Ref. Ares(2020)7854347 - 22/12/2020

AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping

D.2.1: MOSES stakeholder and end-users needs

Document Identification			
Status	Final	**Due Date**	31 October 2020
Version	1.0	**Submission Date**	22/12/2020
Related WP	WP2	**Document Reference**	D.2.1
Related Deliverable(s)	D2.2, D2.3, D2.4	**Dissemination Level**	PU
Lead Participant	PCT	**Document Type:**	R
Contributors	NTUA, CORE, TNO, VPF, TRELL	**Lead Author**	Michael Kotras (PCT)
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 861678. The content of this document reflects only the authors' view and the European Commission is not responsible for any use that may be made of the information it contains.

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Document History			
Version	**Date**	**Change editors**	**Changes**
0.1	30/07/2020	Michael Kotras	ToC and methodology description
0.2	21/9/2020	Mirjam Huis in 't Veld	Comments on structure
0.5	28/9/2020	Nikos Monios, Mercedes de Juan Muñoyerro, Alessandro Zanderigo	Input received by contributors
0.6	24/11/2020	Margarita Kostovasili	Addition of questionnaire analysis
0.7	30/11/2020	Konstantinos Louzis	Addition of results from questionnaire, state of the art, stakeholder analysis,

Document History			
Version	**Date**	**Change editors**	**Changes**
			workshop results and user requirements
0.8	07/12/2020	Michael Kotras	Submitted for internal review
0.9	10/12/2020	Konstantinos Louzis	Addressed comments received by internal reviewers (TNO, MARIN)
1.0	21/12/2020	Michael Kotras	Final version to be submitted

Quality Control		
Role	**Who (Partner short name)**	**Approval Date**
Deliverable leader	PCT	21/12/2020
Quality manager	NTUA	21/12/2020
Project Coordinator	NTUA	21/12/2020

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List of Acronyms

Abbreviation / acronym	**Description**
3G	Third generation of wireless mobile telecommunications technology
4G	Fourth generation of wireless mobile telecommunications technology
5G	Fifth generation of wireless mobile telecommunications technology
AD	Auto Docking
AEOLIX	Architecture for EurOpean Logistics Information eXchange
AI	Artificial Intelligence
AMS	Automated Mooring System
APC	Active Pendulation Control
ARC	Active Rotation Control
AT	Autonomous Tugboat
ATON	Aids to Navigation
AV(s)	Autonomous Vehicle(s)
CAPEX	Capital Expenses
CluCS	Cluster Community System
CoCoRo	Collective Cognitive Robotics
COLREG	International Regulations for Preventing Collissions at Sea
D2.1	Deliverable number 1 belonging to WP 2
D2.2	Deliverable number 2 belonging to WP 2
D2.3	Deliverable number 3 belonging to WP 2
D2.4	Deliverable number 4 belonging to WP 2
DNVGL	Det Norske Veritas and Germanischer Lloyd
DP	Dynamic Positioning
DSA	Dynamic Spectrum Access
DSRC	Dedicated short-range communications
DSS	Deep Sea Shipping
EC	European Commission
ECAs	Emission Control Areas
ESD	Emergency Shut Down
ETA	European Tug-owners Association
ETA	Estimated Time of Arrival
EU	European Union
F	Functional
FV	Feeder Vessel
GDPR	General Data Protection Regulation

Abbreviation / acronym	**Description**
GHG	Greenhouse Gas
GPS	Global Positioning System
H2020	Horizon 2020 - EU Framework Programme for Research and Innovation
IACS	International Association of Classification Societies
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICT	Information and Communications Technology
ID	Identification
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organisation
IMUS	Inertial Measurement Units
IoV	Internet of Vehicles
ISO	International Standards Organisation
LIDAR	Light Detection and ranging
LNG	Liquefied Natural Gas
LOLO	Lift-On/Lift-Off
LPG	Liquefied Petroleum Gas
LSHFO	Low Sulphur Heavy Fuel Oil
LSP	Logistics Service Provider
MarVest	An innovative investment platform which offers retail and institutional investors access to high yield generating maritime assets
MDO	Marine Diesel Oil
MGO	Marine Gasoil
MLE	Maritime Law Enforcement
MLP	Matchmaking Logistics Platform
MOSES	AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping
NB-IoT	Narrowband - Internet of Things
NF	Non-Functional
NorLines	Short sea liner shipping and logistics company based in Norway
NTUA	National Technical University of Athens
OPEX	Operating Expenses
PA	Port Authority
PCT	Piraeus Container Terminal
RCA	Robotic Container-Handlinng System
RoCoPax	Roll-On/Roll-Off Passenger
RORO	Roll-On/Roll-Off
RTD	Research and Technological Development
RTM	Requirements Traceability Matrix
SAR	Search and Rescue

Abbreviation / acronym	Description
Sota	State of the Art
SSS	Short Sea Shipping
TEN-T	Trans-European Transport Network
TEU	Twenty-foot equivalent unit
ToC	Table of Contents
TRL	Technology Readiness Level
TV	Television
USA	United States of America
UUV(s)	Unmanned Underwater Vehicle(s)
V2I	Vehicle-to-Internet
V2R	Vehicle-to-Roadside
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-everything
VANET	Vehicular Ad hoc Network
VFD	Variable Frequency Drive
VPF	Valencia Port Foundation
WiFi	Wireless Fidelity
WP	Work Package

Executive Summary

This deliverable is connected to Task 2.1 'From Stakeholder and user needs to requirements' under Work Package 2 'From User Needs and Requirements to Specifications' of the MOSES project. The current document identifies user and stakeholder needs relevant to the MOSES innovations, translates them into user requirements and documents them in a structured way. The analysis has considered the most relevant technological developments, current research trends, and stakeholders' feedback from engagement activities conducted in the context of Task 2.1.

The main aim of the document is to provide the starting point for the development of the MOSES innovations by describing relevant user requirements. The innovations covered in this document are the following: 1) Innovative Feeder Vessel, 2) Robotic Container-Handling System, 3) Autonomous Tugboats, 4) Automated Docking Scheme, 5) Matchmaking Logistics Platform. The requirements were derived from feedback received from stakeholder engagement activities conducted in the context of Task 2.1 'From Stakeholder and user needs to requirements', based on the conceptual description of the MOSES innovations in Section 3. The identified set of user requirements will inform the development of the MOSES use cases in D2.2 'MOSES use cases and scenarios' and, after being validated by the MOSES Advisory Board in a workshop, will be used to derive the system requirements and specifications in D2.4 'Specifications for MOSES innovations'.

The MOSES User Requirements Extraction Methodology, a four-step process adapted from similar approaches in the literature described in Section 2, was utilized to identify user and stakeholder needs and translate them into formally stated user requirements. Initially, challenges related to the development of the MOSES innovations were identified by a literature review of the state-of-the-art technologies and the current research trends in Section 4. Then, a stakeholder identification was carried out (Section 5), which included the description of key categories of stakeholders and end-users and their relevance to the MOSES project.

Subsequently, the identification of the user needs was performed based on the results from an online survey and two workshops involving both internal and external (in relation to the MOSES Consortium) stakeholders and end-users (Section 6). Finally, the identified user needs were translated into formally stated user requirements.

The analysis resulted in a comprehensive list of 47 functional and non-functional user requirements (Section 7). The scope of the provided set of user requirements reflects the identified user needs, including elements such as safety, security, privacy, environmental footprint, and human-machine interaction.

The majority (87%) of the user requirements in this document are functional, which determine what the MOSES innovations should be able to do. Non-functional requirements, which for example specify performance aspects for the MOSES innovations, will be the main focus of Task 2.4. In addition, most user requirements (72%) cover technical and safety issues, while other important aspects (environmental, societal, and market) seem to have been under-represented. Work in subsequent tasks will focus on providing a wider coverage of these issues.

Finally, a significant result is that most (about 70%) of the stakeholders engaged in the online survey evaluated the included potential aspects of the MOSES innovations positively (i.e. as fairly important and very important). Considering that the results of the online survey helped shape the documented user requirements.

0. Introduction

0.1 Purpose of the document

The purpose of this document is to comprehensively map the stakeholder and user needs and translate them into formally structured user requirements for each MOSES innovation. The five innovations considered in this document are the Innovative Feeder, the Robotic Container-Handling System, the Autonomous Tugboats, the Automated Docking Scheme, and the Digital Matchmaking and Logistics Collaboration Platform.

The document will provide the basis for the user-centric development approach employed in the MOSES project by linking the identified user needs with user and system requirements, and finally system specifications. In this context, it will provide input for determining the MOSES use cases and scenarios (T2.2) and specifications for the MOSES innovations (T2.4).

0.2 Intended readership

This deliverable is public and therefore addressed to the members of the MOSES Consortium, as well as to the stakeholders who are external to the MOSES project.

0.3 Document Structure

The rest of the document is structured as follows:

Section 2 outlines the methodology used in this deliverable to come up with formally structured user requirements that correspond to the innovations that will be developed in the MOSES project.

Section 3 briefly describes the MOSES innovations in a structured manner. This description provides the basis for the development of the innovations.

Section 4 presents a review of the state-of-the-art technologies and processes that are relevant to the MOSES innovations. The aim of the literature review is to identify the main challenges and inform the development of the requirements.

Section 5 presents the results of a structured stakeholder analysis, where the identified stakeholders are mapped in relation to the operational context of the innovations. This analysis has been used to target specific categories for the stakeholder engagement activities performed in the current task, i.e. Task 2.1.

Section 6 summarizes the results of the stakeholder engagement activities, which include two workshops and an online survey. These results are exploited in documenting the formally stated user requirements.

Section 7 systematically documents the identified user requirements for each of the MOSES innovations. Each requirement is described separately to ensure that their implementation is adequately traced during the development within the project.

Section 8 summarizes the main conclusions of this document and describes how the results will be exploited within the project.

Annex 1 includes the questionnaire that was distributed to MOSES stakeholders, as well as the information sheet/consent forms.

Annex 2 includes a summary of answers received for every question included in the online survey.

1. Methodology

MOSES implements a stakeholder and user-centric approach, where stakeholder and user needs are transformed into requirements. According to ISO/IEC/IEEE 29148 [1], requirements are specific, precise, and unambiguous statements that express needs and associated constraints and conditions. Requirements that originate from relevant stakeholders and the intended users of a system may subsequently be translated into system requirements, either functional or non-functional, which finally provide input for determining system specifications. According to ISO/IEC/IEEE 29148 [1], the purpose of the system requirements definition process is to describe the technical implementation (including functional and performance requirements) that will satisfy the desired system capabilities of the users.

Fernandes and Machado [2] have defined a generic requirements elicitation process that consists of the following steps: 1) Study the domain of interest, 2) Identify the requirements sources, 3) Consult and engage stakeholders, 4) Select the techniques to be applied for elicitation, and 5) Elicit the requirements from the stakeholders and other identified sources.

In this Chapter, the MOSES User Requirements Extraction Methodology that is implemented for identifying user needs and translating them into user requirements is presented (Figure 1).

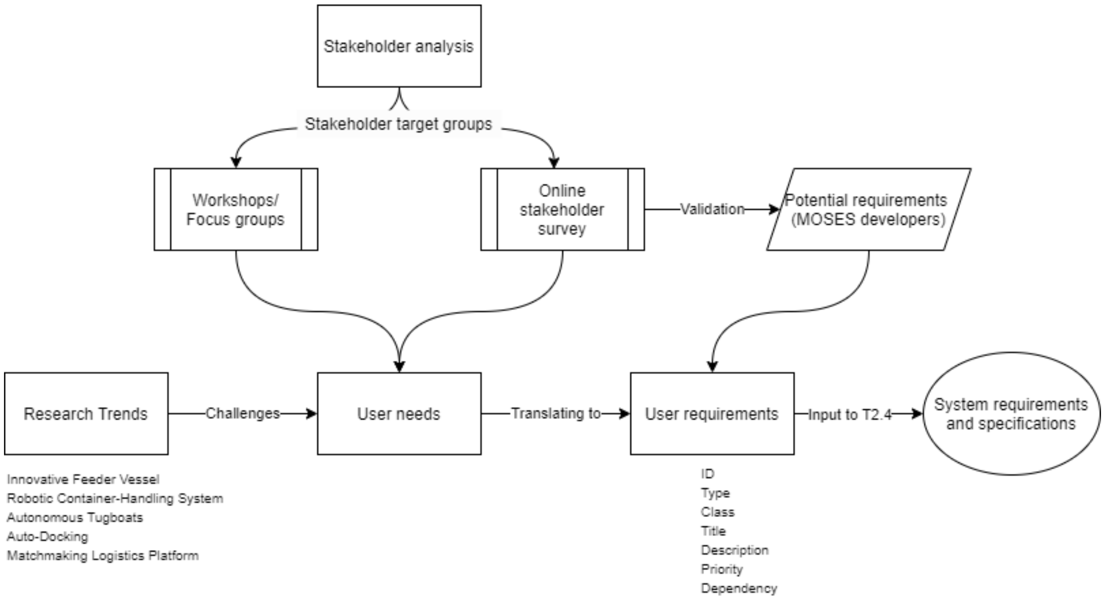


Figure 1 User Requirements extraction methodology.

The employed methodology has been adapted to the needs of the MOSES project from the general framework described by Fernandes and Machado [2], and consists of the following steps:

1. Identifying research trends based on a literature survey. This includes a description of state-of-the-art technologies and processes relevant to the MOSES innovations and associated challenges. Analysing domain specific knowledge is useful for identifying essential, as well as missing, functionality [3]. This mapping can provide input into the design process as potential user requirements [4]. The identified challenges helped identify user needs and shape the resulting user requirements.

2. Identifying and analysing the basic categories of stakeholders and end-users that are relevant to the development and operation of the MOSES innovations.

3. Identifying user needs by directly engaging stakeholders that have been identified in the stakeholder analysis in workshops and user surveys. It is noted that the survey that was conducted in the context of Task 2.1 (see Section 6.3) served a two-fold purpose in the extraction methodology: 1) to evaluate the acceptance by the stakeholders of an initial set of potential requirements that had been identified by the members of the MOSES Consortium, and 2) to identify additional user needs that could be translated into user requirements.

4. Systematically documenting user requirements that are related to the identified user needs and challenges. User requirements are approached from multidisciplinary angles, and address issues such as efficiency, performance, trust, privacy, safety and security.

The user requirements documented in this report will provide input to the system requirements and system specifications that will be derived by the MOSES developers in Task 2.4.

In this report, the following MOSES innovations are addressed: the innovative feeder vessel, the robotic container-handling system, the autonomous tugboats, the automated mooring and docking, and the matchmaking and logistics collaboration platform. The requirements for the MOSES Recharging Station will be treated separately in Task 5.2 ‘Recharging Station design and feasibility study’. Each MOSES innovation is described in Chapter 3 by using an “Innovation Identification Card” (Table 1).

Table 1 Innovation Identification Card.

ID	Name <Name of the Innovation>
Description	Short description of the innovation, including a brief mission statement.
Objectives	The objectives of the project that this innovation addresses.
Setting / context	A short description of the expected operational context.
MOSES TRL	The target Technology Readiness Level (TRL) during the development in the MOSES project.

Requirements are typically classified as Functional and Non-Functional (see [5], [6], [7, p. 291]). Functional requirements describe the different functions and tasks the system should accomplish, i.e. what the system should be able to do. According to Adams [8], functional requirements are also associated with the transformation of inputs to outputs. Non-Functional requirements describe qualities of the system, including connectivity, transportability, reusability, reliability, and maintainability, which support the implementation of the functions in a way that is both acceptable and usable by the user. Adams [8] states that non-functional requirements are associated with the entire system and can also be interacting/competing.

Constraints may be considered as an additional class of requirements. They are boundaries that limit the solution space, and which are outside the control of the designer/developer (e.g., compliance with standards and regulatory requirements, authorizations, and process constraints). For example, the innovative vessels conceptualized in MOSES (i.e. innovative feeder) must comply with the relevant international regulations by the International Maritime Organization (IMO) such as those arising from the Safety Of Life At Sea (SOLAS) and the prevention of Maritime Pollution (MARPOL) as well as other national regulation and class requirements. Therefore, the MOSES innovations will comply with all relevant regulations and standards (or show equivalence in case of non-compliance) and therefore this report does not involve listing such mandatory requirements. Such requirements will be incorporated in the system specification task (Task 2.4).

Typically, requirements are expressed as “shall-statements” that document the functions, qualities, and constraints of a system [9]. Priorities may also be identified by using additional keywords, such as “should” or “may” [10]. In MOSES, several parameters are applied for documenting User Requirements in a structured and formalized way that will enable traceability and level of achievement. These parameters include Unique ID, Classification, Prioritization and Dependency (see Table 2 for a complete overview).

Table 2 User Requirements Template.

Attribute	Description
User Requirement ID	A unique ID of the requirement, with the following format. <Innovation>_ <ascending enumeration of the requirement>
Requirement type	A classification of the requirement to functional and non-functional (F or NF).
Requirement class	A classification of the requirement to a specific category in order to make clear the contribution to the objectives of the project. The classes are environmental, technical, safety, environmental, market and societal.
Title	Formal statement of the requirement.
Description	Short description of the requirement.
Priority	Each requirement is prioritized for implementation to distinguish between absolutely necessary requirements and optional requirements. The priority levels are: must, should, could.
Dependency	ID of requirement whose implementation depends on the requirement described.

2. MOSES Innovations description

2.1 Innovative Feeder Vessel

Table 3 Innovative Feeder Vessel ID Card.

FV	Innovative Feeder Vessel
Description	The MOSES Innovative Feeder Vessel is a low-capacity container feeder vessel equipped with a highly automated loading/unloading arrangement (see below the Robotic Container-Handling System) and environmentally sustainable propulsion in conjunction with the MOSES Recharging Station. The vessel will be designed considering the following time scales: • Short term design: hybrid electric, automated functionalities, improved environmental footprint • Long term design: automated functionalities, environmentally neutral, potentially fully autonomous navigation, potential for simultaneous transportation of containers and passengers. The main mission of the vessel will be to transport containers (and potentially passengers) from large container terminals (DSS ports) to small ports with no container handling infrastructure.
Objectives	• Decongest large container terminals by transferring a substantial part of the land-based transhipment of containers to nearby small ports that are close to the final destination. • Integration of small ports without specialized container loading/unloading and bunkering infrastructure into the container supply chain. • Provide cost-effective transportation alternative to land-based transportation modes (road, rail) and transporting container trucks with Roll-on Roll-off Passenger Ferries (RoPax).
Setting/ context	The innovative feeder will operate in Short Sea Shipping (SSS) routes between large container terminals and small ports in the vicinity. In both large and small ports, it will use its own equipment for loading/unloading containers. The benefit for the large ports is that gantry cranes with high operational cost will not need to be used, while for the small ports the feeder will be able to load/unload without any additional infrastructure (i.e. loading/unloading directly to/from container trucks). Furthermore, the feeder will be able to make multiple small port calls in one journey. Finally, autonomous operation of the feeder vessel between the ports will be examined in the framework of a feasibility study.
MOSES TRL	Level 5 to Level 6

2.2 Robotic Container-Handling System

Table 4 Robotic Container-Handling System ID Card.

FV-RCH	Robotic Container-Handling System
Description	The MOSES robotic container-handling system will be developed in such a way that it (finally) will fit on the MOSES innovative feeder vessel. It will be designed as a fully self-sufficient system that does not need any local help except a quay for berthing and for loading/unloading the containers. It will make use of a MacGregor GLE electric Variable Frequency Drive (VFD) container crane, equipped with an active rotating Swivel and Spreader, to have a reduced environmental footprint. Computer vision and machine learning algorithms will allow the system to sense its surroundings and detect obstacles in order to operate safely. The main mission of the container-handling system will be to load/unload containers to/from the innovative feeder vessel in a (semi)autonomous manner, i.e. without needing a human operator onboard the vessel.
Objectives	Integration of small ports, without specialized container loading/unloading infrastructure, into the container supply chain.
Setting/ context	The system will be able to conduct container-handling (semi)autonomously, coupled with a human operator who will supervise the operation from a shore control station and remain in the loop to intervene if needed. The communication with the Port Authority Control will also be mediated by the remote operator. The MacGregor GLE Crane, which will be the basis for the system, has 25-100 t hoisting capacity, 19-50 m/min hoisting speed and 2—42 m outreach.
MOSES TRL	Level 5

2.3 Autonomous Tugboats

Table 5 Autonomous Tugboats ID Card.

AT	MOSES Autonomous Tugboats
Description	The MOSES Autonomous Tugboats will be highly automated tugboats that will operate collaboratively in a swarm configuration. The tugboats will be fitted with state-of-the-art sensors to enable autonomous navigation (payload, LIDAR, accelerometers, differential GNSS) and collision avoidance (swath multi-beam sonar for seabed mapping). The tugboat swarm will be able to make real-time decisions and adapt to a dynamic environment. Furthermore, the tugboats will be designed to collaborate and exchange information with the MOSES auto-docking system. Tugboats are envisioned with environmentally sustainable propulsion systems considering their operational profile,. To this end the MOSES Recharging Station shall be also considered. The main mission of the tugboats will be to manoeuvre and dock large containerships in large container terminals (DSS Ports).
Objectives	• Reduce manoeuvring and docking time of large containerships in large container terminals. • Improve operational safety, efficiency, and environmental impact of the manoeuvring and docking process in large container terminals.
Setting/ context	The tugboats will operate as a fully autonomous swarm (number of units will depend on the size of the large containership) to manoeuvre and align the large containership to the dock by offsetting its course and velocity using micro-adjustments. The tugboats will be able to accomplish their mission combined with either conventional mooring services or in collaboration with the MOSES auto-docking system (i.e. automated rope free mooring). The automated manoeuvring and docking process is monitored by the tugboat operator with the MOSES Autonomous Tugboat Control Station and an effective communication link is established with the Port Authority Control that effectively integrates this automated process within the normal operation of the port.
MOSES TRL	Level 6

2.4 Auto-Docking

Table 6 Auto-Docking System ID Card.

AD	Auto-Docking
Description	The MOSES Auto-Docking system is an automated, vacuum-based mooring system, which is based on the existing AutoMoor™ system of Trelleborg. The existing system will be re-engineered to include an intelligence layer, coupled with sensors for situational awareness, to effectively collaborate with the MOSES Autonomous Tugboats. The main mission of the system will be to manage the safe docking and mooring of large vessels in an automated way. For the MOSES project the docking and mooring of large containership in large terminal are targeted.
Objectives	• Develop an autonomous, easy to adapt and safe method for the docking of any kind of vessel, targeting mainly at large containerships. • Improve operational efficiency, environmental impact and accuracy in docking.
Setting/ context	The auto-docking system will cooperate with the MOSES autonomous tugboats by enabling a shared intelligence while sharing sensor data information to influence the kinematics of the tugboats and of the large containership.
MOSES TRL	Level 6

2.5 Matchmaking Logistics Platform

Table 7 Matchmaking Logistics Platform ID Card.

MLP	Matchmaking Logistics Platform
Description	The Matchmaking Logistics Platform is a cloud-based digital marketplace for the horizontal collaboration among shippers, freight forwarders and logistics service providers. Its users will be able to communicate information related to transport orders (including but not limited to prospective cargo volumes, origin/destination location and requested time of arrival) and empty containers to the platform. The containers and cargo will be aggregated over multiple shippers and matched with suitable SSS transport options. The platform will include an intuitive graphical user interface that is tailored to the needs of all involved stakeholders. It will also offer user-friendly visualisation options and tools for further data analysis, such as scenario-building capabilities for the examination, in terms of cost and CO_2 emissions, of different transport mode combinations. The main mission of the matchmaking platform will be to facilitate balancing demand and supply, as well as backhaul traffic, to sustain the Short Sea Shipping (SSS) services between large container terminals and small ports in the vicinity.
Objectives	• Optimise SSS cargo streams in order to maximize demand. • Effectively handle changing freight flows in order to balance backhaul traffic. • Achieve optimal cargo consolidation and pooling. • Boost just-in-time connections among transport modes.
Setting / context	One of the main barriers inhibiting quick take-up of ICT-applications in multimodal transport is the lack of effective and efficient information connectivity among and between modes within a complex environment that involves many different actors, such as insufficient information available to users, absence of integrated management systems and incompatibility between existing ICT-systems. Even though shared planning and joint decision making can positively affect the performance of road haulage and SSS firms, their individual competitive strategies prevent cooperation. Therefore, currently, there exists no single dominant coordination platform that offers, to a wide userbase, services that match cargo owners' demand with ship operators' cargo carrying capacity in the shipping sector.
MOSES TRL	Level 5

3. Research Trends

3.1 Introduction

This Chapter contains a review of state-of-the-art technologies that are relevant to the MOSES innovations. The review aims to provide an understanding of the existing systems and their operation, as well as to identify the main challenges and inform the development of the requirements in Chapter 7.

3.2 Innovative Feeder Vessel

Containerships are mainly separated into different categories depending on their size and transportation capacity, which is measured in TEUs (i.e. twenty-foot equivalent unit). These two characteristics determine whether they are suitable for specific routes and ports. A 'feeder' is a ship type that actually "feeds" the hub ports in which transatlantic and ocean liners stop. Only the smallest ships have the ability to connect large hub ports with smaller ports, which transatlantic liners do not visit, because of their size. That is the reason for the existence of feeders which range from several hundred TEUs to 3000 TEUs [11]. This size of vessel is the most likely to have cargo cranes on board, in order to handle TEUs [12].

SSS container feeders are usually single hull and diesel-powered vessels, able to unload their cargo with their own cranes. Their service speed typically does not exceed 20 knots nor does their capacity exceed 1000 TEUs.

Feeders in general are mainly used in the short-sea trades, short-haul operations and in draught-restricted ports. As stated by [13]: "Feeders distribute the TEUs brought to regional load centres or hub ports by deep-sea services and carry coastal traffic". They are small ships that normally operate between small container ports or collect their cargo from small ports, drop it off at large ports for transhipment on bigger containerships and dispense containers from a large port to smaller regional ports [12].

The role of feeders is crucial in global shipping. They are helpful in many different ways, as they contribute to the increase of port range and service frequency, the elimination of port restrictions, the decrease of air pollution in general and the reduction of inland traffic. The evolution of mega containerships over the years led to decreased transportation costs. However, the functionality of Feeders is irreplaceable, as the bigger ships cannot reach specific ports due to their size (e.g. draft or length limitations) or would waste too much time if they did so. In addition, generally large containerships avoid operations in small ports with low demand. In summary, feeder service means a service where containers are transported by a feeder vessel from the regional port to the hub port and vice versa [14].

The low level of automation, the absence of sustainable propulsion and the fact that container feeder vessels trades are still based on traditional port and transit operation methods leaves room for future improvement in terms of cargo handling capabilities and energy efficiency aspects [15]. There are no references on financially advantageous solutions for the SSS area regarding sustainable propulsion systems, but there are ongoing projects making effort to establish solutions on purely electric battery or fuel cell-based configurations or on the use of renewable fuels (biofuels).

There are projects in progress for autonomous SSS feeder vessels, that involve single hull designs either with conventional on-board cranes, such as Samskip's Seashuttle (Figure 2), or without cranes, such as DNVGL's ReVolt (Figure 3) and Kongsberg's Yara Birkeland (Figure 4). Yara Birkeland has already been delivered to its owners and its use is intended to help the moving of transport from road to sea in order to reduce noise, NOx and CO2 emissions [16].

Figure 2 Samskip's Seashuttle [17].

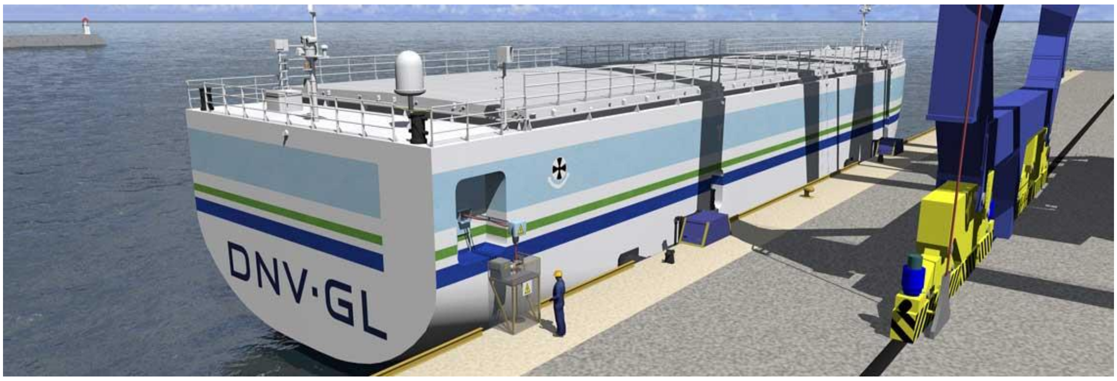


Figure 3 DNVGL's ReVolt [18].

Figure 4 Kongsberg's Yara Birkeland [19].

These vessels are highly depending on the port's infrastructures or need large infrastructural investments as shore-based equipment (e.g. Yara Birkeland). The Cargo Flow concept (Seaway Innovations and Fluxxworks) uses a larger fully automated Ro-Ro vessel (CargoCat -Figure 5) and a smaller vessel which operates as a feeder (CargoKitten) with autonomous container loading and discharging capabilities [20]. The Cargo Ferry concept (NorLines) is a Lift- on/Lift-off (LoLo) cellular container ship with conventional onboard cranes, hybrid propulsion with the ability to use shore power that aims to replace container transport with trucks to and from coastal Norwegian towns [21].

Figure 5 CargoCat [20].

3.2.1 Identified Challenges

To launch a successful innovation, there are some standards to be achieved and challenges to overcome. The innovative feeder vessel should be designed to be efficient in terms of speed, energy consumption, capacity, and cargo handling. In addition, it should be optimized for the characteristics of the intended market segment and area of operations. Specifically, a key challenge to overcome is the achievement of a reduced environmental footprint in all phases of operation (e.g. passage, port operations) compared to other modes of transport. Aiming at a high level of autonomy in terms of navigation is also a challenge to be considered given the relative coastal and short sea operation of the ship. Surveillance and remote control of the ship shall be accounted for in that case. As service ports may not have the same or a high level of infrastructures, the feeder vessel shall be designed to not depend (at least in a high level) from the existing port facilities both for bunkering, cargo handling and port manoeuvrability.

3.3 Robotic Container-Handling System

A major characteristic of a container ship is whether it has cranes installed for handling its cargo or not. The ships that have cargo cranes are called geared (Figure 6, Figure 7). This kind of Feeder ships have the ability to handle cargo on their own without help from the ports they visit. However, they have some disadvantages as well. The cargo handling cranes require an additional investment and also incur greater recurring expenses, such as maintenance and fuel costs [12].

Figure 6: A geared feeder ship [22].

Figure 7 The small Feeder vessel "Mary Artica" with cargo handling cranes (588 TEU) [23].

The gear equipment includes loading booms as well as crane hooks, winches and ropes, with which the cargo can be easily brought ashore [24]. Instead of the rotary cranes, some geared ships have gantry cranes installed. These cranes, specialized for handling containers, are able to roll forward and aft on rails. In addition to the drawbacks stated above, such as the increased capital expense and maintenance costs, these cranes generally load and discharge containers at a much slower speed rate than the shore side counterparts [11].

About sixty percent of vessels with a capacity between 1,500–2,499 TEU usually have their own cranes. Approximately one out of three very small ships (from 100-499 TEU) are geared as well [12].

Currently, MacGregor K-cranes, which are bulk cranes, can perform autonomous unloading. These cranes, with the help of sensor data, specify the position of pick-up and release of the cargo and work autonomously, although a supervisor is always on the bridge during the operation. Various sub functions are also provided by the cranes, such as anti-pendulation, anti-collision, material distribution scanning, self- learning grab filling functions.

The above-mentioned functions use LIDARS, Inertial Measurement Units (IMUs), load cells and pressure sensors to measure the cargo, swing weight and positions. In addition, cameras are used in order to help the supervision of the operation. Planning function calculations are performed in order to coordinate the simultaneous function of several cranes, so that accidents and delays are avoided. Also, ARC (Active Rotation Control) function for power swivels is used to dampen the rotational swing which occurs during the handling of containers or similar cargo. Another function used is the Active Pendulation Control (APC) function for ship motion compensation, which is a 3D-heave function that cancels out the swing due to ship motion out at sea. Finally, reliable software tools that help in the construction of 3D-models have been developed recently. These can be used for task simulation or for situation awareness issues (e.g., Unity3D, Unity Technologies, San Francisco, CA, USA).

As stated above, some ports, which are termed feeder ports or outports, are not included in the normal service because they do not handle enough cargo to make this cost-effective, as the unloading/loading of cardo depends only on the means some type of container or general cargo vessels may have. However, to meet the requirements of the trade, cargo is accepted at outports and feeders are provided to transfer the cargo to a base port [13].

Some ports are so small that it is not worth developing container vessel handling infrastructure and in this way, they are served by geared container vessels or by general cargo vessels with some container capacity handled with mobile cranes [25].

3.3.1 Identified Challenges

In conclusion, there are several challenges penetrating the design and operation of a robotic container handing system. The speed of loading/unloading operations compared to a manual operated crane is a challenge for the time-efficiency of the system, whereas capability in operating in similar conditions is required for competitiveness. Picking up of TEUs in an autonomous way (based on a predefined list) shall be also carried out in an effective way. Furthermore, supervision and situational awareness shall be more enhanced to not downgrade safety, while gaining control of the system, either from a location onboard ship or from the port shall be taken into account. The need to consider ship motions to not disrupt its operability has been also noticed. Maintenance issues, a challenge that exists also for the manual systems, are found to be more critical for automated systems.

3.4 Autonomous tugboats Swarm Operation

3.4.1 Manual operation

Manually operating tugboats usually assist a large ship to perform manoeuvres inside harbour areas, as well as during her docking process. In most cases this is a complex process that requires the involvement of several human operators: a) with good knowledge of navigational issues and b) a clear picture of the port's landscape (e.g. depth variations etc.) and requires also specific environmental conditions (e.g. port currents), in order to guarantee maximum safety and avoid possible accidents and collisions with adjacent bodies.

The main responsibilities of the tugboats that participate in harbour operations are the following:

- Assist the vessel in (un)docking manoeuvres;
- Assist the vessel in the turn in a limited space;
- Offer the necessary support in order for the vessel to counteract the force of the wind, waves or currents.

For these reasons, tugboats that operate inside ports should be compact, having high manoeuvrability and great power.

3.4.2 Autonomous operation

Lately, there have been several projects that have developed and tested tugboat concepts with various degrees of autonomy. Remote control of marine vessels can be thought of as a first step towards the development of vessel autonomy. In this respect, Rolls-Royce demonstrated in 2017 a concept of a remotely operated tugboat from Svitzer that was equipped with a Dynamic Positioning System (DPS) and sensors that provided the remote operator with adequate situational awareness [26]. In addition, the RAmora concept is a tugboat (Figure 8) that is remotely operated from a command tugboat in a master-slave configuration that includes live 360^{o} video feed and real-time electronic position-sensing offering situational awareness to the remote operator [27]. At last, in 2019, Keppel announced a project for developing an autonomous tugboat that will operate in Singapore and will involve the retrofit of an existing 32m tugboat with numerous systems, such as position manoeuvring, digital pilot vision, and collision detection and avoidance functions [28]. Initially the plan was to be delivered during the 4th quarter of 2020. In fact, autonomous harbour tugs are already being put to the test in Singapore, where authorities hope to establish the technological infrastructure to enable fully autonomous ship operations.

Figure 8 The Ramora tugboat concept [27].

Autonomous vehicles (AVs) are capable of sensing its environment and moving safely with little or no human input and/or interference. Although nowadays AVs do not constitute a significant portion of many real-world applications, a strong effort is under way to introduce them in road traffic, manoeuvring, path planning, etc ones. since the routing decisions made by those vehicles have a strong impact on the congestion and efficiency of the applications. In contrast to traditional vehicles, AVs utilize a variety of sensors: LIDAR, radar, sonar, GPS and inertial measurement units to perceive their surroundings while advanced control systems interpret sensory information in order to identify appropriate decisions and navigation paths, as well as obstacles and relevant signage.

The primary means of the development of the control system of AVs is through the utilization of Artificial Intelligence (AI) methods in order to let the vehicle control each of the other autonomous systems and processes. In the literature, a variety of different aspects of multiple autonomous vehicles have been extensively utilized, studied and evaluated.

Within the same context, autonomous operation of tugboats faces various challenges in relation to the inherent complexity of the automation-related systems and the establishment of communication/control among the autonomous tugboats that are meant to operate in a swarm formulation. Such communication would undoubtedly cause an increase in computational overheads and would certainly complicate condition monitoring and fault detection processes. The application of autonomous functions regarding the operation of tugboats is considered as a prime priority for the relevant harbour tugboat industry, since the development of such concepts that will operate in limited spaces is subject to national law directives, bypassing any existing international obligations.

In terms of swarm behaviour of autonomous vehicles, a number of rewarding studies have been carried out in recent years, and some useful outcomes are briefly presented below.

3.4.3 Swarm Behaviours

Floreano and Mattiussi [29] described that, in the swarm robotics domain, individual robots exhibit a behaviour that is based on a local rule set which can range from a simple reactive mapping between sensor inputs and actuator outputs to elaborate local algorithms. Typically, these local behaviours incorporate interactions with the physical world, including the environment and other robots. Each interaction consists of reading and interpreting the sensory data, processing this data, and driving the actuators accordingly. Such a sequence of interactions is defined as basic behaviour that is repeatedly executed, either indefinitely or until a desired state is reached.

Collective Localization

Collective localization allows the robots in the swarm to find their position and orientation relative to each other via establishment of a local coordination system throughout the swarm.

Fox et al. [30] presented a belief-based approach for collaborative multi-robot localization. It fuses localization information from different sources, such as odometry[1], environment measurements, and mutual robot detections by combining visual and range sensors. This allows to improve the robots' perception of the environment by using a data-based detection model employing a maximum likelihood estimator. Experiments demonstrate that a team of robots is superior in localization (position information) compared to single robots with a relatively small communication overhead.

[1] Odometry is the use of data from motion sensors to estimate change in position over time.

Kurazume and Hirose [31] propose the method of cooperative positioning using robots as landmarks. There are two groups of robots that move alternatingly while using the other, stationary group as localization reference. An increased number of robots also increases the redundancy of position information. With the weighted least square method this redundancy decreases the localization error. The authors perform experiments where the robots use range sensors to measure their respective positions. Results show that this localization method performs better than the dead reckoning method including environments with uneven terrain.

Collective Perception

Collective perception combines the data locally sensed by the robots in the swarm into a big picture. It allows the swarm to make collective decisions in an informed way, e.g., to classify objects reliably, allocate an appropriate fraction of robots to a specific task, or to determine the optimal solution to a global problem.

Olfati-Saber and Jalalkamali [32] present a theoretic framework that employs mobility to improve the information sensed by the swarm using the Kalman-consensus filter. It is employed to track a target with a swarm of agents. Each agent tries to improve its sensing while avoiding collisions with the others. Simulations show that this solution can effectively track linear and non-linear manoeuvrable targets.

Mazdin and Rinner [33] present a method for simultaneous coverage of surfaces with a swarm of robots. This method assigns robots to different viewpoints in order to allow effective 3D reconstruction of objects. Simulation results show that this method is able to coordinate the robots while minimizing the mission duration and maximizing the coverage quality.

Synchronization

Synchronization aligns frequency and phase of oscillators of the robots in the swarm. Thereby, the robots have a common understanding of time which allows them to perform actions synchronously.

Hartbauer and Römer [34] employ synchronized oscillators as a communication and navigation system. In a synchronized system, robots at a target area increase their frequency and thereby produce phase waves in the swarm that can be used by the robots to perform wave-front navigation, i.e., travel toward higher frequencies. The authors analyse the robustness of the system by simulating up to 300 robots. The results show that this communication system is robust to changes in signal strength, signalling period length, and communication obstacles. Nevertheless, the signalling period is an important parameter to be fit to the scenario. They conclude that pulse-coupled oscillator synchronization is especially suited for swarms of robots as it has low hardware requirements in terms of communication range and processing power.

Perez-Diaz et al. [35] perform a case study to analyse how motion and sensing capabilities influence the synchronization capabilities of a robot swarm. By altering the field of interaction (e.g., camera field of view) and the speed at which the robots travel, the emergence of synchrony can be influenced. The robot speed influences the time until synchrony is reached whereas a narrow field of interaction results in a low degree of synchronization. Furthermore, high robot densities limit the synchronization possibility due to signal occlusion and robot collisions.

Applications

In the CoCoRo (Collective Cognitive Robotics) project [36] a swarm of 41 heterogeneous UUVs has been developed. There are three types of vehicles: A base station unmanned surface vehicle /autonomous swarm robotic boat (USV), an exploration unmanned underwater vehicle (UUV), and a UUV for relaying information between the explorers and the base station. Communication is performed with sonar and electric fields. The main applications envisioned are environmental monitoring, measuring water pollution and effects of global warming.

V2X Communication

V2X (vehicle-to-everything) communication is defined to be the communication of a vehicle with internal and external environments via wireless technologies. The 4 fundamental interactions of the V2X is the vehicle-to-sensor on board (V2S), the vehicle-to-vehicle (V2V), the vehicle-to-road infrastructure (V2R), and the vehicle-to-Internet (V2I). The Internet of Vehicles (IoV), which is an emerging notion for a “dynamic mobile communication system” which will facilitate the acquisition, process, secure transmission, and computation of data, is based on the aforementioned interactions to establish its multi-level flow of data.

In V2V communications, data generated by a vehicle are securely and effectively circulated to other vehicles in the vicinity or far away vehicles via message hops in a vehicular ad hoc network (VANET). Wu et al. [37] present their research on V2V communication using Dedicated short-range communications (DSRC) at 5.9 GHz, highlighting its effectiveness in supporting the safety of vehicular applications. Ihara et al. [38]in their work researched the Dynamic Spectrum Access (DSA) over TV white space spectrum (54-698 MHz), and managed to establish an autonomous cognitive distributed network for the V2V.

Lately we have seen more and more companies implementing modules and solutions for connecting their vehicles to the Internet and exchange data (V2I). These solutions can either be labelled as “brought-in connectivity”, where the manufacturer provides a medium for accepting tethering 3G/4G smart-phones from the driver or the passengers so as the car accesses the Internet, or “built-in connectivity” where the manufacturer provides integrated cellular connectivity to the Internet. For vehicles that offer none of the previous two methods, researchers have proposed outdoor WiFi for internet access, as WiFi hotspots can be found nearly everywhere in an urban environment. The challenge that WiFi faces is that a vehicle's mobility gives a very short time for connection establishment which will greatly affect the amount of data that could be transmitted in one connection. Amjad et al. [39] in their work propose NB-IoT (Narrowband IoT) as a wireless technology to deal with connectivity and low latency issues in V2I scenarios.

Finally, in V2R Lu et al. [40] in their research mention that DSRC/WAVE is a technology that is expected to play an important role, while Chauhan et al. [41] in their work present a solution based on 5G to establish communication between a vehicle and the infrastructure. Kavuri et al. [42] used the NB-IoT technology for communication between a vessel and the infrastructure.

3.4.4 Identified challenges

The performed review revealed that there is much room for improving the existing technology regarding autonomous tugboats operations. The need for a remote-control station for the continuous monitoring of the status of the autonomous tugboats and the gain of their control either for operational or safety reasons is an important element. One challenge is the synchronization of the autonomous tugboats and the ability to operate as a swarm as well as the swarm to be able to cooperate with other manually or remoted controlled tugboats. Another challenge is the cooperation between the autonomous tugboats swarm, the vessel and port personnel as continuous information for the correct docking operations is interchanged and the ability to adapt to the deviation of the operational conditions. Moreover, the secure connectivity between the autonomous tugboats, the remote-control station and the vessel is needed. Due to the proximity of the operations to the port area, connectivity issues (4G/5G or wireless) are not considered a challenge. The presence of a totally unmanned tugboat poses several difficulties in terms of both practical operations (e.g. setting up the towing arrangement) and from command and situation awareness viewpoint.

3.5 Docking and mooring systems

3.5.1 Manual docking/mooring system

Mooring refers to the procedure of fastening the ship with a fixed or a floating object in order to held them together for various ship (un)loading operations. The ordinary (manual) procedure demands a high degree of teamwork both from ship's and port's crew. It is very significant that all members of the crew involved in this operation are properly trained and equipped, whilst a clear understanding of their duties is crucial.

For a successful mooring operation, a relevant plan has to be made in advance. The latter should have been developed and agreed prior to the vessel's arrival, whereas all responsibilities of crew and officers must have been explained.

The aforementioned show that the traditional mooring procedure is a time-consuming task that could lead to unforeseen events (e.g. breaking of lashing ropes) especially in case of extreme weather conditions.

3.5.2 Automated docking/mooring system

In today's complex global landscape, many ports and container terminals search for automated solutions in order to meet the increasing demands on reducing the delays encountered (more than 45% of container ships currently spend more than 8 hours upon arrival) and eliminate human error by removing the notion of "best guessing". The latter should be replaced by accurate and real-time decision-making procedures.

Safety of port operations is always regarded as a fundamental motivation for the development and introduction of such automated solutions since the adoption of automated mooring technologies will involve fewer employees during berthing operations.

Another benefit of the automated mooring solutions is that they reduce downtime which is caused by passing ship movements. This is a major drawback of mooring lines, as they cannot dampen ship motions resulting in interruption of the operations with a direct impact on cost in time and money due to delayed transfer. In addition, automated mooring infrastructure reduces both the time for a ship to berth, since the impact of the "human element" is limited, as well as increasing the operation window during berth leading to increased vessel throughput, less disruptions during (un)loading of container ships and, ultimately, an optimized facility.

3.5.3 Existing automated mooring technology

Trelleborg's *AutoMoor™ system*

Trelleborg has developed AutoMoor™ which is a rope-free automated mooring system that is capable of making berthing operations smarter, safer and more efficient in terms of cost in time and money (Figure 9). Through its new vacuum pads and passive damping technology, it facilitates the vessel's rapid and secure attachment. Its units are suitable for operating during a wide range of berthing and environmental conditions.

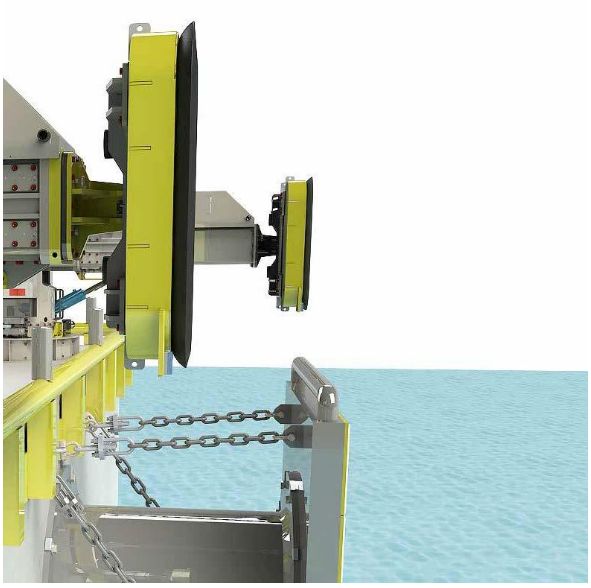


Figure 9 Trelleborg's AutoMoor™ system. Suitable for use in different sectors of the port industry [43].

AutoMoor™ uses technology that allows continuous monitoring of all mooring loads acting on the vessel at berth, while it provides live data to the operator in order to facilitate the optimization of the day-to-day port and terminal operations.

At this stage, AutoMoor™ has a moderate dependence on human action as certain functions are still controlled by a designated port operator. These include the confirmation and acknowledgement of a vessel's approach, the initiation of the mooring and de-mooring operations and the response in case where any alarm is raised which is related to violation of the mooring limits of operation.

A summary of the *AutoMoor™'s* benefits consists of the following:

- Improvement of the operational efficiency since the vessel can be moored in less than a minute and released upon departure in less than 30 seconds, increasing port throughput. Through the damping of peak mooring loads it ensures that port operations may continue safely in a greater variety of environmental conditions (diminished surge and sway motions as a result of the system's installation are depicted in Figure 10). Additionally, emissions in ports are reduced due to the quicker berthing procedure and the reduction of the reliance on the tugboats.
- Installation of Trelleborg's *AutoMoor™* system can minimize infrastructure costs since there is no need for wharf extensions or mooring dolphin[2]

[2] A mooring dolphin is an isolated marine structure for berthing and mooring of vessels with ropes, which effectively reduces the size of piers. In addition, they are commonly used near pier structures to control the transverse movement of berthed vessels [44].

investments for port terminal upgrades. It also makes breakwater infrastructure unnecessary lowering port and terminal investment requirements.

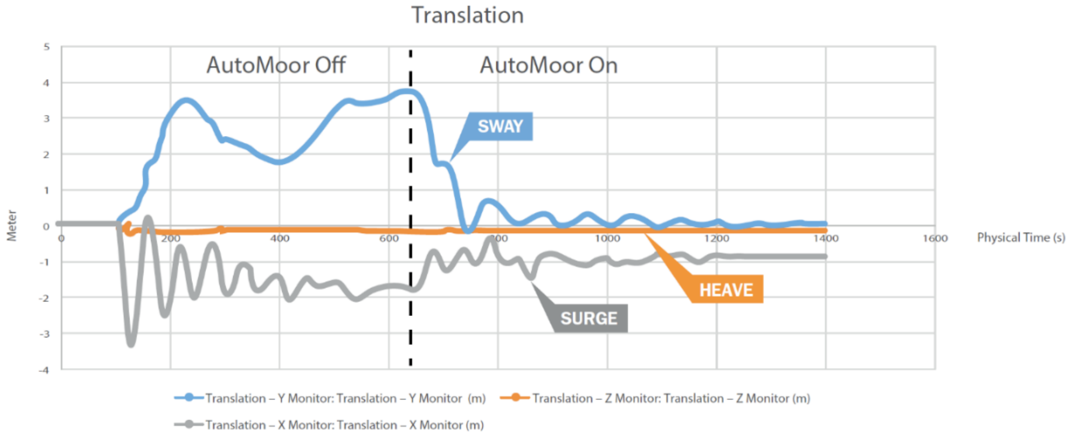


Figure 10 Impact of AutoMoor™ on vessel's motions [45].

Cavotec's MoorMaster™

Cavotec's MoorMaster™ is another automated mooring system that enables vacuum pads for safe berth and release of ships within seconds (Figure 11). Cavotec relies on the vacuum technology provided by Busch through the usage of Mink claw vacuum pumps [46]. The Mink claw vacuum pumps have the task of applying immediate high vacuum when the suction pads attach to the ship's hull, providing a strong seal with which the vessel can be drawn to the quay and held securely

Moreover, the embedded Active Control™ technology offers the possibility to monitor each variable of the system, from position to forces and weather conditions, in order to calculate the optional response instantly.

Figure 11 Cavotec's MoorMaster™ [47].

In general, as with Trelleborg's system, MoorMaster™ improves port's infrastructure and operational efficiency through faster turnaround times and more ship calls, resulting in improved productivity. It also contributes to reducing emissions coming from tugboats and the vessels' engines more than 90%.

Mampaey's Intelligent Dock Locking System (IDL)

Technologies other than vacuum pads are employed as well in order to facilitate the automated mooring of marine vessels. More specifically, Mampaey has developed an automated magnetic mooring system that enables faster and safer mooring procedures [48]. IDL can perform automated mooring operations, whilst it offers constant real-time monitoring and control. Further, it is capable of withstanding the worst motions and forces caused by external influences like passing vessel motions, wind and currents.

MACGREGOR's Automated Mooring System

MacGregor's system is based on a seven-axis robotic arm that takes the mooring ropes with loops and wraps them around bollards on the dock [49]. Additionally, it has built-in movement compensation and track planning that inform the inform the robotic arm where each bollard is located. When the loop has been placed around the bollard, load-controlled winches will hold the vessel in the correct position against the quay. The fact that the robotic arm has a range of 21 meters, is its major drawback, especially when it is needed to moor a very large container ship.

3.5.4 Identified challenges

The conducted review revealed that the existing mooring operations are mainly performed either by adopting a manual process with the use of mooring ropes, or by enabling existing automated mooring solutions that require some level of human intervention and are mainly targeted at large vessels. A challenge that comes out and should be met by novel technologies is to be able to provide information to the vessel and/or the employed tugboats in case the operating parameters are violated. Reliability and availability and ease of installation of the system are also considered important. Additionally, automated mooring systems should be able to adapt to smaller ports and vessels as well, meaning that more compact systems should be designed. Moreover, the ability to continuously monitor the system status through sensors is considered a necessary element for such highly automated systems.

3.6 Matchmaking Logistics Platform

3.6.1 Introduction

Moving goods from one place to another in freight transportation is a process where it is important to evaluate the shipping order, like the size or weight of the goods, and get a suitable offer from the carrier's side for on-time delivery. The usual trend for shippers until recently is to use brokerage companies to help secure capacity, negotiate rates and take care of the associated legal issues. However, due to the increasing cost and unavailability of transportation capacity in regional level led to the development of digital freight-matching platforms that connect all the stakeholders to maximize the efficiency of transportation. The last decade, several relevant platforms have been developed allowing shippers and carriers to exploit the best available opportunities in freight transportation. A list of the top-rated currently in the USA can be found in [50]. Examples of such innovative efforts within Europe consider the CargoStream platform for horizontal shippers' collaboration developed within Clusters 2.0 project, other respective data architectures introduced through NEXTRUST, AEOLIX and SELIS projects and the roadmaps issued by ALICE European Technology platform [51]. Details on the way a matching opportunity can be established through a digital platform are incorporated in the following paragraph.

During the identification stage of a possible collaboration between shippers and carriers, a match should be identified, and a business case is set up. For a collaboration to be successful, a matchmaking service must be established. In this way, a shipper may provide supply chain data to trustee companies which possess a database/platform comparing them with data of other shippers that are doing the same to find bundling opportunities. In this stage a variety of legal issues comes up, such as confidentiality, data security, data ownership, prevention of misuse and the competition law risk of (in)direct information exchange. In this initial phase of matchmaking, the trustee has an active role in finding possibilities to bundle freight flows.

The Trustee could have under market conditions a "contractual" agreement with the participants by offering its matchmaking service. However, as the trustee role is relatively new in the supply chain market and this role is funded by the EU project, the current set up of MOSES pilot cases do not have a contractual agreement in place. A matchmaking logistics platform will be developed instead, which will be the result of the collaborative work among academic and industrial partners.

In this aspect, a cloud based digital platform (marketplace) will be developed within WP6 of the MOSES project, which will employ an advanced matchmaking logic for all the involved stakeholders and tools for further analysis of data. The aforementioned logic will be based on Machine Learning algorithms that will allocate cargo in the best possible way. The matchmaking should ensure high load factors for the SSS for both direction of travels, implying cost reduction and lower environmental footprint. A specific module of the platform will be devoted to information exchange regarding empty containers, offering user-friendly visualisation options on the respective volumes and backhaul routes and offering suggestions for route optimisation using SSS legs based on (i) cost, (ii) CO2 emissions, (iii) their combination.

With respect to the match-making platform intelligence, dedicated state of the art data analytics algorithms for cargo stream optimization will be developed to support the management of logistics operations for SSS, aiming to identify potential additional SSS routes of seminal importance for better integration of local traffic to the current core TEN-T corridors.

Following the introductory paragraph, a thorough discussion is conducted concerning the current ICT trends in Multimodal Transport and Multimodal Transport Planning. The existing inadequacies of the aforementioned technologies and procedures are highlighted, as a way to emphasize the necessity of MOSES' advances in this field.

3.6.2 ICT Trends in Multimodal Transport

The evolution of the terminology that is used to describe aspects of multimodal transport reflects the trends in the freight logistics industry during the last twenty years [52]. Intermodal [53] transport is characterised by the use of the same transportation unit, co-modal [54] is focused on efficient capacity utilisation from the perspective of a single or a group of actors and synchromodal [55] emphasizes the near real-time responsiveness aspect.

Synchromodal services support a-modal booking and coordinate last-minute mode and routing decisions (switching) for each individual transport order within an optimised network of supply chains [56]. Synchromodality is considered [57] to be a step towards the vision of the Physical Internet; an open global logistic system founded on interconnectivity, through encapsulation, interfaces and protocols design [58]. However, according to [59], the two concepts appear to be detached, address different levels of abstraction and have diverging tendencies with respect to system and operations (de)centralisation [59].

Lucassen and Dogger [56] identified five key areas when implementing a synchromodal transport framework: cooperation and control, network and organisation design, infrastructure use, dynamics and the role of the shipper.

Despite the fact that Information and Communication Technology (ICT) solutions can provide real-time visibility through efficient data exchange and the required flexibility to react to unexpected changes during shipment, their uptake has been very slow. One of the main barriers inhibiting quick take-up of ICT applications in multimodal transport is the lack of effective and efficient information connectivity among and between modes within a complex environment that involves many different actors [60].

There are several freight exchange platforms aiming to optimise the load factor for road transport or provide rail and inland waterway alternatives to truck routes, such as MixMove, Cargocore and Haulage Exchange. Two of them were developed within the context of the EU-funded Horizon 2020 Clusters 2.0 project, namely Cargostream and the Cluster Community System (CluCS). The former is an independent pan-European horizontal collaboration platform. The latter's scope is contained within the geographical limits of each individual hub-and-spoke network and aims to support governance and operations through the efficient management of information, within the network nodes and in relation to the surrounding logistics nodes.

Conversely, in the shipping sector, there is currently no single dominant coordination platform that offers, to a wide userbase, services that match cargo owners' demand with ship operators' cargo carrying capacity [61], [62].

ICT will be useful towards the improvement of the competitiveness of SSS as part of the EU's effort to shift the freight modal split in favour of sea transport [63]. An elaborate review of the factors that have been affecting the performance, efficiency and sustainability of SSS is presented in [64]. Those that are related to technical and communication aspects include insufficient information available to users, absence of integrated management systems and incompatibility between existing ICT systems.

Even though shared planning and joint decision making can positively affect the performance, and despite the fact that formalised cooperation is required so that all actors are in control together [56], the individual competitive strategies of road haulage and SSS firms prevent cooperation [64].

According to [65], the lack of transparency and coordination between logistical chains is the main reason for the inefficiencies in sea transportation and port operations. Introducing an electronic freight marketplace would enable industrial cargo owners to transact directly with ship operators in real time, adapt their operations to the market and ensure optimised just-in-time connections. It would make freight transportation supply and demand transparently visible to system, serve as a market-clearing mechanism and allow centralised up-to-date communication that enables all system actors to optimise their own operations and simulate different scenarios [65].

The design of a synchromodal platform is described in [66] and [61], with the former focusing on the best possible combination of transport modes is selected for every transport order while minimising costs, delays, and CO_2 emissions and the latter on utilising contextual information in decision making.

3.6.3 Multimodal Transport Planning

Multimodal freight transport planning problems are categorised based on their time horizon in strategic, tactical and operational dimensions way/manner; the MOSES logistics platform is concerned with the last two and primarily with the latter. Operational problems can be grouped under Itinerary planning and resource management, which are methodologically addressed by using network flow optimisation techniques. The first one, itinerary replanning focuses on real-time optimisation of schedules and response to operational disturbance. The second, resource management, deals with allocating resources to customer orders and distributing them throughout the network, as well as the empty repositioning problem.

In the empty repositioning problem, future customer demand is unknown and the objective function is to minimize empty transportation as well as storage, stockout and substitution costs [67]. The current practice is to consider an environment in which a centralised decision maker determines repositioning decisions independently from routing decisions. It has been argued that the proper timing of repositioning is more important than deciding on the number of containers to be repositioned, and unbounded daily repositioning is the best strategy [68].

Because of the size and complexity of planning problems usually heuristics, decomposition and relaxation techniques are used [69]. It also remains a challenge to take into account the dynamic and stochastic aspects of planning problems. In addition, by considering both the forward supply chain of laden container flows and the backward supply chain of empty container flows in the network design [70], [71], more cost efficient and time saving solutions can be achieved [67], [72].

3.6.4 Identified Challenges

Table 8 lists the challenges that the matchmaking platform needs to address.

Table 8 Challenges per stakeholder relating to the development of the matchmaking platform.

Stakeholder	Needs
European Commission	Increase sea transport share
	Increase infrastructure utilisation
	Introduce added-value services
Shippers and Forwarders	Reduce logistics costs
	Shorten lead times
	Increase cargo volumes
	Increase reliability
Logistics Service Providers and Terminal Operators	Reduce waiting times
	Reduce logistics costs
	Reach wider client-base

4. Stakeholders analysis

4.1 Introduction

Several definitions can be found in literature for the entities characterized as stakeholders. According to the Project Management Body of knowledge Guide [73], a stakeholder is defined as an individual, group, or organisation that might affect, be affected by or perceive itself as affected by a decision, activity, or outcome of a project. Additionally, a stakeholder can be either internal or external to a project, where the former refers to the consortium members[3].

The European Commission (EC) has been pursuing a more user-oriented approach in Research and Technological Development (RTD) policymaking. To this end, the Green Paper on Innovation [74], highlighted the importance of involving end-users in research and development of new technologies as a crucial component of innovation. In 2008, a study conducted on behalf of the EC [75] highlighted several positive aspects of user involvement by analysing theoretical frameworks and experimental approaches focusing on the end-user involvement in innovation actions.

The importance of direct end-user involvement is also stressed in the H2020 - EU Framework Programme for Research and Innovation, as a priority regarding Societal Challenges. "…The active involvement of end-users is of high importance…" [76] while the H2020 - EU Framework Programme for Research and Innovation has called for "innovative solutions for safer… mobility" [77] in response to the societal challenges of Transport.

The involvement of end-users in all project phases (planning, design and validation of products) responds to the EC approach to citizens' involvement in decision-making processes. This contributes to the democratic process and increases citizens' awareness on innovation, research and development conducted by the EU. Moreover, such an approach allows for a high level of transparency and contributes to increased corporate social responsibility.

The EC aims to promote a direct dialogue between manufacturers, manufacturers and (intended) end-users, as a strategy to stimulate innovation and to overcome societal challenges at EU level. Stakeholder involvement through the MOSES project will ensure that the project's deliverables will be tailored to actual end-users needs. Consequently, manufacturing who will further develop, build and sell such products will increase their responsiveness to end-users/citizens' preferences and actual needs. By doing so, the project ensures that its products are highly competitive on the market. In this chapter, the stakeholder groups of MOSES are identified and

[3] The Project Advisory Board Members of MOSES are considered as external stakeholders due to the consulting nature of their role.

categorized. Then, each stakeholder's key role is described, focusing on the relevance to the MOSES project. The selection is rationalized via the identification of the potential interrelationships of the stakeholder groups and their individual points of interest for the MOSES project. The relevance of each stakeholder with MOSES is briefly described hereafter briefly and will be further elaborated in detail in D2.2 'MOSES use cases and scenarios'. Depending on the degree of how stakeholders are affected by the MOSES project, we identify two types of stakeholders:

- Primary stakeholders: are directly affected by the project, decisions or actions of the project.
- Secondary stakeholders: are indirectly affected by the project or decisions or actions of the project.

It is important to note that the distinction between primary and secondary stakeholders is not relevant to the importance of their feedback. The difference is that primary stakeholders have a direct stake in the implementation of the proposed innovations while secondary stakeholders are interested in the impact on the community, regulatory frameworks, science, etc.

4.2 Primary Stakeholders

In MOSES primary stakeholders are defined as all direct beneficiaries, primary operators, and end-users, as well as involved research institutions and academia that potentially could be affected by outcomes of MOSES or could exert influence on the project. In this paragraph, each identified stakeholder group is described focusing on the relevance to the innovations that are being developed in MOSES.

4.2.1 Container Terminal Operators

Description: Container port terminals are facilities where cargo containers are being transhipped between different cargo transportation vehicles. Such facilities offer cargo loading, unloading, and storage services to importers and exporters for large volumes of cargo. Operators in these terminals are responsible for the smooth and timely movement of cargo to minimize the time vehicles stay at port and ensure the safety of operations.

Relevance to MOSES: The autonomous tugboat swarms in collaboration with the MOSES automated docking scheme will permit faster (un)docking for large containerships. This is an advantage for Container Terminal Operators as they can extend the profitability of the terminal.

4.2.2 Tugboat operators

Description: Tugboats typically facilitate the movement of vessels that are unable to manoeuvre safely and efficiently due to heavy harbour traffic or other restrictions and limitations. The role of the tugboat operator requires a high degree of communication and precision between several actors (i.e. tugboat operators) operating collaboratively to fulfil this task.

Relevance to MOSES: MOSES innovations rely on a gamma of automated functions. As a result, changes are expected in manning requirements and personnel training that directly affect the tugboat operators.

4.2.3 Tugboat owners

Description: This stakeholder group refers to the individuals or companies that own the tugboats. In many cases, the interests of this group may conflict with tugboat operators, since the former seeks to invest in cost–effective solutions to maximize the generated profit from tugboat operations.

Relevance to MOSES: MOSES innovations offer effective management of the tugboat fleet while allowing for more flexible, accurate and cost-effective operations.

4.2.4 Ship owners

Description: This stakeholder group refers to the companies or individuals that own the assets (ships). Ship owners seek to maximize profits by various investments such as in building new ships and second-hand purchasing as well as by deploying their fleets optimally.

Relevance to MOSES: The innovations in MOSES target at increasing the demand for freight transportation by sea, thus, creating new business opportunities for ship owners.

4.2.5 Ship operators

Description: This stakeholder group refers to the actors who are responsible for the daily planning and execution of the assigned ship voyages. This includes planning and coordination, handling of the vessel, voyage calculations (e.g., demurrage), insurance, legal matters, as well as a plethora of administrative and financial tasks.

Relevance to MOSES: The innovations in MOSES expand the capabilities of vessels, allowing for greater flexibility in vessel operations, and innovative tools for ship operators. All MOSES innovations are relevant to this stakeholder group.

4.2.6 Logistics Providers

Description: This stakeholder group refers to the organisations that deliver logistics and supply chain management services, focusing on warehousing – and storage - and transportation operations. Services often extend beyond logistics to include value-added services related to the transportation of freight.

Relevance to MOSES: MOSES innovations offer improvement to the hub and port traffic by facilitating efficient delivery times and means of shipments, while reducing cost. This allows for effective use of resources and creates new trade routes expanding the existing logistics network. In addition, the availability to offer combined service of passenger and freight transport can increase the flexibility to service small ports with minimal, or lack of suitable infrastructure.

4.2.7 Information and Communication Technology System Providers

Description: ICT-system providers include a variety of companies, each with different expertise and area of operations. The ICT-tools that are being incorporated in MOSES require a variety of ICT-experts from different domains; indicatively data analytics, connectivity, and software development.

Relevance to MOSES: This stakeholder group is relevant for the implementation of the logistic collaboration platform, the manoeuvrability of the autonomous vessel, including the robotic crane, as well as for docking scheme with regards to the development of the required software tools and hardware modules. This stakeholder group also includes stakeholders relevant to data protection and GDPR related topics.

4.2.8 Port Authorities

Description: Handling different kinds of cargo from numerous ship types, poses a great challenge, especially for small ports which lack the infrastructure to support demanding loading and unloading procedures. Therefore, all ports are both defined and limited by the infrastructure and equipment they operate. For Port Authorities it is important that their port is capable to address the needs of the users following a structured and sound business model, that allows continuous and sustainable development. In addition, port authorities are involved in shipping traffic management.

Relevance to MOSES: Port Authorities represent a stakeholder group that is directly affected by the outputs of MOSES, since the innovative feeder vessel, equipped with the robotic arm, aims to reduce the need for advanced port infrastructure in SSS-ports. In addition, the match-making platform will be developed to support the management of logistics for SSS-ports and enhance their competitiveness.

4.3 Secondary Stakeholders

The secondary stakeholders are described as the stakeholder groups that are indirectly affected by the project. In effect, the term 'secondary stakeholders' refer to the stakeholder groups whose relationships with primary stakeholders are affected as a result of the project's outcomes. With regards to the MOSES project, the identified secondary stakeholder groups include:

4.3.1 Shipyards

Description: This stakeholder group is responsible for the construction of new vessels, as well as for conducting retrofitting activities.

Relevance to MOSES: MOSES innovations create emerging new market demands driven by the innovative new designs. However, MOSES innovations (e.g. Robotic Container-Handling System) can also be integrated into existing vessels, increasing demand for retrofitting the existing fleet.

4.3.2 Electric Propulsion and Control System Manufacturers

Description: This stakeholder group is involved in the manufacturing of the systems for electric propulsion of vessels.

Relevance to MOSES: The innovative feeder vessel is envisioned to rely on hybrid electric propulsion, creating new market demands that lead to the development of new integrated designs of electric engines, batteries, recharging units, etc. In addition to the development, such systems require to be controlled together as well, creating emerging markets in this field.

4.3.3 Small Port Adjacent economy

Description: This stakeholder group refers to the local economies near small ports whose economic activities are interconnected.

Relevance to MOSES: MOSES innovations promote the economic growth of local economies near small ports, allowing greater flexibility despite the lack of suitable infrastructure. Local economies can benefit from smooth transportation of cargo due to the availability of container-freight shipments. In addition, by combining passenger and cargo transportation the quality of service to local areas will increase by all means of safety, cost, time, frequency.

4.3.4 Classification societies

Description: A classification society is a non-governmental organisation in the shipping industry. The purpose of a classification society is to establish and maintain their own technical standards for construction and operation of marine vessels and offshore structures (Rules). The primary role of the society is to classify vessels and validate that their design and claims comply with their rules. This includes periodical surveys of ships.[77] Classification societies are licensed by flag states to survey and classify ships and issue certificates on their behalf. They classify and certify marine vessels and structures based on structural, design and safety standards, while ensuring compliance with international regulations; both during the construction and operational phase of a vessel's life cycle. [73]

Relevance to MOSES: Classification societies are identified as a stakeholder group, being indirectly involved with the design, construction, and operation of ships, such as the innovative feeder vessel and MOSES autonomous tugboats.

4.3.5 Marine/Port equipment supplier

Description: This stakeholder group envelopes a variety of companies, each with different products and area of operations. The innovations that are being developed in MOSES require different degrees of added infrastructure to operate.

Relevance to MOSES: Various MOSES innovations require upgrades on port infrastructure. Indicatively, the autonomous tugboat swarm requires upgrades on communications and wireless network infrastructure while the automated docking scheme requires the installation of new equipment.

4.3.6 Academia and R&D

Description: Academic stakeholders and research centres often have a more holistic view of the entire project since their multi-disciplinary expertise can be exploited to ensure cohesion o the project's proposed innovations. The ongoing state-of-art research directly affects universities and research centres by further enhancing their portfolio. Furthermore, MOSES innovative approach can facilitate curriculums to incorporate the knowledge acquired and, therefore, pass the knowledge to the students and researchers. To deliver applicable solutions, feedback from academic partners is of great value in projects like MOSES. In other words, academic and research groups studying marine engineering, ship automation technologies, information and communication sciences, and logistics as well as naval architects and ship designers can greatly benefit from the results of the project as well as contribute to MOSES' success.

Relevance to MOSES: The decisions of the research partners affect future innovations by setting foundations through knowledge and science and their expertise provides valuable feedback on the already deployed solutions. The innovative models and state-of-art solutions proposed in MOSES may interest relevant academic groups and research centres to facilitate their journey to everyday breakthroughs.

4.3.7 Regulatory and Standardisation Bodies

Description: This stakeholder group includes International Organisations and Associations of utmost importance to the innovations that are being developed in MOSES. These organisations are being funded by both governmental and industrial entities but are non-governmental and act solely for the advancement of the maritime industry. Indicative examples of such organisations include the International Maritime Organisation (IMO) and the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA).

Relevance to MOSES: The outputs of MOSES can be a valuable input to help Regulatory and Standardisation Bodies shape the future regulations and standards for automated vessels.

4.3.8 Coast Guards

Description: Every country's coast guard may have slight variation on assigned duties, but can be summarized in the following categories [78]: Search and Rescue operations (SAR), Maritime Law Enforcement (MLE), Aids to Navigation (ATON), Environmental Protection, Port security, and Military Readiness.

As an example, the assigned duties on the Hellenic Coast Guard are (as defined in the present legislation and specified within its institutional framework of operation): [79]

- Law enforcement at sea, ports and coastal areas. Prevention of illegal immigration. Surveillance of the sea, shipping, ports and borders.
- Search and rescue at sea (jointly with the Hellenic Air Force, which is responsible for search and rescue by air).
- Safety of navigation (except for lighthouses, racons and buoys, which are constructed, purchased, installed and maintained by the Hellenic Navy Lighthouse Service).
- Protection of the marine environment and response to marine pollution incidents.
- Provision of emergency maritime radio communication services.
- Port operations (excluding port pilots service).

Representation of Greece in international organisations and the EC on matters related to these roles.

Relevance to MOSES: The coast guard is the first external organisation that is being called when an accident occurs in the marine environment, while in case of an emergency, the coast guard is summoned to provide search and rescue aid in collaboration with local actors. Therefore, it is of paramount importance for the coast guard to be familiar with the technical layout as well as the behaviour of highly automated systems.

4.4 MOSES Stakeholders

The above analysis shows that the identified stakeholder groups include a wide range of actors with multi-disciplinary backgrounds, varying business interests, and different perspectives towards the proposed innovations of MOSES. In Figure 12, the primary stakeholders are marked with grey colour, while the secondary with yellow colour and the stakeholder groups are divided in the following three areas:

- The 'Operational Work Area' which is inhabited by the stakeholders who are involved in the operational aspects of the innovations.
- The 'Containing Business' referring to stakeholders who benefit from the innovations without being involved in their operation.
- The 'Wider Environment' that includes stakeholders who either exert influence or are being influenced by the MOSES innovations.

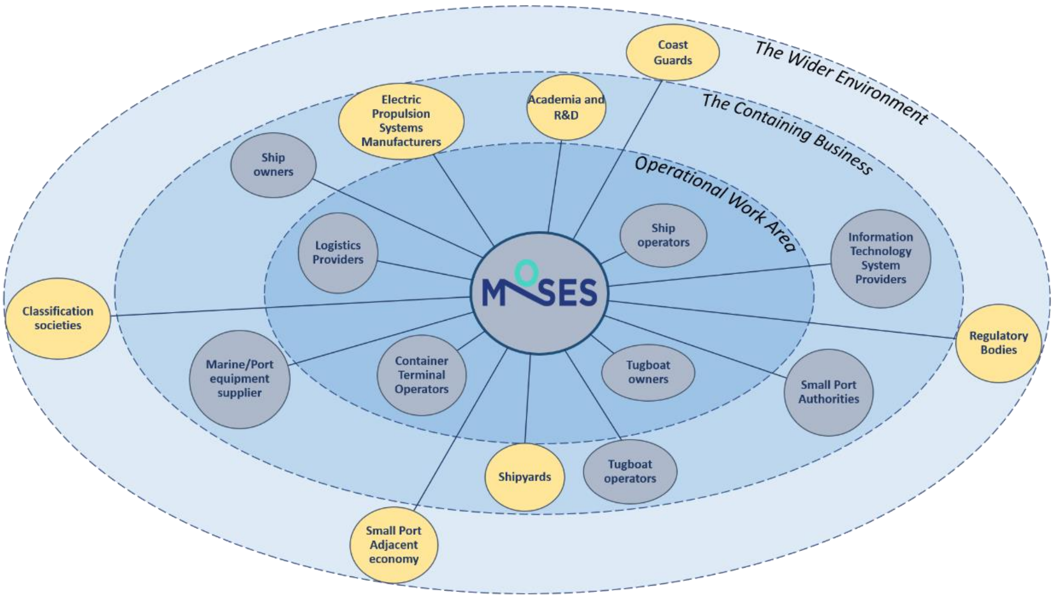


Figure 12 MOSES Stakeholder Universe.

The internal stakeholders (i.e. project beneficiaries) represent most of the stakeholder groups. To further complement the project's outreach, external stakeholders from all stakeholder groups are engaged as described in Chapter 6 'Stakeholder engagement'.

5. Stakeholder engagement

5.1 Introduction

In the first phase of the project, stakeholders were engaged in two ways. They were invited to participate in two online workshops and to fill out an online questionnaire. In this chapter, the specific activities are described in more detail and the main outcomes are reported.

5.2 Workshops

To ensure co-design of the requirements with the MOSES stakeholders' community, two online workshops were carried out and organized by Piraeus (PCT) and Valencia (VPF) respectively. The workshops were attended by participants specialised on the subjects of maritime and port operations as well as of freight transport, ICT, safety and security.

The workshop organised by Piraeus was attended by 56 participants from 26 different organisations. The meeting was attended by 30 members of the MOSES consortium and 26 externals to the MOSES consortium. In Figure 13 and Figure 14, we present the percentage distribution of the participants according to their relationship to the MOSES consortium and according to the organisation type they belong to.

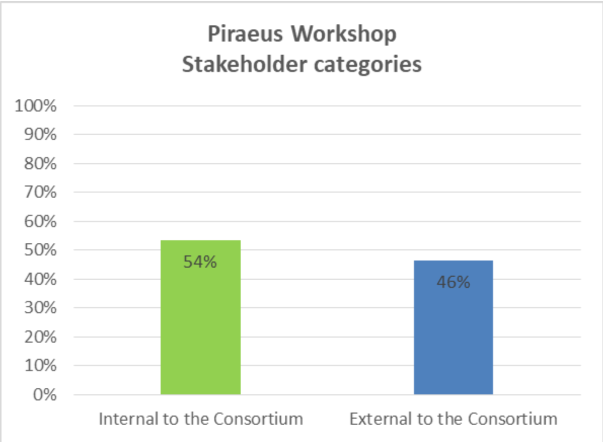


Figure 13 Piraeus Workshop – Stakeholder categories.

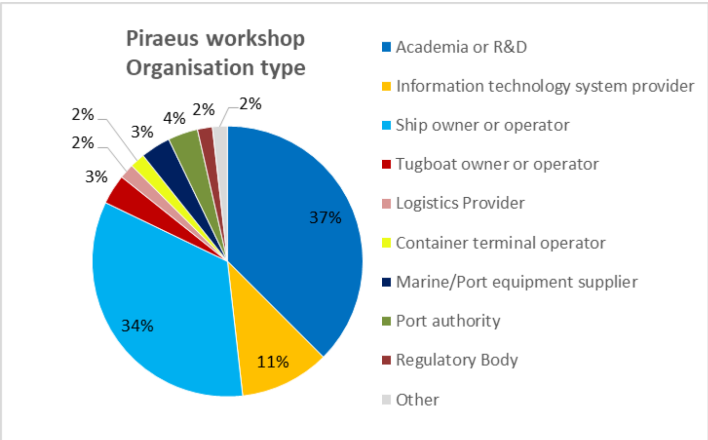


Figure 14 Piraeus Workshop – Organisation type.

The workshop organised by Valencia was attended by 37 participants from 17 different organisations. The meeting was attended by 33 members of the MOSES consortium and 4 externals to the MOSES consortium. In Figure 15 and Figure 16, we present the percentage distribution of the participants according to their relationship to the MOSES consortium and according to the organisation type they belong to.

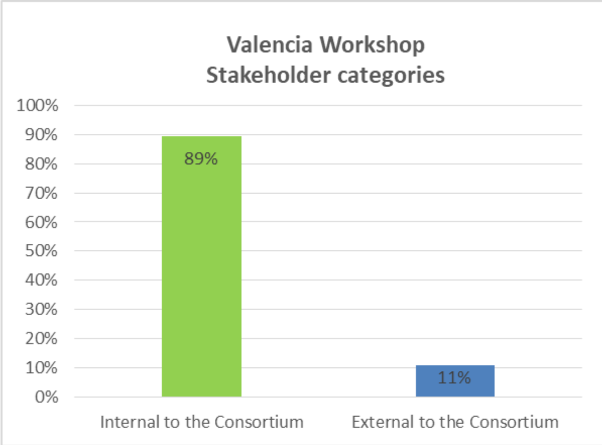


Figure 15 Valencia Workshop – Stakeholder categories.

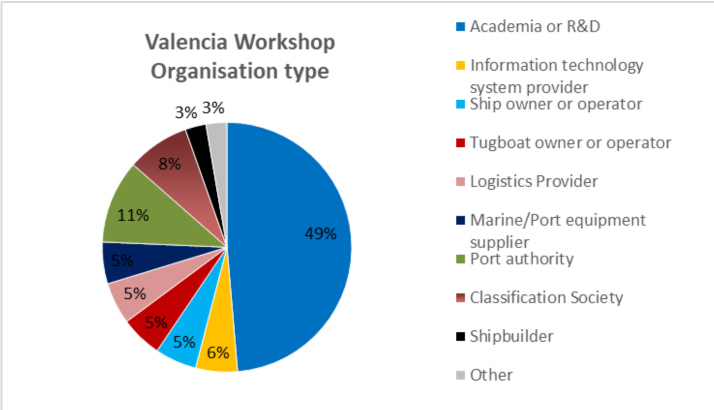


Figure 16 Valencia Workshop – Organisation type.

Each workshop took about 2 hours and was carried out in two parts. The first part included an introduction of the concepts and objectives of the MOSES project and the purpose of the workshop. The second part was an interactive session that included the presentation of the MOSES innovations. Throughout the session the audience was quite active with questions and suggestions that were noted as valuable input for the user requirement extraction process. In Table 9 the main outcomes from both workshops are presented in a tabular form.

Table 9 Workshops Main Outcomes.

Innovation	Requirement	Comment	Workshop
Innovative Feeder Vessel	Autonomy	We need to be clear on the terminology we use about the level of automation/autonomy.	Piraeus
		We need to determine which functions will be automated, so that external stakeholders may be aware of what to expect from MOSES.	
		The difference between autonomous and conventional vessels is in the operational aspects.	
		Autonomy cannot work without real-time communication and reliable situation awareness.	
		The future autonomous operation, which may impact the design of the feeder, needs to be considered during development.	Valencia
	Environmental aspects	We need to investigate deeper into zero-emissions possibilities, including any market-related aspects.	Piraeus
		Baltic Emission Control Areas (ECAs) will affect the design, including the assurance of safety onboard.	
	Different operational contexts to be considered	The different operational contexts (e.g., different distances between large and small ports), which may impact the design of the feeder, need to be considered during development.	Valencia

Innovation	Requirement	Comment	Workshop
Robotic container-handling system	Examples from other industries to be investigated	We could investigate examples from other industries and industrial sectors regarding automated cargo handling, such as inland waterways.	Valencia
Robotic container-handling system	Night shift	Considering that many container-handling operations are conducted during the night, this parameter should be taken into account for the design of the system.	Valencia
Autonomous tugboats	Autonomy	Unmanned tugboats would require approval/certification.	Piraeus
Autonomous tugboats	Autonomy	We need to identify human-related tasks in conventional tugboat operation and decide which of them will be automated in MOSES (e.g., navigation, engine room management etc.).	Piraeus
Autonomous tugboats	Autonomy	The autonomous tugboats should be considered as part of a system, considering that low tugboat performance affects other ships as well.	Piraeus
Autonomous tugboats	Safety	For the design of the fail-safe condition, we should consider that a safe location in the port might not be available and therefore additional back-up/contingency strategies may be required.	Piraeus
Autonomous tugboats	Safety	Conventional tugboats participate in maintaining port safety (e.g., through firefighting).	Piraeus
Autonomous tugboats	Safety	European Tug-owners Association (ETA) guidelines, published recently, should be considered for the risk scenarios.	Piraeus
Autonomous tugboats	Battery optimization functionality	Regarding the battery optimization functionality, we should consider something like "hot swapping" for the tugboat swarm – the towing operation cannot stop if a tugboat runs out of power.	Valencia

Innovation	Requirement	Comment	Workshop
Automated mooring system	Impact of automation on existing port operations to be considered	We should consider the impact of automation (proposed by the MOSES innovations) on existing port operations and competencies of port workers. The EU-funded SkillSea project may have interesting resources about future skills in the maritime industry.	Valencia
	Various data will be required (ref. mooring analyses)	The development of this system will require the exploitation of various data, including currents, port topology, and ship sizes. These are data that are typically used in mooring analyses.	
Matchmaking platform	Maritime industry reluctance/communicate to stakeholders the idea of transparency	We should consider the reluctance of the maritime industry to share information, which may impact the data availability for the platform. We need to communicate to stakeholders that the idea is to introduce transparency into the process and increase its efficiency. The matchmaking platform will consolidate information from many different sources.	Valencia
	Blockchain technology	Blockchain technology could be examined for potential exploitation within the platform. However, even though blockchain has advanced during these last years, the technology may not be mature enough yet.	

The specific outcomes have provided useful information that has been considered in the definition and description of the user requirements in Chapter 7, as provoked by the longer discussion between relevant stakeholders in each case. Special attention has been given to the comments that have bigger impact on the design of the MOSES innovations. Concerning the innovative feeder vessel, the comments related to the reduced environmental footprint and the autonomy level of the vessel were considered significant. Concerning the robotic container-handling system, the ability to operate at similar conditions with the manual handling systems and the ability to operate at low-lighting conditions were considered important. Furthermore, the outcomes connected with the safety and the battery optimization functionality of the autonomous tugboats were also deemed important. Regarding the automated mooring system, the type of data needed, and the particularities of each port are mentioned as key to the design of these systems. Moreover, the reluctancy to share data within the maritime stakeholders is discussed as an issue to be considered for the matchmaking platform.

5.3 Online Questionnaire

5.3.1 Objective

The aim of the questionnaire was to obtain an insight into the stakeholders' expectations and requirements about the MOSES innovations. To achieve this, the respondents were asked to evaluate the importance of an initial set of potential user requirements and to identify new user needs and potential requirements. The initial set of potential user requirements was defined by the MOSES partners, aiming at the feedback on the level of importance of possible design solutions. The general framework of course essentially derived from the concept of the project. For this purpose, an online questionnaire was established on the EU Survey Platform. The complete questionnaire as appeared on the website is included in Annex 1. The stakeholder acceptance of the potential requirements assisted in the determination of the priority of the user requirements in Chapter 7.

5.3.2 Structure

The questionnaire divided into three parts, was designed so that stakeholders could complete it in 20 to 30 minutes based on their intuition by completing multiple-choice questions. The following is a brief description of each part of the questionnaire:

1. The first part of the questionnaire included demographic questions about the participants that allow the identification of organisational details and their relevance to the MOSES project.
2. The second part of the questionnaire was dedicated to general requirements related to MOSES.

3. The third part focused on requirements for each MOSES innovation, which included the Innovative Feeder Vessel and Robotic Container-Handling System, the Autonomous Tugboats, the Auto-Docking System, and the Matchmaking Logistics Platform.

After providing identification and profile data, the user was given instructions on answering the questionnaire. The respondents were asked to evaluate the importance of each requirement included in the questionnaire. Answers were given on a Likert scale of importance as shown in Table 10.

Table 10 Description of scale levels in the questionnaire responses.

Scale level	Description
0 – Not Important	Unimportant requirement. With or without this the innovation is exactly the same.
1 – Slightly Important	Wish requirement. Nice to have, but the innovation will be fully useful even without it.
2 – Important	Important requirement. Without this the innovation will be only partially useful.
3 – Fairly Important	Serious requirement. Without this the innovation will be usable, but not useful enough.
4 – Very Important	Critical requirement. Without this the innovation will be unusable at all.
N/A	The user does not know what the importance of this requirement is, it is not his/her responsibility and/or he/she does not know the technology/term.

The user had the option to navigate back to the instructions page at any time during the process of answering the questionnaire. The option to skip a specific question or an innovation in general and return later to answer it, was also available.

GDPR issues applied

In light of the adoption of the General Data Protection Regulation (GDPR) on May 25th, 2018, measures were taken to ensure that survey participants' personal data was protected, that the use of their data was clearly communicated and that participants were aware of their rights before starting the survey. This was achieved by including specific GDPR-related questions at the beginning of the survey, supported by a specific GDPR-background information document. If participants did not agree with the questions put forward at this stage, then the questionnaire was designed to end.

Dissemination channels

This survey was sent via email on September 24th, 2020. The mailing list comprised of partners' network contacts that had opted in to receive information on maritime related projects such as MOSES. The contacts consisted of people, institutions, authorities and industries involved in the smart port-city and maritime ecosystem. The survey closed on November 6th 2020.

Response rates

On November 6th, 2020, there was a total of 55 respondents that finalised the questionnaire. As shown in Figure 17, the participants came from different industries and organisations. The majority came from Academia or Research Institutes, Shipping Companies, Port Authorities and Maritime/Port Equipment Suppliers (70%). Some other organisations that participated in the survey were represented only by a small number of respondents, as it can be seen in the same Figure. For example, the Coast Guard is represented by 1 person and the Shipbuilder by 2 (this is also the case for some other organisations).

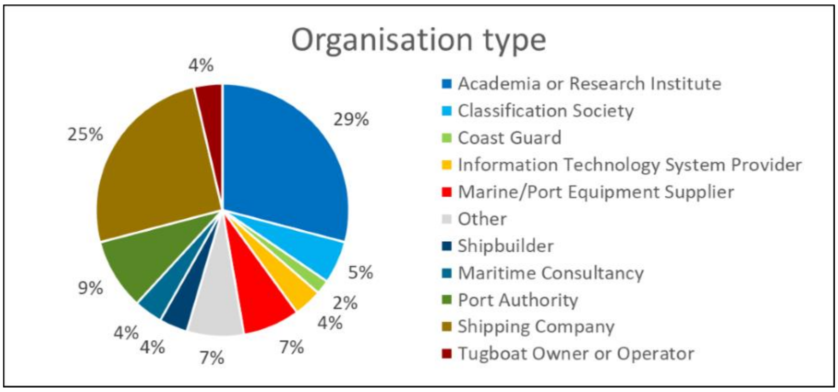


Figure 17 Questionnaire participants per organisation type.

Another important element regarding the participants' profile is their familiarity with maritime and port operations. Here the results are divided in half, with a slight majority of 51% of the respondents dealing with maritime and/or port operations as part of their current occupation (Figure 18).

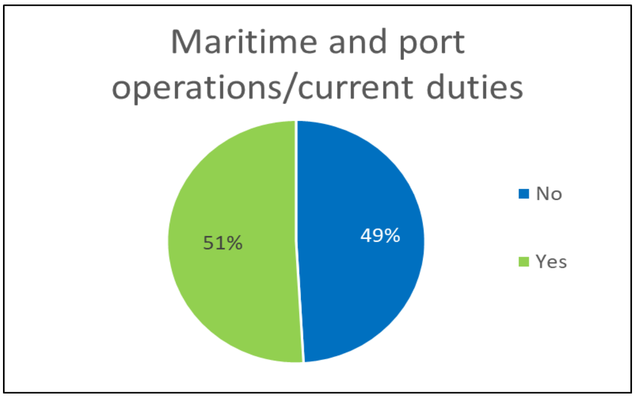


Figure 18 Questionnaire participants' current duties.

5.3.3 Data analysis

The analysis of the collected data provided interesting insights into how relevant stakeholders perceive the importance of the various potential requirements and useful conclusions were drawn that may provide guidance for other MOSES Work Packages (WPs). See Annex 2 for the summarized results of the questionnaire responses, which are analysed in the following section.

The analysis has focused on potential requirements that were evaluated by the majority of respondents as either fairly important or very important. Additionally, the analysis includes commenting on potential requirements that were not clearly evaluated as important or not important by the respondents.

For each innovation, the results are also summarised in tabular form (two tables). The first table presents the acceptance of the potential requirements (see Table 11 for a description of the fields) and the second documents the additional user needs and potential requirements that have been highlighted through the responses on the open-ended questions (see Table 12 for a description of the fields).

Table 11 Description of the fields in the first table.

Field	Description
No.	Question number in the questionnaire.
Potential requirement	Potential requirements that have been assessed in the questionnaire.
%	The total percentage of the participants who consider the potential requirement as either fairly important or very important.
Acceptance	Acceptance of the potential requirement based on the "%" field. In order to classify the "%" we took into consideration that the dataset is small (55 responses per question) and therefore we divided it into quartiles. In addition, in order to facilitate the analysis process, decile ranking has been also selected for the "%" exceeding 90%. Red, orange, yellow, light green and green colours have been applied for 0-25%, 26%-50%, 51%-75%, 76%-90% and 91%-100% respectively.

Field	Description
Comment	Responses to the open-ended questions that are relevant to the specific requirement. Most of the comments have been taken verbatim from the responses to the questionnaire. Each comment is unique and has been mentioned by one respondent.
Organisation	The type of the organisation the participant belongs to.

Table 12 Description of the fields in the second table.

Field	Description
Topic	The topic raised by the comment.
Comment	Responses to the open-ended questions that highlight additional user needs and potential requirements. Most of the comments have been taken verbatim from the responses to the questionnaire. Each comment is unique and has been mentioned by one respondent.
Organisation type	The type of the organisation the participant belongs to.

5.3.4 Innovative Feeder Vessel

The questions regarding the innovative feeder vessel dealt with advanced functionalities and features that could be integrated into it. As depicted in Figure 19, all the questions were answered by over 90% of the respondents.

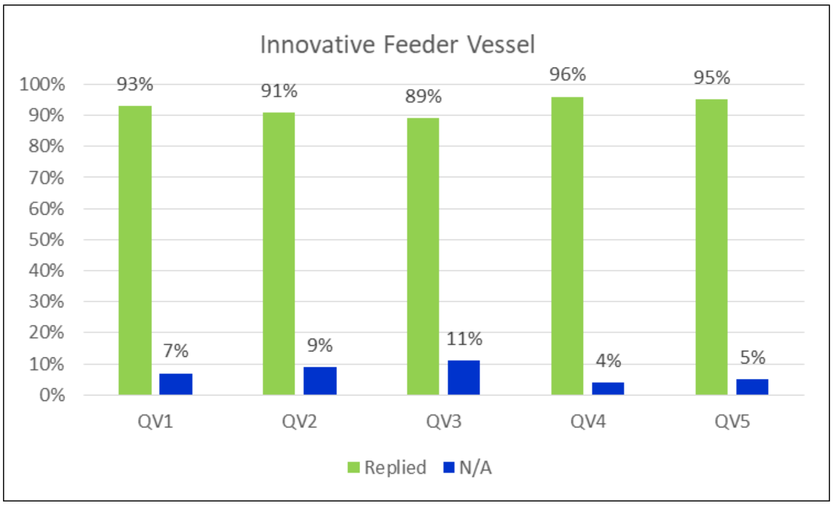


Figure 19 Innovative Feeder Vessel response rates.

One of the features that was evaluated as fairly and very important by 73% of the respondents is the ability of the innovative feeder vessel to operate without requiring any special facilities at service ports, excluding its home port. Another feature that was considered very important is the ability of the innovative feeder vessel to achieve a significant reduction of the environmental footprint during port operations, compared to alternative transport options (road/rail). As shown in Figure 20, this feature was considered as fairly or very important by a total of 93% of the respondents.

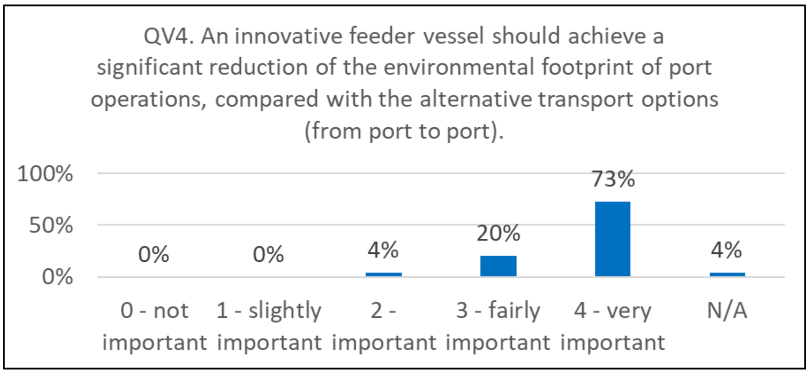
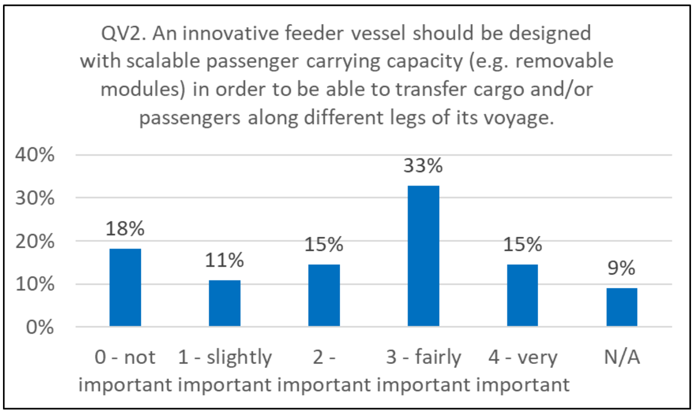


Figure 20 Innovative Feeder Vessel Question 4.

Furthermore, the ability of the innovative feeder vessel to safely approach, enter and manoeuvre in smaller ports that may not offer adequate protection from the weather was assessed, being considered as fairly or very important by 85% of the respondents.

On the other side, the importance of some functionalities that were proposed for the innovative feeder was rated differently by the participants. For example, designing the innovative feeder vessel with automated mooring capabilities (hands-free mooring), was very important to the majority of participants coming from coast guard, marine/port equipment suppliers and tugboat owners or operators, while the participants coming from shipping companies or port authorities evaluated it as slightly important or not important at all. A similar case was regarding the design of the innovative feeder vessel with scalable passenger carrying capacity (e.g. removable modules), in order to be able to transfer cargo and/or passengers along different legs of its voyage. In this case, this feature was considered as not important at all for coast guard and shipbuilders, while all the participants coming from the information technology system providers and the maritime consultancies evaluated it as fairly or very important (Figure 21).



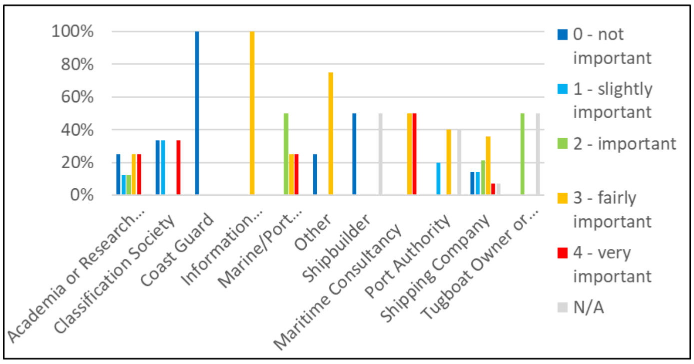


Figure 21 Innovative Feeder Vessel Question 2.

The last part of the innovative feeder vessel section included an open-ended question, where the respondents could propose any additional potential requirements that they considered important for the design and operation of the innovative feeder vessel. In this question, many features were proposed, such as the low underwater noise footprint that was suggested by three participants from academia and one participant from an engineering company, as well as the use of alternative fuels to reduce the vessel's environmental footprint, other than LSHFO and MGO/MDO that was proposed by respondents from academia and classification society. Other requirements that were suggested were the automation in navigation of the vessel at both ports and sea, the alternative energy propulsion systems to assist in the reduction of the vessel's environmental footprint, the ability of the vessel to communicate with the port authorities or the harbour master and the terminal operator regarding dispatch list and a dynamic positioning system to offer stability in adverse weather conditions.

Table 13 presents the acceptance of the potential requirements. Table 14 captures the additional user needs and potential requirements that have been highlighted by the respondents in their responses to the open-ended questions.

Table 13 Innovative Feeder Vessel – Acceptance of potential requirements.

No	Potential requirement	%	Acceptance	Comment	Organisation
QV1	An innovative feeder vessel should not require special facilities at service ports	73		The possible use of alternative fuels to reduce the environmental footprint shall not negatively influence feeder's service or visit in small ports, where such fuels may not be available.	Academia or Research Institute
QV2	An innovative feeder vessel should be designed with scalable passenger carrying capacity in order to transfer cargo and/or passengers along different legs of its voyage	48		The second design option of a RoCoPax vessel is not a significant innovation. It reminds me of the vessels that served the Greek islands in the early 70's where passengers were disembarking by boats, and cargoes and some few cars were unloaded by cranes to barges. Furthermore, nowadays port facilities for vehicles, passengers and containers are located in different areas of the port which automatically adds a disadvantage to the concept. Even the regulatory framework aims to reduce to the minimum the interaction of passengers, vehicles and cargoes.	Coast Guard
				It is not a good idea to mix passengers and cargo, although a modular design could be useful.	Academia or Research Institute
				Passengers shall not be combined with cargo, as regulations are much stricter for passenger vessels, compared to cargo vessels, and these regulations will have an impact on the design probably rendering it economically not feasible.	Classification Society
QV3	An innovative feeder vessel should be designed with automated mooring	55		The vessel shall offer adequate flexibility of small and difficult to approach ports. In that respect, the automated mooring is not very important, as this functionality will not be offered at small ports. A few people at the dock shall be able to handle the mooring lines.	Classification Society

No	Potential requirement	%	Acceptance	Comment	Organisation
	capabilities (hands-free mooring)			Mooring and Breasting/ Fendering Analysis	Maritime Consultancy
QV4	An innovative feeder vessel should achieve a significant reduction of the environmental footprint of port operations, compared with the alternative transport options (from port to port).	93		The innovative feeder vessel must have low GHG's emission levels (>IMO 2020).	Academia or Research Institute
				The vessel shall be capable to at least manoeuvre or even navigate powered by electric engines.	Academia or Research Institute
				If the destination is inside an urban environment, the importance of clean transportation gains credits.	Coast Guard
				A focus area could be the usage of fuels other than LSHFO and MGO/MDO such as LNG/LPG for example. Fuel changeover from HFO to MGO and vice versa that is required for entrance to ECAs could be avoided having as additional advantage the further reduction of emissions.	Classification Society
				Alternative energy propulsion systems should be considered.	Academia or Research Institute
				The vessel should be eco-friendly as this is the core of such projects. Batteries may be a solution already applicable at small passenger vessels at the North Sea.	Classification Society
				The initial requirement that should be taken under consideration and be the fundamental characteristic of the assessment of a vessel is the distance that she will be asked to cover, the difficulty factor of the	Coast Guard

No	Potential requirement	%	Acceptance	Comment	Organisation
				maritime route and the duration of the voyage so that she would be competitive to the other means of transportation for the same voyage.	
				The innovative feeder vessel should have operational characteristics to be competitive, cost-efficient and sustainable, compared to alternative transport options.	Academia or Research Institute
QV5	An innovative feeder vessel should be able to safely approach, enter and manoeuvre in smaller ports that may not offer adequate protection from the weather.	85		The vessel shall be equipped with a dynamic positioning system to offer stability at adverse weather conditions, which is the case at small islands and ports.	Classification Society
				The presence of the feeder vessel in small ports shall not put in danger the usual navigational activity in the wider port area.	Academia or Research Institute

Table 14 Innovative Feeder Vessel – Comments on potential additional requirements.

Topic	Comment	Organisation
Noise Footprint/ Interference in the wider port area	The vessel should have very low underwater noise footprint (ref. Vancouver Port fees).	Academia or Research Institute
	The vessel should have low underwater radiated noise footprint, being a low polluting vessel not only from the point of view of gas emissions but from noise as well.	Other/ Engineering company
	The presence of the feeder vessel shall not burden the quality of environment in the service ports (e.g. noise, emissions).	Academia or Research Institute
	The presence of the feeder vessel in small ports shall not put in danger the usual navigational activity in the wider port area.	Academia or Research Institute
Design Aspects	The 150-200 TEU capacity sounds small, taking under consideration that the daily movement of regional terminals is of some hundreds to thousands.	Coast Guard
	Size optimization of the vessel should be considered.	Shipping Company
	Ballast free vessel should be considered aiming to reduce or eliminate the ballasting/de-ballasting operations.	Classification Society
	Reduced draft of the vessel should be considered.	Port Authority
Autonomous operation	The vessel must be able to navigate autonomously between the ports.	Academia or Research Institute
	Level of autonomy should be considered, where feasible.	Academia or Research Institute
	Communication with port authorities or harbour master and terminal operator regarding dispatch list should be considered.	Port Authority
	High level of automation of the vessel should be considered.	Academia or Research Institute

Topic	Comment	Organisation
	Automation (at both ports and sea) in navigation of the vessel should be considered.	Academia or Research Institute
Cargo/ Cargo Handling	Type of cargo would also be a differentiating issue (e.g. RORO VS LOLO).	Academia or Research Institute
	On-board cargo handling is a cost driver, therefore a challenge to overcome.	Academia or Research Institute
	The vessel should offer the possibility to unload only a few containers in each port.	Marine/Port Equipment Supplier
Specific time slots at the handling terminal are suggested in order to avoid waiting hours/congestion. The feeder vessel would then act as a 'regular public transport' service.		Other/business advisory
Interoperability		Academia or Research Institute
Crew skills issues		

Based on these results, there are potential requirements that have gained the stakeholder's acceptance. Some examples are the improved environmental footprint of the innovative vessel during port operations, its' enhanced manoeuvrability in smaller ports that may not offer adequate weather protection and the feature that the vessel should require minimum facilities at service ports. In parallel, there are potential requirements that have not been sufficiently accepted, as for example the vessel's scalable passenger carrying capacity in order to transfer cargo and/or passengers. Last but not least, through the responses to the open-ended questions, some additional potential requirements have been identified (i.e. reduced underwater noise footprint, dynamic positioning capability etc.).

5.3.5 Robotic Container-Handling System

The questions about the robotic container-handling system were answered by over 87% of the respondents (Figure 22).

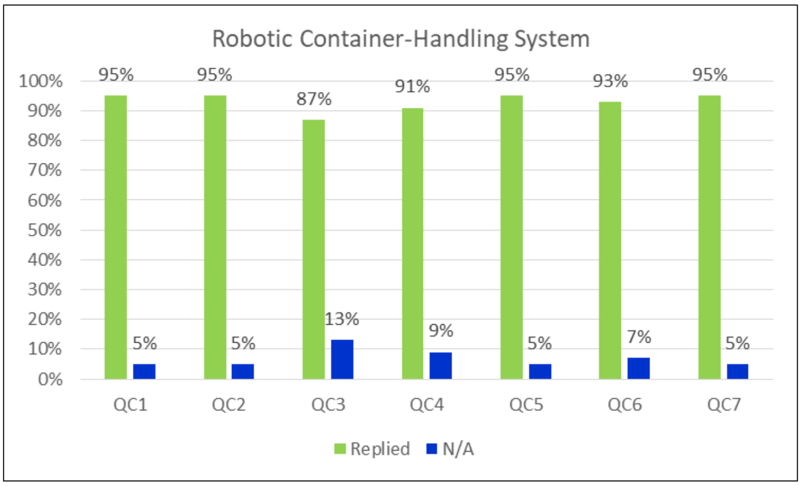


Figure 22 Robotic Container-Handling System response rates.

One of the features that was evaluated in the questionnaire is the ability of the robotic container-handling system to provide the remote operator with a detailed picture of the quay and this feature was considered as fairly or very important by 76% of the respondents. In addition, the ability to operate under operational conditions similar to those of a manually operated crane was considered as fairly or very important by 86% of the respondents (Figure 23). The ability of the robotic container-handling system to operate under low light conditions was also considered as quite important, with 76% of the respondents to evaluating it as fairly or very important.

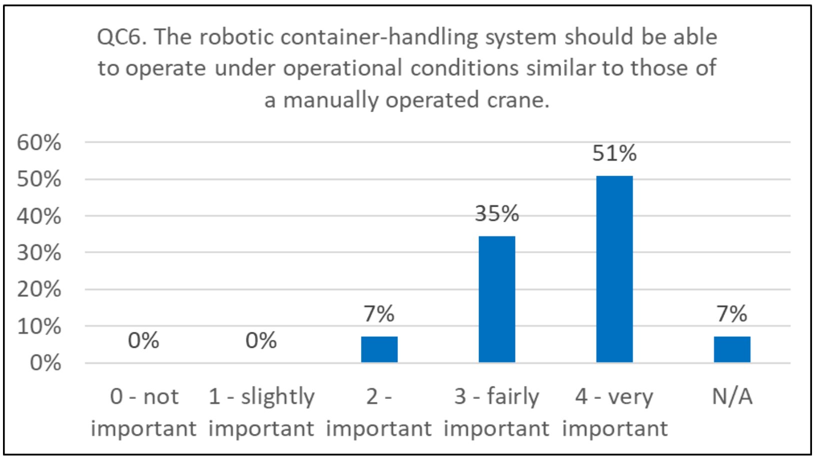
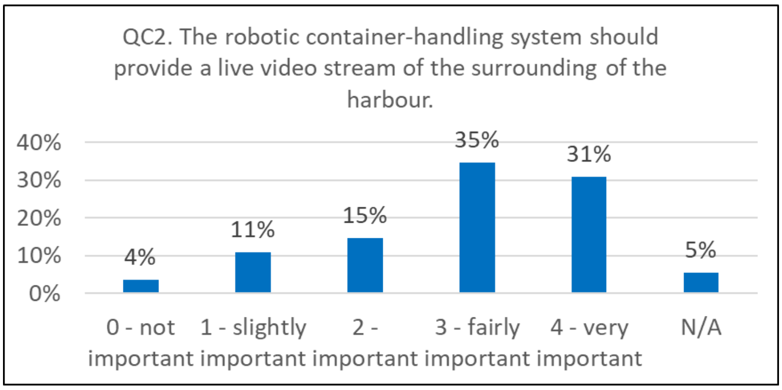


Figure 23 Robotic Container-Handling System Question 6.

In contrast, features such as the capability of the robotic container-handling system to operate without requiring more port space (in terms of container arrangement or spacing) compared to manual operation was considered as fairly or very important by participants from coast guard, tugboat owners and the majority of port authority, while participants from information technology system providers and shipbuilder evaluated this feature as slightly or just important. Also, the requirement to perform a task at least as fast as a manually operated crane was considered as fairly or very important by all participants from classification society, coast guard, information technology system providers, maritime consultancy, port authority and tugboat owners, while participants from shipbuilder companies evaluated this feature as slightly important.

In parallel, the potential requirement to provide a 3D-Blended Reality Environment for the operator resulted in distributed results regarding the importance level of this feature for almost all types of organisations, ranging from slightly to very important. Also, 13% of the respondents considered this requirement as “N/A”, declaring that they are not familiar with this feature. A similar case was the requirement to provide a live video stream of the surrounding of the harbour, which had a wide range of responses based on its importance, as all the respondents coming from classification society, coast guard, maritime consultancy, port authority and tugboat owner or operator considered it as fairly or very important, while participants coming from information technology system providers evaluated it as slightly or just important (Figure 24).



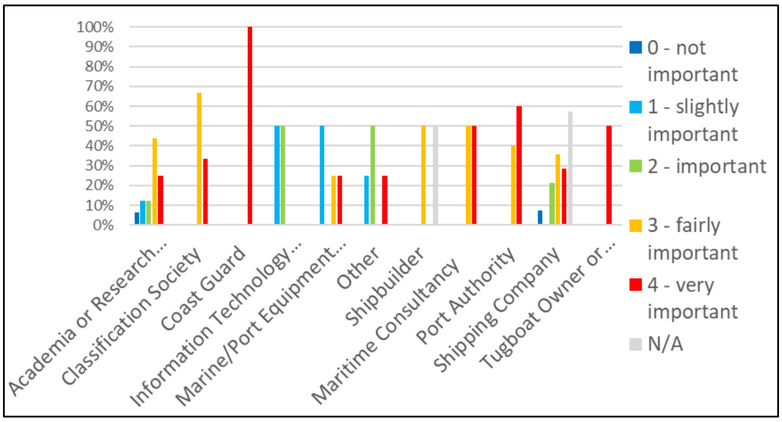


Figure 24 Robotic Container-Handling System Question 2.

The last part of the robotic container-handling system section included an open-ended question, where the respondents could propose any additional potential requirement that they considered important for the design and operation of the robotic container-handling system. In this question, many features were proposed, such as the coordination with the shore container handling system proposed by coast guard, the connection of all machineries in container terminal into one system by port authority, alternative means of power for cranes and automatic ESD (Emergency Shut Down) by classification society. Also, an interesting feature that was proposed by a respondent coming from business advisory was referring to the ability to implement a night shift as well, when a conventional robotic container and its handling activities are not typically operative. Even with lower productivity than the one during morning shifts, this feature would still have a large impact on the congestion of container handling activities that usually occurs during the day, along with the further impact on the hinterland that would be also substantial, as the traditional traffic jams could be avoided.

Table 15 presents the acceptance of the potential requirements. Table 16 captures the additional user needs and potential requirements that were added by the respondents in their responses to the open-ended questions.

Table 15 Robotic container-handling system Acceptance of potential requirements.

No	Potential requirement	%	Acceptance	Comment	Organisation
QC1	The robotic container-handling system should provide to the remote operator a detailed picture of the quay.	76		A good and functional human-automation interface may use other presentation forms than normal video/pictures. More abstract representations may be more useful for the required control functions. Thus, it is critical to design good and realistic use cases.	Academia or Research Institute
QC2	The robotic container-handling system should provide a live video stream of the surrounding of the harbour.	66			
QC3	The robotic container-handling system should provide a 3D Blended Reality Environment for the operator.	46			
QC4	The robotic container-handling system should not require more port space (in terms of container arrangement or spacing) compared to manual operation.	65		We need to define how the small ports are going to handle the containers, in order to anticipate how and where the robotic container-handling system will place the containers. Maybe there could be designated spaces for the system to place the containers (e.g. the trucks which will carry them should be parked in certain place).	Academia or Research Institute

No	Potential requirement	%	Acceptance	Comment	Organisation
QC5	The robotic container-handling system should perform a task at least as fast as a manually operated crane.	69		The robotic container-handling system should ensure better performances compared to manually operated crane.	Shipping Company
QC6	The robotic container-handling system should be able to operate under operational conditions similar to those of a manually operated crane.	86			
QC7	The robotic container-handling system should be able to operate under low light conditions.	76		Statements that ports are congested, is a rather unsubstantiated statement knowing that in 2/3 of container handling activities (that is handling of containers to hinterland feeding services, not the handling of the large container vessels), the work stops at 22.00 hrs. A automatic crane would enable night shift, which would even at a lower productivity, still have a large impact on the 06.00-22.00 congestion. The further impact on the hinterland is also substantial as the traditional traffic jams are avoided.	Other/business advisory

Table 16 Robotic container-handling system Comments on potential additional requirements.

Topic	Comment	Organisation
Safety/ Redundancy	We need to adjust safety depending on the containers' content.	Shipping Company
	The robotic container-handling system should grant more safe working conditions compared to manually operated crane.	Shipping Company
	The robotic cargo handling system shall prove equal safety as the manual operation. Alarms shall exist that will warn both the surrounding field and the remote operator in case of imminent collision or any other danger. At a second level automatic ESD (Emergency Shut Down) shall be in place to freeze all movements to prevent any damage or accident especially involving humans in the surrounding environment. Lastly, the robotic cargo handling system shall maintain a two-ways communication with the dynamic position system of the vessel, as it needs to adapt to the weather conditions to guarantee safe operation.	Classification Society
	The system shall have a control system that shall be able to monitor and detect safety-critical insufficiencies in its functionality. A safe fallback response shall be present. Manual control shall be gained at any time. The system shall not impose the safety level of port.	Academia or Research Institute
	Alternative means of power for cranes must be considered in case the main electric power fails.	Classification Society
Unloading process/ coordination with the shore container handling system	Special measures and arrangements should be designed to handle unexpected disturbance of the unloading procedures coming either from shore or from sea. The automated unloading should be in coordination with the shore container handling system to reduce the time gaps to minimum.	Coast Guard
	The system shall be capable of unloading TEUs both at trucks and at the designated area.	Academia or Research Institute
Operational simplicity	All the machineries in the container terminal would need to be connected into one system, regardless of different production brand.	Port Authority
Eco friendly	The robotic container-handling system should be more eco-friendly compared to manual system.	Shipping Company

Based on these results for the robotic container-handling system, there are potential requirements that have been accepted by the stakeholders, as for example the fact that the system should provide a good visual/spatial perception of the quay to the operator and the ability of the system to operate under conditions similar to those of a manually operated crane. Furthermore, some potential requirements have not been sufficiently accepted from the respondents, taking the ability of the system to provide a 3D Blended Reality Environment for the operator as an example. Last but not least, through the responses to the open-ended questions, some additional potential requirements have been introduced, related with the achievement of at least the same safety level with the manually operated systems

5.3.6 Autonomous tugboats

The questions regarding the autonomous tugboats were answered by over 87% of the respondents (Figure 25).

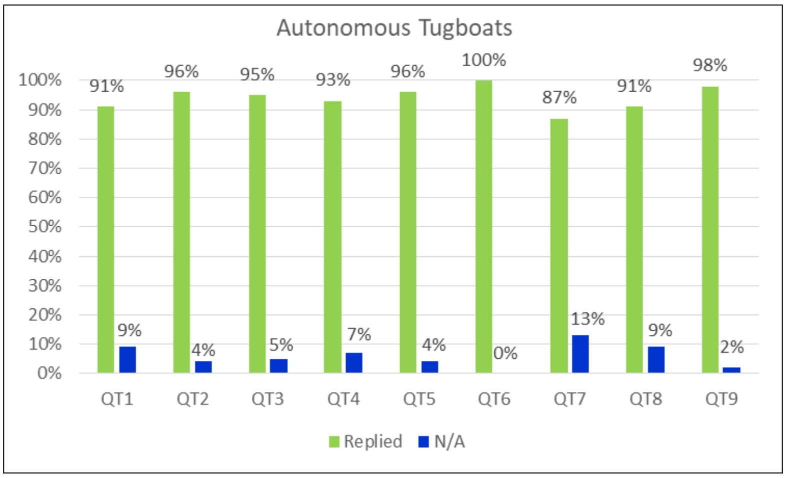


Figure 25 Autonomous Tugboats response rates.

The ability of the tugboats to return autonomously back to the port when the communication with the port control is lost was considered as fairly or very important by 77% of the respondents, while the ability of the autonomous tugboats control system to retain and transmit logs in real time to report positioning and progress of operation was evaluated as fairly or very important by 80% of the respondents. In parallel, features such as the capability for the port operator to take control of the autonomous tugboat at any time or the requirement for the autonomous tugboats remote control and communication to be done in a secure way ranked quite highly based on the importance, with the participants evaluating them as fairly or very important with 85% and 93% respectively (Figure 26).

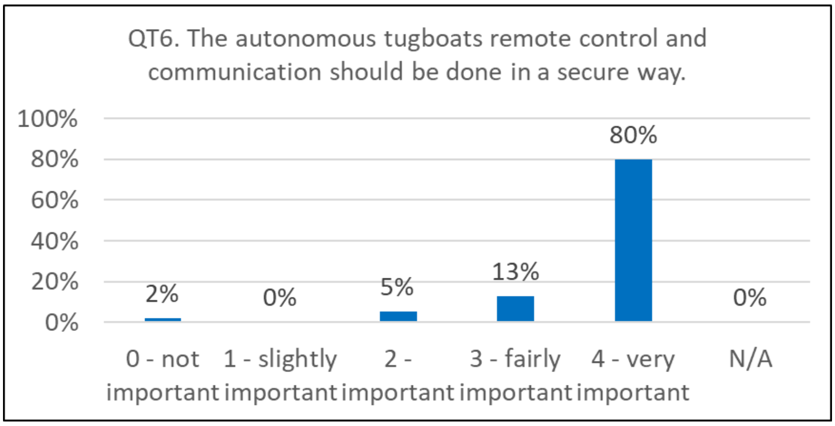
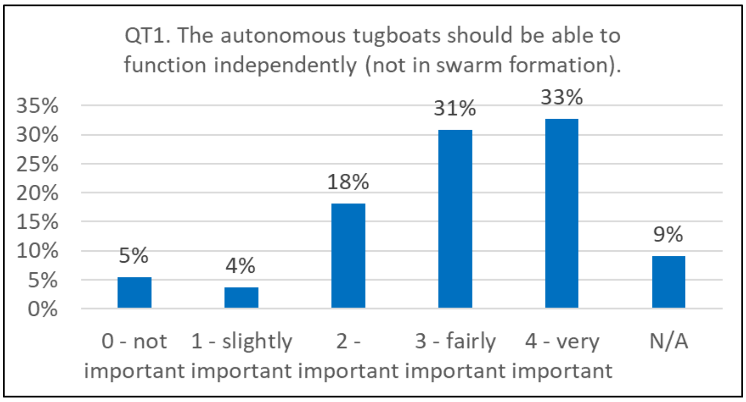


Figure 26 Autonomous Tugboats Question 6.

Moreover, the capability of the autonomous tugboats to adapt to different towing methods (on the line, push-pull method, etc.) was considered as fairly or very important by 69% of the respondents, along with the requirement to have a real-time system which monitors the condition of the autonomous tugboats and can identify crucial damage to them, that was evaluated as fairly or very important by 87% of the respondents. Also, the requirement to enable and efficiently configure different means of communication between autonomous tugboats and a non-autonomous vessel during towing operation (e.g. safeguard secure operation of making fast or cast-off tow lines) were evaluated as fairly or very important by 81% of the respondents.

On the other hand, the ability of the autonomous tugboats to return autonomously back to the port when in extreme weather conditions was considered as fairly or very important for all respondents coming from information technology system provider sector, marine/ port equipment supplier, maritime consultancy and tugboat owner or operator, while the perception of academia and shipping company participants ranged in all levels of importance. Also, the requirement for the autonomous tugboats to be able to function independently (not in swarm formation) was evaluated as fairly or very important from all participants coming from coast guard, shipbuilder, maritime consultancy and tugboat owner or operator, while the participants coming from academia, classification society and port authority had different opinion among them regarding its importance (Figure 27).



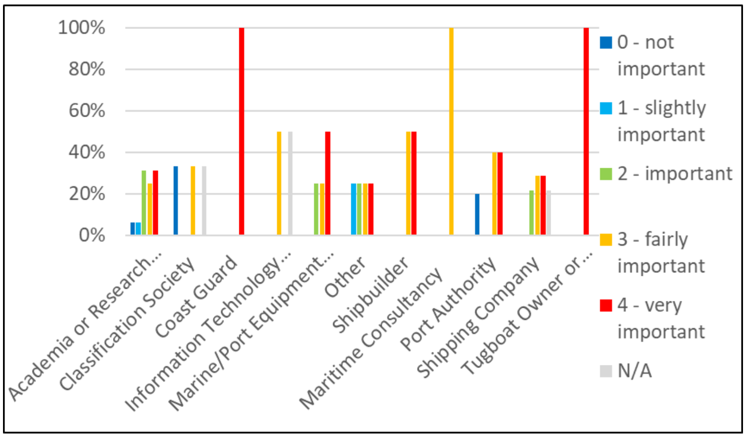


Figure 27 Autonomous Tugboats Question 1.

The last part of the autonomous tugboats section resulted to interesting additional features that were proposed by the respondents, such as the ability to integrate into it different towing methods proposed by the academia, the requirement to be designed with an ecological propulsion system and to support real-time exchange of information between the autonomous vessel and its surrounding traffic proposed by tugboat owner or operator, as well as the ability to recognize damages to non-autonomous vessels carrying the cargo that was proposed by shipping company. Also, one participant from a shipbuilding company suggested that all these functionalities should be transversal across different similar vessels' types.

Table 17 presents the acceptance of the potential requirements. Table 18 captures the additional user needs and potential requirements that have been highlighted by the respondents in their responses to the open-ended questions.

Table 17 Autonomous Tugboats Acceptance of potential requirements.

No	Potential requirement	%	Acceptance	Comment	Organisation
QT1	The autonomous tugboats should be able to function independently (not in swarm formation).	64		This is not an important requirement as the autonomous tugboat swarm will focus on very large containerships.	Classification Society
				The capability to function independently is very important since the adjustments of ship's track needed during a manoeuvre might happen thanks to a single action (push/pull) by one of the tugs in team.	Academia or Research Institute
QT2	The autonomous tugboats should be able to return autonomously back to the port when the communication with the port control is lost.	77		It depends on whether the autonomous tugboats are under operation at that moment or not. If at the given moment they manoeuvre a vessel, they must not stop and return at port at any cost! They should either freeze and maintain their last position or if it is possible to complete the berthing, but this will be probably impossible, if communication has been lost.	Classification Society
QT3	The autonomous tugboats should be able to return autonomously back to the port when in extreme weather conditions.	66		The autonomous tugboats must not stop and return back to the port if they are manoeuvring a vessel at the given moment.	Classification Society
				The capability to return autonomously back to the port is important from the point of view of preserving the unit from potential loss in bad weather (high waves), given the fact that they could not operate.	Academia or Research Institute
QT4	The autonomous tugboats control system should retain and transmit logs in real time	80		The real-time exchange of information between the autonomous vessel and its surrounding traffic should be established at all times, facilitating safe port operations.	Tugboat Owner or Operator

No	Potential requirement	%	Acceptance	Comment	Organisation
	to report positioning and progress of operation.				
QT5	A port operator should be able to take control of the autonomous tugboat at any time.	85		It needs to be clarified what happens in that case with the rest of the swarm.	Classification Society
QT6	The autonomous tugboats remote control and communication should be done in a secure way.	93		A hijacked swarm will be the easiest way to steal 20000 TEUs.	Classification Society
				At all times, the autonomous tugboat should have cybersecure information of the exact engine command, rudder angle etc., of the manoeuvring vessel.	Coast Guard
QT7	The autonomous tugboats should be capable to adapt to different towing methods (on the line, push-pull method, etc.).	69		The towing method of each tug of the swarm shall be one of the many degrees of freedom of the optimization algorithm that will be run live/dynamically during operation.	Classification Society
				Different towing methods have to be implemented to provide adaptability to various ports' needs/manoeuvring techniques.	Academia or Research Institute
QT8	Means of communication between autonomous tugboats and a non-autonomous vessel during towing operation should be enabled and efficiently configured (e.g.	81		The tugboats are used as an additional means of manoeuvring a vessel under confined sea areas as ports. The main means of power remains the vessel's equipment (engine, rudder, bow-thrusters etc). The most important interaction and communication line is between the manoeuvring vessel and the tug. At all times, the autonomous tugboat should have cybersecure information	Coast Guard

No	Potential requirement	%	Acceptance	Comment	Organisation
	safeguard secure operation of making fast or cast-off tow lines).			of the exact engine command, rudder angle etc, to avoid accidents. Legislation requires the Master to be in command of all the parties involved in port berthing/unberthing manoeuvring, under the assistance of the port's pilot. So, the autonomous tugs should automatically follow the Pilot's-Master's orders and regulate its actions accordingly.	
QT9	Having a real-time system which monitors the condition of the autonomous tugboats and can identify crucial damage to them.	87		For autonomous sail from/to port high standard equipment for navigation and look out must be used. Especially in heavy weather, human eye sensitivity should be reached.	Coast Guard

Table 18 Autonomous Tugboats Comments on potential additional requirements.

Topic	Comment	Organisation
Transferability of project's results	The functionalities of autonomous tugboats apply also in other similar ship types. The transferability of these functionalities across different similar vessels' types makes project's results applicable well beyond MOSES applications.	Shipbuilder
Safety issues	Given the huge value of a large container ship and its cargo, the expensive port infrastructure, risks are to be well considered, and pilots performed with smaller boats in smaller ports. I wonder how insurance companies look at this risk.	Other/ business advisory
	The operation of the autonomous tugboat shall not increase the risk level of the port.	Academia or Research Institute
	The autonomous tugboats shall have high level of resilience to systems' failures.	Academia or Research Institute
	It needs to be clarified whether the line connection will be made automatically or by the crew.	Coast Guard
Additional services for the safety of the port	The autonomous tugboat should be able to provide additional services for the safety of the port (e.g. fire-fighting services).	Tugboat Owner or Operator
Design Aspects	The autonomous tugboat should be designed with an ecological propulsion system (batteries, hydrogen cells etc.) in order to minimize the environmental pollution.	Tugboat Owner or Operator
	The autonomous tugboat has to be designed with such a shape for being efficient to operate in narrow and confined spaces within the port.	Tugboat Owner or Operator
Recognize damages to non-autonomous vessels carrying the cargo.		Shipping company
Autonomous tugboats shall have the same operational envelope with manually operated tugboats.		Academia or Research Institute
Monitor applied strengths.		Shipping company

Based on these results for the autonomous tugboats, there are potential requirements that have been accepted by the stakeholders, as for example the feature related to the communication between the autonomous tugboat and the non-autonomous vessel during towing operation and the ability of the tugboat to safely return to the port upon losing communication with the port. In parallel, some potential requirements have not been sufficiently accepted from the respondents, taking the requirement of the adaptability to various towing methods and the ability to function independently (not in swarm formation) as examples. Last but not least, through the responses to the open-ended questions, some additional potential requirements have been introduced (i.e. reduced environmental footprint of the autonomous tugboat).

5.3.7 Automated Mooring System

The questions referring to the automated mooring system were answered by over 95% of the respondents (Figure 28).

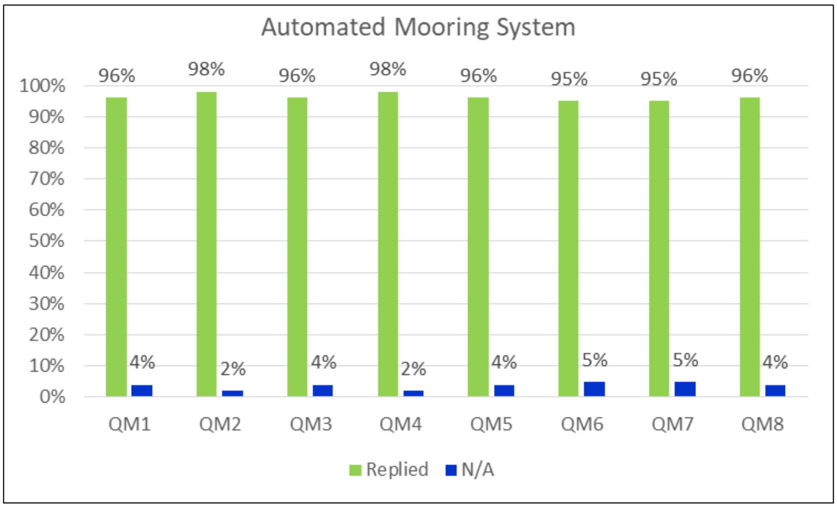


Figure 28 Automated Mooring System response rates.

One of the features that was assessed in the questionnaire was the ability of the automated mooring system to send a warning to the autonomous tugboats if operating parameters are violated (e.g., incorrect approach), considered as fairly or very important by 76% of the respondents. The provision of the mooring service in full operational condition (absence of breakdowns or maintenance) at least 95% of the year was ranked as fairly or very important by 75% of the respondents. In addition, the ability to monitor the condition of the system in real time, in order to identify and report damages to the docking mechanism or the hull during docking, was evaluated as fairly or very important by 85% of the respondents (Figure 29).

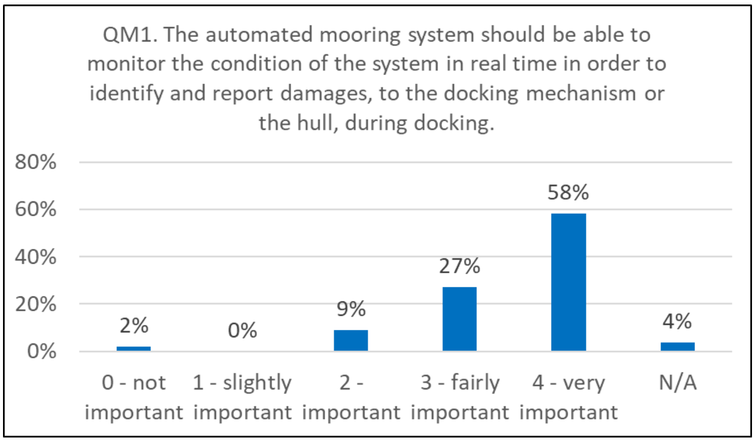
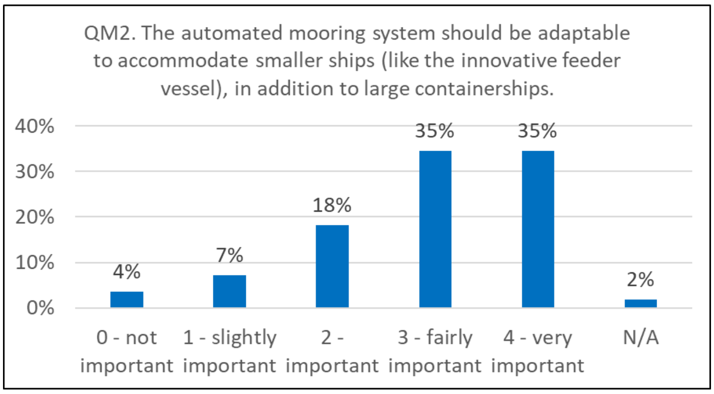


Figure 29 Automated Mooring System Question 1.

A requirement that the participants were asked to evaluate was the 24/7 availability of the automated mooring system, with the specification that if there are more than 8 calls a day in the port, the mooring and unmooring service provider should be able to serve two vessels simultaneously at least during the hours of 7:00 AM to 10:00 PM, based on the port having sufficient AutoMoor™ units along the terminal berth to allow connection to two vessels simultaneously. This feature was considered as fairly or very important by 62% of the respondents, while a 22% of them evaluated it as just important. A quite similar case was the one of the time scheduling, declaring that the operations should start at the time scheduled in the requests, so that the service does not cause unnecessary delays. The maximum response time, defined as the time elapsed from the vessel's or pilot's call until the mooring units are ready in the manoeuvring area, should be 30 minutes, provided that the pilot has requested the service at least 30 minutes in advance. In this case, 71% of the respondents ranked it as fairly or very important and 18% of them as just important. Also, the ability of the system to support information exchanges with the Port Authority and other interested parties, including ships, in order to identify suitable connection points on the ship was considered as fairly or very important by 78% of the respondents.

In parallel, the requirement of the automated mooring system not to require any special port facilities, meaning that its design should allow installation in smaller ports with limited infrastructure, was considered as fairy or very important by marine/port equipment supplier, shipbuilder and tugboat owner or operator, in contrary to the participants from classification society and information technology system provider that ranked it as slightly or just important. Also, the requirement of the automated mooring system to be adaptable to accommodate smaller ships (like the innovative feeder vessel), in addition to large containerships, was evaluated as fairly or very important by all respondents coming from shipbuilder, maritime consultancy and tugboat owner or operator, while the participants from academia and shipping company had diverse opinions among them (Figure 30).



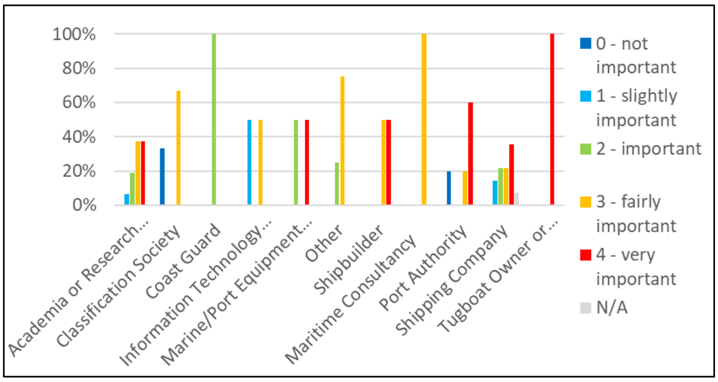


Figure 30 Automated Mooring System Question 2.

The open-ended question regarding the additional potential requirements that the automated mooring system should fulfil resulted to various features. Academia suggested that the design should be able to accommodate a range of ships in terms of their size and within a range of external conditions. Furthermore, the adaptability of the solution to size with different ports was proposed by a shipbuilder company, along with possible back-up arrangements, in case of emergency or power failure or listing of the vessel or other unexpected situations, that were proposed by coast guard.

Table 19 presents the acceptance of the potential requirements that have been evaluated in the questionnaire, from the participants of the online survey. Table 20 captures the additional user needs and potential requirements that have been highlighted from the participants in their responses to the open-ended questions.

Table 19 Mooring System Acceptance of potential requirements.

No	Potential requirement	%	Acceptance	Comment	Organisation
QM1	The automated mooring system should be able to monitor the condition of the system in real time in order to identify and report damages, to the docking mechanism or the hull, during docking.	85		AMS should check tension on mooring lines and raise the appropriate alarms when necessary.	Maritime Consultancy
QM2	The automated mooring system should be adaptable to accommodate smaller ships (like the innovative feeder vessel), in addition to large containerships.	70		Flexibility is the key word. The possibility to use the same mooring system with different ship's types is of paramount importance in setting standards that are applicable to different ships.	Shipbuilder
				This system should be focused on large containerships and not on the feeder vessel. Feeder vessels shall be flexible to approach very small and difficult ports and not to depend on an advance mooring system.	Classification Society
				The system shall be designed to accommodate a range of ships in terms of their size.	Academia or Research Institute
QM3	The automated mooring system should be able to send a warning to the autonomous tugboats if operating parameters are violated (e.g., incorrect approach).	76			

No	Potential requirement	%	Acceptance	Comment	Organisation
QM4	The automated mooring system should not require special port facilities; its design should allow installation in smaller ports with limited infrastructure.	62		The adaptability of the solution to size with different ports is critical to ensure wider applicability.	Shipbuilder
				If this system exists at the small port, birthing will be faster, safer and simpler but we must not oblige small ports to invest on such auto mooring systems.	Classification Society
QM5	The provision of the mooring service shall be in full operational condition (absence of breakdowns or maintenance) at least 95% of the year.	75		A 95% fully operating condition seems very challenging.	Academia or Research Institute
				The 95% availability for very small ports may be a too strict requirement. Also, the seasonality of several small ports must be taken into account.	Classification Society
QM6	Automated mooring services should be available 24/7. If there are more than 8 calls a day in the port, the mooring and unmooring service provider is able to serve two vessels simultaneously at least during the hours of 7:00 a.m. to 10:00 p.m, based on the port having sufficient AutoMoor units along the terminal berth to allow connection to two vessels simultaneously.	62			

No	Potential requirement	%	Acceptance	Comment	Organisation
QM7	Operations should start at the time scheduled in the requests, so that the service does not cause unnecessary delays. The maximum response time, defined as the time elapsed from the vessel's or pilot's call until the mooring units are ready in the manoeuvring area, is 30 minutes, provided that the pilot has requested the service at least 30 minutes in advance.	71			
QM8	The system should support information exchanges with the Port Authority and other interested parties, including ships in order to identify suitable connection points on the ship.	78			

Table 20 Mooring System Comments on potential additional requirements.

Topic	Comment	Organisation
Safety	Back-up arrangement in case of emergency or power failure or listing of the vessel or other unexpected situations should be pre-assessed.	Coast Guard
	The system shall not put in danger either port personnel or crew.	Academia or Research Institute
	The system shall be designed within a range of external conditions (e.g. weather).	Academia or Research Institute

Based on these results for the automated mooring system, there are potential requirements that have gained the stakeholder acceptance. This is the case for the ability of the system to support electronic information exchanges with the Port Authority and other interested parties and the ability of the system to send warning signals to the autonomous tugboats if operating parameters are violated. In parallel, some potential requirements have not been sufficiently accepted; an example is the adaptability of the system to accommodate smaller ships in addition to large containerships.

5.3.8 Matchmaking Platform

The questions regarding the matchmaking platform, as presented in Figure 31, were answered by over 80% of the respondents. It should be noted that the question about listing currently employed data sources and digital collaboration platforms to manage cargo and empty containers was not answered by 95% or the respondents. This may be indicative of the industry to share potentially sensitive business-related information.

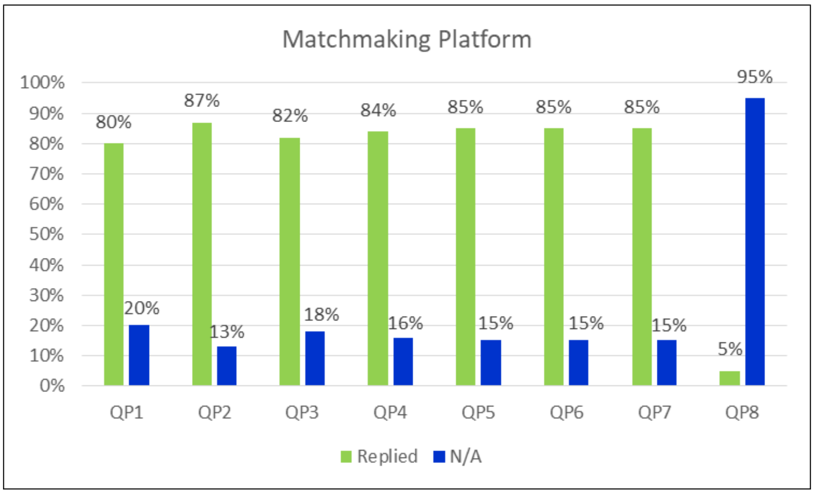


Figure 31 Matchmaking Platform response rates.

The feature of having different user profiles with different roles and access rights to various modules and functionalities of the platform was considered as fairly or very important by 64% of the respondents. In parallel, the ability to allow end-users to list potential transfer requests defining a turn-around-time target value and to allow users to list transport schedules (i.e. vessel schedules, rail calendars, truck availability) was evaluated as fairly or very important by 55% and 54% of the respondents respectively. Additionally, the ability of the platform to offer a module for information sharing and efficient management of empty containers was ranked as fairly or very important by 58% of the respondents, while the requirement of the matchmaking platform to offer a scenario-building capability for the examination of different transport mode combinations was evaluated as fairly or very important also by 58% of the respondents (Figure 32).

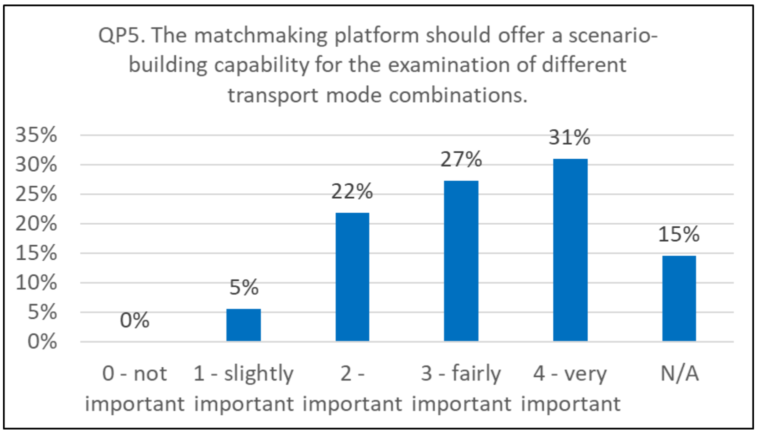
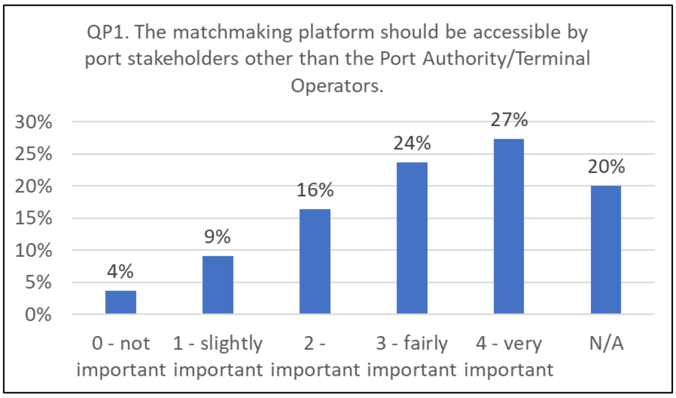


Figure 32 Matchmaking Platform Question 5.

On the other side, the ability of the matchmaking platform to connect to industry-standard data-sources/services and/or consume data from existing datasets was considered as fairly or very important by participants from classification society, information technology system providers and tugboat owner or operator, while the perception of the participants from academia, Port Authority and shipping company regarding this feature was ranging among different levels of importance. Similar results were identified regarding the requirement of the matchmaking platform to be accessible by port stakeholders other than the Port Authority/Terminal Operators, where the participants from port authority and tugboat owner or operator evaluated it as fairly or very important, while the ones coming from coast guard and information technology system provider evaluated as slightly important (Figure 33).



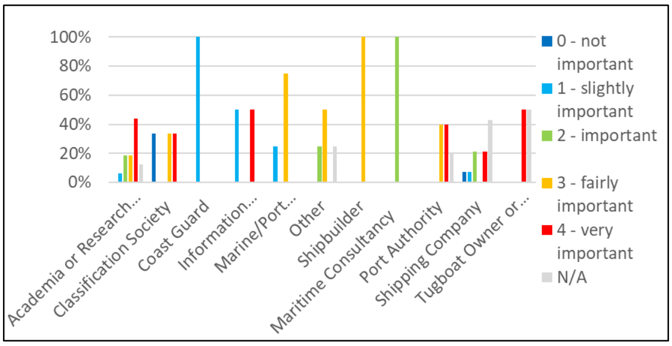


Figure 33 Matchmaking Platform Question 1.

An important note regarding the assessment of the matchmaking platform is that for all requirements that the participants were asked to evaluate, there is a substantial percentage of respondents (13-20% as shown in Figure 31) that did not provide an answer, which may lead to the conclusion that the majority of the participants has no experience in relevant collaborative platforms. This is also clear in Figure 34, where the participants were asked regarding any relevant data-source or collaboration platform that is currently used in their organisation, in order to manage cargo and empty containers, resulting to 95% of them declaring that they do not know whether such a platform or tool is used in their organisations and only 2% of the participants (corresponding to one respondent) mentioning that they currently use their own proprietary system that is connected to the agency network.

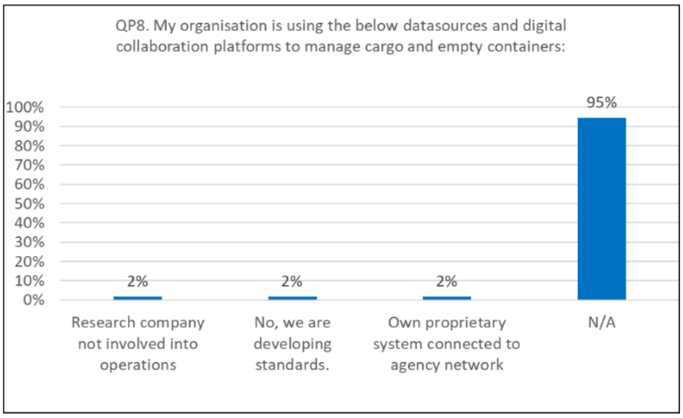


Figure 34 Matchmaking Platform Question 8.

The open-ended section regarding any additional potential requirement for the matchmaking platform resulted into features such as the independent verification of ETA (Estimated Time of Arrival) proposed by the academia, the ability to offer alternative hinterland connections proposed by business advisory company and the requirement for data sharing and data accessibility to ensure data protection for those owning data., proposed by shipbuilder company. Another important comment came from a participant from a business advisory company, declaring that many companies may not want to give insight in their cargo flows and that such a platform could be a direct competitor for many LSP companies, leading to massive obstructions to the platform if it is designed to match the cargo streams (meaning containers full of cargo).

Table 21 presents the acceptance of the potential requirements. Table 22 captures the additional user needs and potential requirements that have been highlighted by the respondents in their responses to the open-ended questions.

Table 21 Matchmaking Platform Acceptance of potential requirements.

No	Potential requirement	%	Acceptance	Comment	Organisation
QP1	The matchmaking platform should be accessible by port stakeholders other than the Port Authority/Terminal Operators.	51		The Interface should also be accessible by other authority and port systems. We should perhaps also consider ship delays, independent verification of ETA etc.	Academia or Research Institute
QP2	The matchmaking platform should have different user profiles with different roles and access rights to various modules and functionalities of the platform.	64		Data sharing and data accessibility should ensure data protection for those owning data.	Shipbuilder
QP3	The matchmaking platform should allow end-users to list potential transfer requests defining a turn-around-time target value.	55			
QP4	The matchmaking platform should allow the users to list transport schedules (i.e. vessel schedules, rail calendars, truck availability).	54			
QP5	The matchmaking platform should offer a scenario-building capability for the examination of	58		The practical use is first to be found in organisation of the empty containers, and offering alternative hinterland connections	Other/ business advisory

No	Potential requirement	%	Acceptance	Comment	Organisation
	different transport mode combinations.			(rail, barge) that express 'the most ecological solution'. This requires though the input of a significant amount of data from container shipping lines, final receivers, logistics service parties.	
QP6	The matchmaking platform should offer a module for information sharing and efficient management of empty containers.	58			
QP7	The matchmaking platform should be able to connect to industry-standard data sources/services and/or consume data from existing datasets.	62			

Table 22 Matchmaking Platform Comments on potential additional requirements.

Topic	Comment	Organisation
Tracking	Owner of the goods should see in any moment where the goods and container are.	Port Authority
Disadvantages	The private sector will have massive obstructions to the platform if it is to match the cargo streams (meaning containers full of cargo).	Other/ business advisory
	The platform may be considered as a direct competitor of many LSP.	
	Many companies do not want to give insight in their cargo flows.	

Based on these results for the matchmaking platform, there are potential requirements that have been considered as significant by the stakeholders. This is the case for the ability of the platform to accommodate different user profiles, roles and access rights. In parallel, some potential requirements have not been sufficiently accepted by the respondents, as for example the possibility of the platform to allow end-users to list potential transfer requests defining a turn-around-time target value. Last but not least, the possible reluctance of the companies to share data and the fact that the platform may be considered as a direct competitor of many logistics service providers need to be also considered in the design of the matchmaking platform.

5.3.9 General direction of the MOSES project

The last section of the questionnaire included questions relevant to the general direction of the MOSES project that the respondents were asked to evaluate. As shown in Figure 35, these questions were answered by over 93% of the respondents.

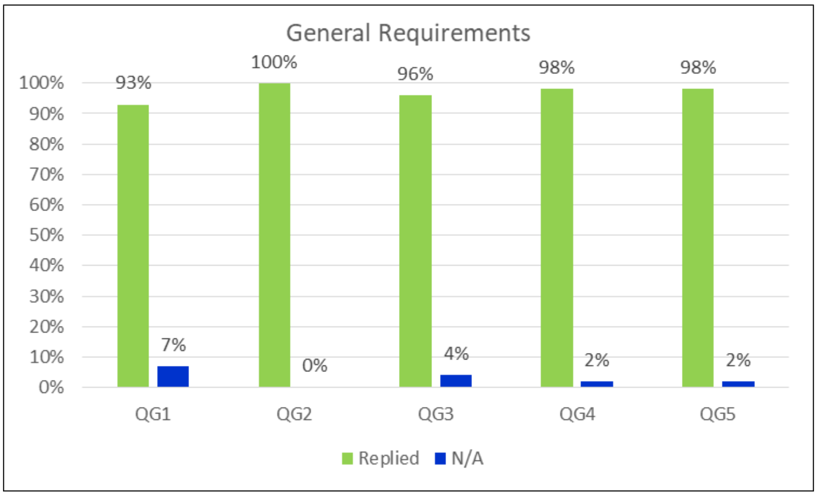


Figure 35 General direction of the MOSES project response rates.

The MOSES objective to create new sustainable container feeder lines from DSS ports to smaller mainland ports, was considered as fairly or very important by 71% of the respondents. The goal to design the MOSES innovations to be cost-effective in their implementation, even if that means that they do not reach their full potential was considered as fairly or very important by 63% of the respondents. In parallel, the ability of the MOSES innovations to ultimately achieve a high level of automation (e.g., unmanned operation, fully automated systems) was evaluated as fairly or very important by 81% of the respondents (Figure 36).

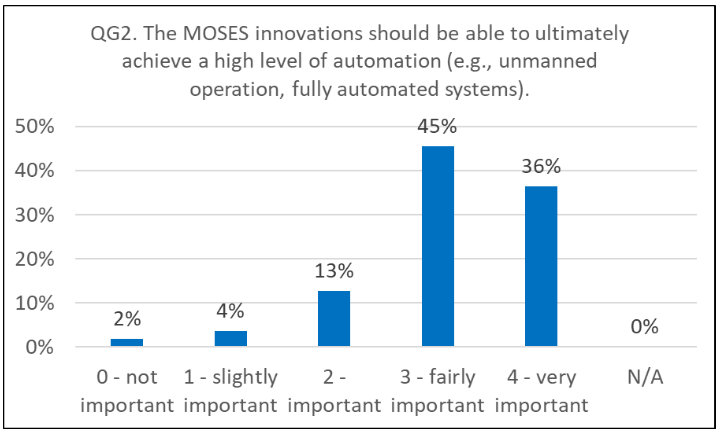


Figure 36 General direction of the MOSES project Question 2.

In contrast, respondents' perception about the importance of the objective that the operation of the MOSES innovations should not require any additional investment on port infrastructure varied from slightly to very important, with most of the organisations not having a clear opinion. This was also the case for the ability of the MOSES innovations not to cause any temporary disruption to ports during their implementation, even if they will improve operations as soon as they become operational, where participants from academia, marine/port equipment supplier and shipping company gave quite diverse answers (Figure 37).

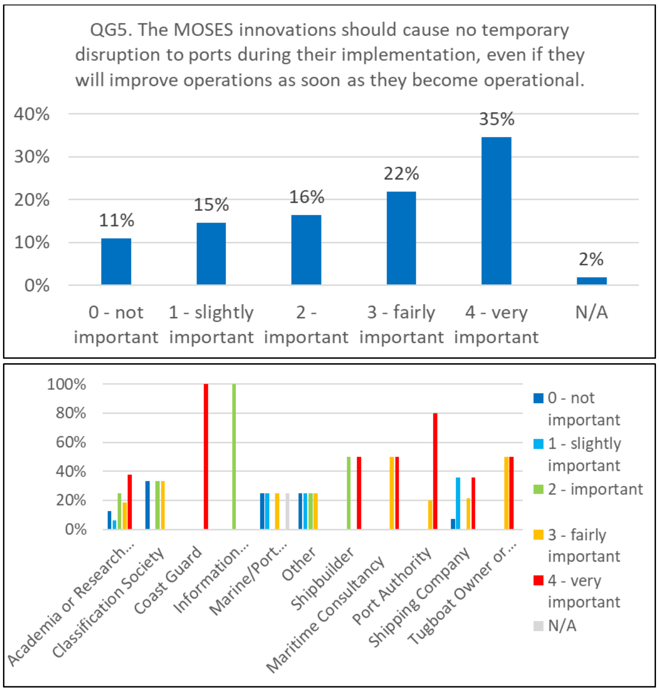


Figure 37 General direction of the MOSES project Question 5.

Finally, the open-ended question resulted into the request for additional features such as the overall cost-effectiveness of the developed innovation, proposed by the academia, as well as the contribution to continuing the services in off-hours and the internalization of external transport costs that was proposed by participants from business advisory company.

Table 23 presents the acceptance of the potential general requirements. Table 24 captures the additional user needs and potential general requirements that have been highlighted by the respondents in their responses to the open-ended questions.

Table 23 Acceptance of potential general requirements.

No	Potential requirement	%	Acceptance	Comment	Organisation
QG1	MOSES should create new sustainable container feeder lines from DSS ports to smaller mainland ports.	71			
QG2	The MOSES innovations should be able to ultimately achieve a high level of automation (e.g., unmanned operation fully automated systems).	81			
QG3	The operation of the MOSES innovations should not require any additional investment on port infrastructure.	40			
QG4	The design of the MOSES innovations should allow for their implementation to be cost-effective even if that means that they do not reach their full potential.	63		Cost-effectiveness is dependent on the whole logistics system. Much more expensive single components are ok if the total cost (OPEX and CAPEX) goes down.	Academia or Research Institute
				The price and financing should not pose a problem, on condition that the real and full external costs of transport are internalized (internalization of external transport costs).	Other/business advisory

No	Potential requirement	%	Acceptance	Comment	Organisation
QG5	The MOSES innovations should cause no temporary disruption to ports during their implementation, even if they will improve operations as soon as they become operational.	57			

Table 24 General Comments on potential additional requirements.

Topic	Comment	Organisation
Working hours	Depending on the volumes and congestion in ports, MOSES innovations can have a significant contribution to continuing the services in off-hours (holidays, weekends, night shifts) in a sustainable manner. The transportation costs can be reduced at night hours since using busy traffic hours means more expensive driving costs, additionally the road tolls are more expensive during 06:00-22:00 hours.	Other/business advisory

In summary, the expectation that all MOSES innovations should achieve a high level of automation has been well documented from the results of the questionnaire. This is in line with the project's inherent orientation towards the incorporation of high-end technologies within the delivered innovations and has to be formalised in relevant user requirements. Other objectives that achieved a high score (above 60%) among respondents', concern the prioritization of the cost-effectiveness of the innovations that should be taken into consideration during their development, as well as the creation of sustainable container feeder lines that will operate from DSS ports to smaller ports offering their services in a more efficient way. The objective related with the need for additional investment in port infrastructure for the efficient operation of MOSES innovations, as well as their limited impact on port operations during their implementation stage are judged to be of minor importance since they succeeded a score of 40% and 57% among the respondents, respectively.

6. MOSES Innovations User Requirements

6.1 Introduction

In this section, user requirements for each innovation are documented, based on the results from the workshops and the online questionnaire. For the documentation of the requirements the format and type of content as presented in Table 2 will be used. It shall be also mentioned that there is no specific order in the appearance of the user requirements.

6.2 Innovative Feeder Vessel

In total, 9 requirements for the feeder vessel were identified. These requirements can be characterised and clustered as follows (see Table 25)

Table 25: Summary of user requirements and type of classes for the innovative feeder vessel.

Total number of requirements	9
Functional requirements	7
Non-Functional requirements	2

Requirement classes

Environmental	Technical	Safety	Societal	Market
2	6	1	1	1

User Requirement ID	FV_1
Requirement Type	NF
Requirement Class	Environmental
Title	Reduced environmental footprint during sea passage
Description	The feeder vessel must comply with the low GHG's emission targets set at least by IMO for 2050 and if possible, achieve the respective targets of the EU. This mean that the goal could be a climate neutral ship.
Priority	Must
Dependency	FV_2

User Requirement ID	FV_2
Requirement Type	NF
Requirement Class	Societal
Title	Improved environmental footprint during port operations
Description	The feeder vessel must have a reduced environmental footprint during port operations and especially within the SSS port operations, including entrance, berthing and loading/unloading. All types of air emissions that affect air quality are included as well as noise and pollution issues.
Priority	Must
Dependency	FV_1

User Requirement ID	FV_3
Requirement Type	F
Requirement Class	Technical
Title	Autonomous navigation for sea passage
Description	The feeder vessel could operate autonomously between service ports. Its status shall be continuously monitored and controlled from a shore control station.
Priority	Could
Dependency	-

User Requirement ID	FV_4
Requirement Type	F
Requirement Class	Technical
Title	Automated mooring capabilities
Description	For the DSS port, the feeder vessel could be designed in a way that the connection with the automated mooring system is ensured. For the SSS ports, the vessel could use DP capabilities for the mooring. Furthermore, typical mooring capabilities shall be also available.
Priority	Could
Dependency	FV_9

User Requirement ID	FV_5
Requirement Type	F
Requirement Class	Technical
Title	Minimum requirements for facilities for the SSS ports
Description	The feeder vessel shall require minimum facilities from the SS port. It shall contain its own loading/unloading equipment while the needs for bunkering facilities shall be minimum.
Priority	Must
Dependency	RCA_1

User Requirement ID	FV_6
Requirement Type	F
Requirement Class	Market
Title	Multipurpose usage/operation
Description	The feeder vessel could have separate passenger accommodation and cargo areas to ensure a non-simultaneous safe passenger and cargo transportation.
Priority	Could
Dependency	-

User Requirement ID	FV_7
Requirement Type	F
Requirement Class	Technical
Title	Reduced ballast operations
Description	The innovative feeder vessel could be designed in a way that ballasting/de-ballasting operations are reduced or eliminated for time saving and environmental reasons.
Priority	Could
Dependency	-

User Requirement ID	FV_8
Requirement Type	F
Requirement Class	Environmental
Title	Reduced underwater noise level
Description	The feeder vessel could have a low radiated underwater noise level in order not to burden the marine life.
Priority	Could
Dependency	-

User Requirement ID	FV_9
Requirement Type	F
Requirement Class	Safety
Title	Enhanced manoeuvrability and capability of position keeping
Description	The feeder vessel must be designed in order to safely approach, enter and manoeuvre in service ports during severe weather conditions. Moreover, DP capabilities to be incorporated to provide capability for maintaining safely a zero speed.
Priority	Must
Dependency	FV_4

6.3 Robotic Container-Handling System

In total, 7 requirements for the robotic container handling system were identified. These requirements can be characterised and clustered as follows (see Table 26):

Table 26: Summary of user requirements and type of classes for the robotic container-handling system.

Total number of requirements	7
Functional requirements	6
Non-Functional requirements	1

Requirement classes

Environmental	Technical	Safety	Societal	Market
0	5	1	0	1

User Requirement ID	RCA_1
Requirement Type	NF
Requirement Class	Safety
Title	The robotic container handling system shall be at least as safe as existing systems and operations
Description	The Robotic container handling system is to be designed in conjunction with the regulatory development that is required to enable operations in national and international waters. Its operation shall result in an accepted safety level, at least similar with the corresponding of existing systems, both for the ship and for the port area.
Priority	Must
Dependency	-

User Requirement ID	RCA_2
Requirement Type	F
Requirement Class	Technical
Title	Lifting requirements for the size and weight of TEUs
Description	The Robotic container handling system must be able to handle at least 20’, 40’ and 45’ containers and a weight of at least 40 tons.
Priority	Must
Dependency	RCA_3

User Requirement ID	RCA_3
Requirement Type	F
Requirement Class	Technical
Title	Lifting requirements in relation to the identification of the size of the containers
Description	The Robotic container handling system should be able to identify the size of the container to be handled.
Priority	Should
Dependency	RCA_2

User Requirement ID	RCA_4
Requirement Type	F
Requirement Class	Technical
Title	Remote Control requirements
Description	The Robotic container handling system should be controlled remotely both by an operator on the feeder vessel and a remote-control station.
Priority	Should
Dependency	-

User Requirement ID	RCA_5
Requirement Type	F
Requirement Class	Technical
Title	RCH loading/unloading plan
Description	The Robotic container handling system should be able to identify the container number and load/unload based on a predefined loading/unloading list.
Priority	Must
Dependency	RCA_2, RCA_3

User Requirement ID	RCA_6
Requirement Type	F
Requirement Class	Market
Title	Efficient operation
Description	The Robotic container handling system must be able to operate under conditions similar to those of a manually operated crane and as fast as a manually operated one.
Priority	Must
Dependency	-

User Requirement ID	RCA_7
Requirement Type	F
Requirement Class	Technical
Title	RCH operator visual/spatial perception
Description	The system must provide to the remote operator a detailed picture of the quay under all lighting conditions. This requirement involves both moving and stationary personnel and objects on the quay side.
Priority	Must
Dependency	RCA_6

6.4 Autonomous Tugboats

In total, 12 requirements for the autonomous tugboats were identified. These requirements can be characterised and clustered as follows (see Table 27):

Table 27: Summary of user requirements and type of classes for the autonomous tugboats.

Total number of requirements	12
Functional requirements	10
Non-Functional requirements	2

Requirement classes

Environmental	Technical	Safety	Societal	Market
0	6	4	1	1

User Requirement ID	AT_1
Requirement Type	F
Requirement Class	Safety
Title	Fail-safe Operation
Description	The tugboat must be able to safely return to a predefined place upon losing communication with the port command centre after exceeding a pre-defined time threshold.
Priority	Must
Dependency	-

User Requirement ID	AT_2
Requirement Type	NF
Requirement Class	Safety
Title	Secure communication
Description	The communication between the port control and the tugboats, as well as between the tugboats themselves, could be interrupted unless secure and encrypted communication protocols are used.
Priority	Should
Dependency	-

User Requirement ID	AT_3
Requirement Type	F
Requirement Class	Technical
Title	Capability to operate with various levels of autonomy
Description	The autonomous tugboats need to be able to operate with various level of autonomy. We need to identify human-related tasks in conventional tugboat operation and decide which of them will be automated in MOSES (e.g., navigation, engine room management etc.).
Priority	Could
Dependency	AT_1, AT_2

User Requirement ID	AT_4
Requirement Type	F
Requirement Class	Technical
Title	Fail-safe operation back-up strategies
Description	For the design of the fail-safe condition, a safe location in the port might not be available and therefore additional back-up/contingency strategies should be developed.
Priority	Should
Dependency	AT_1

User Requirement ID	AT_5
Requirement Type	NF
Requirement Class	Societal
Title	Reduced environmental footprint
Description	The autonomous tugboats must have minimal environmental footprint during their operations by exploiting environmentally friendly power solutions. All types of air emissions are involved, including greenhouse gases and harmful emissions to public health.
Priority	Must
Dependency	-

User Requirement ID	AT_6
Requirement Type	F
Requirement Class	Market
Title	Operational competence
Description	The autonomous tugboats operations should perform at least at the same level as conventional tugboats, in terms of safety, cost of operation, and time to complete a specific task.
Priority	Should
Dependency	-

User Requirement ID	AT_7
Requirement Type	F
Requirement Class	Technical
Title	Operation must be able to continue when a tugboat cannot continue its operation
Description	Towing operation does not have to be stopped when, for example, a tugboat runs out of power. "This could be achieved through, for example, hot swapping" operation for the tugboat swarm.
Priority	Should
Dependency	AT_1, AT_10

User Requirement ID	AT_8
Requirement Type	F
Requirement Class	Technical
Title	Adjustment on towing methods
Description	Autonomous Tugs should be capable to adjust (adopt) to different towing methods (on the line, push-pull method, etc.).
Priority	Should
Dependency	AT_10

User Requirement ID	AT_9
Requirement Type	F
Requirement Class	Safety
Title	Communication between Autonomous Tugboat and non-autonomous vessel
Description	Means of communication between Autonomous Tugboat(s) and a non-Autonomous vessel during towing operation should be enabled and efficiently configured (e.g. safeguard secure operation of making fast or cast-off tow lines).
Priority	Should
Dependency	AT_2, AT_8

User Requirement ID	AT_10
Requirement Type	F
Requirement Class	Technical
Title	A group of autonomous tugboats to be able to cooperate for the towing and berthing of vessels of various sizes
Description	Autonomous Tugboat(s) should be able to operate as a swarm for handling vessels of various sizes in cooperation with other manually or remotely controlled tugboats or alone.
Priority	Must
Dependency	AT_2, AT_7, AT_8, AT_9

User Requirement ID	AT_11
Requirement Type	F
Requirement Class	Technical
Title	The operator (command station ashore) shall have the capability to obtain remotely the control of the tugboat(s)
Description	The operator must be able to intervene and override the autonomous operation of the tugboats when needed.
Priority	Must
Dependency	AT_1, AT_2, AT_10

User Requirement ID	AT_12
Requirement Type	F
Requirement Class	Safety
Title	Continuous condition monitoring
Description	The operator must be able to monitor the status of each autonomous tugboat from a remote-control station.
Priority	Must
Dependency	AT_1, AT_2, AT_11

6.5 Auto-Docking

In total, 8 requirements for the auto-docking system were identified. These requirements can be characterised and clustered as follows (see Table 28):

Table 28: Summary of user requirements and type of classes for the auto-docking system.

Total number of requirements	8
Functional requirements	8
Non-Functional requirements	0

Requirement classes

Environmental	Technical	Safety	Societal	Market
0	2	4	0	2

User Requirement ID	AD_1
Requirement Type	F
Requirement Class	Technical
Title	Support electronic information exchanges with the Port Authority, other Administrations, clients, and other interested parties, including ships.
Description	Use, where appropriate, of common computer systems decided by the Port Authority or port community (using readily available and mature industrial grade equipment). Use of information exchange procedures approved within the framework of the port community, using well established communication protocols and information safeguards.
Priority	Must
Dependency	-

User Requirement ID	AD_2
Requirement Type	F
Requirement Class	Technical
Title	Operational Reliability of the mooring service
Description	The Auto-Docking module must be able to perform its intended function adequately (absence of breakdowns or maintenance), initially for at least 95% of the year.
Priority	Must
Dependency	AD_3

User Requirement ID	AD_3
Requirement Type	F
Requirement Class	Market
Title	Mooring service availability and installation time
Description	The providers of the mooring and unmooring service ensure that the service is available 24 hours a day, 365 days a year. If there are more than 8 calls a day in the port, the mooring and unmooring service provider is able to serve two vessels simultaneously Auto moor units along the terminal berth to allow connection to two vessels simultaneously. Finally, installation time should be as short as possible.
Priority	Must
Dependency	AD_2, AD_4

User Requirement ID	AD_4
Requirement Type	F
Requirement Class	Market
Title	Responsiveness
Description	Operations start at the time scheduled in the requests, so that the service does not cause unnecessary delays or delays to the vessels. Mooring service start time: The maximum response time, defined as the time elapsed from the vessel's or pilot's call until the mooring units are ready in the manoeuvring area, is 30 minutes, provided that the pilot requests the service at least 30 minutes in advance.
Priority	Must
Dependency	AD_1

User Requirement ID	AD_5
Requirement Type	F
Requirement Class	Safety
Title	Provide information about secure connection
Description	Support information exchanges with the Port Authority and other interested parties, including ships, to ensure that suitable and adequate connection points are located on the vessel, and that the mooring system is positioned appropriately so that the ship can be safely moored.
Priority	Must
Dependency	AD_1, AD_4

User Requirement ID	AD_6
Requirement Type	F
Requirement Class	Safety
Title	Transmission of a warning signal
Description	The automated mooring system should send a warning signal to the autonomous tugboats in case operating parameters are violated.
Priority	Must
Dependency	AT_8, AT_9, AT_10

User Requirement ID	AD_7
Requirement Type	F
Requirement Class	Safety
Title	Condition monitoring
Description	The automated mooring system should perform real time monitoring of the condition of the system, so that potential damages to the docking mechanism or the hull, during docking are identified and reported (e.g. the tension on mooring lines should be checked by AMS in order to raise the suitable warning if needed).
Priority	Should
Dependency	-

User Requirement ID	AD_8
Requirement Type	F
Requirement Class	Safety
Title	Provision of a backup arrangement
Description	A backup arrangement should be provided in case of any kind of failure of the main one, or when operational limits are exceeded (e.g. heavy weather).
Priority	Must
Dependency	-

6.6 Matchmaking Logistics Platform

In total, 11 requirements for the matchmaking logistics platform were identified. These requirements can be characterised and clustered as follows (see Table 29):

Table 29: Summary of user requirements and type of classes for the matchmaking logistics platform.

Total number of requirements	11
Functional requirements	10
Non-Functional requirements	1

Requirement classes

Environmental	Technical	Safety	Societal	Market
0	7	0	0	4

User Requirement ID	MLP_1
Requirement Type	NF
Requirement Class	Technical
Title	User roles, authentication and authorization
Description	Assign access rights (view, add, edit, delete users, orders and feature availability) to a user. GDPR rules apply.
Priority	Must
Dependency	-

User Requirement ID	MLP_2
Requirement Type	F
Requirement Class	Market
Title	Transport schedules
Description	Provide details about destination and stops along a transport corridor (road, rail, maritime) including available capacity.
Priority	Must
Dependency	-

User Requirement ID	MLP_3
Requirement Type	F
Requirement Class	Technical
Title	Order Details
Description	Provide the fields to hold the necessary information about an order (cargo type, volume, weight, destination, departure/arrival dates etc).
Priority	Must
Dependency	-

User Requirement ID	MLP_4
Requirement Type	F
Requirement Class	Market
Title	Transport Matchmaking
Description	Propose alternatives of available transport modes to reach a specific destination.
Priority	Must
Dependency	MLP_2, MLP_3

User Requirement ID	MLP_5
Requirement Type	F
Requirement Class	Market
Title	Demand Aggregation
Description	Perform cargo pooling and consolidation. Assign orders to routes/services so as to minimise certain criteria within a network of supply chains based on a number of parameters (timely delivery, cargo types, volumes, weight etc).
Priority	Must
Dependency	MLP_2, MLP_3, MLP_4

User Requirement ID	MLP_6
Requirement Type	F
Requirement Class	Technical
Title	Select Optimisation Criteria
Description	Allow the user to select the criteria used in the multi-objective optimisation (e.g. GHG emissions and cost) and hard constraints such as custom metrics related to service quality and historical disruption levels etc.
Priority	Should
Dependency	MLP_2, MLP_3, MLP_4, MPL_5

User Requirement ID	MLP_7
Requirement Type	F
Requirement Class	Technical
Title	Order Management
Description	Add, view, edit, delete an order.
Priority	Must
Dependency	MLP_2, MLP_3, MLP_4, MPL_5

User Requirement ID	MLP_8
Requirement Type	F
Requirement Class	Technical
Title	Data Interoperability
Description	Import/Export standard formats.
Priority	Must
Dependency	-

User Requirement ID	MLP_9
Requirement Type	F
Requirement Class	Market
Title	Demand Forecasting
Description	Predict demand.
Priority	Should
Dependency	MLP_2, MLP_3, MLP_4, MPL_5

User Requirement ID	MLP_10
Requirement Type	F
Requirement Class	Technical
Title	Messaging
Description	Allow the users to communicate within the platform about an order.
Priority	Should
Dependency	MLP_2, MLP_3, MLP_4, MPL_5

User Requirement ID	MLP_11
Requirement Type	F
Requirement Class	Technical
Title	Show the transport network on a map
Description	Show the transport network on a map including hubs, roads, rail tracks, sea routes and inland waterways.
Priority	Should
Dependency	-

6.7 Discussion on results

In total, 47 user requirements have been documented, which meet the criteria of specificity, precision, and unambiguousness described by ISO/IEC/IEEE 29148 [1]. The requirements are classified as functional (F) or non-functional (NF), while the following requirement classes were assigned: environmental, technical, societal, safety and market. The categorization is applied to show the relevance of the user requirements to the broad objectives of the MOSES project.

About 87% of the user requirements are functional, i.e. describe what the MOSES innovations should be able to do (Figure 38). At the early stages of development, it is important to determine the main functionalities of the MOSES innovations and therefore this report has focused on functional requirements.

In addition, about 51% of requirements relate to technical issues, while 21% relate to safety and 19% to market issues (Figure 39). Furthermore, possible under representation of some class categories of the requirements (e.g. environmental and societal) will be addressed by the output of Tasks 2.2 and 2.3, where MOSES innovations will be examined from different perspectives, and thus their impact will be strengthened on Task 2.4 (system specifications).

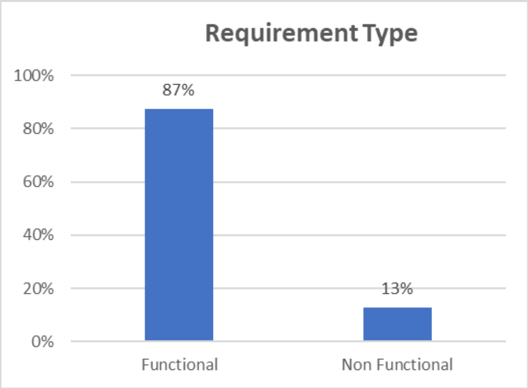


Figure 38 User requirements – Percentage distribution between functional and non-functional requirements.

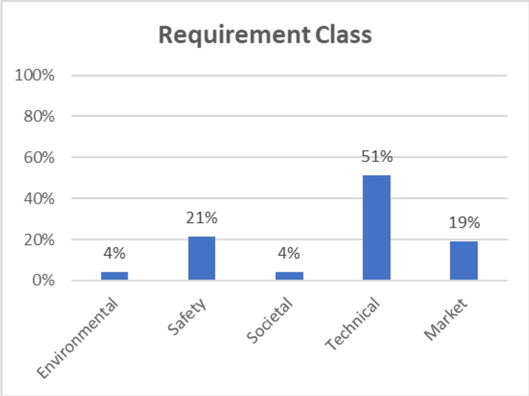


Figure 39 User requirements – Percentage distribution between requirement classes.

In addition, the user requirements were given priorities by using the keywords 'Must', 'Should', and 'Could'. The prioritization was based on the information collected by the MOSES online survey as reflected by the stakeholder acceptance analysis, as well as the expertise of the developers of the MOSES innovations and the objectives of the project. About 60% of the requirements are considered as a must for implementation, while about 28% as should-have and about 13% as could -have and thus optional (Figure 40).

The MOSES stakeholder engagement activities conducted in the context of Task 2.1 (i.e. workshops and online survey) proved to be valuable sources of user requirements. As shown in Figure 41, approximately 30% of the identified user requirements were derived from stakeholder feedback, in addition to the initial set of potential requirements that were stated by the MOSES developers and whose acceptance by the stakeholders was determined through the online survey.

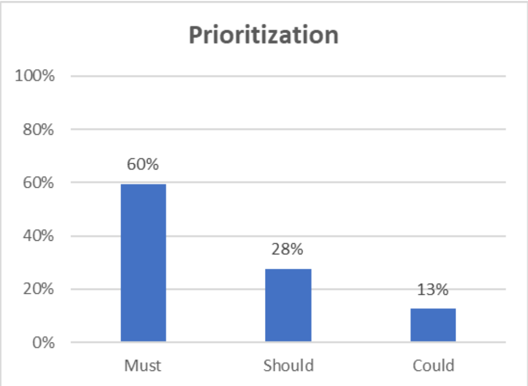


Figure 40 User requirements – Percentage distribution according to the given prioritization.

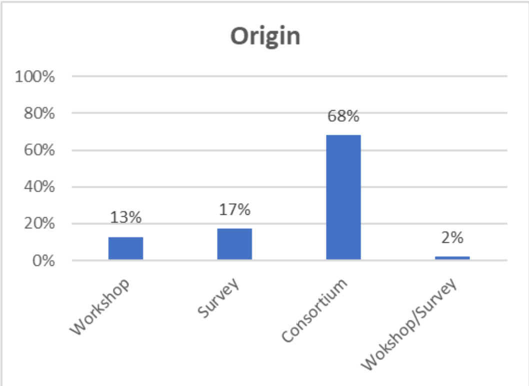


Figure 41 User requirements – Percentage distribution in terms of their origin, where the last category involves requirements identified both during workshops and via the survey.

The user requirements documented in this report will provide input, in addition to the outcomes from Task 2.2 (use cases and scenarios) and Task 2.3 (market-related requirements), to the definition of the system requirements and specifications in Task 2.4.

Conclusions

This report presents user and stakeholder needs based on information from the following sources: 1) identified challenges based on a review of state-of-the-art technologies and processes relevant to the MOSES innovations, and 2) direct engagement of stakeholders through an online survey and two workshops. The online survey was used to gauge the stakeholder acceptance of an initial set of potential requirements (drafted by the members of the MOSES Consortium) and identify additional requirements. The engagement activities were targeted at stakeholders relevant to the MOSES innovations, according to the stakeholder analysis presented in this report. The identified needs were subsequently translated into formal user requirements and documented using a unified template per the following MOSES innovations: 1) Innovative Feeder Vessel, 2) Robotic Container-Handling System, 3) Autonomous Tugboats, 4) Automated Docking Scheme, 5) Matchmaking Logistics Platform.

The requirements elicitation process was based on a concise definition of each of the MOSES innovations, which was also used to familiarize stakeholders with the technical and operational concepts developed in this project.

The scope of the user requirements listed in this report covers a wide range of issues, including safety, security/privacy, and human-machine interactions. The documented user requirements were classified into the following categories: environmental, societal, safety, technical, and market. Considering that about 72% of the requirements are related to technical and safety issues, work in subsequent tasks will focus on complementing the requirements to cover the other aspects as well. In addition, at this stage 7 – 12 requirements per innovation were identified; the majority of which (87%) are functional, which determine what the MOSES innovations should be able to do. Non-functional requirements will be the main focus of Task 2.4, where non-functional system requirements will specify how the MOSES innovations should perform.

In addition, an average of 70% of the respondents in the online questionnaire evaluated all the potential requirements identified by the members of the MOSES Consortium as fairly important and very important. Therefore, the potential requirements are acceptable to the stakeholders and end-users at a sufficient level.

The produced user requirements will be validated by the MOSES Advisory Board in a workshop. The results will be considered for the development of the system specifications (T2.4) and will be documented in D2.4 'Specifications and requirements for MOSES innovations'. Furthermore, the analyses and the user requirements documented in this report will inform the development of the MOSES use cases in D2.2 'MOSES use cases and scenarios'.

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Annex 1 MOSES Questionnaire

MOSES User Needs and Requirements Questionnaire

Fields marked with * are mandatory.

Introduction

You are invited to complete a questionnaire within the context of the **MOSES** research project (auto**M**ated vessels and supply chain **O**ptimisation for sustainable short **SE**a **S**hipping) which is funded by the European Union.

It will only take about **15–20 minutes** of your time to complete this questionnaire, which is a part of the project's user needs and requirements definition phase. You will be asked to assess the importance of several aspects of the MOSES innovations. There is also one open-ended question on each subject so that you can provide more information if you wish to do so.

Before you decide if you want to participate, it is important that you understand the aim of the research, what it involves and your rights as a participant. To ensure that you have a clear understanding of these matters, please carefully read through all the sections of this questionnaire. Please feel free to contact us and ask questions until you are confident that you have received understandable answers before making a decision.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 861678. The content of this questionnaire reflects only the authors' view and the Agency is not responsible for any use that may be made of the information it contains.

The Project

Motivation

The EU is highly dependent on ports for trade. Deep Sea Shipping (DSS) ports are integral nodes within multimodal logistic flows, mainly using road and rail for the backhaul. Short Sea Shipping (SSS) and inland waterways are not so well integrated.

1

The Problem
The predominant challenge for wider adoption of SSS for containerised cargo is that large containerships may only be served by DSS Hub Ports due to navigational restrictions and infrastructure requirements, such as available space and container handling capabilities. Hub Port operations are increasingly less efficient due to congested waterways and manoeuvring and berthing processes which are error-prone, highly time-consuming and costly, vulnerable to disruptions and accidents, and with significant environmental impact. In addition, large containerships generate feeder services that require large vessels that cannot be serviced by many small ports, which might also not offer 24/7 port services.

Aim
MOSES aims to improve the modal split of containerised cargo transport across Europe by enhancing the SSS component of the European container supply chain. The project's innovation potential covers both vessel design aspects as well as software tools and accompanying governance models to improve related logistics processes by reducing the total time to berth for TEN-T Hub Ports and stimulating the use of SSS feeder services in small ports that have limited or no infrastructure.

Objectives

- Improve SSS efficiency.
- Promote the development of small ports.
- Reduce the environmental footprint of port operations.

MOSES Innovations

1. innovative feeder vessels;
2. a robotic container-handling system;
3. autonomous tugboats;
4. an automated mooring system;
5. a digital collaboration and matchmaking platform.

Privacy Policy

The Consortium is hosting the questionnaire on the EUSurvey platform, which is the European Commission's official online survey management system for creating and publishing forms available to the public, e.g. user satisfaction surveys and public consultations.
The European Commission is not responsible for the content of questionnaires created using the EUSurvey service - it remains the sole responsibility of the form creator and manager. The use of EUSurvey service does not imply a recommendation or endorsement, by the European Commission, of the views expressed within them.

This privacy policy explains how your data are processed when you access and use this online platform.

For more information please visit:
EUSurvey - Privacy Statement
EUSurvey - Terms of Service
EUSurvey - Cookies Policy

2

What information is stored by EUSurvey when participants access the platform or submit a contribution?
This survey is anonymous, therefore EUSurvey does not save any user-related information. Any user information, in case a user is logged in with their EU account when submitting a contribution, will be replaced by "Anonymous" by the EUSurvey system. The anonymisation happens at the point and time at which the data are collected, so no personal data are actually processed.
However, the IP of every connection is saved for security reasons for every server request (see privacy statement on the protection of personal data by the European Commission on EUSurvey).

How does the EUSurvey system use cookies?
The EUSurvey system uses session "cookies" in order to ensure reliable communication between the client and the server. Therefore, your browser must be configured to accept "cookies". The cookies disappear once the session has been terminated.
The system uses local storage to save copies of the inputs of a participant to a survey in order to have a backup if the server is not available during submission or the user's computer is switched off accidentally or any other cause. The local storage contains the IDs of the questions and the draft answers. Once a participant has submitted one's answers successfully to the server or has successfully saved a draft on the server, the data is removed from the local storage. There is a checkbox above the survey "Save a backup on your local computer (disable if you are using a public/shared computer)" to disable the feature. In that case, no data will be stored on the used computer.

Privacy policies of other websites
The MOSES User Needs and Requirements Questionnaire contains links to other websites. This privacy policy applies only to this survey, so if you click on a link to another website, you should read their privacy policy.

How to contact us
If you have any questions about this privacy policy please do not hesitate to contact us.

☐ I accept these Terms

Information about the Questionnaire

Background
MOSES is a research project that aims to significantly enhance the Short Sea Shipping component of the European container supply chain by addressing inflexibilities in the operation of large containerships and facilitating the collaboration between logistics stakeholders.

The Consortium
The MOSES Consortium consists of 17 partners, from 7 EU countries, coordinated by Prof. Nikolaos Ventikos on behalf of the National Technical University of Athens:

- NATIONAL TECHNICAL UNIVERSITY OF ATHENS (**NTUA**)
- ENGITEC SYSTEMS INTERNATIONAL LIMITED (**ESI**)

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- CORE INNOVATION AND TECHNOLOGY OE (**CORE**)
- NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO (**TNO**)
- STICHTING MARITIEM RESEARCH INSTITUUT NEDERLAND (**MARIN**)
- ELLINIKI ENOSI PLIOKTITON RIMOULKON, NAYAGOSOSTIKON, ANTIRIPANTIKON KAI PLION IPOSTIRIXIS IPERAKTION EGKATASTASEON (**SAT**)
- DANAOS SHIPPING COMPANY LIMITED (**DANAOS**)
- FUNDACION DE LA COMUNIDAD VALENCIANA PARA LA INVESTIGACION, PROMOCION Y ESTUDIOS COMERCIALES DE VALENCIAPORT (**VPF**)
- DNV GL HELLAS SA (**DNVGL**)
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- STATHMOS EMPOREVMATOKIVOTION PEIRAIA AE (**PCT**)
- DIMOTIKO LIMENIKO TAMEIO MYKONOU (**MHM**)
- NAYTILIAKES METAFORIKES KAI EPIKOINONIAKES EPIXEIRISEIS SEABILITY EPE (**SEAB**)
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- CIRCLE SPA (**CIRCLE**)
- MACGREGOR SWEDEN AB (**MCGRSWE**)
- PROZERO INTERNATIONAL APS (**TUCO**)

Funding
MOSES has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 861678.

Purpose
The objective of this survey is to collect the end-user needs and requirements for the MOSES innovations:

- innovative feeder vessels;
- a robotic container-handling system;
- autonomous tugboats;
- an automated mooring system;
- a digital collaboration and matchmaking platform.

Content
You will be asked to assess the importance of several aspects of the MOSES innovations. There is also one open-ended question on each subject so that you can provide more information if you wish to do so.

Participants
You have been sent the link to this questionnaire by one of our partners within your network of contacts who has identified you as a stakeholder for the project.

Participation
Your participation is voluntary. You do not have to answer all the questions. You have the right to refuse to participate and to withdraw your data or consent to process it at any time without any consequences.

Benefits
Your expertise will help us produce research outcomes that solve real-word problems and have a positive

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impact on your domain. You will not be compensated for your time and effort.

Your Rights

Every participant is entitled to the following rights:

The right to access – Right after your contribution has been submitted, the system will offer you a "Print" or "Get a PDF" option, which includes your "Contribution id". You have the right to request for copies of your personal data; you will have to provide further details, e.g. the submission date, so that we are able to identify your response form.

The right to rectification – You can re-access your contribution by providing your "Contribution id". You have the right to request that The Consortium corrects any information you believe is inaccurate. You also have the right to request The Consortium to complete the information you believe is incomplete. You will have to provide further details, e.g. the submission date, so that we are able to identify your response form.

The right to erasure – You have the right to request that The Consortium erases your data, under certain conditions.*

The right to restrict processing – You have the right to restrict the processing of your personal data, under certain conditions.*

The right to object to processing – You have the right to object to The Consortium's processing of your personal data, under certain conditions.*

The right to data portability – You have the right to request that The Consortium transfer the data that we have collected to another organisation, or directly to you, under certain conditions. You will have to provide further details, e.g. the submission date, so that we are able to identify your response form.

If you make a request, you will get a response within one month.

*You will have to provide further details, e.g. the submission date, so that we are able to identify your response form. This will not have any effect on any summarised survey results or research findings that have already been published. The Consortium will use all reasonable measures to verify the identity of a data subject who requests access but will not retain personal data for the sole purpose of being able to react to potential requests.

Personal Data

No personal information that could be used to directly identify you (name, email address, phone number, etc.) is collected.

Any user information, in case a user is logged in with their EU account when submitting a contribution, will be replaced by "Anonymous" by the EUSurvey system. The anonymisation happens at the point and time at which the data are collected, so no personal data are actually processed.

You directly provide the following data by completing the survey:

- the type of the organisation you belong to;
- your duties within your organisation, if it is related to maritime and port operations;
- your opinion on the project's aims, objectives and innovations.

The Consortium does not receive data about you indirectly from the other sources.

Data Processing

The EUSurvey platform offers basic result analysis capabilities and visualisation of data in histograms and chart views, which means that exporting individual survey contributions to standard spreadsheet formats is

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not required. Only summarised/aggregated information will be exported from the system.

Security
The EUSurvey platform has the infrastructure needed to secure the online forms.
Access is protected with login details and will be granted only to the researchers who lead the research activities for each one of the five innovations.

Confidentiality
Your completed response form will be treated as confidential information. The Consortium will not share the raw information you provide with any other external entities (e.g., companies, organisations, etc.).

Retention
The Consortium will keep your response form for no longer that the duration of the MOSES project plus five years. Once this time period has expired, we will delete all individual response forms by deleting the survey from the EUSurvey platform.

Results
Your contribution will be used to inform the project's user requirements, design revisions and technology development.
The anonymised summarised/aggregated information will be submitted to the European Commission as part of public reports and will be used to write articles for peer-reviewed journals and relevant industry magazines, for presentations at conferences and workshops, and in the promotion of MOSES in general.

Risks
No significant or likely risks have been identified in relation to your participation as your data privacy, confidentiality and anonymity have been taken into account and the nature of the questions does not invite any controversial answers that could cause harm, disadvantage or discomfort.
In the highly unlikely event that such an opinion is submitted as a response to an open-ended question that could potentially be attributed to a specific participant based on the uniqueness of their role within an organisation category it will either be aggregated or ignored altogether.

Contact
If you have any questions about the information that has been provided, our privacy policy, the data we hold on you, or you would like to exercise one of your data protection rights please do not hesitate to contact the Questionnaire's Data Controllers. If you have a complaint or something to report please contact the MOSES Ethics Manager.

☐ I have read and fully understand all the information about the questionnaire and my participation.

Consent

- I am 18 years or older and competent to provide consent
- I was informed about the aims of the research project, the purpose of the questionnaire and possible risks.
- I voluntarily agree to participate in this research study by contributing to this questionnaire.

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- I have read and understood the information; any questions I might have, have been answered satisfactorily.
- I had sufficient time to decide whether I would participate or not.
- I understand that even if I agree to participate now, I am free to withdraw at any time or refuse to answer any question, without any consequences of any kind.
- I understand that at any time I can withdraw my permission to process the data I have provided and that this cannot apply to results that have already been published.
- I understand that all information I provide will be anonymised, securely stored and treated confidentially.
- I have been informed about my rights to access/rectification/erasure/restriction of processing/object to processing/data portability/withdraw consent/lodge a complaint with a supervisory authority.
- I am free to contact any of the people involved in the research, through the contact details that have already been provided to me, in order to seek further clarification and information.

☐ I agree with and confirm all the above statements and consent to the collection and processing of the information I provide.

Instructions

You can save your contribution and submit it later. After clicking on "save as draft", you will automatically be re-directed to a page showing you a link where you can retrieve your draft to edit and submit your answers. Please save this link! You can send it by Email, save it to your favourites or copy it to the clipboard.

Right after your contribution has been submitted, the system will offer you a "Print" or "Get a PDF" option, which includes your "**Contribution id**". You have the right to request The Consortium for copies of your data; you will have to provide further details, e.g. the submission date, so that we are able to identify your response form.

You can re-access your contribution by providing your "**Contribution id**".

For more information please see the FAQs.

Your Organisation

*** Please select the type of your organisation:**

- ○ Port Authority
- ○ Tugboat Owner or Operator
- ○ Coast Guard
- ○ Academia or Research Institute
- ○ Classification Society
- ○ Marine/Port Equipment Supplier
- ○ Law-enforcement agency
- ○ Information Technology System Provider
- ○ Shipping Company
- ○ Seaport Terminal Operator
- ○ Local Government
- ○ Other

*** Organisation type:**

250 character(s) maximum

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* **Maintime and port operations are part of my current duties or responsibilities.**

- Yes
- No

* **Please briefly describe your duties/responsibilities within your organisation:**

500 character(s) maximum

Innovative Feeder Vessels

Three conceptual feeder vessel designs will be developed in order to address operational, economical and logistic needs in the context of Short Sea Shipping:

- two differently sized Short Sea Container (SSC) carriers (TEU range between 100-250) with different operational characteristics, such as capacity, stability, powering, speed, manoeuvring and seakeeping properties;
- a combined roll-on/roll-off, container and passenger (RoCoPax) vessel.

The aim is to relieve crowded DSS ports by transferring a substantial part of the land-based transshipment of containers to nearby small ports which are close to the destination. Several compulsion systems (hybrid electric, fully electric, wind-assisted) will be considered, taking into account their sustainability. The designs will be verified by computer simulations and the operational characteristics of the most promising concept will be demonstrated and evaluated in a model basin using a scaled ship model.

QV1. An innovative feeder vessel should not require special facilities at service ports, excluding its home port.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

8

QV2. An innovative feeder vessel should be designed with scalable passenger carrying capacity (e.g. removable modules) in order to be able to transfer cargo and/or passengers along different legs of its voyage.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QV3. An innovative feeder vessel should be designed with automated mooring capabilities (hands-free mooring).

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QV4. An innovative feeder vessel should achieve a significant reduction of the environmental footprint of port operations, compared with the alternative transport options (from port to port).

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QV5. An innovative feeder vessel should be able to safely approach, enter and manoeuvre in smaller ports that may not offer adequate protection from the weather.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

Please describe any additional requirement that you consider important for the design and operation of an Innovative Feeder Vessel:

5000 character(s) maximum

9

Robotic Container-Handling System

The MOSES robotic container-handling system will be fitted on the MOSES innovative feeder vessels. It will be designed as a fully self-supporting system that does not need any local help except a quay for berthing and for loading/unloading the containers.

It will make use of a MacGregor GLE electric variable frequency drive crane in order to have a reduced environmental footprint. Computer vision algorithms will allow the system to sense its surroundings and handle containers (semi-)autonomously under the supervision of a human o perating from a shore control station and remain in the loop to intervene if needed. The communication with the Port Authority Control will also be mediated by the remote operator.

QC1. The robotic container-handling system should provide to the remote operator a detailed picture of the quay.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QC2. The robotic container-handling system should provide a live video stream of the surrounding of the harbour.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

10

QC3. The robotic container-handling system should provide a 3D Blended Reality Environment for the operator.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QC4. The robotic container-handling system should not require more port space (in terms of container arrangement or spacing) compared to manual operation.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QC5. The robotic container-handling system should perform a task at least as fast as a manually operated crane.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QC6. The robotic container-handling system should be able to operate under operational conditions similar to those of a manually operated crane.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QC7. The robotic container-handling system should be able to operate under low light conditions.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
-

11

2
- 3
- 4
- I don't know

Please describe any additional requirement that you consider important for the design and operation of the Robotic Container-Handling System (e.g., what do you expect such a system to do and what do you, as a user, need to collaborate with it):

5000 character(s) maximum

Autonomous Tugboats

This innovation aims to establish the functional and operational architecture that is needed to transform the ready-made remote-controlled vessels to autonomous tugboats. The central control platform will be used to manage autonomous operation for docking of large ships.

The autonomous tugboats will operate as a fully autonomous swarm to manoeuvre and align a large containership to the dock by offsetting its course and velocity using micro-adjustments. The tugboats will be fitted with state-of-the-art sensors (e.g., cameras, LiDAR, accelerometers, GNSS, multibeam sonar systems) to enable autonomous navigation and collision avoidance through suitable sensor fusion algorithms and the implementation of appropriate kinematic models.

QT1. The autonomous tugboats should be able to function independently (not in swarm formation).

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

12

QT2. The autonomous tugboats should be able to return autonomously back to the port when the communication with the port control is lost.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QT3. The autonomous tugboats should be able to return autonomously back to the port when in extreme weather conditions.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QT4. The autonomous tugboats control system should retain and transmit logs in real time to report positioning and progress of operation.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QT5. A port operator should be able to take control of the autonomous tugboat at any time.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QT6. The autonomous tugboats remote control and communication should be done in a secure way.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
-

13

- 2
- 3
- 4
- I don't know

QT7. The autonomous tugboats should be capable to adapt to different towing methods (on the line, push-pull method, etc.).

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QT8. Means of communication between autonomous tugboats and a non-autonomous vessel during towing operation should be enabled and efficiently configured (e.g. safeguard secure operation of making fast or cast-off tow lines).

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QT9. Having a real-time system which monitors the condition of the autonomous tugboats and can identify crucial damage to them.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

Please describe any additional requirement that you consider important for the design and operation of the Autonomous Tugboats:

5000 character(s) maximum

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Automated Mooring System

Within MOSES, Trelleborg's AutoMoor system, which is an automated vacuum-based mooring system that replaces mooring lines (hands-free mooring) and minimises vessel motions at berth, will be adapted and re-engineered to cooperate with the Autonomous Tugboats.

QM1. The automated mooring system should be able to monitor the condition of the system in real time in order to identify and report damages, to the docking mechanism or the hull, during docking.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QM2. The automated mooring system should be adaptable to accommodate smaller ships (like the innovative feeder vessel), in addition to large containerships.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QM3. The automated mooring system should be able to send a warning to the autonomous tugboats if operating parameters are violated (e.g., incorrect approach).

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

15

QM4. The automated mooring system should not require special port facilities; its design should allow installation in smaller ports with limited infrastructure.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QM5. The provision of the mooring service shall be in full operational condition (absence of breakdowns or maintenance) at least 95% of the year.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QM6. Automated mooring services should be available 24/7. If there are more than 8 calls a day in the port, the mooring and unmooring service provider is able to serve two vessels simultaneously at least during the hours of 7:00 a.m. to 10:00 p.m, based on the port having sufficient AutoMoor units along the terminal berth to allow connection to two vessels simultaneously.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QM7. Operations should start at the time scheduled in the requests, so that the service does not cause unnecessary delays. The maximum response time, defined as the time elapsed from the vessel's or pilot's call until the mooring units are ready in the manoeuvring area, is 30 minutes, provided that the pilot has requested the service at least 30 minutes in advance.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

16

QM8. The system should support information exchanges with the Port Authority and other interested parties, including ships in order to identify suitable connection points on the ship.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

Please describe any additional requirement that you consider important for the design and operation of the Automated Mooring System (e.g., what do you expect such a system to do and what you would need as a user, how you would interact with it):

5000 character(s) maximum

Digital Collaboration and Matchmaking Platform

The MOSES innovations are complemented with an information and communication technology system with machine learning capabilities aiming to optimise SSS cargo streams in order to maximize demand, effectively handle changing freight flows in order balance backhaul traffic and boost just-in-time connections among transport modes.

The Matchmaking Logistics Platform will become a cloud-based digital marketplace for cargo consolidation and horizontal collaboration among shippers and freight forwarders. The users will be able to communicate to the platform information related to empty containers and transport orders (including but not limited to prospective cargo volumes, origin/destination location and requested time of arrival). The containers and cargo will be aggregated over multiple shippers and matched with suitable SSS transport options. The platform will include an intuitive graphical user interface that is tailored to the needs of all the involved

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stakeholders. It will also offer user-friendly visualisation options and tools for further data analysis, such as scenario-building capabilities for the examination, in terms of cost and CO2 emissions, of different transport mode combinations.

QP1. The matchmaking platform should be accessible by port stakeholders other than the Port Authority/Terminal Operators.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QP2. The matchmaking platform should have different user profiles with different roles and access rights to various modules and functionalities of the platform.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QP3. The matchmaking platform should allow end-users to list potential transfer requests defining a turn-around-time target value.

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

QP4. The matchmaking platform should allow the users to list transport schedules (i.e. vessel schedules, rail calendars, truck availability).

0: not important 1: slightly important 2: important 3: fairly important 4: very important

- 0
- 1
- 2
- 3
- 4
- I don't know

18

QP5. The matchmaking platform should offer a scenario-building capability for the examination of different transport mode combinations.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QP6. The matchmaking platform should offer a module for information sharing and efficient management of empty containers.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QP7. The matchmaking platform should be able to connect to industry-standard datasources/services and/or consume data from existing datasets.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QP8. My organisation is using the below datasources and digital collaboration platforms to manage cargo and empty containers:

5000 character(s) maximum

19

Please describe any additional requirement that you consider important for the design and operation of the Matchmaking Platform (e.g., what do you expect such a system to do and what you would need as a user, how you would interact with it):

5000 character(s) maximum

General Requirements

General user needs and requirements that apply to all MOSES innovations and the overall aim of promoting SSS.

QG1. MOSES should create new sustainable container feeder lines from DSS ports to smaller mainland ports.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QG2. The MOSES innovations should be able to ultimately achieve a high level of automation (e.g., unmanned operation, fully automated systems).

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QG3. The operation of the MOSES innovations should not require any additional investment on port infrastructure.

0: not important **1: slightly** important **2: important** **3: fairly** important **4: very** important

- 0

20

- 1
- 2
- 3
- 4
- I don't know

QG4. The design of the MOSES innovations should allow for their implementation to be cost-effective even if that means that they do not reach their full potential.

0: **not** important 1: **slightly** important 2: **important** 3: **fairly** important 4: **very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

QG5. The MOSES innovations should cause no temporary disruption to ports during their implementation, even if they will improve operations as soon as they become operational.

0: **not** important 1: **slightly** important 2: **important** 3: **fairly** important 4: **very** important

- 0
- 1
- 2
- 3
- 4
- I don't know

Please describe any additional requirement that you consider relevant or important:

5000 character(s) maximum

21

thank you for completing the survey

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Annex 2 Questionnaire responses

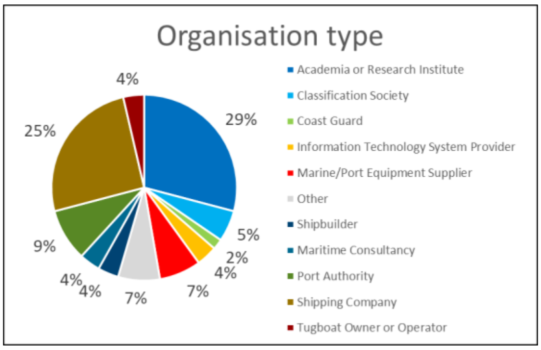


Figure 42 Questionnaire participants per organisation type.

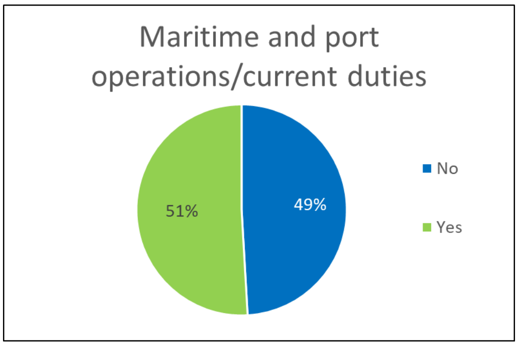


Figure 43 Questionnaire participants' current duties.

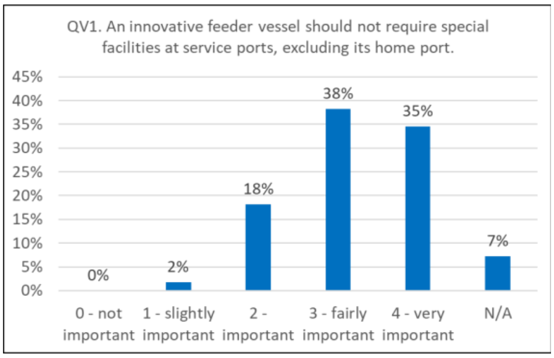


Figure 44 Innovative Feeder Vessel Question 1.

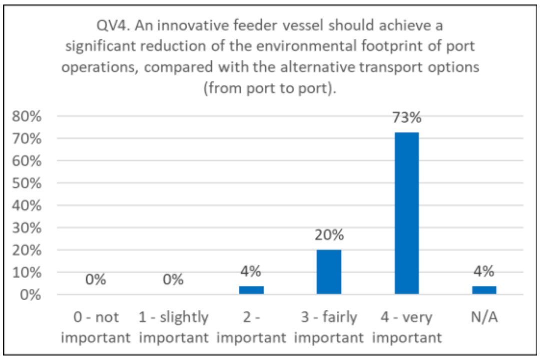


Figure 45 Innovative Feeder Vessel Question 4.

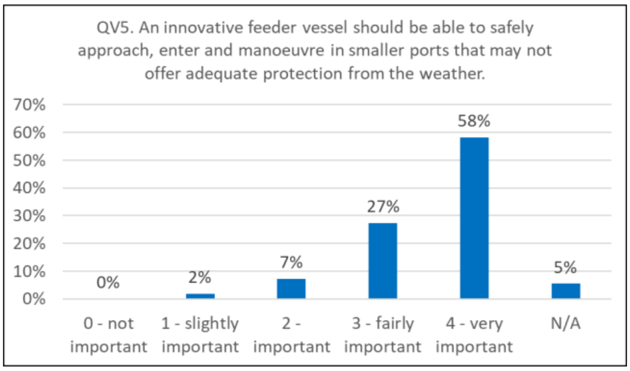


Figure 46 Innovative Feeder Vessel Question 5.

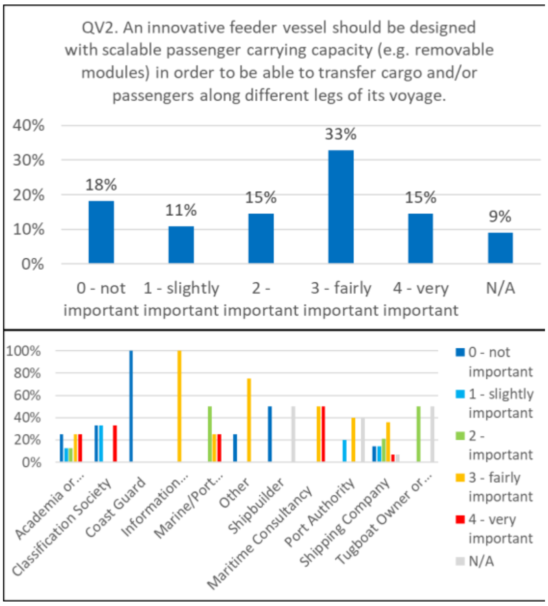


Figure 47 Innovative Feeder Vessel Question 2.

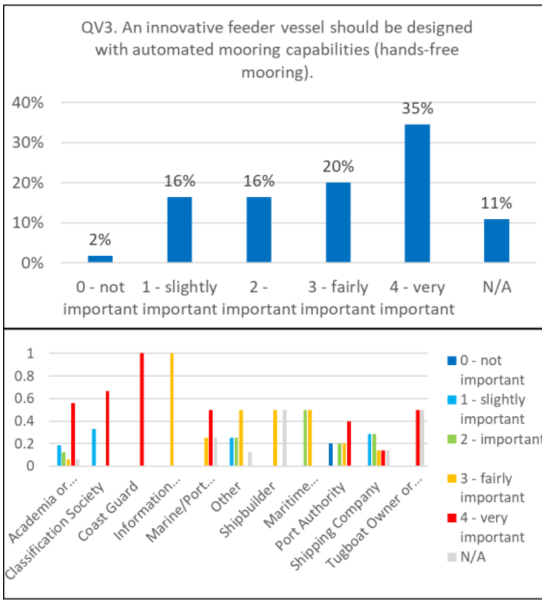


Figure 48 Innovative Feeder Vessel Question 3.

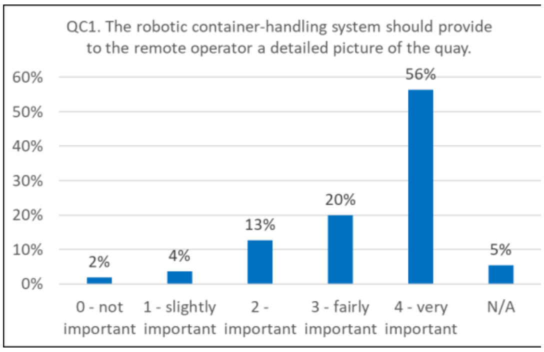


Figure 49 Robotic Container-Handling System Question 1.

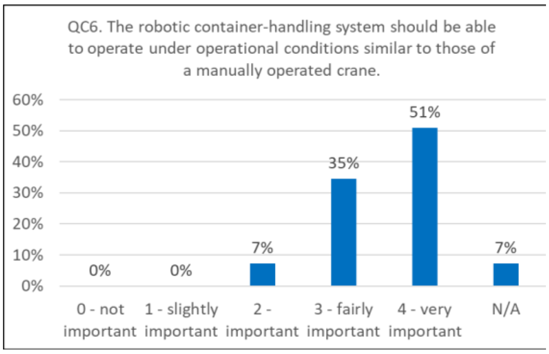


Figure 50 Robotic Container-Handling System Question 6.

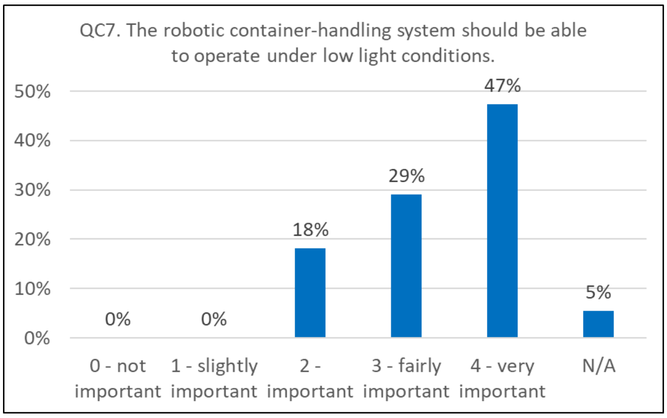


Figure 51 Robotic Container-Handling System Question 7.

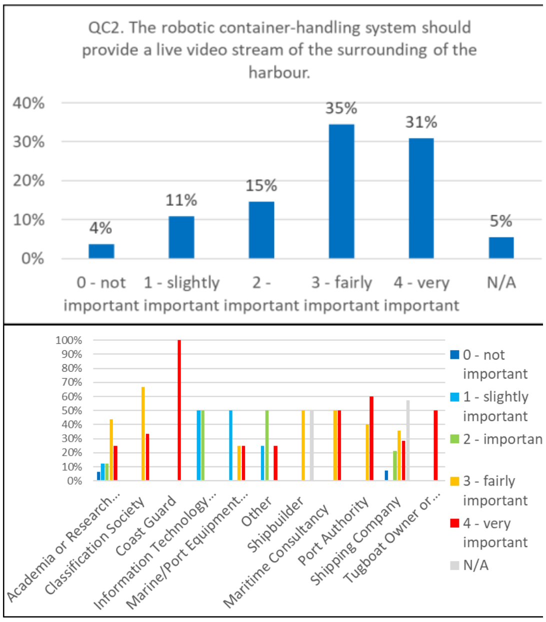


Figure 52 Robotic Container-Handling System Question 2.

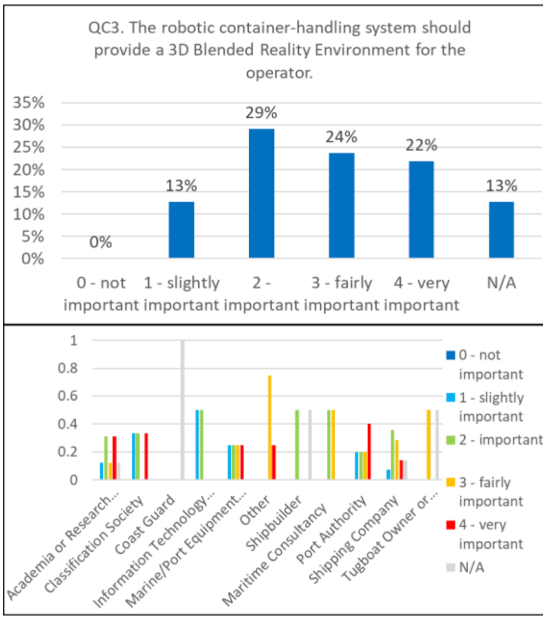


Figure 53 Robotic Container-Handling System Question 3.

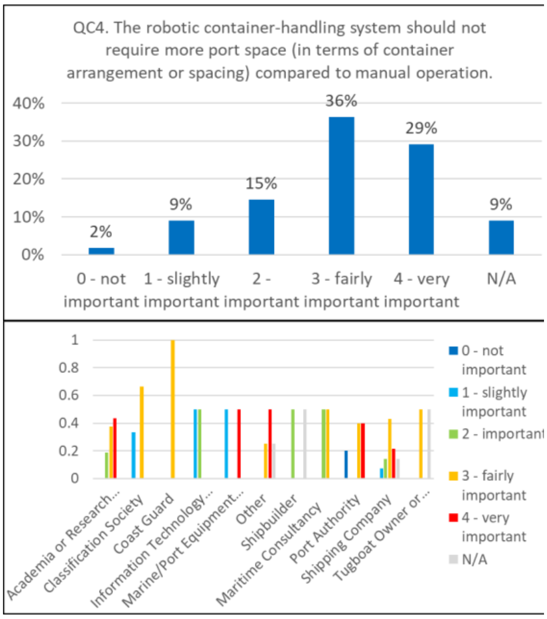


Figure 54 Robotic Container-Handling System Question 4.

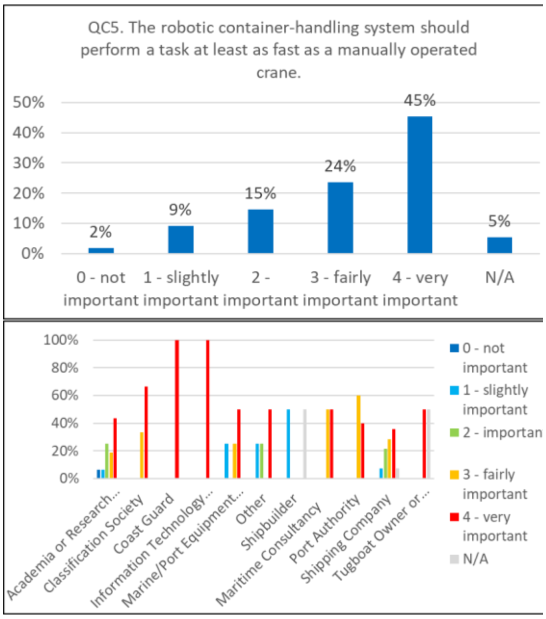
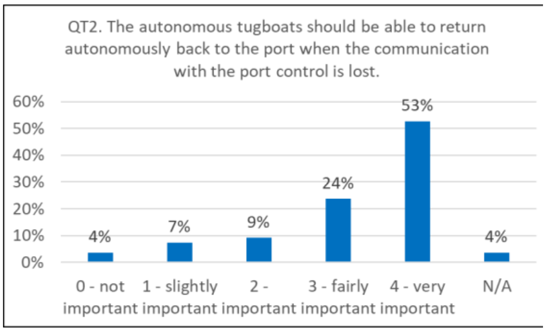


Figure 55 Robotic Container-Handling System Question 5.



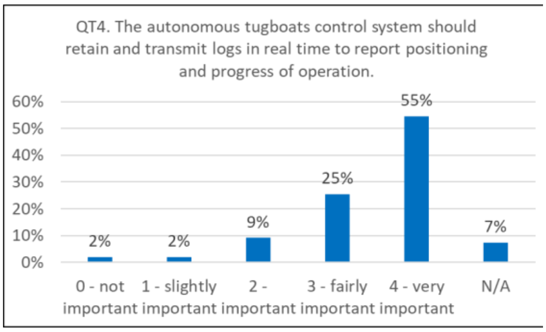
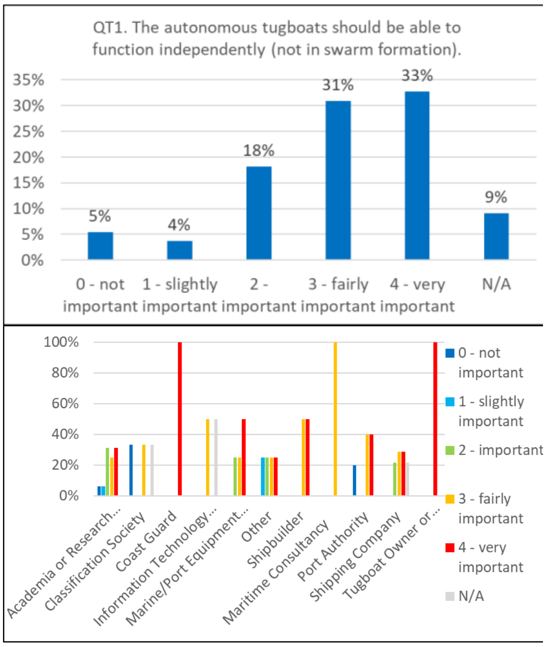


Figure 56 Autonomous Tugboats Question 2

Figure 57 Autonomous Tugboats Question 4



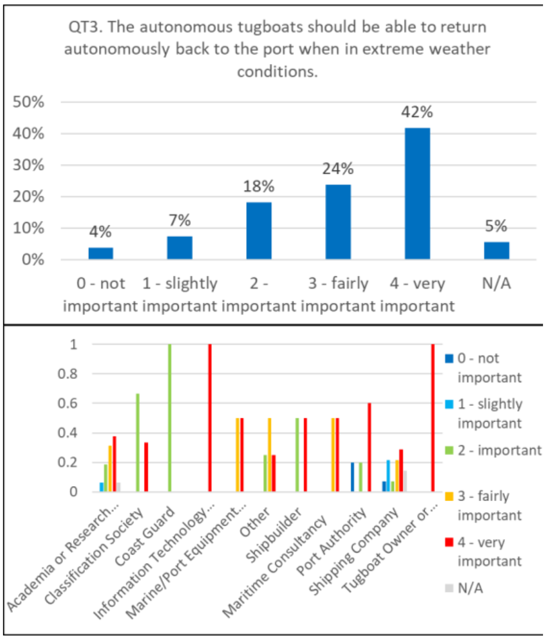
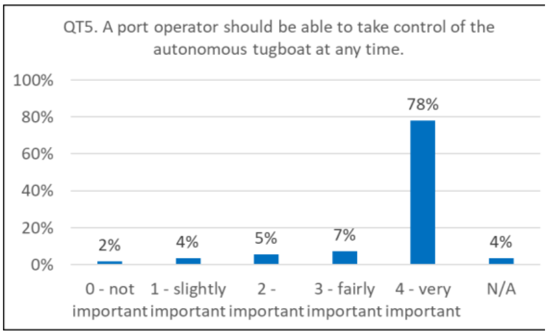


Figure 58 Autonomous Tugboats Question 1.

Figure 59 Autonomous Tugboats Question 3.



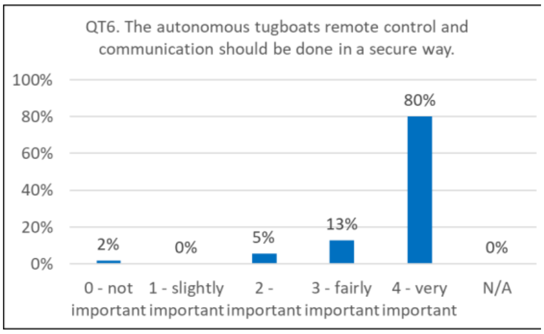


Figure 60 Autonomous Tugboats Question 5.

Figure 61 Autonomous Tugboats Question 6.

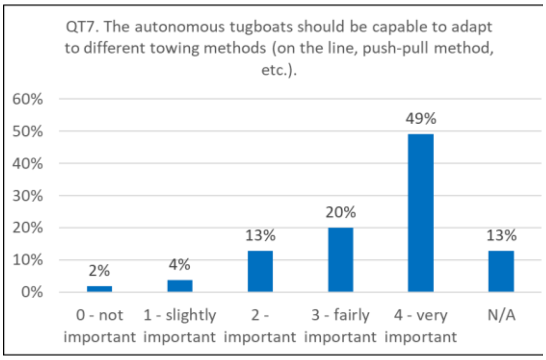


Figure 62 Autonomous Tugboats Question 7.

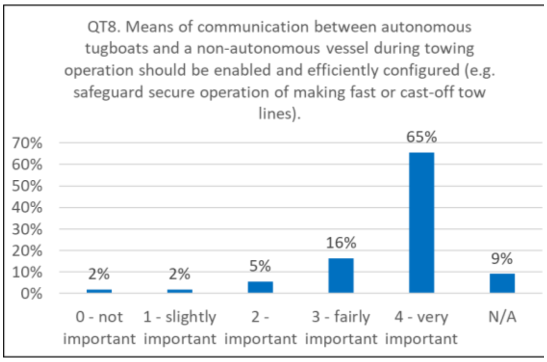


Figure 63 Autonomous Tugboats Question 8.

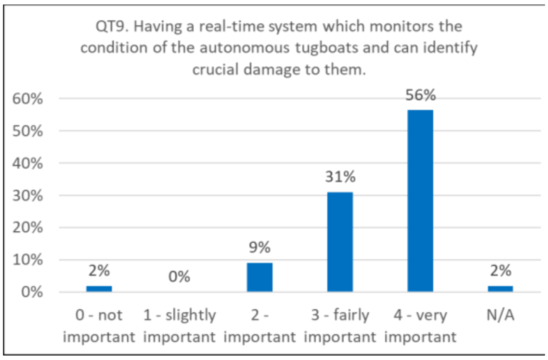


Figure 64 Autonomous Tugboats Question 9.

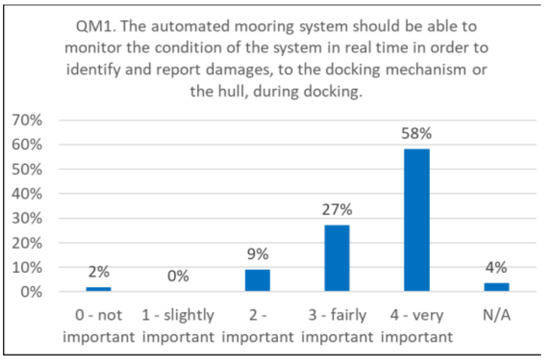


Figure 65 Automated Mooring System Question 1.

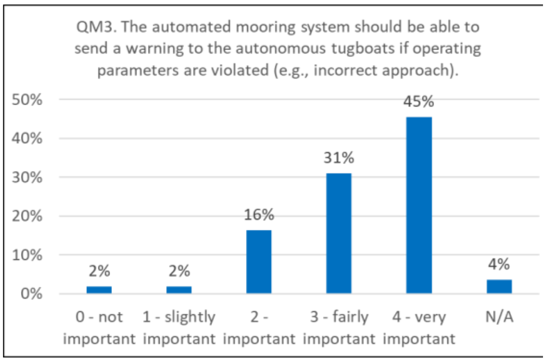


Figure 66 Automated Mooring System Question 3.

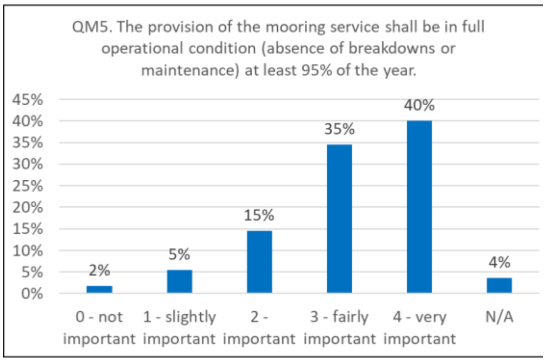


Figure 67 Automated Mooring System Question 5.

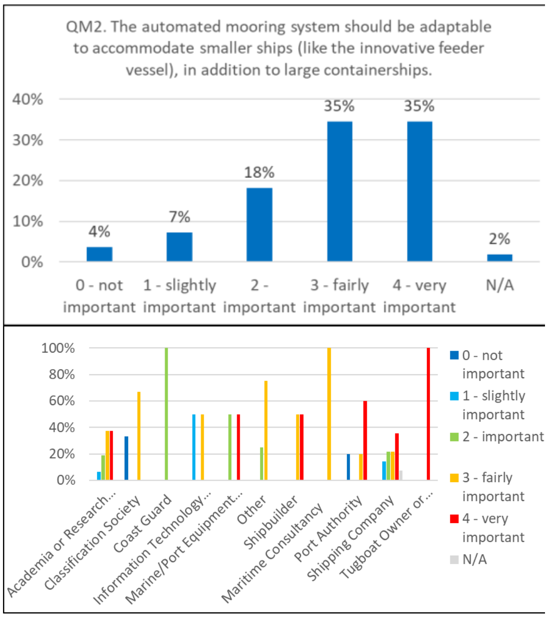


Figure 68 Automated Mooring System Question 2.

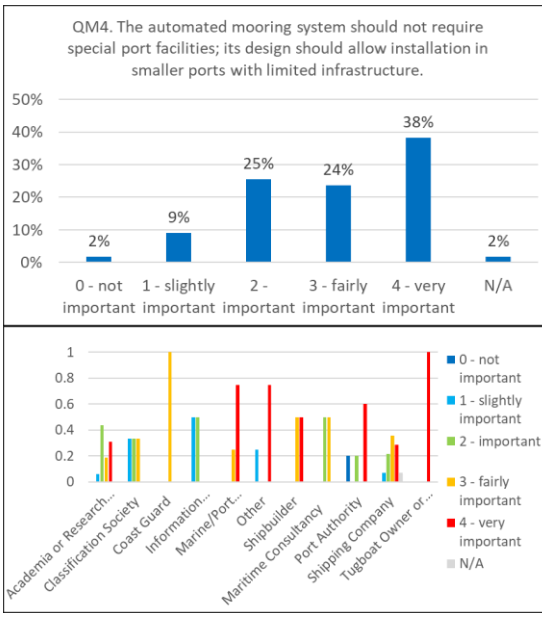


Figure 69 Automated Mooring System Question 4.

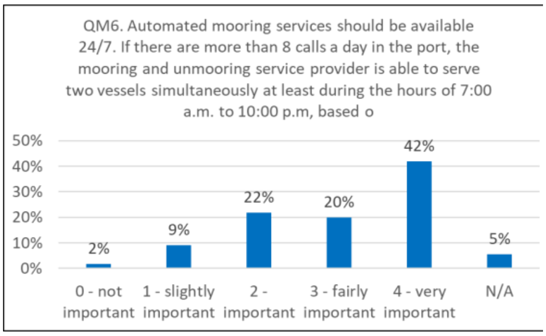
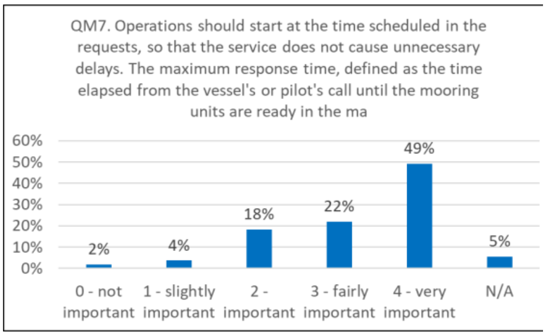


Figure 70 Automated Mooring System Question 6.



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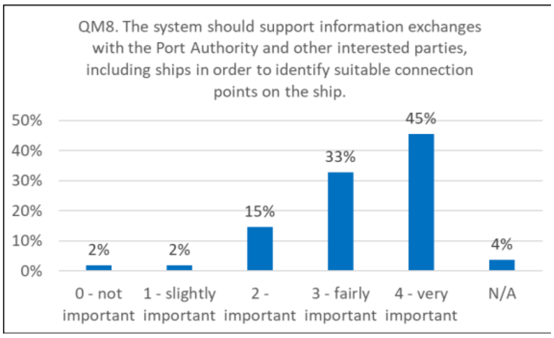

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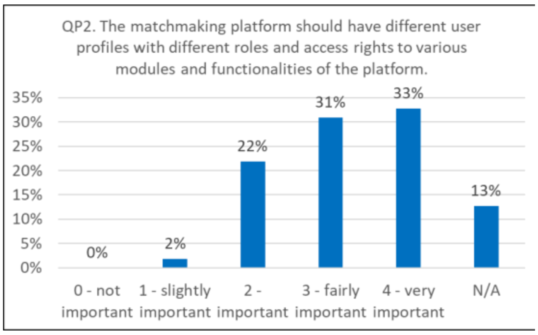


Figure 73 Matchmaking Platform Question 2.

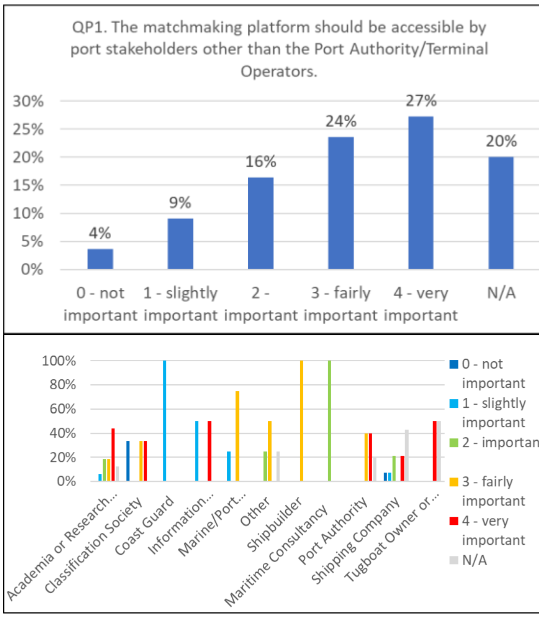


Figure 74 Matchmaking Platform Question 1.

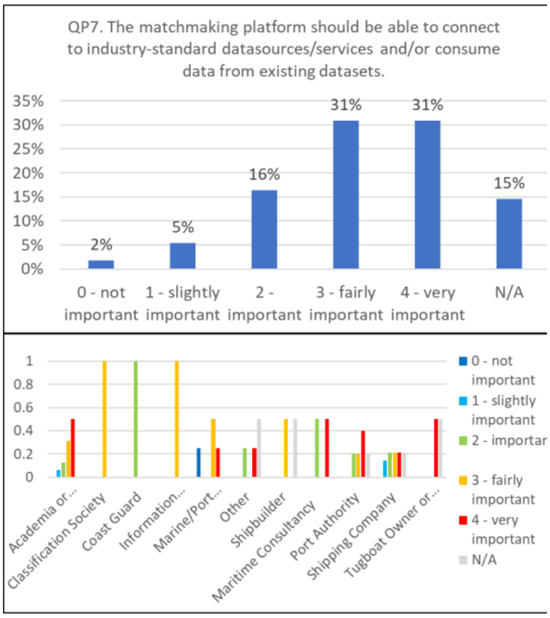


Figure 75 Matchmaking Platform Question 7.

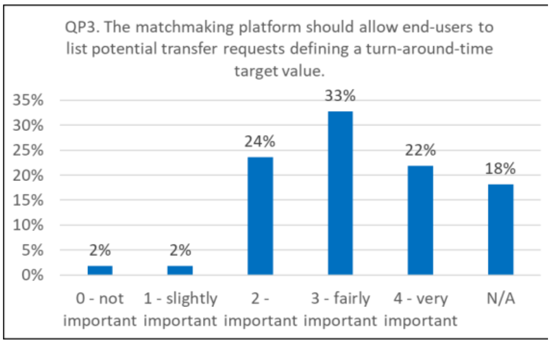
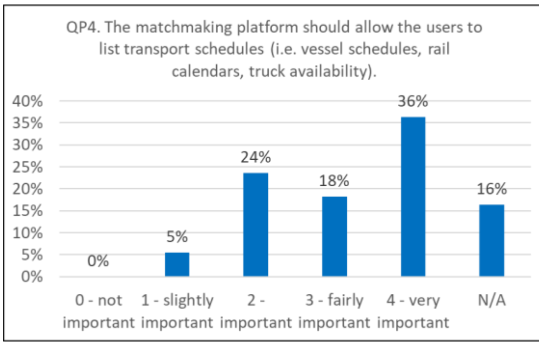


Figure 76 Matchmaking Platform Question 3.



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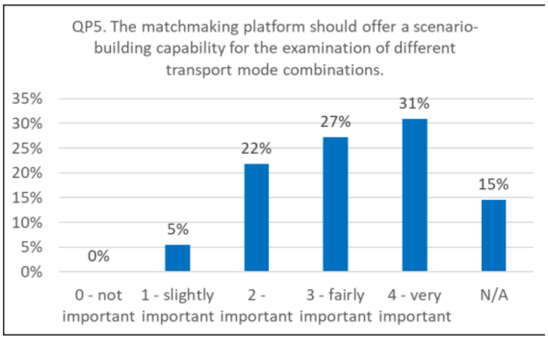

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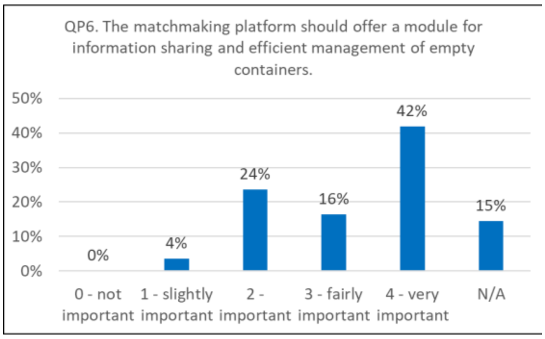


Figure 79 Matchmaking Platform Question 6.

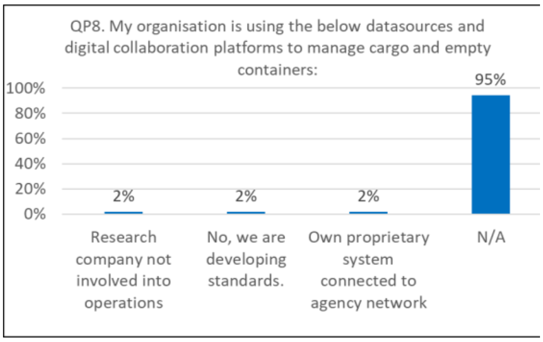


Figure 80 Matchmaking Platform Question 8.

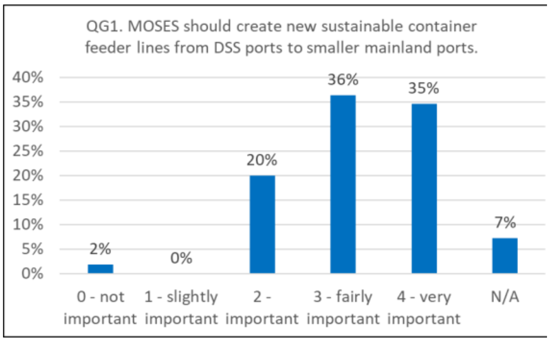


Figure 81 General Requirements Question 1.

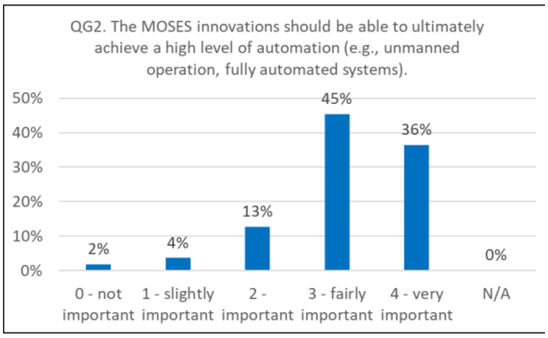
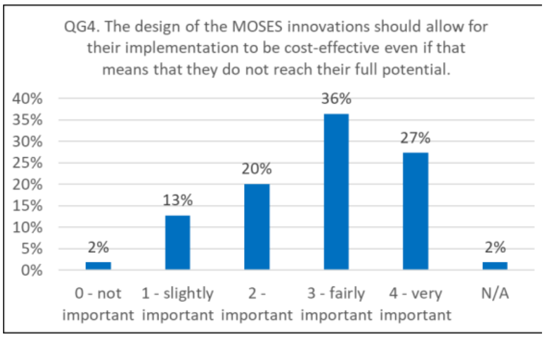


Figure 82 General Requirements Question 2.



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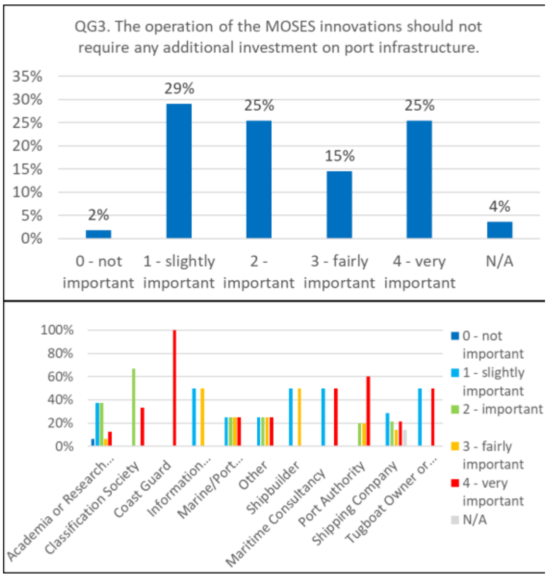

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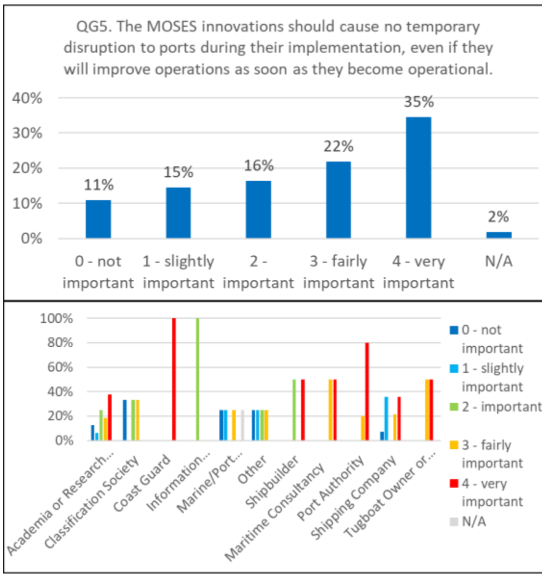

Figure 85 General Requirements Question 5.