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D5.1 – MODALNET SPECIFICATIONS, SYSTEMS ARCHITECTURE AND DESIGN OF CYBER-SECURE COMMUNICATION

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List of Abbreviations

Acronym	Description
ABS	Absentee declaration
ACT	Expected activities declaration
AIS	Automatic Identification System
ALICE	Alliance for Logistics Innovation through collaboration in Europe
API	Application Programming Interface
APT	Advanced Persistent Threats
ATA	Actual Time of Arrival
ATD	Actual Time of Departure
AVSPM	Autonomous Vessel Smart Port Management
BERMAN	Berth Management port notification message
BKA	Bunkers formalities at arrival
BKD	Bunkers formalities at departure
BLU	Safe loading and unloading of bulk carriers
BWA	Ballast water
CERL	Computational Engine for Resilient Logistics
CDM	Continuous Diagnosis and Mitigation
CGA	Cargo declaration at arrival
CGD	Cargo declaration at departure
CGM	Customs Goods Manifest
CLI	Command Line Interface
COLREG	Convention on the International Regulations for Preventing Collisions at Sea
ConOps	Concept of Operations

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CSS	Cascading Style Sheets
CWA	Crew list at arrival
CWD	Crew list at departure
DSC	Digital Selective Calling
DUE	Fairway dues declaration
EBIOS RM	Expression des Besoins et Identification des Objectifs de Sécurité Risk Manager
ECDIS	Electronic Chart Display and Information Systems
ECMA	European Computer Manufacturers Association
EDR	Endpoint Detection and Response
EFF	Crew's effects declaration
EFTI	Electronic Funds Transfer Instruction
EMSWe	European Maritime Single Window environment
ERINOT	Message for the reporting of voyage and cargo details by a ship sailing on inland waterways
ERP	Enterprise Resource Planning
eSRIN	electronic Ship Reporting in Inland Navigation
ETA	Estimate Time of Arrival
ETD	Estimate Time of Departure
EU	European Union
EXP	Notification of expanded inspection
EXS	Customs Exit Summary Declaration
EXT	Exit notification
FAL	Convention on Facilitation of International Maritime Traffic
GDPR	General Data Protection Regulation
GMDSS	Global Maritime Distress and Safety System
GNC	Guidance, Navigation and Control
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HAI	Human Automation Interfaces
HTTP	Hypertext Transfer Protocol Secure
HZA	Notification of hazardous materials (dangerous and polluting goods) on board at arrival
HZD	Notification of hazardous materials (dangerous and polluting goods) on board at departure
HZS	Notification of hazardous materials (dangerous and polluting goods) during a shift
ICAM	Identity, Credential, and Access Management
IDS	Intrusion Detection System
IMO	International Maritime Organization
IPS	Intrusion Prevention System
IRTSX	Institut de Recherche Technologique SystemX
ISL	Institut fur Seeverkehrswirschaft und Logistik
IWT	Inland Waterway Transport
IWW	Inland Waterway
JSON	JavaScript Object Notation
LO-LO	Lift On - Lift Off
MCG	MacGregor Finland Oy
MDH	Maritime Declaration of Health
MIL	Military report
MNSW	Maritime National Single Window

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MOSES	autoMated ships and supply chain Optimisation for Sustainable short sEa Shipping
MVC	Model-View-Controller
NAC	Notification of arrival to the customs office of first entry
NIST	National Institute of Standards and Technology
NOA	Notice Of Pre-Arrival
NOD	Notice Of Pre-Departure
NOS	Notification of shift in port
NPE	Non-Person Entities
NTUA	National Technical University of Athens
PA	Policy Administrator
PAXLST	Crew list at arrival / departure in Inland Waterway
PE	Policy Engine
PEP	Policy Enforcement Point
PKI	Public Key Infrastructure
PNT	Positioning, Navigation and Timing
PPA	Presentation of the Proof (at Arrival)
PRN	Presentation Notification
PXA	Passenger list at arrival
PXD	Passenger list at departure
RA	Remote and Autonomous
RBAC	Role-Based Access Control
REN	Re-Export Notification
REST-API	Representational State Transfer - Application Program Interface
RIM	Harmonised reporting interface module
ROC	Remote Operations Center
RXJS	Reactive Extensions for JavaScript
SCIP	Security Continuous Improvement Plan
SEAMLESS	Safe, Efficient and Autonomous: Multimodal Library of European Shortsea and inland Solutions
SEC	Notification of security information
SHP	Ship Information
SID	Ship Identifiers notification
SIEM	Security Information and Event Management
SIS	Ship Information System
SO	Sintef Ocean As
SOAP	Simple Object Access Protocol
SOAR	Security Orchestration, Automation, and Response
SoTA	State of The Art
SRV	Request for service
SSA	Ship to ship activity declaration
SSS	Short Sea Shipping
STA	Declaration of stores on board at arrival
STD	Declaration of stores on board at departure
STW	Stowaways notification
TEU	Twenty-foot Equivalent Unit
TIC 4.0	Terminal Industry Committee

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TOS	Terminal Operating System
TRA	Electronic transport documents used at arrival
TRD	Electronic transport documents used at departure
TSD	Temporary Storage Declaration
UML	Unified Modelling Language
VAT	Value-added tax identification number
VCOP	Voyage and Container Optimisation Platform
VID	Request for visit ID
VIS	Ship visitors' declaration
VPF	Valenciaport Foundation
VS	Visual Studio
VTS	Vessel Traffic Service
WAR	Waste delivery receipt formalities
WAS	Waste delivery to port reception facilities
WP	Work Package
WSDL	Web Services Description Language
XML	Extensible Markup Language
ZTA	Zero-Trust Architecture

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EXECUTIVE SUMMARY

SEAMLESS technological ecosystem is composed of three building blocks which will be verified and validated through SEAMLESS demonstrations. The objective is to achieve a fully automated and economically viable, cost-effective, and resilient waterborne freight feeder loop service for Short Sea Shipping (SSS) and Inland Waterways Transport (IWT). ModalNET is one of these three building blocks, and will be used by a consignor or a logistics operator to plan, initiate, and monitor any freight transport from an origin to a destination.

SEAMLESS services will be based on a redesigned logistics system that will facilitate seamless freight flows through the supply chain by minimising delays in intermodal nodes (i.e., where waterborne and land-based transport modes are connected). This includes a SEAMLESS digital "bird's-eye" view of the supply chain, which allows the exploitation of real-time information (incl. from SEAMLESS physical assets), for planning optimisation and reconfiguration to support resilient logistics.

This report is deliverable D5.1 – ModalNET Specifications, systems architecture and design of cyber-secure communication on Task 5.1 – Specifications, system architecture, and design and on Task 5.2 – Definition of the architecture of cyber-secure communication. VPF is leader of Task 5.1 and IRTSX is leader of Task 5.2 and other participating partners are NTUA, SO, ISL, TIC4.0, ALICE, and MCG. The task descriptions are as follows:

- Task 5.1. The aim of this task is to identify and document the semantic requirements, technical specifications, and the architecture and design of the integrated supply chain support system (ModalNET), considering the ConOps and requirements documented in T2.5.
- Task 5.2. This task includes the detailed systems' functional and operational architecture that will facilitate a secure communication for control and monitoring purposes of the various physical assets. The architecture will support the demonstration of preventive, protective, reactive, and coercive measures against the identified misuse cases and threat scenarios.

Chapter 1 describes the input and connection to other SEAMLESS Work Packages and Deliverables providing additional background and methodology aspects in which the deliverable is built upon. The methodology to present the ModalNET system architecture and specifications will be the 4+1 View Model published by Philippe B. Krutchen. This technique is effective for understanding the views and perspectives of different stakeholders organizing the description of a software architecture using a set of concurrent "views," each addressing unique concerns for different stakeholders. End users, developers, system engineers, and project managers all have unique views on the system, hence viewpoints are used to describe it from their perspectives.

Chapter 2 describes the 3 building blocks and systems developed in SEAMLESS: Automated Port Interfaces, Modular Ship and operations concepts and Integrated Supply Chain support, where ModalNET will constitute the platform for the integrated supply chain support.

- **Building Block #1 Automated Port Interfaces** will be developed in SEAMLESS WP3. It will optimize SSS and IWW port processes for cargo handling, storage, and seamless transhipment to hinterland, develop a digital stowage plan system to facilitate the automated bay planning and stowage planning of the ship at different loading and discharging points,

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ensure safe and secure autonomous mooring and cargo handling and establish new digital interfaces related to automated ship-port interaction including arrival planning and execution, berthing, mooring and cargo handling. Task 3.3 is providing the SEAMLESS automated cargo voyage planning and stowage execution platform which will be based on the **Voyage and Container Optimization Platform (VCOP)** solution of MacGregor. The main user of the VCOP platform is the liner operator. However other participants can use this platform for automating the cargo-handling processes.

- **Building block #2 Modular ship and operations concepts** will be developed as part of WP4. It will develop a rapid prototyping method for evaluating candidate concepts/designs for SSS/IWT autonomous systems, produce concept ship designs optimized for the SEAMLESS Use Cases. It will also take into consideration fault-tolerant, COLREG-compliant GNC scheme for SSS and IWT autonomous ships, risk-based safety assessment and cost-effective approval of SSS and IWT autonomous ships. Standardized Human Automation Interfaces (HAI) for ROC operators, ship-operator low attention functionality and EU satellite navigation services (Galileo /GNSS) and communication of ship to ship and ship to shore are also part of this building block.
- **Building block #3 Integrated supply chain support** is the main aspect of this deliverable and it will be achieved through the ModalNET platform. The integrated supply chain support will determine the requirements for efficient, secure, and resilient data management (incl. physical assets telemetry) by exploiting data spaces and SoTA cybersecurity practices, developing the architecture required for secure communication among the physical assets participating in the supply chain and introducing a digital collaborative communications framework among terminal operators, road operators, liner operators and logistics companies. This document will describe the ModalNET platform and ModalNET computational engine for resilient logistics (CERL) to achieve a synchromodal and resilient dynamic logistics management using the SEAMLESS concept. SEAMLESS services will be based on a redesigned logistics system that will facilitate seamless freight flows through the supply chain by minimizing delays in intermodal nodes.

Chapter 3 describes the architecture to ensure CyberSECURE communications based on the analyses of different environments, the maritime cyber-threat landscape and the zero-trust architecture to be followed in ModalNET. For the specifications, system architecture and design of ModalNET and the cyber-secure communications it is important to characterize the SEAMLESS established baseline in all its building blocks to carry out this activity. This activity includes the review of the state-of-the-art, the functional specifications established in the project, the system architecture and the design of other SEAMLESS building blocks that are further developed in other WPs and tasks.

Finally, **Chapter 4** includes ModalNET system architecture and specifications by using the 4+1 View Model. The 4+1 view model is used to describe the architecture (design) of software-intensive systems using several, concurrent views. The model has four views, which have been detailed for the implementation of ModalNET and the Computational engine for resilient logistics (CERL):

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1. **Logical View:** The logical view is concerned with the system's functionality as it pertains to end-users.
2. **Process View:** The process view focuses on the system's run-time behaviour and deals with the system's dynamic elements. It explains the system processes and how they communicate.
3. **Development View:** The development view depicts a system from the standpoint of a programmer and is concerned with software administration. "Implementation View" is another name to describe it.
4. **Physical View:** The physical view portrays the system from the perspective of a system engineer. The physical layer, it is concerned with the topology of software components as well as the physical connections between these components. "Deployment View" is another name to describe it.
5. **Scenarios:** A small number of use cases, or scenarios, that become the fifth view, are used to illustrate the description of architecture. Sequences of interactions between objects and processes are described in the scenarios. They are used to identify architectural aspects as well as to demonstrate and assess the design of the architecture.

A technical annex is also included in the deliverable to describe an initial data model to be used in ModalNET for the exchange of logistics information.

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1 INTRODUCTION

This report is deliverable D5.1 – ModalNET Specifications, systems architecture and design of cyber-secure communication on Task 5.1 – Specifications, system architecture, and design and on Task 5.2 – Definition of the architecture of cyber-secure communication. VPF was task lead of Task 5.1 and IRTSX was task lead of Task 5.2 and other participating partners were NTUA, SO, ISL, TIC4.0, ALICE and MCG. The task descriptions were as follows:

- Task 5.1. The aim of this task is to identify and document the semantic requirements, technical specifications, and the architecture and design of the integrated supply chain support system (ModalNET), considering the ConOps and requirements documented in T2.5. ModalNET requirements will include the support for the order, planning, execution, monitor and control of the redesigned logistics chains to all stakeholders, and for becoming an EFTI platform to exchange regulatory information and federating with other existing or future supporting digital services and infrastructures. Initial targeted stakeholders will be SSS and IWT operators offering the different freight feeder service loops, port terminal operators, dry ports, road and rail operators participating in the corridors, logistics companies as main customers of the service, and port and maritime authorities. These stakeholders will adopt distinct roles within each individual transport chain that connects with the feeder service, acting as shippers, dispatch parties, carriers, consignees, depositors and depositaries of the shipments and transport units moved. For regulatory requirements and formalities, different competent authorities will be considered in each stage of the transport chain.
- Task 5.2. This task includes the detailed systems functional and operational architecture that will facilitate a secure communication for control and monitoring purposes of the various physical assets. The architecture will support the demonstration of preventive, protective, reactive, and coercive measures against the identified misuse cases and threat scenarios. It will include specification of security means, critical interfaces, communication protocols, and issues related to the integrity of satellite infrastructure (incl. Galileo/GNSS) that can lead to the degradation of important functionalities. It will qualify interfaces to legacy equipment and propose tailored configurations for each demonstrator to be integrated. The work will be related with WPs 3&4, whilst it will depend on the requirements derived from Task 5.1. Interoperability between the physical assets and the logistics stakeholders will be provided through the digitalisation of all available information via standard data formats/structures. This must be harmonized both on a European level as well as the international level. The latter is critical for sea transport that goes to or arrives from overseas locations. This Task will align with IMO's FAL Compendium and Reference Data Model.

The engagement activities have included a set of workshops, focus groups, surveys, and interviews, and they have involved stakeholders within the Consortium, as well as external stakeholders through the tasks carried out in WP2 for redesigning logistics. This deliverable has taken into account the outcomes achieved so far in D2.1 State-of-the-art and baseline for SEAMLESS use cases, D2.2 SEAMLESS reference logistics architecture, standards, and simplified administrative procedures and D2.3 Concept of operations and requirements for SEAMLESS building blocks. ModalNET will be the technology building block #3 Integrated supply chain support and it will take into account the state of the art, specifications, system architecture and design of the other SEAMLESS technology building blocks (WPs: 3 and 4).

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The mentioned building blocks are:

1. Building block #1 - Automated Port Interface (DockNLoad) (WP3)
2. Building block #2 - Modular Ship and Operations Concepts (WP4)

1.1 LINKS TO OTHER WPS AND DELIVERABLES

This deliverable, constituting the work in Tasks 5.1 and 5.2, it is linked to the Tasks 2.3, 2.4 and 2.5 and the building blocks on WPs, 3-4.

1.2 BACKGROUND

SEAMLESS technological ecosystem is composed of three building blocks which will be verified and validated through SEAMLESS demonstrations. The objective is to achieve a fully automated and economically viable, cost-effective, and resilient waterborne freight feeder loop service for Short Sea Shipping (SSS) and Inland Waterways Transport (IWT). ModalNET is one of these three building blocks, and will be used by a consignor or a logistics operator to plan, initiate, and monitor any freight transport from an origin to a destination..

SEAMLESS services will be based on a redesigned logistics system that will facilitate seamless freight flows through the supply chain by minimising delays in intermodal nodes (i.e., where waterborne and land-based transport modes are connected). This includes a SEAMLESS digital “bird’s-eye” view of the supply chain, that allows the exploitation of real-time information (incl. from SEAMLESS physical assets), for planning optimisation and reconfiguration to support resilient logistics.

ModalNET specifications and architecture are split into three blocks related aligned with the three tasks of WP5:

- **Architecture for cybersecure communications (T5.2).** This architecture will facilitate a secure framework for the implementation of ModalNET and the communication of ModalNET with the other building block components.
- **Computational engine for resilient logistics (T5.3).** The engine for resilient logistics will provide the methods and algorithms (e.g. machine learning algorithms for synchromodal dynamic management) required for ModalNET to facilitate synchromodal dynamic management of the supply chain. The computational engine for resilient logistics will be in charge of the optimisation of supply chain risk control measures. It will be based on advanced frameworks for risk analysis and risk-based optimisation considering criteria that contribute towards the resilience of the supply chain and the SEAMLESS feeder loop service. The engine will integrate tools for risk identification, assessment, and evaluation of candidate mitigative measures.
- **ModalNET platform (T5.4).** The implementation of ModalNET will include publication of a set of APIs and connectors to federate ModalNET with other platforms, systems and formalities. ModalNET will be designed to become an EFTI platform, interfacing with EMSWe or RIS systems to comply with the ship formalities required by the autonomous freight feeder loop services to navigate and call at the ports along its route. As the loop service will be regular and with predictable operations, it will allow for automated reporting to competent authorities. The

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implementation of ModalNET will be carried out following a continuous integration and delivery approach (CI/CD) via agile development techniques, splitting the platform into backend and frontend components. The former will provide identification, access control, security, storage services through big data technologies, server-side application logic for the logistics network, connectors with external systems and API interfaces. The latter will provide the HMI with responsive performance, good design and user experience. The deployment of ModalNET will use cloud technologies and solutions like virtual machines, clustered databases, software containers (e.g., docker) and container orchestrators (e.g., Kubernetes, docker swarm) looking for a secure, highly available and scalable solution. ModalNET will exploit real-time information from all entities (physical/digital) in the supply chain to support logistics planning, timely identification of disruptions, faults and failures and will communicate this information to the computational engine for resilient logistics.

1.3 METHODOLOGY

The methodology to present the ModalNET system architecture and specifications will be the 4+1 View Model published by Philippe B. Krutchen[1]. This technique is effective for understanding the views and perspectives of different stakeholders organizing the description of a software architecture using a set of concurrent "views," each addressing unique concerns for different stakeholders[2]. The 4+1 view model is used to describe the architecture (design) of software-intensive systems using several, concurrent views. End users, developers, system engineers, and project managers all have unique views on the system, hence viewpoints are used to describe it from their perspectives.

The model has four views: logical, development, process and physical. In addition, selected use cases or scenarios are utilized as the 'plus one' view to show the design.

1. **Logical View:** The logical view is concerned with the system's functionality as it pertains to end-users.
2. **Process View:** The process view focuses on the system's run-time behaviour and deals with the system's dynamic elements. It explains the system processes and how they communicate.
3. **Development View:** The development view depicts a system from the standpoint of a programmer and is concerned with software administration. The implementation view is another name for this view.
4. **Physical View:** The physical view portrays the system from the perspective of a system engineer. The physical layer, it is concerned with the topology of software components as well as the physical connections between these components. The deployment view is another name for this view.
5. **Scenarios:** A small number of use cases, or scenarios, that become the fifth view, are used to illustrate the description of architecture. Sequences of interactions between objects and processes are described in the scenarios. They are used to identify architectural aspects as well as to demonstrate and assess the design of the architecture.

[1] Philippe B. Krutchen. Rational Software. **The 4+1 View Model of Architecture**. IEEE Software. 1995
[2] Pasan Devin Jayawardene. **4+1 Architectural view model in software**. Javarevisited. 2021
Available in: 4+1 Architectural view model in Software | by Pasan Devin Jayawardene | Javarevisited | Medium

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Additionally, given the relevance to create cybersecure systems capable to work in an open and federated environment where other different platforms will be connected to ModalNET, we have introduced an additional layer to define an **architecture for cybersecure communications** on top of the 4+1 view model methodology based on the results achieved in T5.2.

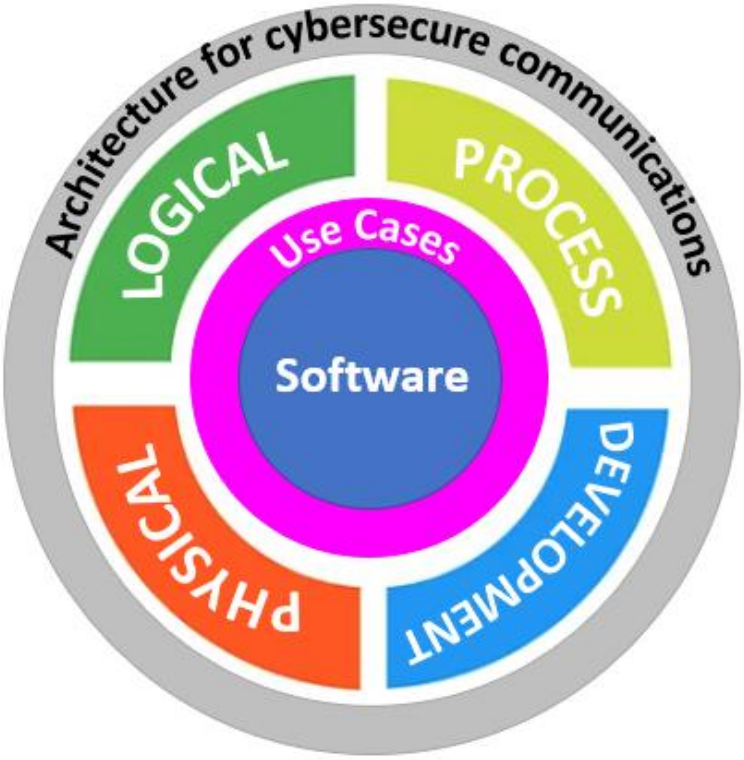

Figure 1. The 4+1 architectural view model in software including the additional layer for the architecture of cybersecure communications

Source: 4+1 Architectural view model in software

Before defining the ModalNET specifications and architecture, next chapter presents the baseline analysis of all SEAMLESS building blocks and components that will be related with the implementation of the platform.

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2 BASELINE ANALYSIS TO BUILD SEAMLESS MODALNET PLATFORM

For the specifications, system architecture and design of ModalNET and the cyber-secure communications it is important to characterize the SEAMLESS established baseline in all its building blocks to carry out this activity. This activity includes the review of the state-of-the-art, the functional specifications established in the project, the system architecture, and the design of other SEAMLESS building blocks.

2.1 BUILDING BLOCK #1. AUTOMATED PORT INTERFACES

WP3 will develop the SEAMLESS **Building Block #1 Automated Port Interfaces**. It will optimise SSS and IWW port processes for cargo handling, storage, and seamless transhipment to hinterland, develop a digital stowage plan system to facilitate the automated bay planning and stowage planning of the ship at different loading and discharging points, ensure safe and secure autonomous mooring and cargo handling and establish new digital interfaces related to automated ship-port interaction including arrival planning and execution, berthing, mooring and cargo handling.

Task 3.3 is providing the SEAMLESS automated cargo voyage planning and stowage execution platform which will be based on the **Voyage and Container Optimisation Platform (VCOP)** solution of MacGregor. The main user of the VCOP platform is the liner operator. However other participants can use this platform for automating the cargo-handling processes.

The automated stowage planning which is required for automating cargo-handling will cover the identified requirements for automation and optimization of the cargo-handling processes and the interfaces towards other parts of the logistics system covered by ModalNET. The VCOP is a web-based application that facilitates the liner (SSS or IWT) operator, the loading and discharging of cargo containers to/from ships for port operations. This solution considers all the needs of the entire cargo shipment process. This includes the reception of cargo booking to prepare the cargo planning and the cargo delivery. Each perspective of this process has been designed and consolidated in the VCOP solution, and they interact with each other through REST-API.

Task 3.6 is providing the **Autonomous Ship Smart Port Manager (AVSPM) sandbox** for the development of the digital port call. The main user of this component will be the port authority in charge of the ship port call.

This component is intended to be integrated with existing and future smart port solutions. It will include just-in-time arrival planning, berth allocation and mooring. It will take into account new digital interfaces for automated ship-port interactions. It will also consider the future authority/VTS exchanges via VHF Data Exchange System (VDES) and standards being developed at international working groups such as DCSA. The functionalities considered in the AVSPM will be safety and security monitoring of the ship port call, port call planning/optimization and change management, exchanging information about situational awareness (e.g. weather conditions, ship positions, etc.). The AVSPM prototype will be implemented only in the port of Antwerp to enable testing of autonomous barges making port calls with limited scope and involving fully understood risks, which will be demonstrated in the full-scale demonstration conducted in T7.4.

Task 3.4 is establishing the concepts for automated port interfaces and intermodal cargo forwarding to the hinterland. This task will provide the initial requirements to optimize port processes for cargo handling and storage (i.e. minimise cargo residence time) for seamless transhipment to the

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hinterland. This task will provide valuable inputs for the design of ModalNET platform for the processes involved within the hinterland-port interface (i.e. gate-in and gate-out operations) and the sea-port interface (i.e. ship port formalities and ship loading and discharge operations).

2.1.1 VCOP: Functional specifications

The main user of the VCOP platform is the liner operator. However other participants can use the information available in this platform for automating the cargo-handling processes.

Cargo owners and cargo bookers can use their current booking systems solutions and communicate with VCOP through REST API. In the loading and discharging phase VCOP is able to communicate with crane systems (whether located on-board or on-quay) in order to update the status of the process. This machine-to-machine capability will help terminal operators to achieve automated solutions.

A **liner operator** can register the schedule for a ship to call at a port in a voyage. The data included is the voyage number, the port, the estimated arrival time and the estimated departure time.

The **schedules** of the ships registered in VCOP by the liner operator will be sent to ModalNET platform and used by the **Transport planning** and the **Computational engine for resilient logistics** modules of ModalNET.

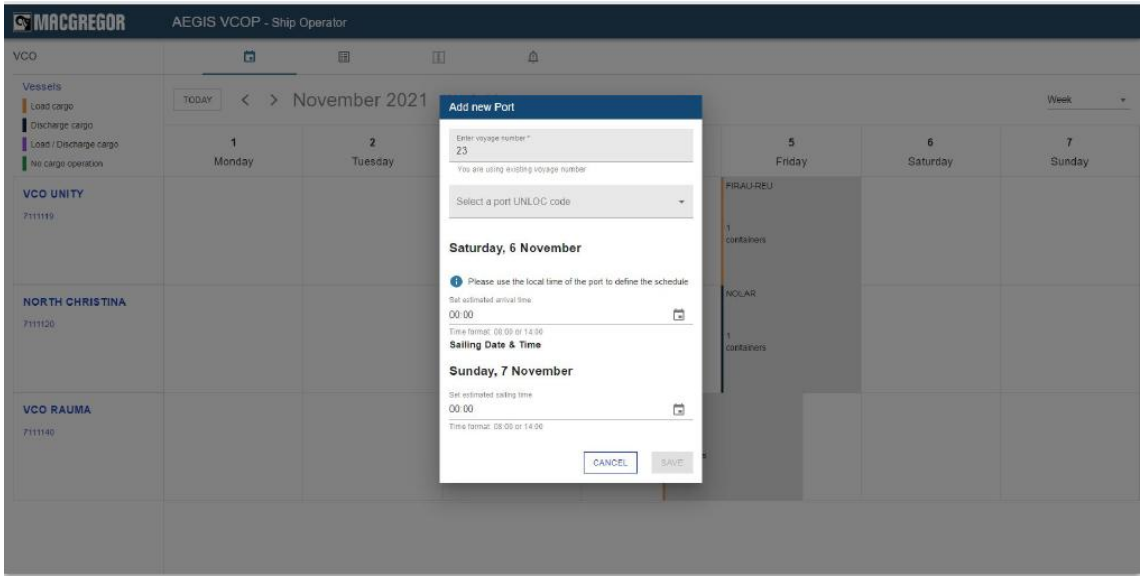

Figure 2. Addition of a new port berth schedule in VCOP.

Source: VCOP Platform. MacGregor

A **cargo booker** or **cargo owner** can register the set of container data that will be send to the bay planner of the liner operator.

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Booking data for the whole transport, including hinterland transport, will be registered by cargo bookers or cargo owners to ModalNET **booking and shipment ordering** module and used by the **Computational engine for resilient logistics** to provide the best transport options. Cargo bookers or cargo can select the best option suggested by this engine and **ModalNET will be transferring the sea or IWT booking to VCOP**.

The data included in the platform for a cargo booking is: ship voyage, booking number, container number, container type, container weight, required temperature, cargo origin address, cargo destination address, port of origin, port of destination, terminal discharge position, truck driver and, possibly, there will be other booking and container data registered in the platform which are not yet known from the initial analysis. A booking can have multiple containers.

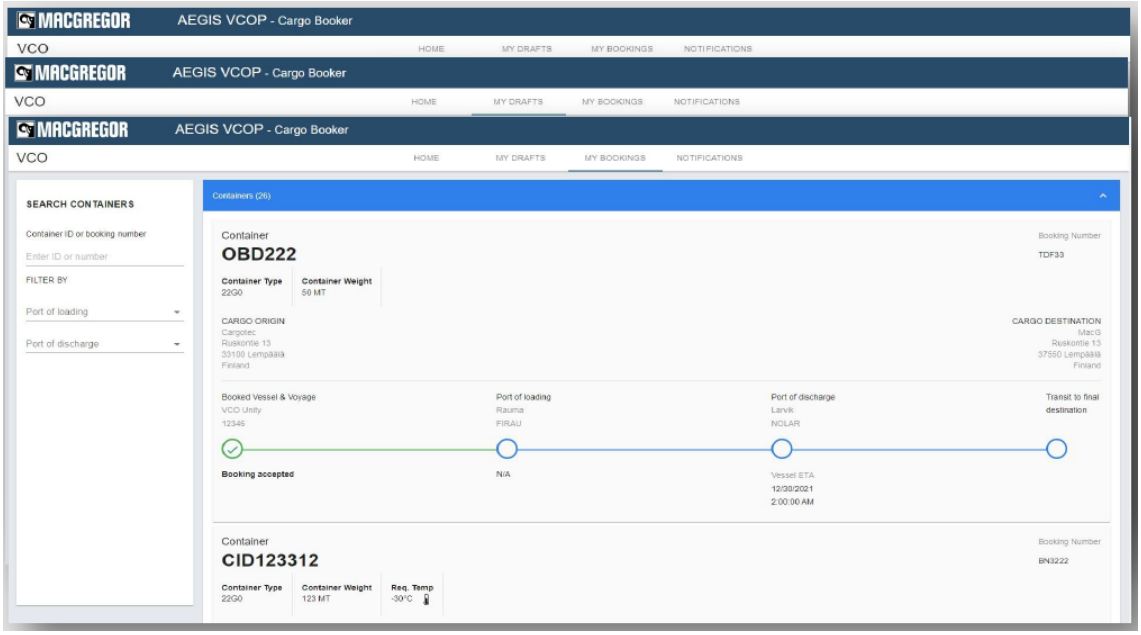

Figure 3. Information of container data registered by a cargo booker in VCOP.
Source: VCOP Platform. MacGregor

The **bay planner** of the liner operator receives the container data from the cargo booker and through an external planning engine the containers are planned to be loaded or discharged from the ship.

VCOP will send the (un)loading ship sequence at a port to the **port terminal** and to **ModalNET** for **cargo traceability**.

When the (un)loading ship operation takes place, VCOP will receive the **port handling status reporting** from the **port terminal,** and it will generate the **(un)loading status reporting**.

VCOP will send (un)loading status reporting at a port to the **port terminal** and to **ModalNET** for **transport planning** and **cargo traceability**.

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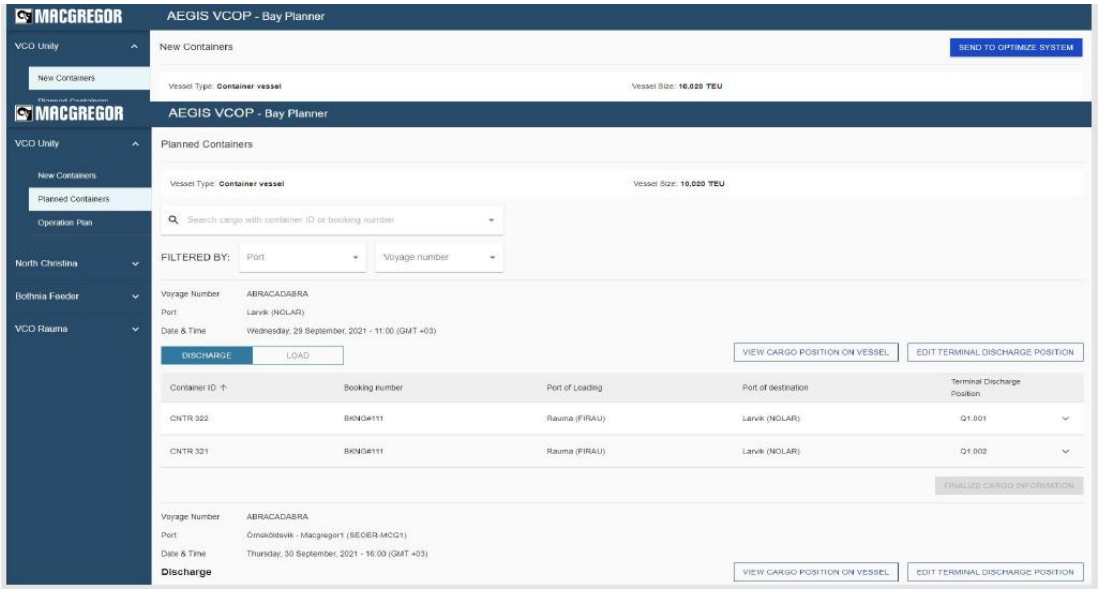

Figure 4. Information of discharge and load operations managed by the bay planner in VCOP.
Source: VCOP Platform. MacGregor

The **terminal operators** can view a summary of the port operations.

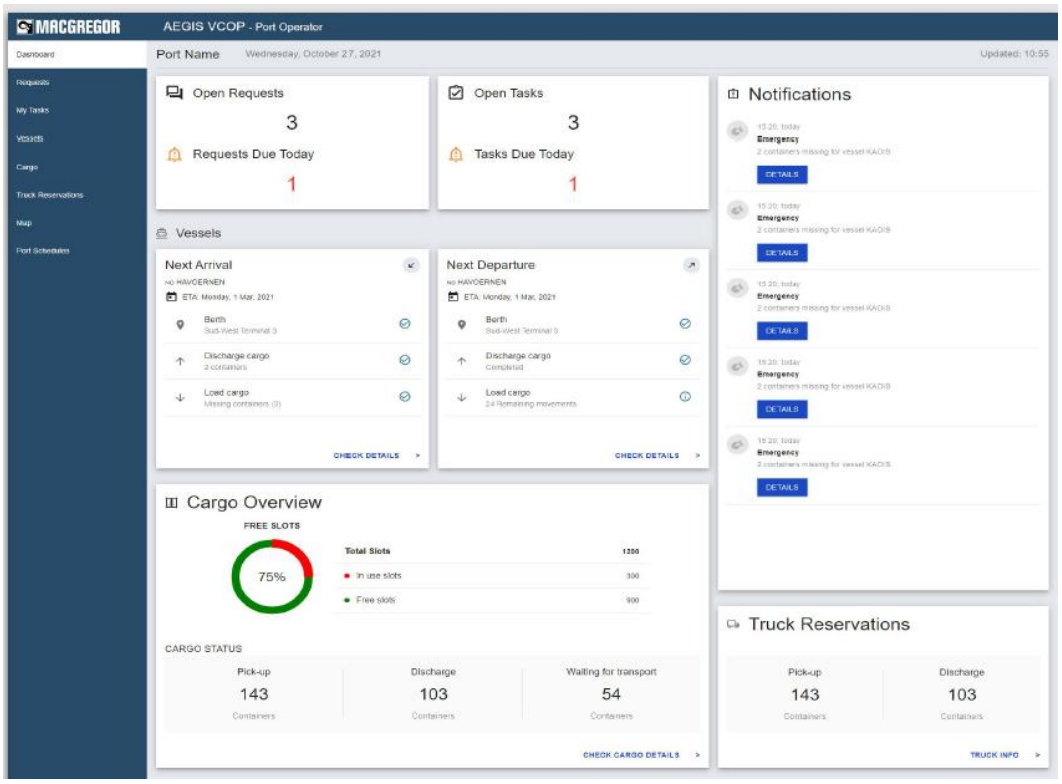

Figure 5. Port operations view in VCOP.
Source: VCOP Platform. MacGregor

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On board professionals can view the ongoing and future load and discharge operations in real time.

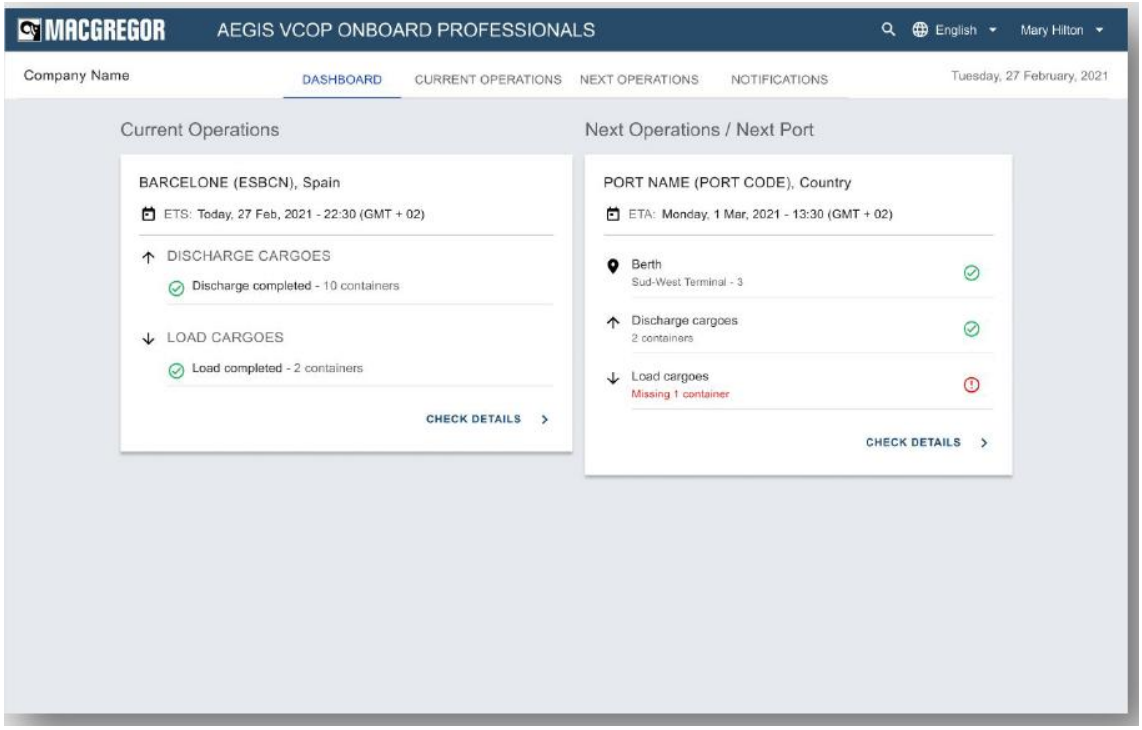

Figure 6. Onboard professionals view in VCOP.
Source: VCOP Platform. MacGregor

Truck drivers receive notifications where there is a task for them to pick up or deliver a container to the quay.

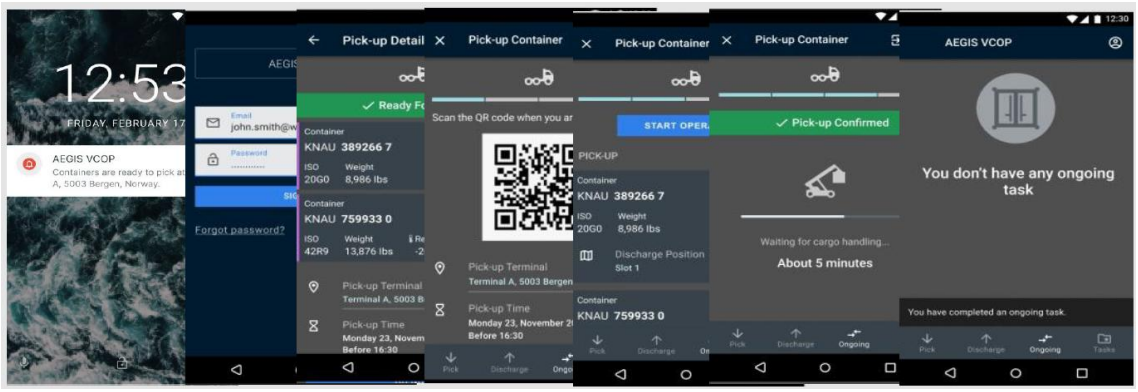

Figure 7. Notifications to truck drivers in VCOP.
Source: VCOP Platform. MacGregor

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Cargo owners are able to search through all their cargo, check their status and see their condition.

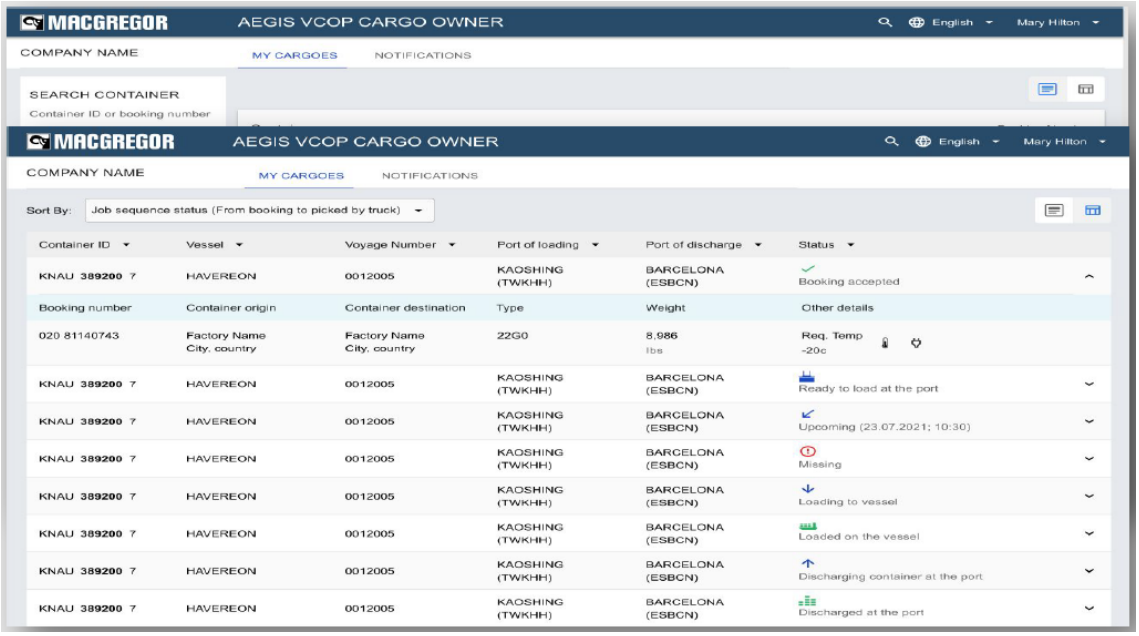

Figure 8. Cargo owners view in VCOP.
Source: VCOP Platform. MacGregor

Cargo owners/bookers, road operators and liner operators will be able to have a full visibility of their shipments and transport operations in the ModalNET through the **cargo traceability module**. They will not only consider the sea/IWW legs but also the inland transport legs.

2.1.2 AVSPM: Functional specifications

The Autonomous Vessel Smart Port Manager is a software prototype, developed by AWAKE.AI, intended for integration with existing and future smart port systems to enable SSS and IWW autonomous vessels to make safe port calls (incl. just-in-time arrival planning, berth allocation, mooring). It will take into consideration the requirements for new digital interfaces for automated ship-port interactions, considering future authority/VTS exchanges via VHF Data Exchange System (VDES) and standards being developed at international working groups such DCSA. This task will specify the system components and define the architecture required to implement functionalities including safety and security monitoring, port call planning/optimisation and change management, exchanging information related to situation awareness (e.g., weather conditions, vessel positions etc.).

The main user of this component will be a port authority in charge of the ships' port calls, and it will be initially prepared for a remote and autonomous barge to make visits through AVSPM tool. The software will require a first step for the *"Technical Setup for RA Barge identification, Secure Communication and Authentication"* that will provide the technical enablers for secure communication, authentication and barge particular information. Communications between barges and remote-control centre will be done through mTLS (mutual TLS) certificate. This will provide a

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secure authentication mechanism to ensure that the caller is a known entity, and that the authentication setup across barges and the AVSPM will be done via secure APIs.

The barge company will provide certain technical information about barge particulars. Things like name, ID, flag, length, width, min & max draft. This is used in planning, for route creation and for safety issues.

AVSPM will be used by port authorities to collect information regarding barges from liner operators or their shipping agencies, while ModalNET will provide a ship reporting module to liner operators or their shipping agents for the **maritime single windows or to other ship formalities reporting systems** to authorize the ship arrival, shift or departure from the port. The use of both systems will be complementary

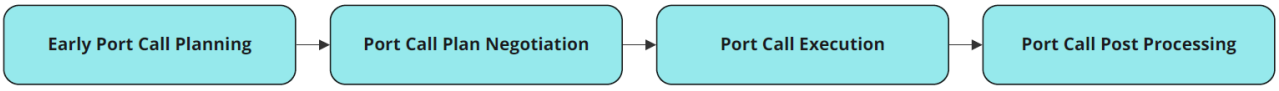

Figure 9. Main phases of the RA Barge port call.

Source: AWAKE.AI

Main phases of the remote and autonomous barge (hereafter named RA Barge) port call will be:

1. Early Port Call Planning: AVSPM can create a draft port call reservation for some weeks before actual port call. Less data is mandatory at this early stage. This draft will be pre-approved by the AVSPM making it verified that this plan can be accepted at this time but does not verify that when its execution time is reached it can still be accepted.
2. Port Call Plan Negotiation: Actual near-term port call planning with all the mandatory details. Some hours before arrival to port. Like 24 / 48 hours, depending on port rules. Smart Port checks berth status, route plan, cargo, timings etc. to find out if port call plan can be accepted or it must be modified or even totally denied.
3. Port Call Execution: When the barge arrives, it initiates its execution. RA Barge starts its voyage to the planned port terminal & berth or sometimes it is just being transferred to port area. There could be also multiple berth visits (berth shifting).
    I. (Anchoring)
    II. Arrival
    III. Port Manoeuvring (including possible locks)
    IV. Berth Stay(s)
    V. Departure

4. Port Call Post Processing: After port call has been fully executed (RA barge has departed port area) there is a post port call step where port call data is saved for later analysis. Basic events are captured for reporting purposes, such as geofence and other events, planned & actual route, navigation decision, emissions and so on. Finally, a report is created (and in later versions data is fed to the ML model(s) to improve them).

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Additionally, the following steps can be taken anytime during the phases previously commented:

- Meteodata Exchange: Remote and autonomous barges can request meteodata from Smart Port. These are observations from port sensors and weather forecast calculations. Also, RA Barge can send meteodata to the port like hyperlocal wind and current conditions it has observed during the voyage.
- Traffic Data Exchange: Smart Port can provide real-time traffic data like nearby ship positions with AIS + Radar accuracy. This data could be used by RA Barge for collision avoidance.
- Safety pulse: This is triggered by the Smart Port at regular intervals towards the RA Barge and ROC. It ensures that connectivity is available to both parties consistently. If connectivity thresholds are breached a safety event is triggered. It is likely that RA Barge is informed in the port call negotiations that inside a given geofence area it must be the initiator of the safety pulse (like UDP packet communication to Smart Port).
- Safety Event: Whenever some level of safety event is automatically detected or manually triggered this phase of the port call has special processing.
- Port Call Plan Change Management: Port call plans can change for many reasons and this capability will manage these changes. Change proposals can be triggered from smart port and ROC.
- Port Call Monitoring: When port call plans start their execution, they are monitored for many reasons. Mainly deviations from plans are detected and warnings or alerts can be raised.
- PNR Pulse: Position, navigation and route pulse. RA Barge informs Smart Port of their position, navigation status and planned route for the next preconfigured (like 10) minutes especially within the port area.

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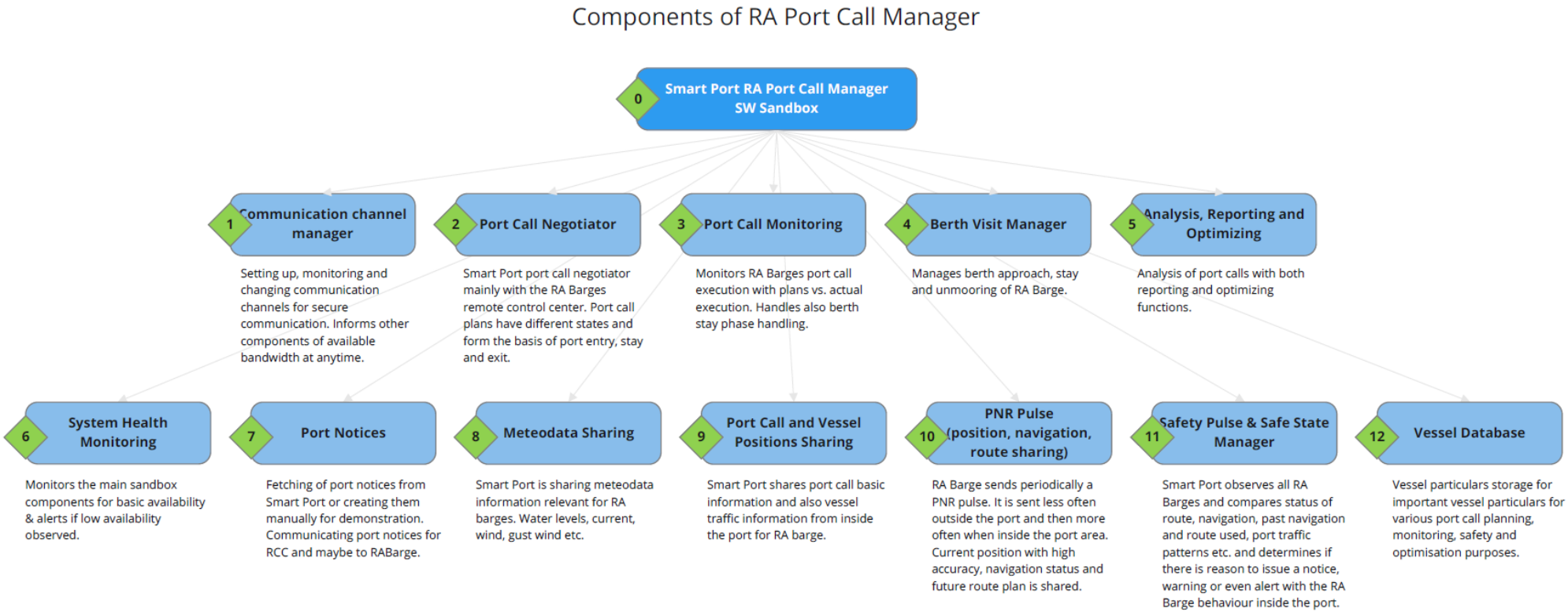

Figure 10. Components of RA Port Call Manager.

Source: AWAKE.AI

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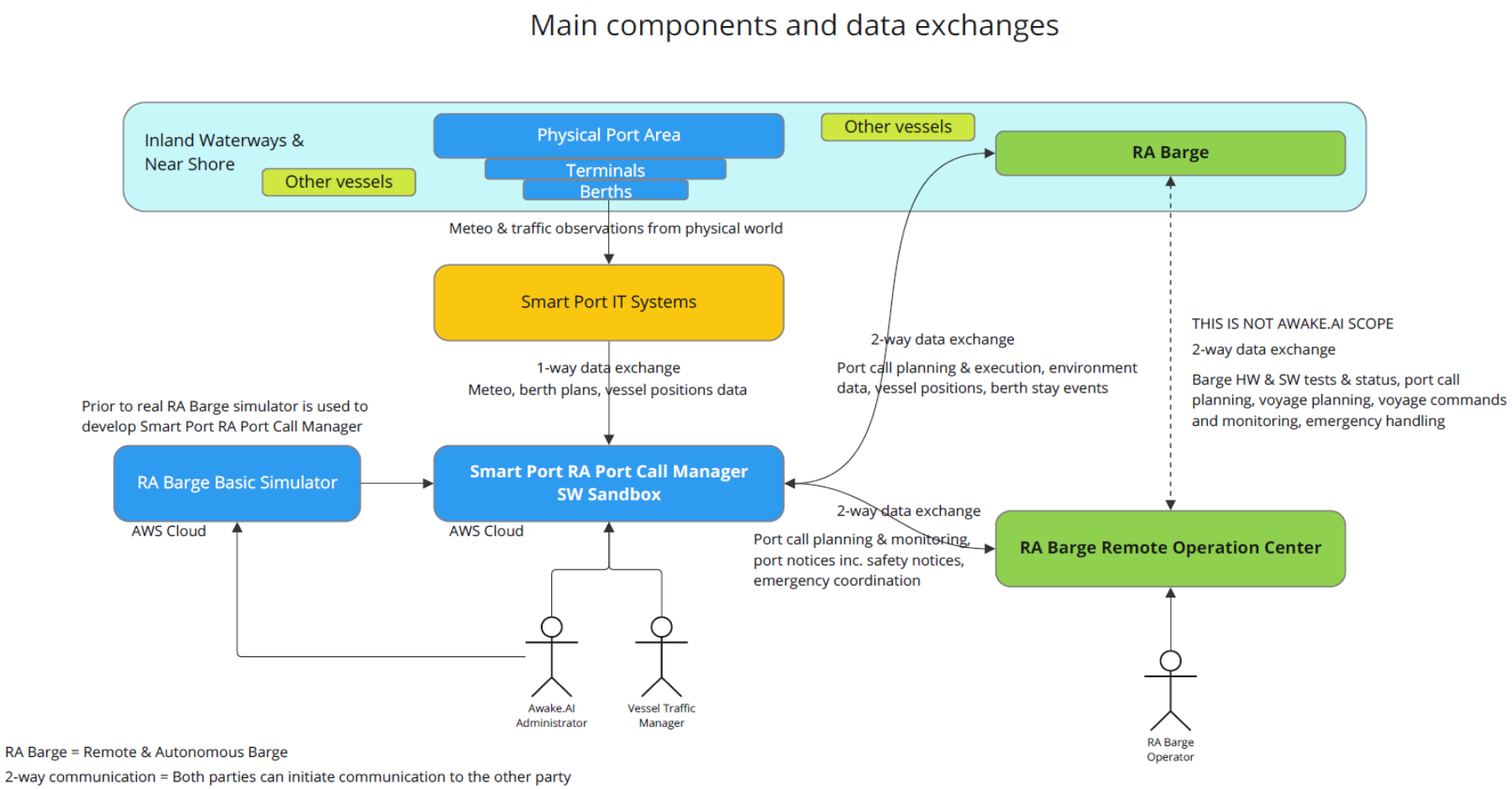

Figure 11. Figure 11. Main components and data exchange

Source: AWAKE.AI

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2.1.3 Automated port interfaces and intermodal cargo forwarding to the hinterland

At this stage, we will outline the functionalities needed for the Automated Port Interface system and how it will interface with VCOP and the TOS derived from the analysis made on D2.3 Concept of operations and requirements for SEAMLESS building blocks. It is important to note that there is no standardized TOS system, implying that operational procedures, technology, and interconnection systems may vary. Thus, it is essential to anticipate this variability in the processes. Moreover, it should be considered that there may be cases in which port terminals do not have computerized support for the development of operations. As an example, in Use Case 1 at the Moss port terminal, the truck access controls to and from the terminal are carried out manually and currently both Moss terminals can be visited without prior unannounced, according to chapter "*2.1.2.2.2 Existing transport concept"* within deliverable *"D2.1 State of the art and baseline for SEAMLESS Use Cases".*

The communication between systems will be through REST APIs, both between VCOP and ModalNET, as well as between VCOP and TOS or TOS and ModalNET. As established earlier in this document, as well as in the progress of D3.4, all the mentioned systems have the capability to intercommunicate through REST APIs.

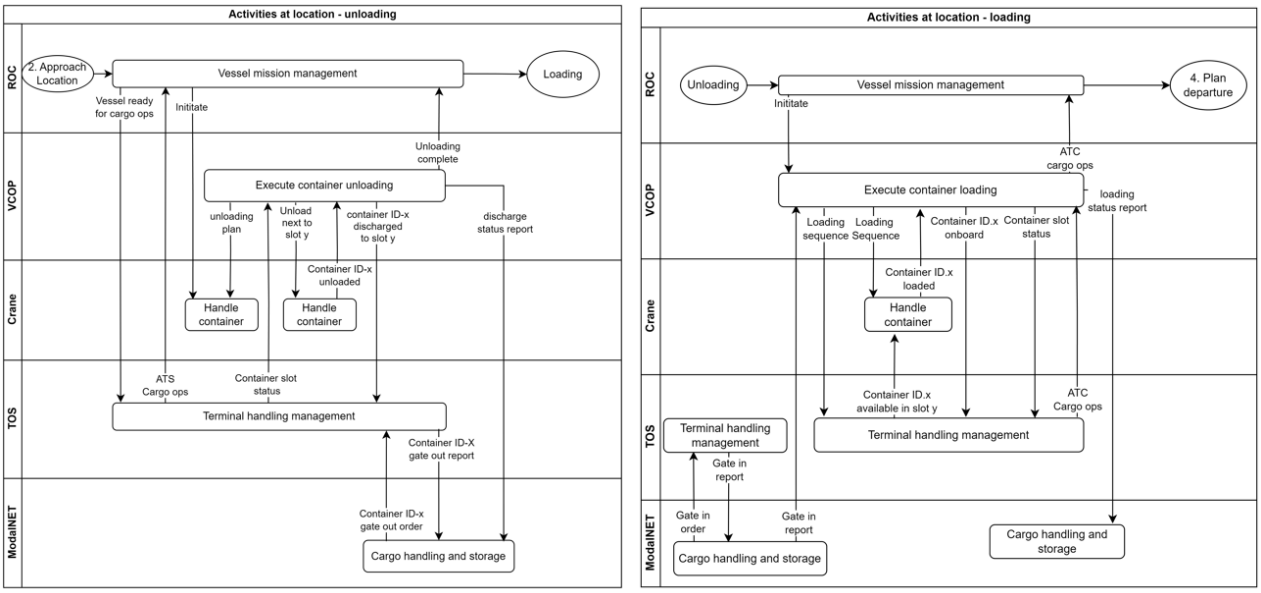

Figure 12. Activities at location, unloading and loading.
Source: SEAMLESS D2.3

At this point, there are two crucial processes. On one hand, it involves the connection with the hinterland (truck or train) through gate-in and gate-out, and on the other hand, it concerns the connection with the ship through the loading and discharge process. In both cases, ModalNET should notify, for instance, in the gate-in and gate-out processes, by sending both the reception and delivery orders and receiving the report once the operation is completed. In the case of loading and discharge, ModalNET only needs to receive a report for each case illustrated in Figure 12.

Beginning with the analysis of gate-in and gate-out orders, this notification is sent by ModalNET to the involved terminals. As mentioned earlier, there is a possibility that the terminals may lack digital resources for the proper control of cargo reception and delivery. In the best-case scenario, the facilities may have a TOS (Terminal Operating System) that manages either an Automatic Gate

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System or at least considers the possibility of manually handling gate-in and gate-out processes. In either case, the TOS would receive the necessary notification through a REST API connection, integrating it into its operations to fulfil the order. In the absence of such resources, ModalNET considers the option for terminal operators to access order information through the interface and manually fulfil the request in user mode.

Cargo/container depositors will provide **the gate-in and gate-out orders** through **ModalNET cargo handling and storage module** to the **automated port interfaces and terminal operating system of the port terminal.**

Continuing with the reception and delivery reports, these are notifications indicating that both gate-in and gate-out, as well as loading and discharge, have been carried out as ordered. If we analyse the gate-in and gate-out report, ModalNET will receive the information in the same way the order was communicated if the terminal has a TOS. In this case, internally, the gate systems will instruct the TOS that the container in question has exited or entered the terminal as expected. In the absence of a TOS, ModalNET will have the option for the terminal to access ModalNET in user mode and manually notify that the container has been delivered or accepted as agreed.

In the specific case of loading and discharge, the communication will be directly between ModalNET and VCOP. In both loading and discharge, VCOP will use the aforementioned REST API connection to provide information about the status report. Prior to this, VCOP will have the list of bookings to be loaded and unloaded from a particular ship, and the necessary bay planning will have been carried out and communicated to the ROC for approval. Once the ship and the terminal are ready to begin operations, the loading and unloading orders are executed between VCOP, the TOS, and the crane without ModalNET's intervention until it receives the report from VCOP confirming that the containers have been loaded or unloaded.

Port terminal automated port interfaces and terminal operating system will provide **the gate-in and gate-out reports** to **ModalNET cargo handling and storage module** and it will be used in the **cargo traceability module.**

2.2 Building block #2. Modular Ship and operations concepts

The objectives of WP4 are to develop SEAMLESS Building block #2 for the Modular ship and operations concepts, developing a rapid prototyping method for evaluating candidate concepts/designs for SSS/IWT autonomous systems, produce concept ship designs optimised for the SEAMLESS Use Cases, develop fault-tolerant, COLREG-compliant GNC scheme for SSS and IWT autonomous ships, develop risk-based safety assessment for cost-effective approval of SSS and IWT autonomous ships, develop standardised Human Automation Interfaces (HAI) for ROC operators, ship-operator low attention functionality and EU satellite navigation services (Galileo /GNSS) and communication of ship to ship and ship to shore.

The concept design for autonomous ships for the SEAMLESS use cases, such as the type of cargo to be carried and ship capacity, the area of operation and the charging/refuelling times, will directly influence the logistics concept design which will need to be supported by MODALNET platform.

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ModalNET will be designed to handle any type of cargo (e.g. conventional cargo, containerized cargo, ro-ro cargo or bulk) for any capacity and capable to work in any area. The **computational engine for resilient logistics** needs to model the logistics network the autonomous ship will be serving.

The **ship (fleet) mission planning component** of the remote operations centre (ROC) is of particular interest in connection with the integrated supply chain. In particular, the systems for the planning, management, and control of multi-ship operations from the ROC should be able to provide to MODALNET platform reliable ship estimated and actual arrival and departure times for each port along its route. Estimated times should be updated each time there are a deviation of these times according to the navigation and operations of the ship which are monitored in the ROC.

ModalNET will receive planned and actual data along its route from the **ship (fleet) mission planning component.** Estimated and actual arrival and departure times will be managed in ModalNET transport planning and cargo traceability modules.

2.3 Building block #3. Integrated Supply Chain Support

The objectives of WP5 are to develop SEAMLESS building block #3 for the integrated supply chain support (ModalNET), determine the requirements for efficient, secure, and resilient data management (incl. physical assets telemetry) by exploiting data spaces and SoTA cybersecurity practices, develop the architecture required for secure communication among the physical assets participating in the supply chain, introduce a digital collaborative communications framework among terminal operators, road operators, liner operators and logistics companies (ModalNET platform) and develop the ModalNET computational engine for achieving synchromodal and resilient dynamic management.

SEAMLESS services will be based on a redesigned logistics system that will facilitate seamless freight flows through the supply chain by minimizing delays in intermodal nodes. It will provide a digital twin that will provide a digital “bird’s eye” view of the supply chain and synchromodal dynamic management through adaptive logistics (i.e., automatic organization and reorganization of the transport chain). Physical assets of the SEAMLESS building blocks will be digitally connected to exchange information in real-time in an implementation of the Physical Internet concept.

ModalNET will include the following automated functionalities:

- when a shipper or logistics operator will be planning and initiating any freight transport from a point of origin to a point of destination, the platform will inform about the best combination of transports, as well as the point of delivery and pickup for the feeder service,
- calculate the most suitable schedule to predict route performance,
- organize the transport chain by generating all the booking and shipment orders for the different modes of transport,
- calculate the associated transport charges,
- manage administrative and documentary procedures.

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To achieve these functionalities, ModalNET platform will be taking advantage of the **matchmaking platform** initially developed by NTUA in the H2020 MOSES project[3] and the **logistics digital platform** initially developed by Fundación Valencia port in the H2020 DATAPORTS project[4].

The MOSES matchmaking platform will be the basis for the development of the **computational engine for resilient logistics**. It will be adapted to the SEAMLESS needs and specific requirements for the planning and initiation of a freight transport from a point of origin to a point of destination and for the calculation of the most suitable schedule to predict route performance within task 5.3.

DATAPORTS digital logistics platform will be adapted to provide the ModalNET **booking and shipment ordering, transport planning, ship reporting, cargo handling and storage,** and **cargo traceability** modules within task 5.4.

2.3.1 MOSES Matchmaking Platform

The MOSES matchmaking platform has been developed to support digital and horizontal collaboration among the logistics services supply group and the logistics services demand group to match demand and supply of cargo volumes by logistics stakeholders.

The platform should be initialized by the data provided by the service providers. Service providers inform the platform with ship schedules for a rolling period of at least 2 months.

For the implementation of the ModalNET **computational engine for resilient logistics** automatic interfaces should be envisaged to register the schedules of SEAMLESS ship services from other components, such as VCOP. Probably more data fields will be required to create the computational engine for resilient logistics.

[3] Moses project (moses-h2020.eu)
[4] DataPorts project (DataPorts-project.eu)

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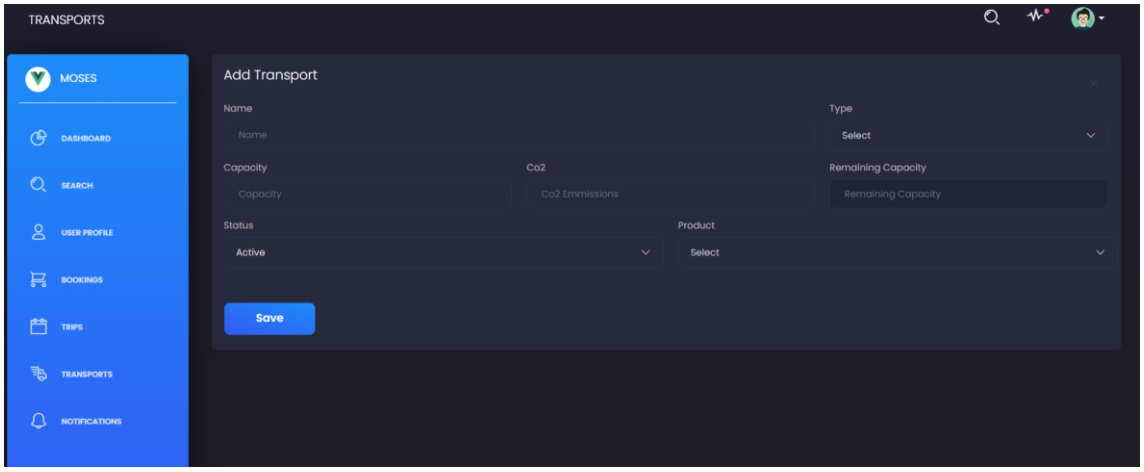

Figure 13. Transports input form in MOSES matchmaking platform.
Source: NTUA

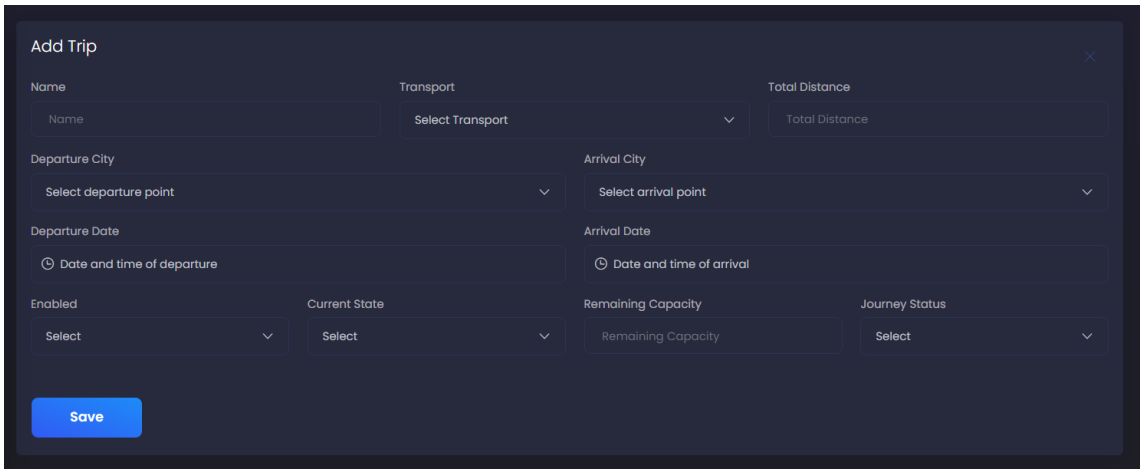

Figure 14. Trip input form in MOSES matchmaking platform.
Source: NTUA

The transport consignors (logistics services demand group as defined in this platform) can search for trip schedules, place transport orders and get notified once the service provider confirms the agreement of this order. The consignor can place an order with their transport needs and the system will look for the optimal transport schedule. When a matching is found both the transport providers and the consignor are notified. The platform utilizes registered ship and train schedules data plus the inland truck connections to build a model of the entire transport network.

The computational engine for resilient logistics will need to configure the transport networks where SEAMLESS transport services are offered.

"Transport orders seem to be filled within the bookings or with other functionality, but it was not accessible during the analysis."

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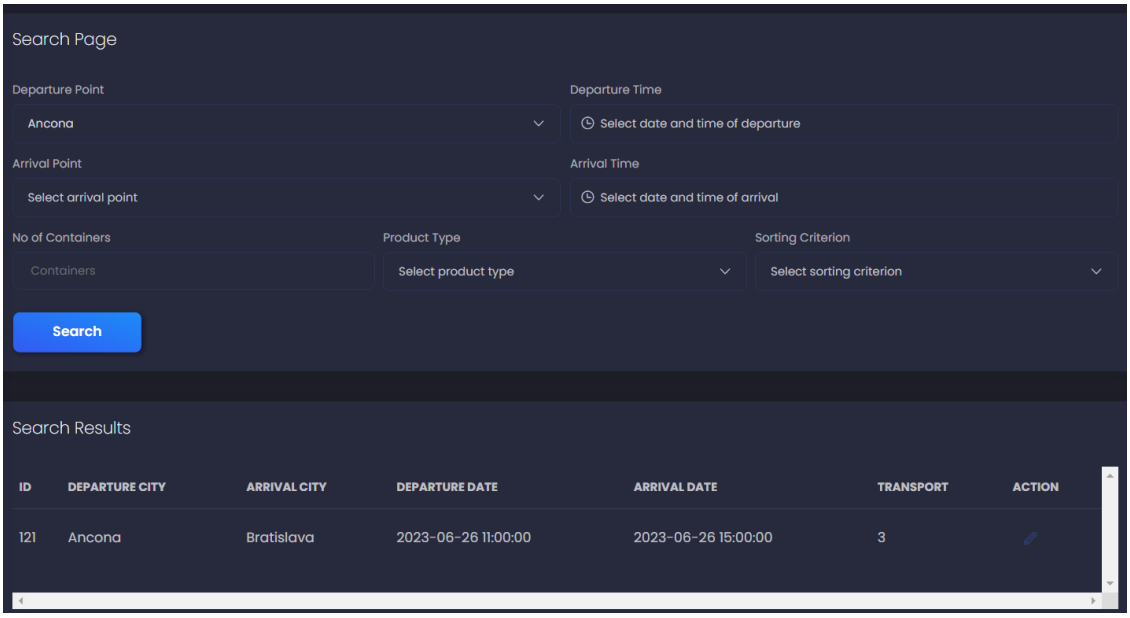

Figure 15. Trip list in MOSES matchmaking platform.

Source: MOSES AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping. NTUA

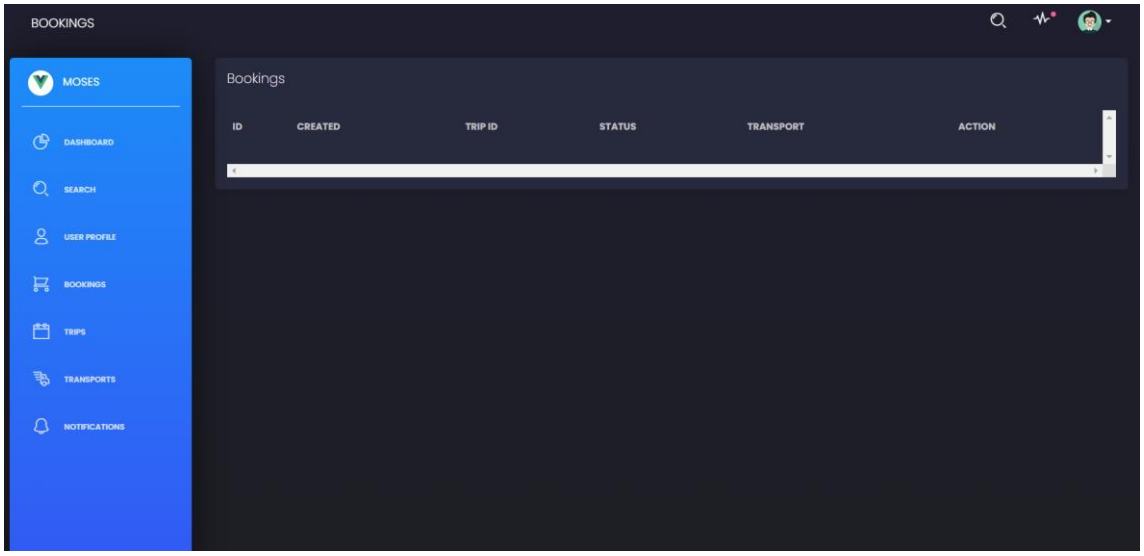

Figure 16. Booking list in MOSES matchmaking platform.

Source: MOSES AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping. NTUA

MOSES Matchmaking platform covers a logistics functionality for matching requests to transport goods placed by a logistics service demand group (consignors) with the transport and trips registered by the logistics services supply group (transport operators).

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2.3.2 DATAPORTS Logistics Platform

The DataPorts Logistics platform was designed to provide a logistics digital twin shared among all logistics stakeholders. The platform included a comprehensive, flexible and complete semantic and data model capable of registering logistics data from any transport mode and any transport data. This digital platform will be used as the starting point for building the ModalNET platform.

The project was devoted to the creation of a secure data platform that allowed sharing the information not only between port agents but also between other ports. Hence, it generated a secure environment of data exchange in a reliable and trustworthy manner, with access permits and contracts to allow data sharing and the exploration of new Artificial Intelligence and cognitive services. DataPorts platform aimed at providing to seaports a secure and private aware-environment where data coming from several sources could be shared by the stakeholders in a trusted and reliable way, in order to get real value from those data, providing a set of novel AI and cognitive tools to the port community.

DataPorts platform was used as a hub for tracking events in the context of a port to which port stakeholders could subscribe to. The data providers will publish relevant information related to a unique identifier relevant in a maritime logistic chain: a container identification number, a ship identifier, or a goods identifier. Such published events will be available to data consumers using the DataPorts data governance framework. For instance, a freight forwarder using DataPorts subscribes to every event related to a container identification number and/or the ship transporting such container. If access is granted by the owners of the data, this freight forwarder will receive in near real-time such events, which can then be used to improve its transport operations. The freight forwarder could, for example, be notified when the ship with the container has arrived at the port, or when the container has left the port facilities by truck, etc. DataPorts will provide a single access point for all the relevant events without the need of implementing specific integration or authentication mechanisms for each data provider. As every event data/message follows the data model already defined by DataPorts, also the process of understanding the received data is simplified: there is no need of understanding the underlying information system of the data provider.

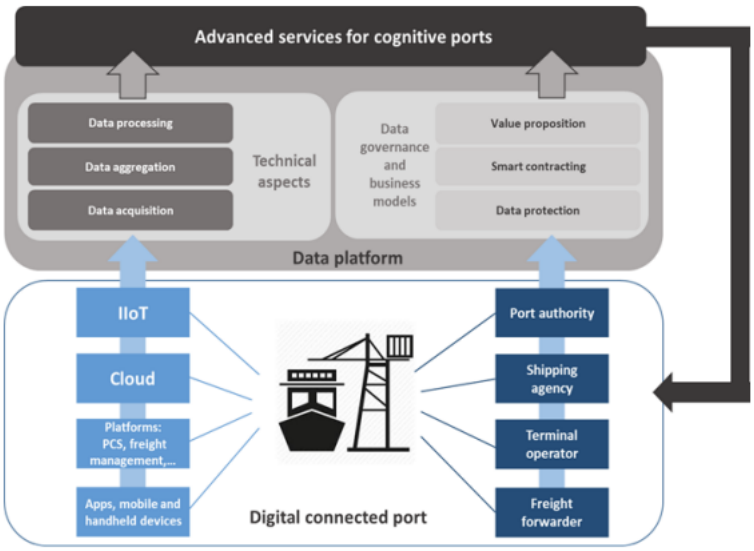

Figure 17. DataPorts project overview.

Source: [Overview | DataPorts (dataports-project.eu)]

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The main data assets to fulfil these capabilities are:

- **Branch Office**: A branch office of an organization, company or public entity that provides and/or consumes logistics and transport services or reporting formalities to move a shipment from an origin to a destination. A branch office can be the headquarters or a branch office located in a given place.
- **User**: A user or data subject is a physical person, or a system associated with an office that is allowed to connect to the platform. The user data entity will compile all the data about the user and associated security tokens that could be used to identify the user in this platform or in external platforms, the email subscriptions and the roles which have been assigned to the user by a user manager.
- **Consignment:** A consignment refers to the process of transporting goods or products (i.e. shipments) from one location to another, typically involving packaging, handling, and delivery.
- **TransportUnit:** A transport unit refers to a standardized container, pallet, or other load-carrying device used for the efficient transportation of goods by various modes of transportation such as trucks, trains, ships, or airplanes. A transport unit data entity in the platform will always be associated and registered together with a shipment (i.e. a maritime container will be a transport unit associated to a maritime shipment).
- **Transport:** A transport refers to the movement of one or multiple shipments from one place to another using a vehicle (i.e., truck, ship, barge, train or aircraft). A transport will always be registered by the carrier.
- **Vehicle:** A vehicle is a mechanical device designed for transportation that is typically powered by an engine or motor. There can be different types of vehicles for different transport modes such as trucks, semi-trailers, trains, wagons, ships, barges or airplanes.
- **StoredItem:** A stored item, encompassing storage facility, loading, discharge, gate-in, and gate-out, refers to goods or materials held within a designated storage location, involving the processes of entering, exiting, loading, unloading, and the overall management of the storage facility.

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3 ARCHITECTURE FOR CYBERSECURE COMMUNICATIONS

3.1 MARITIME ENVIRONMENT OVERVIEW

Like many other industrial sectors, ports and the maritime sector in general, have been experiencing a deep digital transformation with the aim of meeting emerging challenges, optimizing existing processes and introducing new efficient and competitive capabilities. This resulted in the shift from the use of analogue and mechanical systems to the massive use of digital technology, including in land communication, ship control and logistic services.

This change has also led to deep changes in the sector's cyber risk profile, and brings new cybersecurity challenges, both in the Information Technologies (IT) and Operation Technologies (OT) parts. Thus, the multiplication over the past few years of cybersecurity incidents targeting ports around the world, shows the increasing interest given by attackers to maritime sector.

Consequently, introducing any new capabilities, like ModalNET, requires the implementation of security measures during the whole project life cycle. To better address these risks, the American National Institute of Standards and Technology (NIST) provides a Framework that offers a flexible way to address cybersecurity, including cybersecurity's consequences on physical, cyber, and people dimensions. As indicated in Figure 18, the Framework Core[5] consists of the followings five concurrent and continuous functions: Identify, Protect, Detect, Respond, Recover. When considered together, these Functions provide a high-level, strategic view of the lifecycle of an organization's management of cybersecurity risk.

Figure 18. NIST Framework Core.
Source: NIST Cybersecurity Framework | NIST

The NIST Framework Core provides a high-level methodology and leaves the decision on how to conduct the implementation each function to each organization.

For our part, we adopt, in Task 5.2 for securing ModalNET communication, an approach based on two pillars: a) applying a Risk-management methodology to get a deep and accurate assessment of

[5] https://www.nist.gov/cyberframework/framework

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the maritime cyber-environment, the risk it faces and to select the appropriate mitigation measures; b) rely on the adoption of the Zero-trust paradigm to implement the deployment of the solution.

In the following sections, we provide a description of the maritime sector context by indicating its characteristics and specificities and we give an overview of the cyber threat it faces. In the second part, we describe the approach adopted in Task 5.2 for securing cyber-communication in ModalNET. The mitigation measures identified by applying this approach will be then implemented to secure ModalNET in Task 5.4.

3.1.1 Ship/Port architecture and organization

A port is a complex installation that can address using dedicated infrastructures and services, the three main followings categories of activities6:

- Maritime cargo activities: receiving cargo ships and managing related operations (e.g., unloading and loading, storage, customs inspection, sanitary controls, etc.).
- Passengers and vehicles transport activities: receiving passengers and vehicles on ships and managing related operations (e.g., passenger gangways, parking, restaurants and bars, border control, etc.).
- Fishing activities: receiving fishing boats and managing related operations (e.g., fish unloading/loading, fish inspection, fish refrigerated storage, etc.).

3.1.2 Maritime Stakeholders

The profile of the stakeholders involved in port activities is very heterogenous and may vary according to the specificities of each port. However, the following profiles could generally be found in each port[7]:

- Port authority staff: The Port Authority employees, as statuary staff.
- Permanent commercial staff: The companies present permanently in the ports employs people, as statuary staff (terminal operators, permanent service providers, etc.).
- IT/OT staff: The IT and OT staff, employed by the Port Authorities and private companies operates in different systems to set up new solutions and ensure their periodic maintenance (CISO, CIO, administrations, etc.).
- External staff: A plenty of people could operate within a port, like port facility external staff, other service staff (third-parties), temporarily authorized staff (contractors, taxi drivers, etc.).
- Ship crews: When in a port, the ship crew's members can use the different facilities of the port (restaurant, bar, etc.).
- Passengers: The passengers move through the port areas to go up in the cruise ships and ferries.
- General public: Usually, some port areas are opened to the public (tourism, research, etc.).

[6] https://www.enisa.europa.eu/publications/port-cybersecurity-good-practices-for-cybersecurity-in-the-maritime-sector

[7] https://www.enisa.europa.eu/publications/port-cybersecurity-good-practices-for-cybersecurity-in-the-maritime-sector

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3.1.3 Description of the systems

Plenty of IT systems are deployed and used for managing and monitoring ports and ship's operations. These systems could be grouped into 4 main categories:

- systems used by maritime stakeholders' (shipping companies, ship agent, ship master and crew, etc.),
- systems used by other transport stakeholders to share freight or passenger information and enable the transhipment (inland waterborne transport companies, roadway companies, railway companies, etc.),
- systems used by authorities at local, national and European levels and
- systems used for satellite and maritime surveillance.

These IT systems consist of one hand of the following port systems:

- The Port Community System (PCS), an exchange data system of the port community for ship, fishing or freight related services, especially used as pivotal point for data exchange with shipping companies.
- port management information systems, that includes maritime traffic control systems, corporate systems (emails, ERP, etc.), security and safety systems as well as Terminal Operation Management Systems, often owned by private companies.
- Port operational equipment, such as Cranes, Tugboats or Dredging ships

And on another hand, of the following ship systems:

- Communication and Navigation System: VHF, Global Maritime Distress and Safety System (GMDSS), Digital Selective Calling (DSC), network to gather and process data from sensors, Global Navigation Satellite Systems (GNSS), RADAR, Passenger-facing networks like Wi-Fi Internet access, Electronic Chart Display and Information Systems (ECDIS), Automatic Identification System (AIS), Ship Information System (SIS)
- Power Management System.
- Cargo Management System.

3.1.4 Exchanged Data flows

A large amount of data is exchanged between the port and the different stakeholders, which is classified into 5 categories[8]:

- mandatory declarations: encompass information that shipping companies or other stakeholders must report to the Port Authority or other authorities, with respect to the international, European and national legislations.
- control and authorisation given by the authorities to the commercial stakeholders (e.g., authorisation to access to the port, authorisation to unload the goods);
- operational data related to the port services and processes (e.g., needs for ship refuelling, scheduling of cargo operations);
- financial data (e.g., invoicing from the port to its client, payment); and

[8] https://www.enisa.europa.eu/publications/port-cybersecurity-good-practices-for-cybersecurity-in-the-maritime-sector

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- navigation data (e.g. GPS position of a ship in the port area, AIS data).

3.1.5 Information Technology (IT) and Operational Technology (OT) Cybersecurity

Ports and ships systems encompass both IT (Information Technology) and OT (Operational Technology) parts. IT systems manage data and support business functions, whereas OT represents the hardware and software that directly interacts and controls physical devices and processes. Although these two kinds of systems are different, they are some others connected to achieve several tasks as maritime operation monitoring, remote support, etc. This increasing interrelation and interconnection require the implementation of specific and efficient security measures in order to mitigate emerging threats specially tailored to hit cyber-physical systems. The segmentation of the network into several areas and the implementation of filtering mechanisms between these areas are among the mitigations measures that should be applied. Furthermore, it should be ensured that at least potential vulnerabilities in the OT systems are not exposed in the IT network as it's not always feasible to ensure that all components of the OT system are correctly patched and updated.

3.1.6 Satellite communication cybersecurity

Global Navigation Satellite Systems (GNSS) play a significant role in the maritime sector. Thus, a vast array of devices and systems rely on data retrieved from GNSS for functioning. For example:

- ships rely on GNSS for navigation and as the basis for the Automatic Identification System (AIS), which is used to follow shipping movements and location worldwide
- automated cranes could be guided by GNSS for loading/unloading and moving containers
- GNSS is used in ship fleet management/telematics applications, logistics operations and is a key factor in the so-called Just in Time management of supply chains.

However, by design the power level of GNSS signals from space are very low, and can be easily blocked, damaged, or compromised by a growing array of threats[9]. These threats can have natural or accidental origins such as the solar activity, meteorological conditions, natural obstacles due to the topology, constellation failures, interferences with other sources of signals, etc. It can also have malicious origins such as man-made interferences (Jamming), malicious faking of GNSS signals, and the manipulation of position and timing information (Injection of false AIS or GNSS data).

As these threats can cause severe economical and physical damages including threatening human life, implementing appropriate mitigation measures is of high importance, especially when it comes to autonomous ships.

3.1.7 Autonomous ships cybersecurity

From a cybersecurity point of view, autonomous ships inherit the safety needs of traditional ships, augmented and decoupled by their autonomous capabilities. The former are mainly legacy systems and equipment (sensors, actuators, telecommunication systems, PNT systems, etc.) and the latter are:

- Greater dependence on telecommunication systems, especially satellite systems, whose availability, integrity and confidentiality often become essential, when the degree of autonomy is low, or when the mission requires frequent exchanges with the ground;

[9] https://www.spirent.com/assets/wp-fundamentals-of-gps-threats

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- The importance of trusting electronic, visual and sound sensors, which must be particularly reliable.
- Finally, the extensive use of algorithms in decision-making and, more generally, in the operation of the ship and its installations.

Furthermore, along with cyber-risks, threatening the availability and the confidentiality of information systems (reverse engineering, vulnerability scanning, capture of sensitive information of sensitive information, compromise of the uplink etc.) other kind of risks should also be considered like ship capturing and interception, hazardous and dangerous operations, etc.

3.2 MARITIME CYBER-THREAT LANDSCAPE

Ports face numerous cybersecurity threats, some of them are quite generic within any IT and OT environment, while others are quite specific to the maritime sector. Cyber-attacks can be either targeted or untargeted, and can lead to the following consequences [10] :

- Shutdown of operations and port paralysis.
- Cargo and goods stealing.
- Illegal trafficking.
- Systems damage or worst, destruction.
- Human injuries or death, Kidnapping.
- Sensitive and critical data theft.
- Financial loss and costs.
- Fraud and money steal.
- Tarnished reputation, loss of competitiveness.
- Environmental disaster

Furthermore, cyber-threats to maritime systems can come from numerous sources that should be considered part of the risk management strategy. The most common sources of cyber-attacks are[11]:

- Criminal groups operating Bot networks, they can remotely manage a considerable number of infected devices across the world and use them for launching large scale attacks in order to disrupt the targeted system with a denial-of-service attack (DoS).
- Hacktivists or terrorists who are guided by ideological motivations will use cyber-attacks to protest, disrupt or carry out terrorist acts against other groups, nations, and companies.
- State or state-sponsored hackers, also known as Advanced Persistent Threats (APT), who are politically motivated groups, which according to NIST[12], have sophisticated levels of expertise and significant resources which allow them to create opportunities to reach their objectives by using several attack vectors (e.g., cyber, physical, and deception).

[10] https://www.enisa.europa.eu/publications/port-cybersecurity-good-practices-for-cybersecurity-in-the-maritime-sector

[11] https://www.enisa.europa.eu/publications/port-cybersecurity-good-practices-for-cybersecurity-in-the-maritime-sector

[12] https://csrc.nist.gov/glossary/term/apt

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3.2.1 Maritime cyber-security challenges

In its report on Good Practices for the maritime security[13], the European Union Agency for Cybersecurity (ENISA) stressed out the following challenges in applying cybersecurity in the maritime sector:

- Lack of digital culture in the port ecosystem
- Lack of awareness and training regarding cybersecurity
- Lack of time and budget allocated to cybersecurity
- Lack of human resources and qualified people regarding cybersecurity matters
- Complexity of the port ecosystem due to the number and diversity of stakeholders taking part in port operations
- Need to find a right balance between business efficiency and cybersecurity
- Legacy of some systems and practices
- Lack of regulatory requirements regarding cybersecurity
- Difficulty to stay up to date with the latest threats
- Technical complexity of port IT and OT systems
- IT and OT convergence and interconnection
- Supply chain challenges
- Strong interdependencies
- New cyber risks resulting from the digital transformation of ports

3.3 RISK-ANALYSIS METHODOLOGY: EBIOS RM PRESENTATION

EBIOS Risk Manager[14] (EBIOS RM) is the method for assessing and treating digital risks published by National Cybersecurity Agency of France (ANSSI). EBIOS RM allow the assessment of digital risks and the identification of the security measures that should be applied to control them. It also allow the validation of the acceptable level of risk and to carry on in the longer term in a continuous improvement approach. Finally, this method allows to put in place resources and arguments that are useful for communication and decision-making within the organisation and with regards to its several partners.

The EBIOS RM method can be used with the aim to achieve several purposes[15]:

- setting up or reinforcing a management process of the digital risk within an organisation;
- assess and treat the risks relating to a digital project, in particular with the aim of a security accreditation;
- define the level of security to be achieved for a product or service according to its use cases and the risks to be countered, in the perspective of a certification or accreditation for example.

[13] https://www.enisa.europa.eu/publications/port-cybersecurity-good-practices-for-cybersecurity-in-the-maritime-sector

[14] https://cyber.gouv.fr/en/publications/ebios-risk-manager-method

[15] https://cyber.gouv.fr/en/publications/ebios-risk-manager-method

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The EBIOS Risk Manager method adopts to the management of the digital risk an approach going from the highest level (major missions of the studied object) and progressively reaching the business and technical functions, by relying on possible risk scenarios.

EBIOS RM methodology considers that the accidental and environmental risks have already been treated through a compliance approach. Thus, the assessment of the risks through scenarios, therefore, focuses on the intentional threats.

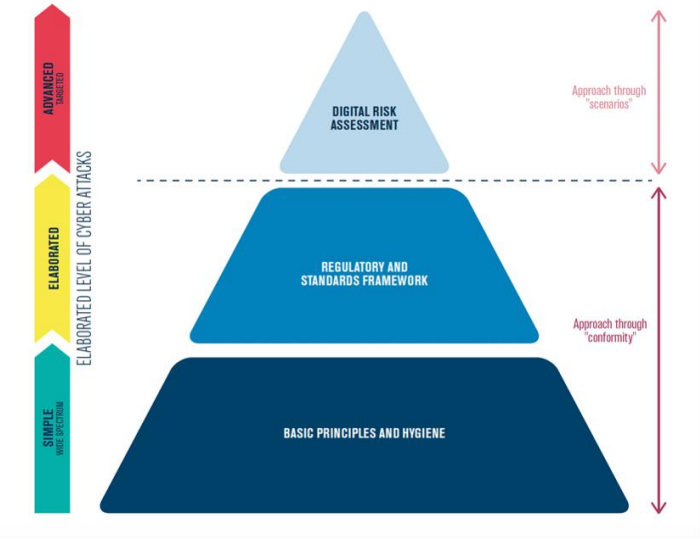

Figure 19. EBIOS RM.

Source: https://www.ssi.gouv.fr/uploads/2019/11/anssi-guide-ebios_risk_manager-en-v1.0.pdf

The EBIOS RM method apply an iterative approach around five workshops and two cycles:

<u>The two Cycles</u>:

The approach calls for two cycles:

- a **strategic cycle** that revisits the entire study and in particular the strategic scenarios;
- an **operational cycle** that returns to the operational scenarios in light of the security incidents that have raised, the disclosure of new vulnerabilities and changes in attack's techniques.

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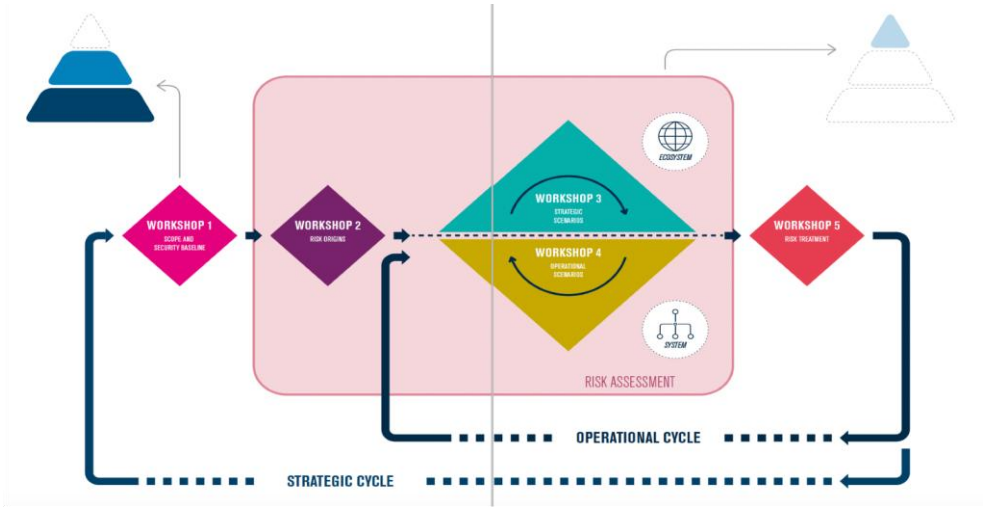

Figure 20. EBIOS RM cycles.

Source: https://www.ssi.gouv.fr/uploads/2019/11/anssi-guide-ebios_risk_manager-en-v1.0.pdf

The five Workshops[16]**:**

- **WORKSHOP 1 (Scope and security baseline):** It's aim is to define the framework of the study, its business and technical scope, the associated feared events and the security baseline. This workshop is a prerequisite for producing a risk assessment. The period to be considered for this workshop is the same as the strategic cycle.
- **WORKSHOP 2 (Risk origins)**: It's aim is to identify the risk origins (RO) and their target objectives (TO), taking in consideration the particular context of the study. The workshop aims to answer the following question: who or what can infringe upon the missions and business assets identified in workshop 1, and for what purposes? The risk origins and the target objectives are then characterised and assessed in order to only keep the most significant ones. They will be useful for building scenarios for workshops 3 and 4.
- **WORKSHOP 3** (**Strategic scenarios):** The ecosystem includes all of the stakeholders related to the studied object and participate in conducting its missions (partners, subcontractors, subsidiaries, etc.). Indeed, more and more cyberattack target the most vulnerable links in this ecosystem in order to reach their target (example: affecting the availability of a service by attacking the Cloud service supplier, booby-trapping the logistics supply chain of servers that facilitate sensitive data exfiltration).
  The objective of workshop 3 is to obtain a clear view of the ecosystem, in order to identify the most vulnerable stakeholders in it. This will then entail building high-level scenarios, called strategic scenarios. These scenarios are attack paths that a risk origin can use to reach its target (i.e. one of the RO/TO pairs selected during workshop 2). Workshop 3 is to be addressed as a preliminary risk study. This can lead to identifying the security measures to be applied with regards to the ecosystem. The strategic scenarios selected in workshop 3 form the base of operational scenarios for workshop 4.
- **WORKSHOP 4 (Operational scenarios)**: It's aim is to build operational scenarios. They diagram the methods of attack that the risk origins could apply to carry out the strategic scenarios. This

[16] https://cyber.gouv.fr/en/publications/ebios-risk-manager-method

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workshop adopts an approach similar to the one of the preceding workshop but focuses on the supporting assets. The likelihood of each operational scenarios is and in its end we will get a summary of all of the risks of the study.

- **WORKSHOP 5 (Risk treatment)**: It's aim is to create a summary of the risk scenarios identified and to define a risk treatment strategy. This strategy results in the definition of security measures, listed in a security continuous improvement plan (SCIP). The residual risks are then identified as well as the framework for following these risks.

This methodology has been analysed as part of the architecture for cybersecure communications to take into account and to be recommended in the secure framework for the implementation of ModalNET in an operational environment.

3.4 ZERO TRUST ARCHITECTURE

3.4.1 ZTA definition

Zero-trust[17] (ZT) is a cybersecurity paradigm that moves defences from static, network-based perimeters to focus on users, assets, and resources. Based on the principle of "never trust, always verify", it assumes that there is no implicit trust granted to assets or user accounts based solely on their physical or network location (i.e., local area networks versus the internet) or based on asset ownership (enterprise or personally owned). Authentication and authorization (both subject and device) are discrete functions performed before a session to an enterprise resource is established.

A Zero-Trust architecture (ZTA) uses zero trust principles to plan enterprise infrastructure and workflows. It relies on four pillars: network segmentation, prevention of lateral movements, prevention of threats on the L7 layer, and simplification of granular user access control.

3.4.2 Principals of zero trust architecture

A zero-trust architecture is designed and deployed with respect to the following principals[18]:

1. All data sources and computing services are considered resources.
2. All communication is secured regardless of network location.
3. Access to individual enterprise resources is granted on a per-session basis.
4. Access to resources is determined by dynamic policy—including the observable state of client identity, application/service, and the requesting asset—and may include other behavioural and environmental attributes.
5. The enterprise monitors and measures the integrity and security posture of all owned and associated assets.

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[17] *Rose, S. , Borchert, O. , Mitchell, S. and Connelly, S. (2020), Zero Trust Architecture, Special Publication (NIST SP), National Institute of Standards and Technology, Gaithersburg, MD, [online], https://doi.org/10.6028/NIST.SP.800-207, https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=930420 (Accessed November 16, 2023)*

[18] *Rose, S. , Borchert, O. , Mitchell, S. and Connelly, S. (2020), Zero Trust Architecture, Special Publication (NIST SP), National Institute of Standards and Technology, Gaithersburg, MD, [online], https://doi.org/10.6028/NIST.SP.800-207, https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=930420 (Accessed November 16, 2023)*

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6. All resource authentication and authorization are dynamic and strictly enforced before access is allowed.
7. The enterprise collects as much information as possible about the current state of assets, network infrastructure and communications and uses it to improve its security posture.

3.4.3 Components of a Zero-Trust Architecture

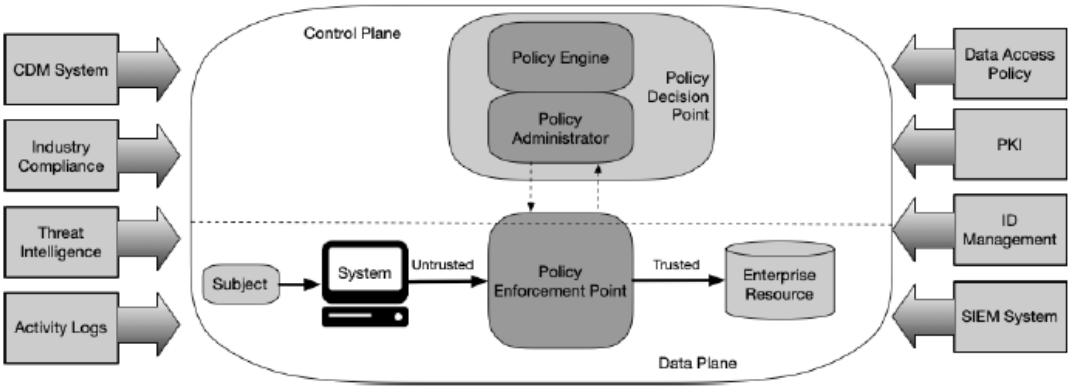

Figure 21. Core Zero Trust Logical Components.
Source: https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-207.pdf

The types of ZTA core components are

- **Policy engine** (PE): This component is responsible for the ultimate decision to grant access to a resource for a given subject. The PE uses enterprise policy based on enterprise policy and information from supporting components to grant, deny, or revoke access to the resource. The policy engine makes and logs the decision (as approved, or denied), and the policy administrator executes the decision.
- **Policy administrator** (PA): The PA executes the PE's policy decision by sending commands to the PEP to establish and terminate the communications path between the subject and the resource. It generates any session-specific authentication and authorization token or credential used by the subject to access the enterprise resource
- **Policy enforcement point** (PEP): This system is responsible for enabling, monitoring, and eventually terminating connections between a subject and an enterprise resource. It operates based on commands that it receives from the PA.

There are also five categories of ZTA supporting components:

- **ICAM**: It includes the strategy, technology, and governance for creating, storing, and managing subject (e.g., enterprise user) accounts and identity records and their access to enterprise resources.
- **Endpoint Security**: EDR, Firewall, etc
- **Data Security**: Encryption, etc
- **Security Analytics**: SIEM, SOAR, etc
- **Resource Protection.**

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3.4.4 Deployment strategy

Deploying a Zero-Trust Architecture is an iterative process axed on the following five-step methodology:

1. Define the Protect Surface.
2. Map the Transaction Flows: To properly design a network, it is crucial to understand how systems should work. The way traffic moves across the network, specific to the data in the protect surface, determines how it should be protected.
3. Build a Zero Trust Network.
4. Create the Zero Trust Policy:
   a. **Who** should be accessing a resource? This defines the "asserted identity."
   b. **What** application is the asserted identity of the packet using to access a resource inside the protect surface?
   c. **When** is the asserted identity trying to access the resource?
   d. **Where** is the packet destination? A packet's destination is often automatically pulled from other systems that manage assets in an environment, such as from a load-balanced server via a virtual IP.
   e. **Why** is this packet trying to access this resource within the protect surface? This relates to data classification, where metadata automatically ingested from data classification tools helps make your policy more granular.
   f. **How** is the asserted identity of a packet accessing the protect surface via a specific application?

   The following Table provides a template for creating a ZTA Policy:

WHO	What	When	Where	Why	How	Action
User-ID	App-ID	Time	System Object	Classification	Content-ID	Allow?

Table 1. Zero Trust Policy

5. Monitor and Maintain the Network: his means continuously looking at all internal and external logs through Layer 7 and focusing on the operational aspects of Zero Trust. Inspecting and logging all traffic on the network is a crucial Zero Trust principal.

3.4.5 Integration of OT in a ZTA

As indicated above, Cyber-physical systems like ships or port infrastructures are operated by both IT (Information Technology) and OT (Operational Technology). Thus, some OT components may not support the technologies or protocols required to fully integrate with a ZTA implementation. As a result, a ZTA implementation might not be practical for some OT devices[19].

To overcome this obstacle, it should consider applying a ZTA to only compatible devices, such as those available at the higher levels of the OT architecture. Another crucial element of ZTA implementation is the need to identify person and non-person entities that access available

[19] https://www.ciscolive.com/c/dam/r/ciscolive/global-event/docs/2022/pdf/BRKIOT-2012.pdf

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resources. Indeed, within OT environments, it is usual to use shared credentials, which could impact the possibility to implement an efficient ZTA strategy.

3.4.6 Challenges and Threats Associated with Zero Trust Architecture:

In spite of the fact that a well implemented maintained ZTA can greatly reduce overall risk and protect against common threats, a few particular threats remain such as:

- Subversion of ZTA Decision Process.
- Denial-of-Service or Network Disruption.
- Stolen Credentials/Insider Threat.
- Visibility on the Network.
- Storage of System and Network Information.
- Reliance on Proprietary Data Formats or Solutions.
- Use of Non-person Entities (NPE) in ZTA Administration.

3.4.7 Proposed architecture:

According to the NIST Special Publication 800-207[20], there are several possible variations on deployment of a Zero-Trust Architecture components. Indeed, the same physical component can perform the task of multiple logical components and in the same way, the task of a logical component can be assumed by multiple physical components. Furthermore, the deployment architecture must be adapted according to the deployment context (Cloud, use of satellite connection, multisite company, etc.).

Among possible deployment architectures, we chose for securing ModalNET communications to apply the so-called “Resource Portal-Based Deployment.” In this deployment model, the Policy Enforcement Point (PEP) is a single component that acts as a gateway for subject requests. This deployment is indicated for cloud-based that could be accessed by users with several profiles and using un-managed devices.

[20] *Rose, S. , Borchert, O. , Mitchell, S. and Connelly, S. (2020), Zero Trust Architecture, Special Publication (NIST SP), National Institute of Standards and Technology, Gaithersburg, MD, [online], https://doi.org/10.6028/NIST.SP.800-207, https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=930420 (Accessed November 16, 2023)*

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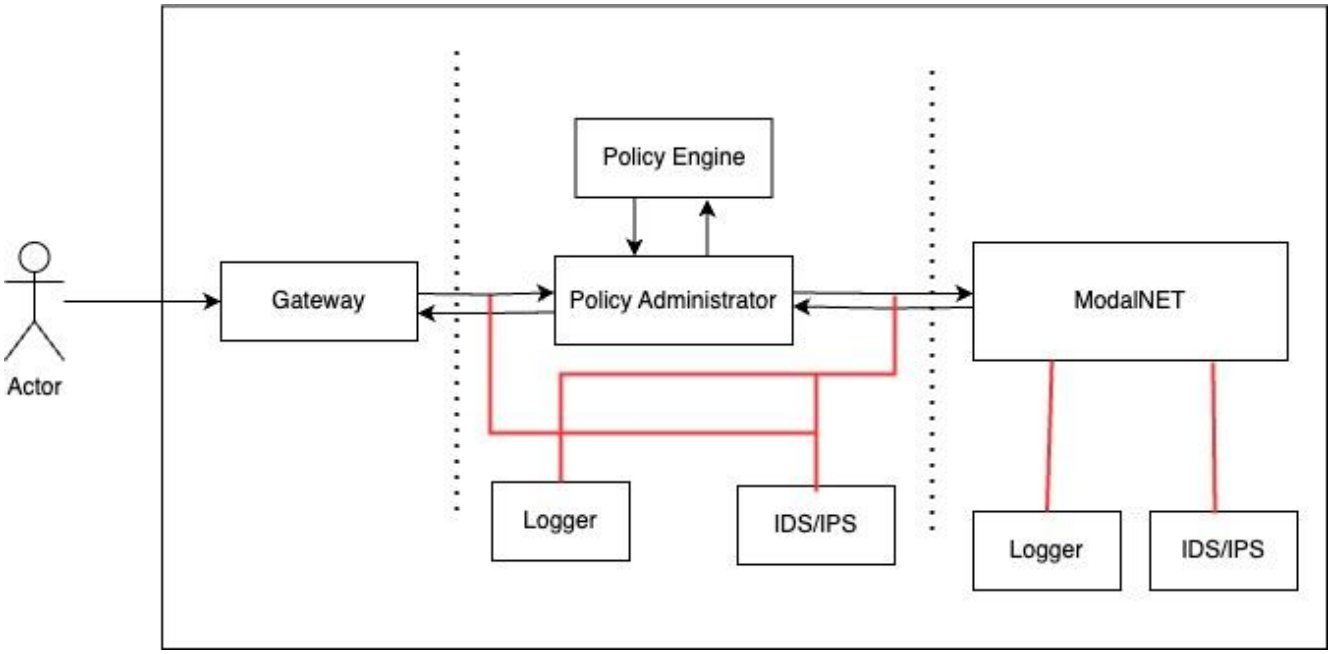

Figure 22. ModalNET deployment Architecture

Indeed, ModalNET will use among others, cloud-technologies and will be accessed by external users mainly with their own devices. This architecture ensures that no software component is needed to be installed on clients' devices and will allow secure, centralized, and monitored access to all ModalNET features through the same portal as depicted in Figure 22.

The drawback of this model is that it can only scan and analyse devices once they connect to the PEP portal and may not be able to continuously monitor them for malware, unpatched vulnerabilities, and appropriate configuration. Therefore, additional security components such as IDS/IPS and logging system will also be deployed for a closing monitoring of all the activities and exchanges.

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4 MODALNET SPECIFICATIONS AND ARCHITECTURE

ModalNET logistics network has the objective of organizing the transport chain by generating all the booking and shipment orders for the different modes of transport, calculate the associated transport charges and manage administrative and documentary procedures.

ModalNET will provide a digital twin to give a “bird’s eye” view of the supply chain and facilitate a synchromodal dynamic management through adaptive logistics. It will be designed to support any mode of transport (sea, inland navigation, rail and road transport) and for any type of goods presentation (containerised, break bulk, semi-trailers, tanks or bulk).

ModalNET platform will be federated with the building blocks #1 and #3 and with the same approach it will be able to federate to any other third-party platform that will take part of the ecosystem where SEAMLESS business and logistics models will be implemented.

4.1 LOGICAL VIEW

Taking into account the SEAMLESS concept architecture presented in D2.2, the logical view of ModalNET is presented in the diagram below:

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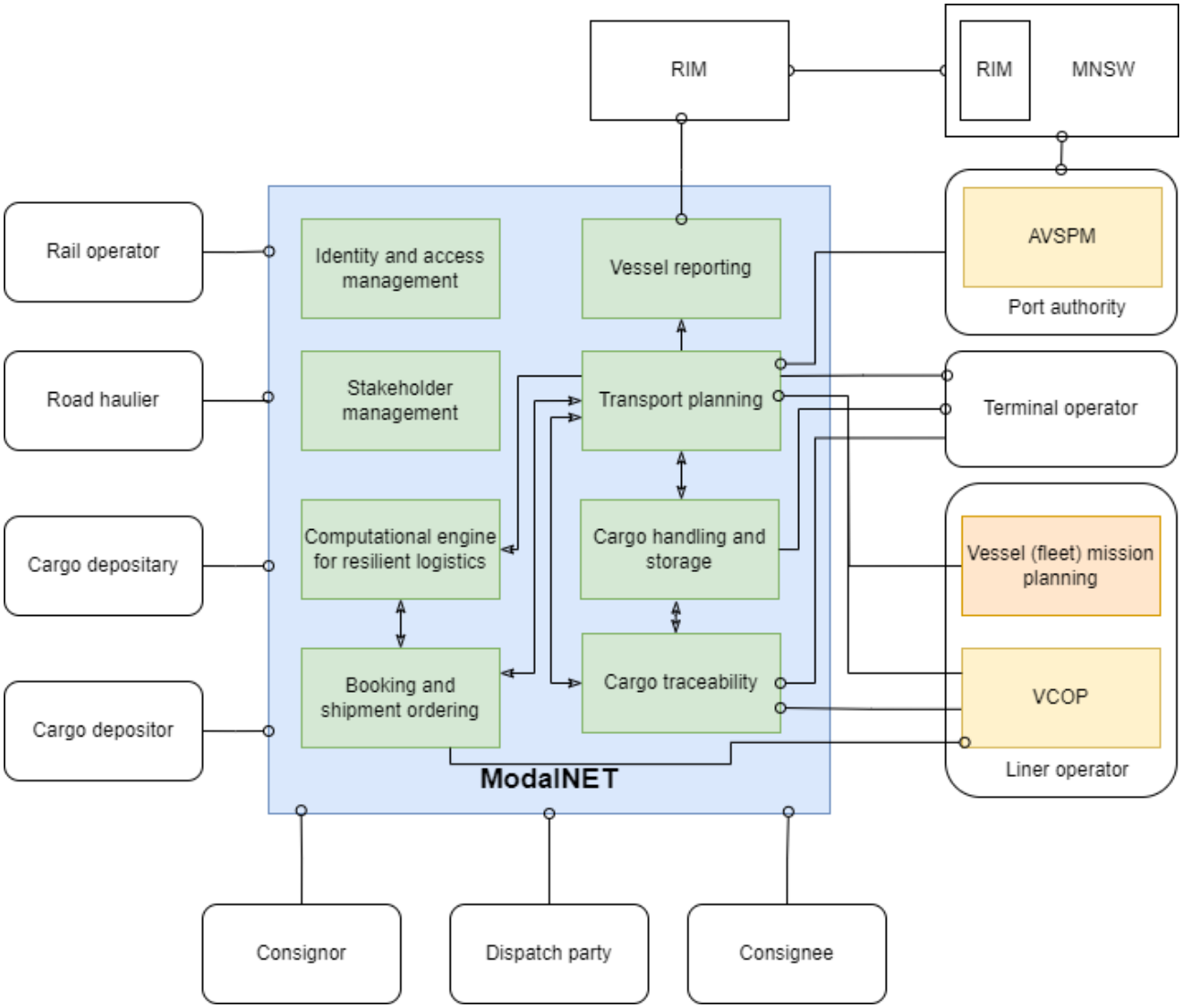

Figure 23. ModalNET logical view diagram

The stakeholders of ModalNET will be the liner operators of the autonomous ship fleets, the terminal operator and port authority, the road haulier and rail hauliers, the cargo depositors and depositaries along the transport route, the consignors, dispatch parties and consignees of the goods.

The modules of the platform will be:

- **Stakeholder management:** This module will allow to register and approve the companies and public entities and their branches that will use the platform.
- **Identity and access management:** This module will allow to register and approve users, assign roles and access permissions to different functionalities. All users will pertain to a branch office of an organization or public entity and there will be admin users in the office branch in charge to approve new users. Users will need to login through this module to access to the platform.
- **Booking and shipment ordering**: This module will allow consignors to place shipment requests to move goods from an origin to a destination. This request will be transferred to the computational engine for resilient logistics that will provide the most suitable transport option to the module and

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it will proceed to place the bookings and transport orders to the different transport providers involved (liner operators, rail operators and road hauliers).

- **Computational engine for resilient logistics**: This module will be configured with the transport networks that ModalNET will operate with and receive from the transport planning module the schedules for rail services provided by rail operators, and barge/sea services provided by liner operators.
- **Transport planning:** The transport planning will be able register the schedules shared by other systems (e.g. VCOP) or stakeholders (e.g. rail operators), register the loading and discharge of the shipments along the route. This module will be connected with the booking and shipment ordering module, the cargo handling and storage module and the cargo traceability module.
- **Cargo handling and storage:** The cargo handling and storage will be able to register all cargo/container entries and departures that take place in port terminals and storage facilities, including ship loading and discharge operations and gate-in, gate-out operations, which can be reported by the liner operator (e.g. VCOP) or directly by the port terminal.
- **Cargo traceability:** The cargo traceability will register events from other systems and stakeholders (e.g., cargo loading/discharge events, gate-in/gate-out events, cargo receipt/delivery events, …) and transfer them to other involved modules of the platform.
- **Ship reporting formalities:** The ship reporting will be in charge of registering, preparing and submitting the data for complying with the formalities for the autonomous ships operated by the liner operators when arriving or departing from a port.

ModalNET will implement some of the formalities defined by the European Maritime Single Window environment (EMSWe) according to the EU 2019/1239 European Maritime Single Window environment (EMSWe) regulation and use the harmonized reporting interface module (RIM) created by the European Commission for to its submission to the Maritime National Single Windows (MNSWs). It will also implement the information requirements for becoming an eFTI platform according to the requirements established in EU 2020/1056 electronic freight transport information (eFTI) regulation. It will also check the information requirements for the IWT formalities according to the EU 2019/1744 technical specifications for electronic ship reporting in inland navigation (eSRIN).

4.1.1 Stakeholder management

ModalNET will adopt the stakeholder management design that was defined previously in DataPorts project, using the entity **Branch Office** as the main component to define the stakeholder management logical view.

The stakeholder management will register the branch offices of different organizations, companies or public entities that provide and/or consume logistics and transport services to move a consignment from an origin to a destination or submit the reporting formalities of the ship when arriving or departing to/from a port.

A branch office can be configured to be the headquarters for the company or the public entity or the headquarters of a group of companies. A headquarter of a group of companies can be associated with several companies' branch offices, including the headquarters, of the companies included in the group. A headquarter of a company or public entity is associated with the different branch offices of this company or public entity. The following characteristics are relevant for the stakeholder management module:

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- An organization, company or public entity has a unique identifier, which usually will be the VAT (Value Added Tax) code but in some cases it can be another kind of code when the VAT code is not suitable. The branch office of an organization has also a unique identifier comprised by the organization identifier and an office code. The office code will be typically the postal code (including the country code if required) where the office is located but it can be any other code to identify the branch office. This approach allows to have a single organization with multiple branch offices distributed in different cities and countries.
- An office can be configured to have different functions and use different services offered by the digital platform using different roles. The data registered in the platform for a branch office includes information about the company, the office, the platform services and roles being used, a list of business collaborators which can be customers, providers, partners or facilities, a set of webhooks to connect and share data with external digital platforms and a repository of shared documents. Webhooks allow the company to be the sovereign of their data and transfer them to other systems.

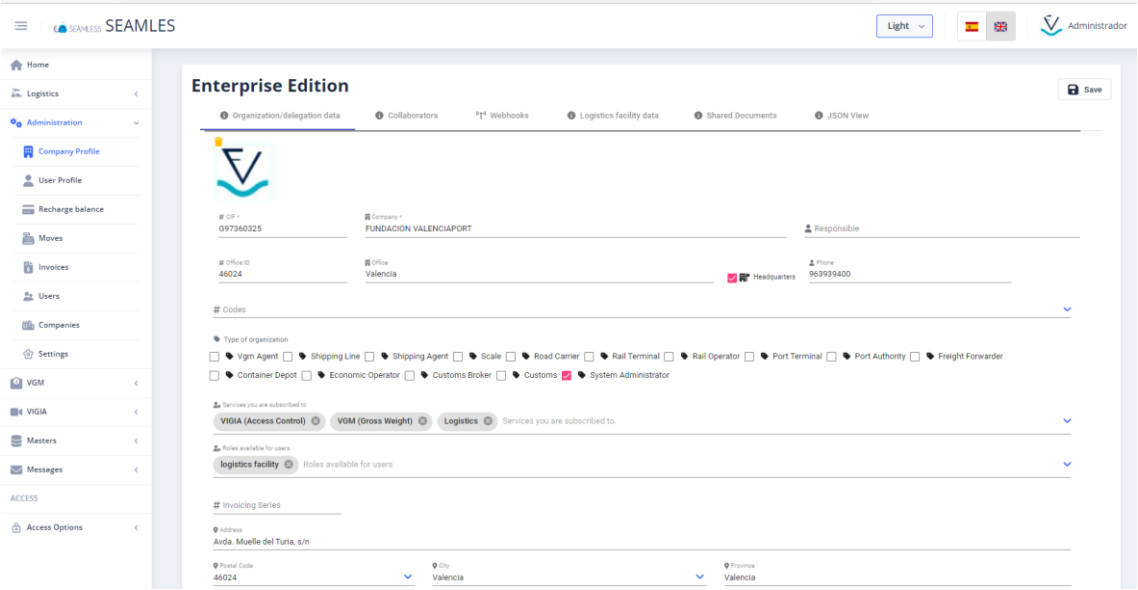

Figure 24. Stakeholder management module

4.1.2 Identity and access management

The identity and access management will be based on the concept of **User** of the platform. This module will identify the user, the branch office where it works and other relevant data for using ModalNET. The identity and access management module will be able to be FEDERATED and use external Identity and access management systems whenever this will be required.

A **User** is a data entity that represents a physical person, or a system associated with a branch office that is allowed to connect and use the resources of the platform. The user data entity will compile all the data about the user and associated security tokens that could be used to identify the user in this platform or in external platforms, the email subscriptions and the roles which have been assigned to the user by a user manager. The security tokens of a user will provide the needed identity and access management for platform federation with the rest of SEAMLESS building blocks and with external systems.

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In ModalNET, there will be some users that could be drivers or crew, driver/crew specific data, including driver or crew's documents and other personal details (e.g. a picture of the user for facial recognition) can be included. To guarantee personal data protection, the user data includes flags that register whether the user consents to store personal data in the platform, agrees in the platform terms and conditions and in the privacy policy of the platform. According to the GDPR, the platform will grant the users (or data subjects) certain rights in connection with the processing of their personal data, including the right to correct inaccurate data, erase data or restrict its processing and receive their data. All these rights will be able to be performed by the user himself online. All the information registered in the platform by the users will be made in the name of its company or branch office and not in as a personal title, so these transactions will pertain to the office and not to the particular user that has fulfilled them.

A user will be uniquely identified by an email address, and it will be associated to an office (i.e. organization identifies and office code). However, a user can change in any moment, the email address if they need to update their email address.

There will be some users which will be the managers of the branch office or of the whole organization and be capable of managing the users of their offices or organizations as well as defining some specific configurations and edit the office profile. There will also be some special users that will be the system or user administrators for all the platforms.

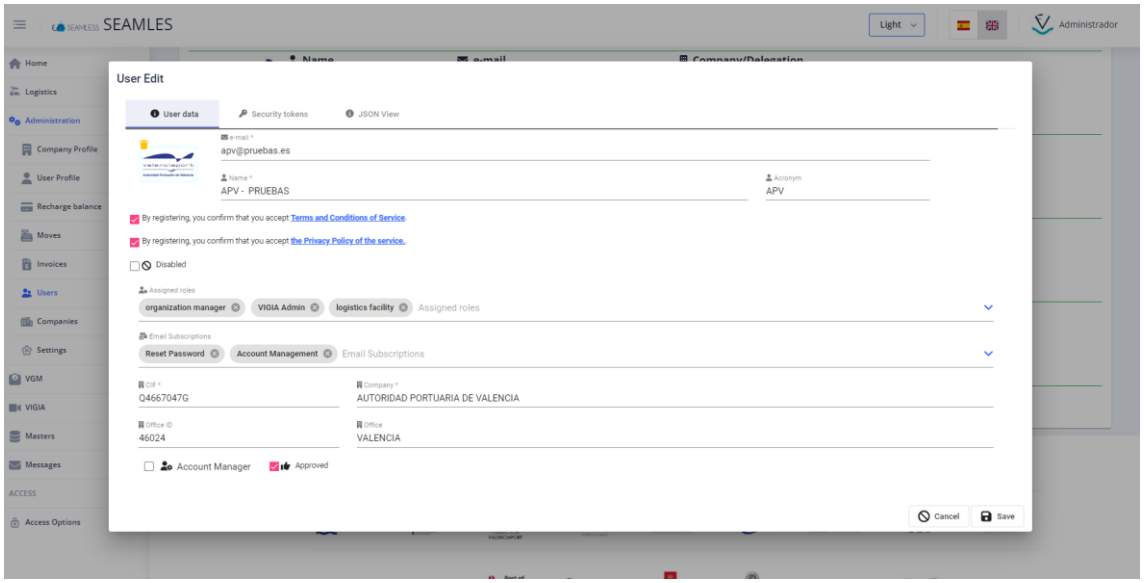

Figure 25. Identity and access management

4.1.3 Booking and consignment ordering

ModalNET will include the functionalities to register a booking or a consignment for a multimodal transport operation. It will use a generic data specification including the main data components of the consignment prepared by the consignor that will be later complemented by the carrier. In the case the consignor is not registering the consignment, the carrier can register the full consignment it has prepared with the instructions received from other channels.

When a booking will be registered by the consignor, the first step will be to submit this booking to the computational engine for resilient logistics which will analyse the characteristics of the transport requested and provide several alternative options for combining different transport modes including

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the SEAMLESS ship transportation options. The consignor will proceed to select the best route suggested and confirm the operation to generate the individual booking and consignments to each individual mode of transportation. These individual booking and consignments will be received by the respective carriers and the relation of the different consignments being created will be linked each other creating the transport chains used for the movement of goods and containers.

The carriers will proceed to complete the information of the consignment and make the transport planning. Carriers will be able to subscribe their respective transport systems to receive notifications about new consignments and connect to ModalNET to retrieve all the associated data. This will be the case for the VCOP platform that will retrieve through this mechanism the booking data generated for the SEAMLESS autonomous ship.

A consignment data entity will include the consignment references, the dates, the mode of transport, the type of transport units delivered, the shipper/requestor, the carrier, the dispatch party, the consignee, the effective haulier, the agent, the notified parties, the transport details, the equipment requested, the origin, loading, discharge and destination details and dates, the gate-out and gate-in orders needed to authorize the pick-up and delivery of the transport units at storage facilities or terminals, the transport units details (e.g. containers), the related shipments (i.e. a consignment can move several shipments or a shipment can comprise several consignments moving the goods through different transport legs), the goods item details, the dangerous substances details and other operational data which will be determined by the logistics processes.

A consignment will be uniquely identified by a reference identifier assigned by a carrier and/or a reference identifier assigned by the consignor. The reference identifiers assigned by these parties should be unique, however different carriers or different consignors could assign the same reference identifier to the consignment. In consequence it is required to know the carrier identifier (i.e., office identifier) to uniquely identify the consignment through its reference or the consignor identifier to uniquely identify the consignment through its reference. If this is not the case, there is a risk to identify wrongly a consignment that has the same reference assigned by another party. There can be other unique references assigned to a consignment as the case of references assigned by third party platforms.

A consignment can be multimodal shipment or unimodal (i.e., maritime, inland waterways, road, rail and air). A multimodal consignment can be the shipment of other multimodal or unimodal consignments comprising the different legs of the transport chain. The registration of a multimodal consignment in ModalNET will be able to be used in the matchmaking platform to determine if this consignment can be matched by an available transport (i.e. a SEAMLESS ship voyage) to move the goods in a combination of road and sea or inland navigation modes. If this combination is feasible, the matchmaking platform will provide the instructions to generate the unimodal consignments that will be combined for the multimodal shipment.

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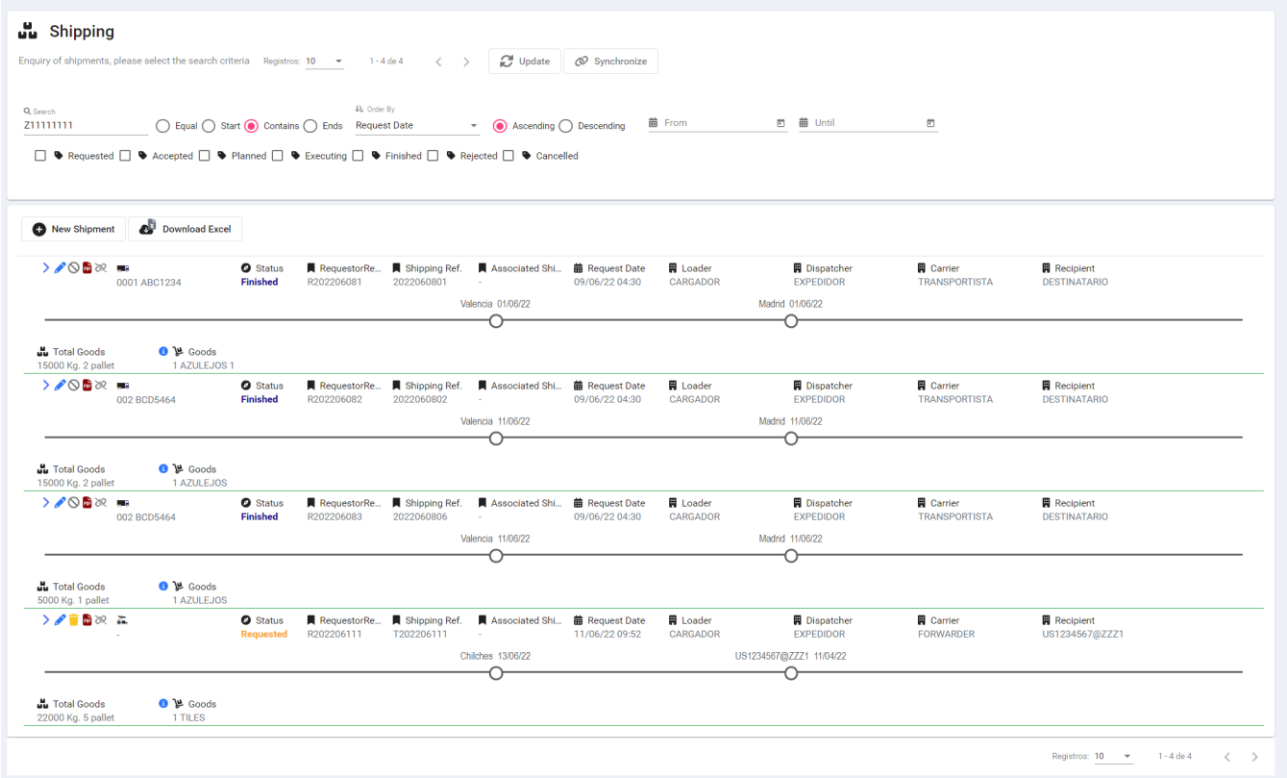

Figure 26. Booking and consignment ordering

4.1.4 Transport unit

A transport unit refers to a standardized container, pallet, or other load-carrying device used for the efficient transportation of goods by various modes of transportation such as trucks, trains, ships, or airplanes. A transport unit data entity in the platform will always be associated and registered together with a shipment (i.e., a maritime container will be a transport unit associated to a maritime shipment).

A transport unit will be uniquely identified by the transport unit number and the shipment reference assigned by the carrier.

It will include the transport unit identification, the type of transport unit, the status (i.e., full or empty), the owner and provider of the transport unit, the tare and gross weight, the oversize, the seals and other operational data which will be determined by the logistics processes and a list of authorized parties related with the transport unit.

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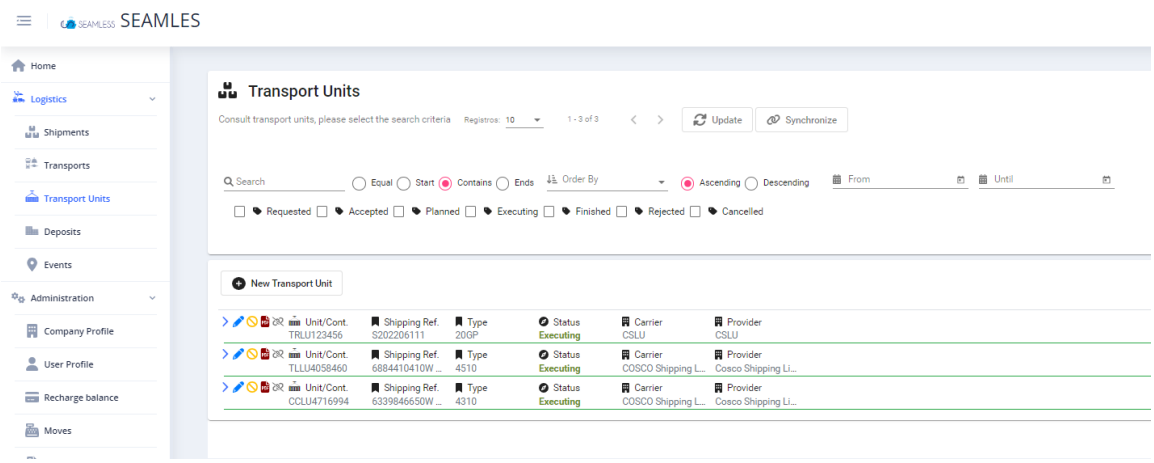

Figure 27. Transport unit list

4.1.5 CERL - Computational engine for resilient logistics

The ModalNET Computational Engine for Resilient Logistics (CERL) will take into account the architecture delineated in the preceding MOSES project. The CERL has been carefully designed to improve and make services in the supply chain work better. It does this by using smart computer algorithms to match the demand for freight transport with the supply of freight space. Different types of users have been identified, splitting how the platform is used into two levels. The first level is for service providers like carriers, freight forwarders, and shipping companies. They use the platform to easily upload their shipping schedules, look at different reports, check customer orders, and get notifications. The second level is for end users and potential customers, like shippers. This part of the platform is designed to give them the best routes and options by analysing data behind the scenes. The system figures out the best routes based on what the users want. Additionally, the CERL's programming interface (API) will be improved to let users digitally submit their transport orders and get route options directly. At the core of the system is the matchmaking feature. Its main job is to give customers the best choices by combining different transportation services offered by providers. This teamwork between technology and logistics not only makes operations smoother but also boosts the overall efficiency and strength of the supply chain.

Based on the user role, the platform uses and produces different input and output data respectively. For the service providers, the input data contains the initial information upon which the transport network model is built. Ship and train owners are able to upload specific information concerning their vessels, such as the following:

- Stopping locations (e.g., ports of call for ships) for the forthcoming period.
- Arrival and departure times for each stopping location (date and time).
- Remaining vessel capacity for each container type, for each transition between two stopping locations (in TEUs).
- Cost of transportation between any two consecutive stopping locations.
- Any information related to the CO2 emissions of the vessel (e.g., CO_2 emissions per hour for a specific speed and level of fullness).

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The platform also enables each ship or train service provider to update relevant information, such as the remaining vessel capacity, arrival/departure times for each stopping location, pertinent costs etc. It also allows the service provider to remove the vessel's schedule entirely or upload information concerning a new vessel.

Truck owners are considered to operate between ports and specific inland destinations. Therefore, they are able to upload the location pairs, i.e., pairs of the form (port → inland location) or (inland location → port) on which they operate, plus any additional information regarding each such pair, i.e., cost of transportation, CO_2 emissions, required time to destination. Due to truck transportation services on-demand nature and aperiodicity, each possible connection between two inland locations considers only the required time to destination plus the estimated CO_2 emissions.

Regarding the input data of end users, the platform allows them to upload information concerning the details of their transport requests. These include request specifications and request preferences. More specifically, request specifications include basic information of the request, such as origin and destination, amount of product to be transported in TEUs, as well as latest possible date of delivery to destination. Depending on the available information, the design may also consider the type of product to be transferred and the type of container needed (e.g., refrigerated, insulated, dangerous goods, etc.). The request specifications are used to parametrize the transport network search algorithms and filter out any resulting routes that do not meet them. In parallel, the request preferences consider the request's criteria of optimality (e.g. total cost, turnover time, earliest date of delivery, CO_2 emissions). Each end user can change the specifics of the order, cancel the order, or declare the order as closed or fulfilled.

As for the output data, the platform applies parametrized search algorithms on the Transport Network model to calculate routes that meet the end user's request specifications. The routes resulting from this searching/filtering process are called feasible routes. Request preferences are subsequently used to sort the resulting feasible routes according to the preferred criteria of optimality. The platform sends a set of transport and matching suggestions (optimally) to each end user, satisfying the end user's request. The suggestions are of the following form:

(Headhaul shipping schedule, Backhaul shipping schedule, matching shippers)

The suggested shipping schedule fields (Headhaul or Backhaul) contain a timely ordered sequence containing the following for each one of the involved legs:

1. Identifier, type (i.e., ship, train or truck) and owner of the corresponding vessel.
2. Leg origin and destination.
3. Departure time from origin and arrival time to destination in case the corresponding vessel is a ship or train. In the case of trucks, the output simply provides the time required to reach the destination.
4. Total cost of the schedule for the end user.
5. Total CO_2 emissions of the schedule.

The matching shippers field contains a set of other end user, each one with orders "matching" the request of the end user under consideration. "Matching" is perceived in the following two-fold sense:

- Headhaul matching i.e., matching end users may utilize the same shipping schedule, or the sea/rail parts of it, in the same direction to fulfil their requests (i.e. their requests have the same origin and destination and nearby shipment/delivery date and times).

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- Backhaul matching: i.e., one end user may utilize the empty containers coming from another end user's order once the second end user's order has been delivered (in its simplest form, this means that the destination of the first end user is the origin of the second, and vice versa, plus the shipping date for the second end user is after and nearby the delivery date of the first end user).

In case the end users match in the Headhaul sense, the Headhaul shipping schedule contains details of a candidate shipping schedule fulfilling their requests (i.e., involved vessels, stopping locations and arrival/departure datetimes, CO_2 emissions), while the Backhaul shipping schedule is blank. In case the end users match in the backhaul sense, the Headhaul shipping schedule contains details of a candidate shipping schedule fulfilling the first end user's requests and the Backhaul shipping schedule details of a shipping schedule utilizing the empty containers for the second end user once the first end user's order has been delivered.

4.1.6 Transport planning

Transport planning will be able to be organized for any means of transport (road, rail and SEAMLESS ships). In the case of ships, trains or barges, transport planning can be registered in anticipation for the transportations creating the schedules of these transports. This will be the case of SEAMLESS ships that whether using the information coming from VCOP or from the Ship fleet mission planning or registering directly this information in the platform, will provide the service schedules that will be also used by the computational engine for resilient logistics.

A transport will be uniquely identified by the voyage number and the carrier identifier (i.e. the company and office code). In consequence, a voyage number shall be unique for each carrier, but different carriers could potentially have the same voyage number.

A transport data entity will be including the transport identification or voyage number, the mode of transport, the means of transport identification (i.e. the truck plate, the ship IMO number), the parties involved in the transport (i.e. carrier, haulier), the actual stowage plan, the origin and destination of the transport and the transport places along its route. For the different transport places, data about dates, parties involved (i.e. agent, depositary), references, and loading and discharge operations can be included.

If the transport is in a planned state, it can be considered as the transport schedule of a particular voyage. Transport information, including the schedule, will be registered in the ModalNET platform and distributed to the port operations system for registering the ship ETA and ETD schedule at each port, and to the matchmaking module for registering the trips schedules from a point of origin to a point of destination.

Once the consignments have been submitted by consignors to carriers or when the carrier registers the consignments it has received from other channels, the carrier will be able to plan the transport of different consignments with their transport means through the transport planning. Before or after doing the transport planning, the consignments could be linked with the gate out and gate in orders that authorize the carrier to pick-up or deliver the goods or the transport units transported from the warehouses, depots or terminals of origin to the warehouses, depots or terminals of destination. The transport planning will define a transport and include the consignments that will be transported with this transport. The requested times for loading and discharge at different places will help to determine the capacity to carry out the consignment with the transport means and the loading and discharge operations will be calculated during the transport planning.

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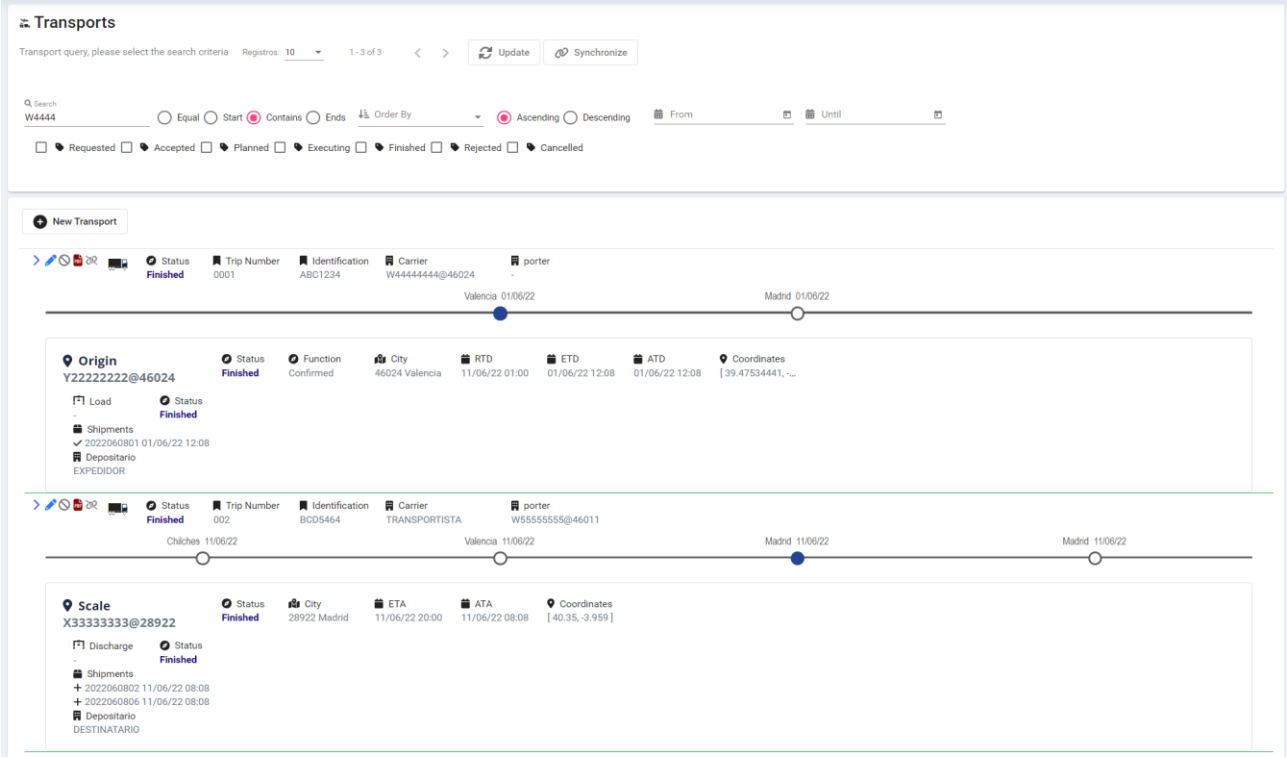

Figure 28. Transport planning

4.1.7 Cargo handling and storage

ModalNET will coordinate the pick-up (i.e., gate-out order) and delivery (i.e. gate-in order) of goods and containers from logistics facilities (i.e. warehouses, depots and terminals). When goods are stored at these locations there will be an entity that will be the depositary (i.e. the warehouse, depot or terminal) that will be storing the goods or containers for other entities that will be the depositors (i.e. the customers of the warehouse, depot or terminal).

For the carrier being able to pick-up or deliver the goods or containers from/to these locations, the depositor will need to authorize the depositary to provide (i.e., gate-out order) or accept (i.e. gate-in order) the goods or containers to/from a given carrier.

In ModalNET we will find different relations between the transport and the storage of goods and containers:

- There will be some consignments where the depositor will be at the same time whether the consignor or the carrier of the goods or containers. In this case the gate-out and gate-in orders will be directly provided to the carrier and the logistics facilities will directly know from the depositor who will be the carrier to deliver or accept the goods and containers.
- There will be some consignments where the depositor will be a provider of the consignor who will be in charge to request a transport to a carrier. In these cases, the depositor will need to authorize the gate-out or gate-in of the goods or containers to the consignor and the consignor provide these authorizations to the respective carrier and provide information of the carrier to the logistics facility.

The way the goods or containers are authorized by the depositor to be retired or stored from/into a logistic facility can be directly informing the depositary, consignor and carrier through gate-out and

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gate-in orders, or informing about the authorizations to deliver the goods or containers through the discharge or the loading orders submitted by the depositor to the logistics facility on those cases where the depositor will be the carrier of the goods or containers when they are discharged in the logistics facility.

ModalNET will handle these operations through the stored items entities that will register the goods or containers arriving and being stored at the logistics facility until these goods or containers are delivered to the next carrier. A stored item will encompass the loading, discharge, gate-in, and gate-out operations, refer to goods or materials held within a designated storage location, involving the processes of entering, exiting, loading, unloading, and the overall management of the storage facility.

A stored item will have a storage identifier which can be assigned by the depositor or by the depositary. Different depositors or depositaries can potentially assign the same storage identifier for their stored items, but a depositor or depositary shall guarantee that the stored item identifier is unique.

A stored item can include a stored item identifier, the depositor reference, the parties involved (depositor, depositary and agent), registration date, main transport of the stored item, a reference of the shipment associated with the stored item and data of the gate in and gate out processes. Gate in and Gate out processes can include the process identifier, the dates (validFrom, expiryDate, eta, ATA, ATD, confirmedDate), the authorized party, the associated and next transport information, shipments and/or transport units information, references, attributes and other related information.

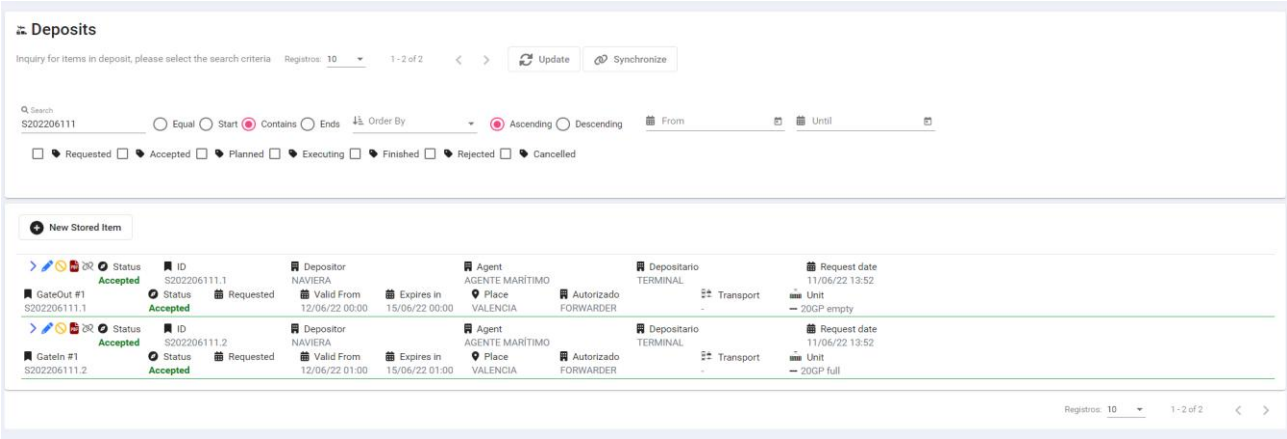

Figure 29. Cargo handling and storage

4.1.8 Cargo traceability

Apart from processing the ordering and planning capabilities of ModalNET which will generate request, order, change, accept, plan, reject and cancel events, the platform will also support the processing of the physical events such as arrived, dispatched, picked-up, gate-out, loaded, delivered, received, gate-in, discharged, inspected, departed, shunting, delayed as well as receive sensor or position data. These events will be linked to the consignments, transports, transportUnits or stored items registered in the platform, providing a virtual representation of the logistics operations and acting as a logistics digital twin.

The access to the transport events to relevant stakeholders will be achieved following the transport chains of related consignments registered in ModalNET to move the goods or containers, including also their storage at the logistics facilities, In this sense, all the consignors, carriers and consignees

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will be able to know all the events associated with the underlying consignments, stored items, transport units and transports so they could be able to achieve a complete end-to-end traceability assuring that only these stakeholders involved in the operations can access to these events.

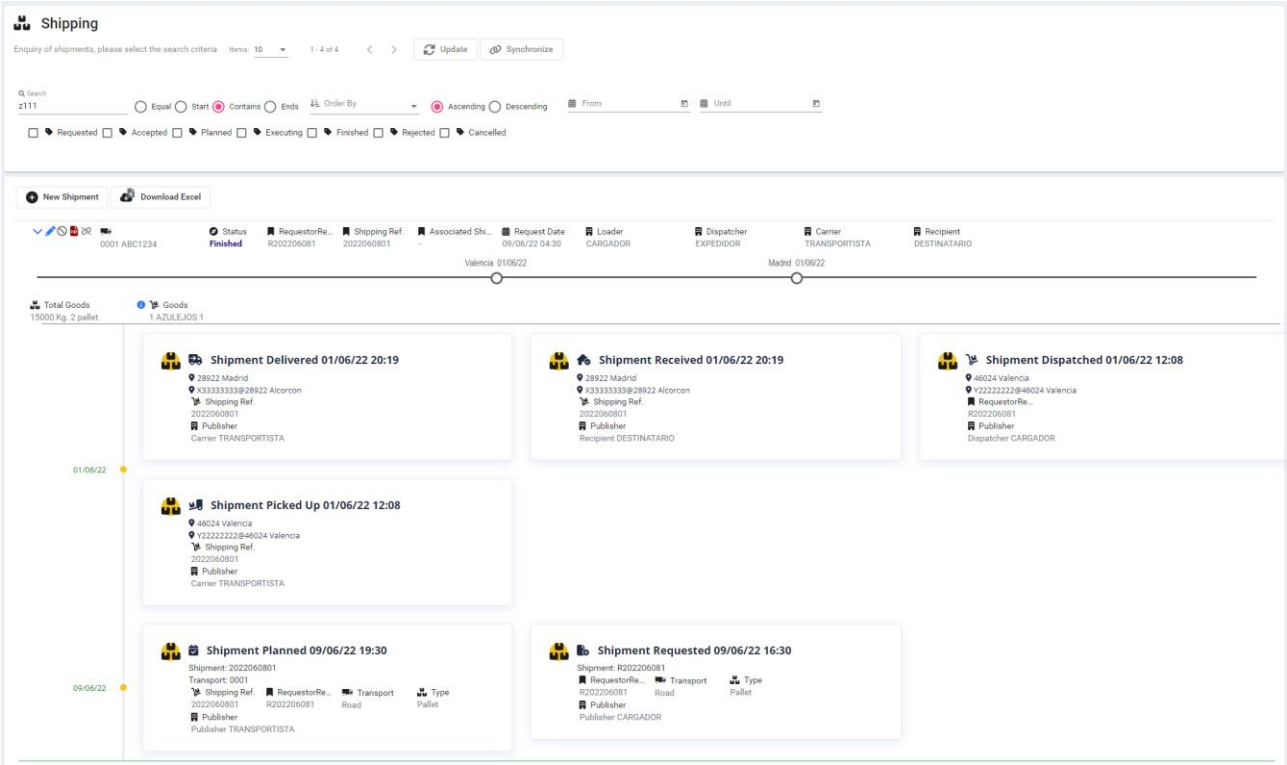

Figure 30. Cargo traceability

4.1.9 Vehicles and ships information

A vehicle is a mechanical device designed for transportation that is typically powered by an engine or motor. There can be several types of vehicles for different transport modes such as trucks, semi-trailers, trains, wagons, ships, barges or airplanes.

A vehicle will be uniquely identified by its vehicle identifier that will be unique for the particular type of vehicle. In the case the identifier is uniquely assigned in a country and the platform is going to register vehicles from different countries, the country code should be part of the vehicle identifier.

A vehicle data entity will be including the vehicle identifier, the mode of transport, the means type, the brand, the inspection expiration date, the owner and the party registering the vehicle in the platform, and other data including documentation that could be attached to the vehicle and a payload which can include any data dependent of the type of vehicle.

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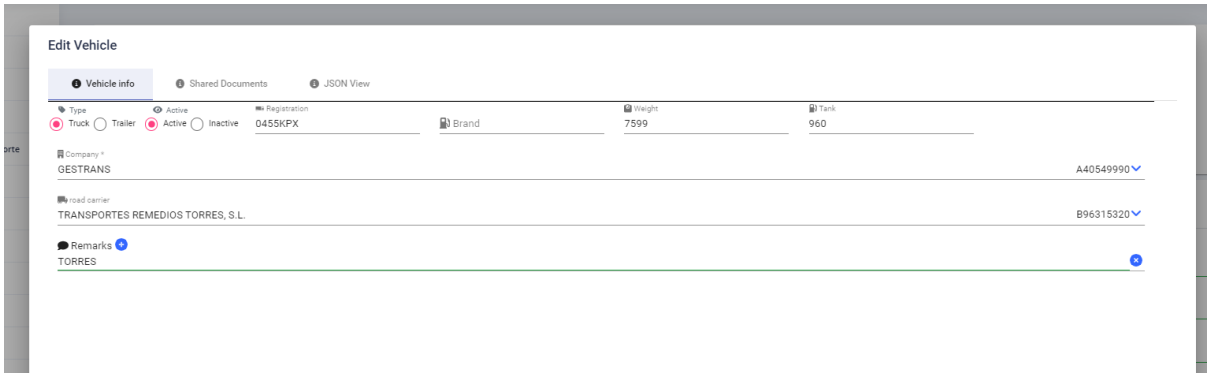

Figure 31. Vehicle input form for a truck

4.1.10 Ship reporting formalities

One of the relevant pieces of information to achieve an integrated supply chain support system will be the schedule of the SEAMLESS ships and the ship characteristics which will constitute one of the starting points to design new logistics systems. According to these schedules, a set of required formalities of the EMSWe regulation and the inland navigation electronic ship reporting formalities, such as the Ship Information (SHP), the Ship Identifiers notification (SID), the Request for visit ID (VID), the Notice of pre arrival (NOA), the Notice of shift (NOS), the Notice of pre departure (NOD), the notification of actual arrival time (ATA) and the notification of actual departure time (ATD). The formalities for the berth management port notification message (BERMAN) of the eSRIN regulation will be also taken into account.

Other formalities foreseen in the EMSWe, in eSRIN regulation or in the AVSPM system will need further analysis depending on the different concept of operations that will be considered on SEAMLESS autonomous ships. For example, it will be relevant to determine whether these ships will be dedicated to the transport of passengers, bulk cargo or carry out military activities, or if they will be only shipping among ports within the Union Customs Territory or within a single country (i.e. Norway), so several formalities may or may not be required. For example, it should be determined in the concept of operations whether the autonomous ships:

- will carry hazardous materials, which will require to present hazardous materials formalities at arrival, departure and during a shift (HZA, HZD and HZS in EMSWe and ERINOT in eSRIN),
- will have crew, which will require to present the crew list formalities at arrival and at departure (CWA and CWD in EMSWe and PAXLST in eSRIN),
- will need to report crew's effects, which will require to present the crew's effects declaration (EFF in EMSWe),
- will need to report waste information, which will require to present the advance notification for waste delivery to port reception facilities and the waste delivery receipt formalities (WAS and WAR in EMSWe),
- will need to report security information, which will require to present the notification of security information formality (SEC in EMSWe),
- will need to report ships' stores, which will require to present the declaration of stores on board at arrival and departure formalities (STA and STD in EMSWe),
- will need to report the cargo, which will require to present the cargo declaration formalities at arrival and departure (CGA and CGD in EMSWe),

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- will need to report inspections and certifications, which will require to present the notification of expanded inspection formality (EXP in EMSWe)
- will need to present the maritime declaration of health formality (MDH in EMSWe),
- will need to report customs formalities, which will require to determine which customs formalities will be required, such as the presentation notification (PRN in EMSWe), the temporary storage declaration (TSD in EMSWe), the Customs goods manifest (CGM in EMSWe), the presentation of the proof of Union Status at arrival (PPA in EMSWe), or the electronic transport documents used for transit at departure and at arrival (TRD and TRA in EMSWe),
- will need to report ballast waters, which will require to present in some European ports the ballast water formality (BWA in EMSWe)
- will need to report the bunkers required, which will require to present in some European ports the bunkers formalities at arrival and at departure (BKA and BKD in EMSWe),
- will need to report some specific formalities required in some ports according to national regulations, such as the notification of actual arrival, departure and shift at a port (ATA, ATD and NOS in EMSWe), the expected activities notification (ACT in EMSWe), the fairway dues declaration (DUE in EMSWe), the request for service (SRV in EMSWe), the ship visitors declaration (VIS in EMSWe), the ship to ship declaration (SSA in EMSWe), the stowaways notification (STW in EMSWe) or the absentee declaration (ABS in EMSWe)

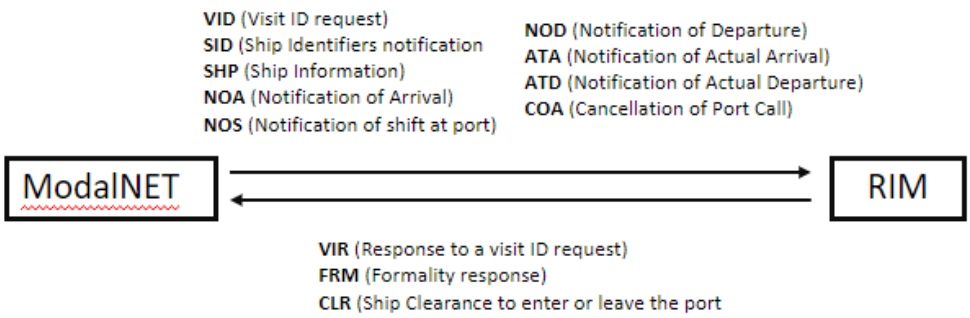

Figure 32. Ship's reporting formalities being considered in ModalNET

Several of the EMSWe formalities mentioned above are still in a design phase and they are not completely defined. There are also still several questions regarding the application of these formalities in each country. For these reasons, only the most relevant formalities for the SEAMLESS use cases will be considered initially in ModalNET (i.e., VID, SID, SHP, NOA, NOS, NOD, ATA, ATD, COA) and other formalities not yet clearly applicable will be analysed during the project.

4.2 PROCESS VIEW

Each ModalNET module will provide an API REST interface for each data entity managed by the platform. These API interfaces will support GET, POST, PUT and DELETE operations. The authorization and result of these operations will depend on the roles of the user, the involvement of the user's company or branch office in the data entity, the status of the entity and the business rules.

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4.2.1 ModalNET Processes

ModalNET processes will be focused on the processing of the different entities that are considered in the platform and described in the logical view. These entities are:

- **Offices**: An office will be a branch of a private company or of a public entity that will be established at a particular location and it will work independently from other branch offices. The processes associated with an office will be:
  - Creation of the office (POST)
  - Modification of the office (POST, PUT)
  - Cancellation of the office (POST, PUT)
  - Deletion of an office (DELETE)
  - Search of offices (GET with search parameters)
  - View of an office (GET)

ModalNET platform will offer a mechanism for self-registration of offices. However, the office will become active only when a system administrator will activate the office and configure the roles and services it can have in the platform and have been requested by the office administrator. Only the system administrator will be able to delete an office.

All registered users in ModalNET will be able to search for offices registered in the platform but they will only have access to public attributes. An office can define their partners and these partners will gain access to private attributes. During the registration of an office, the office administrator could include documents and determine the type of stakeholders that will be able to access these documents.

There will be ModalNET system administrators which will be able to create and manage any office.

- **Users**: A user will be always linked with an office. A user can be the administrator of an office so it will be able to create and configure new users in the office and perform several administration actions such as storing documents or registering vehicles. The processes associated with a user will be:
  - Creation of a user (POST)
  - Modification of a user (POST, PUT, PATCH)
  - Deactivation/Reactivation of a user (POST, PUT, PATCH)
  - Deletion of a user (DELETE)
  - Search of users (GET with search parameters)
  - View of a user (GET)

ModalNET platform will offer a mechanism for self-registration of offices. Only the users of the same office branch or the company will be able to search users of these offices registered in the platform and consult their public attributes. Each user will be able to change their data profile but not their access rights to the different services of the platform that will be assigned by the office administrator. It will not be able to change its office.

There will be ModalNET system administrators which will be able to create and manage the users of any office.

- **Vehicle**: The processes associated with a vehicle will be:

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- Creation of the vehicle (POST)
- Modification of the vehicle (POST, PUT, PATCH)
- Cancellation of the vehicle (POST, PUT, PATCH)
- Deletion of the vehicle (DELETE)
- Search of vehicles (GET with search parameters)
- View of a vehicle (GET)

Only the owners or authorized parties of the vehicle will be able to create, modify or cancel a vehicle. For each type of vehicle there will be a set of attributes that will be accessible by any registered user in ModalNET, while other attributes will be restricted to the stakeholders involved in the transports made by this transport mean. Authorities will have access to all the attributes of the vehicle. During the registration of a vehicle, the owner or the authorized party could include documents and determine the type of stakeholders that will be able to access these documents.

When the vehicle is a ship or a barge, the attributes registered in this entity will be used for the Ship information (SHP) and Ship Identifiers (SID) formalities of the EMSWe using the communication with the Remote Interface Module (RIM).

There will be ModalNET system administrators which will be able to create and manage any vehicle.

- **Consignment**: The processes associated with a consignment will be:
  - Creation of the consignment (POST)
  - Modification of the consignment (POST, PUT, PATCH)
  - Cancellation of the consignment (POST, PUT, PATCH)
  - Deletion of the consignment (DELETE)
  - Search of consignments (GET with search parameters)
  - View of a consignment (GET)

Only users of the branch office of the company acting as the consignor, carrier or consignee will be able to register the consignment. To be able to register consignments, these users shall also have the rights to create, update or delete their own consignments for the ModalNET service. Users acting as dispatch or receiving parties in the consignment will be able to access certain data of the consignment. During the registration of a consignment, the registration party could include documents and determine the type of stakeholders that will be able to access these documents. The carrier of the consignment will be able to assign during the planning phase the transport that will be carrying the consignment. The consignor of the consignment will be able to include the gate-out or gate-in orders that it has created or received from the depositor to pick-up or deliver the goods or transport units to the logistics facility.

There will be ModalNET system administrators which will be able to create and manage any consignment.

- **Transport Unit**: The processes associated with a consignment will be:
  - Search of transport units (GET with search parameters)
  - View of a transport (GET)

The transport units are automatically created when a consignment with transport units or when a stored item with transport units is registered in ModalNET.

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A transport unit will register the reference of its shipment and it will provide information of all events associated with the transport unit to the relevant parties.

- **Transport**: The processes associated with a transport will be:
  - Creation of the transport (POST)
  - Modification of the transport (POST, PUT, PATCH)
  - Cancellation of the transport (POST, PUT, PATCH)
  - Deletion of the transport (DELETE)
  - Search of transports (GET with search parameters)
  - View of a transport (GET)

A user of a carrier branch office will create a transport, and it will include the places along the route. The transport entity can be used to publish the schedules with the information of the route and the estimated times of arrival and departure at each place.

During the transport planning phase, the carrier will also include the consignments that will be loaded and discharged along the route. The transport planning of consignments will be made by the carrier whether at consignment level, indicating which transport will be used by the consignment or transport unit or at transport level indicating the load and discharge operations with the consignments or transport units that will be loaded and discharged at the logistics facilities along the route. In some logistics facilities it will be required the gate-out and gate-in orders to pick-up or deliver the consignments or the transport units. The consignments, transport, transport operations and stored items with the gate-in and gate-out orders will be linked together in such a way that these entities will provide the same information from different perspectives.

When a carrier publishes transport schedules, they will be publicly available to all ModalNET users. However, the data about the consignments to be loaded or discharged at each logistics facility will be only available to the corresponding logistics facility.

- **Transport operation**: The processes associated with a transport operation will be:
  - Creation of the transport operation (POST)
  - Modification of the transport operation (POST, PUT, PATCH)
  - Cancellation of the transport operation (POST, PUT, PATCH)
  - Deletion of the transport operation (DELETE)
  - Search of transport operations (GET with search parameters)
  - View of a transport operation (GET)

A user of a carrier branch office will create a transport operation. A transport operation can be a load or gate-out, or a discharge or gate-in. In the case the transport operation is not registered by the carrier, the logistics facility will be able to confirm the operation through a gate-out, load, discharge or gate-in event and it will be automatically registered.

A transport operation will be linked to the logistics facility and the transport that will perform the transport operation. It will include the references of the consignments or transport units involved in this operation.

In discharge or gate-in operations when the carrier is at the same time the depositor of the logistics facility, the carrier can inform about the party or the carrier that will be authorized to pick-up the stored items automatically generating the corresponding gate-out orders of the stored items.

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- **Stored Item**: The processes associated with a stored item will be:
  - Creation of the stored item (POST)
  - Modification of the stored item (POST, PUT, PATCH)
  - Cancellation of the stored item (POST, PUT, PATCH)
  - Deletion of the stored item (DELETE)
  - Search of stored items (GET with search parameters)
  - View of a stored item (GET)

A stored item will be created by a user of the branch office acting as the depositor or the depositary at the logistics facility. A stored item can have several gate-out or gate-in orders. In the case the stored item is not registered in advance, the logistics facility will be able to confirm the pick-up or delivery of the stored item through a gate-out, load, discharge or gate-in event and the stored item will be automatically registered.

- **Trackable Event**: The processes associated with a trackable event will be:
  - Creation of the event (POST)
  - Modification of the event (POST, PUT, PATCH)
  - Deletion of the event (DELETE)
  - Search of events (GET with search parameters)
  - View of an event (GET)

An event will be created by a user of the branch office that executes an operation with a consignment, a transport unit, a transport, a transport operation, or a stored item. The entity notifying the event will be the publisher. An event can have associated a set of data that will be used to generate the different data entities related with the event, in the case that these entities do not exist yet.

A user registered in ModalNET will be able to subscribe to the events created in the platform and it will receive notifications of these events. The event will not include the data but the reference to be able to access the data in the case the user has enough access rights.

The subscription to events will be made at branch office level and it will assign the user will be able to access the data. The way this user accesses the data can be through the user interface or using the APIs provided by the platform.

- **Master data**: The processes associated with a master data will be:
  - Creation of the master data (POST)
  - Modification of the master data (POST, PUT, PATCH)
  - Deletion of the master data (DELETE)
  - Search of master data (GET with search parameters)
  - View of a master data (GET)

A master data will be created by any user with rights to create their own master data but usually it will contain reference or configuration data created by the ModalNET system administrator. The configuration data will be only accessible by the branch office that has created the data whenever the user of the branch office has rights to access these data. The reference master data will be available to any user of the ModalNET platform. Master data can include several types of reference data such as postal codes, UNLOCODE location codes, country codes and other types of data.

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4.2.2 ModalNET API interfaces

The data entities and API REST end points considered in the ModalNET platform are:

Data Entity	API REST end-point
User	api/users
BranchOffice	api/offices
Consignment	api/consignments
TransportUnit	api/transportUnits
StoredItem	api/storedItems
Transport	api/transports
Process (Transport Operation)	api/operations
Vehicle	api/vehicles
TrackableEvent	api/trackableEvents
MasterData	api/masterdatas

Table 2. Data entities and API REST end points

When updating a data entity, the data submitted will be merged with the existing data. This means that those attributes which are not specified will preserve the existing value and will not be removed. Merging an attribute containing an array of primitive types (strings, dates, Booleans or numbers) will be replaced in the case it is updated but merging an attribute containing an array of objects will check if the object is the same to merge the object or add the object if it does not exist. For deleting an object of the array, a delete attribute needs to be indicated in the object to delete from the array during the update process.

4.2.3 ModalNET Data Model

The ModalNET data model has been designed to be able to comply with EFTI (European Freight Transport Information) regulation and with EMSWe (European Maritime Single Window environment) regulation. However, at the time of writing the report the specification of these data models were not yet complete. In consequence, ModalNET data model could be subject to future changes and adaptations when these data models are completed.

The ModalNET UML entity diagram for the data model is shown in the following diagram and the details of the attributes included in each entity will be detailed in Annex I. The entity diagram only shows the entities and main compositions and aggregations.

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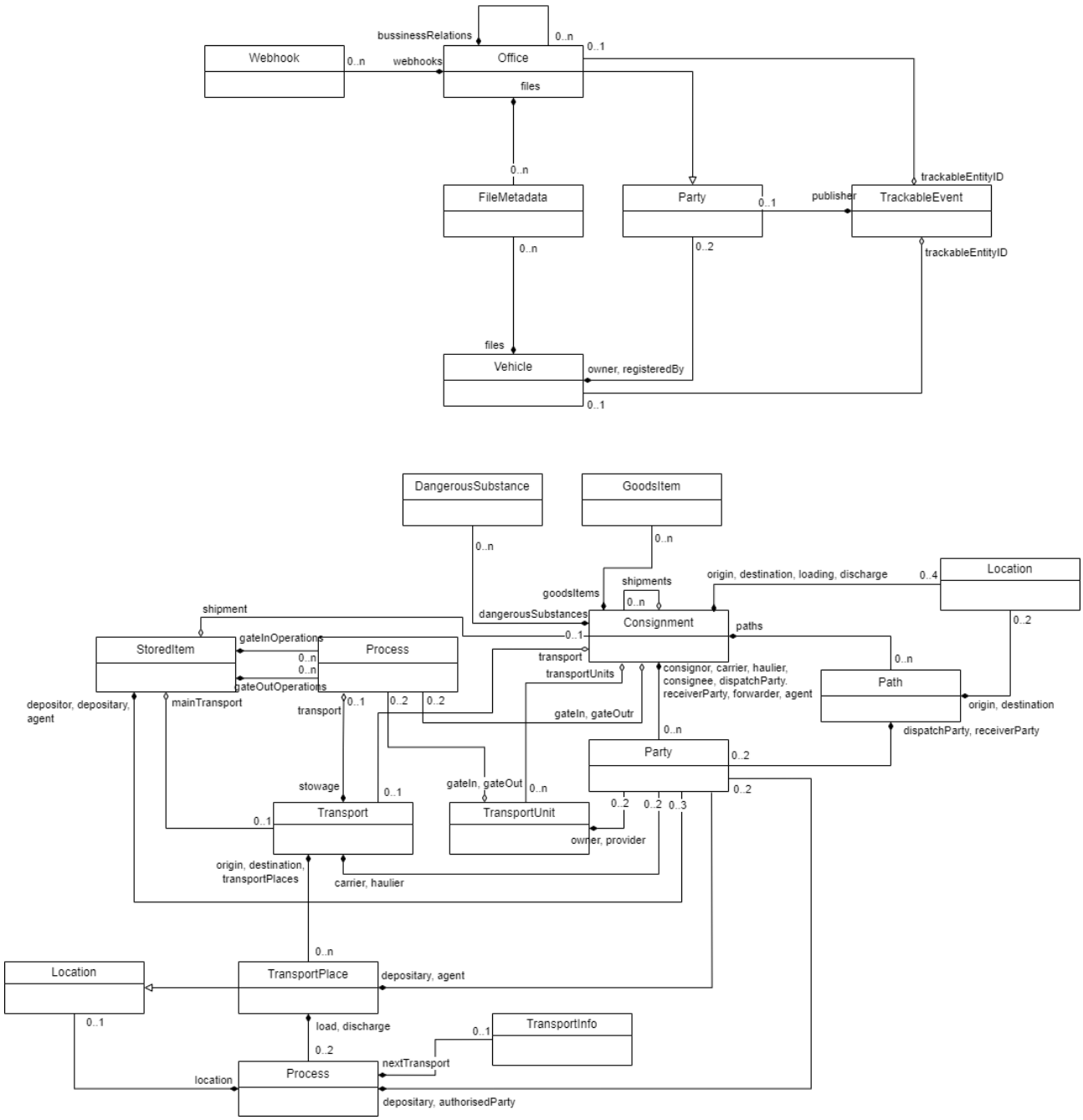

Figure 33. ModalNET entity diagram with main compositions and aggregations

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4.2.4 ModalNET communications with the Remote Interface Module (RIM)

The harmonized Remote Interface Module (RIM) is the middleware component of the maritime National Single Window through which the information can be exchanged between the information system used by the declarant and the relevant maritime National Single Window.

The goal of the RIM is to be able to exchange port administrative procedures in a standardized, reliable, and secure manner with the single-window portal of the public administration.

The architecture of these components are shown in the figure below.

Figure 34. RIM four corner architecture

ModalNET will be the application allowing the registration and subsequent submission of different formalities acting as Corner 1.

RIM is based on an open-source application named Omnibus that implements the eDelivery solution developed by the European Commission that facilitates secure and reliable information exchanges between companies or public administrations. RIM will be acting as the corner two in the information exchange and it will submit the formalities to the RIM corner three of the National Maritime Single Window of the country where SEAMLESS ships will arrive or depart.

Finally, the corner 4 will be composed by the National Maritime Single Window core system that will be developed by the National Competent Authority in each country and it will be in charge of distributing the formalities and centralizing the responses from different public administrations involved in the reporting formalities. For the testing and demonstration purposes, we will simulate in SEAMLESS the RIM Corner 3 and it is out of the scope of SEAMLESS the development of the National Maritime Single Window core system of the country.

3.- Example use case:

1) A user from the port community registers an administrative procedure in ModalNET and requests its submission to the public administration's single-window portal.
2) ModalNET retrieves the WSDL through the web server of RIM Corner 2 to determine the available methods in the RIM API and how to invoke them.
3) ModalNET converts the administrative formality to SOAP XML format and securely sends it via HTTPS to the web server of RIM Corner 2 to invoke the corresponding API method.
4) To ensure the correct and secure message transfer between RIM Corner 2 and RIM Corner 3, an appropriate configuration of the pmode.xml file is established in both, and certificates (truststore/keystore) are configured in both modules (truststore contains the public key to be shared with the other RIM, and keystore contains the private key known only to the RIM where it was generated).
5) RIM Corner 2, through its DOMIBUS module, securely forwards AS4-formatted messages as needed to the DOMIBUS of RIM Corner 3.
6) The single-window portal connects to the web server of RIM Corner 3 in the same way as ModalNET connects to RIM Corner 2, but this time to download the received messages. As they are downloaded, they are removed from the database of RIM Corner 3.

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4.2.5 CERL Processes

CERL processes will be focused on the processing of the different services that are considered in the platform and described in the logical view. Some of them are general interfaces and concern both user groups, such as Dashboard and User Profile, while other are dedicated to specific functionalities provided to either the service providers or the end users. More specifically, the service providers have access to Voyages and Transport Orders UIs, while end users have access to Search interface. There are two methods for data input into the platform; via API or via a user interface, where users can manually input data through the graphical interface provided by the platform. Analysing each user interface, below is a brief summary of the developed user interfaces that support the functionalities offered to satisfy the users' objectives.

4.2.5.1 General Interfaces

Dashboard

There are two methods for data input into CERL, i.e., via API or via User Interface (UI). The dashboard UI concerns both user groups. When a user logs in to the platform, the Dashboard is the first window available (Figure 35). It provides different reporting data to the service provider, such as Total Shipments per month, the Daily Sales or the Completed Tasks per month. The service provider may also examine the current Tasks that are pending or the latest routes that are executing by own fleet vessels. This reporting information is available and the service provider can decide which reports are needed in the user account page. On the other hand, the Dashboard provides an overview of the activity to the end user, such as current or previous bookings, etc.

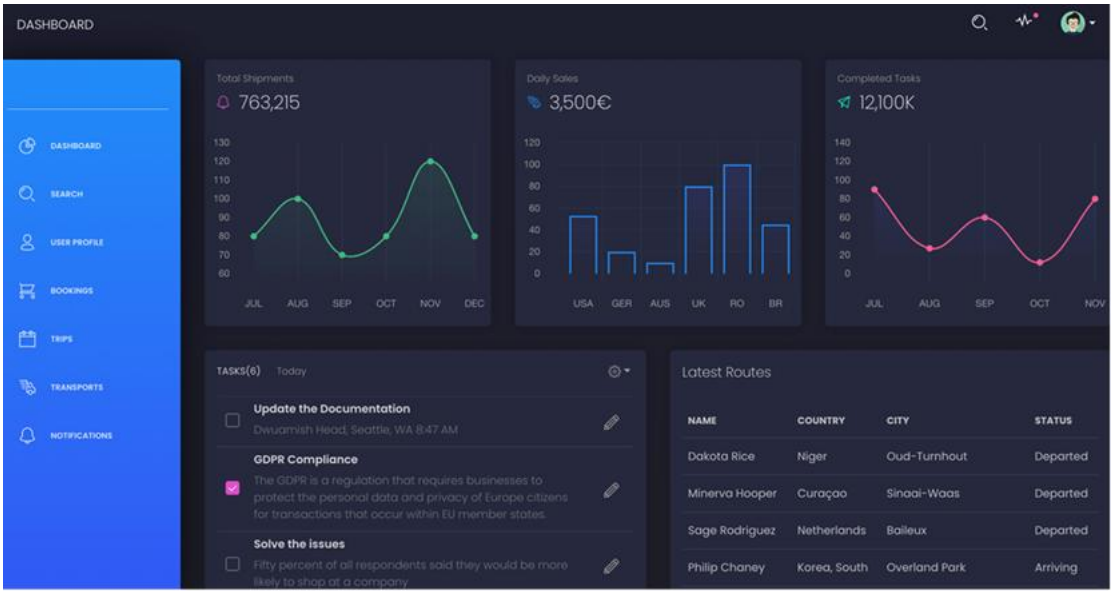

Figure 35. CERL Dashboard mock-up.

Source: MOSES AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping. NTUA

User Profile

There are two methods for data input into CERL, i.e., via API or via User Interface (UI). The User Profile interface is also available for both user groups. The user may edit and store account

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information. This information includes User's first and last name, company, username, city, country and postal code. The service provider is also able to configure which reports will be displayed on the Dashboard page.

4.2.5.2 Interfaces only for Service Providers

Voyages

There are two methods for data input into CERL, i.e., via API or via User Interface (UI). The Voyages interface is dedicated only to service providers. In this section (Figure 36), the service provider can see an analytical list of all scheduled itineraries executed by own fleet vessels. The service provider can also edit any itinerary and modify relevant information, such as name, current state, remaining capacity, or journey status. The system allows the service provider to either upload a list of itineraries through a formatted data file (Figure 37) or to add a single itinerary by inserting the necessary details in the correspondent form.

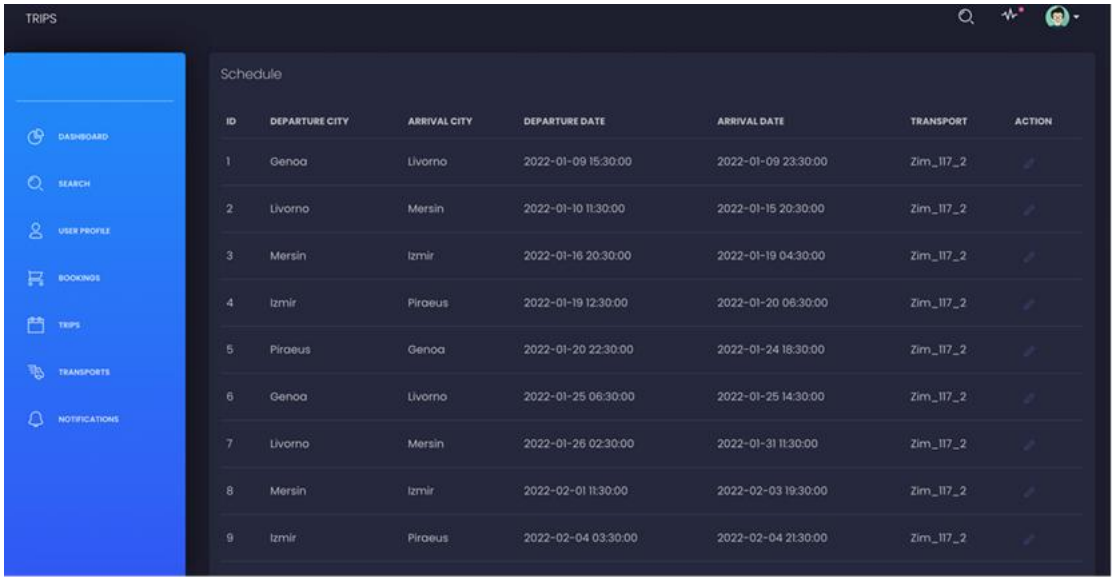

Figure 36. CERL Voyages mock-up.

Source: MOSES AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping. NTUA

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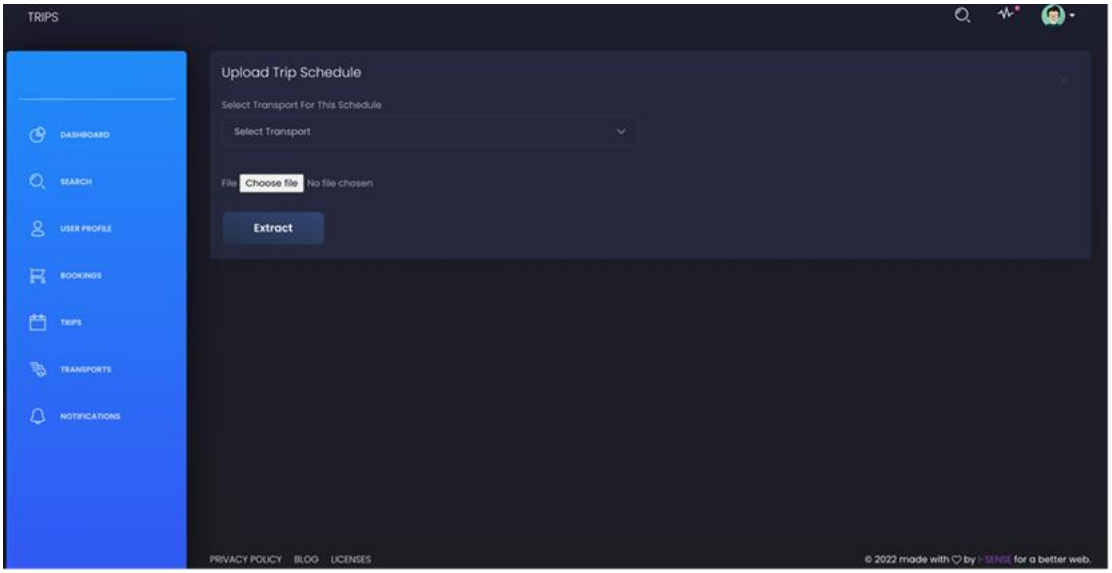

Figure 37. CERL Voyage Uploading mock-up.

Source: MOSES AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping. NTUA

Transport Orders

There are two methods for data input into CERL, i.e., via API or via User Interface (UI). The Transport Orders interface is also dedicated only to service providers. In the Transport Orders section (Figure 38), a list of all available vessels owned by the specific service provider is displayed. The service provider can update the information of a specific vessel by clicking the Action button and provide information such as the vessel's capacity, the type of carried products, the type of vessel (ship, train, truck) and its name and status. The service provider can also add new vessels and provide necessary details in the correspondent form.

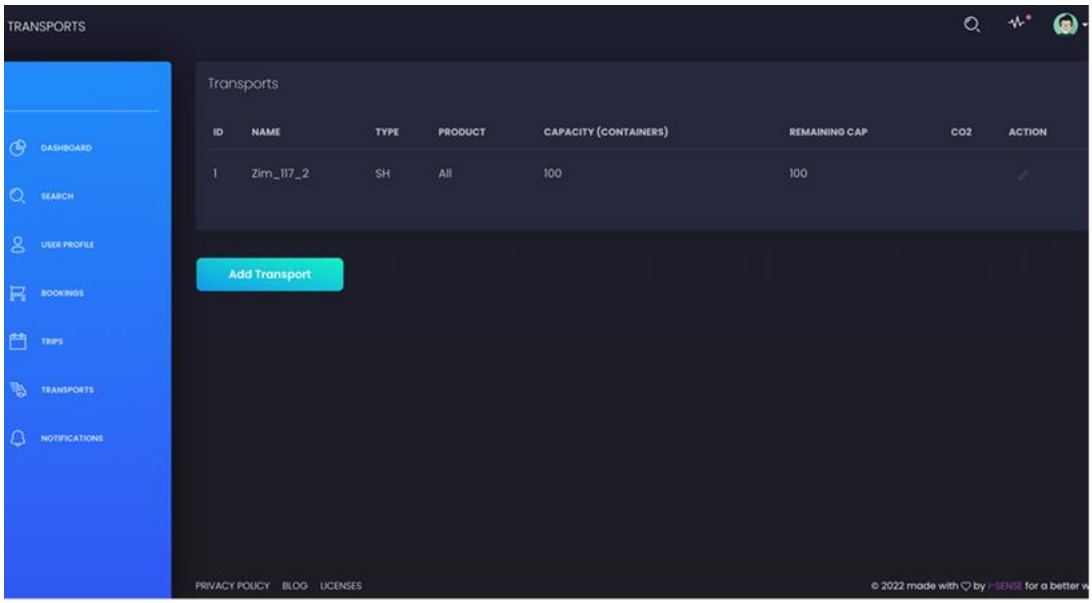

Figure 38. CERL Transport Orders mock-up.

Source: MOSES AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping. NTUA

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4.2.5.3 Interfaces only for End Users

Search

As mentioned before, the second usage level of CERL concerns the functionalities provided to end users who are willing to consume the services provided by service providers. Some of the functionalities that are described above, such as Voyages or Transport Orders are not of end users' interest. However, they can benefit from the main functionality of the system, which is the matchmaking feature. n this window, the platform displays a list of available routes found that fulfil the any search criteria.

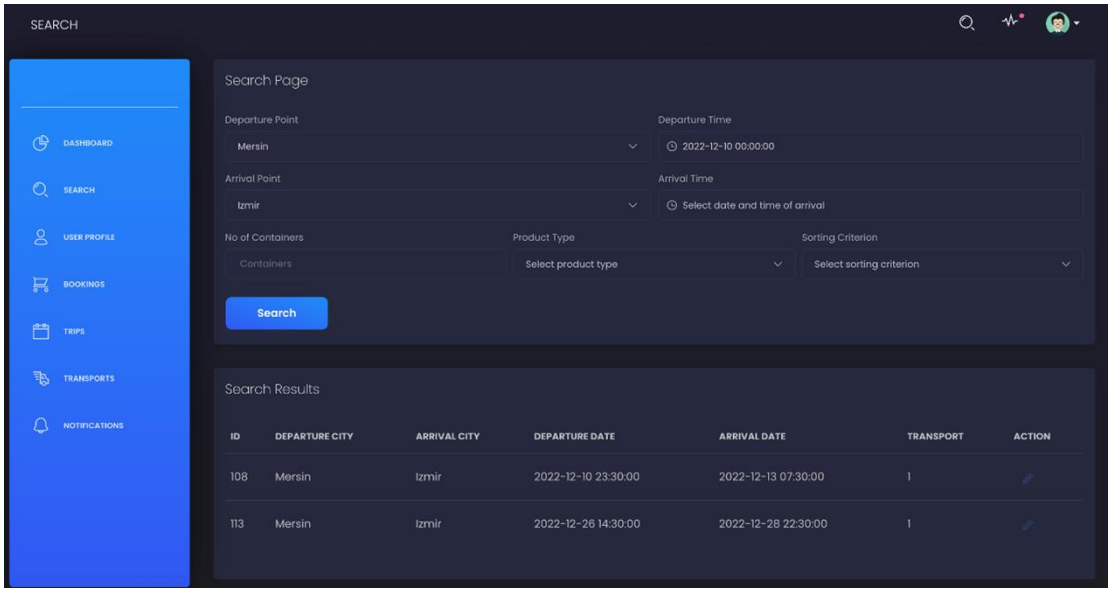

Figure 39. CERL Search mock-up.

Source: MOSES AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping. NTUA

4.2.6 CERL API interfaces

Python Django framework has been used to expose the content of the database to the front-end or to other clients if needed. These APIs have been developed with Django REST framework library. Some of these APIs are appropriate for storing content to the database (through HTTP POST methods), some others for updating the database (e.g., updating vessel schedule through HTTP PATCH) and others for deleting some content (e.g., deleting a vessel entry through HTTP DELETE method). In all services, only path parameters have been defined and the request body is always in JSON format (i.e., HTTP request header "content-type" should always have the value "application/json"). Response bodies are also in JSON format.

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The data entities and API REST end points considered in CERL are:

Data Entity	API REST end-point
Transport Orders	api/v1/transportOrders
Destinations	api/v1/destinations
Voyages	api/v1/voyages

Table 3. Data entities and API REST end points in CERL

When updating a data entity, the data submitted will be merged with the existing data. This means that those attributes which are not specified will preserve the existing value and will not be removed. Merging an attribute containing an array of primitive types (strings, dates, Booleans or numbers) will be replaced in the case it is updated but merging an attribute containing an array of objects will check if the object is the same to merge the object or add the object if it does not exist. For deleting an object of the array, a delete attribute needs to be indicated in the object to delete from the array during the update process.

4.2.7 CERL Data Model

CERL backend is based on Django Python Framework and the front-end is developed using the Vue.js JavaScript web framework. The database that supports the application is PostgreSQL database. In Figure 40, the Entity Relationship Diagram illustrates how all the available entities are related to each other within the system, while each entity is presented in detail in Figure 41. A short description of each entity is the following:

1. auth_group: entity that contains the different user groups
2. auth_permission: entity that contains the permissions given to each group
3. auth_group_permissions: entity necessary to keep the many-to-many relationship between the auth_group and the auth_permission entities
4. authtoken_token: entity that stores the valid tokens for accessing the application
5. users_customuser: entity that stores the extended user model that is used by the system
6. users_customuser_groups: entity that stores the extended groups model that are used by the system
7. users_customuser_user_permissions: entity to store the permissions of extended users
8. django_content_type: contains the different content type that the users may create within the system
9. django_migrations: entity to store the migrations that are applied to the database
10. django_session: entity that contains the different session information
11. django_admin_log: entity that stores actions that admin users may do in the system
12. locations_location: entity that stores the different locations inserted in the system
13. locations_trip: contains the scheduled trips of the transport means
14. bookings_booking: contains the bookings that are made by the clients
15. transports_transport: entity that stores all the records concerning the transport means available
16. notifications_notification: entity for the system notifications that are sent to users
17. uploader_upload: entity that stores information about the uploaded files

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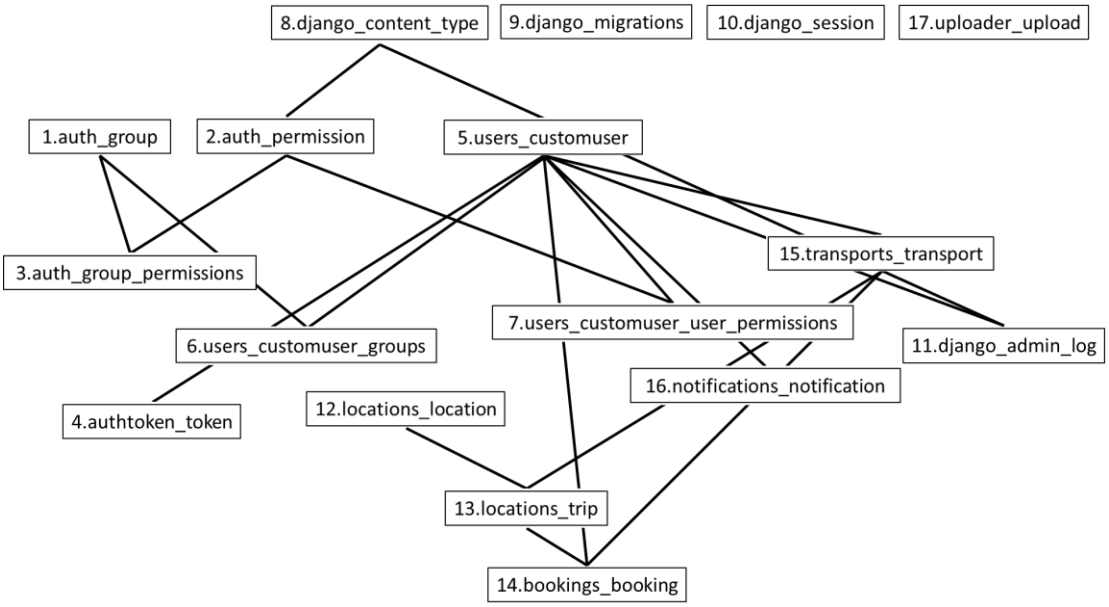

Figure 40. Entity Relationship Diagram

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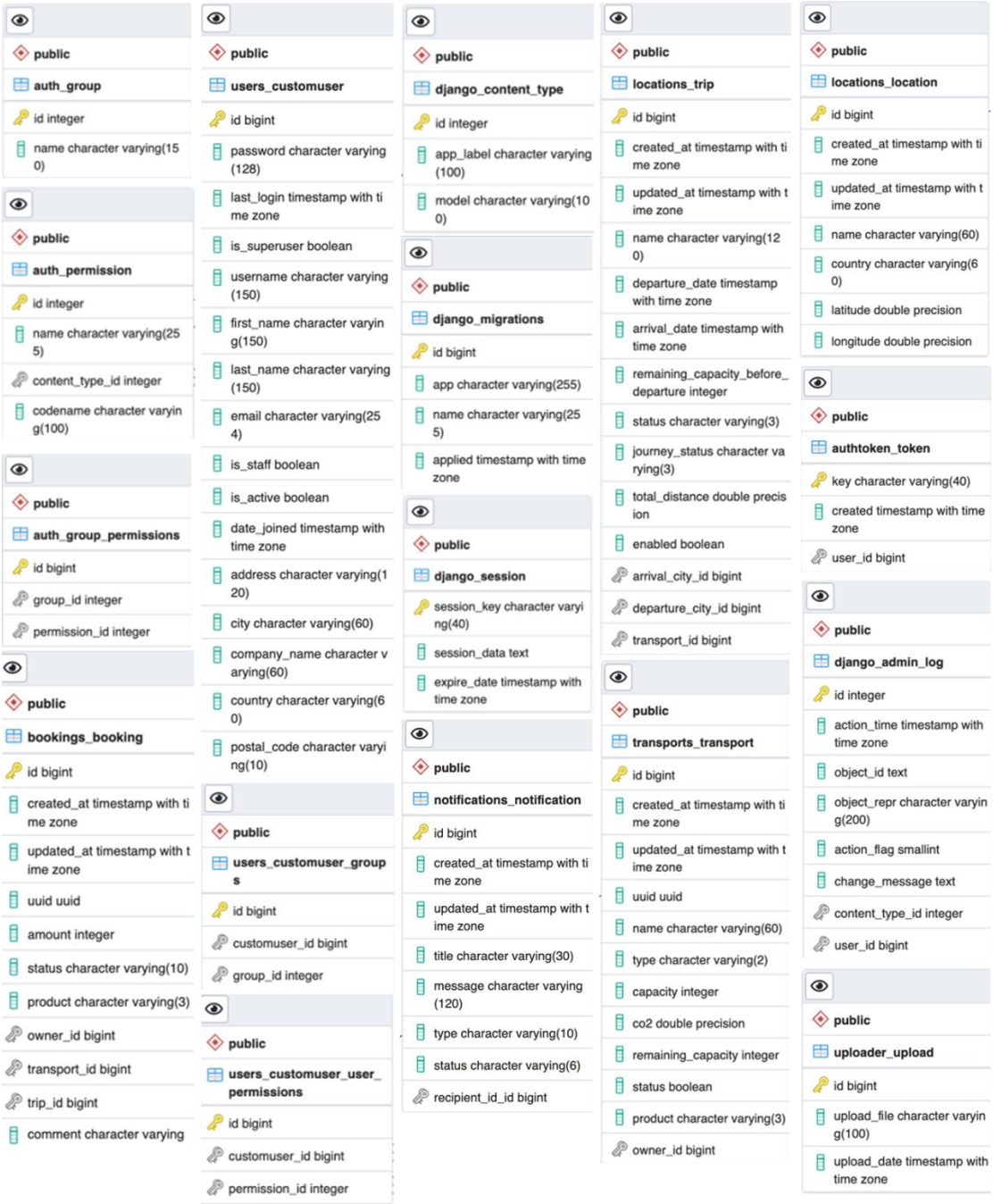

Figure 41. Entities description

4.3 DEVELOPMENT VIEW

The development of ModalNET will adopt the Agile methodology. Agile is not just a set of practices; it is a mindset that prioritizes flexibility, collaboration, and continuous improvement. The key principles and practices that will guide the development will be:

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- *Customer Collaboration*: Agile places a strong emphasis on customer satisfaction. We will actively engage our stakeholders throughout the development process, seeking their feedback and adapting to changing requirements.
- *Individuals and Interactions over Processes and Tools*: While processes and tools are important, we value the individuals on our team and the interactions between them. Open communication and collaboration will be the driving force behind our success.
- *Working Software over Comprehensive Documentation*: Our primary focus is to deliver working software that adds value to our customers. While documentation is necessary, we will prioritize functional code and iterate based on real-world usage.
- *Responding to Change over Following a Plan*: In a dynamic environment, we recognize the inevitability of change. We will embrace changes in requirements, technology, and market conditions, adjusting our course to maximize project success.

The Agile development practices that will be followed in the development of ModalNET are:

- *Scrum Framework*: We will organize our work using the Scrum framework, dividing the project into time-boxed iterations called sprints. This approach allows for regular inspection and adaptation, ensuring that the team is always aligned with project goals.
- *Backlog Management*: The product backlog will serve as a dynamic repository of features, enhancements, and bug fixes. Prioritization will be based on customer needs and business value, ensuring that the team works on the most valuable items first.
- *Continuous Integration and Continuous Deployment (CI/CD)*: Automation will be a cornerstone of our development process. Regular integration and deployment will minimize bottlenecks, allowing us to deliver reliable software faster and with greater confidence.

4.3.1 ModalNET software components

In the dynamic landscape of application development, leveraging robust technologies is essential for creating scalable, performant, and feature-rich solutions. Our approach to develop ModalNET involves the powerful combination of MongoDB as the database, Node.js for server-side development, and Angular for building dynamic and responsive user interfaces.

These technologies have several synergies that make this stack a compelling choice:

- *MongoDB: A Flexible and Scalable Database*. MongoDB, a NoSQL database, serves as the foundation of our application's data layer. Its document-oriented structure allows for flexible schema design, accommodating evolving data requirements. Key features include horizontal scalability, support for complex data structures, and seamless integration with Node.js.
- *Node.js: Powering the Server-Side Logic*: Node.js, built on the V8 JavaScript runtime, is chosen for its event-driven, non-blocking I/O model, making it well-suited for building scalable and efficient server-side applications. It allows us to use TypeScript, that it will compile into JavaScript, across the entire application stack, facilitating code reuse and streamlining development workflows. Node.js seamlessly integrates with MongoDB, enabling smooth communication between the server and the database.
- *Angular: Crafting Dynamic User Interfaces:* Angular, a robust front-end framework developed and maintained by Google, empowers us to create dynamic, single-page applications (SPAs). Its modular architecture, two-way data binding, and extensive set of tools simplify the development of complex user interfaces. Angular seamlessly integrates with Node.js through RESTful APIs, ensuring a cohesive end-to-end development experience.

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The development process will include:

- *Project Setup*: We will initiate the project by setting up the development environment, configuring Node.js and npm for server-side development, and installing Angular CLI for front-end development. MongoDB local instances will be used during the development phase. The
- *Backend Development with Node.js*: Using Node.js, we will develop the backend logic of the application, handling data operations, business logic, and interfacing with MongoDB. Express.js, a minimalist web framework for Node.js, will be employed to streamline the development of RESTful APIs.
- *Database Design with MongoDB*: The flexible schema of MongoDB allows us to design the database to meet the specific needs of the application. Collections and documents are organized to optimize data retrieval and support efficient queries.
- *Frontend Development with Angular*: Angular enables the creation of dynamic and responsive user interfaces. We will design modular components, leverage services for data retrieval from the backend, and implement reactive forms for user input. Angular's powerful features, such as dependency injection and two-way data binding, enhance the development of a seamless user experience.
- *Integration and Testing*: Continuous integration is employed to ensure that changes made to the codebase do not introduce regressions. Unit testing, integration testing, and end-to-end testing will be conducted to maintain code quality and reliability.
- *Deployment and Scaling*: Once development and testing will be complete, the application will be deployed into the sandbox environment for the SEAMLESS project. With the scalability of both MongoDB and Node.js, the application can efficiently handle increased loads.

For the development of the backend and frontend we will use as source code editor Visual Studio Code (VS Code). This is a cross platform free and open-source tool that supports a broad range of programming languages. Git version control is integrated into the editor, providing developers with essential Git features like staging, committing, and pushing changes. The private source code repository used will be GitHub. VS Code will provide debugging support for various programming languages, enabling developers to identify and fix issues directly from this editor. It also provides IntelliSense code completion based on the context of the code. The language used for the development of the backend and frontend development will be TypeScript.

4.3.1.1 ModalNET frontend development

In the ever-evolving landscape of web development, creating dynamic and responsive user interfaces is a crucial aspect of delivering a seamless user experience. Angular, a powerful and open-source front-end framework developed and maintained by Google, emerged as a go-to-choice for building robust single-page applications (SPAs) and complex web interfaces. With its extensive set of features and a structured approach to application development, Angular empowers developers to create scalable, maintainable, and feature-rich frontend applications.

Angular follows the Model-View-Controller (MVC) architectural pattern, providing a well-defined structure for organizing code and facilitating modular development. Its component-based architecture encourages the creation of reusable and encapsulated building blocks, making it easier to manage and scale large projects. Angular's two-way data binding ensures real-time synchronization between the model and the view, simplifying the handling of user inputs and dynamic updates.

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Angular has several standout features, such as its dependency injection system, which promotes the development of loosely coupled and testable code. Angular also incorporates TypeScript, a statically-typed superset of JavaScript, bringing advantages such as enhanced code readability, improved error checking, and better tooling support. Angular embraces a modular approach through NgModules, enabling efficient organization and management of application functionality.

ModalNET frontend development will use Nebular UI library[21] and the ngx-admin template[22], which is one of the most popular and trusted Angular open-source dashboard templates. Nebular library also includes authentication components and token management, and frontend roles and permissions management. Over this template the following main libraries will be used for the development of the application:

- *angular-material*[23]: Angular Material is a UI component library developed and maintained by the Angular team at Google. It is designed to help developers create modern, visually appealing, and responsive user interfaces for Angular applications. Angular Material provides a set of pre-built, customizable components following the Material Design principles, which is a design language developed by Google.
- *ng-bootstrap*[24]: This library includes a set of Angular widgets built from the ground up using Bootstrap 5 CSS with APIs designed for the Angular ecosystem.
- *ngx-translate*[25]: This is the internationalization (i18n) library for Angular that allows the definition of translation labels in json format.
- *file-saver*[26]: FileSaver.js is a solution to saving files on the client-side and is perfect for web apps that generates files on the client or receive them through API-REST responses.
- *jsoneditor*[27]: JSON Editor is a web-based tool to view, edit, format, and validate JSON.
- *moment.js*[28]: Moment is a library to parse, validate, manipulate, and display dates and times in JavaScript.
- *ng2-fileupload*[29]: FileUpload is a library that includes directives for files upload.
- *ngx-webcam*[30]: Webcam is a library to gain access to the camera to take pictures or recording.
- *rxjs*[31]: RxJS is a library for reactive programming using Observables, to make it easier to compose asynchronous or callback-based code.

[21] Nebular - What is Nebular? (akveo.github.io)
[22] GitHub - akveo/ngx-admin: Customizable admin dashboard template based on Angular 10+
[23] Angular Material UI component library
[24] Angular powered Bootstrap (ng-bootstrap.github.io)
[25] GitHub - ngx-translate/core: The internationalization (i18n) library for Angular
[26] file-saver - npm (npmjs.com)
[27] jsoneditor - npm (npmjs.com)
[28] Moment.js | Home (momentjs.com)
[29] ng2-file-upload - npm (npmjs.com)
[30] ngx-webcam - npm (npmjs.com)
[31] RxJS

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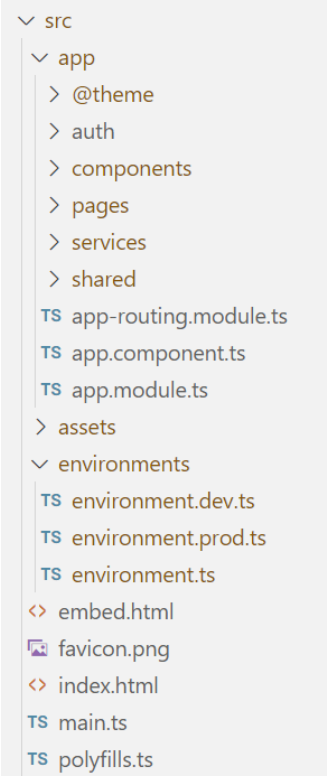

Figure 42. Frontend source code structure

The code will be structured in different sections. It will include a section for theme and auth definitions and behaviour which is an adaptation of the theme and auth sections provided by the ngx-admin template, the components section which will include the dialogs, display items, forms, popups and widgets used by ModalNET, the pages section that will provide the main pages accessible from the pages-menu through the pages-routing components, the services section that will provide the API call operations to the backend modules, the shared section that will include the different data models and common functions used in the frontend, the assets sections which will include fonts, images, translation files, and the environments section that includes the configuration parameters for the development, testing and production environments.

4.3.1.2 ModalNET backend development

In the realm of modern web development, creating robust and scalable backend services is a fundamental aspect of building high-performance applications. Node.js, known for its event-driven architecture and non-blocking I/O operations, has become a popular choice for backend development. When combined with TypeScript, a superset of JavaScript that adds static typing and other advanced features, developers can leverage the power of both worlds to create maintainable, scalable, and type-safe backend solutions.

Node.js, built on the V8 JavaScript runtime, empowers developers to build efficient and scalable server-side applications. Its asynchronous, event-driven nature allows for handling a large number of concurrent connections, making it well-suited for applications with high traffic and real-time communication needs. Node.js has a vibrant ecosystem with a vast array of libraries and frameworks, enabling developers to create diverse and feature-rich backend services.

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TypeScript extends the capabilities of JavaScript by introducing static typing, interfaces, and other advanced features. This brings a level of predictability and maintainability to code, making it easier to catch errors during development and enhancing code readability. By leveraging TypeScript in Node.js backend development, developers can enjoy the benefits of a more structured and scalable codebase without sacrificing the flexibility and rapid development capabilities offered by JavaScript. TypeScript allows developers to specify and enforce data types, reducing the likelihood of runtime errors and enhancing code quality. This is particularly valuable in large and complex backend applications. TypeScript supports the latest ECMAScript features, providing developers with access to modern language constructs and enhancing the overall development experience. TypeScript supports the use of classes, modules, and interfaces, allowing developers to create well-organized and maintainable code structures. This is crucial for managing the complexity of backend systems.

Both Node.js and TypeScript have large and active communities, ensuring a wealth of libraries, frameworks, and tools to streamline the development process. This ecosystem support is vital for building scalable and feature-rich backend applications.

To embark on Node.js backend development using TypeScript, there are tools like npm (Node Package Manager) to manage dependencies, along with popular frameworks like Express.js for building web applications and APIs. The combination of Node.js and TypeScript offers a potent environment for creating scalable, maintainable, and type-safe backend solutions, making it a compelling choice for modern web development projects.

The main libraries to be used to build the ModalNET platform are:

- *accesscontrol*[32]: Role-based access control (RBAC) for Node.js
- atob[33]: A browser and Node.js module for decoding base64-encoded strings
- axios[34]: Promise-based HTTP client for the browser and Node.js
- bcryptjs[35]: Library for hashing and salting passwords
- body-parser[36]: Node.js body parsing middleware
- compression[37]: Node.js middleware for gzip compression
- cors[38]: Cross-Origin Resource Sharing middleware for Express.js
- csv-parser[39]: CSV parsing library for Node.js
- csv-write-stream[40]: CSV writing library for Node.js
- csv-writer[41]: Library for writing CSV files in Node.js
- dotenv[42]: Zero-dependency module for loading environment variables
- express[43]: Fast, unopinionated, minimalist web framework for Node.js

[32] GitHub - onury/accesscontrol: Role and Attribute based Access Control for Node.js
[33] https://www.npmjs.com/package/atob
[34] https://axios-http.com/docs/intro
[35] https://www.npmjs.com/package/bcryptjs
[36] https://www.npmjs.com/package/body-parser
[37] https://www.npmjs.com/package/compression
[38] https://www.npmjs.com/package/cors
[39] https://www.npmjs.com/package/csv-parser
[40] https://www.npmjs.com/package/csv-write-stream
[41] https://www.npmjs.com/package/csv-writer
[42] https://www.npmjs.com/package/dotenv
[43] https://expressjs.com/

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- fast-xml-parser[44]: XML parser for Node.js with a focus on speed and low memory overhead
- formidable[45]: Node.js module for parsing form data, especially file uploads
- gridfs-stream[46]: GridFS stream implementation for MongoDB and Node.js
- handlebars[47]: Templating engine for Node.js
- handlebars-dateformat[48]: Handlebars helper for formatting dates
- he[49]: HTML entities encoder/decoder for Node.js
- helmet[50]: Security middleware for setting HTTP headers in Express.js
- http-status-codes[51]: Constants representing HTTP status codes
- jsonata[52]: JSON query and transformation language
- jsonwebtoken[53]: JSON Web Token (JWT) implementation for Node.js
- lodash.clonedeep[54]: Lodash utility for deep cloning objects
- lusca[55]: Web application security middleware for Express.js
- moment[56]: Date and time manipulation library for Node.js
- mongodb[57]: MongoDB driver for Node.js
- morgan[58]: HTTP request logger middleware for Node.js
- node-xlsx[59]: Excel file parser and builder for Node.js
- passport[60]: Authentication middleware for Node.js
- passport-jwt[61]: Passport strategy for JSON Web Token (JWT) authentication
- passport-local[62]: Passport strategy for local authentication
- puppeteer[63]: Headless Chrome browser automation library
- qrcode[64]: QR code generator for Node.js
- querystring[65]: Query string parsing and formatting for Node.js
- redsys-easy[66]: Simplified integration with the Redsys payment gateway
- rxjs[67]: Reactive Extensions for JavaScript
- sendgrid[68]: SendGrid API client for Node.js

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44 https://www.npmjs.com/package/fast-xml-parser
45 https://www.npmjs.com/package/formidable
46 https://www.npmjs.com/package/gridfs-stream
47 https://handlebarsjs.com/
48 https://www.npmjs.com/package/handlebars-dateformat
49 https://www.npmjs.com/package/he
50 https://www.npmjs.com/package/helmet
51 https://www.npmjs.com/package/http-status-codes
52 https://jsonata.org/
53 https://www.npmjs.com/package/jsonwebtoken
54 https://www.npmjs.com/package/lodash.clonedeep
55 https://www.npmjs.com/package/lusca
56 https://momentjs.com/docs/
57 https://docs.mongodb.com/drivers/node
58 https://www.npmjs.com/package/morgan
59 https://www.npmjs.com/package/node-xlsx
60 http://www.passportjs.org/docs/
61 https://www.npmjs.com/package/passport-jwt
62 https://www.npmjs.com/package/passport-local
63 https://pptr.dev/
64 https://www.npmjs.com/package/qrcode
65 https://www.npmjs.com/package/querystring
66 https://www.npmjs.com/package/redsys-easy
67 https://rxjs.dev/
68 https://github.com/sendgrid/sendgrid-nodejs

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- soap[69]: Simple object access protocol (SOAP) client for Node.js
- speakeasy[70]: Two-factor authentication (2FA) library for Node.js
- stream-buffers[71]: Library for creating in-memory readable and writable streams
- unzipper[72]: Unzipping library for Node.js
- uuid[73]: UUID (Universally Unique Identifier) generation library for Node.js
- winston[74]: Logging library for Node.js
- winston-daily-rotate-file[75]: Winston transport for daily rotated log files
- xlsx-populate[76]: Excel file reader and writer for Node.js
- xmlbuilder[77]: XML builder for Node.js
- xmldom[78]: XML DOM parser and serializer for Node.js
- xmlhttprequest[79]: XMLHttpRequest library for Node.js

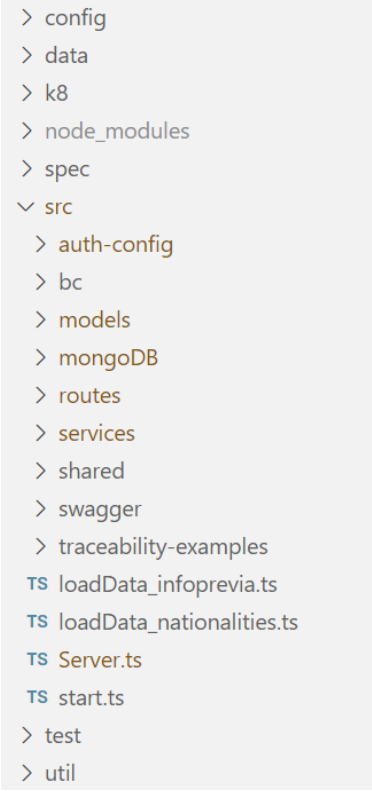

Figure 43. Backend source code structure

[69] https://www.npmjs.com/package/soap
[70] https://www.npmjs.com/package/speakeasy
[71] https://www.npmjs.com/package/stream-buffers
[72] https://www.npmjs.com/package/unzipper
[73] https://www.npmjs.com/package/uuid
[74] https://www.npmjs.com/package/winston
[75] https://www.npmjs.com/package/winston-daily-rotate-file
[76] https://www.npmjs.com/package/xlsx-populate
[77] https://www.npmjs.com/package/xmlbuilder
[78] https://www.npmjs.com/package/xmldom
[79] https://www.npmjs.com/package/xmlhttprequest

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The code will be structured in different sections as show. It will include a section for authentication and roles configurations, for data models, for database secure connection, collection and index definitions and functions, for REST API interfaces (routes), for business services definitions, and for shared functions,

The code will include also a configuration section that will include the configuration parameters for the development, testing and production environments and other files to initiate the web server and to automate the deployment.

4.3.2 CERL - Computational engine for resilient logistics Processes software components

The development of Computational engine for resilient logistics Processes complements and exploits the outcomes of the MOSES Matchmaking platform. The architecture of CERL consists of the back-end module, the storage/database module and the front-end module. These modules include all the subcomponents of the platform, such as the optimization component, the user interface etc. More specifically, the structure is as follows:

- The front-end module is where all necessary information is collected and includes the available user interfaces that are provided to the users based on their role.
- The database module is where all collected resources and intermediate results are stored.
- The back-end module is where the search and matching algorithms run and includes the server and optimization component.

4.3.2.1 CERL Front-end development

CERL front-end is developed using the Vue.js JavaScript web framework, including use of JavaScript, CSS and images (i.e., static content). Vue.js is a mature and battle-tested framework. It is one of the most widely used JavaScript frameworks in production today, with over 1.5 million users worldwide. Vue.js allows the consumption of APIs in order to extend the system's capabilities or connect with other systems.

4.3.2.2 CERL database module

The database that supports the application is PostgreSQL database. PostgreSQL is the world's most advanced open-source relational database. It is a powerful, open-source object-relational database system with over 30 years of active development that has earned it a strong reputation for reliability, feature, robustness and performance.

4.3.2.3 CERL Back-end development

CERL backend is based on Django Python Framework. Django provides a database-abstraction API that allows the creation, retrieval, update and deletion of objects (i.e., records in a database table). This database-abstraction API belongs to the ORM (relational mapping layer), a layer useful for the interaction with CERL data. Then, on top of Django is the Django REST framework that is a powerful and flexible toolkit for building Web APIs. Django REST framework serializes data from the Django ORM and allows access/updates via a RESTful API. The APIs can then be consumed by a pertinent JavaScript framework like Vue.js, that was used to build CERL front-end in order to extend the system's capabilities or connect with other systems. The workflow described above is depicted in Figure 44 .

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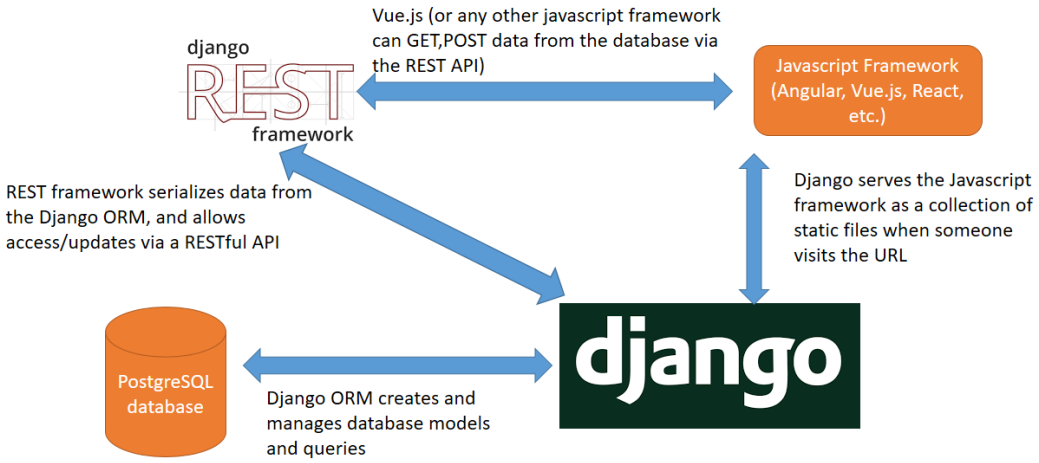

Figure 44. Interaction between the main components of CERL

Python Django framework has been used to expose the content of the database to the front-end or to other clients if needed. These APIs have been developed with Django REST framework library. Some of these APIs are appropriate for storing content to the database (through HTTP POST methods), some others for updating the database (e.g., updating vessel schedule through HTTP PATCH) and others for deleting some content (e.g., deleting a vessel entry through HTTP DELETE method). In all services, only path parameters have been defined and the request body is always in JSON format (i.e., HTTP request header “content-type” should always have the value “application/json”). Response bodies are also in JSON format.

4.4 PHYSICAL VIEW

In the realm of modern software development, deploying applications efficiently and consistently across different environments is a crucial challenge. Docker, a containerization platform, has emerged as a game-changing technology that simplifies the deployment process by encapsulating applications and their dependencies into lightweight, portable units known as Docker images[80].

Docker provides a standardized and isolated environment for applications through containerization. Containers package an application along with its runtime, libraries, and dependencies, ensuring consistency across various environments, from development to production. This eliminates the infamous "it works on my machine" issue and streamlines the deployment pipeline.

At the heart of Docker's containerization is the concept of Docker images. An image is a standalone, executable package that includes everything needed to run a piece of software, including the code, runtime, libraries, and system tools. Images are created from a set of instructions defined in a Docker file, a declarative configuration file that specifies the application's dependencies and configuration.

The key aspects and benefits of Docker Images for deployment are:

[80] Docker: Accelerated Container Application Development

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- *Consistency*: Docker images encapsulate all dependencies, ensuring that the application runs consistently across different environments, from a developer's laptop to a production server.
- *Isolation*: Containers provide isolation for applications, preventing conflicts between dependencies and reducing potential security risks.
- *Portability*: Docker images are portable and can be easily shared between development, testing, and production environments, streamlining the deployment process.
- *Scalability*: Docker simplifies horizontal scaling by enabling the deployment of multiple instances of the same application in containers, responding dynamically to varying workloads.
- *Versioning and Rollbacks*: Docker images support versioning, allowing for easy rollbacks to previous versions in case of issues, enhancing reliability during deployment.

ModalNET will use container images for the deployment of a *MongoDB* cluster, the ModalNET backend and the frontend instances, the CI/CD tool *Jenkins*, the private Docker registry *Harbour*, the container orchestration tool *Kubernetes,* the container management platform *Rancher* and the reverse proxy server *nginx*[81].

Continuous integration and continuous delivery (CI/CD) is a set of modern software development practices that aim to enhance the efficiency, speed, and reliability of the software development lifecycle. These practices involve automating various stages of the development process to enable frequent, incremental, and consistent delivery of high-quality software. The CI/CD tool used in ModalNET will be *Jenkins*. *Jenkins*[82] is an open-source automation server widely used for building, testing, and deploying software projects. Jenkins automates repetitive tasks, enabling software development teams to focus on writing code and delivering high-quality software efficiently. Jenkins will use docker registries and Kubernetes to deploy ModalNET components.

Docker registries are repositories for storing and distributing *Docker* images. They serve as a central hub where these images can be uploaded, stored and retrieved and play a crucial role in the containerized workflow, allowing for efficient collaboration, versioning, and distribution of container images across development, testing and production environments. In ModalNET, we will use *Harbour*[83] as a private registry to upload the ModalNET images generated in the CI/CD tool and distribute these images along the *Kubernetes* nodes.

Kubernetes[84], often abbreviated as K8s, is an open-source a container orchestration tool that help to automate the deployment, scaling, and management of containerized applications, particularly in complex, multi-container scenarios. It was developed by Google and later released as an open-source project, Kubernetes provides a robust and extensible framework for container orchestration, allowing organizations to efficiently manage and scale containerized workloads in production environments.

For the management of containerized applications across Kubernetes environment we will use *Rancher*. *Rancher*[85] is an open-source container management platform that provides a centralized and user-friendly interface for managing container clusters, supporting the container orchestration frameworks *Kubernetes* used in ModalNET. Rancher's comprehensive set of features makes it a

[81] https://nginx.org/
[82] Jenkins
[83] Harbor (goharbor.io)
[84] Kubernetes
[85] Enterprise Kubernetes Management Platform & Software | Rancher

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valuable tool for organizations seeking to streamline containerized application deployment and management. *Rancher* includes a built-in reverse proxy and load balancer known as the Rancher Load Balancer (Rancher LB). The Rancher Load Balancer is a software-defined networking component within the Rancher platform that provides layer 7 (HTTP/HTTPS) load balancing for services deployed in a Rancher-managed environment.

All the components and services deployed in ModalNET will be protected and configured to use TLS encrypted communications. These components and servers will be hosted by Virtual Private Servers (VPS) in a cloud environment hosted by a European operator in European data centres. All VPS servers will be protected with firewalls publishing only the ports for HTTP and HTTPS communications, for secure remote access and Kubernetes connectivity between nodes. HTTP and HTTPS connectivity will be based on reverse proxies and it will use let's encrypt certificates[86]. The access of backend components to the MongoDB cluster will be made within the Kubernetes internal network and they will use client certificates and TLS to secure the access and communications.

4.4.1 ModalNET physical view

The following diagram represents the physical view of ModalNET platform which will be used in SEAMLESS project for the development of the functionalities described in the physical view and the processes, interfaces and data model specified in the process view.

The physical view has been designed to demonstrate and evaluate the capabilities of ModalNET on the SEAMLESS use cases. The physical architecture has been designed to be resilient and to support the architecture for cybersecure communications in a non-trusted environment such as Internet. The Zero-Trust architecture presented in the architecture for cybersecure communications is very suitable in this environment where there is no implicit trust granted to assets or user accounts based solely on their physical or network location. The physical view of ModalNET will follow the principals of the cybersecure communications and it will be extended to include additional components identified such as Continuous Diagnosis and Mitigation (CDM), Industry Compliance, Data Access Policies, activity logs, ID management or Security Information and Event Management (SIEM) system, data access policy, threat intelligence and PKI.

[86] Let's Encrypt (letsencrypt.org)

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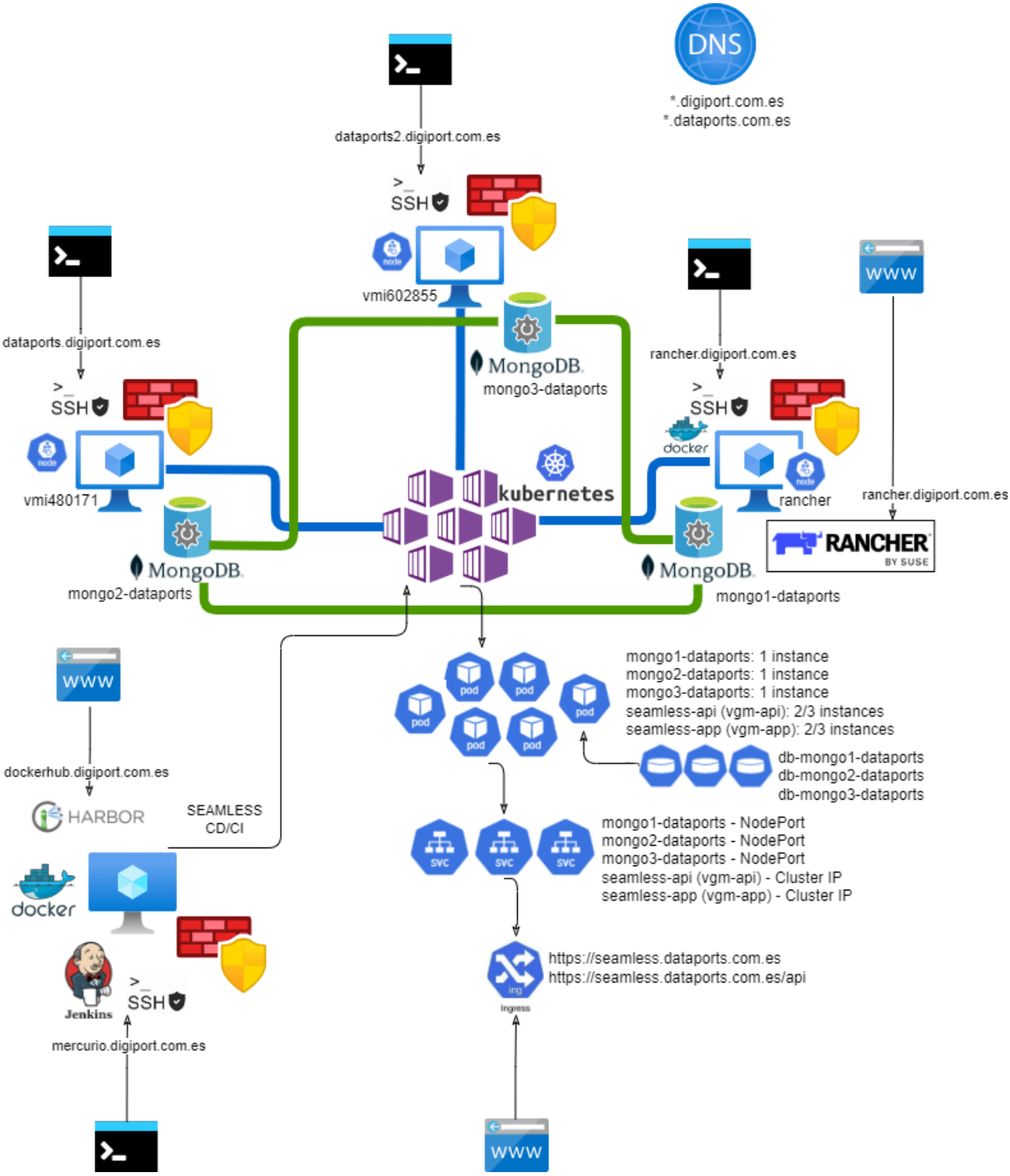

Figure 45. ModalNET physical view diagram

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4.4.2 Computational engine for resilient logistics physical view

The development of Computational engine for resilient logistics Processes complements and exploits the outcomes of the MOSES Matchmaking platform. The physical view of CERL for the development of the functionalities described in the physical view and the processes, interfaces and data model specified in the process view, is presented below.

The server used to deploy CERL is a virtual machine in Proxmox 3 with the following characteristics:

- OS: Ubuntu 20.04
- RAM: 16GB
- CPU Cores: 2
- DISK: 80GB

4.5 USE CASE VIEW

4.5.1 Definition of ModalNET scenarios

The SEAMLESS project is developing a platform called ModalNET to optimize logistics and reduce carbon emissions. ModalNET will track goods, containers and transport within the road, rail and sea/river movements made by autonomous ships, providing real-time information to shippers and other stakeholders.

The project will focus on two main scenarios:

1. **A combined transportation of goods or containers from a place of origin to a place of destination uses an autonomous ship service available along the route.** This scenario will use a combination of road and/or rail and sea/river transports. For the first scenario, we will need to consider the following steps:
   a. Booking from origin to destination: ModalNET will help shippers to book the best possible route and schedule for their containers from an origin to a destination. The computational engine for resilient logistics will consider all feasible routes and take into account the transport services offered by autonomous ships. A combined transport using road/rail and autonomous ship is chosen by the consignor and the booking and transport orders are communicated to the different road/rail and autonomous ship carriers.
   b. Road/Rail transport from point of origin to the port of loading: ModalNET will organize and track the goods or container movements from the point origin to the port of loading into de autonomous ship. There are two possibilities:
      i. The point of origin is in the hinterland, and it should be moved to the port of loading by road or by a combination of road and rail legs. The pick-up of the empty container before load the goods need also to be envisaged when required.
      ii. The point of origin is located at the same port as the container was previously discharged from another ship and it needs to be moved to another terminal unless the same terminal is also used to load the container into the autonomous ship.
   c. Autonomous ship transport from port of origin to port of destination: Goods/containers will be loaded at the port of origin onto the ship, and it will navigate from port of loading to port of discharge and discharge the goods/containers. A set of formalities will need to be presented at the port of loading and at the port of discharge to authorize the departure and the arrival of the ship.

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d. Road/Rail transport from port of discharge to point of destination: ModalNET will organize and track the goods or container movements from the port of discharge to the destination. There are two possibilities:
   i. The point of destination is in the hinterland, and it should be moved from the port of discharge by road or by a combination of rail and road legs. The delivery of the empty container after discharging the goods needs to be envisaged when required.
   ii. The point of destination is located at the same port as the container is planned to be loaded in another ship and it needs to be moved to another terminal unless the same terminal is also used to load the container in the subsequent ship.

2. **A single or combined transportation of goods or containers from a place of origin to a place of destination but there is not any autonomous ship service available along the route in the available timeframe**. This scenario will use a single or a combination of road and/or rail transport. For the second scenario, we will need to consider the following steps:
   a. Booking from origin to destination: ModalNET will help shippers to book the best possible route and schedule for their containers from an origin to a destination. The computational engine for resilient logistics will consider all feasible routes and consider the transport services offered by autonomous ships. If there is not any autonomous ship schedule available for the transport, a single or combined transport using road and rail options will be chosen by the consignor and the booking and transport orders are communicated to the different road/rail carriers.
   b. Road/Rail transport from point of origin to the port of loading: ModalNET will organize and track the goods or container movements from the point origin to the point of destination. In the case of container transport, the pickup and/or delivery of empty containers shall be envisaged if required.

Within these scenarios, ModalNET aims to improve the efficiency and transparency of the logistics industry, reducing costs and environmental impact. It needs to consider the possibility of using multiple inland and sea legs for the transport. The project wants to optimize logistics operations by providing real-time tracking and information across various modes of transport using multiple transport legs.

By capturing and tracking the container's journey across multiple inland and sea transport legs, ModalNET can provide shippers with comprehensive visibility into their shipments and enable them to make informed decisions about their transportation needs.

The main goal of ModalNET will be to improve the efficiency and transparency of logistics operations, achieving a synchromodal transport solution. Autonomous ship carriers will need to engage different road and rail transport companies offering their individual or combined transport services together with the autonomous ships services and provide real-time tracking.

To achieve this, the project proposes two options for involving inland transport operators during the booking process, taking into account that transport could be combined with the autonomous ship leg (scenario 1) or directly made by road or a road/rail combination when the autonomous ship is not available (scenario 2).

- Option 1: All inland transport companies appear during the booking process and the shipper can select which one will be in charge of carrying out the transport, either by truck, railway or a combination of both from the place of origin to the port of loading, from the port of discharge to

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the place of destination (scenario 1) or from the place of origin to the place of destination (scenario 2).

- Option 2: A pool of inland transport companies (truck and/or rail operators) is created and ModalNET platform will iteratively select the inland transport operator, allowing all of them to have a similar volume of business. When there is not enough capacity from a transport company, it will automatically transfer to the next one the request and carry out the land transport.

The choice between these options will depend on the specific business needs and agreements between the autonomous ship operator and the road/rail transport operators.

After discussing the role of inland transport in the logistics supply chain, we considered incorporating a pricing table into ModalNET. Inland transport operators (truck or rail) would provide pricing information based on specific parameters:

- Mode of transport (inland and maritime legs)
- Origin location
- Destination location

By integrating a computational engine, shippers could use these variables to identify the optimal transport option based on factors such as price, travel time, and carbon footprint.

4.5.2 ModalNET use cases capabilities

The definition of ModalNET scenarios serves as a foundation for examining ModalNET's capabilities in each of the DUCs (demonstration use cases). We will delve into how ModalNET addresses each scenario discussed earlier. To explain the functionality of ModalNET platform, we will showcase the core functionalities associated with each use case.

For example, when a shipper or logistics operator will be planning and initiating any freight transport from a point of origin to a point of destination, this platform will be in charge of the following tasks:

- Inform about the best combination of transports as well as the point of delivery and pickup for the autonomous ship feeder service.
- Calculate the most suitable schedule and predict route performance.
- Organize the transport chain by generating all the booking and shipment orders for the different modes of transport.
- Calculate associated transport charges.
- Manage administrative and documentary procedures.

The information fused within ModalNET will enable real-time optimization, supported by federated learning predictions for route performance and cargo flows, and re-planning in case of disruptions taking advantage of the PI concept to improve synchromodality and supply chain resilience. ModalNET will also address cyber-security 'by design' to ensure data confidentiality, integrity, and service availability. The cyber-resilience of the platform will be further verified and tested through a series of penetration tests to eliminate design pitfalls and identify vulnerabilities.

As SEAMLESS services will not be operational during the project, ModalNET demonstration use cases will be based on different logistics scenarios based on real transport corridors where the platform will show their capabilities to organize and share data among different stakeholders and systems along the logistics chains facilitating and fostering the movements of freight along the corridors using autonomous vessels running as shuttle connections along its route.

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4.5.2.1 SEAMLESS Demonstration Use Case #1: Northern Europe (SSS)

The Port of Moss, which is Norway's second largest port in tonnage and currently located within city limits, is expected to be moved in Horten. A smaller cargo terminal will be operated in Moss and cargo is expected to be transported through a 26km driving distance with roads and bridges, which will need to be extensively improved to handle the increase in truck traffic. To minimize cargo transport through trucks between the two ports, currently there are plans for using a 60 TEU feeder ship. In 2030 it is estimated that these feeder loops will need to handle an annual volume of 23,000 TEU.

The demonstration for this use case will involve ASKO's highly automated ship and the activities will include the following SEAMLESS building blocks: port operations; mooring, shore-connection and charging, cargo (un-)loading for Ro-Ro and Containers; the communication between ROCs; autonomous functionality gen in sheltered waters and heavy traffic; and verification of operational constraints such as weather-window, tide, etc, and full utilization of the ModalNET modules.

The ROC that will be used in the DUC1 is the KM/Massterly ROC in Horten Norway. This ROC is already interfaced to the ASKO ferries and supporting their daily operations. These details were described in detail in deliverable D2.1 "*State of the art and baseline for the SEAMLESS use cases".*

4.5.2.1.1 ModalNET use case in DUC 1

The use of ModalNET in the DUC 1 will follow the steps below for the movements from Moss to Horten. The movements from Horten to Moss will be similar but taking the opposite direction.

<u>Booking from Moss hinterland to Horten hinterland or port</u>

To move cargo from Moss hinterland to Horten hinterland or to connect with ships departing from this port, the consignor will register a booking in ModalNET including details regarding the point of origin and destination as well as the requested times for departure and arrival at these points together with information about the goods and quantity of containers required. With this information the computational engine for resilient logistics will be able to make the matchmaking and provide the best options. If the schedule of the autonomous ship is suitable for the transport, the possibility to move the goods through the autonomous ship will be provided. The consignor will choose the option it prefers according to different parameters (e.g., price, times, carbon footprint). After the consignor confirms the transport, ModalNET will automatically place the booking and transport orders and gate-out and gate-in orders to the involved transport operators, port terminals and logistics facilities, as well as to send via API-REST the booking to other SEAMLESS systems that need this information (e.g. VCOP for the autonomous barge operator).

As mentioned before, inland transport operators can be selected if there is more than one by the shipper or chosen through a calculation engine before confirming the transport to send the road and rail transport orders to the corresponding inland transport operator. After ModalNET places the booking and transport orders, they will be accepted or rejected by the transport operators. If there is any rejection, ModalNET will try to place the order to another transport operator. Before starting the transport, the consignor will need to complete any required data for creating the IWT waybills and consignment notes (e.g. cargo description, number of packages, gross weight, net weight, volume, harmonized code).

<u>Road transport from point of origin in Moss hinterland to port of Moss</u>

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Taking into account that the shipper has filled all the details and it has selected a combined transport using the autonomous ship connecting Moss with Horten, the next step will take place when the empty container will be picked-up from the empty container facilities and transported by the road transport operator to the consignors´ warehouse to load the cargo.

It is important to keep in mind that if, after filling out this process, the consignor or dispatching party will confirm the dispatch of the cargo and if they need to make any change, they will report these changes to ModalNET and they will be distributed to all interested stakeholders. With this process all stakeholders will have access to the same information and each transport legs, whether inland or maritime, will match avoiding possible failures in the chain.

Before initiating the transport, the road transport operator will fill-in the details of their transport (e.g. truck plate, estimated times) to complete the empty gate-out and full gate-in orders. ModalNET cargo handling and storage module will register this information and provide access to this information to empty container facilities and Moss port terminal. The autonomous ship operator through VCOP will inform to ModalNET and Moss terminal of the containers expected to be loaded in each ship.

Terminal Gate in

Upon completion of the cargo transport by the road transport operator and arrival at the Moss terminal, the next event will be reported by the Terminal Operating System (TOS) or a Gate operator at the terminal through the ModalNET interface, indicating the container's entry into the terminal, thereby confirming the gate-in event. This information will be shared by the TOS or Gate operator with ModalNET, which will then forward it to VCOP via an API-REST connection. Port terminal automated port interfaces and TOS will provide the gate-in and gate-out reports to ModalNET cargo handling and storage module and they will be used in the cargo traceability module.

Truck transport must also consider terminal limitations for truck capacity, meaning, the possibility for simultaneous truck loading/unloading is limited and must be accounted for in the booking process. In this case, in DUC1 we are going to simulate that all containers can be unloaded alongside the ship in the area provided for that purpose. As per Deliverable 2.1 *"State of the art and baseline"* we can see that loading and unloading process with this container it will be done with a reach stacker (as per chapter 2.1.4.1 "*Identified Implications for Building Block Development*")

Once the container is within the terminal facilities, ModalNET will not receive any further updates during this period (as it cannot determine whether the container has been unloaded onto the quayside next to the ship or if it has been stacked for subsequent handling and transfer to the quayside next to the ship).

Container stowage inside the ship

The next event to be reported by VCOP in ModalNET involves confirming the container has been loaded onto the ship. Upon completion of loading all containers onto the ship, VCOP will provide the final report confirming that all containers scheduled have been loaded. On the other hand, VCOP will also notify the ROC that all operations have been finalized.

However, in the demonstration case and as per chapter 4.1.7 "*Requirement and limitations summary*" inside the Deliverable "*Concept of Operations and requirements for SEAMLESS Building blocks*" the AVSPM is not part of the DUC1, and the estimated times will need to be sent by the ROC to the TOS directly and be forwarded to ModalNET in order to inform the rest of stakeholders of the

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whole supply chain. The ROC will also need to interface with the TOS for planning start of cargo operations.

Ship arrival and departure events and ship formalities at the port of Moss

It is expected that port authorities will provide updated ships' ETA, ETB, ETD, ATA, ATB and ATD through the AVSPM system to ModalNET through the transport planning and cargo traceability modules. This information will be used by the computational engine for resilient logistics for the replanning the cargo flow whenever required. Before that, ship arrival and departure formalities shall be fulfilled by the autonomous ship operator using ModalNET with data managed by ROC or stored in the platform. These formalities will use the autonomous ship schedule that have been already shared to ModalNET and, if during the process there is any change, the formalities will be updated in ModalNET, and the platform will provide the new information to the rest of stakeholders.

As per chapter 2.1.2.3 "*Existing Nautical Conditions"* inside deliverable D2.1 "*State of the art and baseline for the SEAMLESS use cases"* related to Ship Traffic Services (VTS) and Port Control we can see the following details:

"The ships traffic from and to Moss is organized and managed by the Fedje Ship Traffic Service. All ships wishing to navigate within the VTS area must request sailing clearance from the Fedje VTS at least 1 hour before their arrival at the limit of the VTS area."

"Within the port, a port control centre serves as a central hub for managing and coordinating various activities related to maritime operations within the port waters. Its primary function is to ensure safe, efficient, and organized movement of ships and cargo in and out of the port. Ships shall send their ETA to Port Control at least 1 hour prior to arrival.

Ship arrival and departure events and ship formalities at the port of Horten

In the same way as in the port of Moss, the ship formalities and the ship arrival and departure events will be informed at the port of Horten.

As per information shared in chapter 2.1.2.3 "*Existing Nautical Conditions*" inside deliverable D2.1 "*State of the art and baseline for the SEAMLESS use cases*" ASKO´s ship who should send their ETA to the ROC at least 1 hour prior to arrival. For this reason, the ROC should share with ModalNET, Horten terminal and VCOP the ETA, as this will allow the terminal to prepare the quay for the unloading of containers. ModalNET will share with the rest of stakeholders this information.

Ship mooring at terminal in port of Horten

When the ROC confirms the ship is already moored, this event will be shared by the ROC to VCOP and ModalNET, allowing to the first one to start the unloading container process.

Containers discharged at terminal

VCOP will be in charge to inform to ModalNET and the port terminal about this event, and ModalNET will share the information to the relevant stakeholders and update if necessary the delivery transport order that was initially placed during the booking process in the case the final destination is in the Horten hinterland. In the case the containers were to be loaded in a subsequent ship departing from Horten, the information about this ship was informed during the booking process and the terminal in Horten will be aware of the transhipment operation and the process will finish at this moment.

Terminal Gate Out

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In the case the transport continues with a subsequent road transport, the next event reported to ModalNET shall be the gate-out of the container through the terminal gates, and this event should be done by the terminal gate operator through ModalNET interface confirming the event.

Delivery at final destination

When the container has been finally delivered to the reported destination place, the consignee of the goods and/or the carrier will confirm the delivery and reception of the cargo to ModalNET. Finally, the road haulier will return the empty container to an empty container facility or to the terminal.

4.5.2.2 SEAMLESS Demonstration Use Case #2: Central Europe (IWT)

Originating from one of Europe's largest seaports, the Port of Antwerp-Bruges, this use case route splits into one route to Dourges via Lille (both Northern France) and another one to Europe's largest inland port, Duisburg, Germany, via Dordrecht and Nijmegen (both the Netherlands).

The demonstration will use ZULU's X-Barge design, which is a highly automated, inland container barge carrying up to 80 TEU and offering low to zero emission through an exchangeable battery-electric energy provision system. The activities will include the following SEAMLESS building blocks: 1) ship navigation and remote fleet operation through a ROC supporting high-attention level of autonomy, interaction with crewed ships, and smooth passage of locks and bridges, 2) digital port call within the Port of Antwerp-Bruges, 3) autonomous mooring, 4) automated container (un-)loading through the quayside infrastructure, 5) utilization of ModalNET to ensure data flows and smooth communication.

Figure 46. Route from Antwerp to Dourges via Lille and to Duisburg via Dordrecht and Nijmegen and further to Dortmund and Minden .

Source D2.1 – State-of-the-art and baseline for the SEAMLESS Use Cases

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4.5.2.2.1 ModalNET use case in DUC 2

In this case the process will start assuming that the containers have been unloaded from a previous ship at the port of Antwerp and they want to be moved to different destinations in Duisburg hinterland area, which is quite extensive as it is supported not only by road but also by rail connections. The idea is to try to recreate an import process, starting from Antwerp to the final destination and for this purpose combined road/rail transportation can be used together with the autonomous barges.

Trying to be more realistic, the containers discharged in a deep-sea container terminal in Antwerp will need to be moved to a barge container terminal to be able to be loaded onto ZULU´s barge.

The use of ModalNET in the DUC 2 will follow the steps below. The use of ModalNET in the DUC 2 will follow the steps below for the movements from Antwerp to Duisburg. The movements from Duisburg to Antwerp or from any other intermediate port will be similar but taking the corresponding direction.

<u>Booking from Antwerp port to a Duisburg hinterland destination</u>

To move cargo from Antwerp port to Duisburg hinterland destination, the consignor will register a booking in ModalNET including details regarding the deep-sea terminal where the containers have been downloaded as the point of origin and destination as well as the requested times for departure and arrival at these points together with information about the goods and quantity of containers required. With this information the computational engine for resilient logistics will be able to make the matchmaking and provide the best options. If the schedule of the autonomous barge is suitable for the transport, the possibility to move the goods through the autonomous barge will be provided. The consignor will choose the option it prefers according to different parameters (e.g., price, times, carbon footprint). After the consignor confirms the transport, ModalNET will automatically place the booking and transport orders, and gate-out and gate-in orders to the involved transport operators, port terminals and logistics facilities, as well as to send via API-REST the booking to other SEAMLESS systems that need this information (e.g., VCOP for the autonomous ship operator).

As mentioned before, inland transport operators can be selected if there is more than one by the shipper or chosen through a calculation engine before confirming the transport to send the road and rail transport orders to the corresponding inland transport operator. After ModalNET places the booking and transport orders, they will be accepted or rejected by the transport operators. If there is any rejection, ModalNET will try to place the order to another transport operator. Before starting the transport, the consignor will need to complete any required data for creating the IWT waybills and consignment notes (e.g. cargo description, number of packages, gross weight, net weight, volume, harmonized code, containers).

<u>Road transport from deep-sea to barge terminal in port of Antwerp</u>

Taking into account that the shipper has filled all the details and it has selected a combined transport using the autonomous barge connecting Antwerp with Duisburg, the next step will take place in case that the deep-sea terminal is separated from the barge terminal where autonomous barges operates and it is required to pick-up the containers from the deep-sea terminal and transport them to the barge terminal by the road transport operator.

Before initiating the transport, the road transport operator will fill-in the details of their transport (e.g. truck plate, estimated times) to complete the container gate-out and gate-in orders. ModalNET cargo

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handling and storage module will register this information and provide access to this information to the deep-sea and barge terminals in Antwerp. The autonomous barge operator (ZULU) through VCOP will inform to ModalNET and Moss terminal of the containers expected to be loaded in each barge.

Deep-sea terminal gate-out and barge terminal gate-in

The deep-sea terminal will confirm the gate-out of the containers and the barge terminal will confirm the gate-in of the containers. With this process all stakeholders will have access to the same information at each transport leg, whether inland or maritime, will match avoiding possible failures in the chain. This information will be shared by the TOS or Gate operator with ModalNET, which will then forward it to VCOP via an API-REST connection. Port terminal automated port interfaces and TOS will provide the gate-in and gate-out reports to ModalNET cargo handling and storage module and they will be used in the cargo traceability module.

Container stowage inside the ship

The next event to be reported by VCOP in ModalNET involves confirming the container has been loaded onto the ship. Upon completion of loading all containers onto the ship, VCOP will provide the final report confirming that all containers scheduled have been loaded. On the other hand, VCOP will also notify the ROC that all operations have been finalized.

Barge arrival and departure events and barge formalities at the port of Antwerp

It is expected that port authorities will provide updated ships' ETA, ETB, ETD, ATA, ATB and ATD through the AVSPM system to ModalNET through the transport planning and cargo traceability modules. This information will be used by the computational engine for resilient logistics for the replanning the cargo flow whenever required. Before that, ship arrival and departure formalities shall be fulfilled by the autonomous ship operator using ModalNET with data managed by ROC or stored in the platform. These formalities will use the autonomous barge schedule that have been already shared to ModalNET and, if during the process there is any change, the formalities will be updated in ModalNET, and the platform will provide the new information to the rest of stakeholders.

Barge arrival and departure events and barge formalities at the port of Duisburg

In the same way as in the port of Antwerp, the barge formalities and the barge arrival and departure events will be informed at the port of Duisburg. However, it is possible that the AVSPM system will not be available at this port.

Barge mooring at terminal in port of Duisburg.

When the ROC confirms the ship is already moored, this event will be shared by the ROC to VCOP and ModalNET, allowing to the first one to start the unloading container process.

Containers discharged at terminal

VCOP will be in charge to inform to ModalNET and the port terminal about this event, and ModalNET will share the information to the relevant stakeholders and update if necessary, the delivery transport order that was initially placed during the booking process in the case the final destination is in the Horten hinterland. In the case the containers were to be loaded in a subsequent ship departing from Horten, the information about this ship was informed during the booking process and the terminal in Horten will be aware of the transhipment operation and the process will finish at this moment.

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Duisburg Terminal Gate Out

In the case the transport continues with a subsequent rail transport, the next event reported to ModalNET shall be the gate-out of the container when the train leaves the terminal, and this event should be done by the terminal gate operator through ModalNET interface confirming the event.

Container transfer to train

When the container it will be discharged from ZULU´s ship, VCOP will report this information to the terminal and ModalNET. After this event, the terminal will move the container to the quay next to the railway tracks to be loaded on the train requested by the consignee at booking.

The event when container it will be load in the train should be shared by the TOS to ModalNET or, if the terminal has not TOS, it will be the port terminal operator through ModalNET interface who shall be the notifier of this event.

Train transport to intermodal terminal

ModalNET will share the information above with the rest of stakeholders, and to be able to do this topic, the rail operator previously have added in ModalNET the estimated time of departure (ETD) and estimated time of arrival (ETA) for each train. When the train leaves Duisburg´s terminal, the rail operator will send the final report with all containers that were loaded to ModalNET through ModalNET interface enable for this purpose, and ModalNET will inform the rest of stakeholders involved.

The rail operator will communicate the updated ETA in ModalNET, and the platform will forward it to the intermodal terminal at which the convoy will arrive. This information will allow the intermodal terminal to prepare for the arrival of the train and prepare the unloading area.

Container discharge at intermodal terminal

The information about container has been unloaded from the train will be provided by the intermodal terminal to ModalNET (via API-REST or through the ModalNET interface used by the intermodal terminal operator). This will allow the consignee to schedule the delivery order via direct truck.

Intermodal Terminal Gate Out

Once the container is discharge at the intermodal terminal, the next event reported to ModalNET shall be the gate-out of the container through the terminal gates, and this event should be done by the terminal gate operator through ModalNET interface confirming the event.

Delivery at final destination

When the container has been finally delivered to the reported destination place, the consignee of the goods and/or the carrier will confirm the delivery and reception of the cargo to ModalNET. Finally, the road haulier will return the empty container to an empty container facility or to the intermodal terminal.

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5 NEXT STEPS

Once the ModalNET Specifications, systems architecture and design of cyber-secure communication have been defined, the next steps for the ModalNET development will be to start the development of the computational engine for resilient logistics in task 5.3 and the development of the ModalNET platform in task 5.4, described on section 2.2 Background. During the development of the platform, more detailed knowledge and refinement of the ModalNET data model will be gained taking into account the data models and message implementation guides published for EFTI, the MNSW and other standards to be aligned in the solution.

One of the objectives of ModalNET is to connect with the other systems being developed in SEAMLESS (e.g., the Remote Operation Centre, the Voyage and Container Optimisation Platform, the Autonomous Vessels' Smart Port Manager, and the DockNLoad Module), and to connect with existing systems being used by other stakeholders (e.g. TOS, Asko systems, Danser systems). However, we discover that many ports where the autonomous ship plans to call have not any TOS.

ModalNET has been designed to handle the information of intermodal transport using the autonomous ships considered in SEAMLESS and be able to connect to other current legacy or new systems, such as a PCS (Port Community System), an MNSW (Maritime National Single Windows), an EFTI gateway, a terminal operating system, or a road, rail or deep-sea transport system. All the ModalNET functionalities are designed to be used through a user interface and through APIs providing a maximum level of interoperability. ModalNET will be focused on the following transport legs that will be demonstrated in WP7:

- Origin - Road/rail – Autonomous ship/barge – Road/rail – Destination
- Origin – Road/rail - Destination
- Port – Autonomous ship/barge – Road/rail - Destination
- Origin - Road/rail – Autonomous ship/barge - Port

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ANNEX I. MODALNET DATA MODEL

The ModalNET data model was presented in the process view as a UML diagram representing the main entities and concepts used to support the logical view. This annex specifies the complete data model with all classes that have been identified during the semantic requirements activity in task 5.1.

ModalNET Data Model is organized in the definition of enumerable types, entities and concepts. This initial data model will be further adapted as the development of the platform advances and the definition of the reference data models for EFTI platform and EMSWe are being further specified.

AI.1 MODALNET CONSTANTS AND ENUMERABLES

```
export const OrganizationTypes = ['roadHaulier', 'railHaulier', 'economicOperator', 'forwarder', 'customsBroker', 'scaleOperator', 'vgmAgent',
   'shippingAgent', 'shippingLine', 'portTerminal', 'railTerminal', 'emptyDepot', 'portAuthority'];

export const OrganizationTypesAdmin = ['admin', 'customs'];

export const Services = [
   { service: 'logistics', roles: ['logisticsAdmin', 'user', 'haulier', 'roadHaulier', 'railHaulier', 'shippingLine', 'agent'], requireAuthorization: false },
   { service: 'vigia', roles: ['vigiaAdmin', 'roadHaulier', 'driver', 'logisticsFacility', 'portAuthority'], requireAuthorization: false },
   { service: 'messaging', roles: ['messagingAdmin', 'sender', 'receiver'], requireAuthorization: false },
];

export const DocumentationVisibility = ['headquarters', 'organization', 'delegation', 'official', 'restricted', 'public'];

export const Events = [
   { asset: 'shipment', events: ['*', 'requested', 'ordered', 'changed', 'accepted', 'rejected', 'cancelled', 'planned', 'dispatched', 'pickedUp', 'loaded',
'delivered', 'received', 'discharged', 'inspected'] },
   { asset: 'storedItem', events: ['*', 'requested', 'ordered', 'changed', 'accepted', 'rejected', 'cancelled', 'gateIn', 'gateOut'] },
   { asset: 'transport', events: ['*', 'requested', 'ordered', 'changed', 'accepted', 'rejected', 'cancelled', 'planned', 'arrived', 'departed', 'shunting',
'loaded', 'discharged', 'delayed', 'position', 'inspected'] },
   { asset: 'transportUnit', events: ['*', 'rejected', 'cancelled', 'position', 'sensor', 'inspected'] },
   { asset: 'operation', events: ['*', 'requested', 'ordered', 'changed', 'accepted', 'rejected', 'cancelled', 'loaded', 'discharged'] },
   { asset: 'vehicle', events: ['*', 'requested', 'ordered', 'changed', 'accepted', 'rejected', 'cancelled'] },
   { asset: 'document', events: ['*', 'requested', 'ordered', 'changed', 'accepted', 'rejected', 'cancelled'] },
   { asset: 'masterData', events: ['*', 'requested', 'ordered', 'changed', 'accepted', 'rejected', 'cancelled'] },
   { asset: 'locationFacility', events: ['*', 'requested', 'ordered', 'changed', 'accepted', 'rejected', 'cancelled'] },
   { asset: 'storageFacility', events: ['*', 'requested', 'ordered', 'changed', 'accepted', 'rejected', 'cancelled'] },
   { asset: 'office', events: ['*', 'requested', 'ordered', 'changed', 'accepted', 'rejected', 'cancelled'] },
   { asset: 'user', events: ['*', 'requested', 'ordered', 'changed', 'accepted', 'rejected', 'cancelled'] },
];

export const USER_ROLES = [
   'guest', 'user', 'roadHaulier', 'driver', 'shipper', 'shippingAgent', 'logisticsFacility', 'portAuthority', 'usrmanager', 'orgmanager', 'system',
   'messageSystem', 'sender', 'receiver', 'admin', 'vigiaAdmin', 'messagingAdmin',
];

export const EMAIL_SUBSCRIPTIONS = [
   'resetPassword', 'accountManagement', 'changeStatus',
];

export const STATUS = ['requested', 'accepted', 'planned', 'executing', 'finished', 'rejected', 'cancelled'];

export const VehicleTypes = ['truck', 'semitrailer'];

export const FormatTypes = ['json', 'xml', 'edifact', 'pdf'];

// ENUMERABLES

/** Enumerables for asset status */
```

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```
export type AssetStatus = 'requested' | 'accepted' | 'planned' | 'executing' | 'finished' | 'rejected' | 'cancelled';

/** Enumerables for documentation status */
export type DocumentationStatus = 'pendingValidation' | 'rejected' | 'approved' | 'expired';
export const DocumentationStatusMachine = {
  'pendingValidation': ['rejected', 'approved', 'expired'],
  'rejected': [],
  'approved': ['rejected', 'approved', 'expired'],
  'expired': [],
}

/** Enumerables for entity types */
export type EntityType = 'transport' | 'shipment' | 'storedItem' | 'transportUnit' | 'operation' | 'vehicle'
  | 'document' | 'message' | 'customsProcedure' | 'service' | 'charges' | 'masterData'
  | 'locationFacility' | 'storageFacility' | 'trackableEvent' | 'office' | 'user' | 'ack';

/** Enumerables for organization types */
export type OrganizationType = 'consignor' | 'shipper' | 'dispatchParty' | 'consignee' | 'trader' | 'carrier' | 'haulier'
  | 'agent' | 'receiverParty' | 'deliveryParty' | 'forwarder' | 'depositor' | 'depositary' | 'customsBroker'
  | 'roadHaulier' | 'railHaulier' | 'seaCarrier' | 'provider' | 'owner' | 'bank'
  | 'portAuthority' | 'customs' | 'borderInspectionAgency' | 'transportInspectionAgency'
  | 'shippingAgent' | 'shippingLine' | 'vgmAgent' | 'scaleOperator' | 'sender' | 'receiver' | 'publisher'
  | 'usrmanager' | 'officemanager' | 'orgmanager' | 'admin' | 'system';

/** Enumerables for reference types */
export type ReferenceType = 'dispatch' | 'pickUp' | 'transport' | 'arrival' | 'departure' | 'delivery'
  | 'reception' | 'weighingService' | 'transportManifest' | 'carrierManifest' | 'load' | 'discharge' | 'stowage'
  | 'shipment' | 'bolNumber' | 'transportUnit' | 'storedItem' | 'gateIn' | 'gateOut' | 'verifiedGrossMass' | 'customsRelease' | 'certificate'
  | 'document' | 'procedure' | 'barCode' | 'pin' | 'additionalInfo' | 'arrivalNotice' | 'licensePlate' | 'trailerPlate'
  | 'wagonID' | 'portCall' | 'voyage' | 'berth' | 'freightCharges' | 'serviceCharges' | 'storageCharges'
  | 'transportCharges' | 'authorization' | 'system';

/** Enumerables for event status */
export type EventType = 'requested' | 'ordered' | 'changed' | 'accepted' | 'rejected' | 'cancelled' | 'planned' | 'arrived' | 'departed' | 'shunting'
  | 'dispatched' | 'pickedUp' | 'loaded' | 'started' | 'finished' | 'delivered' | 'received'
  | 'discharged' | 'gateIn' | 'gateOut' | 'delayed' | 'stopped' | 'declared' | 'released'
  | 'detained' | 'position' | 'registered' | 'sensor' | 'inspected' | 'doorOpened' | 'doorClosed';

/** Enumerables for event results */
export type EventResult = 'processed' | 'pending' | 'rejected';

/** Enumerables for event functions */
export type EventFunction = 'added' | 'confirmed' | 'changed' | 'cancelled' | 'removed' | 'rejected' | 'warning';

/** Enumerables for shipment clauses */
export type ShipmentClause = 'lcl' | 'fcl';

/** Enumerables for document types */
export type DocumentType = 'seaWaybill' | 'bl' | 'express' | 'memo' | 'house' | 'roadConsignmentNote' | 'railConsignmentNote' | 'airWaybill'
  | 'arrivalBayPlan' | 'departureBayplan' | 'loadOrder' | 'loadReport' | 'dischargeOrder' | 'dischargeReport' | 'invoice' | 'document';

/** Enumerables for format types */
export type FormatType = 'json' | 'xml' | 'pdf' | 'edifact';

/** Enumerables for transport modes */
export type TransportMode = 'road' | 'rail' | 'sea' | 'river' | 'air' | 'multimodal' | 'combined';

/** Enumerables for vehicle types */
export type VehicleType = 'truck' | 'semitrailer' | 'trailer' | 'van' | 'locomotive' | 'wagon'
  | 'train' | 'ship' | 'barge' | 'airplane' | 'dron';

/** Enumerables for payment methods */
export type PaymentMethod = 'cash' | 'credit' | 'transfer';
```

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```
/** Enumerables for haulage arrangements */
export type HaulageArrangement = 'merchant' | 'carrier' | 'agent';

/** Enumerables for ship operations */
export type ShipOperation = 'load' | 'discharge';

/** Enumerables for gate operations */
export type GateOperation = 'in' | 'out';

/** Enumerables for location types */
export type LocationType = 'portOfCall' | 'nextPortOfCall' | 'previousPortOfCall' | 'countryOrEntry' | 'loading' | 'discharge'
    | 'departure' | 'stopover' | 'arrival' | 'origin' | 'destination';

/** Enumerables for facility types */
export type FacilityType = 'venue' | 'address' | 'street' | 'neighbourhood' | 'borough' | 'localadmin' | 'locality' | 'county' | 'macrocounty'
    | 'region' | 'macroregion' | 'country' | 'coarse' | 'postalcode' | 'locode' | 'iata' | 'port' | 'railTerminal' | 'roadTerminal' | 'airport'
    | 'postalOffice' | 'multimodal' | 'fixedTransport' | 'inlandPort' | 'borderCrossing';

/** Enumerables for carriage conditions */
export type CarriageCondition = 'door-door' | 'door-pier' | 'pier-door' | 'pier-pier' | 'rail-door'
    | 'rail-pier' | 'door-rail' | 'rail-pier';

/** Enumerables for time types */
export type TimeType = 'containerStatusPickUp' | 'containerStatusDelivery' | 'blSurrenderDate' | 'chargesPaymentDate' | 'freeDemurrageTime' |
'freeDetentionTime';

/** Enumerables for measure types */
export type MeasureType = 'weight' | 'verifiedGrossMass' | 'volume' | 'temperature';

/** Enumerables for transport unit types */
export type TransportUnitType = 'container' | 'pallet' | 'box' | 'bulk';
```

AI.2 MODALNET ENTITIES

```
/** User data model */
export class User extends Meta {

    /** User ID */
    public ID?: string;
    /** e-mail */
    public email?: string;
    /** Pashsword hash (bcrypt) */
    public password?: string;
    /** Pashword verification string */
    public verifyPassword?: string;
    /** Password salt */
    public salt?: string;
    /** Password reset token string */
    public passwordResetToken?: string;
    /** Passport reset expires */
    public passportResetExpires?: Date;
    /** TFA data (double factor of authentication) */
    public tfa?: any;
    /** Disabled flag */
    public disabled?: boolean;
    /** Approved flag */
    public approved?: boolean;
    /** User code */
```

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```
    public code?: string;
    /** Login from IP */
    public createdFromIP?: string;
    /** Date of first creation */
    public createdFirst?: Date;
    /** Agreement on privacy terms */
    public privacyTerms?: boolean;
    /** Agreement on legal terms */
    public legalTerms?: boolean;
    /** Facebook token */
    public facebook?: string;
    /** Access tokens */
    public tokens?: AuthToken[];
    /** Full name */
    public fullName?: string;
    /** Acronym */
    public acronym?: string;
    /** User id (i.e. Id number) */
    public userId?: string;
    /** Picture set */
    public pictureSet?: PictureSet;
    /** Company name */
    public companyName?: string;
    /** Company VAT */
    public companyVAT?: string;
    /** Office name */
    public officeName?: string;
    /** Office code */
    public officeCode?: string;
    /** Headquarters flag */
    public headquarters?: boolean;
    /** Driver data of user (if any) */
    public driver?: Driver;
    /** Roles */
    public roles?: string[];
    /** Requested roles */
    public requestedRoles?: string[];
    /** e-mail subscriptions */
    public emailSubscriptions?: string[];
    /** Preferred language */
    public lang?: string;
    /** Payload data */
    public payload?: any;
}

/** Office data model */
export class Office extends Party {

    /** Headquarters indicator */
    public headquarters?: boolean;
    /** List of requested services */
    public requestedServices?: string[];
    /** List of services */
    public services?: string[];
    /** List of roles */
    public roles?: string[];
    /** List of requested roles */
    public requestedRoles?: string[];
    /** Invoice serie identifier */
    public invoiceSerie?: string;
    /** Geolocation coordinates */
    public position?: GeoJSON;
    /** List of parties with business relations */
```

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```
  public businessRelations?: Party[];
  /** List of scale in the case the office is a scale operator */
  public scales?: Scale[];
  /** List of webhooks */
  public webhooks?: Webhook[];
  /** List of files metadata */
  public files?: FileMetadata[];
  /** List of files requirements */
  public requirements?: string[];
  /** Has admin indicator */
  public hasAdmin?: boolean;
  /** Blockchain enrollment id */
  public bcEnrollmentID?: string;
  /** Blockchain encrypted wallet */
  public bcEncryptedWallet?: string;
  /** Blockchain MSP */
  public bcMSP?: string;
}

// EVENTS

/** Trackable event data model */
export class TrackableEvent extends Meta {

  /** ID */
  public ID?: string;
  /** Event status */
  public status?: string;
  /** Event name */
  public name?: ReferenceType;
  /** Event type */
  public eventType?: EventType;
  /** Event function */
  public eventFunction?: EventFunction;
  /** Event result */
  public eventResult?: EventResult;
  /** Event category */
  public eventCategory?: string;
  /** Publisher */
  public publisher?: Party;
  /** Location ID */
  public locationID?: ResourceLocator;
  /** Location */
  public location?: Location;
  /** Positions */
  public positions?: Location[];
  /** Trackable entity ID */
  public trackableEntityID?: ResourceLocator;
  /** Trackable parent entity ID */
  public trackableParentEntityID?: ResourceLocator;
  /** Trackable entity status */
  public trackableEntityStatus?: string;
  /** Actual time of arrival */
  public ata?: Date;
  /** Performed time */
  public performedTime?: Date;
  /** Actual time of departure */
  public atd?: Date;
  /** Participants */
  public participants?: Party[];
  /** References */
  public references?: Reference[];
  /** Transport information */
```

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```
    public transport?: TransportInfo;
    /** Shipment information */
    public shipments?: ShipmentInfo[];
    /** Transport units information */
    public transportUnits?: TransportUnitInfo[];
    /** Additional details */
    public additionalDetails?: string;
    /** Reason */
    public reason?: string;
    /** Attributes */
    public attributes?: Attribute[];
    /** Message file metadata */
    public message?: FileMetadata;
}

// DIGITAL TWINS (ASSETS)

/** Trackable entity data model */
export class TrackableEntity extends Meta {

    /** ID */
    public ID: ResourceLocator;
    /** Platform reference */
    public platformReference?: string;
    /** Trackable entity name */
    public name?: string;
    /** Status */
    public status?: AssetStatus;
    /** Parent entity ID */
    public parentEntityID?: ResourceLocator;
    /** Content Type */
    public contentType?: string;
    /** Contents */
    public contents?: ResourceLocator[];
    /** References */
    public references?: Reference[];
    /** Payments */
    public payments?: ResourceLocator[];
    /** Registration time */
    public registrationTime?: Date;
    /** Time infos */
    public timeInfos?: TimeInfo[];
    /** Remarks */
    public remarks?: string[];
    /** Errors */
    public errors?: string[];
    /** Last trackable event */
    public lastTrackableEvent?: EventInfo;
}

/** Transport data model */
export class Transport extends TrackableEntity {

    /** Transport ID */
    public transportID?: string;
    /** Transport mode */
    public transportMode?: TransportMode;
    /** Transport identification */
    public identification?: Code;
    /** Trailer identification */
    public trailerIdentification?: Code;
    /** Transport flag */
    public flag?: Code;
```

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```
  /** Carrier */
  public carrier?: Party;
  /** Haulier */
  public haulier?: Party;
  /** Driver */
  public driver: Contact;
  /** Origin */
  public origin?: Location;
  /** Destination */
  public destination?: Location;
  /** Transport places */
  public transportPlaces?: TransportPlace[];
  /** Stowage process */
  public stowage?: Process;
}

export class Shipment extends TrackableEntity {

  /** Shipment ID */
  public shipmentID?: string;
  /** Bill of lading number */
  public bolNumber?: string;
  /** Order date */
  public orderDate?: Date;
  /** Requestor reference */
  public consignorReference?: string;
  /** Transport mode */
  public transportMode?: TransportMode;
  /** Transport unit type */
  public transportUnitType?: TransportUnitType;
  /** Operation type */
  public operationType?: string;
  /** Carriage condition */
  public carriageCondition?: CarriageCondition;
  /** Haulage arrangement */
  public haulageArrangement?: HaulageArrangement;
  /** Requestor */
  public consignor?: Party;
  /** Dispatch party */
  public dispatchParty?: Party;
  /** Consignee */
  public consignee?: Party;
  /** Carrier */
  public carrier?: Party;
  /** Haulier */
  public haulier?: Party;
  /** Agent */
  public agent?: Party;
  /** Notified Parties */
  public notifiedParties?: Party[];
  /** Transport */
  public transport?: TransportInfo;
  /** Equipment requests */
  public equipmentRequests?: EquipmentRequest[];
  /** Gate out process */
  public gateOut?: ProcessReference;
  /** Origin */
  public origin?: Location;
  /** Load */
  public load?: Location;
  /** Discharge */
  public discharge?: Location;
  /** Destination */
```

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```
  public destination?: Location;
  /** Gate in process */
  public gateIn?: ProcessReference;
  /** Item count */
  public itemCount?: number;
  /** Transport units */
  public transportUnits?: TransportUnitInfo[];
  /** Total declared weight */
  public totalDeclaredWeight?: number;
  /** Total actual weight */
  public totalActualWeight?: number;
  /** Total Volume */
  public totalVolume?: number;
  /** Shipments */
  public shipments?: ShipmentInfo[];
  /** Goods items */
  public goodsItems?: GoodsItem[];
  /** Dangerous substances */
  public dangerousSubstances?: DangerousSubstance[];
  /** Instructions */
  public instructions?: Code[];
  /** Warnings */
  public warnings?: string[];
}

/** Stored item data model */
export class StoredItem extends TrackableEntity {

  /** Stored item ID */
  public storedItemID?: string;
  /** Depositor reference */
  public depositorReference: string;
  /** Depositor */
  public depositor?: Party;
  /** Depositary */
  public depositary?: Party;
  /** Agent */
  public agent?: Party;
  /** Order Date */
  public orderDate?: Date;
  /** Main transport */
  public mainTransport?: TransportInfo;
  /** Shipment */
  public shipment?: ShipmentReference;
  /** Gate in operation processes */
  public gateInOperations?: Process[];
  /** Gate out operation processses */
  public gateOutOperations?: Process[];
}

/** Transport Unit data model */
export class TransportUnit extends TrackableEntity {

  /** Transport unit ID */
  public transportUnitID?: string;
  /** Shipment information */
  public shipment?: ShipmentInfo;
  /** Transport unit type */
  public type?: TransportUnitType;
  /** Container type */
  public containerType?: Code;
  /** Container status */
  public containerStatus?: string;
```

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```
    /** Shipment clause */
    public shipmentClause?: ShipmentClause;
    /** Owner */
    public owner?: Party;
    /** Provider */
    public provider?: Party;
    /** Tare weight */
    public tareWeight?: Measure;
    /** Seals */
    public seals?: Seal[];
    /** Oversize */
    public oversize?: Oversize;

}

export class Vehicle extends TrackableEntity {

    /** Vehicle ID */
    public vehicleID?: string;
    /** Means type */
    public meansType?: VehicleType;
    /** Brand */
    public brand?: string;
    /** Inspection expiration date */
    public inspectionExpirationDate?: Date;
    /** Registered By */
    public registeredBy?: Party;
    /** Owner */
    public owner?: Party;
    /** Tank Volume */
    public tankVolume: number;
    /** Total Declared Weight */
    public totalDeclaredWeight?: number;
    /** Files */
    public files?: FileMetadata[];
    /** Has admin flag */
    public hasAdmin?: boolean;
}

/** Document */
export class Document extends TrackableEntity {

    /** Document ID */
    public documentID?: string;
    /** Document type */
    public documentType?: DocumentType;
    /** File name */
    public filename?: string;
    /** Date */
    public date?: Date;
    /** Format */
    public format?: FormatType;
    /** Public flag */
    public?: boolean;
    /** Sender */
    public sender?: Party;
    /** Receiver */
    public receiver?: Party;
    /** Publisher */
    public publisher?: Party;
    /** Origin */
    public origin?: Location;
    /** Destination */
```

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```
    public destination?: Location;
    /** Attributes */
    public attributes?: Attribute[];
    /** Hash */
    public hash?: string;
    /** File Id */
    public fileId?: string;
    /** Files */
    public files?: FileMetadata[];
    /** Has admin flag */
    public hasAdmin?: boolean;
}

/** Message datamodel */
export class Message extends Document {

    /** Message ID */
    public messageID?: string;
    /** Message Status */
    public status?: AssetStatus;
    /** Message function */
    public messageFunction: string;
    /** Message type */
    public messageType?: string;
    /** Payload metadata */
    public payloadMetadata?: FileMetadata;
    /** Payload */
    public payload?: any;
    /** Parsed metadata */
    public parsedMetadata?: FileMetadata;
    /** Parsed */
    public parsed?: any;
    /** Transformed metadata */
    public transformedMetadata?: FileMetadata;
    /** Transformed */
    public transformed?: any;
    /** Type */
    public type?: string;
    /** Retries */
    public retries?: number;
    /** Next retry */
    public nextRetry?: Date;
    /** Action */
    public action?: string;
    /** User */
    public user?: User;
}

/** Customs procedure data model */
export class CustomsProcedure extends TrackableEntity {

    /** Customs procedure ID */
    public customsProcedureID?: string;
    /** Declaring party */
    public declaringParty?: Party;
    /** Exporting party */
    public exportingParty?: Party;
    /** Importing party */
    public importingParty?: Party;
    /** Warehouse party */
    public warehouseParty?: Party;
    /** Customs office party */
    public customsOffice?: Party;
```

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```
    /** Customs location */
    public customsLocation?: Location;
    /** Customs regime */
    public customsRegime?: string;
    /** Origin */
    public origin?: Location;
    /** Export Location */
    public exportLocation?: Location;
    /**  Destination */
    public destination?: Location;
    /** Transport information */
    public transport?: TransportInfo;
    /** Has predeclaration flag */
    public hasPredeclaration?: boolean;
    /** Exit type */
    public exitType?: string;
    /** Automatic transhipment */
    public automaticTranshipment?: boolean;
    /** seals */
    public seals?: Seal[];

}

/** Service data model */
export class Service extends Process {

    /** ID */
    public ID?: string;
    /** Parent entity ID */
    public parentEntityID?: ResourceLocator;
    /** Service ID */
    public serviceID?: string;
    /** Requestor */
    public requestor?: Party;
    /** Provider */
    public provider?: Party;
    /** Involved parties */
    public involvedParties: Party[];
    /** Payload */
    public payload?: any;
}

/** Location facility data model*/
export class LocationFacility extends Location {

    /** ID */
    public ID?: ResourceLocator;
    /** Facility ID */
    public facilityID?: string;
    /** Facility type */
    public facilityType?: FacilityType;
    /** Status */
    public status?: AssetStatus;
    /** Owner */
    public owner: Party;
    /** Parent entity ID */
    public parentEntityID?: ResourceLocator;
    /** Last trackable event */
    public lastTrackableEvent?: EventInfo;
    /** Classifiers */
    public classifiers?: FacilityType[];
    /** Capacities */
    public capacities?: Capacity[];
```

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```
    /** Attributes */
    public attributes?: Attribute[];
}

/** Charges data model */
export class Charges extends TrackableEntity {

    /** Charges ID */
    public chargesID?: string;
    /** From */
    public from?: Party;
    /** To */
    public to?: Party;
    /** Issue date */
    public issueDate?: Date;
    /** Due date */
    public dueDate?: Date;
    /** Subject */
    public subject?: string;
    /** Exchange */
    public exchange?: ExchangeRate;
    /** Charges */
    public charges?: Charge[];
    /** Subtotal */
    public subtotal?: Amount;
    /** Taxes */
    public taxes?: Charge[];
    /** Total */
    public total?: Amount;
    /** Payed */
    public payed?: Amount;
    /** Pending */
    public pending?: Amount;
    /** Payment method */
    public paymentMethod?: PaymentMethod;
    /** Bank account */
    public bankAccount?: string;
    /** Bank */
    public bank?: string;
    /** Invoice number */
    public invoiceNumber?: string;
    /** Payload */
    public payload?: any;
}

/** Master data model */
export class MasterData extends Meta {

    /** ID */
    public ID?: ResourceLocator;
    /** Code */
    public code?: string;
    /** Name */
    public name?: string;
    /** Master data type */
    public type?: string;
    /** Language */
    public lang?: string;
    /** Owner */
    public owner?: string;
    /** Classifiers */
    public classifiers?: string[];
    /** Options */
```

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```
    public options?: any;
    /** Content */
    public content?: string;
    /** Entity type */
    public entityType?: EntityType;
}

// NOTIFICATIONS

/** Business notification data model */
export class BusinessNotification extends TrackableEvent {

    /** Webhook data */
    public webhook?: Webhook;
}

/** Sequence data model */
export class Sequence extends CommonModel {

    /** Database Id */
    public _id?: string;
    /** Sequence type */
    public type?: string;
    /** Sequence */
    public sequence?: number;
}
```

AI.3 MODALNET CONCEPTS

```
/** Resource Locator */
export type ResourceLocator = (string);

/** Metadata common base class */
export class CommonModel {

}

/** Metadata common base class */
export class Meta extends CommonModel {

    /** Internal id */
    public _id?: any;
    /** Date of creation */
    public createdAt?: Date;
    /** Date of modification */
    public updatedAt?: Date;
    /** Object version */
    public version?: string;
    /** Message identifier */
    public messageID?: string;
    /** Identifier of the entity who reported it */
    public reportedByID?: ResourceLocator;
    /** Code of the identity that has reported it */
    public reportedByCode?: string;
    /** Role of the identity that has reported it */
    public reportedByRole?: OrganizationType;
    /** Asset type */
    public assetType?: EntityType;
    /** User identifier */
    public userId?: string;
    /** Whether or not it is stored on the Blockchain */
```

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```
    public inBC?: boolean;
    /** Object change history */
    public history?: any[];
    /** Deleted or not */
    public delete?: any;
}

/** Array element deleted or not */
export class ArrayItem extends CommonModel {

    /** Deleted or not */
    public delete?: boolean;

}

export class AuthToken extends ArrayItem {

    /** Delete flag */
    public delete?: boolean;
    /** Access token data */
    public accessToken?: any;
    /** Kind of token */
    public kind?: string;
    /** Is platform JWT flag */
    public isPlatformJwt?: boolean;
    /** Creation date */
    public created?: Date;
    /** Expiration date */
    public expiryDate?: Date;
    /** Encrypted token flag */
    public encrypted?: boolean;
}

/** Code data model */
export class Code extends ArrayItem {

    /** Delete flag */
    public delete?: boolean;
    /** Code */
    public code?: string;
    /** Name */
    public name?: string;
}

/** Attribute data model */
export class Attribute extends ArrayItem {

    /** Name */
    public name?: string;
    /** Value */
    public value?: string;
}

/** Address data model */
export class Address extends CommonModel {

    /** Street */
    public street?: string;
    /** City */
    public city?: string;
    /** Postal Code */
    public postalCode?: string;
    /** Province */
```

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```
    public province?: string;
    /** Country */
    public country?: Code;
}

/** Contact data model */
export class Contact extends ArrayItem {

    /** Contact type */
    public type?: string;
    /** Contact id */
    public id?: string;
    /** Contact name */
    public name?: string;
    /** e-mail */
    public email?: string;
    /** Contact phone */
    public phone?: string;
}

/** Geo JSON data model */
export class GeoJSON extends CommonModel {

    /** Geo JSON type */
    public type?: string;
    /** Coordinates */
    public coordinates?: number[];
}

/** Amount data model */
export class Amount extends CommonModel {

    /** Value */
    public value?: number;
    /** Currency */
    public currency?: Code;
}

/** Exchange rate data model */
export class ExchangeRate extends CommonModel {

    /** Source currency */
    public sourceCurrency?: Amount;
    /** Destination currency*/
    public destinationCurrency?: Amount;
}

/** Charge data model */
export class Charge extends ArrayItem {

    /** Concept */
    public concept?: Code;
    /** Original amount */
    public originalAmount: Amount;
    /** Exchanged amount */
    public exchangedAmount?: Amount;
}


/** Logo data model */
export class Logo extends CommonModel {
```

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```
  /** Image in base64 */
  public image?: string;
}

/** Party data model */
export class Party extends Meta {

  /** Delete flag */
  public delete?: boolean;
  /** Party ID */
  public ID?: string;
  /** Organization code and name */
  public organization?: Code;
  /** Office code and name */
  public office?: Code;
  /** Party role */
  public role?: OrganizationType;
  /** Business functions of the party */
  public types?: string[];
  /** Address */
  public address?: Address;
  /** Contacts */
  public contacts?: Contact[];
  /** Remarks */
  public remarks?: string[];
  /** Codes */
  public codes?: string[];
  /** Amount balance in the platform */
  public balance?: Amount;
  /** Logo */
  public logo?: Logo;
}

/** Reference data model */
export class Reference extends ArrayItem {

  /** Reference type */
  public type?: ReferenceType;
  /** Reference value */
  public value?: string;
  /** Reference ID */
  public ID?: ResourceLocator;
}

/** Location data model */
export class Location extends Meta {

  /** Delete flag */
  delete?: boolean;
  /** Sequence number */
  public sequence?: number;
  /** Location type */
  public type?: LocationType;
  /** Location code */
  public location?: string;
  /** Location name */
  public locationName?: string;
  /** Address */
  public address?: Address;
  /** Coordinates */
  public position?: GeoJSON;
  /** Requested time of departure */
  public rtd?: Date;
```

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```
    /** Estimated time of departure */
    public etd?: Date;
    /** Actual time of departure */
    public atd?: Date;
    /** Requested time of arrival */
    public rta?: Date;
    /** Estimated time of arrival */
    public eta?: Date;
    /** Actual time of arrival */
    public ata?: Date;
    /** Positioning time */
    public positionTime?: Date;
}

/** Measure data model */
export class Measure extends ArrayItem {

    /** Measure type */
    public type?: MeasureType;
    /** Measure value */
    public value?: number;
    /** Size text */
    public sizeText?: string;
    /** Unit of measure */
    public UOM?: string;
}

/** Oversize data model */
export class Oversize extends CommonModel {

    /** Front */
    public front?: Measure;
    /** Back */
    public back?: Measure;
    /** Right */
    public right?: Measure;
    /** Left */
    public left?: Measure;
    /** Top */
    public top?: Measure;
}

/** Seal data model */
export class Seal extends ArrayItem {

    /** Owner string*/
    public owner?: string;
    /** Number */
    public number?: string;
}

/** Time info data model */
export class TimeInfo extends ArrayItem {

    /** Timing type */
    public timingType?: TimeType;
    /** Time */
    public date?: Date;
    /** Period */
    public period?: number;
}

/** Document info data model */
```

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```
export class DocumentInfo extends ArrayItem {

    /** Document ID */
    public documentID?: ResourceLocator;
    /** Document type */
    public type?: DocumentType;
    /** Document date */
    public date?: Date;
    /** Document identification */
    public identification?: Code;
    /** Document attributes */
    public attributes?: Attribute[];
}

/** Shipment reference data model */
export class ShipmentReference extends ArrayItem {

    /** ID */
    public ID?: ResourceLocator;
    /** Shipment ID or booking reference*/
    public shipmentID?: string;
    /** Bill of lading number */
    public bolNumber?: string;
    /** Requestor reference */
    public consignorReference?: string;
    /** Transport mode */
    public transportMode?: TransportMode;
    /** Transport unit type */
    public transportUnitType?: TransportUnitType;
    /** Requestor */
    public consignor?: Party;
    /** Dispatch party */
    public dispatchParty?: Party;
    /** Carrier */
    public carrier?: Party;
    /** Consignee */
    public consignee?: Party;
}

/** Transport info data model */
export class TransportInfo extends ArrayItem {

    /** ID */
    public ID?: ResourceLocator;
    /** Carrier */
    public carrier?: Party;
    /** Transport ID */
    public transportID?: string;
    /** Stop over number */
    public stopOver?: string;
    /** Transport mode */
    public tranportMode?: TransportMode;
    /** Transport identification */
    public identification?: Code;
    /** Requested time of departure */
    public rtd?: Date;
    /** Requested time of arrival */
    public rta?: Date;
    /** Transport places */
    public transportPlaces?: Location[];
}

/** Process reference data model */
```

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```
export class ProcessReference extends ArrayItem {

  /** Process type */
  public type?: ReferenceType;
  /** Process value */
  public value?: string;
  /** ID */
  public ID?: ResourceLocator;
  /** Auhorised party */
  public authorisedParty?: Party;
  /** Depositary */
  public depositary?: Party;
  /** Requested date */
  public requestedDate?: Date;
  /** References */
  public references?: Reference[];
  /** Estimated time of arrival */
  public eta?: Date;
  /** Actual time of arrival */
  public ata?: Date;
  /** Performed date */
  public performedDate?: Date;
  /** Estimated time of departure */
  public etd?: Date;
  /** Actual time of departure */
  public atd?: Date;
  /** Location */
  public location?: Location;
  /** Valid from */
  public validFrom?: Date;
  /** Expiration date */
  public expiryDate?: Date;
  /** Container status */
  public containerStatus?: string;
  /** Transport info */
  public transport?: TransportInfo;
  /** Remarks */
  public remarks?: string[];
  /** Event function */
  public eventFunction?: EventFunction;
}

/** Transport unit info data model */
export class TransportUnitInfo extends ArrayItem {

  /** ID */
  public ID?: ResourceLocator;
  /** Transport unit ID */
  public transportUnitID?: string;
  /** Provider */
  public provider?: Party;
  /** Transport unit type */
  public type?: TransportUnitType;
  /** Container status */
  public containerStatus?: string;
  /** Container type */
  public containerType?: Code;
  /** Shipment process reference */
  public shipment?: ShipmentReference;
  /** Gate in process reference */
  public gateIn?: ProcessReference;
  /** Gate out process reference */
  public gateOut?: ProcessReference;
```

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```
    /** References */
    public references?: Reference[];
    /** Gross mass */
    public grossMass?: Measure;
    /** Is VGM flag */
    public isVGM?: boolean;
    /** Maximum weight */
    public maximumWeight?: Measure;
    /** Tare weight */
    public tareWeight?: Measure;
    /** Temperature */
    public temperature?: Measure;
    /** Air flow */
    public airFlow?: Measure;
    /** Seals */
    public seals?: Seal[];
    /** Oversize */
    public oversize?: Oversize;
    /** Attributes */
    public attributes?: Attribute[];
    /** Confirmation date */
    public confirmedDate?: Date;
    /** Instruction */
    public instruction?: string;
    /** Inspection */
    public inspection?: string;
    /** Inspection date  */
    public inspectionDate?: Date;
    /** Customs status */
    public customsStatus?: string;
    /** Event function */
    public eventFunction?: EventFunction;
}

/** Transport unit reference data model */
export class TransportUnitReference extends ArrayItem {

    /** ID */
    public ID?: ResourceLocator;
    /** Transport unit ID */
    public transportUnitID?: string;
    /** Provider */
    public provider?: Party;
    /** Transport unit type */
    public type?: TransportUnitType;
    /** Container status */
    public containerStatus?: string;
    /** Container type */
    public containerType?: Code;
    /** Shipment reference */
    public shipment?: ShipmentReference;
    /** References */
    public references?: Reference[];
    /** Gross mass */
    public grossMass?: Measure;
    /** Is VGM flag */
    public isVGM?: boolean;
    /** Maximum weight */
    public maximumWeight?: Measure;
    /** Tare weight */
    public tareWeight?: Measure;
    /** Temperature */
    public temperature?: Measure;
```

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```
  /** Air flow */
  public airFlow?: Measure;
  /** Seals */
  public seals?: Seal[];
  /** Oversize */
  public oversize?: Oversize;
  /** Attributes */
  public attributes?: Attribute[];
  /** Confirmed date */
  public confirmedDate?: Date;
  /** Instruction */
  public instruction?: string;
  /** Inspection */
  public inspection?: string;
  /** Inspection date */
  public inspectionDate?: Date;
  /** Customs status */
  public customsStatus?: string;
  /** Event function */
  public eventFunction?: EventFunction;
}

/** Shipment information data model */
export class ShipmentInfo extends ArrayItem {

  /** ID */
  public ID?: ResourceLocator;
  /** Shipment ID or booking number */
  public shipmentID?: string;
  /** Bill of lading number */
  public bolNumber?: string;
  /** Requestor reference */
  public consignorReference?: string;
  /** Transport mode */
  public transportMode?: TransportMode;
  /** Transport unit type */
  public transportUnitType?: TransportUnitType;
  /** Requestor */
  public consignor?: Party;
  /** Carrier */
  public carrier?: Party;
  /** Haulier */
  public haulier?: Party;
  /** Gate in process reference */
  public gateIn?: ProcessReference;
  /** Gate out process reference */
  public gateOut?: ProcessReference;
  /** Confirmation date */
  public confirmedDate?: Date;
  /** Event function */
  public eventFunction?: EventFunction;
  /** References */
  public references?: Reference[];
}

/** Event information data model */
export class EventInfo extends ArrayItem {

  /** ID */
  public ID?: string;
  /** Event name */
  public name?: ReferenceType;
  /** Event type */
```

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```
    public eventType?: EventType;
    /** Location ID */
    public locationID?: ResourceLocator;
    /** Location */
    public location?: Location;
    /** Performed time */
    public performedTime?: Date;
}

export class Process extends Meta {

    /** Process type */
    public type?: ReferenceType;
    /** Process name */
    public name?: string;
    /** Process value */
    public value?: string;
    /** ID */
    public ID?: ResourceLocator;
    /** Owner */
    public referenceOwner?: Party;
    /** Authorised party */
    public authorisedParty?: Party;
    /** Depositary */
    public depositary?: Party;
    /** Hash */
    public hash?: string;
    /** Status */
    public status?: AssetStatus;
    /** Remarks */
    public remarks?: string[];
    /** Quantity */
    public quantity?: number;
    /** Unit */
    public unit?: string;
    /** Requested date */
    public requestedDate?: Date;
    /** Valid from */
    public validFrom?: Date;
    /** Expiration date */
    public expiryDate?: Date;
    /** Estimated time of arrival */
    public eta?: Date;
    /** Actual time of arrival */
    public ata?: Date;
    /** Estimated time of departure */
    public etd?: Date;
    /** Actual time of departure */
    public atd?: Date;
    /** Performed date */
    public performedDate?: Date;
    /** Confirmed date */
    public confirmedDate?: Date;
    /** Location */
    public location?: Location;
    /** Shipment count */
    public shipmentsCount?: number;
    /** Units count */
    public unitsCount?: number;
    /** Shipments */
    public shipments?: ShipmentInfo[];
    /** Transport units */
    public transportUnits?: TransportUnitInfo[];
```

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```
    /** Transport */
    public transport?: TransportInfo;
    /** Next transport */
    public nextTransport?: TransportInfo;
    /** Container status */
    public containerStatus?: string;
    /** Event function */
    public eventFunction?: EventFunction;
    /** References */
    public references?: Reference[];
    /** Attributes */
    public attributes?: Attribute[];
    /** Last trackable event */
    public lastTrackableEvent?: EventInfo;
}

/** Transport place data model */
export class TransportPlace extends Location {

    /** Status */
    public status?: AssetStatus;
    /** Event function */
    public eventFunction?: EventFunction;
    /** Positioning time */
    public positionTime?: Date;
    /** Agent */
    public agent?: Party;
    /** Depositary */
    public depositary?: Party;
    /** Discharge proces */
    public discharge?: Process;
    /** Load process */
    public load?: Process;
    /** References */
    public references?: Reference[];
    /** Document infos */
    public documentInfos?: DocumentInfo[];
    /** Time infos */
    public timeInfos?: TimeInfo[];
    /** Transport info */
    public transport?: TransportInfo;

}

/** Certificate data model */
export class Certificate extends Process {

    /** Government agency */
    public governmentAgency?: string;
    /** Release date */
    public releaseDate?: Date;
    /** Has physical inspection flag */
    public hasPhysicalInspection?: boolean;
    /** Type of inspection */
    public typeOfInspection?: string;
    /** Inspection Id */
    public inspectionId?: string;
    /** Items to inspect */
    public itemsToInspect?: string[];
    /** Inspection date */
    public inspectionDate?: Date;
    /** Additional data */
    public additionalData: string;
```

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```
}

/** Package data model */
export class Package extends ArrayItem {

    /** Package type */
    public type?: Code;
    /** Package position */
    public position?: string;
    /** Quantity */
    public quantity?: number;
}

/** Dangerous goods substance data model */
export class DangerousSubstance extends ArrayItem {

    /** UNDG number */
    public undg?: Code;
    /** UNDG Class */
    public undgClass?: string;
    /** Packing group */
    public packingGroup?: string;
    /** IMDG Page */
    public imdgPage?: string;
    /** Authorization certificates */
    public authorizations?: Certificate[];
    /** Shipment flash point */
    public shipmentFlashPoint?: Measure;
    /** Additional infos */
    public additionalInfos?: Reference[];
    /** Emergency contact */
    public emergencyContact?: Contact;
    /** Gross weight */
    public grossWeight?: Measure;
    /** Net weight */
    public netWeight?: Measure;
    /** Volume */
    public volume?: Measure;
    /** Radioactivity */
    public radioactivity?: Measure;
    /** Acid concentration */
    public acidConcentration?: Measure;
}

/** Goods item data model */
export class GoodsItem extends ArrayItem {

    /** Gooods item ID */
    public goodsItemID?: string;
    /** Goods description */
    public goodsDescription?: Code;
    /** Marks and Numbers */
    public marksAndNumbers: string[];
    /** Customs certificates */
    public customsCertificates: Certificate[];
    /** Required certificates */
    public requiredCertificates: Certificate[];
    /** Goods references */
    public goodsReferences?: Reference[];
    /** Document references */
    public documentReferences?: Reference[];
    /** Packages */
    public packages?: Package[];
```

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```
    /** Gross weight */
    public grossWeight?: Measure;
    /** Net weight */
    public netWeight?: Measure;
    /** Volume */
    public volume?: Measure;
    /** Additional units */
    public additionalUnits?: Measure[];
    /** Dangerous substances */
    public dangerousSubstances?: DangerousSubstance[];
    /** Country of origin */
    public countryOfOrigin?: Code;
    /** State of origin */
    public stateOfOrigin?: Code;
}

/** Equipment request data model */
export class EquipmentRequest extends ArrayItem {

    /** Container type */
    public containertType?: Code;
    /** Equipment supplier */
    public equipmentSupplier?: Party;
    /** Number of units */
    public numberOfUnits?: number;
    /** Number of units delivered */
    public numberOfUnitsDelivered?: number;
    /** Instructions */
    public instructions?: Code[];
    /** Oversize */
    public oversize?: Oversize;
}

/** Capacity data model */
export class Capacity extends ArrayItem {

    /** Day */
    public day?: Date;
    /** Type */
    public type?: Code;
    /** Quantity */
    public quantity?: Measure;
    /** Quantity used */
    public used?: Measure;
}

/** File metadata data model */
export class FileMetadata extends ArrayItem {

    /** Database identifier */
    public _id?: any;
    /** File name */
    public filename?: string;
    /** Original name */
    public originalname?: string;
    /** Content type */
    public contentType?: string;
    /** Upload date */
    public uploadDate?: Date;
    /** File size */
    public length?: number;
    /** Owner */
    public owner?: string;
```

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```
  /** File Hash */
  public hash?: string;
  /** Database MD5 */
  public md5?: string;
  /** Aliases */
  public aliases?: string[];
  /** Asset name */
  public assetName?: string;
  /** Asset type */
  public assetType?: string;
  /** Action */
  public action?: string;
  /** Attributes */
  public attributes?: any;
  /** Content */
  public content?: string;
}

/** Endpoint data model */
export class Endpoint extends ArrayItem {

  /** Entity type */
  public entityType?: EntityType;
  /** Message code */
  public messageCode?: string;
  /** Format */
  public format?: string;
  /** End point address */
  public endpoint?: string;
  /** Events */
  public events?: EventType[];
}

/** Web hook data model */
export class Webhook extends ArrayItem {

  /** Webhook name */
  public name?: string;
  /** user */
  public user?: string;
  /** Token */
  public token?: string;
  /** URL */
  public url?: string;
  /** Type */
  public type?: string;
  /** Endpoints */
  public endpoints?: Endpoint[];
}
```

AI.3 MODALNET API METADATA

```
/** List Metadata model */
export class ListMetadata {

  /** Asset name */
  asset?: string = '';
  /** Filter data object */
  filter?: any;
  /** Order data object */
```

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```
  order?: any;
  /** Select data comma separated string*/
  select?: string = '';
  /** Action */
  action?: string = '';
  /** Count */
  count?: number = 0;
  /** Page size */
  pageSize: number = 10;
  /** Page number */
  pageNumber?: number = 1;
  /** Start */
  start?: number = 0;
  /** Is first page flag */
  firstPage?: boolean = false;
  /** Is last page flag */
  lastPage?: boolean = false;
  /** Language */
  lang?: string = 'es';
  /** Office ID */
  office?: string;
  /** Error string */
  error?: string;
}

/** Asset list model */
export class AssetList {

  /** List metadata */
  metadata: ListMetadata;
  /** Asset list retrieved data array or error object */
  data?: any;
}

/** Asset metadata */
class AssetMetadata {
  /** Operation */
  operation?: string;
  /** Asset name */
  asset?: string;
  /** Identifier */
  id?: string;
  /** Language */
  lang?: string = 'es';
  /** Error string */
  error?: string;
}

/** Asset data model */
export class Asset {
  /** Asset metadata */
  metadata: AssetMetadata;
  /** Retrieved asset data object or error object */
  data?: any;
}

export class AssetDefinition {
  selectParams: string[];
  filterParams: string[];
  orderByParams: string[];
}
```

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