MOSES

AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping

D.1.5: MOSES Final Report

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List of Acronyms

Abbreviation / acronym	**Description**
3DVR	3D Virtual Reality
3DWI	3D World Interpreter
AI	Artificial Intelligence
AMS	Automated Mooring System
ARC	Active Rotation Control
AT	Autonomous Tugboats
BPMN	Business Process Modelling Notation
CCU	Crane Control Unit
ConOps	Concept of Operations
D1.1	Deliverable number 1 belonging to WP 1
DSS	Deep-Sea Shipping
EAB	Exploitation Advisory Board
EC	European Commission
EtA	Estimated time of Arrival
EtD	Estimated time of Departure
EU	European Union
FOV	Field Of View
GA	Grant Agreement
GPS	Global Positioning System
GUI	Graphical User Interface
ICE	Internal Combustion Engine
IFV	Innovative Feeder Vessel
ILME	National Logistics Council of Greece
IMU	Inertial Measurement Unit
IOSS	Intelligent Operator Support System
KER	Key Exploitable Result
KPI	Key Performance Indicator
LiDAR	Light Detection and Ranging

Abbreviation / acronym	**Description**
ML	Machine Learning
MLP	Matchmaking Logistics Platform
MO	Market Objective
MoSCoW	Must-have, should-have, could-have, and won't-have, or will not have right now
MRC	Minimum Risk Condition
PCS	Port Community System
PESTEL	Political, Economic, Social, Technological, Legal, and Environment
PPO	Proximal Policy Optimization
RCHS	Robotic Container-Handling System
RoPax	Roll On – Roll Off Passenger vessel
Ro-Ro	Roll On – Roll Off vessel
SI	Success Indicator
SMB	Seakeeping and Manoeuvring Basin
SO	Societal Objective
SSS	Short Sea Shipping
STCS	Shore Tugboat Control Station
STPA	Systems Theoretic Process Analysis
SWB	Shallow Water Basin
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TO	Technical Objective
ToT	Turnover Time
TRL	Technology Readiness Level
UML	Unified Modelling Language
WP	Work Package

Executive Summary

The main objective of this deliverable is to describe the tangible outcomes and main achievements of the MOSES project, which was completed on December 31, 2023, as well as to provide an overall assessment of its performance with respect to technical implementation, communication and dissemination, and the project objectives described in the MOSES Grant Agreement (GA).

This is accomplished by providing a summary of the tangible outcomes of MOSES regarding the business cases, the technologies, and the policy recommendations for Short Sea Shipping (SSS) that were developed within the project. The deliverable also summarises the main achievements in each of the following four stages of development: 1) determining the requirements and specifications, 2) designing, developing, and testing the technologies, 3) validating the innovations in Pilot Demonstrations and evaluating their impact in terms of sustainability, and 4) providing a plan for post-project exploitation and developing the policy recommendations for SSS. Furthermore, the deliverable describes the project's performance with reference to the KPIs associated with the technical implementation and communication and dissemination, as well as the Success Indicators (SIs) associated with the project's specific objectives.

Regarding technical performance, the project faced delays in deliverable submission and milestone achievement during the first year of the project due to the COVID-19 crisis. However, these delays did not have a significant impact on achieving the project objectives and expected impact. Regarding communication and dissemination, the project performed very well with respect to its social media and presenting the project results to scientific conferences and stakeholder events (incl. publishing scientific paper in conference proceedings). On the other hand, although the number of publications in scientific journals was below our initial expectations, some publications have been planned for the year following the project end.

Regarding the performance against the project objectives, all the technical and associated societal and market objectives were achieved. The technical objectives relate to the development of the MOSES innovations, while the societal and market objectives are related to environmental performance and efficiency of SSS, as well as developing business cases that promote the development of small ports with minimal investment.

The deliverable concludes with lessons learned from the research that was conducted within the project related to the competitiveness of the innovative feeder and the viability of the MOSES sustainable feeder services, as well as to the steps taken to automate the manoeuvring and docking process for large containerships in DSS ports.

1. Introduction

1.1 Purpose of the document

MOSES aims to significantly enhance the SSS component of the European container supply chain by creating sustainable container feeder services from large container terminals (DSS ports) to small ports that have limited or no infrastructure to replace trucks on Ro-Ro ships and improve the modal split in favour of SSS over land-based transportation. The innovations that have been developed in MOSES are:

(i) the MOSES Innovative Feeder Vessel (IFV) outfitted with the MOSES Robotic Container-Handling System (RCHS).

(ii) the MOSES AutoDock system, which consists of the MOSES Autonomous Tugboat (AT) swarm and the MOSES Automated Mooring System (AMS).

(iii) the MOSES Matchmaking Logistics Platform (MLP).

Proof of concepts have been conducted for the MOSES innovations through Pilot Demonstrations in relevant testing environments (TRL5). Their added value and viability have been validated with the MOSES Sustainability Framework.

This deliverable aims to provide an overview of the main achievements within the MOSES project and an overall evaluation of its performance with respect to the project objectives. It includes an extended summary of the periodic progress reports, of the main results of the project, and a general evaluation of the outcomes against the MOSES objectives and the quality KPIs defined in D1.2 [1].

1.2 Intended readership

'MOSES Final Report' is a public deliverable, which accumulates research and findings produced and documented in all previous project deliverables. It is addressed not only to the consortium members and the EC, but also to stakeholders that are relevant to the MOSES innovations, as well as to any interested reader.

1.3 Document Structure

The rest of this document is structured as follows. Section 2 describes the tangible outcomes that reflect the development for the MOSES innovations. Section 3 provides an overview of the project activities in the different phases of the project. Section 4 evaluates the performance of the project (self-assessment) in terms of technical coordination, communication and dissemination, as well as against the project objectives. The document concludes with the most significant results and lessons learned from the project.

2. The tangible outcomes of MOSES

This section describes the main outcomes from the MOSES project regarding the business cases for the sustainable feeder services, the MOSES innovations, and the policy recommendations for enhancing the role of SSS in the EU container supply chain.

2.1 Business Cases

The MOSES business cases were developed, in accordance with the project's main objectives, to include routes for feeder services from DSS ports that connect to TEN-T corridors to small ports that have limited or no cargo handling infrastructure. The following two cases were developed: 1) Eastern Mediterranean – Greece, 2) Western Mediterranean – Spain (see D2.3 [2]). The main differences between these cases related to the estimated demand for containerized cargo, the round-trip distance, and the modality of transporting cargo from the DSS port to the hinterland of the final destinations.

The main objective for the Greek case was to decongest the large container terminal of Piraeus and integrate small Greek ports without specialized container handling infrastructure into the container supply chain. Currently, cargo is transported to these islands through trucks on RoPax vessels. As shown in Figure 1, the route (266 nm roundtrip) includes the port of Piraeus and the ports of Kea, Syros, Tinos, Mykonos, Naxos, and Paros, which had the highest Ro-Ro traffic in 2019, based on data from the Hellenic Statistical Authority. For this service to be economically viable, it was estimated that at least 80% of the maximum estimated current demand in general cargo traffic would have to captured by the innovative feeder and that it should call on each port at least with a bi-weekly frequency.

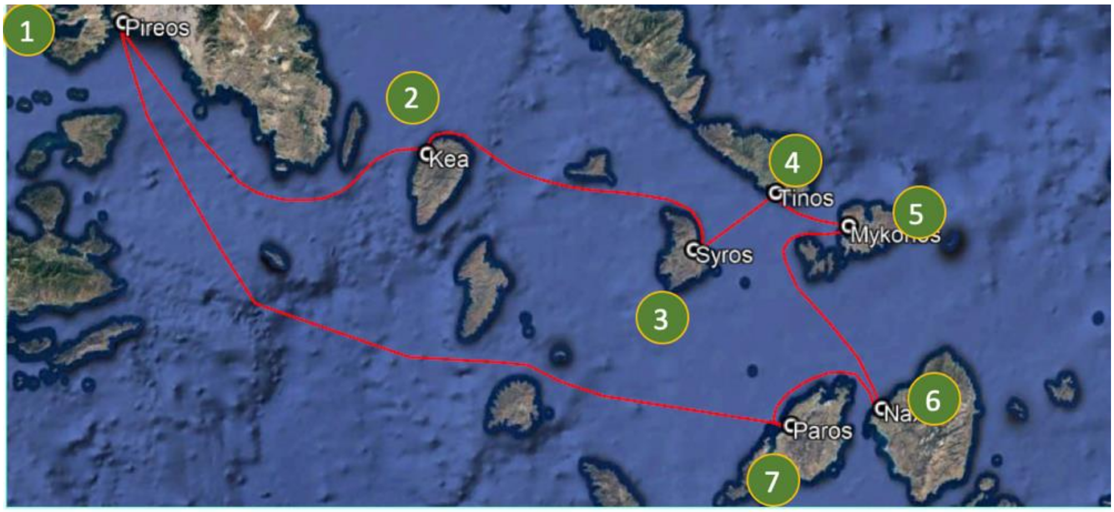

Figure 1: The route of the feeder service for the Greek business case.

The main objective for the Spanish case was to decongest the roads in the Valencia area by connecting the port of Valencia with its satellite ports of Gandia and Sagunto, which is an 85 nm roundtrip (Figure 2). Currently, cargo is transported to the hinterland of the port of Valencia through trucks. For this service to be economically viable, it was estimated that at least 40% of the maximum estimated demand in container truck traffic would have to be captured by the innovative feeder, it should call on each port at least with a frequency of three times per week, and there should be at least three truck haulages per day from the small ports to the final destinations in their hinterland.

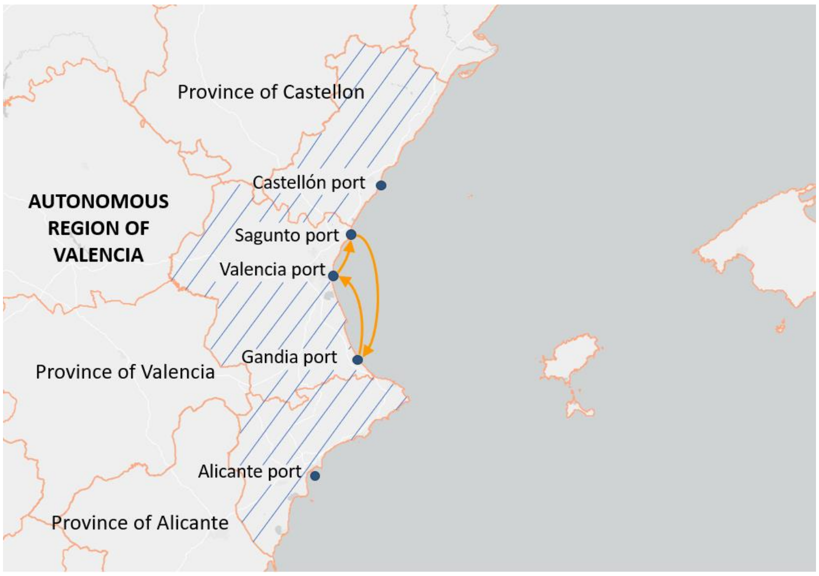

Figure 2: The route of the feeder vessel for the Spanish business case.

Both cases were considered as viable alternatives, in terms of transport unit cost, to maritime transport of trucks on RoPax vessels (Greek case) and land-based truck transportation (Spanish case) as described in Section 4.2.

2.2 Innovative Feeder Vessel

Three concept designs were developed for the autonomous, zero emission IFV, two for the Greek case and one for the Spanish case (documented in D3.1 [3]). The designs included determining the main particulars, the selection of power configurations, preliminary hazard analysis, and operational cost analyses. Although the basic development was conducted for both cases, the Greek concept design was further developed with a feasibility study for mixed pax/freight services (see D3.6 [4]), with simulations for autonomous operation (documented in D3.2 [4]) and was also demonstrated in Pilot Demonstration 2 (documented in D7.3 [5]). The innovative features of the IFV compared to existing container feeders include sustainable propulsion, azimuth thrusters as main propulsors for enhanced manoeuvrability, bridge positioned at the fore of the vessel, and automated cargo handling (see Section 2.3). Table 1 lists the main particulars of the Greek concept designs, which were verified through logistical trip simulations and are illustrated in Figure 3 and Figure 4.

Table 1: Main particulars of the Greek feeder design (I and II).

Particular	Greek design I	Greek design II
Cargo space	Open Top	Hatch Covers
Length (Lpp) [m]	80	71.0
Payload [TEU]	180	100
Service speed (v_S) [kn]	10	10
Range [nm]	266	266
Shaft Power (P_{Shaft}) [kW]	800	650

Figure 3: Innovative feeder design (I) for the Greek business case.

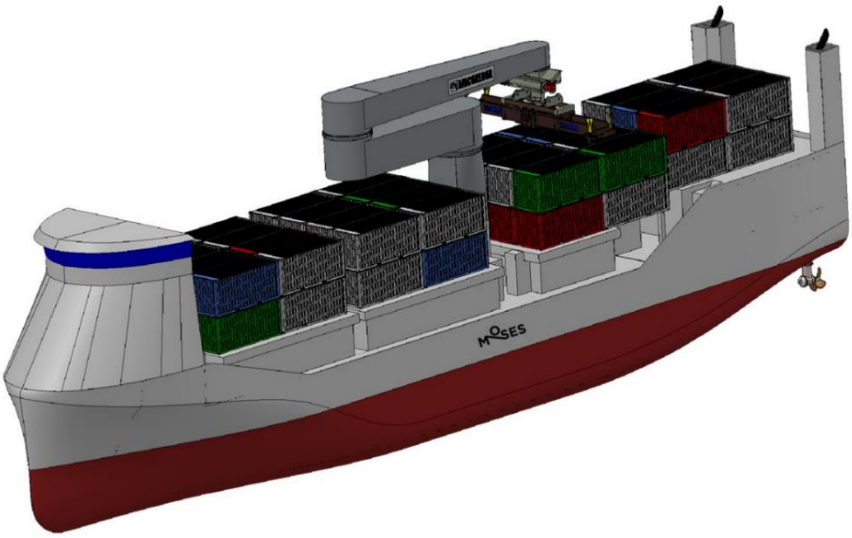

Figure 4: Innovative feeder design (II) for the Greek business case.

The most feasible solution for the power configuration of the Greek concept design was a hybrid powered solution involving a methanol fuelled Internal Combustion Engine (ICE) combined with a battery, which involves shore power and charging during sailing. This configuration enables partly zero emission operation, provides sufficient battery capacity to operate the vessel in the ports of the Greek islands, and has been estimated to have 10% lower operating costs compared to the fully electric option. A hydrogen fuel cell option was considered feasible but has several challenges, especially safety-related, and a fully electric option with 46 MWh batteries whose storage significantly reduces cargo space.

A preliminary hazard analysis was conducted for the Greek concept design and focused on the feeder's innovative features (i.e. onboard crane, bridge position, propulsion. The analysis identified nine high risk events related to the cargo space, accommodation, fuel/energy storage system, and engine/propulsion machinery (Table 2).

Table 2: High risk events identified through the preliminary hazard analysis conducted for the Greek concept designs.

Ship area / System	Hazardous event
Cargo space	• Onboard crane impedes port cranes resulting in slower cargo handling. • Water accumulation in cargo hold (open top design) resulting in stability degradation and damage to cargo.
Accommodation	• Mustering process takes too long in the event of an evacuation. • Limited visual monitoring of the cargo space resulting in fire, cargo shift/loss not being detected.
Fuel/Energy storage	• Methanol leakage (hybrid power configuration). • Batteries overheating (fully electric configuration).
Engine/Propulsion machinery	• Hybrid configuration operation and maintenance. • Generator fails due to load variations in extreme weather. • Design speed is appropriate only for the MOSES business cases.

In a preliminary end-to-end (i.e. from the DSS port to the small port) operational cost analysis for the Greek concept designs, the costs of the innovative feeder were compared to those of a conventional feeder serving the same routes. The cost categories that were included in the analysis related to port fees and services, charter and bunker costs, and last-mile connection. The results showed that the innovative feeder would have 13% - 14% higher end-to-end costs due to the higher price of the selected energy carrier and not accounting for possible crew reduction onboard due to automated functionalities. However, these costs could be lowered in the future if a tax related with CO_2 emissions is introduced.

A feasibility study was conducted to explore the possibility for the innovative feeder to exploit waiting time between port calls for transporting passengers to nearby islands in the context of the Greek business case. The study focused on technical and design feasibility, as well as regulatory limitations for design approval, safety issues, operational issues, and additional structural and operational costs for the feeder. Two case studies were examined: 1) a service between the ports of Mykonos and Delos, and 2) a service between the ports of Naxos and the ports of Irakleia, Schinoussa and Koufonisia.

The technical solution that was developed in line with the concept designs was a modular concept based on combining a number of specially designed FEUs for accommodation, which would be loaded and unloaded depending on the required capacity using the feeder's Robotic Container-Handling System (Figure 5).

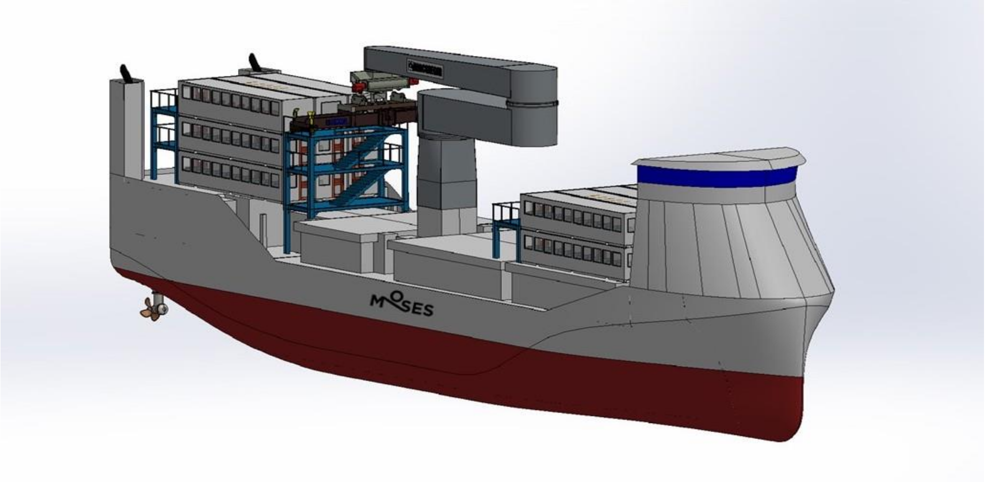

Figure 5: The technical solution for the mixed pax/freight concept (Greek II design).

For simulating the autonomous operation of the feeder, a time-domain simulation model was developed, which consisted of a physical model (ship, ports, and environment), a control system model (estimators, controllers, and allocation algorithm) and a mission execution model (state machine, operational states and state transitions). The simulations were conducted for a round-trip scenario with different wind and sea states between the ports of Piraeus and Mykonos, where the vessel autonomously executes port approach and departure, open sea navigation, and berthing manoeuvres (documented in D3.2 [6]).

The autonomous port-to-port operation of the IFV was demonstrated in Pilot Demonstration 2 (documented in D7.3 [5]) that took place in MARIN's Seakeeping and

Maneuvring Basin (SMB)[1] (Figure 6). The demonstration represented the route from the port of Piraeus to the port of Mykonos of the Greek Business Case. The demonstration employed the models for track following, Dynamic Positioning (DP) while manoeuvring, and docking, which were specifically developed for conducting the time-domain simulations of the feeder's autonomous operation. For the demonstration, a 1:17 scale model of the Greek design II was constructed and used for demonstrating open sea navigation, manoeuvring and docking during port approach. The demonstration included simulation of environmental conditions (irregular waves and gusting wing), as well as models of the ports of departure and arrival. Furthermore, a state machine GUI was developed to simulate a basic shore control station for the autonomous ship model, which included visualization of vessel data and sending high-level user commands to the model, and to control the operational states during the demonstration.

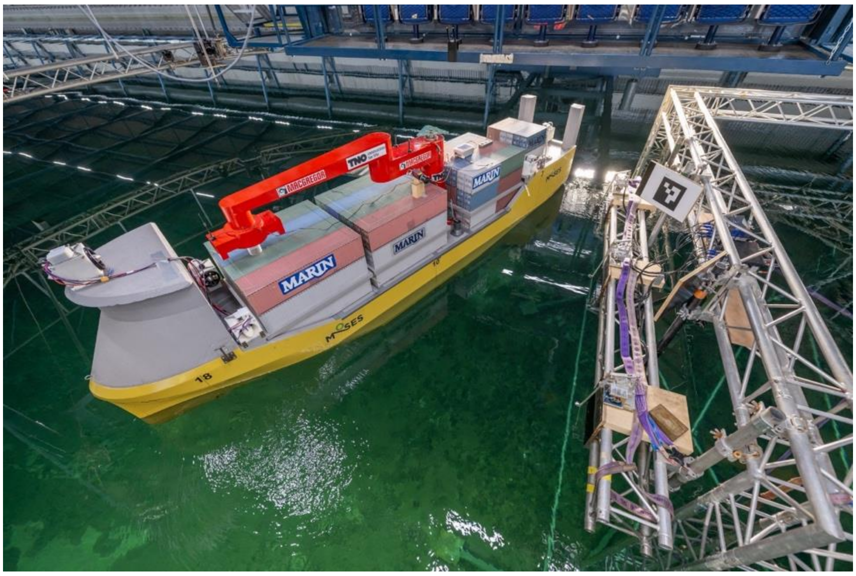

Figure 6: Scale model of the Greek design II during Pilot Demonstration 2.

2.3 Robotic Container-Handling System

The Robotic Container-Handling System consists of a crane equipped with a sensor suite, a 3D World Interpreter (3DWI), and a Crane Control Unit (CCU) that enable autonomous operation and the Intelligent Operator Support System (IOSS) that enables remote monitoring of multiple operations (Figure 7). The components of the MOSES RCHS are described in deliverables D3.3 [7], D3.4 [8], and D3.5 [9] respectively.

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[1] https://moses-h2020.eu/moses-pilot-2-demonstration-autonomous-sailing-of-an-innovative-container-feeder-vessel-making-a-roundtrip-between-two-ports-14-09-2023/

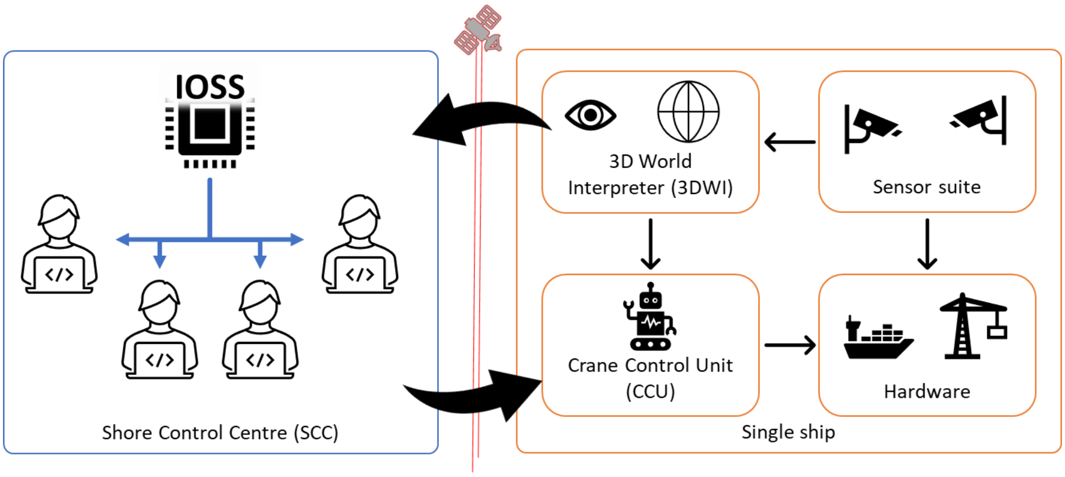

Figure 7: The components of the MOSES Robotic Container-Handling System.

The 3DWI, which is housed on the crane, creates a virtual 3D world model to build and maintain situation awareness by implementing object recognition and 3D reconstruction algorithms, specifically developed in the project, as well as obstacle avoidance algorithms based on computer vision. The 3DWI takes information about the operational environment from the sensor suite, which consists of cameras and LiDARs, to detect static obstacles and containers, to assist the autonomous crane operation, and to detect human activity and other objects that may risk the autonomous crane operation. The 3DWI includes the following three modes of operation: 1) vessel arrival, 2) picking up a container, and 3) dropping off a container.

The IOSS aims to assist a remote operator who monitors various loading operations in parallel. The following three main support functionalities were defined and developed (Figure 8): 1) dynamic allocation of operations to suitable and available operators, 2) continuous and explainable risk assessment to increase situational awareness recovery and shorten the time to action to mitigate risks, and 3) progressive disclosure of the interface to prevent micro-management on a single operation while still providing the possibility for a remote operator to immerse themselves in the operation. Data from the 3DWI are visualised in the IOSS through a 3D Virtual Reality (3DVR) system that can operate with limited bandwidth. This data includes the 3D rendering of the crane with updates from the CCU, a pre-captured 3D environment, live captured 2D/3D sensor data and detections, buttons for the operator to interact with the 3DWI, and the option to generate an immersive VR view.

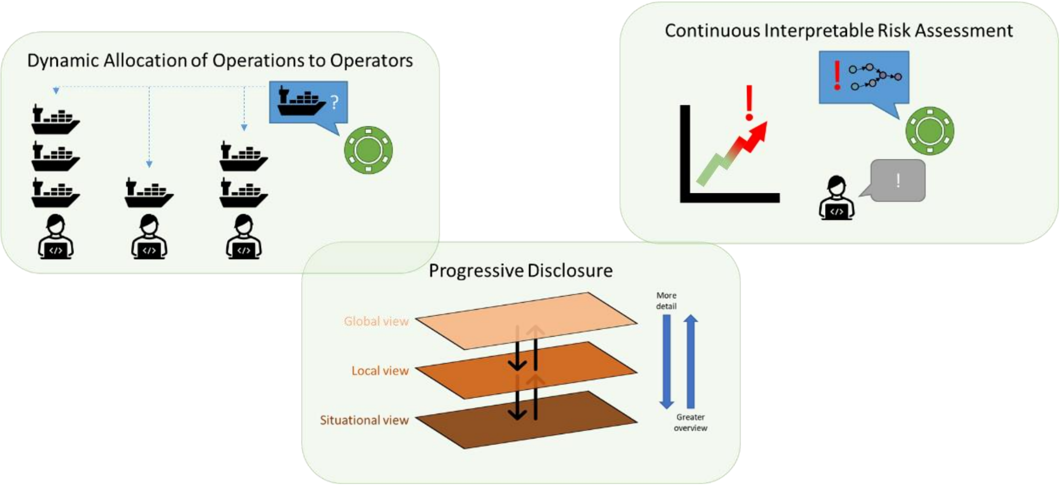

Figure 8: Main functions of the Intelligent Operator Support System (IOSS).

The MOSES RCHS was initially tested using a digital twin that was specifically developed in the project and based on MacGregor's C-HOW virtual environment. The virtual environment communicates with the CCU (hardware in the loop) and replaces sensor data with simulated values and includes a very realistic physics engine. The second level of validation was done in Pilot Demonstration 3[2] (documented in D7.4 [10]), for which a full-scale crane provided by MacGregor in Sweden (see Figure 9) autonomously identified and handled containers in pre-defined scenarios and the operation was monitored remotely from TNO's facilities in the Netherlands through the IOSS. The scenarios included handling a single container, handling two containers, detecting misaligned containers, verifying container properties, scanning operational environment, scanning containers, object detection, threat detection, and emergency stop.

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[2] https://moses-h2020.eu/moses-pilot-3-demonstration-robotic-container-handling-system-28-09-2023/

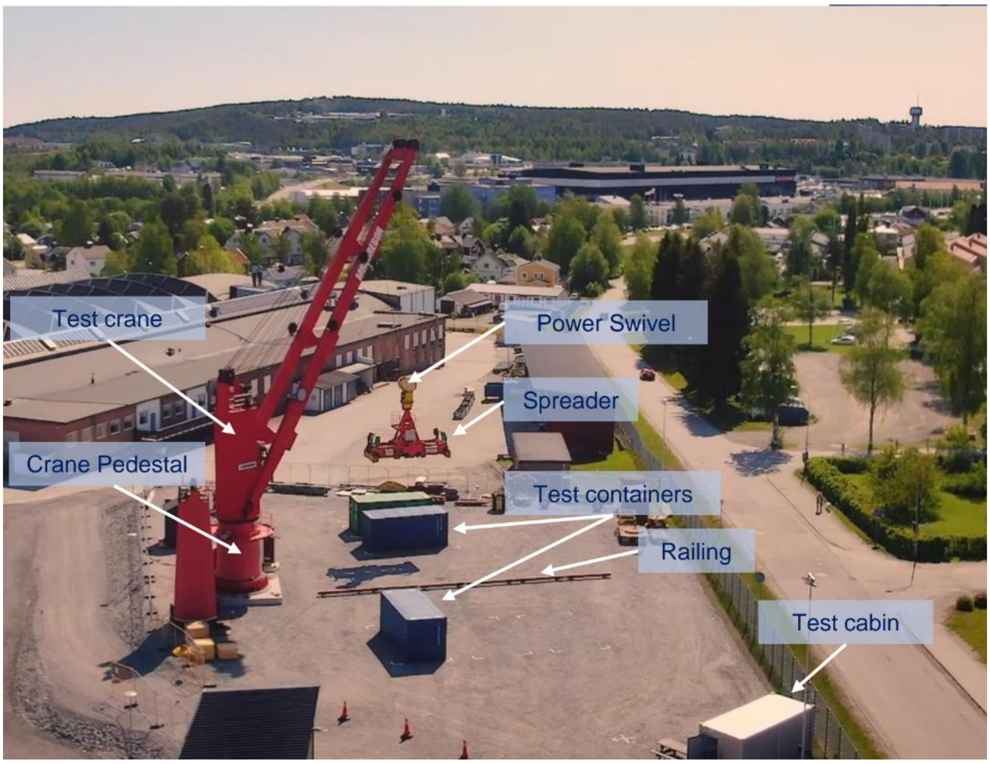


Figure 9: Test site for Pilot Demonstration 3 at MacGregor's premises in Sweden.

2.4 AutoDock System

The development of the MOSES Autonomous Tugboat swarm included the following outcomes: 1) the architecture for enabling autonomous tugboat operation (documented in D4.1 [11]), 2) the virtual training environment that was used for developing the algorithm that drives the swarm (documented in D4.2 [12]), 3) training the swarm algorithm and simulating the manoeuvring and docking of large containerships (documented in D4.3 [13]), 4) a preliminary study on the swarm's fail-safe functionality (documented in D4.3), and 5) the Shore Tugboat Control Station (see D4.4 [14]).

The architecture of the autonomous tugboats was designed to be modular and consisted of the following modules (Figure 10):

1. Detection: Responsible for sensor data-processing, providing the necessary input to the AI algorithms.
2. Path planning: Responsible for autonomous navigation and manoeuvring, including all the motion control operations.
3. Control: Responsible for translating the high-level decisions from the AI navigation algorithms into actionable steering and propulsion commands.

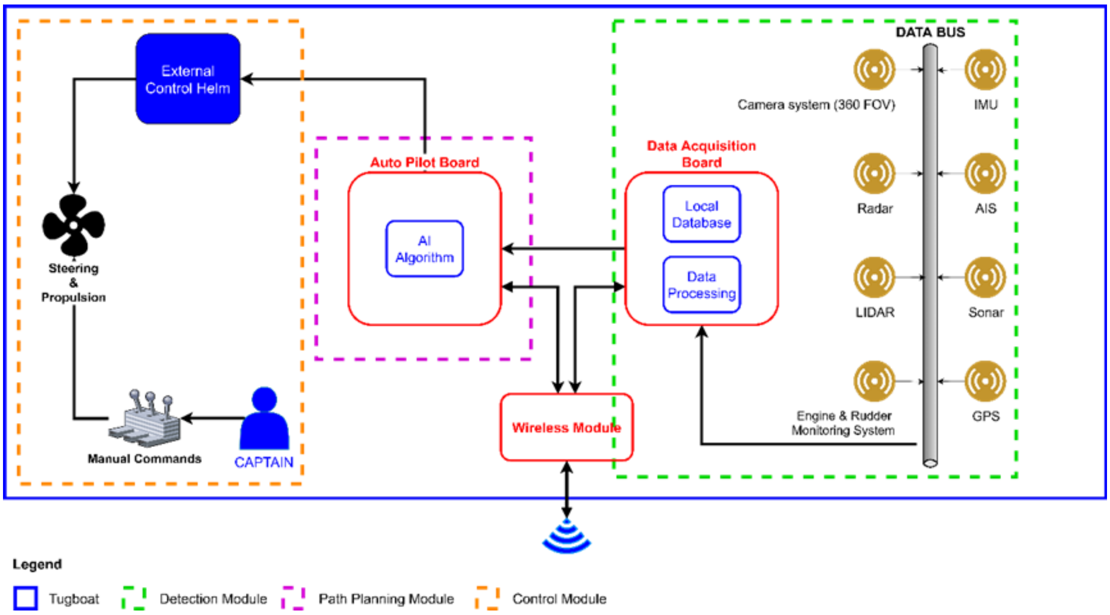
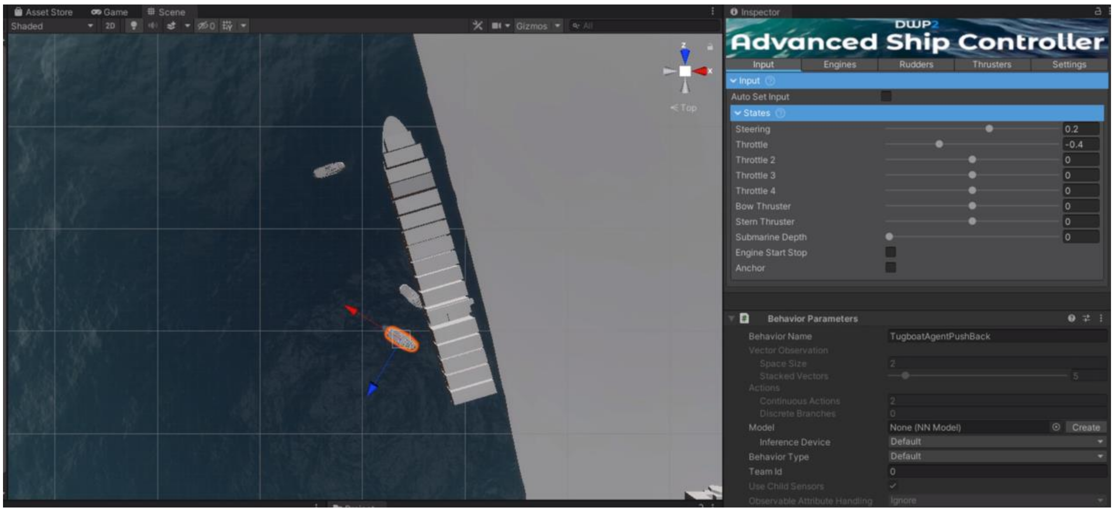


Figure 10: Main components in the architecture of the autonomous tugboats.

The virtual training environment was developed in the Unity Game engine and included a virtual twin of the port, water physics, a basic control system that consisted of virtual rudders and thrusters, engine with simulated power and torque, virtual sensors (LiDAR, GPS, accelerometer), and a telemetry logging system. The operational scenarios that were considered involved a group of tugboats assisting a large containership during the manoeuvring and docking phase of the ship's approach to the port of Piraeus (Figure 11). Specifically, the following two training scenarios were considered: 1) one pulling tugboat, which was tethered to the stern of the containership, and one pushing tugboat, and 2) two pulling tugboats, one tethered to the stern and one to the bow of the containership, and one pushing tugboat.



Auto Set Input ☐

Steering 0.2
Throttle -0.4
Throttle 2 0
Throttle 3 0
Throttle 4 0
Bow Thruster 0
Stern Thruster 0
Submarine Depth 0
Engine Start Stop ☐
Anchor ☐

Behavior Name TugboatAgentPushBack
Vector Observation
Space Size 2
Stacked Vectors 5
Actions
Continuous Actions 2
Discrete Branches 0
Model None (NN Model)
Inference Device Default
Behavior Type Default
Team Id 0
Use Child Sensors ✓
Observable Attribute Handling Ignore

Figure 11: An indicative scene from the Unity environment during a training simulation.

The Unity Machine Learning Agents Toolkit (ML-Agents) was used for implementing reinforcement learning to train the swarm with the Proximal Policy Optimization (PPO) algorithm, which is effective in continuous action spaces and stable during training. The training was based on the development of a reward system. Rewards were given when the large containership reached its target point, as well as related to an assigned tugboat pushing or pulling the containership and to swarm performance. Penalties were assigned in the following cases: a) leaving the operational area, b) collisions with any object, c) unsafe interactions with the manoeuvred vessel.

The study on the fail-safe functionality of the autonomous tugboat swarm aimed at identifying how an adequate level of safety can be maintained given a failure has occurred (i.e. Minimum Risk Condition, MRC, states) and the requirements for the algorithmic implementation of such a functionality. The analysis included identifying hazardous scenarios through the Systems Theoretic Process Analysis (STPA), the MRC states (see Table 3), and the decision paths between the two. The implementation of this functionality would depend on a Health monitoring module within the Detection module that evaluates the system safety level and a fail-safe software within the path planning module that generates the actions that need to be taken by the system (Figure 12).

Table 3: Minimum Risk Condition states identified for the fail-safe functionality of the autonomous tugboat swarm.

State ID	MRC State	MRC State Description
MRC-1	Hot swap	The remote operator at the STCS halts the swarm operation. The mission is completed autonomously after the “malfunctioning” tugboat is replaced.
MRC-2	Manual control onboard	The tugboat Captains disengage the AutoPilot on all tugboats and manually navigate them to complete the mission.
MRC-3	Remote-control	The mission is completed by the STCS operator remotely.
MRC-4	Sharing situation awareness	The swarm members make up for the lack of situation awareness by sharing information. The mission is completed autonomously.

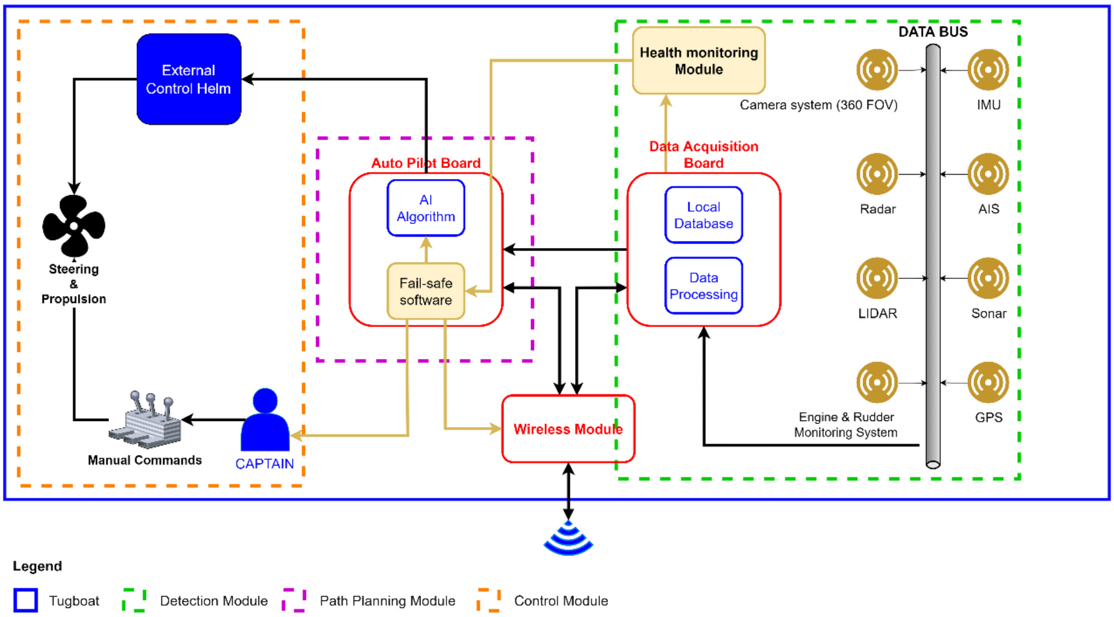
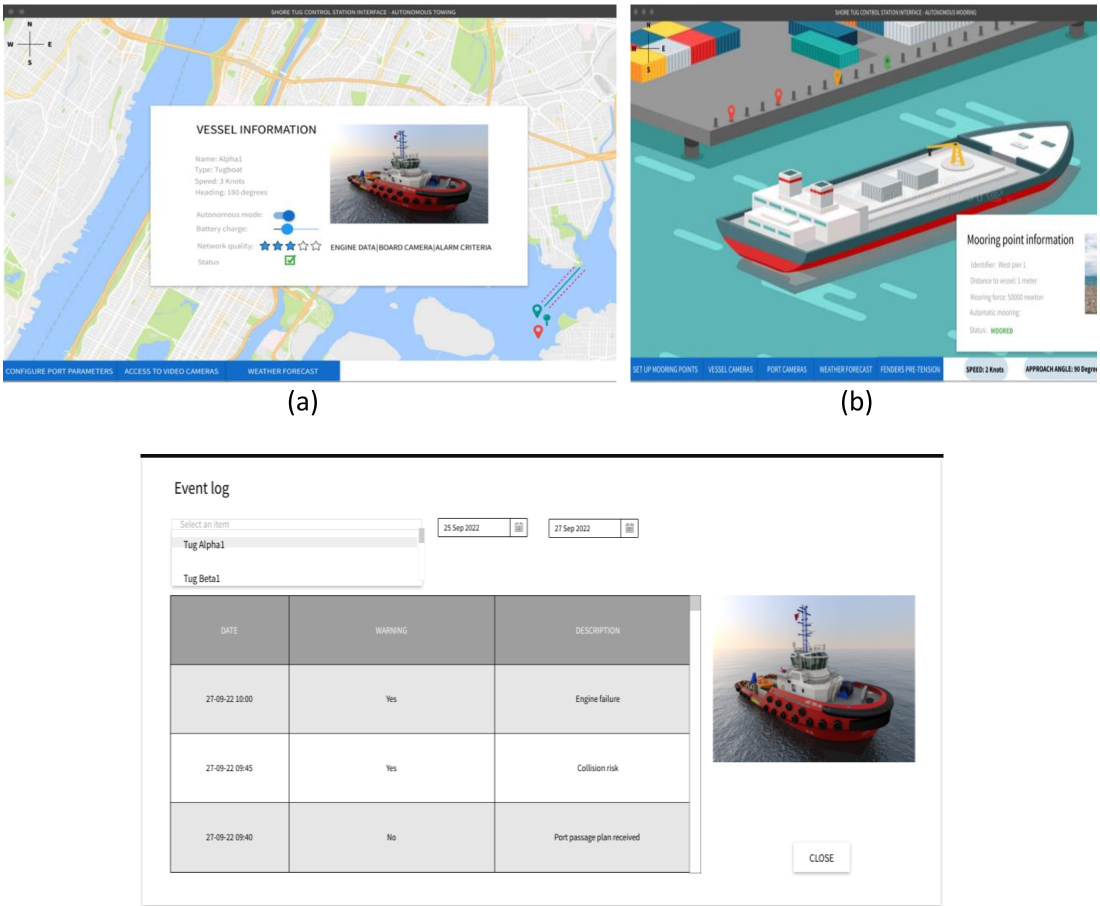


Figure 12: The required modules for implementing the fail-safe functionality.

The development for the STCS included determining the main functionalities and requirements, the information that needs to be relayed to the remote operator for maintaining situation awareness, and a mock-up of the interface. The main functionalities of the STCS involved monitoring the operational parameters (e.g. information from the sensors of each tugboat and weather conditions), secure and robust communication with the swarm members and the automated mooring system, and the ability to change the level of autonomy during the operation (e.g. from autonomous to manual when the network conditions are poor). The information identified as necessary for the remote operator are the positions and movements of the vessels involved in the operation, the effect of the weather conditions on the operation, and the communication network (speed connectivity, communication breaks, cybersecurity).

The interface included two physically separated workstations for engineering, which duplicate actual marine automation workstations, and which are currently widely implemented on-board vessels, and navigation. The navigation workstation consisted of 3 separate components for fulfilling the following functionalities (see Figure 13):

1. Supervising the autonomous towing phase.
2. Supervising the autonomous mooring phase.
3. Logging operational data and reporting.



VESSEL INFORMATION

Name: Alpha1
Type: Tugboat
Speed: 3 Knots
Heading: 180 degrees
Autonomous mode:
Battery charge:
Network quality: ★★★☆☆
Status ☑

(a)

Mooring point information

Identifier: West pier 1
Distance to vessel: 1 meter
Mooring force: 50000 newton
Automatic mooring:
Status: MOORED

SPEED: 2 Knots
APPROACH ANGLE: 90 Degre

(b)

Event log

Select an item
Tug Alpha1
Tug Beta1

25 Sep 2022
27 Sep 2022

DATE	WARNING	DESCRIPTION
27-09-22 10:00	Yes	Engine failure
27-09-22 09:45	Yes	Collision risk
27-09-22 09:40	No	Port passage plan received

(c)

Figure 13: The interface mock-ups for (a) towing, (b) mooring, and (c) data logging.

The MOSES AMS is a re-engineered version of Trelleborg's existing AutoMoor system, which consisted of a single mooring unit that can hold a vessel with a holding capacity of up to 5T, with an additional safety margin to accommodate for unexpected environmental or meteorological conditions (see D5.1 [15]). The control system consisted of both the existing operator-based control module and an autonomous module that can send and receive appropriate signals to interact with other autonomous control systems such as the MOSES Autonomous Tugboats and the MOSES Shore Tugboat Control Station. The design included the following innovations compared to the existing system by Trelleborg: adoption to a smaller scale, including a smaller connection system, the control system interfaces with the other MOSES innovations, dampening vessel surge motion using passive rubber damping system, harvesting some energy from vessel sway motions, and the control system software.

Figure 14: The Automated Mooring System prototype built for the MOSES project.

The AutoDock system was tested and validated in Pilot Demonstration 1 (documented in D7.2 [16]), which took place at the port of Faaborg, Denmark[3]. The demonstration involved two workboats (acting as the tugboats) collaborating in a swarm configuration to manoeuvre a floating barge (acting as the containership) and dock it using the small-scale prototype of the AMS that was specifically built for the purposes of the project (Figure 15). The barge was outfitted with a steel superstructure, which was specifically designed and built for the purposes of the project to provide an adequate contact surface for the vacuum pad of the AMS. Furthermore, a foundation was specifically designed and built for the AutoMoor prototype to ensure safe operation during the demonstration. Due to challenges related to integration of the control systems onboard the vessels, one of the workboats was controlled by the trained algorithm, while the other was manually navigated. However, considering that the trained algorithm was not “aware” that one of the workboats was manually navigated, the demonstration was successful in proving the concept of the autonomous tugboat swarm. Furthermore, the operation was remotely monitored by a STCS mock-up setup in Valencia.

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[3] https://moses-h2020.eu/moses-pilot-1-demonstration-autodock-16-20-10-2023/

Figure 15: Pilot 1 demonstration, the autonomous tugboats pushing a barge to the AMS.

2.5 Recharging Station

A feasibility study and a cost-benefit analysis for the MOSES Recharging Station was conducted with a focus on the innovative feeder (see D5.2 [17]). The study considered the operational profile of the feeder and was based on the following assumptions: 1) recharging should not disrupt the operation of the feeder or the port, 2) the required power needs to be available from the grid, 3) the batteries should not be drained below 20% of their maximum capacity, and 4) port real-estate needs to be available for the station. The scope of the study included the terminal infrastructure, the ship-to-shore interface, as well as onboard power generation.

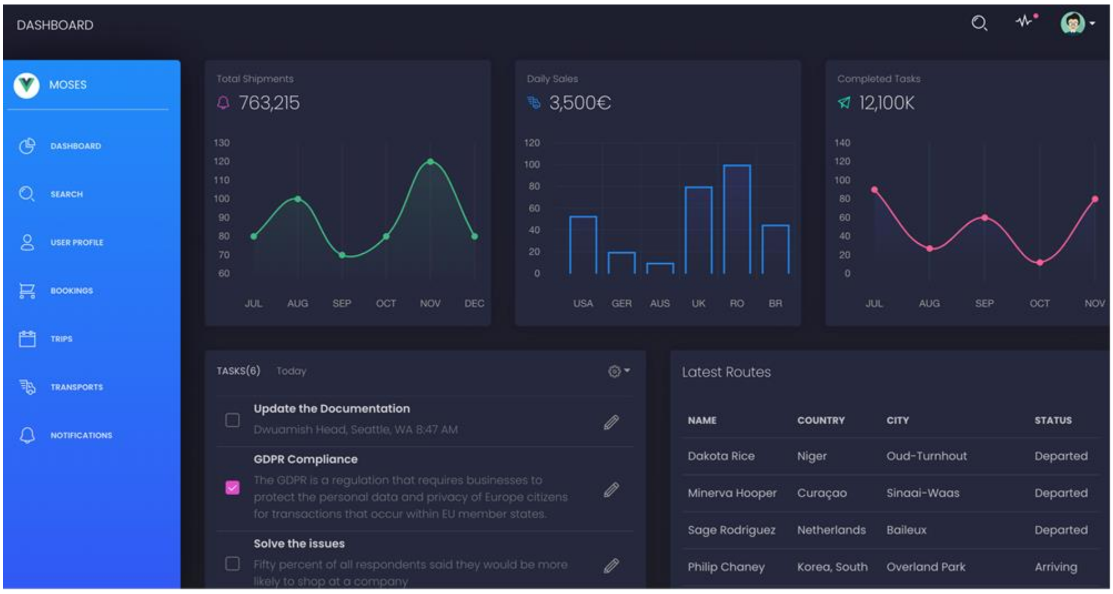
For the Greek case, the study concluded that the feeder should recharge only at the DSS port (Piraeus) with direct transfer. Although recharging at the small port (Mykonos) was considered technically feasible with the installation of a batteries buffer to avoid the risk of port black-out, the option did not seem promising given the current state of the grid and the existing recharging technology. For the Spanish case, the study concluded that recharging the batteries onboard the feeder can be provided by direct transfer from the port grid in both the DSS port (Valencia) and the small ports (Sagunto and Gandía).

2.6 Matchmaking Logistics Platform

The MOSES platform is a digital collaboration and matchmaking platform that aims to maximize and sustain SSS services in the container supply chain by matching demand and supply of cargo volumes by logistics stakeholders using data driven-based analytics (see D6.1 [18]). It can dynamically and effectively handle freight flows, increase the cost-effectiveness of partial cargo loads and boost last-mile/just-in-time connections among the transport modes and backhaul traffic. In this way, its users can experience the benefits of a collaboration and optimization tool that prioritizes SSS and is able to deliver impactful results for all stakeholders involved. The MOSES platform advances current state-of-the-art by supporting cargo consolidation (at container level) and fully exploiting the bundling potential among different shippers to enable multimodal transport routes containing at least an SSS leg. This is done in existing but underutilized SSS routes, currently not preferred by shippers due to increased costs or low service frequency and reliability.

The MOSES platform focuses on collecting available information and datasets related to logistics supply and demand from relevant stakeholders, such as shippers, carriers, freight forwarders, shipping lines etc. Through the combination of these datasets, valuable information can be extracted, supporting the optimization of the logistics process. The main benefit of this analysis is the provision of multimodal transportation options, combining different transportation means and modes that can reduce the delivery time and the overall cost. In parallel, the combination of multimodal transport services with freight cargo bundling can increase the efficiency of transport operators and improve the management of empty containers.

The platform’s interface supports custom sorting and filtering of available options, according to each user’s criteria, such as cost or time (documented in D6.2 [19], see Figure 16). The results have several attributes such as the associated environmental footprint, the number of transhipments, the estimated times of arrival and departure (EtA, EtD), and the turnover time (ToT). Furthermore, the MOSES Platform calculates the estimated times of arrival/boarding/departure taking into account the transhipment windows or buffer times required for each transport mode or stakeholder group, providing more accurate estimations and thus more reliable transport options. The platform is also designed to interact and exchange information with federated logistics platforms and public authorities.



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Minerva Hooper	Curaçao	Sinaai-Waas	Departed
Sage Rodriguez	Netherlands	Baileux	Departed
Philip Chaney	Korea, South	Overland Park	Arriving

Figure 16: Indicative representation of the MOSES Matchmaking Platform Dashboard.

2.7 Policy Recommendations

The main objective for the MOSES policy recommendations is to strengthen the positioning of SSS in the EU, while being compliant with existing adopted policies and using as a basis the MOSES innovations. The developed guidelines aim to support the industry in picking up new technologies for complying with new and stricter environmental legislation and ease the integration of SSS in the entire logistic chain. Furthermore, the development of the policy recommendations aimed to address how to promote SSS, how to create incentives, how to promote collaboration, and how to increase competitiveness. The following categories have been identified as potential areas of improvement for policy development: Collaboration, Infrastructure, Regulations and Finance. Figure 17 lists the MOSES Policy Recommendations for SSS for each of the identified areas of interest (see D8.8 [20]).

Collaboration

- Proposal 1: Support business incubators and entrepreneurship hubs (*Paradigm: ICT and Aerospace industry)*
- Support the development of new companies (e.g. start-ups) that serve as collaborative links and would establish new business models hereby facilitating commercialisation of innovative ideas.

Infrastructure

- Proposal 2: Support demonstrator development with major stakeholders and locality features (*Paradigm: Northern Lights project)*
- Proposal 3: Map optimal technology uptake for TEN-T corridor improvement (*Paradigm: SuperGreen project)*
- Recognize important EU nodes according to Green corridors / TENT network and develop strategic planning of demonstrators aligned with EU fuel policy and locality elements (that influence technology uptake).

Regulations

- Proposal 4: Balance enablers/mandates at regulatory level (*Paradigm: Nordic countries; NOx fund)*
- Improve existing regulatory schemas

Finance

- Proposal 5: Promote collaboration through EU-funded Joint Undertaking projects (Paradigm: EU Chips Act)
- Proposal 6: Subsidies and grants at the national level with well-defined targets and simpler application processes (*Paradigm: Takman and Gonzalez, 2023)*
- Spotted funding to grow technologies and infrastructure and industry paradigms.

Figure 17: MOSES policy recommendations with a baseline paradigm / reference.

3. Achievements per development phase

This section describes how the main outcomes of MOSES were achieved in its four project phases (Figure 18). The research questions for the first phase of the development (WP2) included: 1) Who are the MOSES stakeholders and what do they consider important, 2) How will the MOSES innovations be used, which actors are involved, and how they should perform within their operational context, and 3) What are the conditions for the MOSES feeder service to be competitive. The first phase provided the basis for the technical development of the innovations. During the second phase, the general research question was how the MOSES innovations should be designed to accomplish their goal (WP3 – WP6). For the third phase, which involved integration activities and the Pilot Demonstrations (WP7) the research question was how the innovations perform and what their impact is. For the fourth phase, which included the innovation and exploitation activities (WP8), the research question was related to the next steps for the development of the MOSES innovations. The following sections describe the main achievements development phase in the project.

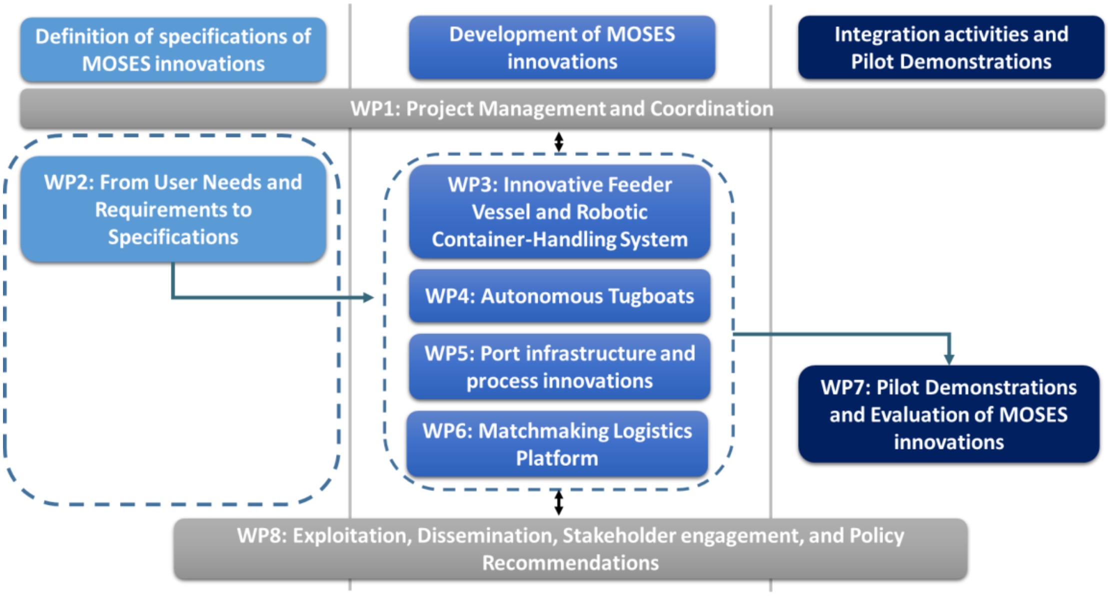

Figure 18: MOSES Methodology.

3.1 From User Needs and Requirements to Specifications (Phase 1)

The first phase of development included the following objectives: To identify the stakeholder and user needs for the MOSES innovations; To describe the most beneficial use cases for the MOSES innovations in the context of the container supply chain; To identify market opportunities for the MOSES innovations and develop specific, viable business cases; To describe the system specifications and requirements for the MOSES innovations in a formal manner; To provide input for the technical WPs of the project.

The system requirements and high-level specifications for the MOSES Innovations, which formed the basis for the development in WP3, WP4, WP5 and WP6 were formally described to enable tracking of the progress of each innovation and addressed architectural, functional, and operational characteristics. These requirements were based on end-user needs (D2.1 [21]), use cases and scenarios (D2.2 [22]), the business cases (D2.3 [2]), and the Concept of Operations (ConOps) for each innovation (D2.4 [23]).

The user needs were identified by engaging relevant stakeholders in two workshops, one at Piraeus (56 participants from 26 organisations) and one at Valencia (37 participants from 17 organisations), followed by an online survey, which was disseminated to 400 stakeholders worldwide (incl. policy makers, regional administrative bodies, port authorities, terminal operators, shipping companies, shipping agents, freight forwarders, transport companies etc.) and was used to rank the importance and validate the identified requirements. The use cases and scenarios, which describe the interaction of the end users with the MOSES Innovations, were derived from an approach that involved defining 13 key types of end-users ("personas") and 12 representative operational scenarios. UML diagrams were constructed to describe the use cases and operational scenarios.

Based on an analysis that aimed to identify market opportunities for the MOSES Innovations, two business cases were developed, one for Western MED (Spain) and one for Eastern MED (Greece). The analysis included a preliminary evaluation of the benefits of implementing the MOSES innovations for these cases, an assessment of the required costs and the technical and operational limitations, and the development of business models, in the form of business canvasses, for each of the MOSES innovations in order to examine the relationships between economic, environmental, and societal aspects.

A ConOps was developed for the following innovations: the Innovative Feeder Vessel, the Autonomous Tugboats, the Automated Mooring System, and the Matchmaking Logistics Platform. The ConOps included identifying similar existing systems, defining the desired changes, describing the proposed new system, defining operational scenarios, and identifying the relevant regulatory context. Within the context of the ConOps, the user requirements were translated into formal system specifications after being refined based on the use cases, scenarios, and market opportunities. The specifications addressed architectural, functional, and operational characteristics and were defined using the MoSCoW approach. Measurable KPIs and the corresponding verification tests were also described.

3.2 Development of MOSES Innovations (Phase 2)

The second phase included the core technical development of the MOSES innovations, which included translating the requirements and system specifications from the first phase into design requirements, as well as conducting testing through simulation.

3.2.1 Innovative Feeder Vessel and Robotic Container-Handling System

The development of the innovative feeder included the following objectives. For the feeder, to conceptually design one RoCoPax and two SSS small feeder vessels, to provide the configurations for sustainable propulsion for both the RoCoPax and the SSS Feeder designs at a conceptual level, and to simulate the autonomous operation of the feeder. For the Robotic Container-Handling System, to define the operational requirements and create the control architecture, to develop a real-time 3D operational picture of the environment (world model), and to create the Intelligent Operator Support System.

Based on the technical system requirements and the market-based requirements derived in WP2, three different conceptual designs for the innovative feeder were developed. The design process followed an iterative approach for determining the hull form and general arrangement, where voyage simulations and potential flow calculations were used to verify the characteristics of the designs focusing on energy needs. A multi-criteria assessment approach and power plant simulations were used to determine the most feasible options for the powering arrangement. The design process also included preliminary analyses for a structural design of the foundation of the Robotic-Container Handling System, for the operational costs, and for identifying hazardous scenarios. The concept designs were complemented by a feasibility study for mixed pax/freight services, where two case studies were examined within the context of the Greek Business Case. The study was based on data provided by the ports and the Hellenic Statistical Authority to determine the number of passengers transported between these ports and subsequently the passenger capacity required for the MOSES feeder. The feasibility of the technical solutions was evaluated based on whether the additional passenger transport service would disrupt the schedule of the feeder's main mission, considering parameters such as the time needed to load and assemble the modular components onboard, as well as the time required for embarking and disembarking passengers. An additional criterion was related to whether the Robotic Container-Handling System could lift the estimated weight of the FEUs.

The time-domain simulation model for simulating the autonomous operation of the feeder was implemented using MARIN's XMF simulation framework and included the vessel and all the necessary sensors and actuators to study autonomous operation performance. The models developed for the simulation were implemented for demonstrating the autonomous operation of the innovative feeder in Pilot Demonstration 2.

For the Robotic Container-Handling System, the sensor suite, the 3DWI, and the crane handling and control architecture were developed. The development of the sensor suite considered the following parameters: the Field of View (FOV) and data density requirements for the world-modelling algorithms and the detection of dynamic objects, as well as the amount of information required for the operator to resolve various scenarios. Development for the 3DWI included the multi-sensor data capture, storage, and playback, as well as the data fusion modules, an initial 3D calibration of all sensors, and development of testing of different algorithms, including an object detector and a method to construct static and dynamic obstacle maps. The jib-top camera, which detects pedestrians, cyclists, cars, and trucks and is part of the Robotic Container-Handling System sensor suite was included in the 3DWI. Data processing from the sensor suite was developed for 3D world scanning and container/obstacle detection. The detectors for red-alerts and generic objects were designed to provide more information to the 3DWI about true red-alerts. The development of the architecture included determining the requirements, the different modules of the crane control system, as well as the creation of a digital twin environment and initial hardware in the loop tests. To test the crane architecture, a digital twin was developed in MacGregor's C-How environment that included advanced crane functionalities in a simulated environment.

The development of the remote crane control centre included a story board in narrative form and the subsequent identification of user stories, which described the envisioned functionalities. The Intelligent Operator Support System (IOSS), which included a Graphical User Interface (GUI) and a dynamic allocation of loading operations, was designed iteratively, and employed domain experts for review. For the GUI, the requirements for data exchange between the crane and the IOSS were determined and the technical exploration for the dynamic allocation feature was initiated. The functionalities of the IOSS were designed and implemented to an initial proof of concept. For the dynamic allocation of operations and the continuous risk assessment functionalities, the implementation included the algorithmic design and evaluation. For the progressive disclosure functionality, the GUI was designed, and usability experiments were conducted.

3.2.2 Autonomous Tugboats

The development of the autonomous tugboat swarm included the following objectives: to establish the architecture and the necessary technological requirements that enables autonomous operation; to develop a virtual environment for training the swarm; to simulate various autonomous navigation scenarios based on the use-cases defined in WP2; to develop swarm intelligence algorithms for autonomous tugboat-assisted docking of large ships; to develop the Shore Tugboat Control Station.

A preliminary, reference architecture for enabling autonomous tugboat operation was designed, including the key hardware, sensor, and software components, as well as their specifications. Preliminary tests for selected components in the architecture were also conducted.

For training the machine learning-based algorithms, a virtual training environment was developed in the Unity game engine. The control system was calibrated using data derived from numerical simulations of the vessels' motion and their interaction with the environment derived from physics-based models. The virtual training environment was tested through a series of scenarios grouped in the following two categories: 1) free sailing scenarios, to validate the behaviour of the individual vessels, and 2) interaction scenarios, to validate the interaction between the tugboats and the containership.

The Unity Machine Learning Agents Toolkit (ML-Agents) was used for implementing the swarm algorithms. Several different learning approaches were examined, including imitation learning, cooperative environments, environment randomization, and curriculum learning. Research was also conducted on sophisticated techniques that contribute to speeding up the agent training process, which included fine tuning the following parameters: the reward function, environmental parameters of the ML-Agents toolkit, parameters of the virtual environment in Unity, and selecting the appropriate machine learning model. A set of baseline scenarios were developed, where the agents take over the mother vessel when it is aligned and at a fixed distance to the dock and guide it in a parallel position to the berth while continuously ensuring that the yaw angle of the vessel is within specified limits. The autonomous behaviour of the swarm within the simulated environment was fine-tuned by adjusting the reward parameters and the ML model hyperparameters.

The work on the autonomous tugboats also included the development of a fail-safe functionality. This consisted of a study that resulted in determining requirements for the algorithmic implementation of such a functionality and involved the following steps: identifying potential failure scenarios through Systems Theoretic Process Analysis (STPA), determining the Minimum Risk Condition (MRC) states and the "last resort" states, based on the specifications (documented in D2.4 [23]) and the architecture (documented in D4.1 [11]), describing the decisions paths for transitioning to the fail-safe states depending on the failure type and criticality. Furthermore, a preliminary study for the tugboat swarm's battery optimization component was conducted based on state-of-the-art research for an algorithmic approach on battery-powered vehicles. Although the autonomous tugboats were envisioned in the MOSES concept as hybrid or fully electric, implementing the battery optimization functionality was considered out of the scope of the project.

With respect to the concept design of the Shore Tugboat Control Station (STCS), the requirements were determined based on an analysis of the information exchanged during the port call and berthing manoeuvring processes between the Port Community System (PCS), the STCS, the autonomous tugboat swarm, and the AMS. The concept design was also based on requirements provided by Classification Societies (e.g. DNV) and culminated in creating a mock-up of the STCS interface. The mock-up was demonstrated in Pilot Demonstration 1.

3.2.3 Port infrastructure and process innovations

The development of the innovations related to port infrastructure included the following objectives: to adapt Trelleborg's AutoMoor to work with the MOSES autonomous tugboats by including a component for intelligent collaboration; to investigate and define the technical details of the recharging station; to estimate the capital cost and lifecycle cost for the recharging station; to propose changes to port operations for facilitating the implementation of the MOSES innovations.

Based on the ConOps and requirements, the main characteristics of the re-engineered AutoMoor system by Trelleborg were determined, as well as the implication of introducing the MOSES AutoDock system in large ports. In addition, the communication interface requirements between the MOSES STCS, the AMS, and the AT were defined in order for the AutoMoor prototype to be automatically triggered by the autonomous tugboat swarm. Based on these requirements, the concept design of the new AutoMoor prototype was developed.

For the conceptual design of the MOSES Recharging Station, the specifications were determined based on the power required for the MOSES Innovative Feeder Vessel and the MOSES Autonomous tugboats considering parameters related to safety, vessel motion, tidal fluctuations, and operational constraints. A cost-benefit analysis was carried out to evaluate the viability of the investment. This required determining the size of the installation based on the required power for the two MOSES business cases and considering scenarios where the MOSES Innovative Feeder Vessel recharges only at the DSS ports (Piraeus, Valencia) and where there is intermediate recharging at the small ports (Sagunto, Gandia, Mykonos). The analysis also included identifying the location of the system within the ports under investigation considering the concentration of berths of similar vessels, possible interference with port operations, prevailing environmental conditions, and availability of electrical power at the quay.

With respect to evaluating the impact from the implementation of the MOSES innovations on normal port operations, the current port call processes for the Consortium ports of Piraeus and Valencia were studied in depth, including the roles of the involved agents, through Business Process Modelling Notation (BPMN).

3.2.4 Matchmaking Logistics Platform

The development of the matchmaking platform included the following objectives: to make a comprehensive review on best practices, challenges and lessons learned from similar platforms and tools; to classify through a two-staged participatory approach all relevant stakeholders of the platform; to analyse the rights of each stakeholder, the workflows and their communication channels and map them to a list of system requirements; to develop the functionalities of the platform to improve the cargo load factor and to exploit empty containers information sharing.

The business logic for the matchmaking platform was determined based on the identification of logistics roles and analysis of use cases and scenarios that need to be addressed by the platform. This led to the extraction of a list of functionalities that the platform should provide, which were validated by engaging core stakeholders through unstructured interviews. Based on these requirements, the platform's architecture was developed, which included identifying the main user groups, describing the different modules (front-end, back-end, database) and the data exchange communication scheme.

A graph model of the transport network was implemented using previously evaluated software libraries for complex network/graph analysis, where the nodes (locations such as seaports, inland ports etc.) and edges (direct connection between two locations via ship, train, or truck) were modelled. Furthermore, a general customised search algorithm was designed and implemented, which receives user defined origin and destination locations, required dates of departure and arrival plus product quantity and type, as well as user-defined criteria for optimality (incl. latest date of delivery, turnover time, number of transhipments or vessel changes, cost, and CO_2 emissions). The algorithm was tested in various scenarios, including for the subnetwork of Italy and the Balkan peninsula, in order to improve its time efficiency. A database schema for defining how data is organised within the relational database was designed and implemented and the GUI was developed and integrated with the modules of the matchmaking platform. This work led to the finalisation and release of the alpha version of the MOSES platform.

To evaluate the platform, an Open Call was published to attract interested parties to provide a dataset for container transport information in Northern Europe. The requested dataset included information such as volumes of cargo flows of different stakeholders, current and potential ones, cost of transportation, and estimated emissions. The Open Call process included the description of the Request for Proposals (RfP), the supporting documents to be provided by each candidate, the evaluation process and the evaluation committee that would select the logistics actor. Specific eligibility and selection criteria were also defined for the evaluation of interested parties (e.g. compatibility of dataset with the requirements, geographical area covered, proximity to SSS routes etc.). Even though the Open Call was running for two months, no application form was submitted, leading to the completion of the process without success. Other alternatives were explored to validate the MOSES Matchmaking Platform, which included exploiting existing repositories, collaborating with additional industry partners, leveraging publicly available information, and contacting the Greek Institute of Logistics Management (ILME), as described in D6.4 [24]. This process resulted in a consortium partner providing a comprehensive 12-month dataset that was ultimately used for identifying specific volume patterns with the potential for transitioning from road transport to either rail or Short Sea Shipping (SSS) routes. With this dataset, the MOSES Matchmaking Platform could be partially validated.

For the platform's sustainability model, preliminary information was gathered to derive the possible business models. Potential market opportunities and business cases were identified, considering the MOSES business cases. The sustainability of the platform was evaluated through the triple-layer business model canvas approach that helps to determine the economic, environmental, and social impacts of the platform (documented in D6.3 [25]). This process was supported with information collected from a survey related to exploitation that was conducted within the consortium. Other elements in the sustainability model of the platform included a real-time data access business model and a membership scheme for stakeholders. Members of ALICE and Motorways of the Sea platform (e.g. freight forwarders), which could become active actors for possibly supporting the operation of the platform beyond the end of the project, were engaged to discuss the matchmaking platform's overall logic. Since external datasets from the Open Call could not be provided, the final testing of the platform exploited data from the project's business cases and consortium partners' logistics networks.

3.3 Pilot Demonstrations and Evaluation of MOSES innovations (Phase 3)

The third phase of development included the following objectives: to plan the MOSES pilot demonstrations; to create a unified framework for recording and evaluating the results of the MOSES pilot demonstrations; to demonstrate the combined operation of the MOSES autonomous tugboats and the MOSES AutoDock (Pilot Demonstration 1); to conduct model basin demonstration of one conceptual feeder vessel design

(Pilot Demonstration 2); to demonstrate the automated container handling capabilities of the MOSES robotic container handling system and the shared control between the human (remote) driver and the robotic crane system (Pilot Demonstration 3); to assess and evaluate the cost-benefit and environmental performance of the MOSES innovations;.

The MOSES Pilot Demonstrations were planned through a common framework (see D7.1 [26]) that involved: 1) scheduling of preparatory, integration, and demonstration activities, 2) determining specific testing scenarios and Key Performance Indicators (KPIs), 3) risk management, 4) evaluation of the results and their relevance to the project's objectives, and 5) communication and exploitation. The activities commenced with revising the preliminary list of testing scenarios and associated KPIs documented in D2.4 [23], as well as making clear connections between the project's objectives and associated Success Indicators (SIs) to each Pilot Demonstration.

For Pilot Demonstration 1, after defining the exact testing site at the port of Faaborg, Denmark, the demonstrator workboats were outfitted for the purposes of the demonstration and sea trials were conducted, while the AutoMoor prototype components were shipped to Denmark and installed on site. The required equipment for demonstrating the autonomous operation was defined based on the architecture and included sensors (swath sonar, IMUs, GPS, LiDAR), network equipment (wireless routers), and the AutoPilot computing units that hosted the ML algorithm that was trained for the specific testing scenarios. Following a series of integration tests in laboratory conditions and on site, the Pilot Demonstration was conducted by implementing the defined testing scenarios.

For Pilot Demonstration 2, the requirements were obtained from the time-domain simulations documented in D3.2 [6]. A preliminary test plan was prepared including descriptions of the models, instrumentation, environmental conditions, test programme, data analysis and reporting. Preparatory activities included creating the production drawings for the ship model, engineering and/or selecting the instrumentation, the wireless measurement system, which enabled communication to the basin carriage, the on-board battery, the on-board wind fans, and the quay fender models. Preliminary tests included basin tests in MARIN's Shallow Water Basin (SWB) to evaluate the correct functioning of all individual technical components, the various operational states of the autonomous operation and the transitions between them, as well as tests to determine the properties of the ship and optimize its control (e.g. standard manoeuvring experiments). The Pilot Demonstration was conducted during a visitor's day organized with speakers and information booths, where MOSES partners and external visitors were invited.

For Pilot Demonstration 3, the sensors (jib-top camera, swing sensor, LiDARs, cameras) and Crane Control Unit (CCUs) were installed on the crane, software was tested on the CCU, and communications tests were conducted. The container spreader was delivered and commissioned on site, and the software to identify container corners and conduct machine-to-machine communication was installed on the CCU and tested. Furthermore, the digital twin developed in the C-HOW environment was supplemented with a model of the test area, the CCU and Active Rotation Control (ARC) system in the loop. The Pilot Demonstration was conducted by executing the test cases described in D7.1 [26].

With respect to the MOSES Sustainability Framework, the main objective was to measure the value generated by the project's innovations against "business as usual" with respect to the dimensions of sustainability (see D7.5 [27]). The MOSES innovations were associated to defined stages in the "lifecycle" of a SSS feeder service, to project objectives and associated SIs, and the sustainability dimensions (environmental, societal, economic). The SIs were evaluated against their target values based on data and information collected from the development work in the technical WPs (WP3 – WP6), the results of the Pilot Demonstrations, as well as from the relevant international literature where appropriate.

3.4 Exploitation, Stakeholder engagement and Policy Recommendations (Phase 4)

The fourth phase of development included the following objectives: to define the project's exploitable results and produce sustainable business models for their exploitation; to ensure successful implementation and viability of the project's innovative ideas; to produce policy recommendations while pointing out specific domains for policy intervention necessary for the reinforcement of SSS.

The exploitation activities were initiated with the outline of an Exploitable Results Taxonomy and Analysis, followed by a survey on MOSES key exploitable results and their relation to the MOSES innovations. A two-fold approach to exploitation was developed, which included outlining the framework for the MOSES exploitation plans and designing the preparatory activities (e.g., the formulation of an International Exploitation Advisory Board (EAB) and the conduct of an International Workshop that will support the provision of generic recommendations for further deployment and post-project exploitation. The methodology for developing the final exploitation plan (documented in D8.6 [28]) included conducting three workshops for the MOSES Pilot Demonstrations, an international workshop, communication with relevant stakeholders, the survey for the MOSES Key Exploitable Results (KERs), and the establishment of the EAB. The international workshop aimed to present the results from the MOSES Pilot Demonstrations to the EAB, the Advisory Board, and well-known stakeholders and platforms such as EMSA, ECSA, ESPO, ALICE, Waterborne TP, and

Connecting EU. The plan focused on enhancing pilot sustainability, extending research outcomes, and ensuring post-project utilization. It also involved market analysis, customer segmentation, and technology partnerships.

The initial innovation management activities related to the development of a Market and Societal End User Needs methodology and the conduct of a questionnaire survey (documented in D8.7 [29]). These activities were followed by a preliminary analysis of the needs of the end-users, as well as their expected benefits, and a matching of the MOSES innovations with user market and societal needs, which led to three different value propositions. Furthermore, a preliminary weighted SWOT Methodology was designed, and a weighted SWOT Questionnaire was developed. The SWOT questionnaire was disseminated to the consortium and a follow-up Market TRL workshop was conducted, where feedback was provided about market insights for determining the Innovation Margins, which describe the margins between current market and technology readiness level of MOSES technologies and the ideal path to successful commercialisation. A Patents Registry was created to monitor exploitable technological developments and innovations that are similar to the MOSES innovations. The innovation management activities also included a Porter 5 Forces Analysis and a Profit Simulation with three scenarios for the MOSES Autonomous Tugboat Swarm.

The MOSES Policy Recommendations for SSS included an analysis of the current state of the EU SSS market, as well as the existing regulatory and policy frameworks, to assess the baseline and the barriers related to the implementation and uptake of the MOSES innovations. A PESTEL analysis was carried out to identify the potential for the MOSES innovations towards addressing the identified gaps and contributing to the identified areas for improvement. Furthermore, a questionnaire that reflected key impacts of the MOSES innovations on the PESTEL categories was produced and disseminated to selected stakeholders including members of the MOSES Advisory Board. The results of the questionnaire were presented in a workshop with relevant stakeholders and the feedback obtained was used to support the drafting of the MOSES Policy Recommendations.

4. MOSES Self-Assessment

This section describes the performance of the MOSES project in terms of its technical implementation and how well its results were communicated and disseminated to the wider public, as well as with respect to its objectives as supported by its tangible outcomes and achievements.

4.1 Project implementation

The implementation of the MOSES project was monitored on a bi-annual basis through the KPIs described in D1.2 (also included in Annex 1 for reference), which relate to technical and communication and dissemination performance.

4.1.1 Technical performance

The KPIs for evaluating the project's technical implementation involved the timely achievement of milestones and submission of deliverables, the number of assigned reviewers for each deliverable, the number of Project Board and Work Package Leaders' meetings, as well as the project's overall risk level.

With respect to milestones and deliverables, the KPIs were calculated as the ratio of the actual month of achievement/submission compared to the month planned in the MOSES GA. The target for these KPIs was ≤ 1. As shown in Figure 19, the maximum delays in milestone achievement were faced during the second semester of the project (M7 – M12), while the delays for the following semesters ranged from 1,05 – 1,08, which translates to 1 – 2 months. The milestones associated with WP2, WP4, and WP5 faced the greatest delays in their achievement, i.e. 3 – 4 months (Figure 20). This was due to a slow start-up phase compounded by the COVID-19 crisis for WP2 and technical challenges in WP4 and WP5. The delays in achieving the milestones did not have a significant impact on the overall implementation of the project. With respect to deliverable submission, most of the significant delays were faced on average during the first twelve months of the project (Figure 19). With the mitigative actions from the technical coordination perspective, in the following semesters the delays were significantly reduced. The most significant delays were faced in WP2 (Figure 20) due to the amount of information that needed to be gathered, and the number of partners that needed to collaborate in order to derive the requirements for the development of all MOSES innovations in the technical WPs (WP3 – WP6). The delays in deliverable submission had a minor impact on project implementation in terms of cascading delays. However, overall, the project was not significantly impacted. For internally reviewing the project deliverables, two reviewers were assigned to each one, while the Quality Manager and Project Coordinator (NTUA) also reviewed the final versions of the documents.

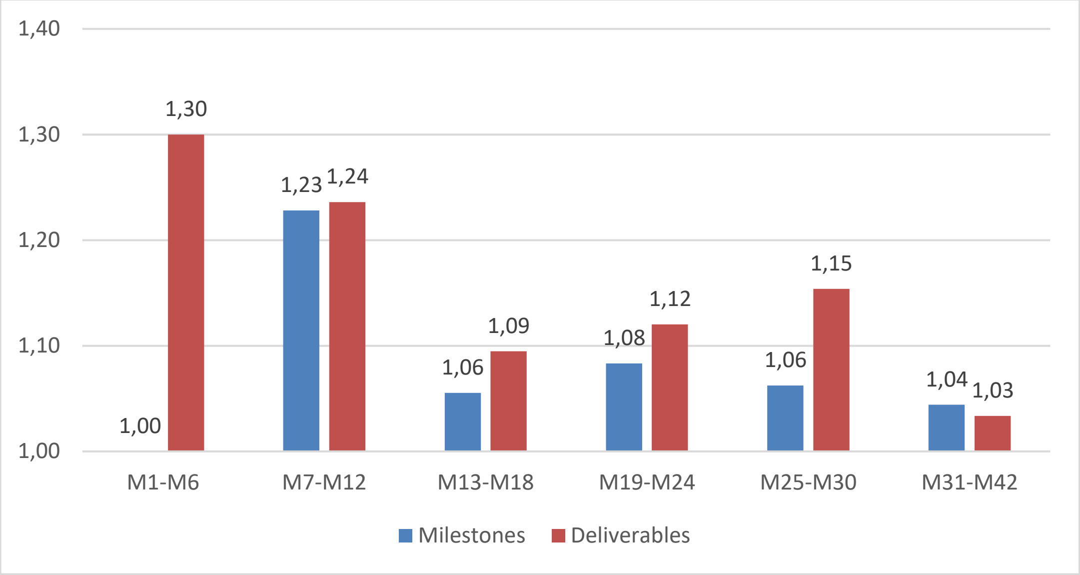

Figure 19: Average delays for milestone achievement and deliverable submission.

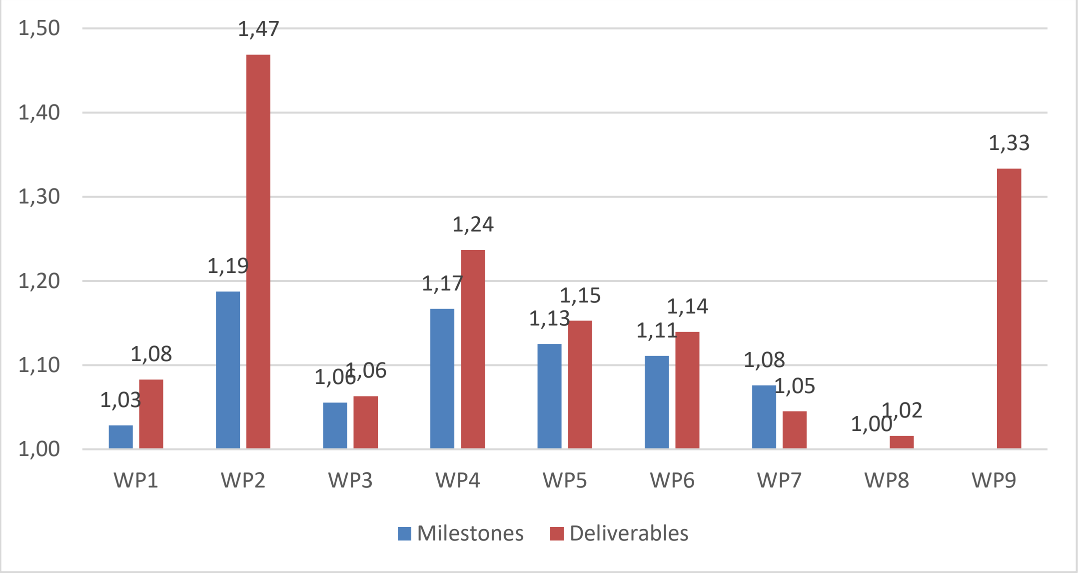

Figure 20: Average delays for deliverable submission per WP.

The scheduled number of Project Board Meetings was 2-3 / year (see target in Annex 1). This target was achieved as nine meetings were conducted during the course of the project’s implementation, out of which five were conducted online and four were conducted physically and hosted by different Consortium members.

The scheduled number of Work Package Leaders Meetings was 12 / year (see target in Annex 1). Eight such meetings were conducted online during the course of the project, three in 2020, two in 2021, and three in 2022. Although the actual number was significantly below the target, it was considered adequate for the purposes of the project's technical coordination considering the large number of meetings (both physical and online) that were conducted within and between the WPs with the participation of the technical and the project coordinators.

4.1.2 Communication & dissemination performance

In the context of the close, effective, and efficient monitoring of the dissemination, communication, and scientific activities, and in addition to the already identified risk management and compliance matrix, a complementary communication and dissemination related KPI matrix has been developed. This matrix was regularly updated on a monthly basis and included the KPIs' names, along with their current value and the achieved and expected results. After having set the thresholds per activity (using a linear and/or exponential interpolation when needed) and the reference period, the results for the KPIs were recorded. This allowed the precise monitoring of each KPI throughout the duration of the project.

Most of the defined MOSES KPIs have been successfully met and fulfilled (Figure 21). However, by taking into consideration post project exploitation, efforts will be further strengthened, after project end, towards the direction of MOSES scientific dissemination (papers in conference proceedings and publications in scientific journals).

Furthermore, MOSES identified opportunities, such as events, workshops, and exhibitions, for boosting the project's outreach as well as relevant projects for establishing liaison activities. Specifically, links with the following EU research projects were created: AEGIS, AUTOSHIP, PLATINA3, ENTRANCE, BOOSTLOG, IW-NET, Current Direct, ST4W, NOVIMOVE, AUTOBarge and LASTING. Special attention was also given in establishing cross-fertilising communication links with networking organisations, platforms, associations, and agencies including ALICE[4], EMSA[5], Waterborne[6], ERTICO[7], and ILME[8].

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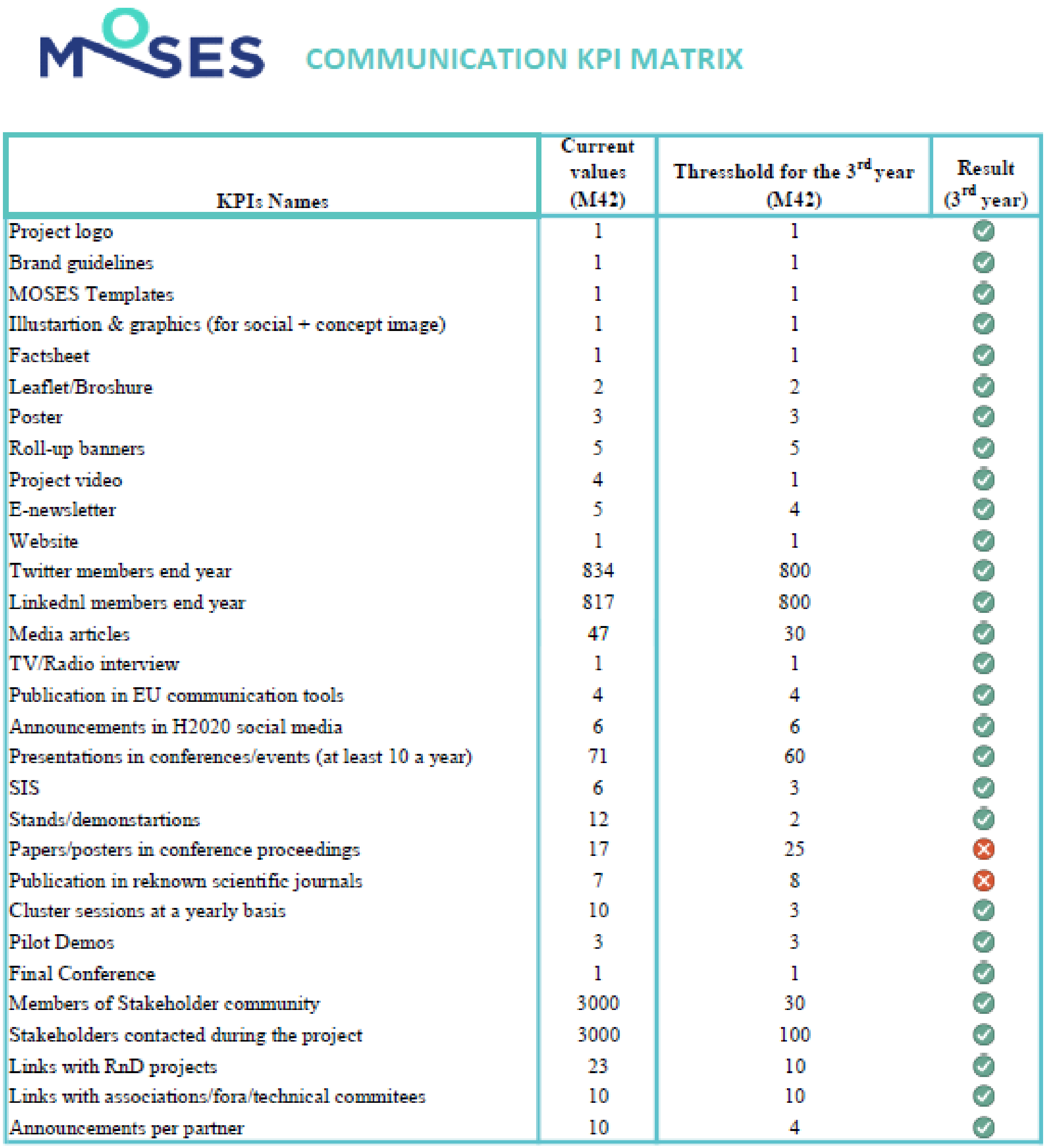
[4] European Technology Platform ALICE, https://www.etp-logistics.eu/
[5] European Maritime Safety Agency, https://www.emsa.europa.eu/
[6] European research and innovation platform for waterborne industries https://www.waterborne.eu/
[7] ERTICO – ITS Europe, https://ertico.com/
[8] Institute of Logistics Management of Greece (ILME), https://ilme.gr/



MOSES COMMUNICATION KPI MATRIX

KPIs Names	Current values (M42)	Thresshold for the 3rd year (M42)	Result (3rd year)
Project logo	1	1	✓
Brand guidelines	1	1	✓
MOSES Templates	1	1	✓
Illustartion & graphics (for social + concept image)	1	1	✓
Factsheet	1	1	✓
Leaflet/Broshure	2	2	✓
Poster	3	3	✓
Roll-up banners	5	5	✓
Project video	4	1	✓
E-newsletter	5	4	✓
Website	1	1	✓
Twitter members end year	834	800	✓
Linkednl members end year	817	800	✓
Media articles	47	30	✓
TV/Radio interview	1	1	✓
Publication in EU communication tools	4	4	✓
Announcements in H2020 social media	6	6	✓
Presentations in conferences/events (at least 10 a year)	71	60	✓
SIS	6	3	✓
Stands/demonstartions	12	2	✓
Papers/posters in conference proceedings	17	25	✗
Publication in reknown scientific journals	7	8	✗
Cluster sessions at a yearly basis	10	3	✓
Pilot Demos	3	3	✓
Final Conference	1	1	✓
Members of Stakeholder community	3000	30	✓
Stakeholders contacted during the project	3000	100	✓
Links with RnD projects	23	10	✓
Links with associations/fora/technical commitees	10	10	✓
Announcements per partner	10	4	✓

Figure 21: MOSES Communication & Dissemination KPIs.

4.2 Project objectives

The objectives of MOSES are grouped into Technical (TO), Societal (SO), and Market (MO) objectives. Each objective was associated with specific SIs with either qualitative or quantitative targets that reflect the added value of the MOSES Innovations. Each SI was assigned a satisfaction level depending on the proximity to the target (low – high for quantitative targets, marginal – full for qualitative targets). The validation of all SIs through the MOSES Sustainability Framework has been documented in D7.5 [27]. This section provides a summary of the main findings from the analysis, while Annex 2 lists all SIs with their satisfaction levels.

MOSES included three technical objectives with 13 associated SIs, two societal and two market objectives with 6 associated SIs each. As shown in Figure 22, TO1 and TO3 have the highest number of associated SIs that have been validated to a high satisfaction level, while only one SI could not be validated within the project. SO1 has the highest number of SIs validated to a high satisfaction level and all societal SIs were validated within the project (Figure 23). MO2 has the highest number of SIs validated to a high satisfaction level, while only 1 market SI could not be validated (Figure 24).

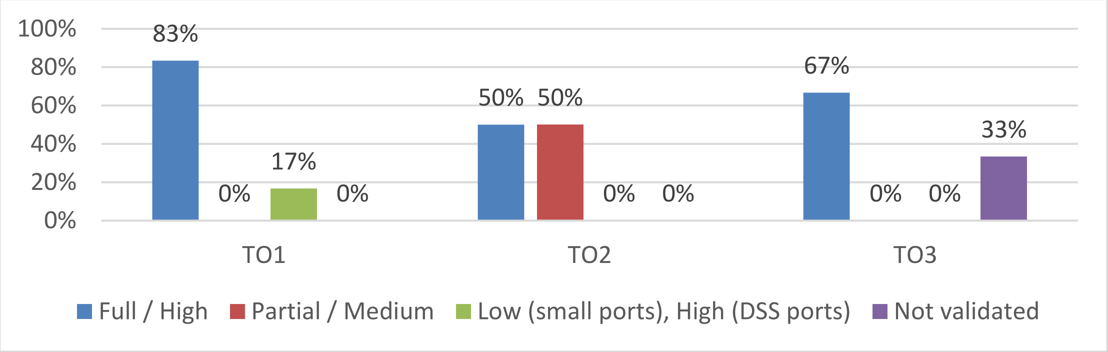


Figure 22: Percentage distribution of the SI satisfaction levels (technical objectives).

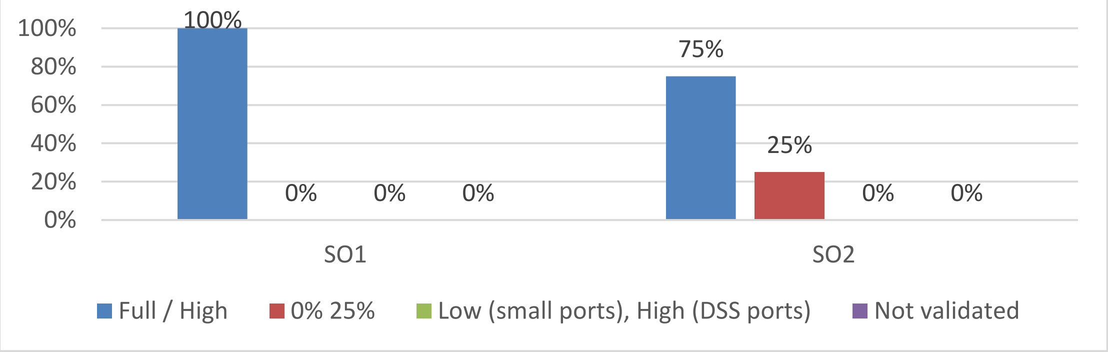


Figure 23: Percentage distribution of the SI satisfaction levels (societal objectives).

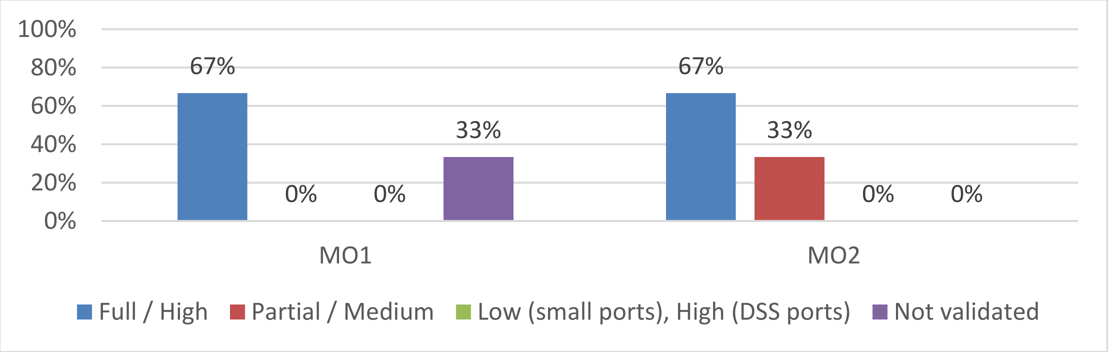


Figure 24: Percentage distribution of the SI satisfaction levels (market objectives).

The technical objectives of MOSES contribute to achieving its societal and market objectives with the relationships shown in Figure 25. The following describes the most significant results for each of the technical objectives, how they contribute to its other objectives, as well as the aspects that could not be fully validated.

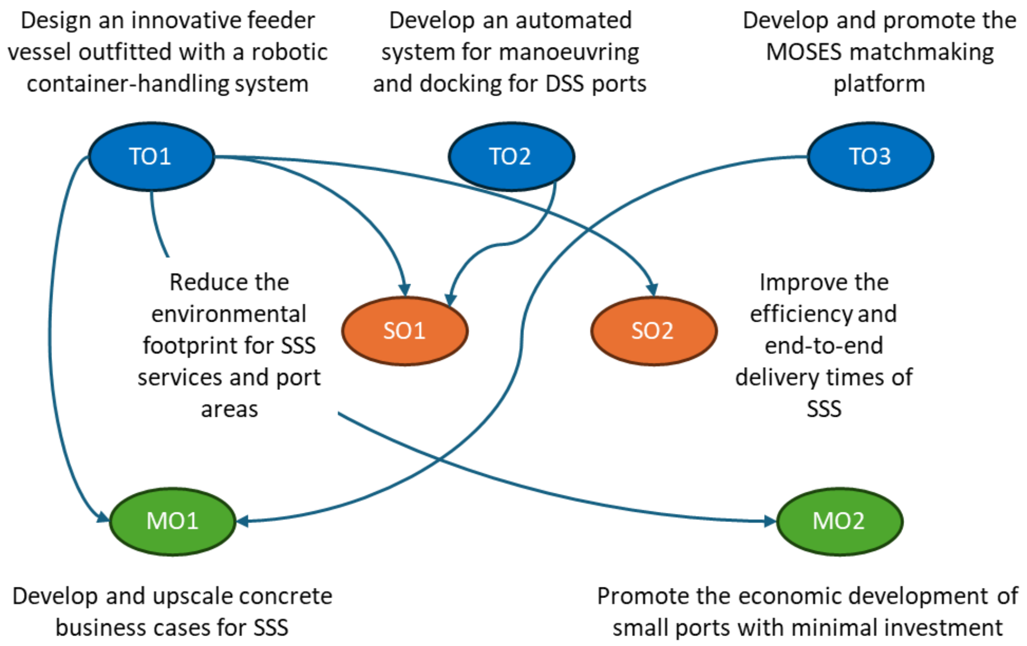


Figure 25: Relationship between the technical, societal, and market objectives of MOSES.

Design an innovative, hybrid electric feeder vessel outfitted with a robotic container-handling system (TO1)

The MOSES Innovative Feeder Vessel was designed to be competitive against land-based transportation and maritime transportation of container trucks on RoPax vessels in terms of cost, efficiency, and environmental performance. Furthermore, the innovative feeder was designed to be completely independent from port infrastructure due to the onboard MOSES Robotic Container-Handling System, which has been validated as a proof of concept through the MOSES Pilot Demonstration 3 (documented in D7.4 [10]).

The added value of the innovative feeder was validated within the context of the two business cases developed within the project (i.e. the Greek and the Spanish case). In the Greek case, where the benchmark was trucks on RoPax vessels from the DSS port to the small island ports, a cost analysis resulted in 8.6% reduction in container transport unit costs (see D2.3 [2]). This reduction was estimated with the assumption that the feeder replaces at least 40% of the existing Ro-Ro traffic used to transport containers on trailer trucks. In the Spanish case, where the alternative was container transport with trucks from the DSS port to the hinterlands of the small ports, the unit costs for the innovative feeder were lower with the assumption of three truck haulages per day from the small ports to their hinterland. For this case, the operation of the innovative feeder would result in an increase in SSS cargo transfer from the small ports that ranges between 22% and 155% considering the modal shift from land-based transportation.

The innovative feeder is more efficient during its port approach to DSS ports, compared to similar vessels, as a 70% reduction in time required for manoeuvring and docking has been estimated. This reduction is owed to its improved manoeuvrability and Dynamic Positioning capabilities, as well as to its combined operation with the MOSES AMS. For small ports, a 12.5% – 30% reduction in required time was estimated considering that existing cargo ships that call on such ports take less time to dock compared to large containerships in DSS ports.

The innovative feeder is also more efficient in terms of the time it takes to load and unload the vessel using the MOSES Robotic Container-Handling System. As indicated by the results of Pilot Demonstration 3, loading at a DSS port (assuming quay cranes are not used) and unloading at a small port are reduced respectively by 25%. The combined effect from the reduction of time required to manoeuvre, dock, and (un)load the feeder vessel is expected to reduce end-to-end transit time[9] for SSS, which contributes to the project's Societal Objective 2 (i.e. to improve efficiency and end-to-end delivery times of SSS). However, the impact of this combined effect on end-to-end transit time has not been quantified within the project. Furthermore, the robotic crane can autonomously load and unload containers directly from/to trucks, as validated in Pilot Demonstration 3 in terms of container positioning accuracy, and therefore does not require the port cranes at DSS ports, which makes them fully available for other port operations. This also contributes to Societal Objective 2. For small ports, this capability means that they would require zero investment to serve the innovative feeder and participate in the container supply chain, which contributes to the project's Market Objective 2 (i.e. promote economic development of small ports with minimal investment).

In terms of environmental performance, the selected energy carriers that were considered most feasible for the innovative feeder are methanol in a hybrid electric configuration, which emit 78% less CO_2 equivalent emissions compared to diesel, and renewable hydrogen in a fuel cell configuration, as well as a fully electric configuration, which emit 100% less CO_2 equivalent emissions. These reductions have been

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[9] Within the context of MOSES, end-to-end transit time for SSS is defined as the sum of the duration of the following processes for a small feeder: loading at a DSS port, trip to a small port, docking at a small port, and unloading at a small port (see D7.5).

benchmarked against average emissions by existing container feeders and also contribute to the MOSES Societal Objective 1, which is to reduce the environmental footprint for SSS services and port areas.

Develop an automated system for reducing manoeuvring and docking time for DSS ports (TO2)

The MOSES AutoDock system has been designed to improve the following aspects of the manoeuvring and docking process for large containerships in DSS ports: efficiency, in terms of the utilisation of tugboat and port resources, safety, and environmental performance.

Based on simulations (documented in D4.3 [13]) and the results of Pilot Demonstration 1 (documented in D7.2 [16]), the AutoDock system is estimated to reduce the time required to manoeuvre and dock a large containership by 25% - 37.5% compared to the corresponding time for a post-panamax containership calling the port of Piraeus in similar conditions. This increase in efficiency and given the level of automation that allows less dependence on tugboat and port personnel, is expected to increase the availability of tugboat and mooring services at port up to 100% (i.e. on a 24/7 basis). In addition, lower operational time is expected to reduce the associated air emissions by the same amount (assuming the same loading level of the machinery and type of fuel as for conventional tugboats) and air pollutants, although the reduction for the latter could not be quantified within the project. In addition, tugboat air emissions are estimated to be further reduced by 8.5% if they are hybrid electric, which is based on an analysis for the hybrid electric power configuration of the innovative feeder assuming the percentage reduction in emissions between diesel and hybrid-electric will be the same irrespective of the size of the propulsion installation and the type of vessel. This expected reduction in port emissions also contributes to the project’s Societal Objective 1, which is to reduce the environmental footprint for SSS services and port areas.

Regarding safety, the autonomous tugboats can contribute with the potential to reduce the accidents caused by ineffective communication and coordination between the Pilot and the tugboat Captains, who have a monitoring role, as well as those caused by fatigue and judgement errors. Furthermore, the AMS can contribute with eliminating exposure of port personnel to risks related to rope failures. However, the improvement in terms of reducing the number of accidents could not be estimated within the project due to the lack of relevant statistical data.

Develop & promote the MOSES matchmaking platform to boost SSS (TO3)

The MOSES Matchmaking Logistics Platform was designed to stimulate modal shift from land-based transportation to SSS, improve the backhaul traffic for its subscribers, and reduce logistics costs for container cargo destined to small ports.

Regarding modal shift, it was estimated that the platform can shift 13% of the existing road container traffic from the port of Piraeus to the cities of Thessaloniki, Patra, Volos, Alexandroupoli, Kavala (see D6.4 [24]). The estimated modal shift, supported by the identification of groupage opportunities and shared container loads through the platform, is also expected to reduce road traffic in the vicinity of DSS ports from container trucks. Regarding backhaul traffic, although the improvement could not be quantified within the project due to the lack of relevant operational data, the reduction of the number of trips for the same freight volume shows that there is significant capacity left that could lead to the achievement of the set objectives. Regarding logistics costs for transporting containerised cargo to small ports, it is expected that they will be reduced on average by 46% by using the innovative feeder and hiring trucks for last mile delivery, compared to transporting unaccompanied trailers on RoPax vessels and hiring trucks for last mile delivery (see D6.4 [24]).

The platform has been effectively promoted to relevant stakeholders through various activities. The platform subscribers by the project end (i.e. December 31, 2023) consisted of 27 stakeholders. Furthermore, the National Logistics Council of Greece (ILME) has shown interest in the platform and the platform subscribers are expected to reach 100 during the first half of 2024 with the registration of its members.

Finally, the capabilities of the platform, as well as the positive outlook regarding its subscribers, contribute to the project's Market Objective 1, which is to develop and upscale concrete business cases for SSS.

5. Conclusions

The MOSES project has fully achieved all its technical objectives, which are related to the tangible outcomes for the MOSES innovations, and their associated societal and market objectives that respectively focus on reducing the environmental footprint and improving the efficiency of SSS container transport, as well as developing business cases that promote the development of small ports with minimal investment. The implementation of the MOSES innovations is expected to add significant value to the SSS network by supporting the creation of sustainable feeder services from DSS to small ports.

The analysis for the Greek and Spanish business cases has shown that there is a significant number of small ports that can be integrated in the EU container supply chain through the MOSES innovations. The MOSES feeder services can be economically viable and contribute to shifting cargo from land-based transportation to SSS, depending on the container transport demand captured by the feeder. In cases where lower demand is expected, a higher percentage needs to be captured by the feeder for the service to be competitive to existing alternatives.

The Innovative Feeder Vessel with its hybrid electric-methanol power solution is expected to provide an environmentally friendly and sustainable alternative to transporting trucks on RoPax vessels (Greek case) and container hauling trucks (Spanish case). It is also technically and economically feasible to charge the batteries at the DSS port, while the significantly smaller payload capacity of the innovative feeder, compared to conventional container feeders, has been shown to be cost-effective. Furthermore, fully autonomous, port-to-port operation is technically feasible and could also be a commercial advantage due to the less human resources that are required. For the Robotic Container-Handling System, the demonstration has indicated faster loading compared to manual-driven cranes, given the assumptions and the level of technology readiness, which enable the transition of small ports to container terminals with zero investments for port infrastructure.

The Autonomous Tugboat swarm and the Automated Mooring System (i.e. the MOSES AutoDock system) seem to significantly reduce the manoeuvring and docking time of large containerships at DSS ports, given the results of the demonstration. The reinforcement learning approach used to train the swarm algorithm is very promising as it produces movements that are similar to manually operated tugboats given that the position of the tugboats is provided to the algorithm with high accuracy (i.e. lower than 1 m) and considering the challenges related to integration with existing control systems. Regarding the safety of this autonomous operation, the fail-safe study showed that the human-in-the-loop approach is necessary considering the criticality of the operation. Furthermore, as the AMS is an improvement of an existing commercial system, it has higher technology readiness compared to the other MOSES innovations and therefore is more mature for commercialization.

The Matchmaking Logistics Platform, which is the logistics enabler for sustaining the MOSES feeder services, can contribute to improving modal shift to SSS, optimizing cargo transport in regional networks, and therefore reducing the generalized unit transportation costs in environmental and economic terms.

The feeder services enabled by the MOSES innovations are a promising and sustainable idea, whose success depends on end-user engagement and innovation uptake, as well as integration with the supply chain. The MOSES feeder services require shipowners willing to build and operate the innovative feeder vessel and cargo owners willing to change how cargo is currently transported. The MOSES innovations need to be integrated in the existing supply chain with a specific focus on cost-effective last mile transportation in ports, such as the ones examined in the Greek business case. Finally, the MOSES feeder services need to be complemented with new business models that, for example, account for alternative ways to consolidate general cargo into containers for transportation with the innovative feeder.

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Annex 1: Key Performance Indicators for project implementation

Monitoring of the progress of the project objectives was done by the Technical Manager (NTUA) and the PC (NTUA), through KPIs, monitored bi-annually. The KPIs are shown in Table 4 and have been documented in D1.2 [1].

Table 4 Key Performance Indicators (KPIs) for project implementation.

KPI	Goal (Justification and Goal)
Real month of milestone achievement / due month	Keep the project on schedule (KPI=1). Six-Monthly internal activity reports are compiled and consolidated (Process described in D 1.1). **Target**: KPI<=1 , per milestone
Overall project risk level	Flag any deviations from targets in advance to allow preventive action. **Target**: Risk level below moderate
Real month of deliverable submission / Due month	Ensure compliance with task and deliverable performance procedures. **Target**: KPI<=1, per deliverable
Number of reviewers per deliverable / assigned reviewers	All deliverables undergo at least a two-phase review procedure: review by two appointed reviewers (coordinated by the QM) and by the PB (coordinated by the PC). Ensure that all deliverables follow defined quality criteria. **Target**: KPI>=1
Actual number of meetings / Scheduled meetings	Maintain coherence and focus of the consortium, monitor project progress and decisions made, synchronise activities, discuss technical, administrative and other issues regularly. Scheduled Project Board meetings 2-3 times/year. Scheduled WPLs meetings 12 times/year. **Target**: KPI >= 1
Creation of a recognisable brand identity	1 project logo, brand guidelines, MOSES templates, illustrations and graphics.
Communication kit	2 brochures, 3 posters, 5 Roll-up banners, 1 final video, 4 e-Newsletter issues.
Dedicated website	1 public website
Social media channels	Active LinkedIn and Twitter accounts posting news in a regular (weekly) base. At least 300 members per account the 1st year; at least 800 members by the end of the project. At least 4 announcements per partner in individual social media accounts; at least 6 announcements in H2020 social media sites. At least

KPI	Goal (Justification and Goal)
	10/year and 60 presentations in total; 3 special sessions; 2 stands and/or demonstrations;
Participation in Conferences and events	At least 10/year and 60 presentations in total; 3 special sessions; 2 stands and/or demonstrations;
Peer-reviewed publications	At least 25 project papers in conferences; 8 publications in re-known scientific journals;
Mass Media &Press	30 media articles in popular and/or specialised media; At least 1 interview in Radio and/or TV
Use of EU dissemination networks & tolls	At least 4 publications in EC communication tools; Participation in EU events
Project Events	3 pilot demonstrations; 1 intl. conference; Clusters sessions at a yearly base.
MOSES Networking/ Engagement activities	At least 30 members of the Stakeholders Community; at least 100 stakeholders contacted during the project; establish links with 10 R&D projects and 10 associations, fora, technical committees.

Annex 2: Satisfaction levels for Success Indicators

Table 5 summarizes the satisfaction levels for all the SIs related to the MOSES Technical, Societal, and Market objectives.

Table 5: Summary of satisfaction levels for all MOSES SIs.

Objectives	Success Indicators (SIs)	Value Dim.	Target	Satisfact. level
TO1: Design an innovative, hybrid electric feeder vessel outfitted with a robotic container-handling system	MOSES feeder vessel offering complete independence from port infrastructure	ECONOMY	Qualitative	Full
	Logistic supply chain through SSS comparable in business values with existing transport alternatives	SOCIETY	Qualitative	Full
	(near) Zero emissions operation	ENVIR.	~ 0	High
	Replacement of Ro-Ro traffic used to transport containers on trailer trucks in selected destination ports	SOCIETY	> 15%	High
	Increase of SSS cargo transfer from Consortium ports	SOCIETY	20%	High
	Reduction of docking time combined with the MOSES AutoDock	ECONOMY	~ 70%	High (DSS) Low (small port)
TO2: Develop an automated system for reducing manoeuvring and docking time for DSS ports	Reduction of human error-related accidents for manoeuvring and docking	SOCIETY	Any reduction acceptable	Partial
	Reduction of air pollutants in port areas	ENVIR.	Any reduction acceptable	Partial
	Reduction of manoeuvring and docking time compared to current norm (pilots and human operated tugboats)	ECONOMY	> 20%	High
	Increase of port services availability	SOCIETY	≤ 100%	High
TO3: Develop & promote the MOSES matchmaking platform to boost SSS	Number of logistics stakeholders in the platform at the project end	SOCIETY	> 10	Full
	Improve backhaul traffic for platform subscribers	ECONOMY	> 20%/40% mid/long-term	Not validated
	Modal shift to SSS in designated areas	SOCIETY	> 10%	High

Objectives	Success Indicators (SIs)	Value Dim.	Target	Satisfact. level
SO1: Reduce the environmental footprint for SSS services and port areas compared to other modes	Reduction of port emissions using the MOSES autonomous tugboats and when they become hybrid-electric	ENVIR.	25%/30% (diesel/hybrid)	High
	Reduction in GHG emissions using the MOSES feeder vessel compared to the average values emitted by the existing feeders and the potential of being climate neutral until 2050	ENVIR.	40%	High
SO2: Improve efficiency and end-to-end delivery times of SSS mode	Decrease of end-to-end transit time for SSS	ECONOMY	> 10%	Medium
	Decrease the usage time of large cranes in the DSS port for (un)loading feeder vessels	ECONOMY	10%	High
	Increase of EU ports able to host container feeder vessels	SOCIETY	10%	High
	Decrease end-to-end costs for container transport for captive and DSS feeder traffic	ECONOMY	> 5%	Full
MO1: Develop and upscale concrete business cases for SSS	Reduce logistics costs for (im-) exporters of container cargo destined to small ports	ECONOMY	Any reduction acceptable	Full
	Reduce road traffic around hub ports from container-hauling trucks	SOCIETY	Any reduction acceptable	Not validated
	Improve modal-split in favour of SSS	SOCIETY	Any improvement acceptable	Full
MO2: Promote economic development of small ports with minimal investment	Infrastructure investment for small ports (initial estimation, to be revised by the cost-benefit analysis to be conducted in Task 7.5)	ECONOMY	< 250k EUR	Partial
	Demonstration of MOSES feeder and robotic container-handling system	SOCIETY	Qualitative	Full
	Demonstration of the re-engineered smaller scale AutoMoor system.	SOCIETY	Qualitative	Full