



USER-DRIVEN DEVELOPMENT IN MOSES: FROM STAKEHOLDERS NEEDS TO USER REQUIREMENTS

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ABSTRACT	2
1. INTRODUCTION	2
2. METHODOLOGY	3
2.1 The MOSES User Requirements Extraction Methodology	3
2.2 Stakeholder analysis	4
2.3 Workshops and questionnaire survey design	5
2.4 Documentation of user requirements	5
3. STAKEHOLDER IDENTIFICATION AND ANALYSIS	6
4. IDENTIFICATION OF STAKEHOLDER NEEDS	8
4.1 Innovative feeder vessel	9
4.2 Robotic Container Handling System	9
4.3 Autonomous Tugboats.....	10
4.4 Automated Mooring System.....	11
4.5 Matchmaking Platform.....	12
5. MOSES INNOVATIONS USER REQUIREMENTS	12
5.1 Innovative Feeder Vessel.....	13
5.2 Robotic Container Handling System	14
5.3 Autonomous Tugboats.....	15
5.4 Automated Mooring System.....	Error! Bookmark not defined.

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5.5 Matchmaking Platform	Error! Bookmark not defined.
6. CONCLUSIONS	18
ACKNOWLEDGMENTS	19
REFERENCES	19
AUTHOR(S) BIO NOTE(S)	19

ABSTRACT

The H2020 MOSES project aims to significantly enhance the short sea shipping component of the European supply chain by developing the following innovations: an Innovative Feeder vessel outfitted with a Robotic Container-Handling System, an Autonomous Tugboat swarm that cooperates with an Automated Mooring System, and a Digital Matchmaking and Logistics Collaboration Platform. Towards this goal, the MOSES project implements a user-driven development approach that aims to ensure that the systems are designed to satisfy actual stakeholder needs. This paper aims to comprehensively map the needs of the MOSES stakeholders and translate them into formally structured user requirements for each innovation, which will be used at a later stage of development to determine system requirements and specifications. The employed MOSES User Requirements Extraction Methodology includes determining key design goals, identifying the stakeholder categories that affect the future operation of the MOSES innovations, eliciting stakeholder needs from the results of an online survey and two stakeholder workshops. The results show that the MOSES stakeholders focus on environmental impact, safety of automated and autonomous functionalities, and operational flexibility and dependability. Based on the identified needs, this paper documents essential requirements that determine the main functionalities of the MOSES innovations and relate to the project's broad objectives. These requirements provide the basis for elaborating the qualities and performance characteristics of the innovations at a later stage of development.

Keywords: User-driven development, stakeholder needs, user requirements, H2020 MOSES project

1. INTRODUCTION

MOSES aims to significantly enhance the short sea shipping (SSS) component of the European container supply chain by addressing the vulnerabilities and strains related to large container ships' operation. This goal will be achieved by following a two-fold strategy that reduces the total time to berth for Deep Sea Shipping (DSS) ports and stimulating SSS feeder services to small ports with limited or no cargo handling infrastructure. MOSES will achieve its objectives by implementing the following innovations:

1. An innovative feeder vessel equipped with an automated Robotic Container Handling System, which provides independence from existing port infrastructure.
2. An autonomous vessel manoeuvring and docking scheme for DSS ports (Auto-Dock), which is based on the cooperation of a swarm of autonomous tugboats with a re-engineered version of an existing automated mooring system.
3. A digital collaboration and match-making platform (MOSES Platform) that aims to maximise SSS traffic by matching demand and supply of cargo volumes and enabling horizontal collaboration among logistics stakeholders.

A user-driven development approach has been followed to correlate user needs with the system specifications of the various innovations, accounting for the identified challenges. Therefore, stakeholder involvement through the MOSES project is crucial. It will ensure that the delivered technologies will meet their needs for safer, greener and more efficient enhancement of the SSS leg of the logistics chain. Such an approach has been dictated by the European Commission (EC) in Research and Technological Development (RTD) policymaking. The Green Paper on Innovation



highlighted the importance of involving end-users in the research and development of new technologies as a crucial component of innovation [1].

In 2008, a study conducted on behalf of the EC highlighted several positive aspects of user involvement by analysing theoretical frameworks and experimental approaches focusing on end-user involvement in innovation actions [2]. The importance of direct end-user involvement is also stressed in the H2020 – European Union (EU) Framework Programme for Research and Innovation, as a priority regarding Societal Challenges, while calling for “innovative solutions for safer mobility” in response to the societal challenges of Transport [3]. 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 of the EU’s innovation, research, and development. Moreover, such an approach allows for a high level of transparency and contributes to increased corporate social responsibility.

A thorough understanding of the user and other key stakeholders’ expectations for a project is one of the most important steps in the system engineering process to determine key system aspects, such as functions, characteristics, behaviour, appearance, and performance [4]. System stakeholders can be authoritative sources for system requirements that represent their interests or area of expertise [5]. However, they are usually not familiar with how to transform their needs and expectations into well-formed requirements’ statements, i.e. specific, precise and unambiguous statements that express needs and associated constraints and conditions [5]. Moreover, the stakeholders’ initial concerns and, often latent, needs cannot be used directly as stakeholder requirements since they often lack definition, analysis, and possibly consistency and feasibility. Therefore, the stakeholder needs must be processed and refined to be transformed into requirements by implementing a systematic approach. These requirements may subsequently inform the development of system requirements, either functional or non-functional, which finally help to determine system specifications.

This paper aims to comprehensively map the needs of the MOSES stakeholders and translate them into formally structured user requirements for each innovation. In order to achieve this, a structured methodology has been employed for eliciting requirements, which includes identifying stakeholder categories that directly or indirectly affect the design and operation of the MOSES innovations and extracting information from stakeholder engagement activities. The requirements will be used later in development to determine system requirements and specifications.

The rest of this paper is structured as follows. After the introductory part, the methodology adopted to translate the user needs into system requirements will be described. The following section lists the stakeholders that have been identified as relevant to the MOSES innovations. The following two sections present each innovation’s user needs and requirements. Finally, the paper concludes with a summary of the results from the analysis.

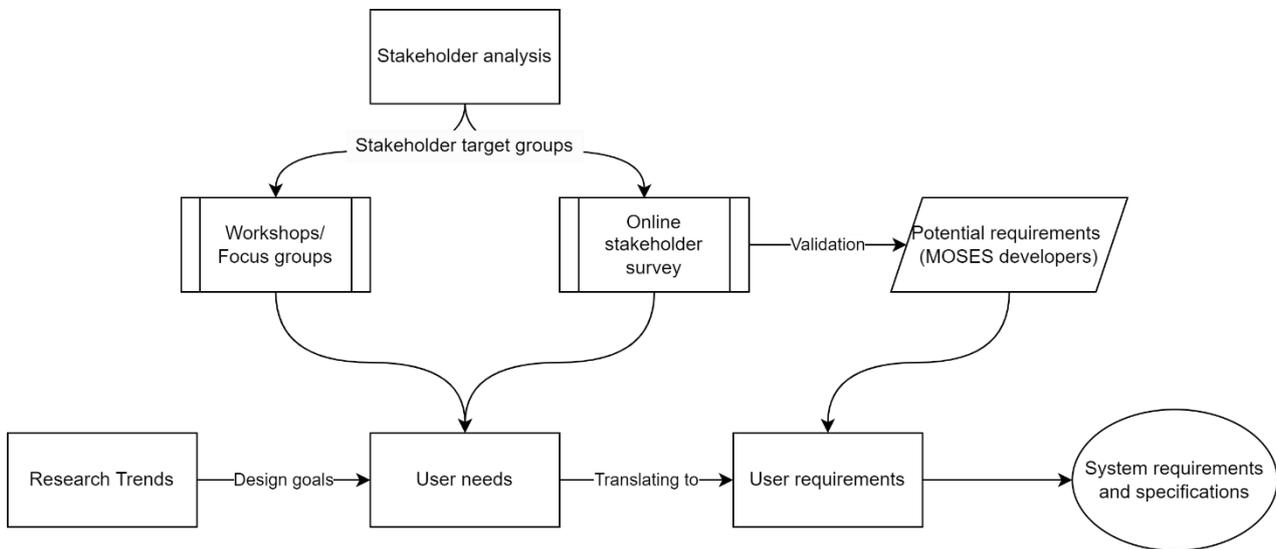
2. METHODOLOGY

2.1 The MOSES User Requirements Extraction Methodology

Fernandes and Machado [6] have defined a generic requirements elicitation process as one consisting 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. Analysing domain specific knowledge helps identify essential, as well as missing, functionality [7]. Furthermore, this mapping can inform the design process with potential user requirements [8]. Based on this process, Figure 1 outlines the MOSES User Requirements Extraction Methodology that is implemented for identifying

user needs and translating them into user requirements. This process was based on familiarising stakeholders with the technical and operational concepts developed in the project by providing them with a concise definition of each of the MOSES innovations.

Figure 1: MOSES User Requirements extraction methodology



Source: Authors

The employed methodology 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. The identified challenges helped identify the basic design goals mentioned in the introduction and will not be elaborated in the following sections.
2. Identifying and analysing the basic categories of stakeholders and end-users relevant to the development and operation of the MOSES innovations.
3. Identify user needs by directly engaging stakeholders identified in the stakeholder analysis in workshops/focus groups and through an online stakeholder survey.
4. Systematically documenting user requirements related to the identified user needs and challenges. The scope of the user requirements includes aspects such as safety, security, privacy, environmental footprint and human-machine interaction. In addition, the user requirements have been stated to meet the criteria of specificity, precision, and unambiguousness described by the ISO/IEC/IEEE 29148 standard [5].

2.2 Stakeholder analysis

According to the Project Management Body of Knowledge Guide, a stakeholder is defined as an individual, group, or organisation that might affect, be affected by or perceive itself as affected by a project's decision, activity, or outcome [9]. Therefore, depending on the degree of how stakeholders are affected by the MOSES project, we identify two types of stakeholders:

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

Once the stakeholders are identified, they are classified into the following three areas:



- The “Operational Work Area” includes the stakeholders who are involved in the operational aspects of the innovations.
- The “Containing Business” includes the stakeholders who benefit from the innovations without being directly involved in their operation.
- The “Wider Environment” includes the stakeholders who either exert influence or are being influenced by the MOSES innovations.

2.3 Workshops and questionnaire survey design

Two online workshops were carried out and an online questionnaire was populated to ensure co-design of the requirements with the MOSES stakeholders’ community. The workshops were attended by participants specialised on maritime and port operations as well as freight transport, ICT, safety and security. The workshops were structured in three sessions. The first included presentations of the MOSES concept and innovations. The second involved an interactive session where participants were asked to provide input and refine the requirements. The third was a brainstorming session where challenges and possible solutions were discussed.

The aim of the online questionnaire survey, which was conducted through the EU Survey Platform², was to obtain an insight into the stakeholders’ expectations about the MOSES innovations. The survey served a two-fold purpose: 1) to evaluate the acceptance by the stakeholders of an initial set of potential requirements that the members of the MOSES Consortium had identified, and 2) to identify additional user needs that could be translated into user requirements.

The questionnaire was divided into the following three parts: 1) demographic questions, 2) design goals and objectives of the MOSES project, and 3) requirements for each MOSES innovation. The questionnaire was designed so that stakeholders could complete it in 20 to 30 minutes and included multiple-choice questions. The requirements were included as brief statements, which the respondents were asked to evaluate their importance by answering on a 4-point Likert scale, as shown in Table 1.

Table 1: 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.

Source: Authors

2.4 Documentation of user requirements

Requirements are typically classified as functional and non-functional. Functional requirements describe the different functions and tasks the system should accomplish, i.e. what the system should be able to do, and are also associated with the transformation of inputs to outputs [10]. 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 and can also be interacting/competing. Typically, requirements

² <https://ec.europa.eu/eusurvey/>

are expressed as “shall-statements” [11] and may be prioritised by using additional keywords, such as “should” or “may” [12].

Within the MOSES Methodology, several attributes have been used to document user requirements in a structured and formalised way that will enable traceability and verify the achievement level (Table 2). The requirement class is used to assign each one to a specific category that reflects the contribution to the project’s objectives. The prioritisation was used to distinguish between necessary and optional requirements.

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	Environmental, technical, safety, environmental, market and societal
Title	Formal statement of the requirement
Description	Short description of the requirement
Priority	“Must”, “Should”, “Could”
Dependency	ID of requirement whose implementation depends on the requirement described

Source: Authors

In addition to the tabular documentation, the user requirements have also been illustrated in diagrams that follow the SysML typology. SysML requirements diagrams use different relationships among requirements and between requirements and system components to ensure traceability [13]. The SysML relationships included are described in Table 3.

Table 3: SysML relationships used in the requirements diagrams for the MOSES user requirements

Relationship	Symbol	Description
Derive	<<deriveReq>>	A requirement (client) is derived from another requirement (supplier). The relationship is transitive and therefore, if the supplier requirement changes, it also impacts the client requirement.
Satisfy	<<satisfy>>	A system component (client) satisfies a requirement (supplier). The relationship denotes an allocation of a requirement to a system component.
Rationale	<<rationale>>	The rationale is a specialised comment that documents the reasoning the requirement is based on.

Notes: The arrows point from the client to the supplier

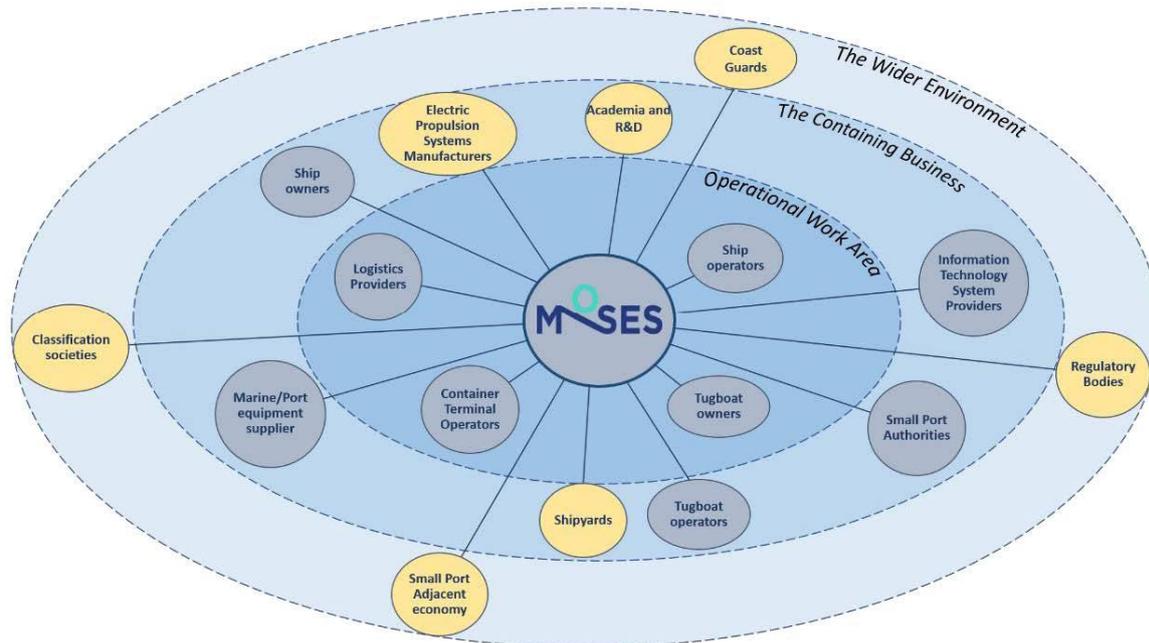
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3. STAKEHOLDER IDENTIFICATION AND ANALYSIS

The identified stakeholder groups include a wide range of actors with multi-disciplinary backgrounds, varying business interests and different perspectives concerning the proposed innovations of MOSES. In Figure 2, the primary stakeholders are marked with grey colour, while the secondary with yellow colour and the stakeholder groups are divided into three areas, namely the Operational Work Area, the Containing Buisness and the Wider Environment, depending on their proximity to the operation of the MOSES innovations.

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 or could exert influence on the project. The relevance to the project’s mission of each primary stakeholder group appearing in Figure 2 is shown in Table 4.

Figure 2: MOSES Stakeholder Universe



Source: Authors

Table 4: Primary stakeholders and their relevance to the MOSES project

Stakeholder	Relevance to MOSES
Container Terminal Operators	The MOSES Auto-Dock system 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.
Tugboat Operators	Within the operational context of the MOSES autonomous tugboats, changes are expected in manning requirements and personnel training that directly affect the tugboat operators.
Tugboat Owners	MOSES innovations offer effective management of the tugboat fleet while allowing for more flexible, accurate and cost-effective operations.
Shipowners	The innovations in MOSES target increasing the demand for freight transportation by sea, thus, creating new business opportunities for ship owners.
Ship operators	The innovations in MOSES expand the capabilities of vessels, allowing for greater flexibility in vessel operations and innovative tools for ship operators.
Logistics providers	MOSES innovations improve 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.
Information and communication technology providers	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. In addition, this stakeholder group also includes stakeholders relevant to data protection and GDPR related topics.
Port authorities	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.

Source: Authors



The secondary stakeholders are those groups that are indirectly affected by the project. In effect, the term “secondary stakeholders” refers to the stakeholder groups whose relationships with primary stakeholders are affected due to the project’s outcomes. The relevance of each secondary stakeholder to the project’s mission is shown in Table 5.

Table 5: Secondary stakeholders and their relevance to the MOSES project

Stakeholder	Relevance to MOSES
Classification societies	Classification societies are indirectly involved with the design, construction, and operation of ships, such as the innovative feeder vessel and MOSES autonomous tugboats.
Academia and R&D	The innovative models and state-of-art solutions proposed in MOSES may interest relevant academic groups and research centres as a knowledge basis for further innovation.
Regulatory and Standardisation Bodies	The outputs of MOSES can be a valuable input to help Regulatory and Standardisation Bodies shape the future regulations and standards for automated vessels.
Coast guards	The coast guard plays a crucial role in maritime emergency response and search and rescue operations. Therefore, it is of paramount importance for the coast guard to be familiar with the technical layout and the behaviour of highly automated systems.
Marine/port equipment suppliers	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.
Shipyards	MOSES innovations create new market demands driven by innovative designs. However, MOSES innovations (e.g. Robotic Container-Handling System) can also be integrated into existing vessels, increasing demand for retrofitting the existing fleet.
Electric propulsion and control system manufacturers	The innovative feeder vessel is envisioned to rely on hybrid-electric propulsion, creating new market demands that lead to new integrated designs of electric engines, batteries, recharging units, etc.
Small port adjacent economy	MOSES innovations promote the economic growth of local economies near small ports by allowing them to be integrated into the container supply chain despite the lack of suitable infrastructure.

Source: Authors

4. IDENTIFICATION OF STAKEHOLDER NEEDS

The stakeholder engagement activities included an online questionnaire survey, and two online workshops were carried out. The workshops were attended by 93 participants (63 MOSES Consortium members and 30 externals) from 43 different organisations specialised on maritime and port operations and freight transport, ICT, safety, and security. In the online questionnaire survey, 55 responses were gathered from different industries and organisation, 70% of which consisted of participants from Academia or Research Institutes, Shipping Companies, Port Authorities and Maritime/Port Equipment Suppliers. In addition, 51% of the respondents stated that their current occupation involves maritime and/or port operations.

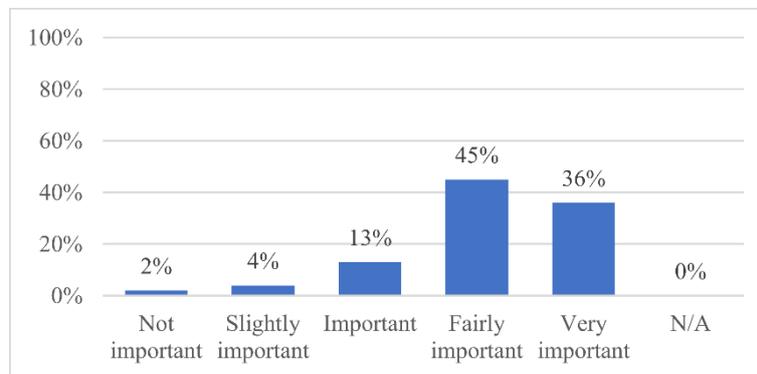
For each innovation, the analysis presented in this section focuses on potential requirements that over 50% of the respondents evaluated as either fairly important or very important.

Concerning the MOSES design goals, the following were considered as the most important by respondents in the questionnaire:

- the possibility for the MOSES innovations to ultimately achieve a high level of automation (e.g., unmanned operation, fully automated systems); 81% of the respondents (Figure 2).
- create new sustainable container feeder lines from DSS ports to smaller mainland ports; 71% of the respondents.

- the MOSES innovations to be cost-effective in their implementation, even if that means that they do not reach their full potential; 63% of the respondents.

Figure 2: Rating of the statement “The MOSES innovations should be able to ultimately achieve a high level of automation (e.g. unmanned operation, fully automated systems)”

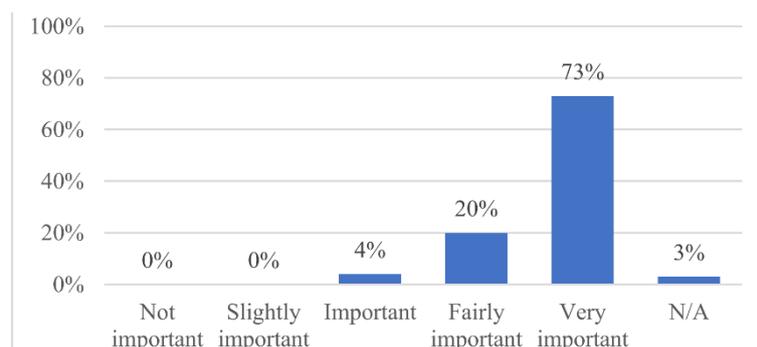


Source: Authors

4.1 Innovative feeder vessel

The most important requirement for the feeder vessel, rated by 93% of the respondents, is the achievement of significant reduction of the environmental footprint during port operations, compared to alternative transport modes (Figure 3). In addition, 85% stated that the innovative feeder vessel should safely approach, enter and manoeuvre in smaller ports that may not offer adequate protection from the weather. Finally, 73% of the respondents rated as important the ability of the innovative feeder vessel to operate without requiring any special facilities at service ports, excluding its home port.

Figure 3: Rating of the statement, “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)”



Source: Authors

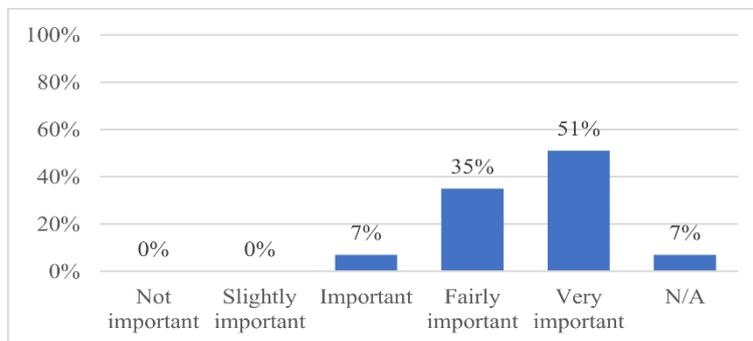
New requirements identified by the respondents included low underwater noise footprint and the use of alternative fuels, other than Low Sulphur Heavy Fuel Oil (LSHFO) and Marine Gas Oil/Marine Diesel Oil (MGO/MDO), as a way to reduce the vessel’s air emissions.

4.2 Robotic Container Handling System

The most important requirement for the Robotic Container Handling System was its ability to operate under operational conditions similar to those of a manually operated crane (86% shown in Figure 4).

76% considered the ability to provide the remote operator with a detailed picture of the quay as important.

Figure 4: Rating of the statement, “The robotic container-handling system should be able to operate under operational conditions similar to those of a manually operated crane”



Source: Authors

New requirements identified by the respondents included the following:

- the coordination with the shore container handling system while operating (Coast guard).
- the connection of all machineries in the container terminal into one system (Port authority).
- alternative means of power for cranes and automatic Emergency Shut Down (Classification society).
- the ability to implement a night shift when a conventional container handling system is not typically operative (Business advisory).

4.3 Autonomous Tugboats

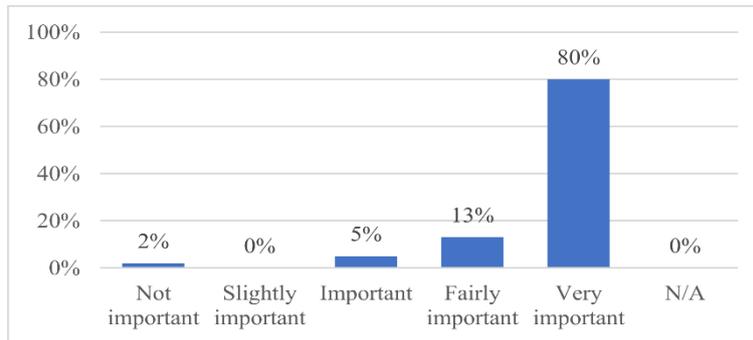
With regards to the MOSES Autonomous tugboats, the following requirements were considered as important by the respondents in decreasing order of importance:

- security of remote control and communication (93% shown in Figure 5).
- capability of real-time monitoring of their condition and identification of damage (87%).
- capability for the port operator to take control of the autonomous tugboat at any time (85%).
- enable and efficiently configuring different means of communication between autonomous tugboats and a non-autonomous vessel during towing operation (81%).
- the ability of the autonomous tugboats' control system to retain and transmit logs in real time to report positioning and progress of operation (80%).
- the ability of the tugboats to return autonomously to the port when the communication with the port control station is lost (77%).

New requirements identified by the respondents included the following:

- the ability to incorporate different towing methods (Academia).
- outfitting the tugboats with an environmentally-friendly propulsion system and supporting real-time information exchange between the autonomous vessel and its surrounding traffic (Tugboat owner/operator).
- the ability to recognize damages to non-autonomous cargo vessels (Shipping company).

Figure 5: Rating of the statement, “The autonomous tugboats remote control and communication should be done in a secure way”



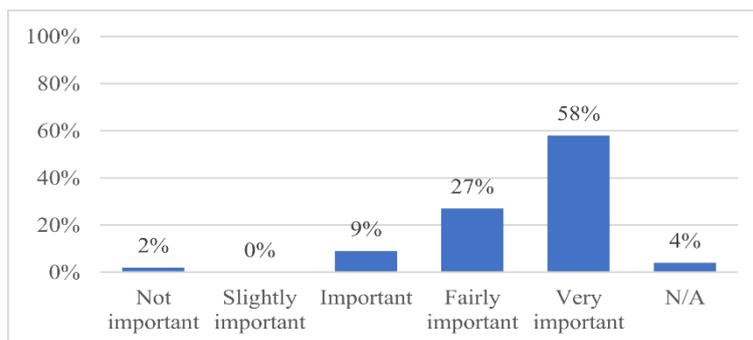
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4.4 Automated Mooring System

The following requirements were considered as important regarding the MOSES Automated Mooring System:

- the ability to monitor the system's condition in real-time, to identify and report damages to the docking mechanism or the hull during docking (85% shown in Figure 6).
- the ability of the automated mooring system to send a warning to the autonomous tugboats if operating parameters are violated (e.g., incorrect approach) (76%).
- the provision of the mooring service in full operational condition (absence of breakdowns or maintenance) at least 95% of the year (75%).

Figure 6: Rating of the statement, “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”



Source: Authors

New requirements identified by the respondents included the following:

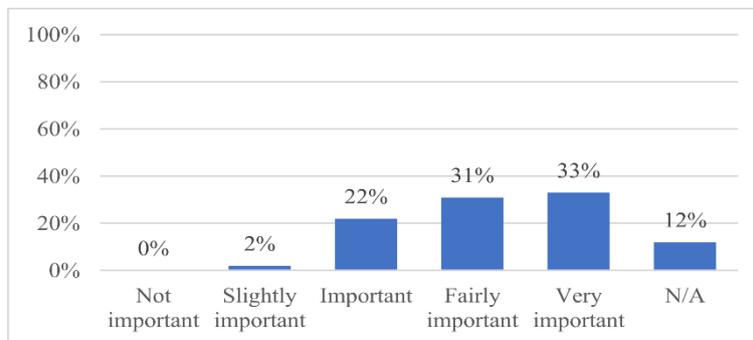
- the design should accommodate a range of ships in terms of their size and within a range of external conditions (Academia).
- the adaptability of the solution to size with different ports (Shipbuilding company).
- possible back-up arrangements, in case of emergency or power failure or listing of the vessel or other unexpected situations (Coast guard).

4.5 Matchmaking Platform

The following requirements were considered as important regarding the MOSES Matchmaking Platform:

- different user profiles with different roles and access rights to various modules and functionalities of the platform (64% shown in Figure 7).
- offer a module for information sharing and efficient management of empty containers (58%).
- offer a scenario-building capability to examine different transport mode combinations (58%).
- ability to allow end-users to list potential transfer requests defining a turn-around-time target value (55%).
- allow users to list transport schedules (i.e. vessel schedules, rail calendars, truck availability) (54%).

Figure 7: Rating of the statement, “The match-making platform should have different user profiles with different roles and access rights to various modules and functionalities of the platform”



Source: Authors

New requirements identified by the respondents included the following:

- independent verification of Estimated Time of Arrival (Academia).
- offer alternative hinterland connections (Business advisory).
- data sharing and accessibility to protect data owners (Shipbuilding company).

Another important comment came from a participant from a business advisory company. It declared that many companies may not want to give insight into their cargo flows and that such a platform could be a direct competitor for many logistics service providers (LSP), leading to massive obstructions to the platform if it is designed to match the cargo streams (meaning containers full of cargo).

5. MOSES INNOVATIONS USER REQUIREMENTS

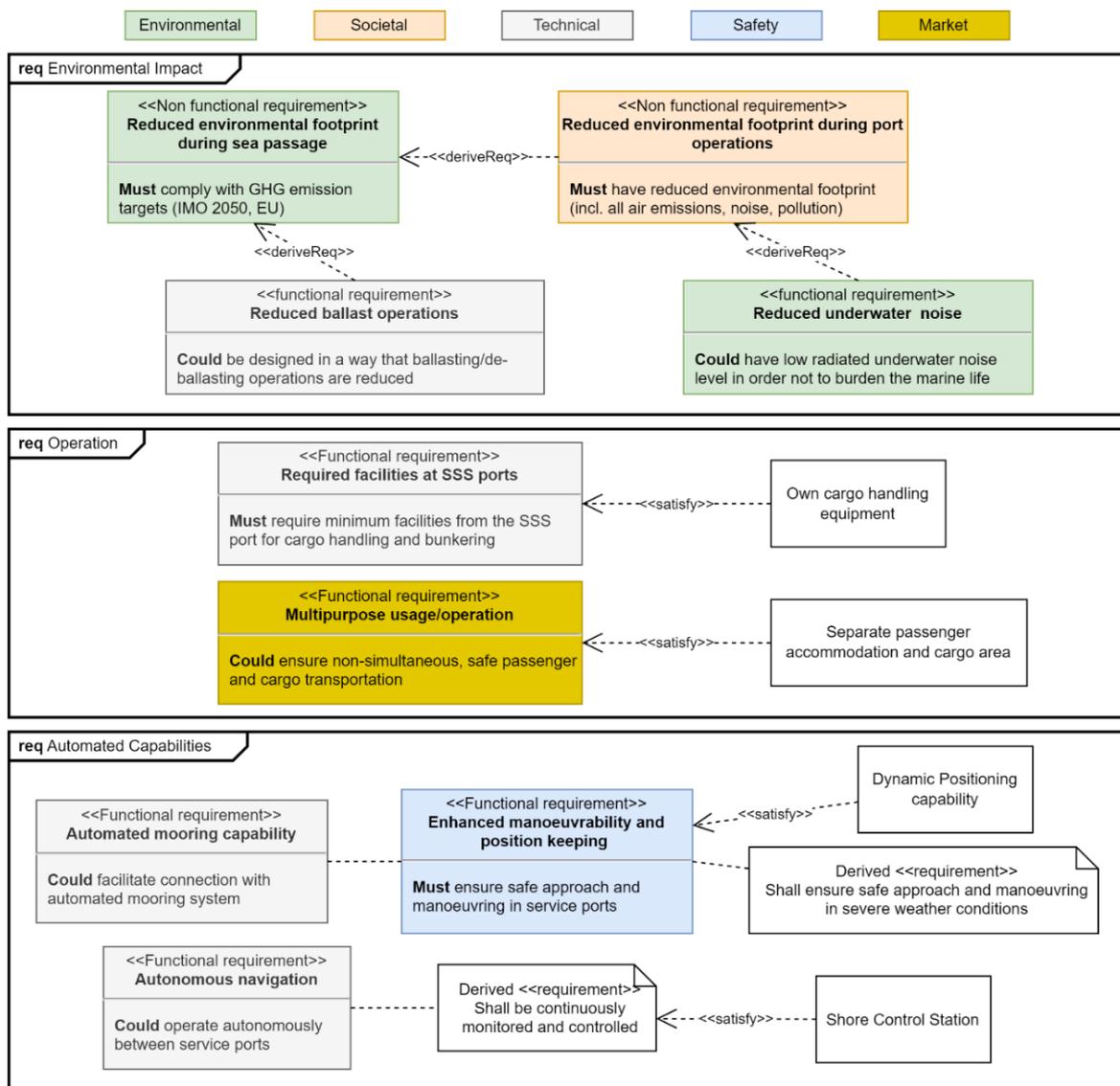
In this section, user requirements for each innovation are documented. The results from the stakeholder engagement activities were used to refine the potential requirements and derive formal requirement statements. In addition, the following sections include comments concerning how some of the identified requirements can be satisfied.

5.1 Innovative Feeder Vessel

For this innovation, 9 requirements (7 functional and 2 non-functional) have been formally stated and grouped into categories related to environmental impact, operational issues, and automated capabilities (Figure 8). The scope of the requirements covers the following aspects: environmental (2), societal (1), technical (4), safety (1), market (1).

The innovative feeder vessel must have a reduced environmental footprint, including air emissions, noise, and pollution, during sea passage and port operations and comply with the GHG emission reduction targets set by the IMO and the EU. From the operational perspective, the innovative feeder must require minimum facilities from the SSS port for cargo handling and bunkering. This requirement is satisfied by outfitting the innovative feeder with its cargo handling equipment, i.e. the Robotic Container Handling System. A potential requirement is a possibility for non-simultaneous, safe passenger and cargo transportation. Within MOSES, this will be examined through a feasibility study for a passenger accommodation module that will be separated from the cargo area.

Figure 8: User requirements for the MOSES innovative feeder vessel



Source: Authors

Concerning her automated capabilities, the innovative feeder vessel must safely approach and manoeuvre within service ports (SSS and DSS), including in severe weather conditions. This requirement can be partly satisfied by designing the feeder with dynamic positioning capabilities. Furthermore, the innovative feeder could operate autonomously between service ports. The feeder should be continuously monitored and controlled by a dedicated Shore Control Station to ensure safe autonomous operation.

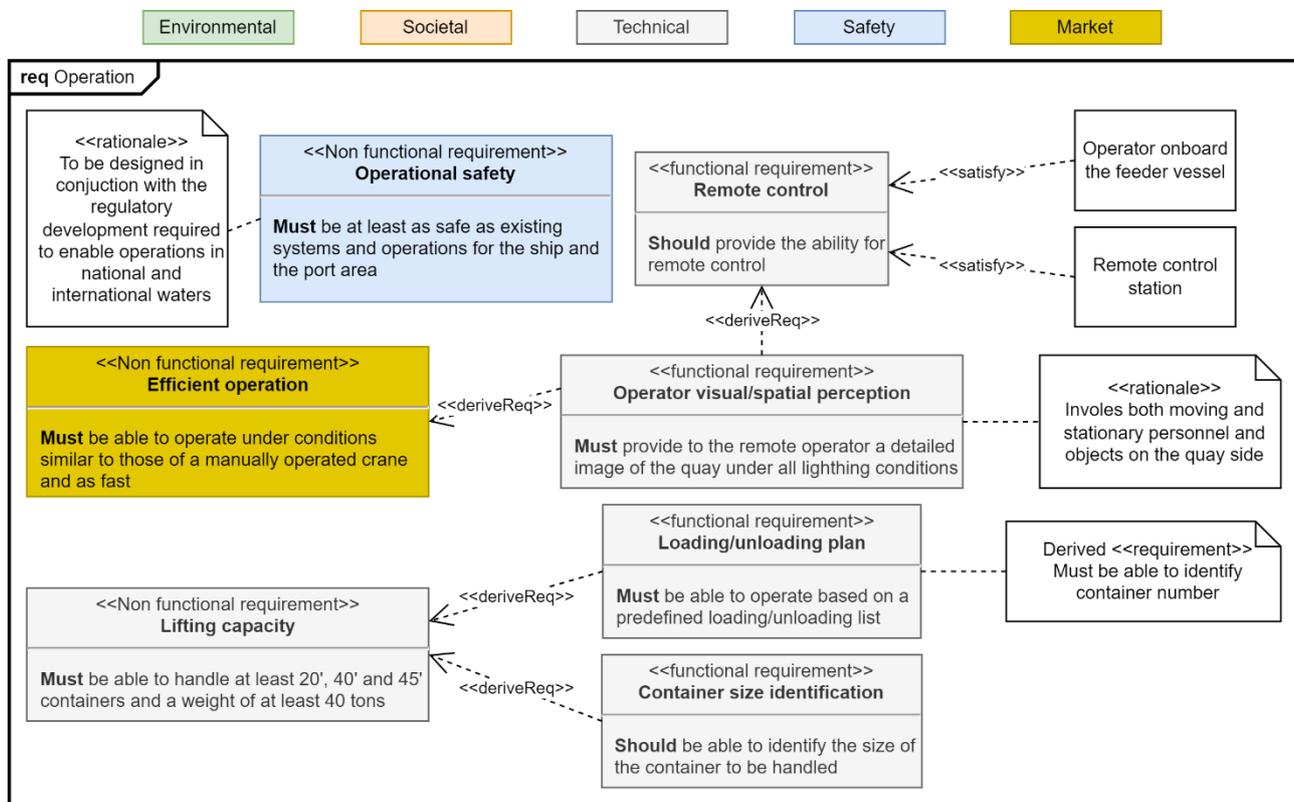
5.2 Robotic Container Handling System

7 requirements (4 functional and 3 non-functional) for this innovation have been formally stated relevant to the operational aspect (**Error! Reference source not found.**). The scope of the requirements covers the following aspects: technical (5), safety (1), and market (1).

The essential requirements for this innovation include operating at least at the same safety level and in similar conditions as existing, conventional cargo handling systems. These requirements will be satisfied by the ability of an operator at a remote control station to monitor and control the system if necessary. In addition, the robotic system should provide the remote operator sufficient situation awareness through a detailed image of the quay under all lighting conditions.

Another essential requirement relates to lifting capacity. The Robotic Container Handling System must handle at least 20', 40', and 45' containers and a weight of at least 40 tons. Related requirements include that it must be able to operate based on a predefined (un)loading plan and that it should be able to identify the size of the container to be handled.

Figure 9: User Requirements for the MOSES Robotic Container Handling System

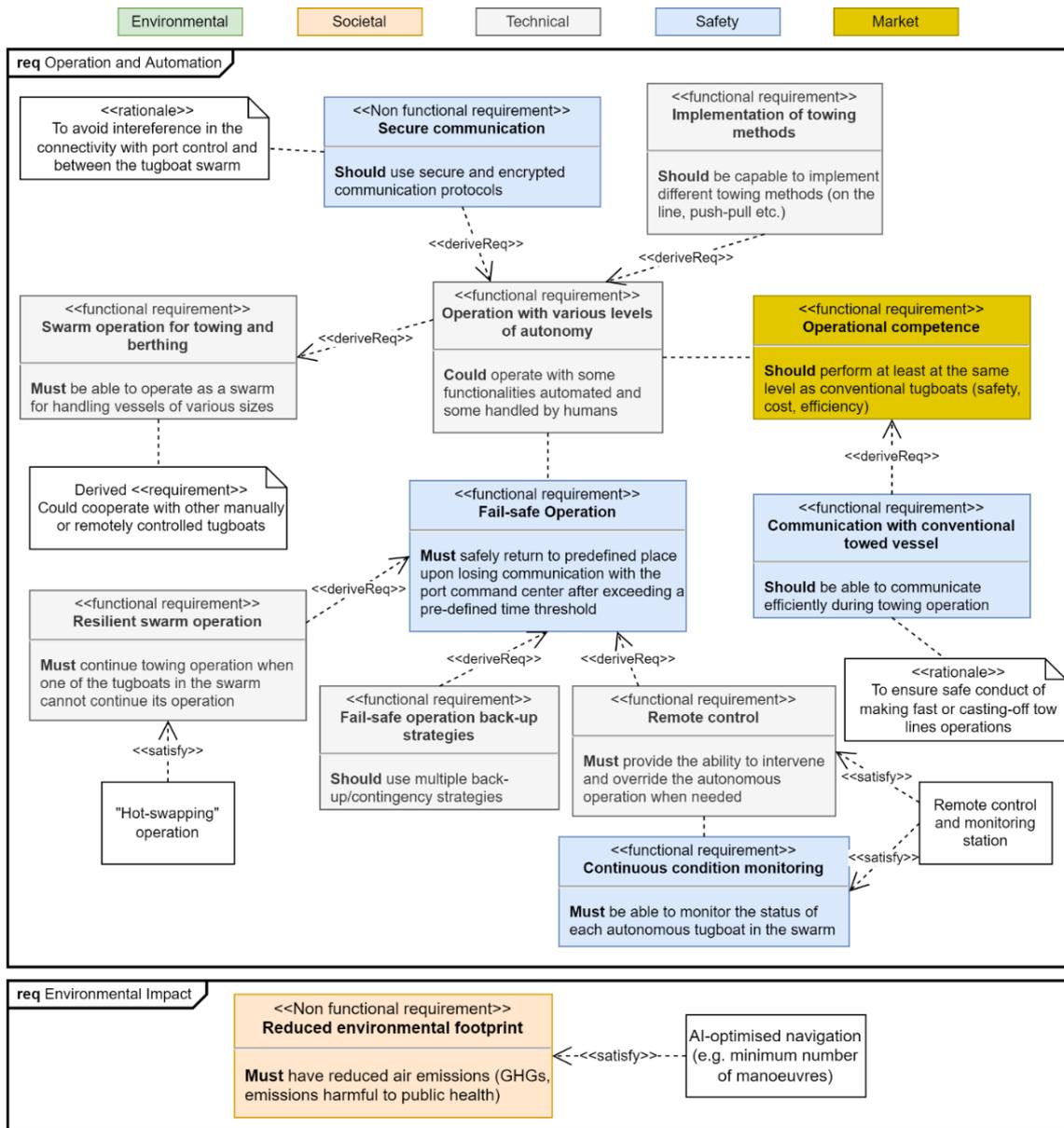


Source: Authors

5.3 Autonomous Tugboats

For this innovation, 12 requirements (10 functional and 2 non-functional) have been formally stated and grouped into categories related to operation/automation and environmental impact (**Error! Reference source not found.**). The scope of the requirements covers the following aspects: societal (1), technical (6), safety (4), and market (1). As shown in **Error! Reference source not found.**, most of the requirements relate to ensuring the safety of autonomous operation, even though there is a requirement for reducing the environmental footprint. In addition, it is noted that development regarding the powering arrangement of the autonomous tugboats is outside the scope of the MOSES project. However, this requirement can be partly satisfied by the Artificial Intelligence (AI) algorithm developed for the tugboat swarm's autonomous navigation, e.g. by optimising the number of manoeuvres required for completing the operation.

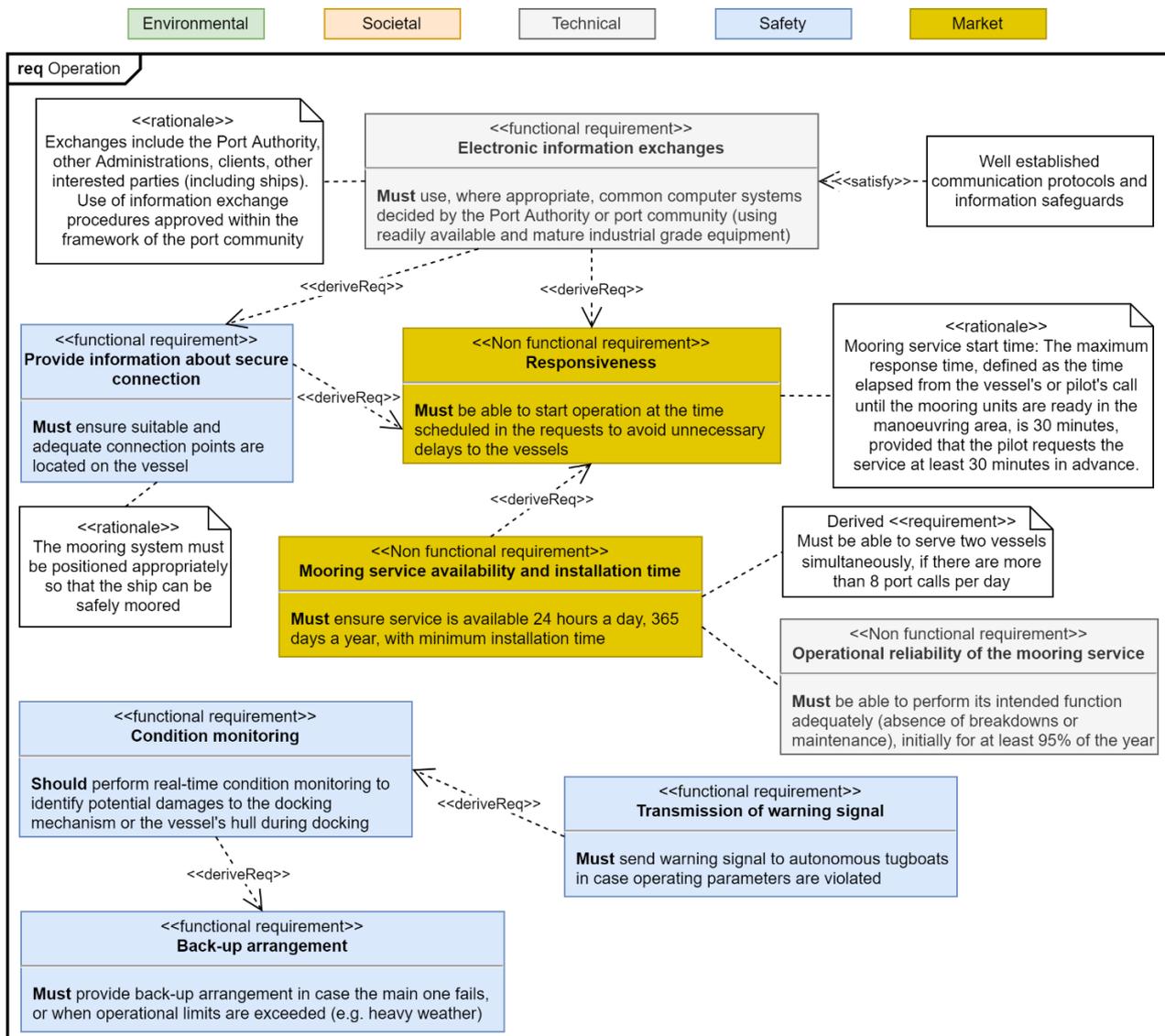
Figure 10: User requirements for the MOSES Autonomous Tugboats



Source: Authors

The Autonomous Tugboats must operate as a swarm for handling vessels of various sizes, including the possibility of cooperating with manually or remotely-controlled tugboats, at least at the same level as conventional tugboats in terms of safety, cost, and efficiency. A derived requirement is that the autonomous tugboats could operate at various levels of autonomy, i.e. with some functionalities automated and some handled by humans. Essential requirements related to autonomous operation are the capabilities for fail-safe (e.g. must be able to safely return to a predefined place if communication with the port is lost) and resilient swarm operation, which means that the towing operation must continue even in case one of the tugboats in the swarm cannot continue its operation. The latter capability can be satisfied by implementing a “hot-swapping” operation, where the swarm halts its operation, one of its members is replaced, and the swarm operation is resumed. Fail-safe operation is complemented by including the ability of an operator in remote control and monitoring station to override the autonomous operation, which depends on continuously monitoring the status of each tugboat in the swarm.

Figure 11: User requirements for the MOSES Automated Mooring System



Source: Authors

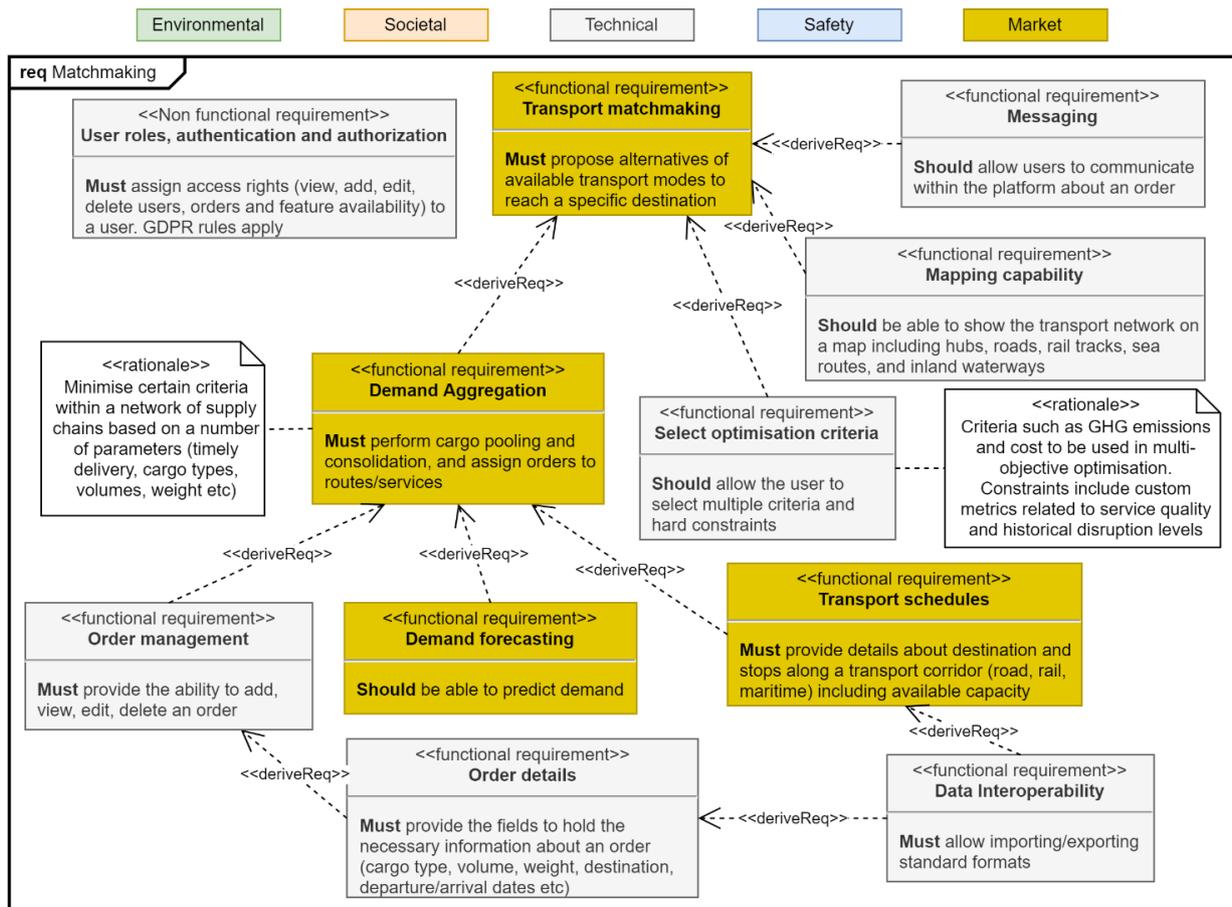
5.4 Automated Mooring System

For this innovation, 8 requirements (all functional) have been formally stated relevant to the operational aspect (**Error! Reference source not found.**). The scope of the requirements covers the following aspects: technical (2), safety (4), and market (2). The essential requirements for the Automated Mooring System relate to the integration into existing port operations and the cooperation with the Autonomous Tugboats for ensuring the vessel will be safely moored.

In terms of operational efficiency, the system must be able to start operation at the scheduled time to avoid delays, which depends on electronically exchanging information with existing port information systems using well-established communication protocols and information safeguards. Furthermore, the system should be available 24 hours a day, 365 days a year, which implies a minimum level of operational reliability (i.e. absence of breakdowns or maintenance) at least 95% of the year.

In terms of operational safety, the system should be able to send warning signals to the Autonomous Tugboat swarm in case operating parameters are violated. The latter depends on a real-time condition monitoring arrangement that will also be used for identifying potential damages to the docking mechanism or the vessel’s hull during docking.

Figure 12: User requirements for the MOSES Matchmaking Platform



Source: Authors



5.5 Matchmaking Platform

For this innovation, 11 requirements (10 functional and 1 non-functional) have been formally stated relevant to the match-making functionality of the platform (Figure 12). The scope of the requirements covers the following aspects: technical (7), and market (4). In order to achieve its main functionality, the platform must propose alternatives of available transport modes to reach a specific destination, complementing an optional mapping capability.

The platform must perform cargo pooling and consolidation, and assign orders to routes/services (demand aggregation) by considering criteria, such as timely delivery, cargo types, volumes, and weight, which the user should select. In order to perform demand aggregation, the platform must provide details about destination and stops along a transport corridor, including available capacity, and should be able to predict demand. Furthermore, the platform must technically provide the user with the ability to manage orders (e.g. add, edit, view, delete an order), which depends on being able to store the necessary information (e.g. cargo type, volume, weight, destination etc.).

6. CONCLUSIONS

To ensure the innovations developed within the MOSES project satisfy actual needs, the first step of the user-driven approach was to determine the relevant stakeholder categories and their needs. For the innovative feeder, the MOSES stakeholders mainly require a vessel that offers a reduced environmental footprint compared to other transport modes, while for the onboard Robotic Container Handling System, they consider important the provision of a remote operator with adequate situation awareness to ensure safe operation. For the Autonomous Tugboats, the needs are focused on remote monitoring and control capabilities and exchanging information securely in real-time with the shore and with surrounding traffic. For the Automated Mooring System, the stakeholders would need a flexible design to accommodate various vessel sizes and port layouts and the capability to continuously monitor the system's condition. With respect to the Matchmaking Platform, focus was given to providing users, who are offered different functionalities depending on their profile, with scenario-building capabilities that include alternative hinterland connections.

By implementing the MOSES User Requirements Extraction methodology, 47 user requirements that capture the identified stakeholder needs have been documented. About 77% of the user requirements are functional, i.e. describe what the systems should do, while 60% are considered essential and 28% as "should-have". The aforementioned necessary functional requirements have been used to determine the main functionalities of the MOSES innovations at the early stage of development. The non-functional requirements described in this paper (23%) will be used as a starting point for elaborating the qualities and performance characteristics of the MOSES innovations. In addition, most of the user requirements cover safety and technical issues (72%), while 19% cover market issues and 8% environmental and societal issues.

The main requirements for the innovative feeder relate to a reduced environmental footprint and the safety of automated functionalities, and her potential autonomous operation. The feeder's cargo handling functionality is automated by the onboard Robotic Container Handling System, which must be at least as safe as conventional cargo cranes and operate in the same conditions. An expected benefit of this automation is expanding the operational envelope to night-time conditions. The main requirements for Autonomous Tugboats aim to ensure their operational flexibility by operating at various levels of autonomy and the safety of the towing operation by integrating adequate fail-safe capabilities. Operational safety strongly depends on communication with the Automated Mooring System as well. The latter must also be efficiently integrated into existing port operations and ensure the automated system's availability to avoid vessel operation delays. The Matchmaking Platform



must identify the best alternative route by optimising user-selected criteria and providing the users with the necessary transport information.

Finally, the user requirements presented in this paper will be complemented by use cases, scenarios and market-related requirements that will be identified and will provide input to the definition of the system requirements and specifications at a later stage of development.

ACKNOWLEDGMENTS

This research has been conducted as part of MOSES project, which has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 861678. The content reflects only the authors' view, and the Agency is not responsible for any use that may be made of the information it contains.

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