9. ES_UC Data Format Unification FR.

Functional Requirement	Baseline	Solvers Related	Metrics	Target
Data Format Unification				
ES-FR1: Translation of different data formats (XML, EDI, JSON) to a common one	Up to now, there is no support for translating messages around the involved stakeholders	Not a specific solver supports this Functional requirement	This metric is not quantifiable	Up and running system which supports the translation of messages around the systems of the involved stakeholders

ES-FR2: Data anonymisation	Up to now, there is no support for the anonymisation of data around the involved stakeholders	Not a specific solver supports this Functional requirement	This metric is not quantifiable	Up and running system which supports the anonymisation of messages around the systems of the involved stakeholders

Table 3-10. ES_UC Accessibility Management Functional requirements.

Functional Requirement	Baseline	Solvers Related	Metrics	Target
Accessibility Management				
ES-FR3: Integrate different UI for different actors	Up to now, the integration has not been supported.	Not a specific solver supports this Functional requirement	This metric is not quantifiable	The demonstration of a local platform supporting the integration of different UI for different actors.
ES-FR4: Allow different levels of accessibility / authorisation	Up to now, there is no system supporting this functionality.	Not a specific solver supports this Functional requirement	This metric is not quantifiable	The demonstration of a local platform supporting a RBAC functionality.

Table 3-11. ES_UC Automation of Information Exchange Functional Requirements.

Functional Requirement	Baseline	Solvers Related	Metrics	Target
Automation of Information Exchange				
ES-FR5: Automated digitalisation of administrative tasks	Up to now, there is no system supporting this functionality.	ES_16: Digital proof of delivery at the final destination ES_17: Decentralised system for sharing data and documents between different stakeholders	This metric is not quantifiable	The demonstration of a local platform supporting the electronic document exchange.

ES-FR6: Real-time monitoring of container/ parcel locations and conditions	Up to now, there is no system supporting this functionality.	ES_04: Estimated transport cost to carry freight A-B ES_08: Number of parcels MDM can serve ES_09: Number of man-hours required at MDM Depot and MDM station on request ES_12: Optimal E2E route before journey ES_13: Optimal E2E route during journey ES_14: Tracking of location, status and conditions of container ES_15: Tracking of location, status and conditions of roller cage ES_17: Decentralised system for sharing data and documents between different stakeholders	Route planning optimising cost, time and emissions via ES_04, ES_12, ES_13. ES_08 will provide the capacity of parcel and roller cages at MDM stations. ES_09 will provide man-hours required to perform operations at MDM facilities. ES_14 and ES_15 will keep the tracking of containers and roller cages.	The demonstration of a local platform supporting the monitoring of the cargo, locations and conditions, routing planning and the MDM lockers booking.
ES-FR7: Real-time and visible flow of transport requests and acceptance	Up to now, there is no system supporting this functionality.	ES_16: Digital proof of delivery at the final destination ES_17: Decentralised system for sharing data and documents between different stakeholders	ES_16 and ES_17 ,both solvers, will facilitate delivery verification and transaction tracking as well as enable seamless communication and coordination between the different stakeholders.	The demonstration of a local platform supporting the electronic document exchange.

Table 3-12. ES_UC Planning and Management Resources Functional Requirements.

Functional Requirement	Baseline	Solvers Related	Metrics	Target
Planning and Management Resources				
ES-FR8: Real-time routing and loading planning	Up to now, there is no system supporting this functionality.	ES_01: ETA Berth vessel ES_02: ETA truck ES_03: Predict the total stay duration of the cargo at the Port of Valencia	ES_01 will improve ETA berth accuracy, enabling decision-makers at terminals and ports to make more informed choices, which will result in a more optimised resource management strategy.	The demonstration of a local platform supporting the routing and

		ES_06: Predict the capacity of train wagons ES_07: Predict the capacity of trucks ES_08: Number of parcels MDM can serve ES_09: Number of man-hours required at MDM Depot and MDM station on request ES_14: Tracking of location, status and conditions of container ES_15: Tracking of location, status and conditions of roller cage ES_04: Estimated transport cost to carry freight A-B ES_05: Estimated GHG emissions A-B ES_12: Optimal E2E route before journey ES_13: Optimal E2E route during journey	ES_02 will predict the arrival time of trucks, thus allowing for more optimal planning of loading resources. ES_03 will predict container dwelling time, providing resource planners with a better understanding of when containers will be retrieved and thus improving the allocation of human resources and machinery. ES_06 and ES_07 will reduce loading time in terminals and improve load planning. ES_08 will provide the capacity of parcel and roller cages at MDM stations, which will influence resource planning in the DHL warehouse as well as MDM. ES_09 will provide the man-hours required to perform operations at MDM facilities. ES_14 and ES_15 will keep tracking of containers and roller cages. ES_04, ES_05, ES_12 and ES_13 will provide planning for the type of transport to be used based on cost, time and emissions, which will influence the load planning. Information will be represented on TIC4.0 data model, from which further data can be extracted (origin, destination, container cargo weight, truck/van cargo, roller cage weight, number of roller cages, emission factor if available…)	loading planning.
ES-FR9: Proactive planning of port (trucks at the terminal, loading/unloading, ITU/container dwell time in port) and warehouse operations.	Up to now, there is no system supporting this functionality.	ES_01: ETA Berth vessel ES_02: ETA truck ES_03: Predict the total stay duration of the cargo at the Port of Valencia	ES_01 will improve ETA berth accuracy, enabling decision-makers at terminals and ports to make more informed choices, which will result in a more optimised resource management strategy. ES_02 will predict the arrival time of trucks, thus allowing	The demonstration of a local platform supporting the routing planning.

		ES_04: Estimated transport cost to carry freight A-B ES_05: Estimated GHG emissions A-B ES_06: Predict the capacity of train wagons ES_07: Predict the capacity of trucks ES_08: Number of parcels MDM can serve ES_12: Optimal E2E route before journey ES_14: Tracking of location, status and conditions of container ES_15: Tracking of location, status and conditions of roller cage	for more optimal planning of loading resources. ES_03 will predict container dwelling time, providing resource planners with a better understanding of when containers will be retrieved and thus improving the allocation of human resources and machinery. ES_06 and ES_07 will predict the capacity of trains and trucks, which will influence the load planning. ES_04, ES_05, ES_12 and ES_13 will provide planning for the type of transport to be used based on cost, time, and emissions, which will influence the load planning. Information will be represented on the TIC4.0 data model, from which further data can be extracted (origin, destination, container cargo weight, truck/van cargo, roller cage weight, number of roller cages, emission factor if available…). ES_08 will provide the capacity of parcel and roller cages at MDM stations, which will influence resource planning in the DHL warehouse as well as MDM. ES_14 and ES_15 will keep the tracking of containers and roller cages.	
ES-FR10: Resource allocation planning and adjustment	Up to now, there is no system supporting this functionality.	ES_01: ETA Berth vessel ES_02: ETA truck ES_03: Predict the total stay duration of the cargo at Port of Valencia	ES_01 will improve ETA berth accuracy, enabling decision-makers at terminals and ports to make more informed choices, which will result in a more optimised resource management strategy. ES_02 will predict the arrival time of trucks, thus allowing	The demonstration of a local platform supporting the routing planning.

		ES_04: Estimated transport cost to carry freight A-B	for more optimal planning of loading resources. ES_03 will predict container dwelling time, providing resource planners with a better understanding of when containers will be retrieved and thus improving the allocation of human resources and machinery. ES_06 and ES_07 will predict the capacity of trains and trucks, which will influence the load planning. ES_08 will provide the capacity of parcel and roller cages at MDM stations, which will influence resource planning in the DHL warehouse as well as MDM. ES_09 will provide the man-hours required to perform operations at MDM facilities. ES_14 and ES_15 will keep the tracking of containers and roller cages. ES_04, ES_05, ES_12 and ES_13 will provide planning for the type of transport to be used based on cost, time and emissions. Information will be represented on TIC4.0 data model, from which further data can be extracted (origin, destination, container cargo weight, truck/van cargo, roller cage weight, number of roller cages, emission factor if available…)	
		ES_05: Estimated GHG emissions A-B		
		ES_06: Predict the capacity of train wagons		
		ES_07: Predict the capacity of trucks		
		ES_08: Number of parcels MDM can serve		
		ES_09: Number of man-hours required at MDM Depot and MDM station on request		
		ES_12: Optimal E2E route before journey		
		ES_13: Optimal E2E route during journey		
		ES_14: Tracking of location, status and conditions of container		
		ES_15: Tracking of location, status and conditions of roller cage		

3.2.1.3 Trial tools and methods

For the development of the trial site of the two Spanish UC scenarios, HW and SW were used to cover the different technical needs required and prepare the solutions.

<u>HW components</u>

- **GPS tracking devices:** Two Teltonika FMP100 GPS tracking devices were chosen offering a comprehensive feature set that includes functionalities for advanced vehicle monitoring. These devices were installed within cooperating trucking company vehicles participating with CSLS, and will capture information related to the trip and the vehicle for different routes.

- **Phone devices:** Two phone devices with Galileo and 5G capabilities that will be used in the Madrid scenario to conduct tests and QR lectures.

<u>SW systems</u>

- **Solvers**: In order to respond to the needs of stakeholders within the Spanish use case from the port to the last mile, a series of solutions/solvers have been developed, which are grouped into thematic categories that refer to the needs they will solve. The features are associated with each specific solver, ranging from ML-based predictions to blockchain components. The main categories are highlighted as follows:
    - **ETA predictors**: the ETA predictors utilise AI/ML algorithms to forecast the arrival time of containers/materials at designated destinations. These predictors leverage real-time data exchange and monitoring capabilities to continuously update ETA predictions based on factors such as traffic conditions, weather, transportation mode, current situation of the port, etc. The Spanish UC will cover the maritime ETA of ships based on their berthing and the ETA associated with trucks.
    - **Resource Allocation Planning predictors:** these solvers optimise resource allocation within the logistics process. By analysing historical data and real-time inputs, they determine the most efficient allocation of vehicles, personnel and other resources to maximise operational efficiency.
    - **Route Prediction of transport time, cost and GHG emissions**: this group of solvers predicts the optimal routes for transportation considering factors such as time, cost, and GHG emissions. Using AI/ML algorithms, they analyse various route planning options and select the most efficient one based on predefined criteria, covering the different A-B trips or the whole E2E route.
    - **Container Stay Duration predictors**: it will estimate the duration of containers at the port of Valencia. By analysing historical data, it will provide a prediction aiming for better resource and operational planning.
    - **Localizers for container/freight tracking**: through IoT sensorisation, 5G connectivity and digital twin technology, it will be possible to track the real-time location and status of containers and freight. It will enable stakeholders to monitor the movement of goods throughout the supply chain.
    - **Digitalisation of processes and data sharing collaboration**: these solutions digitalise and automate administrative processes that are currently manual, streamlining operations and reducing processing times. It will also facilitate real-time data exchange and collaboration among currently disconnected stakeholders within the logistics ecosystem.

3.2.1.4 Data collection and analysis

The successful operation of the various solvers within the Spanish UC relies on data collection, processing and sharing. Each solver interacts with specific inputs and produces outputs that contribute to the different solutions of the FOR-FREIGHT platform. Solver outputs will be one of the tools with which data can be obtained and compared with these UC KPIs. Below is a summary of the inputs and outputs of the different solvers:

Table 3-13. Expected Inputs and Outputs of the Spanish UC.

Solver ID	Description	Input	Data format	Output	Data format	Description of output
ES_01	Predict the arrival time of the container ship at Port of Valencia (ETA Berth).	Port call identifier	Number (e.g., 3202301192)	ETA Berth Vessel identification fields	Datetime (e.g., 2024-03-28 09:12:49.356681) Vessel Identification fields: Integer, float, string	ETA Berth of the container ship arriving at the Port of Valencia
ES_02	Predict the arrival time of truck, departing from A to B (Port of Valencia to MDM Depot)	To be defined 3rd drop	To be defined 3rd drop	ETA trucks/ van	To be defined 3rd drop	ETA of trucks/ vans
ES_03	Predict the total stay duration of the cargo at Port of Valencia, from the moment of vessel arrival until its departure from this port (from the discharge of the container (COARRI) and terminal gate's exit (CODECO).	Port call identifier of the vessel transporting the cargo or (if possible) the ID of the cargo	Number integer (e.g., 3202301192)	Estimated time container stayed at the port	float number (e.g. 1,5 hours)	Number of hours that the cargo will stay at the port
ES_04	Predict the transport cost to carry a freight from A to B (Port-DHL Warehouse, Port-Transloading point; Transloading point-Warehouse; DHL warehouse-MDM depot; MDM depot-MDM station).	TIC4.0 data model	JSON	TIC4.0 data model (updated with cost prediction)	JSON	How much money is anticipated to cost the route from A-B, updating the cost values on the TIC4.0 data model
ES_05	Predict the CO2 footprint to carry a freight from A to B (Port-DHL Warehouse, Port-Transloading point; Transloading point-Warehouse; DHL warehouse-MDM depot; MDM depot-MDM station).	TIC4.0 data model	JSON	TIC4.0 data model (updated with CO2 prediction)	JSON	How much GHG emissions are anticipated for the route to emit from A-B, updating the CO2 emissions values on TIC4.0 data model
ES_06	Predict the capacity of train wagons in the near future horizon.	To be defined 3rd drop	To be defined 3rd drop	Active/ available train wagons	To be defined 3rd drop	To be defined 3rd drop

ES_07	Predict the capacity of trucks in the near future horizon.	To be defined 3rd drop	To be defined 3rd drop	Trucks required on request	To be defined 3rd drop	To be defined 3rd drop
ES_08	Predict the capacity of MDM (each station considered) in the near future horizon	Number of parcels coming to a depot in a day, within 7 days	JSON Real number	Prediction of number of parcels coming in a day	JSON Real number	Prediction of the number of parcels coming in a day
ES_09	Predict the demand for MDM metro transport in near future horizon: Number of man-hours required.	1) Number of parcels coming to each station in a day, within 7 days. 2) Number of man-hours for a specific stage.	JSON 1) Real numbers 2) Real number	Number of man-hours	JSON Real number	Number of man-hours
ES_12	Recommend (**before journey**) the E2E route planning which optimises time, cost and emission factors. Be able to also present the individual recommendation of choosing individually time, cost or emissions factors to minimise.	TIC4.0 data model	JSON	TIC4.0 data model (updated with time, costs and CO2 prediction)	JSON	Optimal route recommendation based on time, cost and emissions factors.
ES_13	Recommend (**during journey**) the E2E route planning which optimises time, cost and emission factors. Be able to also present the individual recommendation of choosing individually time, cost or emissions factors to minimise.	TIC4.0 data model	JSON	TIC4.0 data model (updated with time, costs and GHG prediction)	JSON	Optimal route recommendation based on time, cost and emissions factors.
ES_14	Real-time tracking (update coordinates) of container	Container ID	JSON	Location (longitude, latitude)	JSON	Location (long, lat)
ES_15	Tracking (update coordinates) of roller cages	Roller Cage ID	JSON	Location (longitude, latitude)	JSON	Location (long, lat)

ES_16	Digital proof of delivery at the final destination	There are no inputs and outputs of these solvers, just the “check” of working adequately.	-	Digital proof of delivery at the final destination	-	ES_16 is the blockchain component of the platform.
ES_17	A decentralised system for sharing data and documents between different stakeholders.	Solvers ES_16 and ES_17 are functionalities/services embedded inside platform developed by FV.	-	A decentralised system for sharing data and documents between different stakeholders.	-	ES_17 is the connection established between the different users that take place inside this platform.

3.2.1.5 Trial execution phases and timeline

The Spanish UC covers the two different scenarios from the Port of Valencia to the last mile in the Madrid Metro, where different solutions will be applied through which the end-users (in this case, CSLS, DHL and MDM) will be able to support decision-making, having more accurate information for resource and route planning of their respective transports and communicate with each other eliminating the existing information silos and improving the interoperability in the T&L chain.
The trial execution for the Spanish Trial Site will be conducted in several phases, encompassing solvers development, local integration, pilot testing and scenario-specific trials at the Port of Valencia and Metro de Madrid that will serve as data-collection and validation of the solutions.
Although the actual connection between the two scenarios does not currently take place, due to current business and operational arrangements, the existing connections between CSLS and DHL warehouses will be simulated based on historical data. The validation phase will be related to these simulations that "connect" both scenarios, being able to provide solvers in situations where this connection is simulated and can be applied in or for future reference when the connection re-established operationally, for example, E2E planning to represent the whole transport from the port of Valencia to the last-mile locker.

<u>Scenario 1: Valencia</u>

The execution of the trial site in Scenario 1, focusing on the activities at Valencia Port and the hinterland, involves different phases aimed at testing and validating the effectiveness of the solutions through demonstrations and data collection via IoT devices.

Solver validation phase:

The successful operation of the various solvers within the Spanish trial site relies heavily on the validation of their functions by the end-users, ensuring that it answers their needs. Each group of solvers interacts with specific inputs and produces outputs that contribute to the overall optimisation and efficiency of the logistics process or offer some concrete functionalities aimed to solve the different necessities of the T&L stakeholders.

In this initial phase, the focus is on demonstrating the functionality and capabilities of the solvers developed for the Valencia Port scenario. This involves showcasing the algorithms, blockchain technology, IoT devices and digital twin applications. The solvers to be demonstrated include ETA predictors, resource allocation planners, route prediction models, container stay duration predictors or localizers for tracking freight. The time plan of this phase is related to the three drops of solutions of FOR-FREIGHT, being able to demonstrate after each drop the solutions associated with it, with a functional version of all solutions planned to be available for the last drop of solutions, with an expected date of November/December 2024. The following solutions are going to be part of this phase:

- **ETA predictors**: The ETA predictors will use AI/ML algorithms to forecast the arrival time of vessels and trucks at Valencia port. Integrating the ETA berth of the vessels on the trial site, it will enable stakeholders to make informed decisions regarding planning and resource allocation of inland transport (truck or train + truck) and have available the scheduling of the different vessels that arrive at the port of Valencia facilities; then it will be followed by the ETA of trucks, boosting an optimal planification of resources. It will be covered through solvers ES_01 and ES_02.
- **Resource Allocation Planning predictors**: These predictors optimise resource allocation within the port environment by analysing demand forecasts, availability of vehicles and operational constraints. It will be covered by ES_06, ES_07 and the support of the DT.
- **Route planning predictors optimising time, cost and emissions**: This group of solutions will offer route planning aiming to optimise time, cost and emissions of the inland transport leg from the port of Valencia to the warehouses, via truck or a combination of truck and train. Through these predictors, stakeholders will be able to improve their decision-making processes and adapt their route planification to minimise delays, reduce environmental impact and reduce the costs associated with each trip. The solvers ES_04, ES_05, ES_12 and ES_13 will cover this category.
- **Container stay duration prediction**: This solution will estimate the duration of containers staying inside the port of Valencia facilities since the container is discharged from the vessel and exited from the port via truck or train. It will support resource allocation and improve turnaround times and productivity. Solver ES_03 will cover this trial site demonstration.
- **Digitalisation and automation of processes**: The Digital Proof of Delivery will enable the demonstration of this category, via the functionality of solver ES_16.

Physical trial phase:

The physical trial phase for the Valencia scenario will be focused on the IoT devices deployed on trucks to gather information about routes and container movements. This phase will be closely related to the initial phase, integrating the real-world data collected from this physical trial into the solvers and powering the DT. Below is the development time plan for this phase:

Table 3-14. Summary of the physical trial phases of Scenario 1 ES UC

Activities	Description	Methodology	Expected date
Deployment of IoT devices on trucks	Install IoT devices on trucks to track route data and monitor container movements during transportation from Valencia Port to different destinations.	Initially, two IoT devices (Teltonika FMP100 GPS) were installed on trucks to capture real-time data on route trajectories associated with CSLS trip, speed and stops. These sensors will also monitor the status and condition of the truck/freight during transit.	April 2024

Testing of IoT devices	Validate the deployment of the IoT devices and check that information is received.	Activation of IoT devices on some CSLS truck routes. CERTH confirmed signal and data reception from IoT devices.	April 2024
Tracking of route data for CSLS	Initial tracking of route data for CSLS-associated trips by a truck transporter for approximately one month.	The truck transporter will operate within Valencia Port, transporting containers along predefined routes. Route data, including the duration of stops and movements, will be tracked and recorded using IoT devices installed on trucks.	May 2024
Data gathering and feedback	Gather data from IoT devices and provide feedback to digital twins and other solvers for analysis and optimisation.	Data collected over the routes associated with CSLS freight will then be fed into digital twins and other solvers to refine solutions, optimise route planning and enhance resource allocation.	Second half of 2024
Extension of measurements	Evaluate the need to extend the physical routes based on initial trial results and feedback.	Following the initial trial period, the effectiveness of the tracked routes will be assessed. If necessary, routes may be extended or traced to gather additional data.	Second half of 2024

The physical trial phase provides a chance to validate the effectiveness of the solvers and DT in a real-world scenario. By deploying IoT devices on trucks and gathering route data, stakeholders can assess the accuracy and reliability of the solutions, using real transport cases to validate them. The feedback loop established between data gathering, analysis and optimisation ensures continuous improvement and refinement of the solvers.

<u>Scenario 2: Madrid</u>

Scenario 2 focuses on the transportation and distribution operations within Madrid from a DHL warehouse to distributing packages using the Metro de Madrid subway system on lockers situated at the stations. The trial site execution will involve different phases aimed at testing and validating the effectiveness of various solvers in optimising last-mile distribution, route planning and resource allocation and also to demonstrate via physical real-life tests to validate solutions and get data. The different phases are as follows:

<u>Solver validation and simulation phase:</u>

This phase focuses on modelling the transportation network within the Metro de Madrid system and testing the solvers. The primary objectives of this phase include:

- Modelling transportation routes within the Metro de Madrid network using digital twin technology. This will be performed due to extensive simulations prepared by DHL and MDM to represent the operational processes and activities that would take place from the warehouse to the locker;
- Testing the effectiveness of solvers such as ETA predictors, demand estimation model and resource allocation planners in optimising last-mile distribution;
- Identification of potential bottlenecks and optimisation opportunities within the transportation network. Through the simulation of a real-life environment, it will be possible to replicate this new business model and to see the different agents, actions, and operations that will appear in different simulated scenarios.

During this phase, stakeholders will test how solvers work and interact and validate the different solutions they provide within scenario 2.

The following solutions are going to be part of this phase:

- **ETA Predictors**: Demonstrate the ability to accurately forecast delivery times within the Madrid scenario, optimising last-mile distribution delivery times. The solver ES_02 will cover this solution, offering the ETA of the different vehicles (vans/body trucks) going from the DHL warehouses up to the different depots.
- **Route planning based on transport Time, Cost, and GHG Emissions**: Showcase the optimisation of transportation routes focusing on the routes from DHL warehouse to the depots, and its posterior transport to the final lockers, considering factors such as time, cost, and environmental impact as well as transportation options of truck or van. Solvers ES_04, ES_05, ES_09, ES_12 and ES_13
- **Resource Allocation Planning Predictors**: Optimise resource allocation for last-mile distribution operations, ensuring efficient utilisation of vehicles and personnel within the Metro de Madrid network. Solvers ES_08 and ES_09 will support this, offering demand prediction beforehand on the different MDM stations and man-hours required to perform operations at Metro de Madrid facilities Digital Twin processes will back up the simulations of potential scenarios.
- **Digitalisation and Automation of Processes & Data Sharing**: Automate administrative processes related to last-mile distribution, reducing paperwork and manual errors. Facilitate real-time data exchange and collaboration among stakeholders within the Metro de Madrid network, enhancing transparency and decision-making. Through the functionalities offered by solver ES_16 and ES_17, DHL and MDM will have a common point for sharing documents and follow the request acceptance/rejection of the parcel delivery process. Solver ES_15 will also support the processes of keeping the track of the information of the different packages.

Physical trial phase:

Following the simulation and testing phase, the physical trial phase involves replicating of real-world distribution operations within the Metro de Madrid network. The primary objectives of this phase include:

- Deployment of DHL vans/trucks loaded with parcels for last-mile distribution within Madrid.
- Loading parcels onto subway trains for transportation within the Metro de Madrid network.
- Testing the effectiveness of solvers in real-world distribution operations, including ETA predictors, route prediction models, and resource allocation planners.
- Integration of information from simulation results into real-time decision-making processes.

This physical phase will be closely related to the Spanish UC solutions, making use of those solvers that can be applied during this trial phase preparation and provide relevant features to prepare a realistic scenario 2 (given that such operations do not occur today between DHL and MDM). Parameters such as the expected demand, the different operation times or which routes, lines and stations will be used in the trial site can be extracted from solutions such as ES_08, ES_12 or the Digital Twin simulations.

An initial time plan has been prepared, based on which the scenario is expected to represent the joint scenario with DHL and MDM.

Table 3-15. Summary of the physical trial phases of Scenario 2 ES UC

Activities	Description	Methodology	Expected date
Preparation and Setup	Finalise logistics plans and coordinate with all stakeholders.	Clarify DHL and MDM procedures and requirements for securing infrastructure and dates for the physical trial site. Define the parameters necessary for the execution of the trial site (trucks/van to be used, roller cages to be rented, packages to be	June-September 2024

		delivered, depot/metro line, stations with lockers...).	
Preparation and distribution of DHL Vans/ Trucks	Loading DHL vans/trucks with parcels and roller cages destined for MDM depot.	Load into roller cages different packages with the same depot destination. Arrange the route from the DHL warehouse to the selected depot.	Nov-Dec 2024
Depot operations and loading onto subway train	Coordinating the loading of parcels from DHL trucks onto subway trains at the depot.	Unload the roller cages from the DHL van/truck at the selected depot and load them onto the subway train. Coordinate personnel requirements and selected station lockers.	Nov-Dec 2024
Delivery to Metro de Madrid Lockers	Coordinate final delivery of parcels to designated lockers within the Metro de Madrid network.	Unload the roller cages from the metro at the designated stations. Perform the necessary operations with the packages and put them inside the lockers.	Nov-Dec 2024
Data gathering and feedback	Gather data from the real and provide feedback to digital twin and other solvers for analysis and optimisation.	Data collected over the physical trial will be fed into digital twins and other solvers to refine solutions, optimise route planning and enhance resource allocation.	1Q 2025
Extension of measurements	Evaluate the need to perform more operations on initial trial results and feedback.	Following the initial trial, the effectiveness of the physical demonstration will be assessed. If necessary, extra demonstrations may be extended or traced to gather additional data.	1Q 2025

By closely monitoring and analysing scenario 2 trial site processes, stakeholders can assess the effectiveness of the solvers in optimising last-mile distribution, reducing delivery times and improving overall operational efficiency. This phase ensures that the developed solutions are robust, scalable and capable of meeting the expected needs of the end-users. This trial site will also serve as a representation of how this business model using the subway to last-mile delivery could work in a real-life scenario.

3.2.2 Greek UC

3.2.2.1 Route for the KPI satisfaction

The pathway to achieving KPI satisfaction involves a comprehensive examination of specific metrics within the GR_UC, their interconnections with participating solvers, the resultant solver output, and the methodologies utilized for solver completion. This route delineates a set of representations detailing the intricacies of KPIs, ensuring a thorough understanding of their performance and the factors influencing their satisfaction.

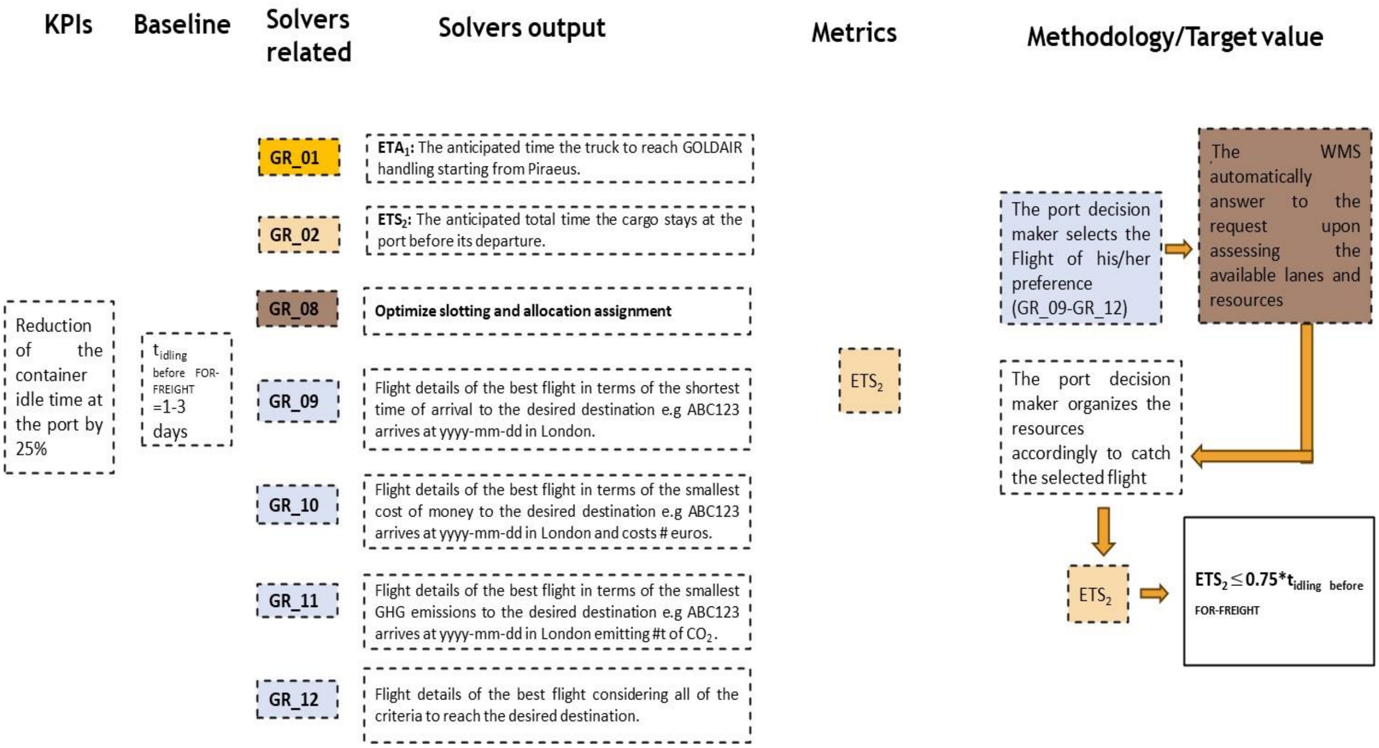


Figure 3-7. The methodology for the reduction of the container idle time at port KPI.

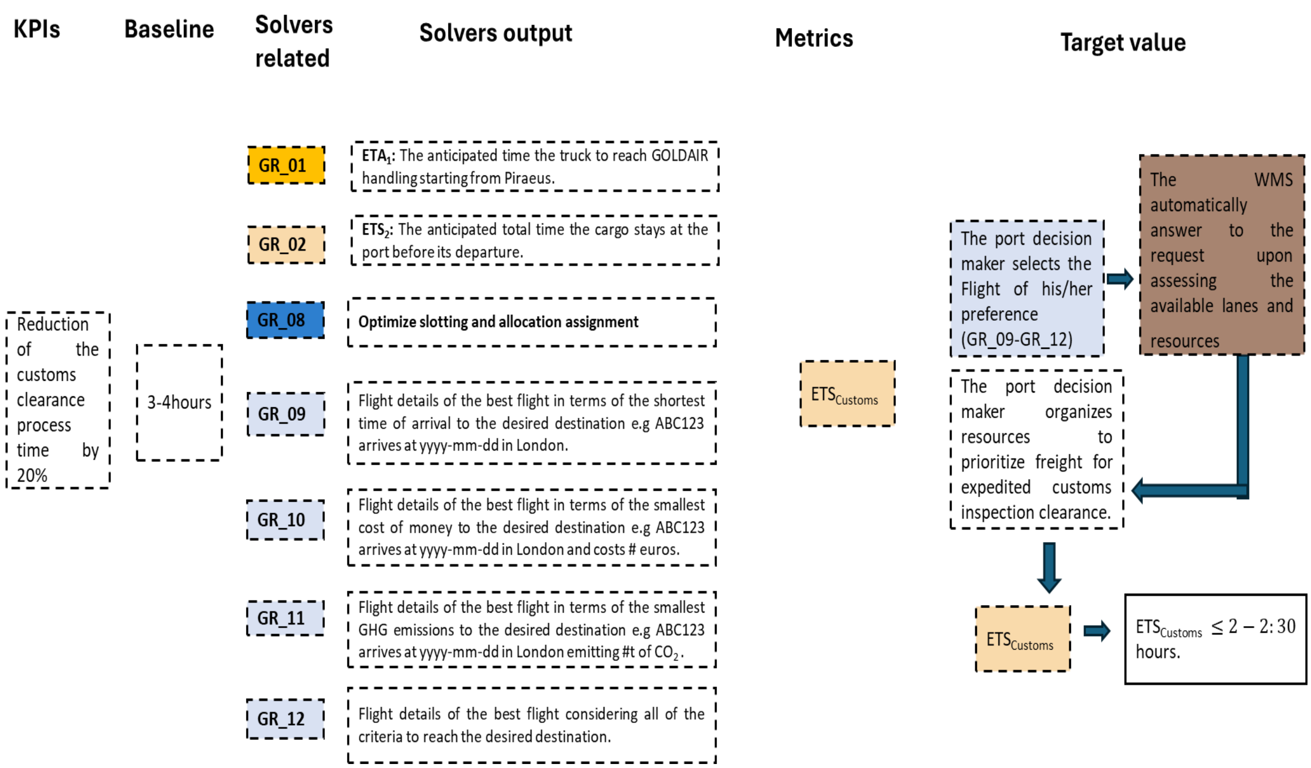


Figure 3-8. The methodology for the reduction of the customs clearance process.

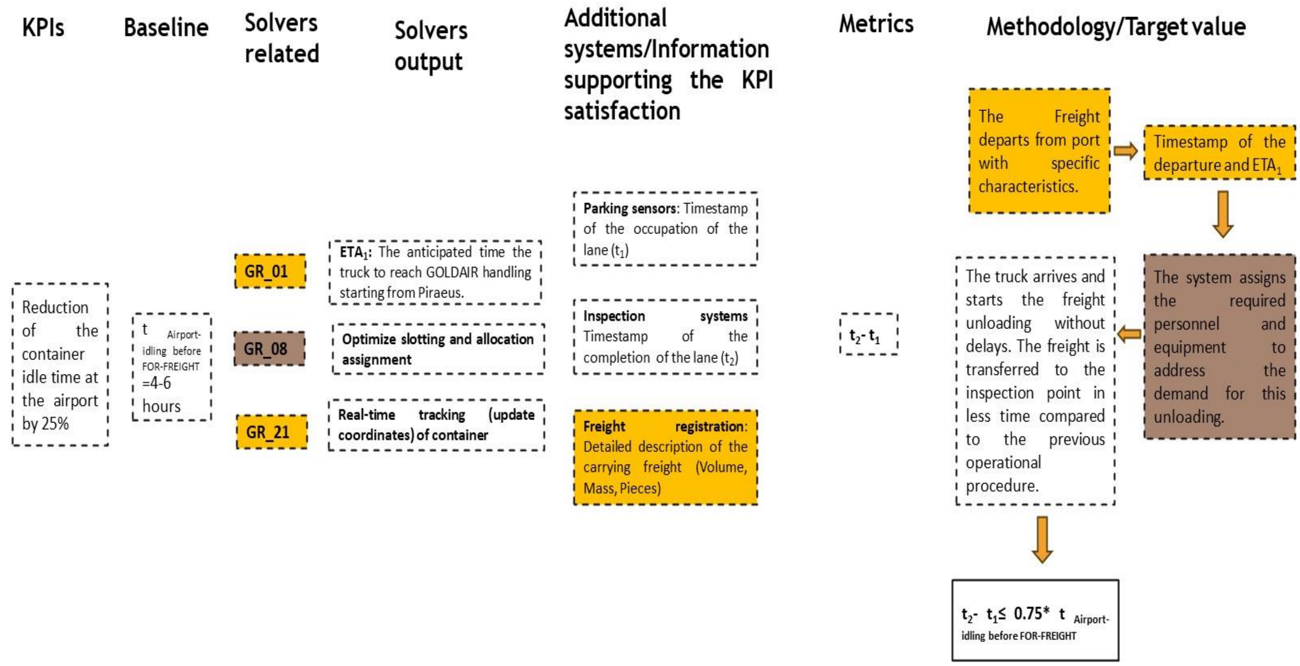


Figure 3-9. The methodology for the reduction of the container idle time at the airport.

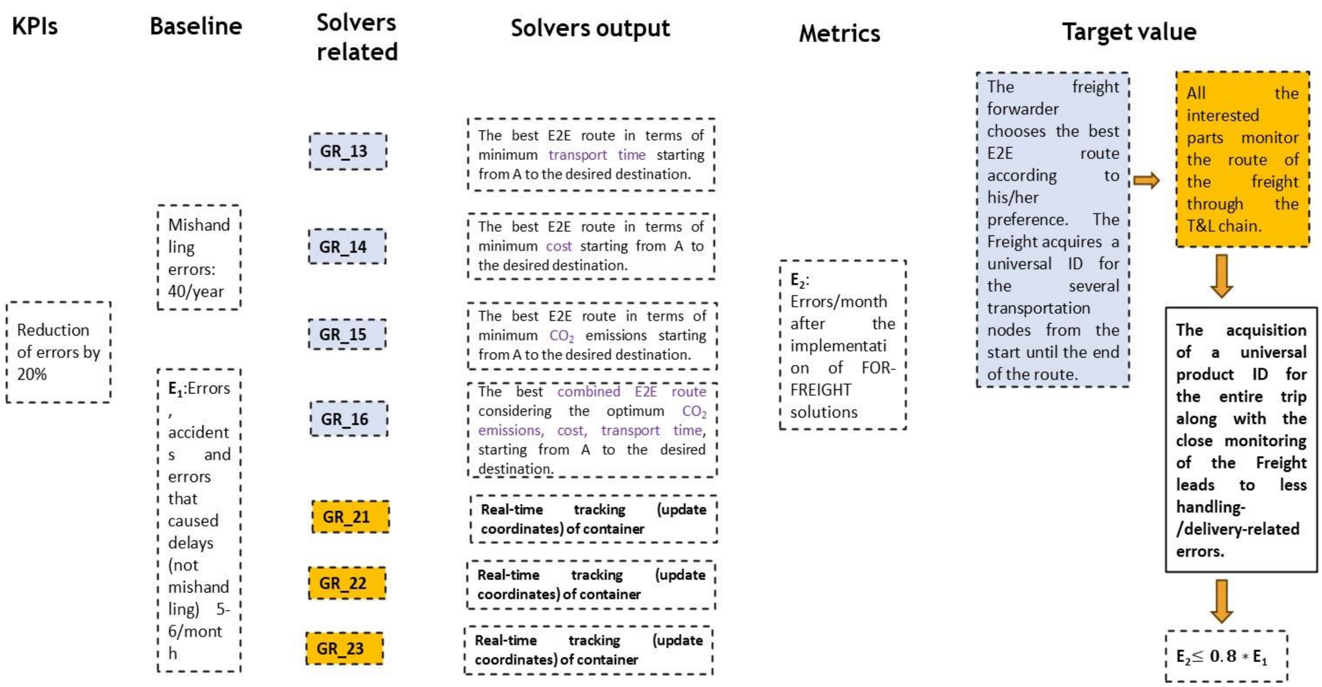


Figure 3-10. The methodology for the reduction of errors.

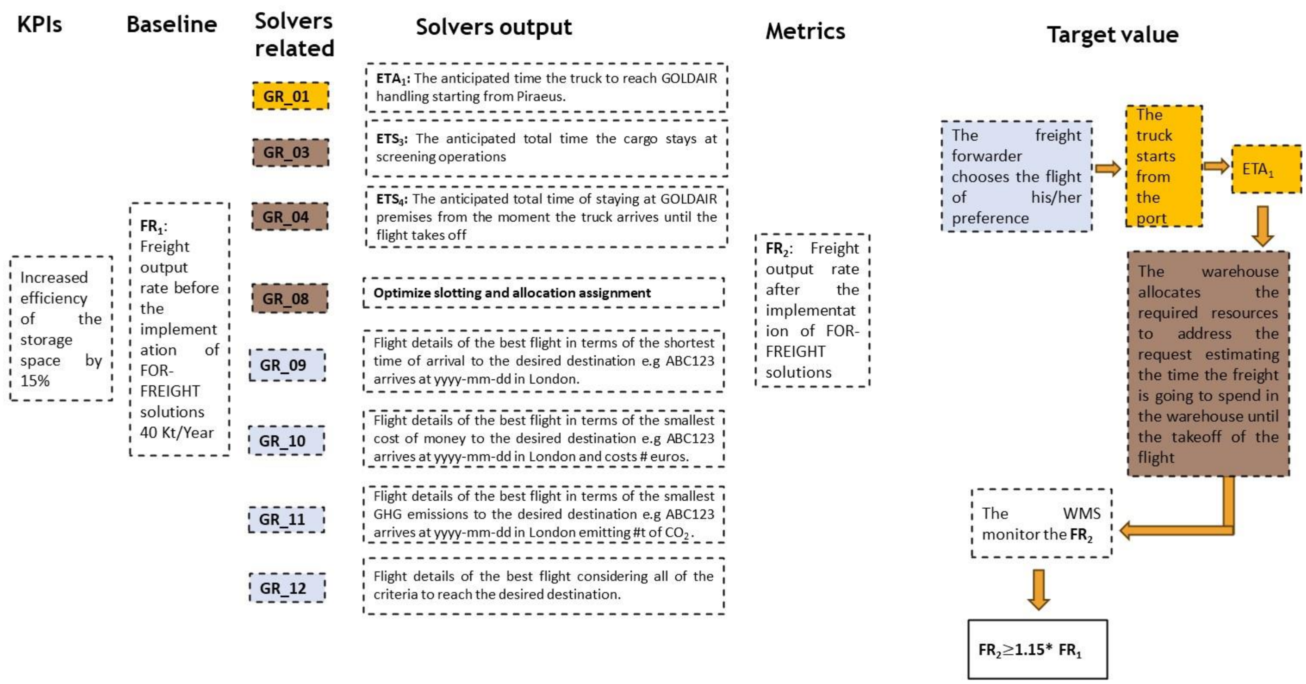


Figure 3-11. The methodology for the increased efficiency of storage space.

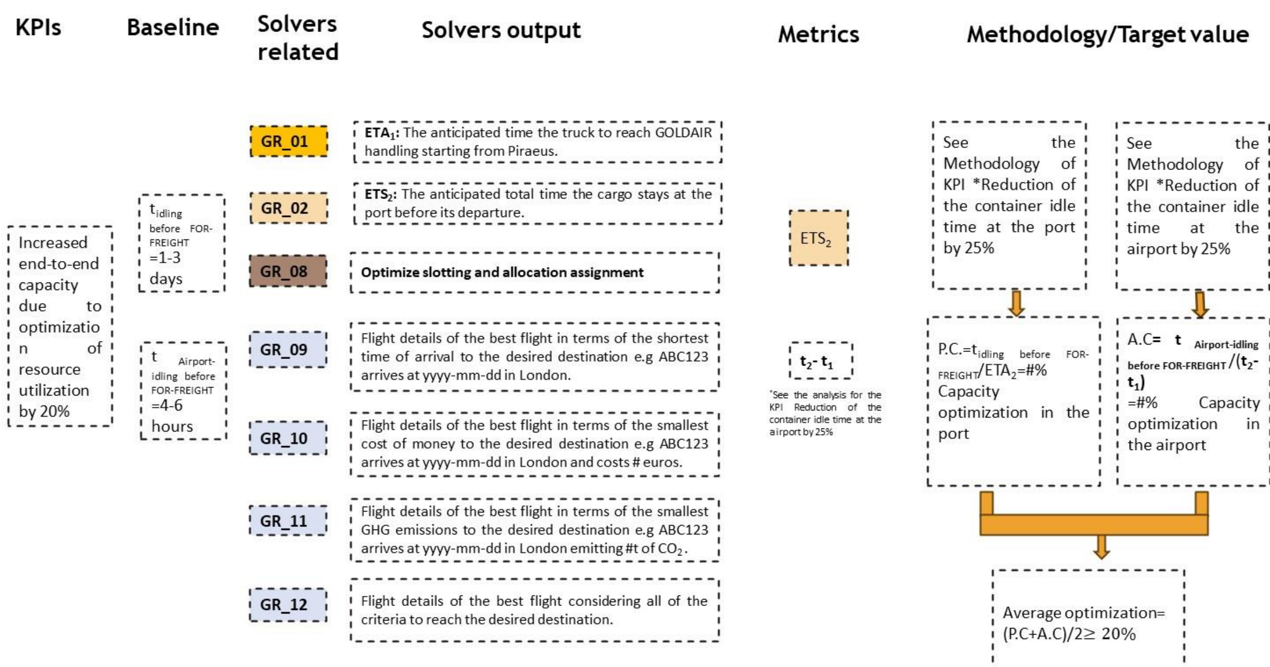


Figure 3-12. The methodology for the increased E2E capacity due to optimisation of resource utilisation.

3.2.2.2 Route for the Functional Requirements Satisfaction

Figures illustrate the connections of the FR of the GR_UC with the current status described by the baseline, the relevant solvers, any applicable metrics, and the anticipated targets. This is a structured framework for assessing the efficacy of FRs, ensuring their alignment with project goals and objectives while acknowledging the current state described by the baseline.

	Functional requirements	Baseline	Solvers related	Metrics	Target
Data format unification	**GR-FR1**: Translation from/ to SQL, .NET, EDI from/to XML, Crgo iQ, EDI (COSCO ERP-GoldFreight software).	Up to now, there is no support for the translation of messages around the involved stakeholders	Not a specific Solver supports this Functional requirement	This requirement is not quantifiable.	Up and running system which supports the translation of messages around the systems of the involved stakeholders
	GR-FR2: Real-time and non-real time data integration.	Up to now, there is no support for the translation of messages around the involved stakeholders	Solvers: GR_01-GR_23	This requirement is not quantifiable.	Up and running system which supports the translation of messages around the systems of the involved stakeholders

Figure 3-13. The connections of GR-FR1 and GR-FR2 with their baseline, the relevant solvers, any applicable metrics, and anticipated targets.

	Functional requirements	Baseline	Solvers related	Metrics	Target
Accessibility management	**GR-FR3**: Integrate different UI for different actors.	Up to now, the integration is not supported.	Not a specific Solver supports this Functional requirement	This requirement is not quantifiable.	The demonstration of a local platform supporting the integration of different UI for different actors. This is going to be implemented by WINGS Charriot platform at a local level.
	GR-FR4: Allow different levels of accessibility/authorization.	Up to now, there is no system supporting this functionality.	Solvers: GR_01-GR_23	This requirement is not quantifiable.	The demonstration of a local platform supporting a RBAC functionality. This is going to be implemented by WINGS Charriot platform at a local level.

Figure 3-14.The connections of GR-FR3 and GR-FR4 with their baseline, the relevant solvers, any applicable metrics, and anticipated targets.

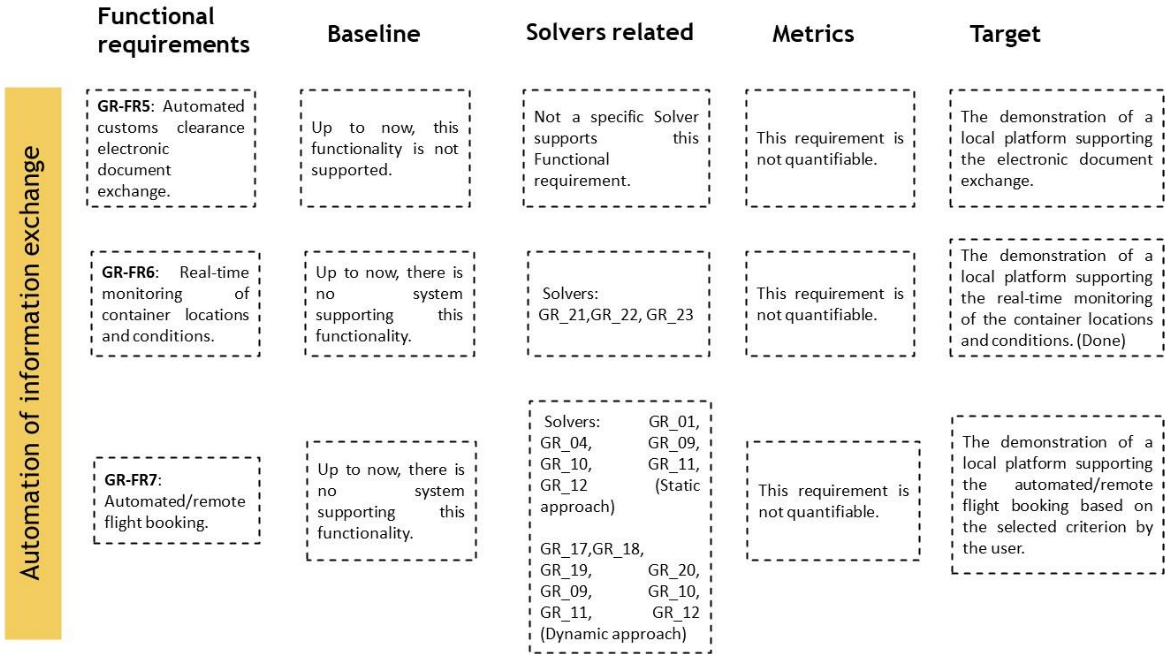


Figure 3-15. The connections of GR-FR5, GR-FR6, an GR-FR7 with their baseline, the relevant solvers, applicable metrics, and anticipated targets.

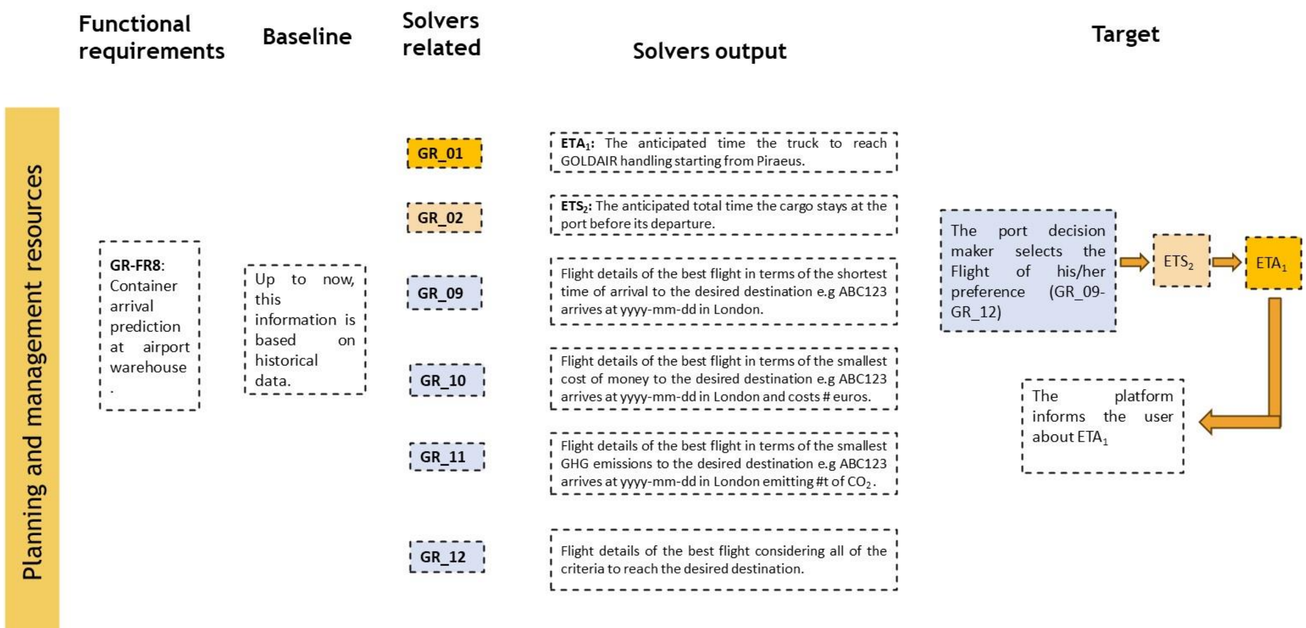


Figure 3-16. The connections of GR-FR8 with the baseline, the relevant solvers, any applicable metrics, and anticipated targets.

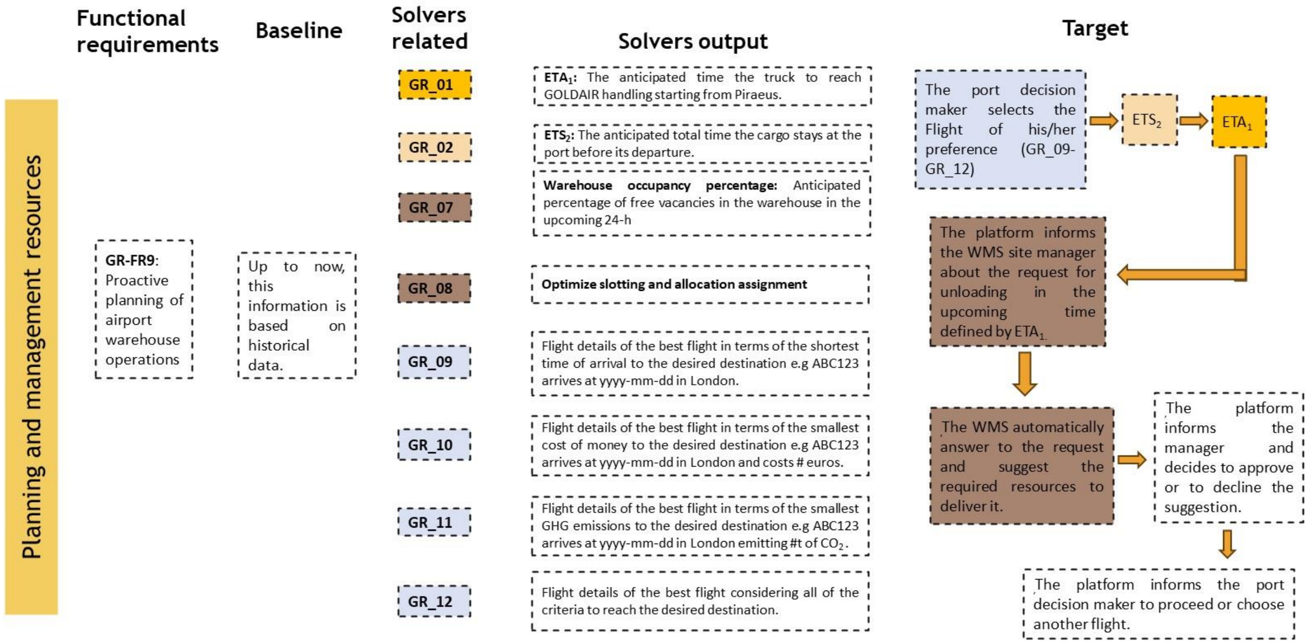


Figure 3-17. The connections of GR-FR9 with the baseline, the relevant solvers, any applicable metrics, and anticipated targets.

3.2.2.3 *Trial tools and methods*

The focus of this section is to present the tools and methods used in the trial used for testing and validating the effectiveness of the proposed solutions for the GR_UC.

HW components

- **OBUs:** The devices were installed on trucks departing from the port to the airport. Real-time data can be captured on vehicle movements, routes taken, and plenty of parameters can be provided based on the installed sensors.
- **Parking Sensors:** Advanced parking sensors were positioned in GOLD's warehouse on loading and unloading lanes. These sensors detected parking events, providing insights into warehouse operations and resource utilisation.

SW systems

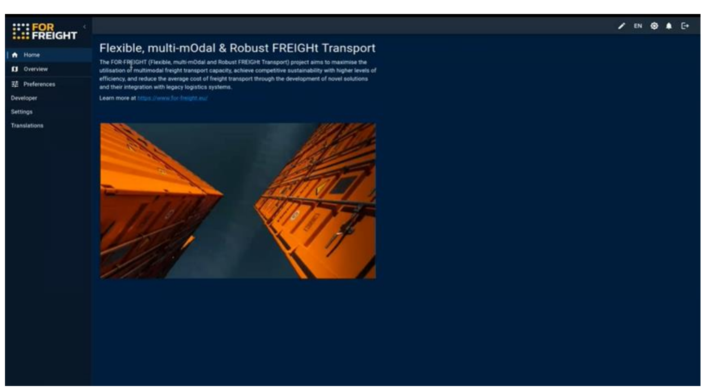


Figure 3-18. Illustration of the main page of the integration/data collection platform for the GR_UC.

- **Data Collection and Integration Local Platforms:** SW systems and a local platform were employed for data collection, analysis, and integration of legacy systems. The platform facilitated the aggregation and processing of data from OBUs, parking sensors, and existing infrastructure. In addition, the suite of solvers was incorporated in the local platform.

- **Solvers**: A suite of solvers has been developed to optimise the T&L operations between the Port and the airport.

  1) Localizer for Freight Tracking: A solution designed to track the movement of freight in real-time, providing visibility into the location and status of shipments within the transportation network.

  2) Real-time Routing Recommenders: Algorithms developed to recommend optimal routes for trucks based on real-time traffic conditions, road closures, and other factors affecting transportation efficiency.

  3) ETA Predictors: Predictive models implemented to estimate accurate ETA for trucks and shipments, enabling better coordination and planning of logistics activities.

  4) Aircraft Automated Booking/Next Aircraft Recommender: Software tools to automate the booking process for aircraft cargo space and recommend the next available aircraft based on cargo volume, destination, and scheduling constraints.

  5) Resource Capacity Predictors: Algorithms to predict resource capacity utilisation in warehouses and transportation fleets, optimising resource allocation and scheduling to minimize bottlenecks and Maximise throughput.

  6) Per-sub-route Transport Time, Cost, and Emission Predictors: Models developed to estimate transportation time, cost, and emissions for each sub-route within the logistics network, facilitating informed decision-making and route optimisation.

  7) Warehouse Planning Optimiser: This software solution optimises warehouse layout, inventory management, and order fulfilment processes to improve efficiency and reduce handling time.

  8) Cargo's Dwelling Time/Duration Stay Predictors: Predictive analytics tools to forecast the duration of cargo dwelling time at various stages of the logistics chain, aiding in resource planning and scheduling.

3.2.2.4 Data collection and analysis

In this section, the focus shifts to the process of **gathering and analysing data** crucial for the solvers performance stemming from both the **legacy systems and the HW components** which have been deployed around the T&L line. In these tables, the basic outcomes of the analysis can be obtained for each solver accompanied by its description.

Table 3-16. Summary of the solvers of the GR_UC with the description the actual input/output with the associated data formats.

Solver ID	Description	Input	Data format	Output	Data format	Description of output
GR_01	Predict the arrival time of truck, departing from Port of Piraeus PCT/DC warehouse to GOLD warehouse	1.Information from the OBU 2. Historical data of the route	CSV, XML, SQL, .NET and EDI, JSON	ETA1	JSON	How much time is anticipated the truck to reach GOLD starting from Piraeus

GR_02	Predict the total Temporary Stay duration of the cargo at Port of Piraeus PCT, from the moment of vessel arrival until its transfer to the GOLD warehouse This includes dwelling time and service time (tugboat, pilot, unloading, custom clearance, in-port warehouse storage, etc.)	1.flight options. Estimate 2. time for the warehouse operations. (WMS)	CSV,XML	ETS1	JSON	Given the information from the airport, Predict the total Temporary Stay duration of the cargo at Port of Piraeus PCT, from the moment of vessel arrival until its transfer to the GOLD warehouse This includes dwelling time and service time (tugboat, pilot, unloading, custom clearance, in-port warehouse storage, etc.)
GR_03	Predict the duration of the screening stage of the cargo at GOLD Warehouse, before it is transferred for storage	historical data and available resources to deliver the request. (WMS)	CSV,XML	ETS2	JSON	How much time is anticipated the cargo to spend in Warehouse screening operations.
GR_04	Predict the total stay duration of the freight/parcel at GOLD Warehouse, from the moment of truck arrival until freight/parcel's departure from this depot. This includes dwelling time and service time (unloading from truck, loading in aircraft, etc.).	historical data and available resources to deliver the request. (WMS)	CSV,XML	ETS3	JSON	How much time is anticipated to spend in All-around Warehouse operations until the taking off of the flight.

GR_05	Predict the transport cost to carry a freight from A to B (For instance: Port Warehouse Airport Warehouse, etc.)	Selected route. Historical data	JSON, CSV	Value in euros for the selected route.	JSON	How much money is anticipated to cost the route from A-B
GR_06	Predict the CO2 footprint to carry a freight from A to B (For instance: Port Warehouse - Airport Warehouse, etc.)	Selected route. Historical data	JSON,CSV	CO2 value in Kg	JSON	How much CO2 is anticipated the route to emit from A-B

GR_07	Predict the capacity of GOLD in near future horizon (e.g., for every hour within 24 hours ahead)	Information about the real-time occupancy status. The real-time rate of freight input and output . (WMS)	XML	Percentage of occupancy	JSON	What percentage of free vacancies is anticipated in the warehouse
GR_08	Optimise slotting and allocation assignment	Information about the booking status of the lanes and the available resources	XML	1. Suggested time slot to the truck company 2. Suggested resources to be planned by the Warehouse site manager to address the upcoming needs of unloading	JSON	

GR_09	Recommend the next aircraft to put a cargo which departs from GOLD warehouse, in order to minimize the time of transport	flight details for the available destinations (WMS)	XML, CSV	Flight details of the best flight e.g ABC123 arrives at yyyy-mm-dd	JSON	Which is the flight that satisfies the criterion of minimum transport time of the cargo to the desired destination
GR_10	Recommend the next aircraft to put a cargo which departs from GOLD warehouse, in order to minimize the cost of transport	flight details for the available destinations (WMS)	XML, CSV	Flight details of the best flight e.g ABC123 arrives at yyyy-mm-dd and costs # euros	JSON	Which is the flight with minimal shipment cost.

GR_11	Recommend the next aircraft to put a cargo which departs from GOLD, in order to minimize the CO2 footprint	flight details for the available destinations (WMS)	XML, CSV	Flight details of the best flight e.g ABC123 arrives at yyyy-mm-dd with GHG emission of #t of CO2	JSON	Which is the flight with minimum CO2 emissions
GR_12	Recommend the next aircraft to put a cargo which departs from GOLD warehouse, in order to optimise time, cost and emission factors.	flight details for the available destinations (WMS)	XML, CSV	Flight details of the best flight e.g ABC123 arrives at yyyy-mm-dd with GHG emission of #t of CO2 and cost of #euros	JSON	Which is the flight that satisfies the criteria as a whole minimum transport time , minimum cost, minimum CO2 emission of the cargo to the desired destination

GR_13	Recommend (before journey) the E2E route planning which minimizes the transport time, given transport/freight constraints.	1. CSV file from the WMS including the flight details for the available destinations. 2. Greenlight from Port and Airport warehouse. 3. Historical data of the route. 4. CSV file with	XML,CSV	ETA5 : for the best E2E route of the Cargo in terms of minimum time Details of the route	JSON	Which is the shortest route in time through the E2E chain starting from A to the desired destination
GR_14	Recommend (before journey) the E2E route planning which minimizes the total transport cost, given transport/freight constraints.			Value in euros with the report of the optimum route	JSON	Which is the best route in terms of money through the E2E chain starting from A to the desired destination

GR_15	Recommend (before journey) the E2E route planning which minimizes the CO2 emission, given transport/freight constraints.	historical data of the estimated time of staying in the warehouse.		Kgr CO2 of the optimum route.	JSON	Which is the best route in terms of minimum CO2 emissions through the E2E chain starting from A to the desired destination
GR_16	Recommend (before journey) the E2E route planning which optimises time, cost and emission factors (whose solution might be different from that when one of these is optimised separately).			Value in euros, Kgr of CO2 emissions and ETA5 with details of theoptimum route.	JSON	Which is the best route in terms of MINIMUM co2 emissions, minimum cost, best time through the E2E chain starting from A to the desired destination

GR_17	Recommend (during journey) the adapted route to cope with real-time incidents (e.g., road blockage, congestion, extreme weather, strike, etc.). The adapted planning ensures the fastest possible travel time of the remaining journey.	1. OBU-based data. 2. CSV file from the WMS including the flight details for the available destinations.	JSON,CSV	1.ETA of the remaining fastest route. 2.Map of the new route. 3. Details of the new flight with the earliest time of arrival in the place of destination.	JSON	Given an incident in the route what is the best alternative for the truck in terms of minimum time to reach GOLD starting from Piraeus. In addition, if necessary recalculate which is the new flight if the truck cannot catch the scheduled flight before route.
GR_18	Recommend (during journey) the adapted route to cope with real-time incidents (e.g., road blockage, congestion, extreme weather, strike, etc.). The adapted planning ensures the most cost-effective solution for the remaining journey.	1. OBU-based data. 2. CSV file from the WMS including the flight details for the available destinations.	JSON,CSV	1.Value in Euros of the remaining route 2.Map of the new route 3. Details of the new flight with the minimal	JSON	Given an incident in the route what is the best alternative for the truck in terms of minimum cost to reach GOLD starting from Piraeus. In addition, if necessary recalculate which is the new flight if the truck cannot catch the scheduled flight before route.

				shipment costs.		
GR_19	Recommend (during journey) the adapted route to cope with real-time incidents (e.g., road blockage, congestion, extreme weather, strike, etc.). The adapted planning ensures the most environmental-friendly solution for the remaining journey.	1. OBU-based data. 2. CSV file from the WMS including the flight details for the available destinations.	JSON,CSV	1. GHG in Kgr of the remaining route 2.Map of the new route 3. Details of the new flight with the minimal GHGs emmisions.	JSON	Given an incident in the route what is the best alternative for the truck in terms of minimum GHG emissions to reach GOLD starting from Piraeus. In addition, if necessary, recalculate which is the new flight if the truck cannot catch the scheduled flight before route.

GR_20	Recommend (during journey) the adapted route to cope with real-time incidents (e.g., road blockage, congestion, extreme weather, strike, etc.). The adapted planning ensures optimisation in parallel of time, cost and emission factors for the remaining of the journey.	1. OBU-based data. 2. CSV file from the WMS including the flight details for the available destinations.	JSON,CSV	1. ETA, GHG in Kgr of the best remaining route 2.Map of the new route 3. Details of the new flight with the minimal GHGs emmisions.	JSON	Given an incident in the route what is the best alternative for the truck in terms of minimum GHG emissions to reach GOLD starting from Piraeus. In addition, if necessary recalculate which is the new flight if the truck cannot catch the scheduled flight before route.
GR_21	Real-time tracking (update coordinates) of container	Timestamps and locations OBU-based data	JSON	Timestamps and locations OBU-based data	JSON	
GR_22	Real-time tracking (update coordinates) of pallet/cage	Timestamps and locations WMS-based data	JSON	Timestamps and locations WMS-	JSON	

				based data		
GR_23	Real-time tracking (update coordinates) of individual package/parcel.	Timestamps and locations WMS-based data	JSON	Timestamps and locations WMS-based data	JSON	

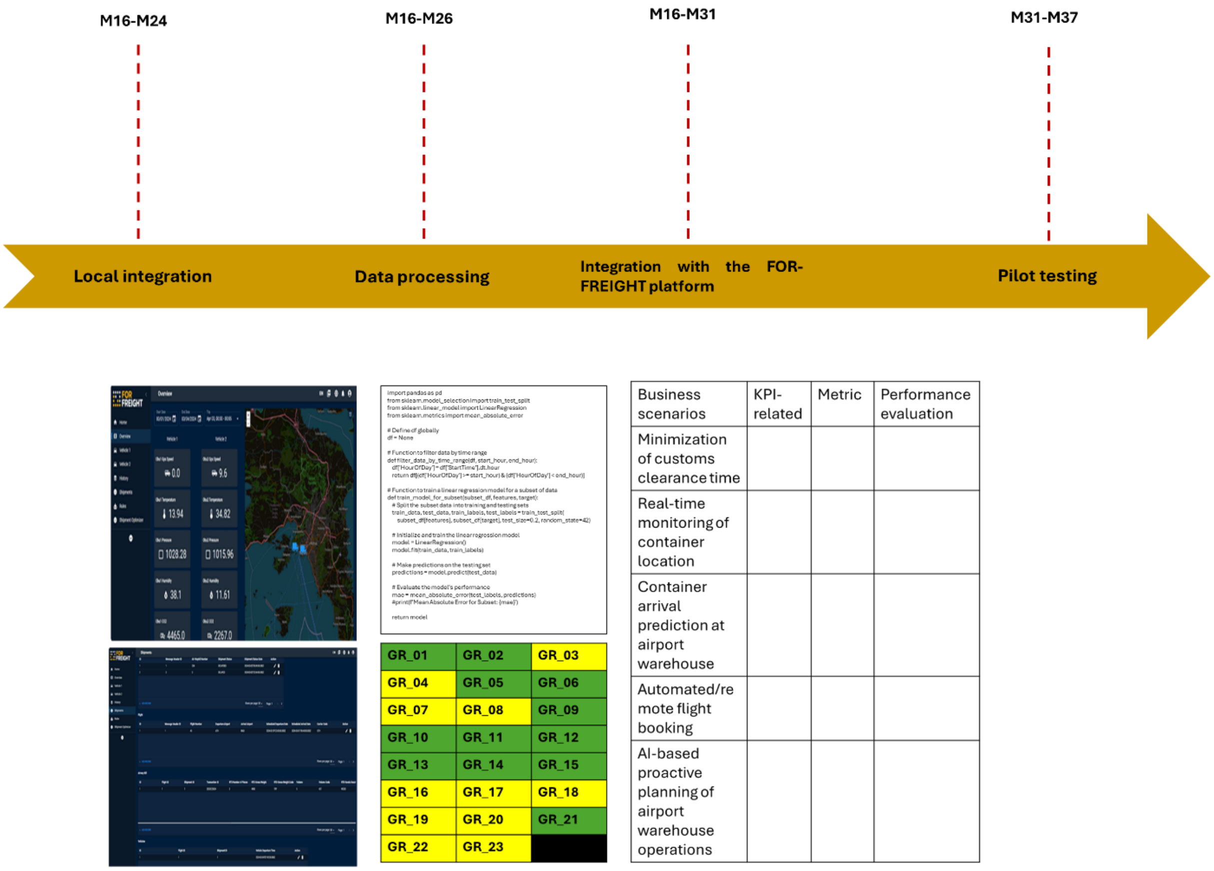
3.2.2.5 *Trial execution phases and timeline*

The Greek UC endeavours to revolutionize the T&L operations between AIA and PCT by automating processes and integrating legacy systems. To achieve this ambitious goal, the trial execution has been structured into several key phases, each playing a crucial role in the successful implementation of the UC. These phases encompass **system integration**, **data processing**, **integration with the FOR-FREIGHT platform, and pilot testing.** In the following sections, each phase will be outlined in detail, highlighting its objectives, activities, and significance. From the initial integration of legacy systems to the final integration with the overarching FOR-FREIGHT platform, these phases represent a path towards realizing a streamlined and efficient T&L solution.

Table 3-17. Summary of the individual phases for the implementation of UC2.

Phases	**Description**
Local integration	The focus is on the integration of GOLD's and COEL's legacy systems and the deployed OBUs and parking sensors with the local platform at WNGS premises.
Data processing	The main goal of this phase is the development of several solvers to enhance efficiency and optimise operations. These include a Localizer for freight tracking, real-time routing recommenders, ETA predictors, Aircraft Automated Booking/Next Aircraft Recommender, resource capacity predictors, per-sub-route transport time, cost, and emission predictors, warehouse planning optimiser, and cargo's dwelling time/duration stay predictors. These solvers aim to streamline processes, improve decision-making, and enhance overall efficiency in T&L operations.
Integration with the FOR-FREIGHT platform.	The local data processing platform will be integrated with the FOR-FREIGHT platform allowing for cenralised management, monitoring, and analysis.
Pilot testing	The pilot testing phase within the GR trial aims to rigorously assess the effectiveness and reliability of the integrated solutions provided. This testing will be centered around the following:

	• **Business Scenario Evaluation:** Detailed assessment of predefined business scenarios to ensure that the solutions meet the expected outcomes. Each scenario will be tested to simulate real-world conditions and challenges. • **KPI Alignment:** Ensuring that the solutions align with KPIs is crucial. Specific metrics related to efficiency, accuracy, and throughput will be monitored to evaluate performance against established benchmarks. • **Performance Metrics:** Collection and analysis of performance metrics will provide quantitative data on the solutions' capabilities. Metrics such as response times, error rates, and processing speeds will be key indicators of success. • **User Feedback:** Gathering feedback from end-users who interact with the solutions during the pilot phase is essential. Their insights and experiences will offer valuable perspectives on usability and effectiveness. • **Operational Procedures:** Evaluating the operational procedures involved in implementing and maintaining the solutions will be part of the pilot testing. This includes assessing the ease of integration, training requirements, and support mechanisms. • **Data Analysis:** Comprehensive analysis of the data collected during the pilot phase will be conducted to identify trends, correlations, and areas of improvement. This will inform any necessary adjustments before full-scale implementation.



Business scenarios	KPI-related	Metric	Performance evaluation
Minimization of customs clearance time			
Real-time monitoring of container location			
Container arrival prediction at airport warehouse			
Automated/remote flight booking			
AI-based proactive planning of airport warehouse operations			

Figure 3-19. The timeline of the trial execution phases for the GR_UC.

3.2.3 Romanian UC

3.2.3.1 Route for the KPI satisfaction

The successful achievement of KPIs depends on a methodically designed route that evaluates the specific KPIs comprising the RO_UC. This initial route will examine the connectivity between these metrics and the participating solvers, linking each KPI with their general KPI group. The resulting outputs of the solvers and the methodologies employed will be analysed, establishing a clear picture of the entire KPI route until its completion. To ensure the best possible performance, the route and methodologies followed for the measurement of the KPIs may be adjusted retrospectively to reflect a more accurate measurement in the RO_UC.
For defining the linkage between the solver outputs and the impacted KPIs, we will specify the precise components of each KPI that can be influenced, the base values for those components, the associated solvers, and the envisioned method that explains how the services developed within the platform impact the relevant metrics.
As will be highlighted, some KPIs can represent components for other KPIs. Therefore, the order in which each KPI will be addressed will not follow their acronyms.

Decrease loading/unloading time by 20%

This KPI "Decrease loading/unloading time by 20%"refers to the time needed for all the containers from the ship to be unloaded and loaded onto the train wagons once the ship is ready for the unloading process. Several factors impact the loading and unloading time of the containers. First, there are the capabilities of the cranes involved and the skills of the personnel. Second, the Synchronisation between port and rail resources and the arrival of the ship must be high enough to minimize any wasted time for the ship to receive a spot for unloading or for waiting for the proper train wagons to be positioned correctly. The services planned for development within the project cannot affect the efficiency of personnel or machinery but rather aim to eliminate unnecessary delays by offering better Synchronisation across resources in the port area. This is summarised in Table 3-18.

The overall formula for determining the specific KPI is as follows: $\boldsymbol{T_{lu} = t_{ac} + t_d + t_{au} + t_{ar}}$ (where T_{lu} represents the total loading/unloading time)

Table 3-18. Summary of the components for the satisfaction of the " Decrease loading/unloading time" KPI.

KPI	Metric	Metric description	Baseline	Overall Baseline	Target	Related Solvers	Methodology
Decrease loading/ unloading time by 20%	t_{ac}	Time until access to cranes can be granted	1h	3h	2,4h	RO_01, RO_02, RO_03, RO_04, RO_05	Solver RO_01 predicts the time of arrival for the ship in port, and Solver RO_04 predicts the necessary resources (number of cranes) required from the port side. With this information, the appropriate resources can be allocated at the correct time for ship docking. Similarly, Solver RO_02 and RO_05 provide several options for a train to pick up the goods, allowing the most time-efficient solution to be chosen.
	t_d	Time for ship docking	50 min				
	t_{au}	Time for actual unloading	1h 30m				
	t_{ar}	Time until access to rail resources can be granted	40m				

Document digitalisation by 80%

Document digitalisation refers to the digitalisation of documents resulting from transport processes, as well as the digitalisation of various information collected by sensors or humans. The overall formula for determining the specific KPI is as follows: $\boldsymbol{Q_d = (q_a + q_t) / 2}$ (where Q_d represents the percentage of total documents that are digitalised).

Table 3-19. Summary of the components for the satisfaction of the " Document digitalisation" KPI.

KPI	Metrics	Metric description	Baseline	Overall Baseline	Target	Related Solvers	Methodology

Document digitalisation	q_a	Percentage of Administrative documents that are digitalised	0%	25%	80%	RO_10	Solver RO_10 will act as a digital hub for all the telematics data collected. Additionally, it will also provide the capability for uploading and downloading administrative documents.
	q_t	Percentage of telematics data that is digitalised	50%				

Reduction of the container idle time by 25%

Although similar to the "Decrease loading/unloading time by 20%" KPI, container idle time in the port area encompasses all the possible delays that prevent the ship from entering the port and unloading its goods, including the delays addressed by "Decrease loading/unloading time by 20%" KPI. The overall formula for determining the "Reduction of the container idle time by 25%" KPI is as follows: $T_i = t_{da} + t_{de} + t_{rb} + t_{pt} + T_{lu}$ (where T_i represents the total idle time).

Table 3-20. Summary of the components for the satisfaction of the " Reduction of the container ide time" KPI.

KPI	Metrics	Metric description	Baseline	Overall Baseline	Target	Related Solvers	Methodology
Reduction of the container idle time by 25%	t_{da}	Time for document approval	3 days	1 days 9h, 1 day 2h 24m		RO_01, RO_02, RO_03, RO_04, RO_05, RO_10	Through RO_10, document management will be made much easier, improving administrative processes. At the same time, RO_01 will aid in detecting
	t_{de}	Time until entry in the port is granted	7 days				
	T_{lu}	The total loading/unloading time	2h				

	t_{rb}	Time for possible railway infrastructure problems to be resolved	1 day		18-19h		potential port closures ahead of time. The methodology for RO2 remains as described in its section.
	t_{pt}	Idle time for giving priority to a passenger train	9h				

Reduction of routing errors by 20%

The “Reduction of routing errors by 20%” KPI addresses container misplacement. This includes cases where containers from a specific shipment are not loaded onto the correct ship or are placed on the wrong ship. Similar cases apply to railway transport as well . The overall formula for determining the specific KPI is as follows: $Q_{re} = q_{cms} + q_{cmt}$ (where Q_{re} represents the total percentage of containers that get misplaced)

Table 3-21. Summary of the components for the satisfaction of the " Reduction of routing errors” KPI.

KPI	Metrics	Metric description	Baseline	Overall Baseline	Target	Related Solvers	Methodology
Reduction of routing errors by 20%	q_{cms}	Percentage of containers misplaced in ship	5%	15%	12%	RO_10	Through the container tracking offered by RO_10, validations will be conducted to catch errors ahead of time.
	q_{cmt}	Percentage of containers misplaced in train	10%				

Increased E2E capacity due to optimisation of resource utilisation by 20%

Increasing the E2E capacity requires either increasing the volume of containers transported in a single shipment, decreasing the time of a shipment, or both. Since none of the solvers can address the number of containers that can be loaded on a ship, the KPI will be impacted by optimising the overall time of the door-to-door transport. For this we will define a singular metric – the total transport time – T_{tt}

Table 3-22. Summary of the components for the satisfaction of the " Increased end-to-end capacity due to optimisation of resource utillization” KPI.

KPI	Metrics	Metric description	Baseline	Overall Baseline	Target	Related Solvers	Methodology

Increased E2E capacity due to optimisation of resource utilisation by 20%	T_{tt}	Total transport time	2 weeks	2 weeks	0.8 * baseline	RO_01, RO_02, RO_03, RO_04, RO_05, RO_06, RO_09, RO_10	The methodology for RO3 and RO5 results in shorter overall times. After the containers have been transferred to the train, using solvers RO_06 and RO_09 to recommend the route that results in the shortest time will further reduce the overall times for the railway section of the T&L line. Transporting the same amount of containers in a shorter time from door to door results in more containers being transported per unit of time overall.

GHG emissions by 25%

The "GHG Emissions" KPI is currently planned to be completely defined at a later stage. The inclusion of this KPI is contingent upon the completion of a comprehensive study to accurately define its components and establish a reliable baseline. The complexity of measuring and analysing GHGs necessitates a detailed understanding of the various factors contributing to these emissions within the port and rail operations.

Table 3-23. Summary of the components for the satisfaction of the " GHG emissions" KPI.

KPI	Metrics	Metric description	Baseline	Overall Baseline	Target	Related Solvers	Methodology
GHG emissions	Q_{em}	Total emissions	0.014 t CO2e (Tonnes as CO2 equivalent)	0.014 t CO2e (Tonnes as CO2 equivalent)	0.85 * baseline	RO_01, RO_02, RO_03, RO_04, RO_05, RO_06, RO_09, RO_10, RO_11	In general, the reduction of emissions will be achieved through shorter operational times and more efficient operations due to solvers. A more comprehensive approach will be developed after the study.

Reduction of accidents by 30%

It is considered to redefine the "Reduction of accidents" KPI from the RO_UC as a FR. The primary reason for this decision is the limited ability to accurately track and attribute changes in accident rates to the methodologies and solutions implemented in this project. The implementations will not be integrated into a fully commercial setting for an extended period (at least a few months) during the project, making it difficult to establish a clear link between the solutions and any reduction in accidents. Any testing that might put the safety of others at risk is also not feasible. As a result, maintaining this KPI would not accurately reflect the capabilities and outcomes of the project. By removing it, we ensure a more precise and relevant evaluation of our project's impact on the RO_UC.

3.2.3.2 Route for the Functional Requirements Satisfaction

The tables below illustrate the pathway to fulfilling the FRs within the RO scenario. This methodical framework evaluates the alignment of the FRs with the project's aims and objectives, taking into account the present system's constraints and coordinating with the various solvers that will facilitate these FRs.

Table 3-24. Summary of the components for the satisfaction of the " GHG emissions" KPI.

Functional Requirement	Baseline	Solvers Related	Metrics	Target
Data Format Unification				
RO-FR1: **Translation of data to a common format.**	Up to now, there is no common format	Not a specific solver supports this Functional requirement	Not quantifiable	Up and running system which supports the translation of messages to a common format (TIC4.0)
RO-FR2: **Real-time and historical data integration.**	Up to now, there is no support of integrating of historical and real-time data	RO_10	Not quantifiable	Up and running system which supports the integration of real-time and historical data
Accessibility management				
RO-FR3: **Integrate different UI for different actors.**	Up to now there is no unified UI	Not a specific solver supports this Functional requirement	Not quantifiable	Up and running system that offers different UI depending on the needs of the actor.
RO-FR4: **Allow different levels of accessibility/authorisation.**	Up to now there is no rights management	Not a specific solver supports this Functional requirement	Not quantifiable	Up and running system that offers rights management within the system and the data.

Automation of information exchange				
RO-FR5: Automated ETA update of the ship in the Port of Galati.	Up to now the ETA **is calculated using only classical methods.**	RO_01	ETA_{Galati}	An up and running system that offer ETA that considers possible delays and updates in real-time.
RO-FR6: Real-time monitoring of freight locations and conditions.	Up to now there is no monitoring of freight location or conditions	RO_10	Not quantifiable	Up and running system that can independently monitor the freight location
RO-FR7: Automated railway booking.	Up to now there is no automated railway booking	Not a specific solver supports this Functional requirement	Not quantifiable	Up and running system that allows automated railway booking.
Planning and management resources				
RO-FR8: Container arrival prediction at Port.	Up to now the ETA **is calculated using only classical methods.**	RO_01	ETA_{Galati}	Up and running system that offer ETA that considers possible delays and updates in real time.
RO-FR9: Suggestions on resource planning are provided to the port authorities, the logistics operator and customs agencies.	Up to now there is no system that can offer suggestions regarding port resources	RO_04	Not quantifiable	Up and running system that offer suggestions regarding port resources

RO-FR10: **Notifications and advice to the rail freight operators on storage space and resources forecast.**	Up to now there is no system that can offer suggestions regarding railway resources	RO_05	Not quantifiable	Up and running system that offer suggestions regarding railway resources
RO-FR11: **Enhanced Safety for the personnel through Automated Procedures, reducing Human-Prone errors**	Safety protocols are present in operational practices, but no automation is implemented.	RO_11	Not quantifiable	Automated systems are free from human-prone errors.

3.2.3.3 *Trial tools and methods*

In this section, we will detail the HW and SW components that have been deployed to support the development and trialling activities within the RO UC.

HW components

- **Teltonika TAT100 Trackers** are compact and reliable GPS tracking devices designed for asset and vehicle tracking. These trackers provide real-time location data, ensuring efficient fleet management and asset monitoring. They are equipped with long-lasting batteries and various sensors to monitor parameters such as movement, temperature, and tampering, making them ideal for logistics and transportation applications.
- **Libelium Smart Environment PRO Stations** are advanced environmental monitoring systems designed to measure a wide range of atmospheric parameters. These stations can monitor air quality, temperature, humidity, noise levels, and more. They are equipped with high-precision sensors and wireless connectivity options, allowing for real-time data collection and analysis. These stations are ideal for urban planning, pollution monitoring, and environmental research.
- **ADCON Weather Stations** are high-precision meteorological instruments designed for comprehensive weather monitoring. These stations can measure parameters such as temperature, humidity, wind speed, wind direction, rainfall, and solar radiation. They are equipped with robust sensors and offer wireless data transmission for real-time weather data collection. ADCON weather stations are widely used in agriculture, environmental monitoring, and research applications to provide accurate and reliable weather data.

SW components

- **Local Use Case Node** was deployed as a dedicated server setup designed to deploy solvers for data collection and testing within the specific use case environment. This node leverages Docker to create a flexible, scalable, and isolated environment for running various solvers and related applications.
- **Grafana** is an open-source platform for monitoring and observability, widely used for visualising time-series data from various sources. It provides powerful and customisable dashboards that allow users to

gain insights into their systems and applications in real-time. Even if there is no plan to use the platform as a permanent UI, a Grafana deployment is used for testing.

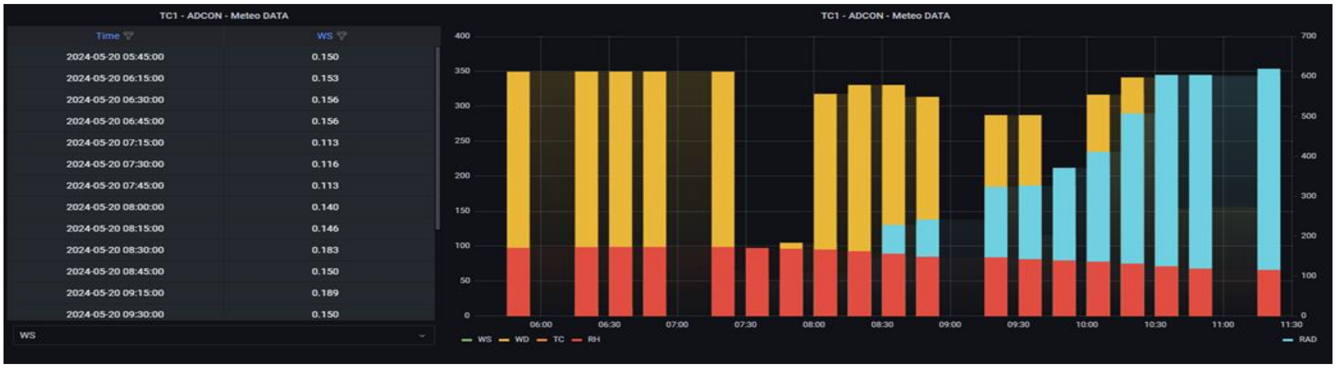


Figure 3-20. UI example for UC3.

3.2.3.4 Data collection and analysis

Data collection and analysis are crucial for our project, ensuring accurate and reliable information to assess the impact of our interventions. Our data collection efforts span multiple sources: sensors and IoT devices capturing real-time data on container movements and equipment status, digital administrative records of logistics operations, periodic manual observations by personnel, and external data feeds integrating weather and traffic reports.

We employ various tools for efficient data collection, including telematics systems for tracking container positions and movements, and custom software solutions to aggregate data from different sources. Collected data undergoes rigorous processing to ensure usability, involving data cleaning to remove inaccuracies and data integration to unify datasets for comprehensive analysis.

Analytical methods applied include descriptive analysis to summarise data features, predictive analysis to forecast future trends and identify potential issues, and prescriptive analysis to recommend specific actions for optimising logistics operations. We use advanced tools and technologies such as statistical software for complex analysis, machine learning algorithms for predictive and prescriptive capabilities, and custom dashboards for real-time insights.

Table 3-25. Summary of the solvers of the RO_UC with the description the actual input/output with the associated data formats.

Solver ID	**Description**	**Input**	**Data format**	**Output**	**Data format**	**Description of output**
RO_01	Predict the arrival time of container ship at Port of Galati	1. RO_10 2. ADCON	JSON	1. ETA1 2. All stages ETA	JSON	What is the estimated time of arrival of the ship, at the port of Galati

RO_02	Predict the arrival time of train departing from Port of Galati to the (final) destination	1. RO_10 2. RO_03	JSON	ETA3	JSON	What is the estimated time of arrival of the train, at the final destination
RO_03	Predict the total stay duration of the cargo at Port of Galati, from the moment of vessel arrival until its departure from this port.	1. RO_10 2. RO_01	JSON	ETA2	JSON	What is the predicted stay duration of the containers at the port of Galati
RO_04	Predict the demand of port resources that need to be reserved, based on the incoming flow of goods/containers	1. RO_10	JSON	resource type and date for demand	JSON	What resources should be reserved from the port side in order to accommodate the unloading of a ship
RO_05	Predict the demand of rail resources that need to be reserved, based on the flow of goods/containers departing from Port of Galati	1. RO_10	JSON	resource type and date for demand	JSON	What resources should be reserved from the rail side in order to transport a certain number and type of containers
RO_06	Recommend the next train to put a container which departs from Port of Galati, in order to minimize the time of transport	1. RO_10	JSON	train ID and route	JSON	What train should be chosen to transport the containers to the final destination based on the shortest time
RO_07	Recommend the next train which departs from Port of Galati, in order to minimize the cost of transport	1. RO_10	JSON	train ID and route	JSON	What train should be chosen to transport the containers to the final destination based on the cost of transport

RO_08	Recommend the next train which departs from Port of Galati, in order to minimize the CO2 footprint	1. RO_10	JSON	train ID and route	JSON	What train should be chosen to transport the containers to the final destination based on possible emissions
RO_09	Recommend the next train which departs from Port of Galati, in order to optimise time, cost and emission factors	1. RO_10	JSON	train ID and route	JSON	What train should be chosen to transport the containers to the final destination based on a balanced consideration of multiple parameters
RO_10	Real-time tracking (update coordinates) of container	1. TAT140 data 2. Ship data 3. Train data	JSON, Codec8	1. Container position (logistic and geographic) 2. Ship/Train position	JSON	what is the position of the container, the position of the ship that is transporting the container/ the position of the train that is transporting the container.
RO_11	Automated crane operation	1. Video feed	JSON	Status of crane operation	JSON	Status reports regarding the current status and commands issued to the cranes that are being operated

3.2.3.5 *Trial execution phases and timeline*

In order to ensure proper use of resources within the project, and successful trials that gather useful data, a series of phases needs to be defined. Each phase should have a series of requirements that need to be met before moving forward.

Table 3-26. Summary of the timeline of the trial execution phases for the RO_UC.

Phases	**Description**	**Start date – end date**
Local integration	The integration within the use case needs to happen from 2 perspectives: • The integration with legacy systems from ships and trains	October 2023 – September 2024

	• The deployment of weather equipment in Galati, and trackers on containers for real-time data.	
Data processing	After the integration and the establishment of the local node, each solver involved in a trial needs to be developed. For the RO UC this means the development of the unifying tracking solver (RO_10) for data integration, the training and deployment of the ETA predictors, the resource predictors and the Decision Support System (formed from solvers RO_06,07,08,09)	November 2023 – October 2024
Integration with the FOR-FREIGHT platform.	All the solvers, after being validated locally, need to be integrated with the central node, and in turn, the UI of the FOR-FREIGHT platform.	May 2024 – October 2024
Pilot testing	After end-to-end functionality is established, pilot testing will start. Trials defined to validate the impact of the application on the KPIs and use case objectives will be conducted in collaboration with the UC partners. **Phases:** 1. Preparation (September 2024): • Setup Test Environment: Configure the testing environment, including hardware, software, and network setups. • Define Test Scenarios: Develop detailed test scenarios based on real-world use cases. • Training: Provide necessary training for the stakeholders involved in the pilot testing. 2. Initial Testing (October - December 2024): • Dry Runs: Conduct dry runs to identify any immediate issues and make necessary adjustments. • Data Collection: Start collecting data on system performance and user interactions.	September 2024 – August 2025

	3. Full-Scale Testing (January - March 2025): • Execution of Test Scenarios: Implement the defined test scenarios at full scale. • Continuous Monitoring: Monitor system performance and collect data continuously. 4. Evaluation and Adjustment (April - June 2025): • Data Analysis: Analyze the collected data to evaluate system performance against KPIs. • Feedback Incorporation: Gather feedback from users and make necessary adjustments to the system. 5. Final Assessment (July - August 2025): • Final Testing: Conduct final rounds of testing to ensure all adjustments have resolved any issues. Reporting: Prepare a detailed report on the pilot testing outcomes, including success metrics and areas for improvement.	

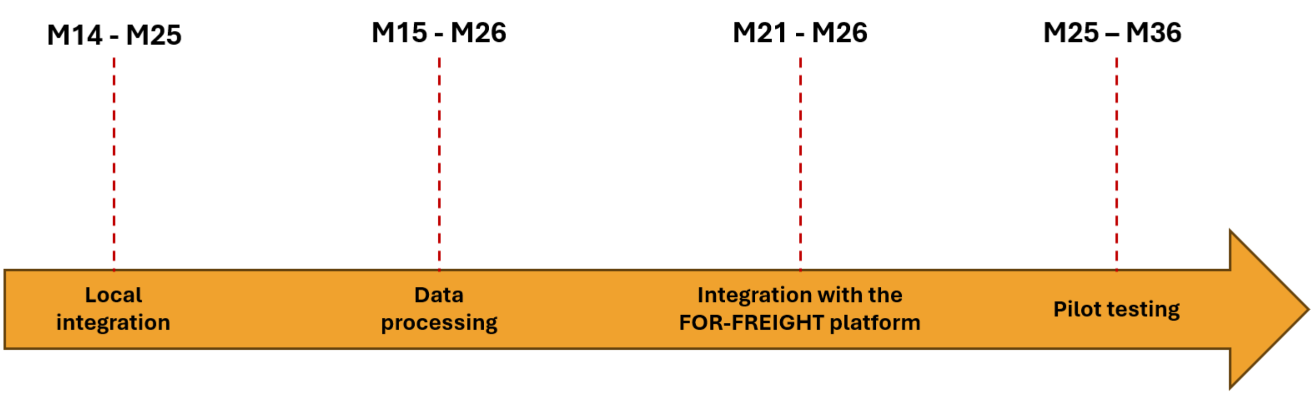


Figure 3-21. The timeline of the trial execution phases for the RO_UC.

4 Potential Risks and Mitigation actions

Recognizing the complexity of trial planning and execution, D3.1 also addresses potential risks and outlines mitigation actions to ensure the success of each trial. Effective risk management is crucial to maintaining the integrity of the trial process and achieving the desired outcomes. Key risks identified include technical failures, data inaccuracies, timeline delays, and resource constraints. To mitigate these risks, D3.1 incorporates a range of strategies designed to proactively identify, manage, and resolve potential issues. The following table summarizes the key risks and the corresponding mitigation actions:

Table 4-1. Summary of the risks and mitigation actions included in the trial planning and experimentation methodology.

Risk	**Description**	**Mitigation Actions**
Technical failures	Potential technical issues with hardware or software components that could disrupt trial processes.	- Implement a robust testing and validation phase to identify and address issues early. - Conduct regular maintenance and updates of technical components.
Data inconsistencies	Inaccurate or incomplete data collection could lead to erroneous conclusions and analysis.	- Utilize advanced data collection and analysis tools to ensure high-fidelity performance metrics. - Establish strict data validation protocols
Timeline delays	Delays in the trial execution timeline could affect project deadlines and outcomes.	- Establish a detailed and realistic execution timeline with built-in contingencies. - Monitor progress continuously and adjust plans as needed.
Resource Constraints	Insufficient resources (personnel, equipment) that could hinder trial execution.	- Ensure adequate resource allocation from the outset.

5 Trial validation methodology - Holistic approach

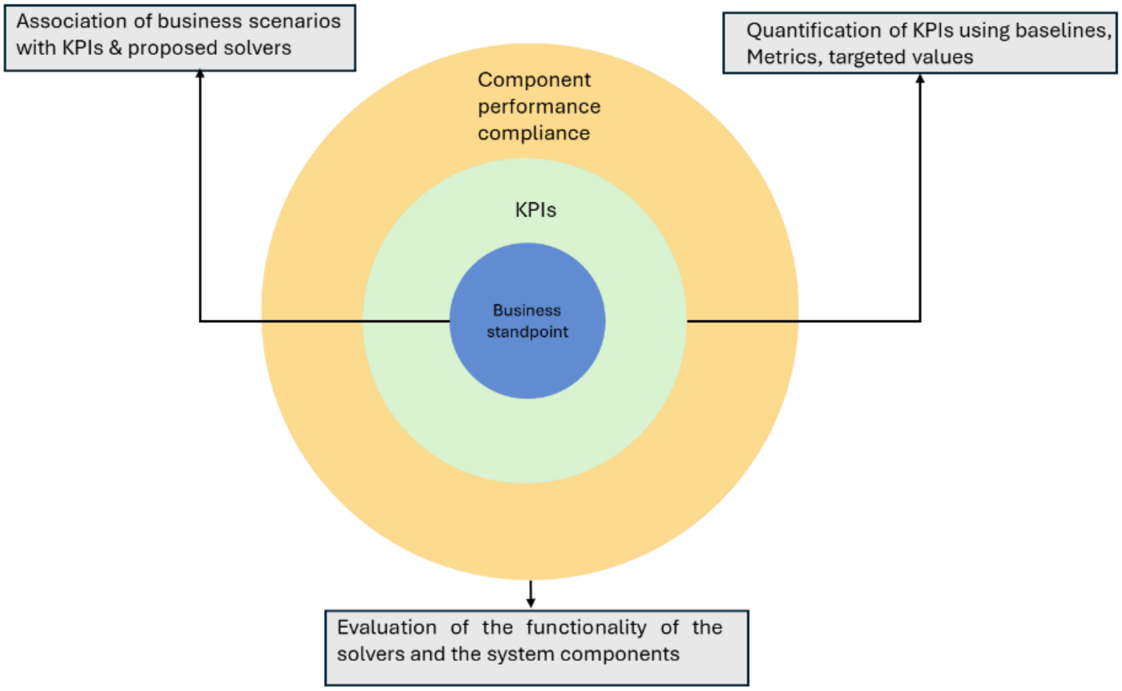


Figure 5-1. Validation pillars of the trial validation methodology.

A holistic validation methodology is a backbone element for evaluating the proposed solutions with respect to the satisfaction of the business scenarios, the technical and performance criteria. The focus is shifted towards the following pillars [1] H2020-ICT-17-2018 5G-EVE project, https://www.5g-eve.eu/ :

1. The association of Business scenarios with the described KPIs and the proposed solutions.
2. The quantification of the KPIs using baselines, metrics, and targeted values.
3. The evaluation of the functionality of the solvers and the system components.

5.1 Evaluation from the Business Standpoint (Lean Startup Methodology)

The developed modules and solvers are briefly evaluated under the lean startup methodology in order to highlight their business-added value and contributions. In the following text we will be focused on five points:

1) Relevance: Alignment of the modules and solvers with the project's objectives.
   - The deployment/development of a set of sensors/solvers around the UCs ensures real-time data collection, monitoring, automation, increased level of security aligning with the project's objective of increasing operational capacity and efficiency in multimodal and transshipment T&L services.
   - Exploiting legacy systems from stakeholders and previous EU funded projects demonstrates an effort to leverage existing infrastructure and resources to achieve project objectives.
   - The developed solvers directly address the need for increased efficiency, sustainability, and reduced freight transport costs outlined in the project objectives.
2) Technical feasibility: Technical challenges during the development.
   - Ensuring compatibility between the data generated by deployed sensors and the formats required by the solvers can be complex, especially when dealing with heterogeneous data sources.

- Legacy systems may use outdated data formats or proprietary protocols, making it challenging to integrate them with modern solutions.
- Developing standardized interfaces and protocols for data exchange and communication is necessary to enable seamless integration between systems and sensors.
- Developing solvers that can perform complex computations and analysis on streaming data with low latency requires specialised expertise and efficient system architecture.

3) Value proposition: The value of the provided solutions.
   - The developed solutions offer significant value by providing real-time tracking, optimised routing, and accurate ETA predictions, which contribute to increased operational efficiency and reduced transport costs.
   - Solvers such as Aircraft Automated Booking/Next Aircraft Recommender and Resource Capacity Predictors offer automation and optimisation capabilities, leading to improved resource utilisation and cost reduction.
   - The Warehouse Planning Optimiser and Cargo’s Dwelling Time/Duration Stay Predictors contribute to enhanced warehouse management and resource planning, resulting in improved efficiency and reduced handling time.
   - Development of new business models supported by FOR-FREIGHT solutions: use of subway systems to last-mile delivery using lockers on stations (Metro de Madrid scenario).
   - Development of unifying systems for implementing automated railway booking and suggestions
4) Impact: Foreseen business imprint of the developed solutions.
   - Reduction of the port and airport idling time by 25%.
   - Reduction of customs clearance process time by 20%.
   - Reduction of errors by 20%.
   - Increased efficiency of the storage space by 15%.
   - Increased E2E capacity due to resource utilisation by 20%.
   - Reduction of time that containers stay at the port by >15%
   - Enhancing the use of rail transport alternatives.
   - Improve interoperability among stakeholders unconnected to each other.
   - Reduction of GHG emissions by 15%
   - Reduction of container mishandling by 20%
5) Feedback loop integration: Continuous gathering of feedback from users and stakeholders to refine and improve the T&L solutions.
   - Implementation of system usage analytics. Capture data how users interact with the system and utilize data analytics to assess the user activity and engagement.
   - Analyze the performance data to identify areas for optimisation and improvement, such as optimising database queries, improving code efficiency.
   - Record user interactions and behaviour patterns.
   - Combine user feedback data with the analytics to gain a holistic understanding of user satisfaction and identify areas for improvement.

5.2 KPI compliance evaluation with predetermined targets

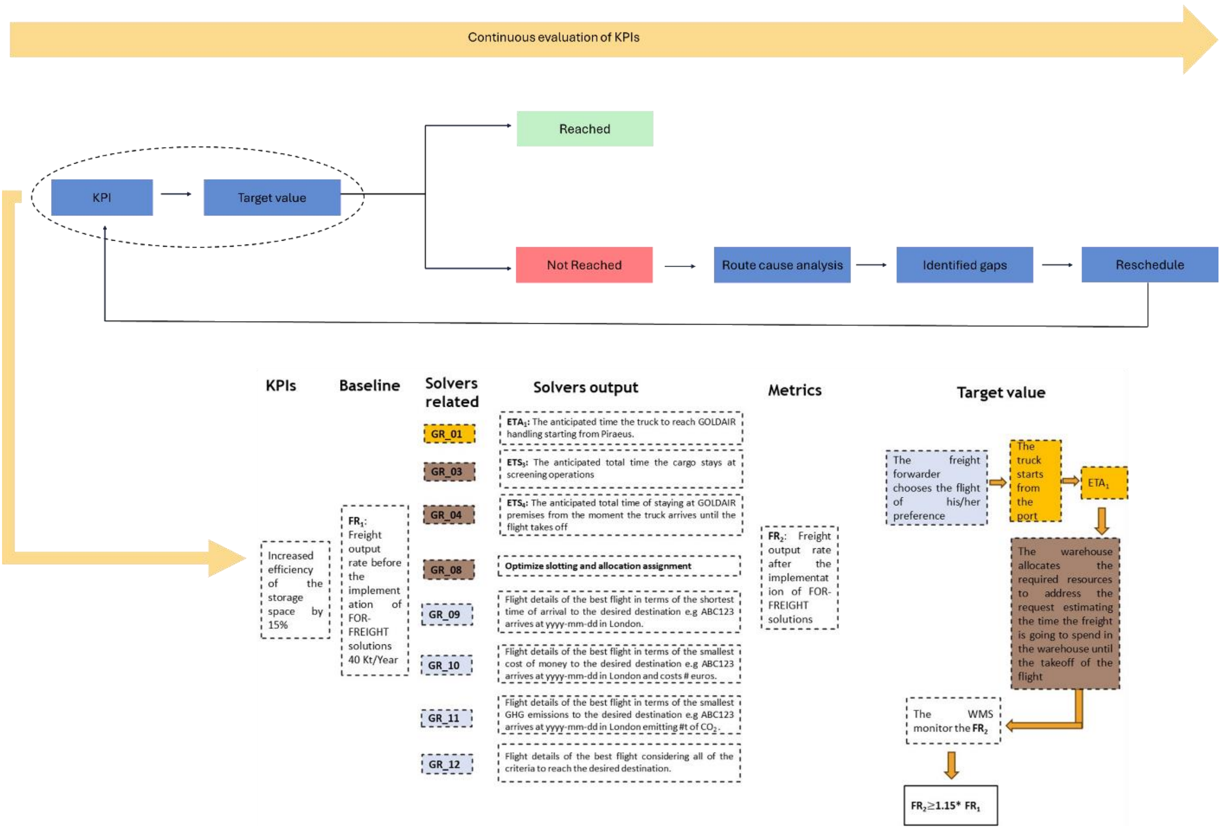


Figure 5-2. The illustration of the KPI compliance evaluation flow.

As highlighted in sections 3.2.1, 3.2.2, and 3.2.3, each specific KPI is assigned a target value which serves as the benchmark for success. Attainment of this target value signifies KPI compliance and overall performance effectiveness. In case the KPI fail to meet the predetermined target, a comprehensive root cause analysis is initiated to identify and diagnose the underlying issues contributing to the shortfall. This analytical process involves a detailed examination of performance data, identification of deviations from expected outcomes, and assessment of contributing factors. Based on the findings of the root cause analysis, a strategic corrective action plan is formulated. This plan includes the development of a revised timeline and implementation schedule aimed at bridging the performance gaps and realigning the KPI trajectory towards the desired target value. Continuous monitoring and iterative adjustments are employed to ensure that the KPI achieves and sustains the stipulated performance criteria.

5.3 Component functionality assessment for performance compliance

Component functionality assessment for performance compliance involves evaluating the functionality of individual system components (HW as well as SW) to ensure they meet specified performance criteria. This assessment aims to verify that each component operates effectively within the system architecture, contributing to overall performance and efficiency. During the assessment process, each component's functionality is scrutinised against predetermined performance metrics, including speed, responsiveness, and consistency of extracted data, level of confidence, matching score.

Based on the assessment results, adjustments, optimisations, or remediation actions may be required to enhance the component's performance and ensure compliance with performance requirements. This may include fine-tuning configuration settings, optimising algorithms, or implementing performance-enhancing techniques. Continuous monitoring and periodic reassessment of component functionality are essential to maintain performance compliance over time, as system requirements, operational, and environmental conditions may change.

5.3.1 Spanish UC

The Spanish use case includes the deployment of HW components, such as IoT sensors and solution clusters that make up the different solvers. The different solution clusters have been developed taking into account the different performance criteria and features that ensure their optimal functioning, responding to the needs of the stakeholders, and being configured according to the performance requirements. The following figures show this link between the different components and solutions and the performance criteria.

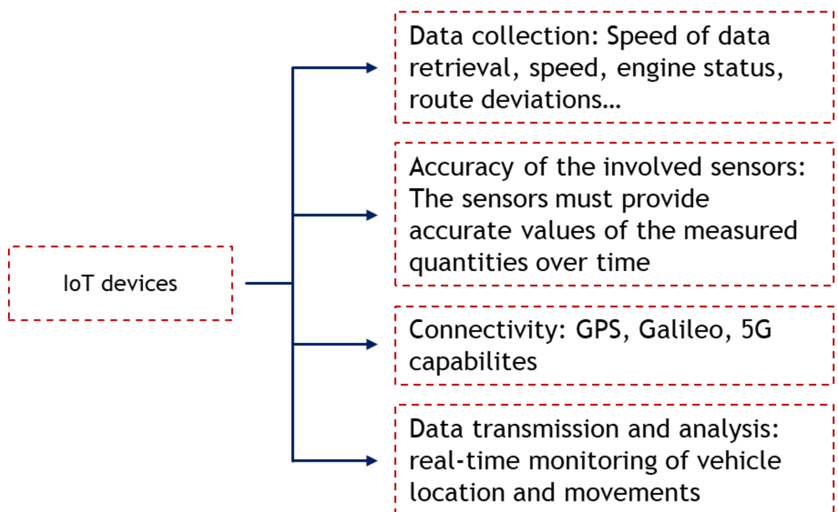


Figure 5-3. The IoT devices with the related performance criteria.

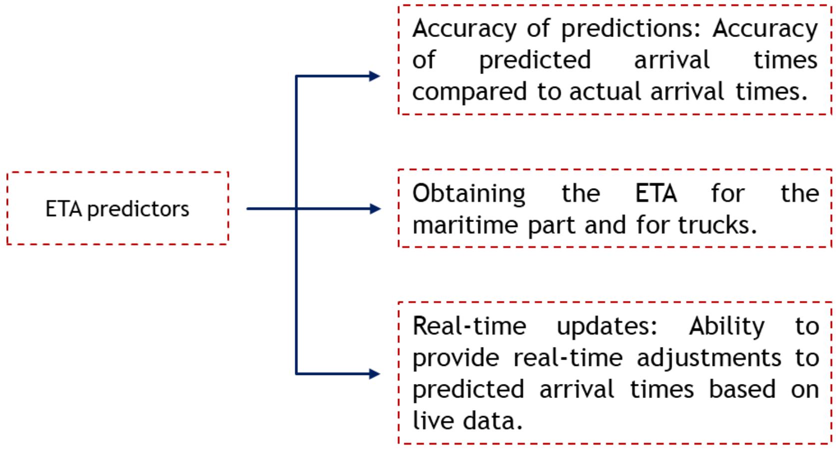


Figure 5-4. The ETA predictors solvers with the related performance criteria.

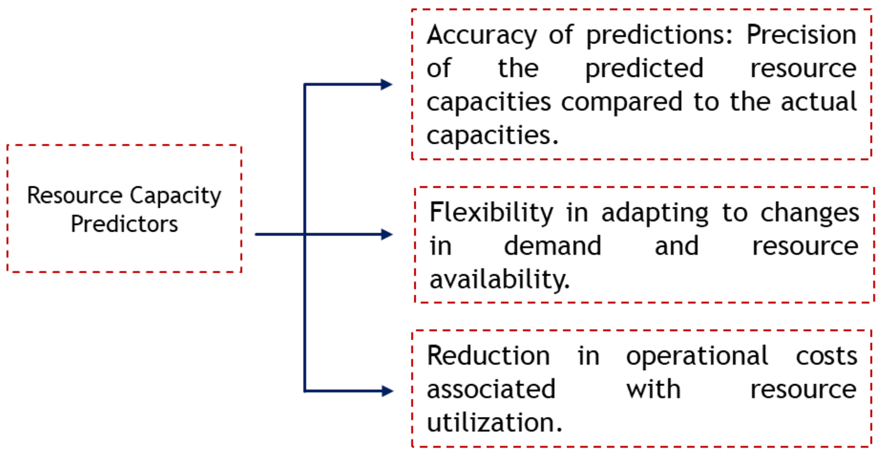


Figure 5-5. The Resource Capacity Predictors with the related performance criteria.

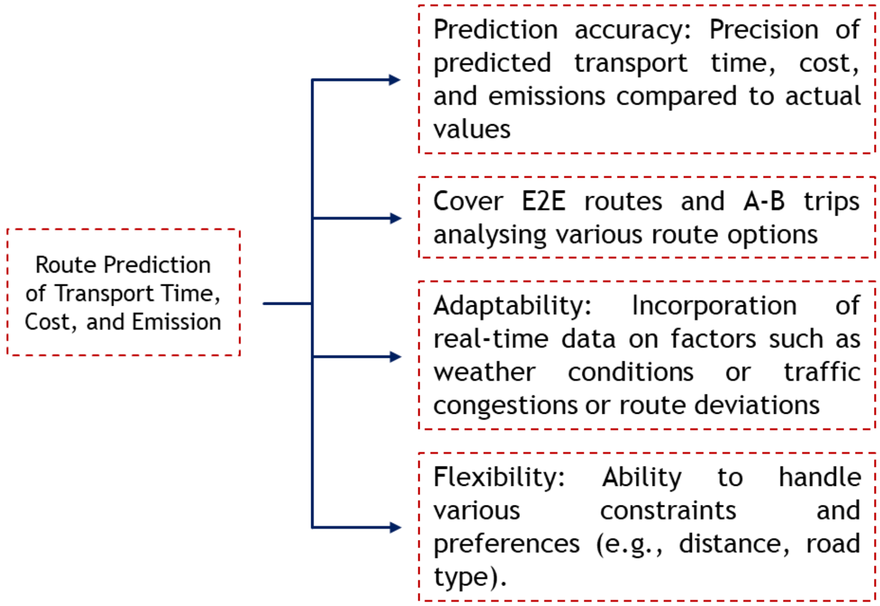


Figure 5-6. The Route Prediction of transport time, cost, and emissions solver with the related criteria.

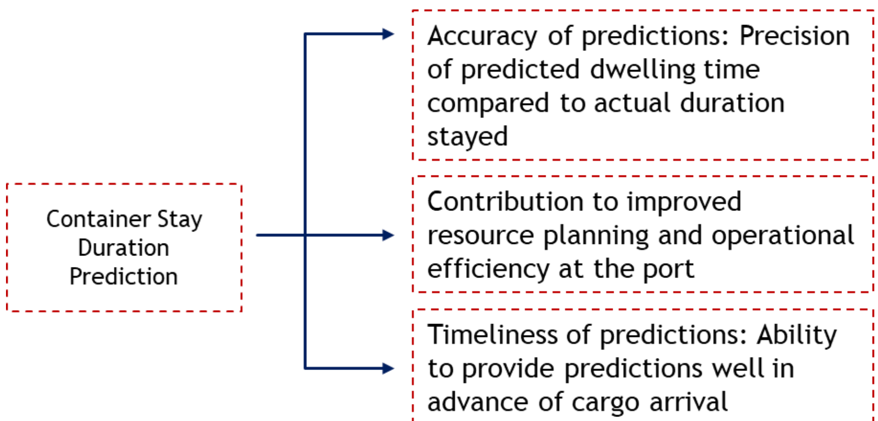


Figure 5-7. The container stay duration prediction solver with the related performance criteria.

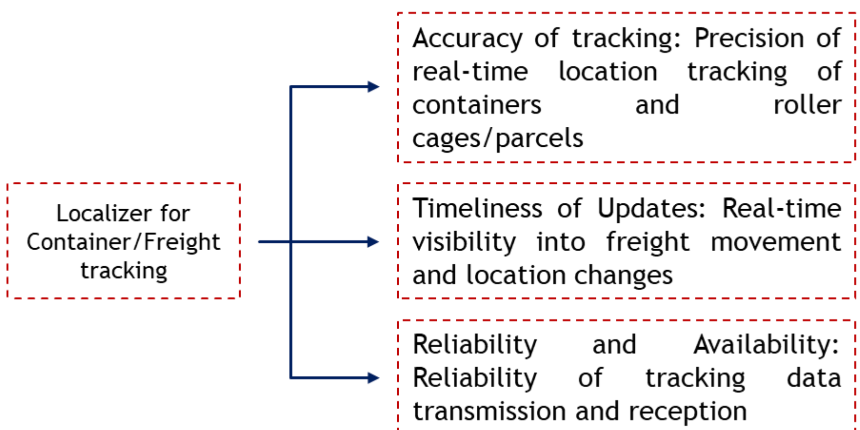


Figure 5-8. The Localizer Container / Freight tracking solver with the related performance criteria.

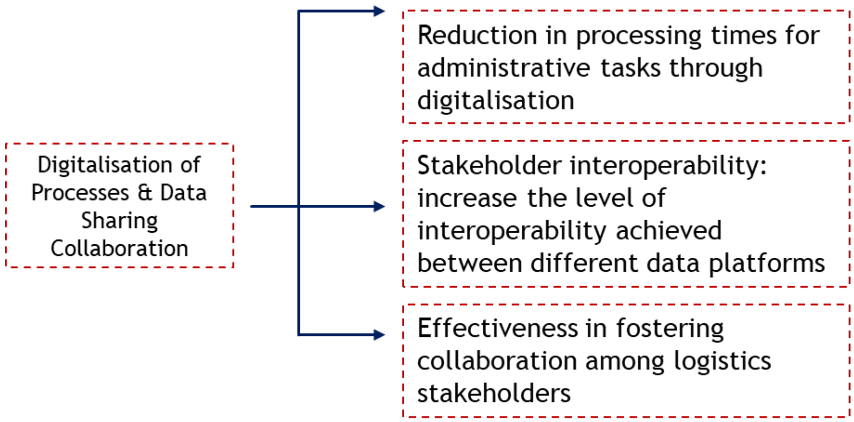


Figure 5-9. The Digitalisation of processes & Data sharing collaboration solver with the related performance criteria.

5.3.2 Greek UC

The HW components which are deployed in the GR_UC include OBUs, parking sensors, port, and warehouse legacy systems. These modules are designed with a focus on meeting specific performance criteria to ensure smooth communication and operation across different domains. Moreover, the solver clusters are illustrated in Figs. 5-10-5-18 describing the connections between the specific solver groups and the performance criteria which are foreseen. The involved components are selected and configured to prioritize reliability and adhering to the highest performance standards creating a cohesive T&L ecosystem across the GR_UC T&L line.

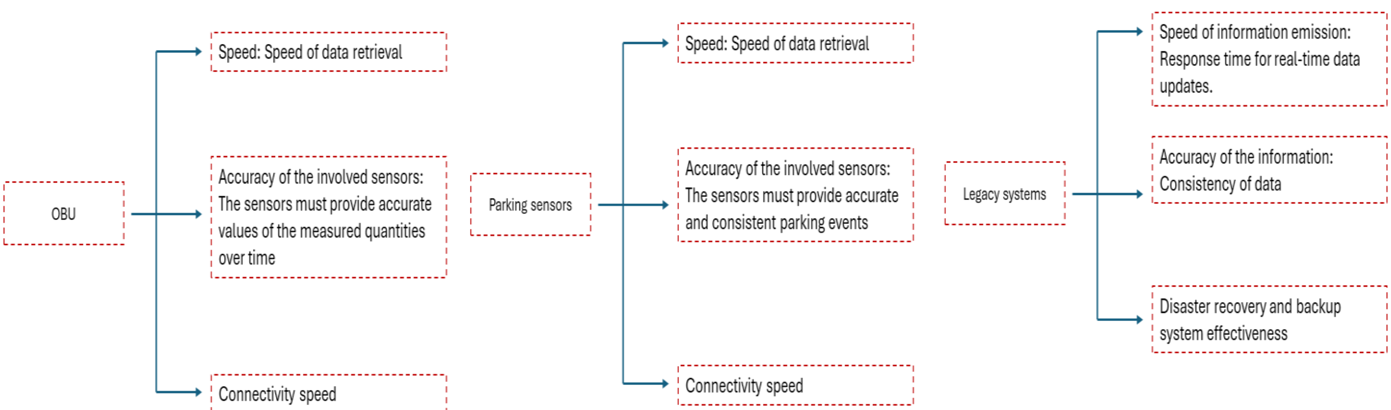


Figure 5-10. The HW components and the legacy systems with the corresponding performance criteria.

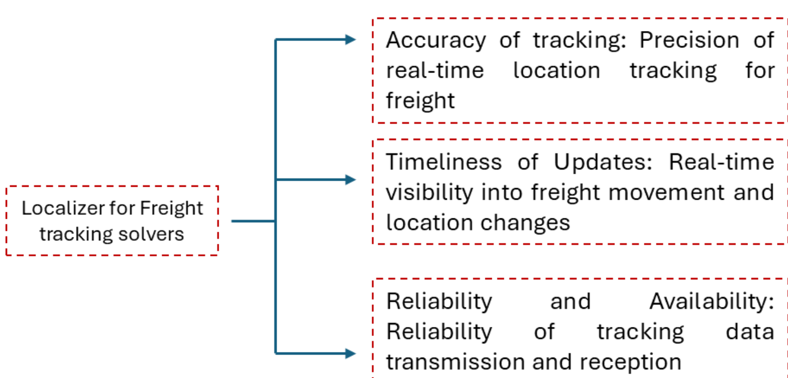


Figure 5-11. The localizer for Freight tracking solvers with the corresponding criteria.

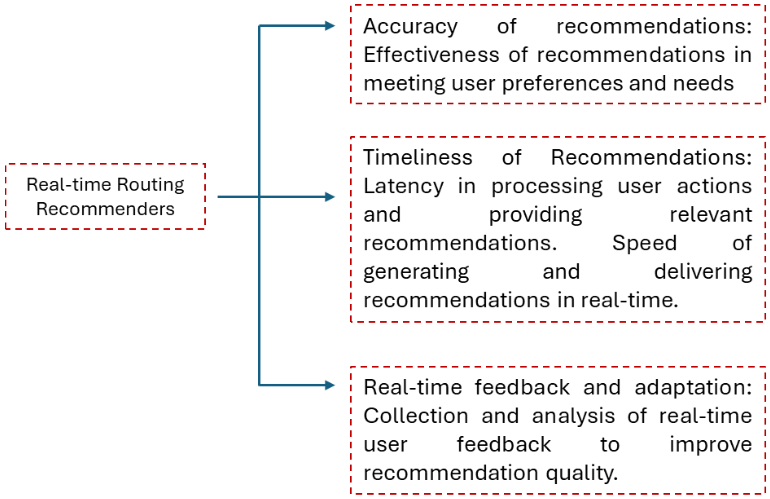


Figure 5-12. The Real-time routing recommenders solver cluster with the corresponding criteria.

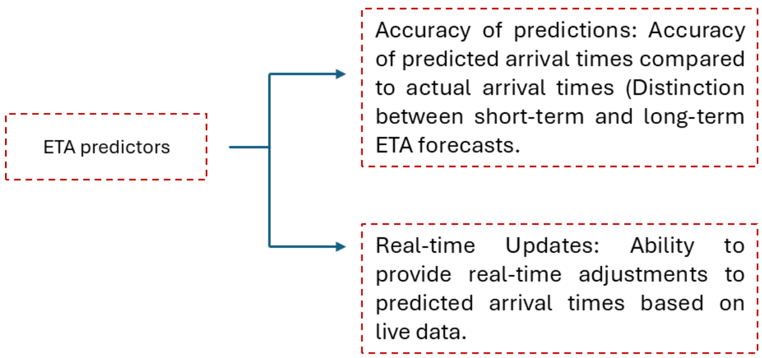


Figure 5-13. The ETA predictors solver cluster with the corresponding criteria.

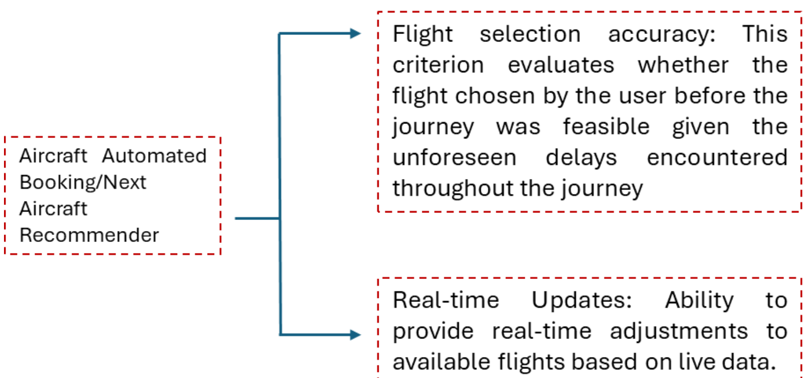


Figure 5-14. The Aircraft Automated Booking/ Next Aircraft Recommender solver cluster with the corresponding criteria.

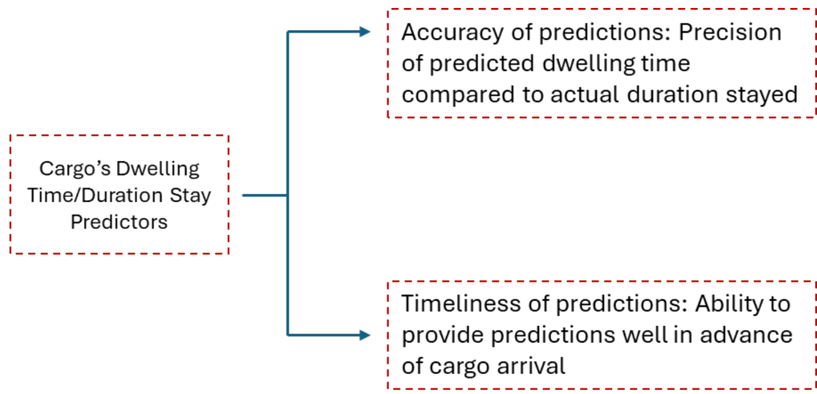


Figure 5-15. The cargo's Dwelling Time/ Duration Stay Predictors with the corresponding performance criteria.

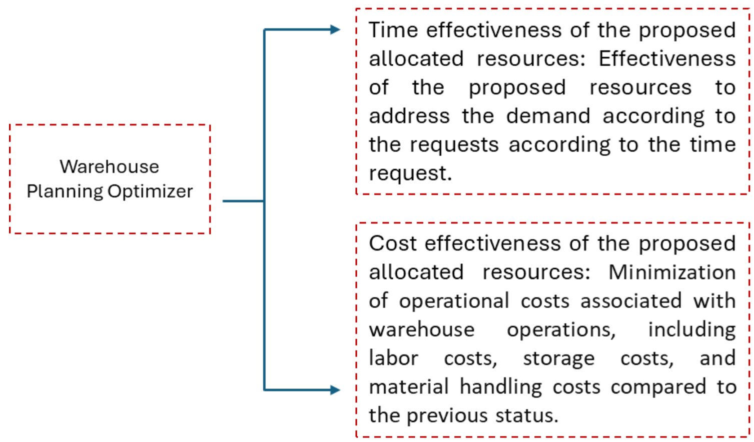


Figure 5-16. The warehouse planning optimiser solver cluster with the performance criteria.

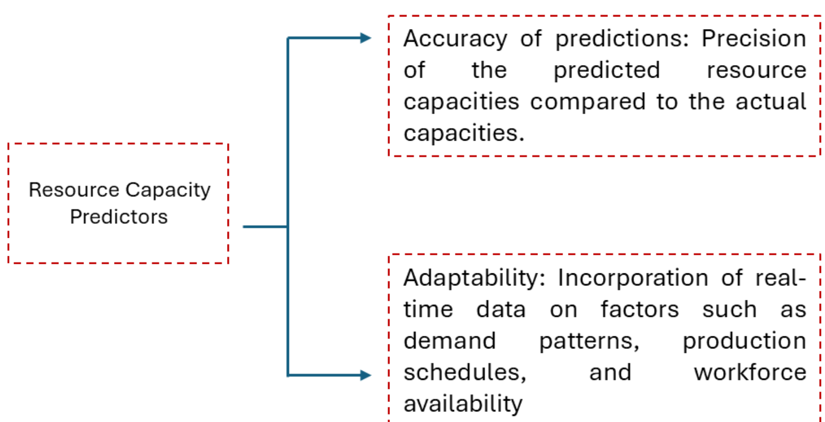


Figure 5-17. The resource capacity predictors solver clusters with the performance criteria.

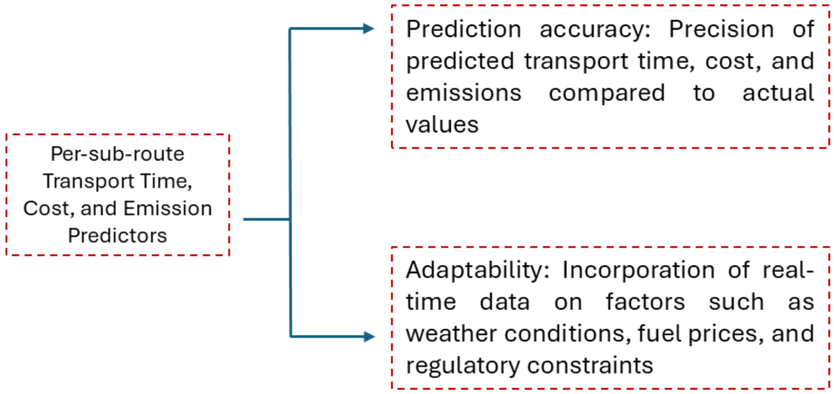


Figure 5-18 . The Per-sub-route Transport Time, Cost, and Emission Predictors cluster with the performance criteria.

5.3.3 Romanian UC

The hardware components deployed in the RO_UC include Teltonika TAT100 Trackers, Libelium Smart Environment PRO Stations, and ADCON Weather Stations. These components are specifically chosen to meet the performance requirements for efficient operation and communication within the logistics and transportation domains. They ensure seamless integration and high performance across the various operational stages in the Romanian Use Case.

The performance criteria for these components include:

- **Teltonika TAT100 Trackers**
  - Speed: Quick retrieval of location and status data
  - Accuracy: Reliable and precise sensor readings over time
  - Connectivity: Fast and stable data transmission
- **Libelium Smart Environment PRO Stations**
  - Speed: Efficient data retrieval from environmental sensors
  - Accuracy: Consistent and precise environmental data collection
  - Connectivity: Reliable wireless data communication
- **ADCON Weather Stations**
  - Speed: Prompt collection and transmission of weather data
  - Accuracy: High-precision measurement of meteorological parameters
  - Connectivity: Robust wireless data transfer capabilities

6 Conclusions

The trial planning and experimentation methodology provides a comprehensive framework for evaluating the effectiveness and efficiency of logistical operations and infrastructure. The conclusions drawn from such a methodology encompass various aspects of the trial, including planning of each site, experimentation, and validation of trial results.

Firstly, the facility layout and infrastructure optimisation are key outcomes. The trial planning allows for a detailed analysis of the facilities' layout and infrastructure, identifying bottlenecks and inefficiencies. This leads to actionable recommendations for improvements, resulting in enhanced spatial arrangement and utilisation of storage areas, loading docks, and transportation routes within the facilities. These improvements streamline operations and reduce transit times.

Secondly, the effectiveness of the experimentation methodology is confirmed. The structured approach ensures that all relevant variables are systematically tested and evaluated, including different logistical strategies, technological implementations, and workflow processes. The robustness of the methodology allows for reproducibility and scalability, providing a reliable framework for future trials and implementations in other logistical contexts.

Validation of trial outcomes is another crucial conclusion. From a business standpoint, the trial's impact on operations is assessed, including cost savings, revenue enhancements, and improvements in customer satisfaction. This evaluation confirms whether the trial meets strategic business objectives. Compliance with KPIs is monitored throughout the trial, ensuring predetermined targets are met, including metrics such as delivery times, error rates, resource utilisation, and throughput. Additionally, the performance of individual components, such as automated systems, software, and physical infrastructure, is assessed to ensure they meet required standards and performance benchmarks.

The trial also provides valuable insights into best practices and lessons learned. These insights include optimal handling procedures, effective use of technology, and efficient resource allocation. Lessons learned from the trial can be used to refine future planning and experimentation methodologies, contributing to continuous improvement in logistics management.

Overall, the trial planning and experimentation methodology offers a rigorous and systematic approach to evaluating and enhancing logistical operations, providing a clear pathway for continuous improvement and strategic decision-making in the logistics domain. It establishes a reliable foundation for future trials and implementations in diverse logistical contexts. Validation of trial outcomes includes assessing impacts on operations such as cost savings, revenue enhancements, and improved customer satisfaction, ensuring alignment with strategic objectives. Continuous monitoring of KPIs like delivery times, error rates, and resource utilisation validates performance against predetermined targets. Moreover, the trial yields valuable insights into best practices and lessons learned, informing optimal handling procedures, technological applications, and resource allocation strategies. These insights contribute to ongoing refinement of planning and experimentation methodologies, fostering continuous improvement in logistics management. D3.1 defines a solid framework for D3.2 as well as D3.3 for the report on intermediate experimentation results of the FOR-FREIGHT trials and FOR-FREIGHT trial results analysis, evaluation & lessons learned, respectively.

7 References

[1] H2020-ICT-17-2018 5G-EVE project, https://www.5g-eve.eu/

[2] H2020-ICT-18-2018 5G-CARMEN project, https://5gcarmen.eu/about/

[3] H2020-ICT-18-2018 5G-MOBIX project, https://www.5g-mobix.com/

[4] H2020-ICT-53-2020 5G-ROUTES project, https://www.5g-routes.eu/

[5] H2020-ICT-41-2020 VITAL-5G project, https://www.vital5g.eu/

[6] H2020-ICT-52-2020 DEDICAT 6G project, https://dedicat6g.eu/

[7] H2020-ICT-52-2020 Hexa-X project, https://hexa-x.eu/

[8] Silva et al., "Sustainable Urban Last-Mile Logistics: A Systematic Literature Review", Sustainability 2023, 15(3), 2285; https://doi.org/10.3390/su15032285

[9] Handbook on the external cost of transport, Version 2019, https://op.europa.eu/en/publication-detail/-/publication/e021854b-a451-11e9-9d01-01aa75ed71a1/language-en

[10] https://www.datapine.com/blog/kpi-management-and-best-practices/

