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Paving the way for the future of Short Sea Shipping: The MOSES project

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Abstract

As the European Union (EU) has aimed for a modal shift from road transport to other more sustainable transport modes, such as rail or waterborne transport, Short Sea Shipping (SSS) has gained more attention. In order to provide an overview of SSS component in the European supply chain, the current status, established networks and legislative drivers for its promotion are analyzed, as well as relevant shortcomings and potential market opportunities. In parallel, the contribution of MOSES project to SSS is examined, through the development of innovative solutions aiming to address the vulnerabilities and strains related to the operation of large containerships and the engagement of port community stakeholders. Finally, associated business cases are presented, along with the expected results of MOSES project and the foreseen benefits towards SSS promotion and enhancement.

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Keywords: Waterborne transport; Container supply chain; Automated docking; Container handling; Horizontal logistics collaboration; Short-sea and deep-sea shipping

1. Introduction

Ports play a decisive role in the EU's external and internal trade. About 74% of imports/exports and 37% of exchanges go through ports, making Europe highly dependent on ports for external and internal trade. In the European container supply chain, Short Sea Shipping (SSS) and Inland Waterways Transportation (IWT) are not so well integrated in contrast to Deep Sea Shipping (DSS) ports (also referred to as Hub ports). In recent years, the European Union (EU) has tackled the negative impacts of land transport such as road accidents and congestion, through setting

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goals for a competitive and also resource-efficient transport system. One of the main goals has been a modal shift from road transport to other transport modes which are more sustainable, such as rail or waterborne transport, with SSS gaining more attention. In this way, not only reduction in the emissions is achieved, but also Europe benefits from decreased congestion and accidents. Developing the Trans-European Network (TEN-T), which aims at creating a sustainable and efficient transportation network by 2050 through the integration of all transportation modes, the European Commission planned thirty priority axes and projects, including land to sea transport networks and the implementation of SSS lines and services (European Commission, 2022). The European Commission also defined SSS as maritime transport of goods between ports across the EU (Comi et al., 2020). The MOSES project is a European project, funded under the Horizon 2020 Work Programme, proposing a novel approach where almost every local small port can be used to (un)load containers, while the entire ecosystem of stakeholders around the small port is activated and engaged with SSS services. The following sections provide an overview of: i) current status of SSS in Europe, along with relevant networks and legislation, shortcomings and potential market opportunities; ii) contribution of MOSES project towards SSS enhancement and promotion, and iii) relevant business cases, validation and expected results based on MOSES pilot demos.

2. SSS in Europe

2.1. Current status, networks and legislation

According to the Motorways of the Sea (MoS) programme, six major sea basins can be distinguished in Europe: Baltic Sea, North Sea, Atlantic, Western and Eastern Mediterranean and Black Sea (Bodewig, 2020). In general, the share of SSS in total sea transport varies considerably between the EU countries, having a particularly high share in the Baltic Sea, the Eastern Mediterranean and the Black Sea. Currently, containers have been the dominant type of cargo in EU SSS, after liquid bulk (Eurostat, 2022). In terms of the freight quantity transported to/from the main European ports, in 2017, SSS counted more than half (Comi et al., 2020). For the majority of the EU countries, the highest part of their goods was transported by SSS with the partner ports located in the same sea regions. With regards to the EU Mediterranean countries, long coastlines and/or many settled islands, play an important role in answering the high share of SSS. A large volume of feeder services to or from hub ports can also explain the high degree of SSS transport in countries serving as regional trans-shipment points. In 2020, the predominance of SSS of goods over deep sea shipping was in particular noticeable in Malta, Cyprus, Finland, Sweden, Denmark, Bulgaria, Ireland, Norway, Latvia, Italy, Croatia, Estonia, Romania, Greece, Poland and Montenegro, all with Short Sea Shipping shares of 70 % or more in their main ports. However, the share of SSS is lower than 50 % in countries with major ports focused on intercontinental trade, such as Spain (Eurostat, 2022) (Fig. 1).

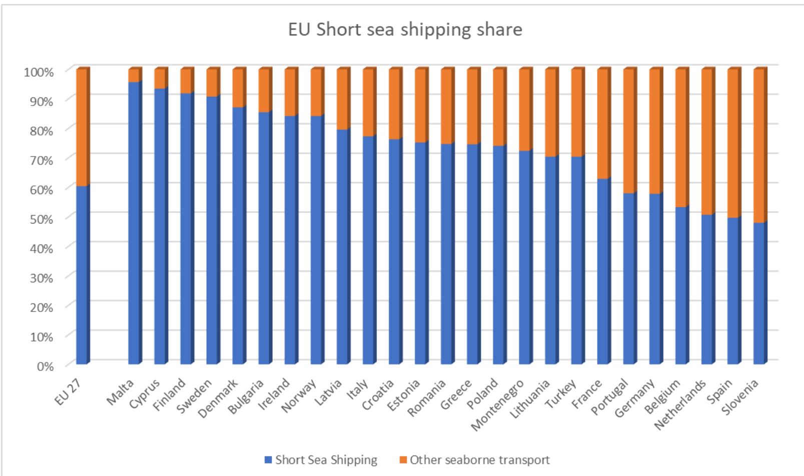

Fig. 1. Short sea shipping of freight in total sea transport, 2020 (% share in tonnes), Source: Eurostat 2022

The perspectives of container shipping in western Mediterranean reveal a trend of expansion of major infrastructure in the main ports, while Black Sea and Suez Canal regions in Eastern Mediterranean offer a significant opportunity for transporting containers to Eastern European trade areas. Maritime networks in the Mediterranean have their own hierarchy with a pronounced distinction between hub and gateway ports. European hub ports in the Mediterranean Sea are mostly located close to the Mediterranean's maritime trunk line, resulting in an intense competition for transshipment cargo among transshipment hubs. Most transshipment ports are in Europe, while gateway ports in the Mediterranean serve as the maritime trade gateways to their hinterlands. Container-terminal productivity differs widely across the Mediterranean ports, as it depends on the throughput volume and ship size and on the call size that allow more efficient operations. The main drivers of maritime networks are industry strategies by the shipping lines. In Mediterranean container shipping, major actors have united their operations towards a hub-and-spoke port system, including also regionally focused shipping lines that feed secondary ports in the Mediterranean basin. Traffic from major shipping alliances seems to be an important driver for maritime connectivity and port efficiency. The share of intra-Mediterranean traffic in total Mediterranean traffic is increasing, with the majority of traffic going between European ports (mainly east–west). With regards to the local networks, Mediterranean shipping services are getting centralized, becoming more uniform and offering fewer alternatives for main port calls. In terms of port connectivity, the Mediterranean has polycentric but increasingly centralized maritime networks that reflects a strong east–west divide, with Piraeus–Ambarli (Turkey) and Marsaxlokk (Malta)–Valencia (Spain) to be the respective central nodes (Arvis et al., 2019).

The legal framework of maritime transport driven by the International Maritime Organization (IMO) is implemented in EU through Directives or Regulations, with some of them serving as legislative drivers for SSS, either from the environmental point of view or regarding the operational efficiency and digitalization of the shipping sector. The European Green Deal has set targets for the reduction of emissions and the European Emissions Trading System (EU ETS) is expected to be extended to the maritime sector, while energy efficiency targets have been defined (Directive 2018/2002/EC) and member states need to comply with the deployment of Alternative Fuels Infrastructure (EU Directive 2014/94/EU). With regards to air pollution, several regulations have set targets for the reduction of pollutants (MARPOL Convention-Annex VI, Directive 2016/802/EU), while the Environmental Impact Assessment Directive 2014/52/EU sets the rules for assessing the potential environmental effects of projects, including coastal zones and the marine environment. From the operational point of view, the transition towards digitalization and automation is speeding up in the maritime industry, aiming to increase competitiveness and enhance decarbonization in the international shipping. The reporting obligations have been digitalized (Directive on Ship Reporting Formalities) and the European Maritime Single Window environment (EMSW) has been adopted (Regulation 2019/1239) to ensure competitiveness, efficiency and environmental sustainability of European maritime transport sector. In addition, a proposal for a Regulation on Electronic Freight Transport Information (eFTI) was also introduced by the European Commission in 2018 to simplify and optimize communication between transport operators and authorities. All these regulations and directives have laid the legal groundwork towards the broader utilization of SSS services that can serve as a solution for many environmental and operational burdens and provide significant benefits to the maritime sector.

2.2. Shortcomings and market opportunities

As already mentioned, EU is highly dependent on ports for external and internal trade, with DSS ports serving as integral nodes within multimodal logistic flows, using mainly road and rail for the backhaul. However, SSS and IWT are not so well integrated due to several shortcomings and burdens related to their characteristics and operation. The most important limitation is that large containerships exceeding 15.000 TEUs can only be served by DSS ports due to navigational restrictions, topological restrictions (e.g. available water depth), limited container handling infrastructure and lack of available space at smaller ports. In addition, larger containerships generate feeder services to small ports that require larger feeders (typically carrying up to 3.000 TEUs). As larger feeders cannot be serviced by many small ports that also lack 24/7 port services, the container supply chain depends more on land-based transportation modes for distributing cargo from Hub Ports to the hinterland. Considering the significant imbalance of traffic flows at origins/destinations (backhaul traffic challenge) and the high cost and unreliability of SSS services, logistics stakeholders remain unwilling to adopt SSS. In parallel, many logistics actors (ports, freight forwarders, transport operators) have recognized unsatisfactory lead times, port capacity and insufficient hinterland links, along with the reluctancy of local communities to invest in port infrastructure as the main obstacles of adopting SSS. For these reasons, small ports in coastal areas or islands with minimal/no infrastructure remain underutilized despite their potential to play a major role in enabling SSS routes and alleviating congestion in other areas, such as hub ports or busy land-based routes.

These limitations lead to the identification of significant gaps and needs of the supply chain sector, which create several market opportunities for further development and growth. Hub Port operations are increasingly less efficient due to congested waterways and maneuvering and berthing processes that are error-prone, highly time-consuming and costly, vulnerable to disruptions (e.g., tugboat service unavailability etc.) and accidents, and with significant environmental impact. Shipping accounts for 70-100% of port emissions in developed countries, while maneuvering and docking accounts for 50% of the emissions (Chang et al., 2013). So, it is easily understood that the enhancement of SSS utilization can improve the efficiency of the supply chain, with the addition of small ports to the logistics network and the increase of available routes and services, and reduce emissions by 50% compared to land-based modes for the same route.

3. MOSES contribution towards SSS enhancement and promotion

MOSES addresses key business challenges related to SSS, including delays caused by congestion and dependence on human-operated services in DSS ports; bottlenecks during transshipment from hub ports to land-based modes; the inability of small ports to provide 24/7 container handling and their lack of infrastructure to accommodate container traffic. In order to overcome the limitations of small ports to handle large containerships due to lack of necessary infrastructure and available services, MOSES follows a two-fold strategy, in order to reduce the total time to berth for TEN-T Hub Ports and to stimulate the use of SSS feeder services to small ports that have limited or no infrastructure, targeting to a 10% modal shift to SSS in designated areas. In parallel, the communication between shippers and carriers is strongly supported, minimizing empty backhaul traffic and associated costs, while the awareness about available SSS routes is increased, improving the overall performance of SSS component. The main innovations developed within the MOSES project are: 1) the MOSES AutoDock system, an autonomous vessel maneuvering and docking scheme, 2) the MOSES innovative feeder vessel outfitted with a robotic container-handling system, 3) the MOSES Platform, a digital collaboration and matchmaking platform with specific application to SSS traffic. The MOSES concept and relevant innovations are presented in Fig. 2, while the following sections describe the main aspects of these innovations.

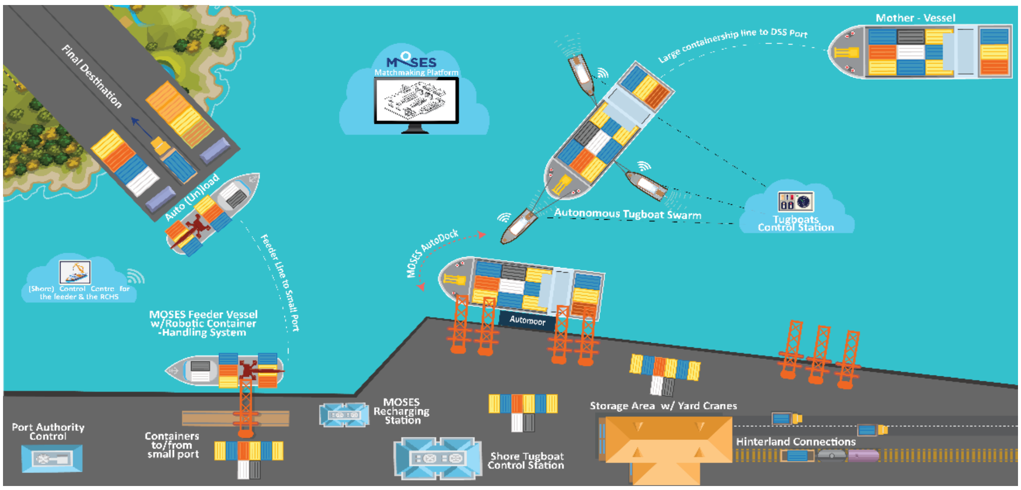

Fig. 2. MOSES concept and innovations

3.1. Innovative Feeder Vessel and Robotic Container-Handling System

MOSES develops three different designs for the innovative feeder that are fit for purpose for the requirements of the MOSES business cases (see Section 4.1). Compared to existing container feeder vessels, the MOSES feeder includes the following innovative features: low cargo capacity (ranging from approx. 90 – 680 TEU), environmentally sustainable engine configuration; superstructures positioned at the fore and mid ships; enhanced maneuverability; and automated onboard crane. For achieving (near) zero emission operation, several engine configuration alternatives have been evaluated, with the selected ones resulting to an estimated 10% lower operating costs. Furthermore, the concept design for the MOSES feeder is compatible with the MOSES AutoDock system (see Section 3.2) by including thrusters and azimuth propulsion, which provide enhanced maneuverability for the feeder and therefore minimize the required number of tugboats, while the hull form of the feeder has adequately large flat surfaces for facilitating the connection with the MOSES Automated Mooring System. It can also operate in parts of its voyage with a certain degree of autonomy. Due to the selected engine configurations, the MOSES Innovative feeder can have (partly) zero emissions throughout all operational phases, contributing to the reduction of the environmental footprint of SSS services from large container terminals to smaller ports. The feeder is also expected to reduce the environmental footprint within the port area and in its vicinity by: 1) having been designed to use its onboard battery systems and shore power connections for the required power while berthed, and 2) capturing part of the hinterland container traffic, currently moved by container trucks. A recharging station for automated vessels is also developed providing a fully automated shore power connection solution without the need for assistance from the vessel and ensuring the minimization of energy transfer losses from the port's electric grid to the ship.

The MOSES feeder is equipped with the MOSES Robotic Container-Handling System (RCHS) that provides autonomous (off)loading either at the quay or directly on trucks at the small port and is remotely monitored by a Shore Control Centre. The RCHS is an integrated system that can operate without direct human involvement, supported by a remote operator to a varying degree. It requires a sub-system for situation awareness (e.g. to detect containers or people and other objects for safety reasons), consisting of an advanced sensor suite, while the data from the sensors are used to build an accurate 3D-world model of the operating environment. Based on continuous risk assessment, the remote operator can supervise and take immediate action in case the situation is outside the problem-solving ability of the on-board crane. The MOSES Innovative Feeder with the RCHS is designed to minimally require port infrastructure, services, and personnel both for large DSS ports and smaller SSS ports with limited or no infrastructure. With respect to cargo-handling, the onboard crane can be also used at DSS ports instead of port cranes, which have higher operational costs and may not be available due to increased vessel traffic, which can contribute to a reduction in the total usage time of port cranes for container feeder vessels. Considering the operational self-sufficiency of the MOSES feeder, its operation is expected to increase the number of EU ports able to host container feeder vessels, which will effectively integrate them into the EU container supply chain. The feeder with the RCHS is intended to be used for the SSS leg and is designed to match dominant SSS business cases, increasing the utilization rate of small ports in TEN-T corridors promoting SSS feeder services for last mile delivery.

3.2. AutoDock system

The MOSES AutoDock system aims to automate the maneuvering and docking of large containerships in DSS ports, which is currently conducted with manually operated tugboats in a typically complex and time-consuming process. This is an intelligent system comprising autonomous tugboats operating in a swarm configuration at various levels of autonomy and supported by the MOSES Shore Tugboat Control Station (STCS), which will cooperate with the MOSES Automated Mooring System; a re-engineered version of Trelleborg's AutoMoor system. MOSES develops an architecture for autonomous tugboat operation that is compatible with existing equipment on conventional tugboats and therefore can be used for retrofitting. The architecture includes sensors that provide situation awareness to AI algorithms that control steering and propulsion. The automated mooring system is a vacuum-based system for hands-free mooring that includes rubber damping elements to allow and control surge motion of a connected vessel and energy harvesting systems. The MOSES STCS acts as a communication hub between the tugboat swarm and the mooring system, as well as a central platform for supervisory control of the process.

With the AutoDock system, MOSES aims to decrease docking and maneuvering times for containerships in large terminals by 20% and therefore reduce the cost of ship handling within the port. This reduction will be achieved by minimizing the number of necessary maneuvers conducted by the AI in the autonomous tugboats and mooring without mooring lines. The system is also expected to improve safety by limiting human involvement in both maneuvering and mooring operations, which implies a reduction in human error-related accidents or incidents attributed to pilots, ship captains, ineffective ship-tugboat communication and mooring lines handling. Currently, more than half of accidents (collision, grounding, contact, etc.) occur in terminal areas (Pagiaziti et. al., 2015), while 75% of the accidents occurring during the maneuvering and mooring of the ship are caused by human errors (lack of knowledge, training experience, poor communication and breach of working procedures etc.) (Çakır et. al., 2017). According to the Australian Maritime Safety Authority, between the years 2010-2014 a total of 227 mooring-related incidents were reported, whereas 51 (22%) concern injuries (Maritime Safety Awareness, 2015). These accidents may have significant socioeconomic impact with an equivalent financial cost of millions per year and in many cases human losses. Through the automation of these processes and the reduction of human involvement, potential human errors will be minimized and the associated socioeconomic impacts will be mitigated. The utilization of AutoDock system could lead in an elimination of the risks/injuries caused by the traditional line mooring techniques and the accidents occurring during maneuvering. From the environmental perspective, a reduction in air pollutants in port areas is expected due to the optimized operation of the autonomous tugboats and the energy harvesting capability of the automated mooring system. The availability of port services is also expected to be improved due to reduced manning on the tugboats and shore-side, which may address disruptions due to unavailable tugboats (high demand) and unavailability/low availability of mooring personnel, as well as due to the reduction of human-error related accidents.

3.3. Matchmaking Platform

The MOSES platform is a digital collaboration and matchmaking platform that aims to maximize and sustain SSS services in the container supply chain by matching demand and supply of cargo volumes by logistics stakeholders using data driven-based analytics. It can dynamically and effectively handle freight flows, increase the cost-effectiveness of partial cargo loads and boost last-mile/just-in-time connections among the transport modes and backhaul traffic. In this way, its users can experience the benefits of a collaboration and optimization tool that prioritizes SSS and is able to deliver impactful results for all stakeholders involved. The MOSES platform advances current state-of-the-art by supporting cargo consolidation (at container level) and fully exploiting the bundling potential among different shippers to enable multimodal transport routes containing at least an SSS leg. This is done in existing but underutilized SSS routes, currently not preferred by shippers due to increased costs or low service frequency and reliability. The MOSES Platform focuses on collecting available information and datasets related to logistics supply and demand from relevant stakeholders, such as shippers, carriers, freight forwarders, shipping lines etc. Through the combination of these datasets, valuable information can be extracted, supporting the optimization of the logistics process. The main benefit of this analysis is the provision of multimodal transportation options, combining different transportation means and modes that can reduce the delivery time and the overall cost. In parallel, the combination of multimodal transport services with freight cargo bundling can increase the efficiency of transport operators and improve the management of empty containers.

4. Business cases, validation and expected results (pilot demos)

The MOSES business cases are developed on key SSS routes of the TEN-T network and cover all SSS traffic types. In parallel, three pilot demonstrations will be performed, aiming to validate them in relevant testing environments and showcase their functionalities.

4.1. MOSES business cases

Within MOSES, the following business cases are developed that aim to highlight the market opportunities and exploitation potential of the MOSES innovations: 1) Eastern MED-Greece, and 2) Western MED-Spain. The methodology applied for these business cases included the following steps: analyzing the current container transport system between the specific DSS and SSS ports (Ro-Ro), estimating the potential demand for the feeder line (Lo-Lo), conducting a comparative cost analysis between the potential feeder line and the current transport solutions, and defining the circumstances under which the new feeder line is more cost effective, as well as the technical and operational limitations that may act as a barrier for implementation. The Eastern MED-Greek case evaluates the viability of a container feeder line that links Piraeus with the ports of Kea, Siros, Tinos, Mykonos, Naxos, and Paros, which currently receive general cargo traffic handled by trucks and trailers through Ro-Pax and Ro-Ro lines. The port of Piraeus is connected to the Orient/East-Med TEN-T corridor and handles approximately 80% of Greek imports. The island ports that have been selected gather 87% of the total general cargo traffic (based on 2019 data). The assumptions that the MOSES feeder captures 80% of existing cargo traffic and a two-weekly round-trip frequency has led to an estimated capacity of approximately 300 TEUs required for the line to be viable (i.e. lower operational costs compared to existing transport solution).

The Western MED-Spanish case evaluates a feeder line connecting three ports managed by Valencia Port Authority: Valencia, Sagunto and Gandia. Valencia port is connected to the Mediterranean TEN-T corridor and handles over five million TEU annually by serving several container lines with principal ports globally. Sagunto serves three lines, while Gandia does not serve any container line. In addition, currently, there is no feeder line connecting these three ports and hinterland traffic is handled through trucks and rail. The following hinterland areas have been considered for the development of this business case: (a) for the port of Sagunto, the south of the province of Castellón and the north of the province of Valencia, and (b) for the port of Gandia, the south of the province of Valencia and the north of the province of Alicante. The assumptions that the MOSES feeder captures 40% of existing container traffic, a three-weekly service frequency, and three trucks haulages per day to the hinterland has led to an estimated capacity of approximately 600 TEUs required for the line to be viable. In parallel, a third business case will be selected through an open call mechanism to evaluate the transferability of MOSES innovations. This dynamic element will allow to further enrich visibility and potential impacts by selecting an existing yet underperforming SSS route for the third SSS traffic type (domestic traffic competing with other modes) in a different TEN-T corridor (besides MED, Orient/EastMED) and will use the matchmaking platform for evaluating the potential increase in container volumes.

4.2. MOSES Pilot demonstrations

MOSES will test and validate the developed innovations at TRL 5-6 by conducting three Pilot Demonstrations in a relevant testing environment. The systems’ performance will be assessed and evaluated with specific KPIs that are related to the MOSES objectives in a quantitative and qualitative manner. The demonstrations will involve the following innovations as described below: 1) MOSES AutoDock system, 2) MOSES Innovative feeder, and 3) MOSES Robotic Container-Handling System (RCHS). The objective of the AutoDock demonstration will be to showcase the intelligent cooperation between autonomous tugboats for maneuvering a large container ship and the collaboration with an automated mooring system for berthing. The MOSES Autonomous Tugboat swarm will be represented by two workboats that will be retrofitted for autonomous operation based on the architecture developed within MOSES. The workboats will be used to maneuver a floating vessel that will simulate the large container vessel. A small-scale prototype of the MOSES Automated Mooring System, which will be manufactured within the project, will be used to secure the floating vessel.

The objective of the innovative feeder demonstration will be to test and validate the innovative characteristics of the MOSES feeder with respect to its potential autonomous operation in the future in various operational conditions and scenarios. The demonstration will be conducted in a Seakeeping and Maneuvering Basin, using a free sailing model of one of the designs developed for the feeder (see Section 3.1). The autonomous operation of the feeder will be tested by making round trips between two simplified container ports in the basin in calm water and wave conditions, while its maneuvering characteristics will be demonstrated in dedicated testing scenarios. Finally, the RCHS demonstration will aim to test and validate the autonomous container handling capability of the system, the shared control between the human (remote) driver and the system, and intervention options for the remote operator. The demonstration will involve a full-scale, operational crane that will be outfitted with the sensor suite developed within MOSES and the interaction between the RCHS and the MOSES feeder will be simulated through a dedicated software solution. The autonomous operation will be demonstrated in two stages: 1) with the “remote” operator onsite but with no direct line of sight on the container handling process, and 2) remote operation where the operator is located off-site.

5. Conclusions

The EU has aimed for a modal shift from road transport to other more sustainable transport modes, such as rail or waterborne transport, while the development of the TEN-T networks concept, along with rising concerns related to the transport impacts have increased EU’s interest to promote SSS. MOSES is an ambitious project that bears significant innovation potential in the context of European SSS uptake. Its innovation potential covers technological system development, as well as software tools and accompanying governance models to improve related logistics processes. By developing concrete business cases, MOSES will enable the promotion of smart port development with minimal investment and the integration of small ports and related SSS services to the supply chain, which will subsequently bring economic prosperity and stimulate the workforce. Specifically, the contribution of MOSES towards sustainable SSS cargo transport is related to expected benefits in the safety, environment, and efficiency domains. Impact on safety includes minimizing human error in towing, reducing accidents during berthing, and minimizing cargo handling risks in the absence of port infrastructure. From the environmental perspective, MOSES is expected to reduce air emissions in ports and total emissions per transported TEU by exploiting green propulsion technologies, as well as reducing road congestion in port areas through a modal shift to SSS. In terms of supply chain efficiency, MOSES will stimulate new, sustainable SSS feeder services with lower end-to-end delivery times that will be effectively promoted as an alternative to land-based transshipment. MOSES innovations will also have an impact on operations at DSS and small ports that will accommodate the proposed automated/autonomous systems. As the EU is working towards creating a comprehensive TEN-T network by 2050, MOSES paves the way by shaping the future of European Short Sea Shipping.

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