AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping

D.5.3: As-Is and To-Be Call Process

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List of Acronyms

Abbreviation / acronym	**Description**
ATD	Actual Time of Departure
CT	Container Terminal
EC	European Commission
ETA	Estimated Time of Arrival
PCT	Piraeus Container Terminal
SL	Shipping Line or its Authorized Agent
TDR	Terminal Departure Report
VO	Vessel Operator
WP	Work Package
SCS	Shore Control Station
SSS	Short Sea Shipping

Executive Summary

MOSES aims to significantly enhance the SSS component of the European container supply chain by addressing the vulnerabilities and strains that relate to the operation of large containerships and container freight operations at small-to-medium sized ports that are lacking the infrastructure to operate on containerized cargo. For stimulating the use of SSS feeder services to small ports (hub and spoke traffic) that have limited or no infrastructure, MOSES project has developed container feeders specifically designed for meeting the requirements of Spanish and Greek business cases along with on vessel robotic arms that are able to handle containerized cargo.

This document collects and analyses the current vessel call process at MOSES ports and specifically the berthing, docking and stevedorage processes. It provides an overview of the characteristics and components of each of the MOSES innovations related to these processes.

It then proceeds to describe the new altered processes and operational model for the vessel calls in ports and vessels that have implemented the relative MOSES Innovations.

1. Introduction

1.1 Purpose of the document

This report is part of the MOSES project. MOSES has an impact on various port processes by implementing its innovations. This document explores and evaluates the impact on normal port operations from the implementation of the MOSES innovations, including issues such as container handling at small ports, where no relevant infrastructure (i.e., crane for handling containers at the yard) exists, after being discharged from the MOSES Innovative Feeders with the use of the Robotic Container-Handling System. The current port call processes are studied in depth and the roles of involved parties are identified.

Subsequently, the parts of the current processes that are affected by MOSES innovations are laid out and the new process after implementing the MOSES innovations is being described.

1.2 Intended readership

The intended readership of this public document is any decision maker involved in the development of zero-emission technologies in ports. This mainly includes Port Authorities, terminal operators, shipping companies, tugboat operators, the coastal guard and any interested party willing to know more about the advantages brought by tugboat automation and modernization of the berthing/docking process in freight ports and the MOSES project innovations.

1.3 Document Structure

This deliverable is structured in three chapters: Chapter 1 introduces the MOSES project and main objectives of this deliverable. Chapter 2 documents the current vessel call processes in MOSES ports. Chapter 3 describes the new vessel call process after the implementation of MOSES Innovations.

2. As-Is Call Process

2.1 Port of Piraeus

In the Piraeus container terminal, the berthing planning is prepared, taking into consideration the following parameters:

- Pro-Forma berthing windows
- Vessel Berthing Appointments
- Arrival announcement & work application
- Availability of berth
- Vessel Connections
- Submission of the Import Bay Plan and Export Pre-stowage
- Vessels' Particulars

The pro-forma berthing windows for the particular main trade vessels are negotiated between the Vessel Operator (VO) and PCT. The berth window is related to an estimated number of container moves and the required day and time of the week. For PCT, berthing window times start with the beginning of shifts, i.e. 07:00, 15:00, 23:00. Unless otherwise agreed, vessels will be planned to arrive and depart on the proforma berth window arrival and departure times. In case a vessel is delayed on the pro-forma schedule, PCT will try to sail the vessel as close to the pro-forma sailing time as possible, without negatively affecting other vessel's schedules and terminal's normal work flow. In any case, vessels arriving within pro-forma always have priority over vessels out of pro-forma or incidental vessel calls. In case of vessels of the same line only, this line may set its own priorities, provided that it does not impact the berth windows of other lines and terminal's normal work flow. PCT has the obligation to berth vessels that have arrived within their berthing windows, except if there are special circumstances or force majeure.

With regards to the vessel berthing appointment, feeder services that comply with specific conditions, may negotiate with PCT commercial department their berthing under rendezvous system. In these cases, the VO has to notify PCT for the upcoming appointment 5 days before the estimated time of arrival (ETA), 72 hours before ETA, 54 hours before ETA and 36 hours before ETA. The 36-hour notice is considered as conclusive and the VO cannot change the appointment afterwards. In case the vessel does not arrive on time, the appointment is lost. There is always one-shift allowance for both the vessel and PCT. All other feeder services that are not under rendezvous system, are served by PCT on a First come – First served basis.

The announcement of vessel's arrival and work application together with detailed call information has to be submitted to PCT berth planning by filing out and sending particular application forms. For all vessel calls, the VO has to proceed to the announcement of the arrival of the vessel at least 24 hours prior to the required berthing time via e-mail with the ANNEX I. Also, at least 16 hours prior to the required working time of the vessel, VO has to provide ANNEX II. In case of port congestion due to e.g. external incidents, delayed vessels etc., the availability of PCT berths may be restricted. In this case, the Berth Planning of PCT will consult the VO to discuss priority setting for the vessel calls. The detailed workflow of the berthing process is presented in Figure 1.

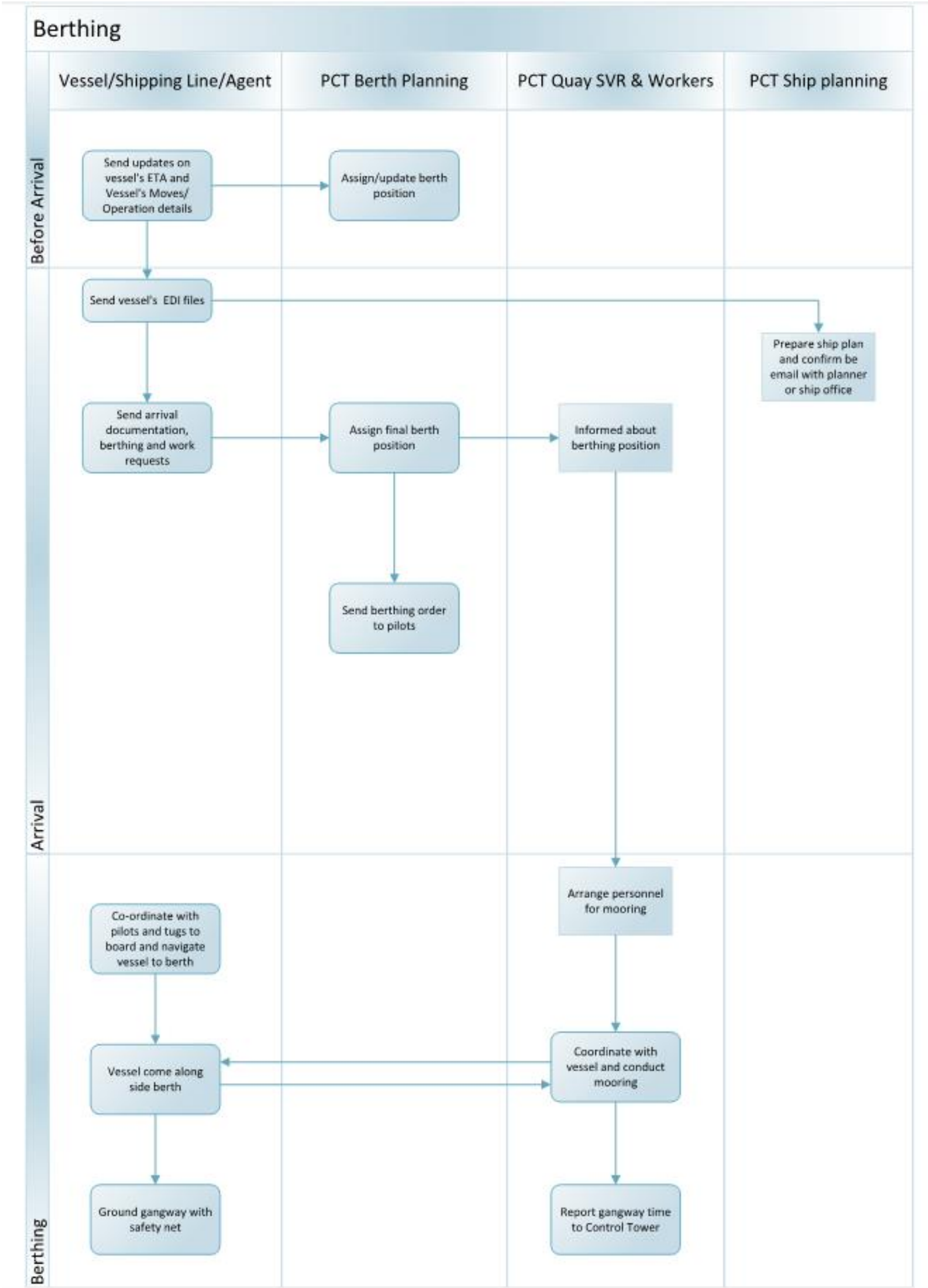

Figure 1. Vessel berthing process at Piraeus port

Position of calling vessels into PCT's berths is communicated to the pilot service by PCT 4 hours before berthing at the latest, via email. However, all other arrangements that may be required with the pilot service are responsibility of the vessel and the VO or their agent at Piraeus. The VO or the Shipping Line (SL) are responsible for any possible delays to vessel's berthing or departure that may be caused due to late embarkation of pilots, late preparation of formalities etc., and in this case, PCT reserves the right to claim remuneration for possible delays. The mooring and unmooring of vessels are conducted by PCT stevedores.

Regarding the unberthing of the vessels, the terminal operator informs the vessel or the agent about the completion time and confirms the completion of all moves, while the vessel communicates with the tugs. When the quay cranes are in safe position and the tugs are stand-by, the quay staff unmoors the vessel, the operator records the ATD and the tugs navigate the vessel to safe passage off port. Afterwards, the tugs disembark and the vessel departs, while the ship planning team prepares and sends the TDR (Figure 2).

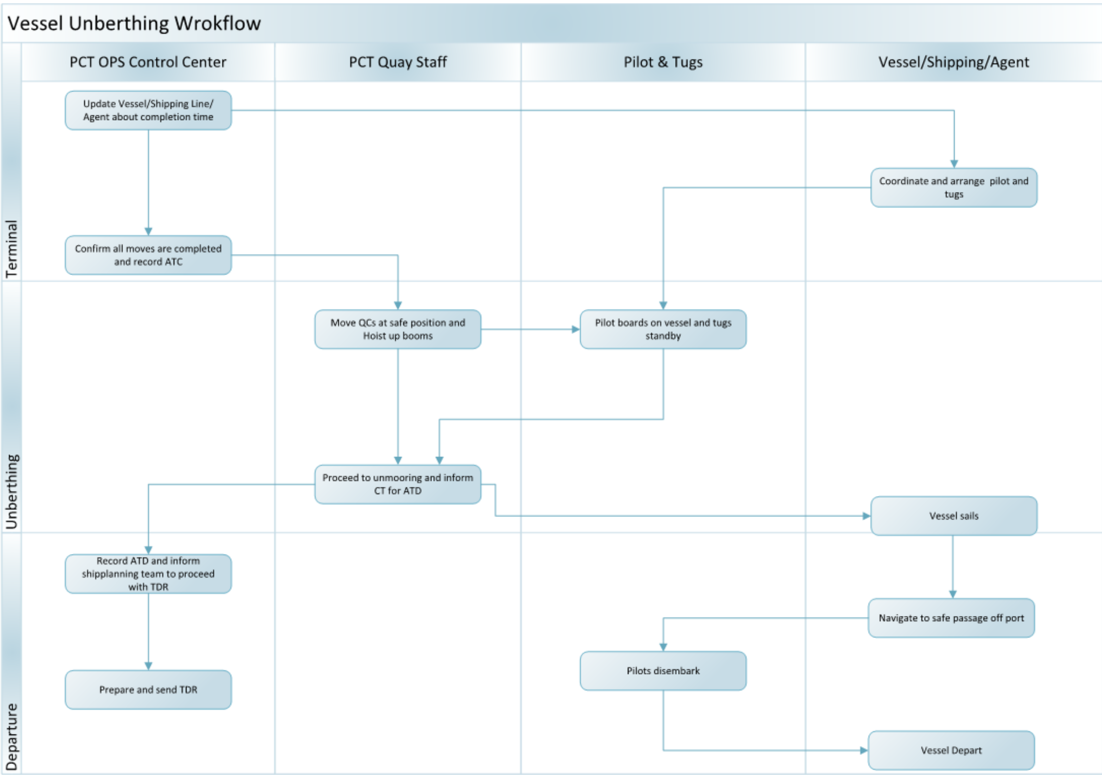

Figure 2. Vessel unberthing process at Piraeus port

Another important process that takes place in the port is the stevedoring process, during which cargo is discharged from and loaded to the vessel. With regards to the vessel discharge, the process is performed in two parts, the quay-side operations and the yards-side operations. The first part includes the provision of instructions about vessel bay from the control tower to the quay crane operator, who unleashes discharging containers on board the vessel. As the control tower activates the discharging job orders, the yard truck moves towards the vessel's discharging position at quay and the crane starts to discharge containers to the yard truck. Each container gets unpinned and its condition is verified by the tallyman. In case the container is damaged, the tallyman co-signs the CIR report with vessel's office and proceeds with the confirmation of container number to the terminal's TOS. During all these activities, the control tower monitors the quay-side operations. The second part takes place at the yard side, where the yard truck and yard crane receive the order and proceed to yard position, in order to stack the container. The yard crane verifies the container number and yard position for stacking, selects relevant job order and unload the container from yard truck to yard position. During all these activities, the control tower monitors the yard-side operations. This process is depicted in Figure 3.

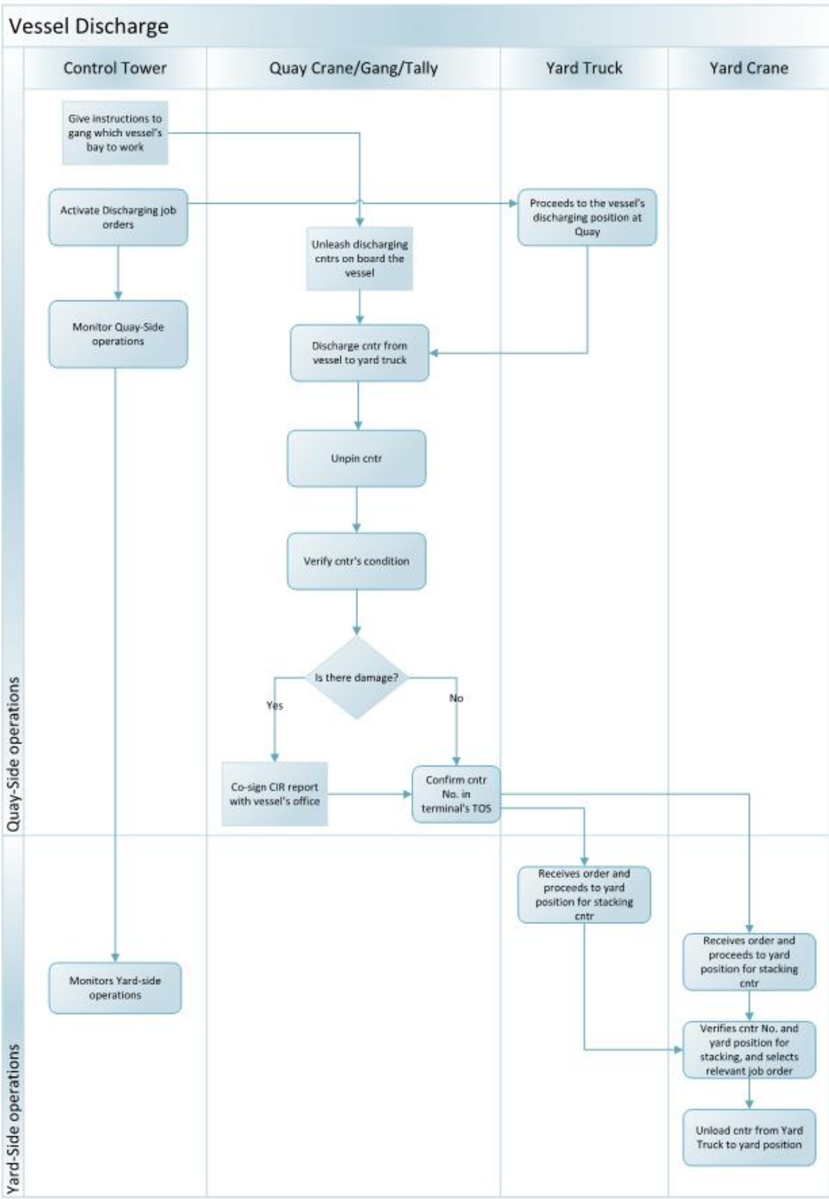

Figure 3. Vessel discharge process at Piraeus port

On the other hand, the loading of containers to the vessel follows a similar process but in reverse sequence and it is split in the yard-side and the quay-side operations. As in the discharge process, the control tower also initiates the loading process by activating the loading job orders, while the yard crane and the yard truck receive the order and proceed to the container position in the yard. In parallel, the quay crane receives the order and understands the loading request. Then, the yard crane checks whether yard shiftings are needed to uncover the loading container and if so, proceeds with the yards shiftings and then loads the container onto the yard truck. The latter proceeds to the vessel loading position at the quay, where the quay crane confirms the container number and loading position, pins the twist locks, loads it from the truck to the vessel and secures the container on board. The control tower monitors both yard-side and quay-side operations. The process is presented in Figure 4.

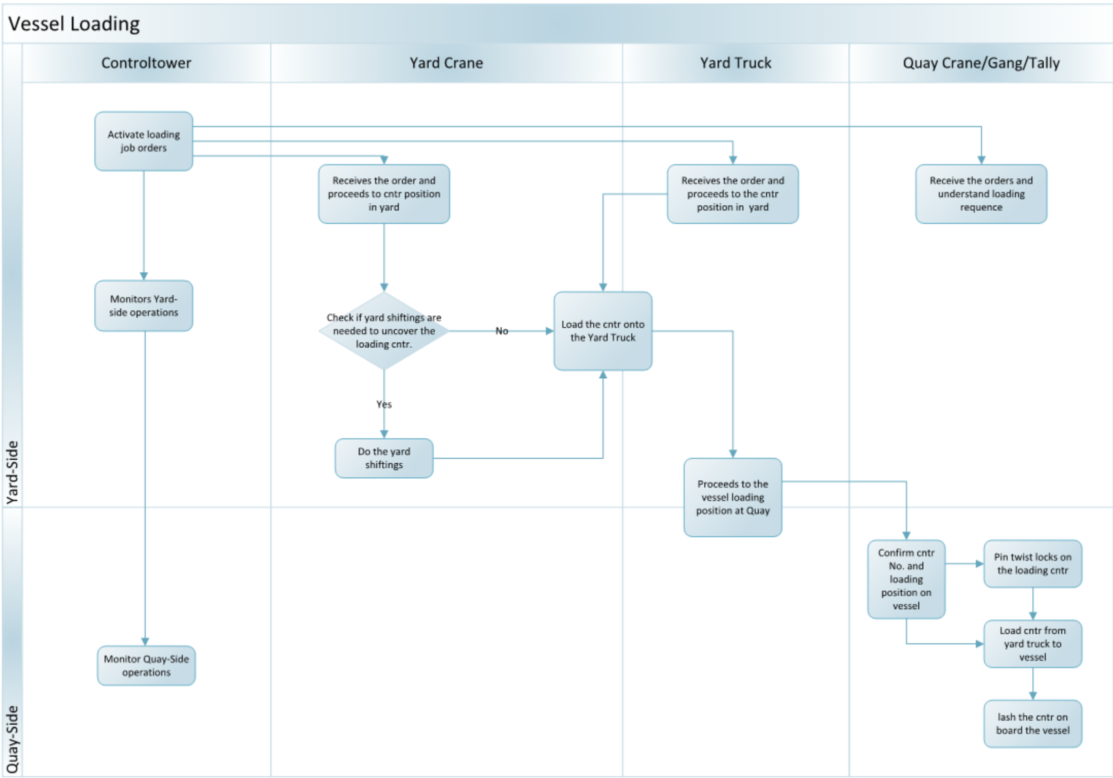

Figure 4. Vessel loading process at Piraeus port

2.2 Port of Valencia

The port call process is the port-ship interface where several agents, both from the ship and the port perspectives, cooperate and exchange relevant information under different means and formats. The port call process can be divided into two sub-processes:

1. Port Call Request, depicted in Figure 5**Error! Reference source not found.**.
2. Port Call Execution, depicted in Figure 6**Error! Reference source not found.**.

Sub-process 1 takes place prior to the ship arrival and comprise important formalities and exchange of information among national authorities and the shipping company / ship agent aiming at calling at a certain port. Sub-process 2 comprises the operative execution of the port call once all the corresponding authorisations have been approved prior to the ship arrival. Depending on the port's governance model, different barriers may manifest or influence both processes. The port call request involves the following agents:

- Ship Agent
- Port Authority
- Maritime National Authority
- Port National Authority

Figure 5 shows the information flows established by the aforementioned agents when managing a port call request according to the guidelines established by the Convention on Facilitation of International Maritime Traffic. This diagram shows a generalised version of this sub-process, which may vary depending on the world region and national / local regulations.

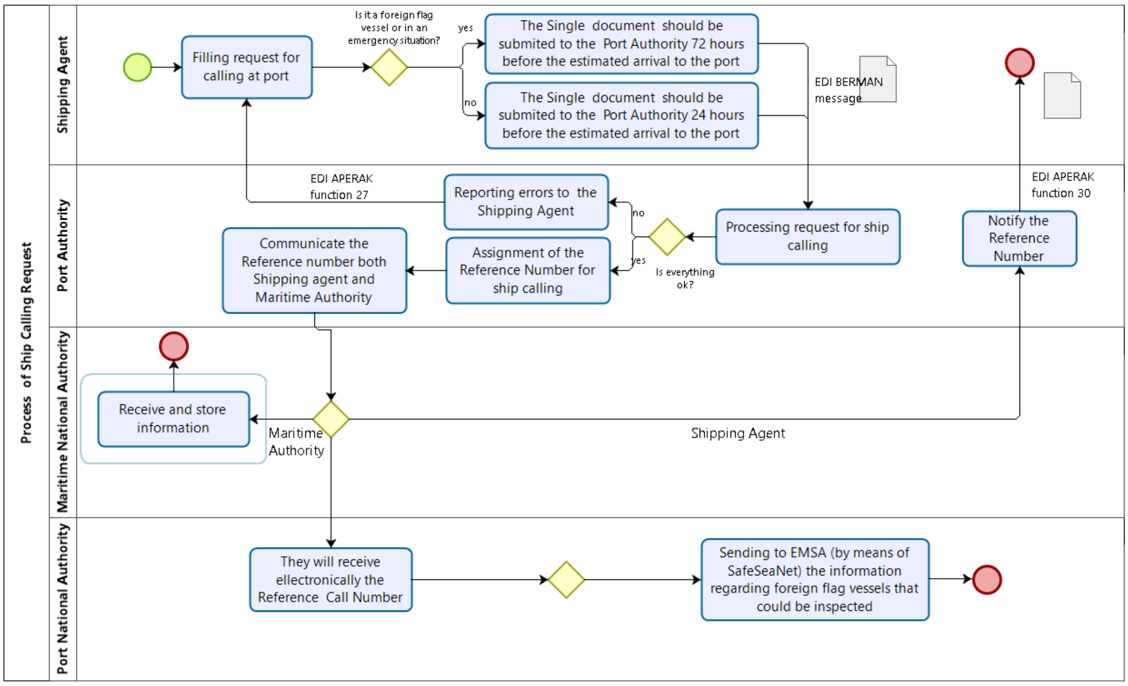

Figure 5. Port Call Request Flow Process (Source: Fundación Valenciaport)

This sub-process starts with the request by the shipping agent of a port call to the corresponding port authority. This request can be made electronically through a Port Community System or similar port information-exchange system or by other means (e-mail, fax, paper format).

If the request is made by electronic means, the information exchange between the shipping agent and the port authority takes place by means of the standardised EDI messages BERMAN (Berth Management Message) and APERAK (Application Error and Acknowledgement Message).

The Berth Management Message follows the UN/EDIFACT[1] standards and is a message from a carrier, its agent or means of transport to the authority responsible for port and waterway management, requesting a berth, giving details of the call, ship, berth requirements and expected operations. The BERMAN message is used in Electronic Data Interchange (EDI). The Berth Management Message may be used for both national and international applications. It is based on universal practice related to administration, commerce and transport, and is not dependent on the type of business or industry.

If the port call request is correct, the Port Authority informs both the shipping agent and the corresponding Maritime National Authority about the port-call reference number assigned to the port call request. The Port Call Execution corresponds to the

[1] United Nations/Electronic Data Interchange for Administration, Commerce and Transport UN/EDIFACT is the international EDI standard developed under the United Nations.

operative process of facilitating approach, berthing and departure of ships at ports. Figure 6 shows a generalised port call process, where the agents involved are provided.

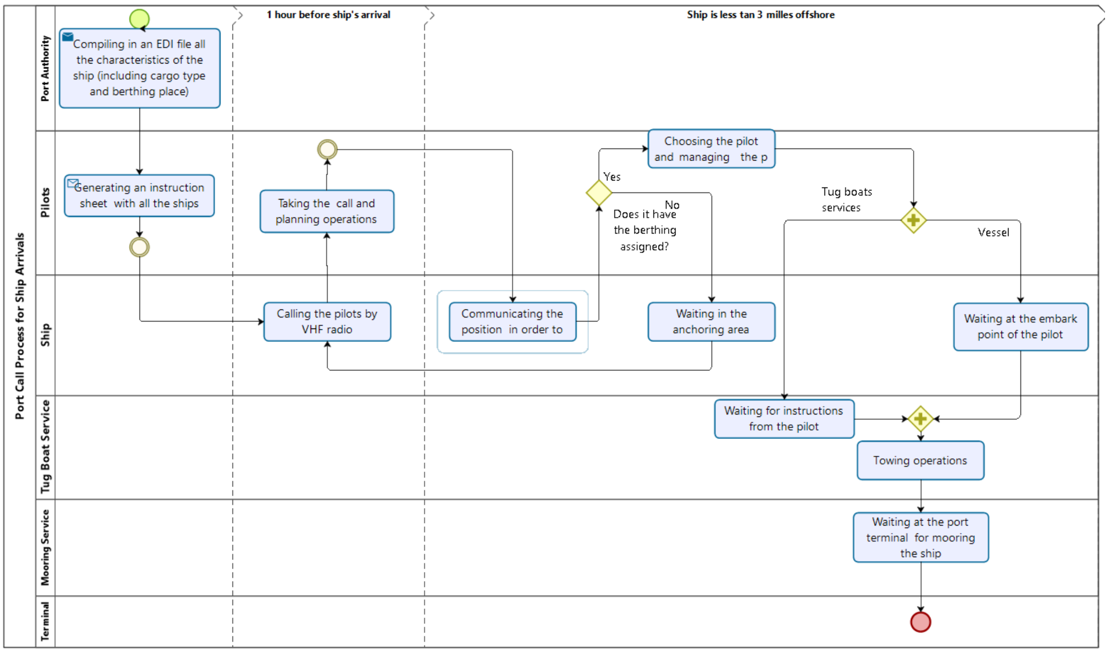

Figure 6. Port Call Execution Flow Process (Source: Fundación Valenciaport)

The port authority plays the role of port call coordinator in most ports regardless of the port governance model (service, tool, landlord or private).

Today, the landlord port is the dominant port model in larger and medium-sized ports, although service and tool port models are still in place in developing countries. Under the landlord port-governance model, the port authority usually lease the nautical services defined as pilotage, towage and mooring to specialised companies or corporations. This scheme is widely adopted in developed countries.

Assuming the landlord port governance model as the most extended in the sector, the port call process usually starts with a planning task of the port authority taking as a reference the current situation of the port (number and location of ships berthed at present) and the foreseen situation within the next hours (scheduled Estimated Time of Arrivals and Departures). This task is repeated under an iterative cycle and is adapted according to the operative reality of the port.

Within this process, the port authority establishes coordination for the next iterative cycle (e.g. next 24 hours) with the nautical service providers, who are the agents in charge of executing the berthing and departure operations of ships. In this respect, when a ship enters the approaching area of a port and has berth authorisation (e.g. one hour before arrival), she establishes contact via radio VHF with the port, usually being the pilots organisation the first agent contacted. Pilots usually monitor the approaching of the ship and give instructions according to the current and expected situation at port. Examples of these instructions are:

- Increase speed to arrive early to the pilot boarding area, since a berth slot will be released earlier than expected.
- Reduce speed to arrive lately to the pilot boarding area, since a berth slot will be released later than expected.
- Sail towards the anchorage area due to different reasons: port congestion, ship technical constraints, prioritisation of traffics (e.g. passenger ships), etc.

If the port has a slot berth available for a certain ship, pilots start coordination with the tug boats company and mooring companies in order to organise the port call operations: number of tug boats required, type of manoeuvring, berth allocation, etc. In parallel, communication with the ship takes place in order to start the pilot boarding at the agreed boarding area. All the aforementioned communications take place via radio under the same VHF Channel (commonly known as Port Control channel).

The type and complexity of operations involved in port calls can vary significantly from one port to another, ranging from less than one hour of port call and berthing operations (open seaports) to several hours (river ports), especially in ports which require channel navigation until reaching the cargo terminal.

Once the ship is moored at the berth, the port call process is finished from the operative perspective. Then the cargo handling process starts with loading and unloading operations (container, bulks, ro-ro, passengers, etc.). The departure process can be described as a mirror of the port call process, since the last event of the port call process is the first action of the departure process.

2.3 Port of Mykonos

The Port of Mykonos is different than the other two MOSES ports both in size and functionality. It is mainly a passenger port hosting cruise vessels and ferries carrying both passengers and cargo in the form of either containers on trailers or palletized/bulk cargo on trucks or trailers.

The Port of Mykonos follows the same legal framework as the Port of Piraeus and thus the berthing process is identical to that of the Port of Piraeus represented in Figure 1. There are modifications in local operations related to different cargo types during the high tourist season (June-September) when the port is flooded by passenger traffic consisting of cruise vessels, ferries and private yachts, sailing boats and speed boats. Bulk cargo consisting of building materials (i.e. sand, cement) are only discharged at Ramp 6 of the port throughout the year except the period of 7 days prior and after the Greek Easter and the period between the 1st of June and the 30th of September. During the months that discharging of such materials is allowed, this type of cargo is not allowed to be stored at the port premises and has to move to the inland upon discharge. Figure 7 shows the cargo unloading process followed by the Port of Mykonos.

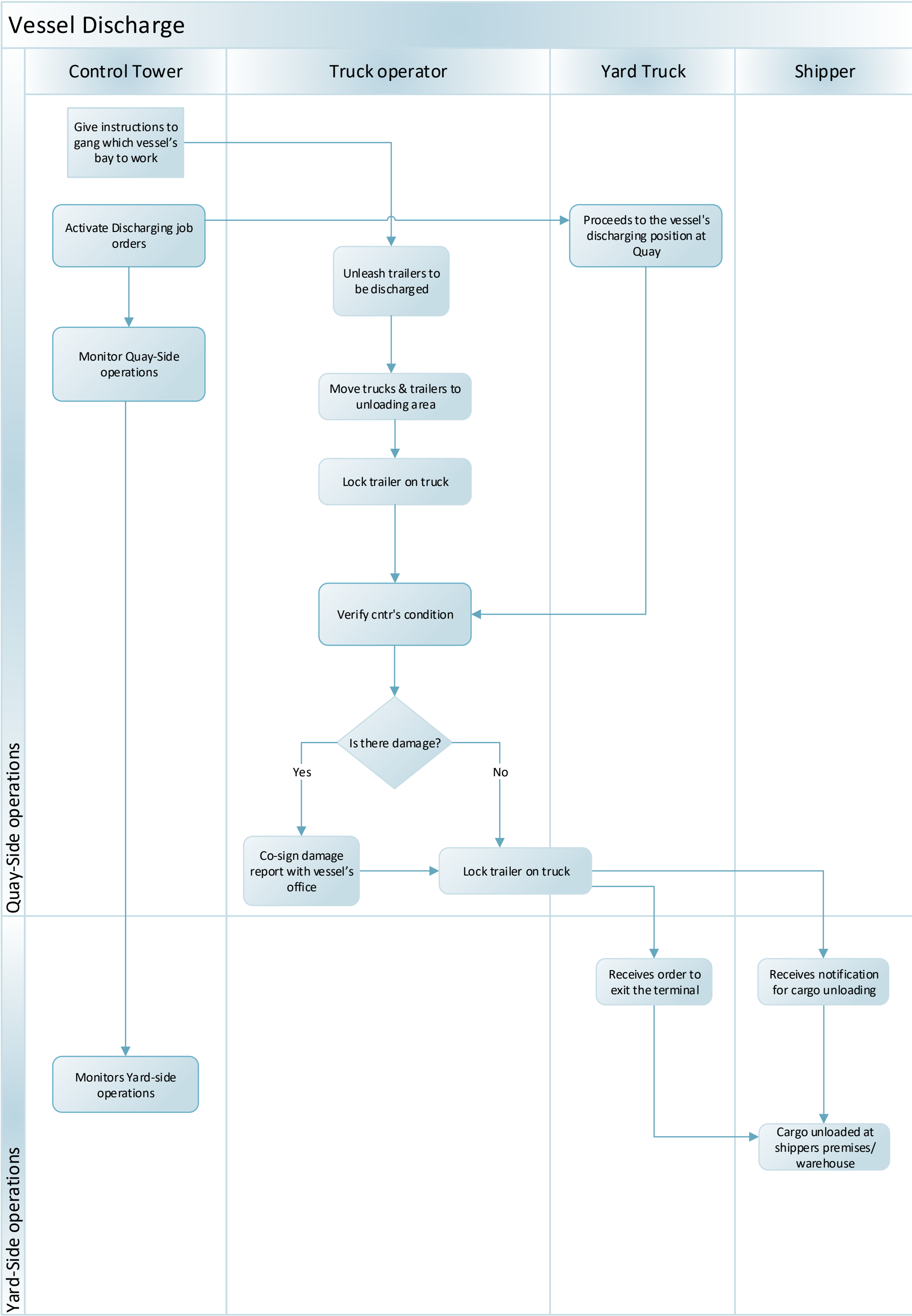

Figure 7: Port of Mykonos cargo unloading process

3. To-Be Call Process

3.1 MOSES Innovations involved in call process

3.1.1 Innovative Feeder Vessel

MOSES develops three different designs for the innovative feeder that are fit for purpose for the requirements of the MOSES business cases. 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, as described in deliverable D3.1, 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 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 configuration, 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 also be 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.

3.1.2 Robotic Container Handling System

The MOSES Robotic Container Handling System is an autonomous crane that will operate during vessel calls at ports that are lacking the necessary infrastructure for loading and discharging containerized cargo. The core of the proposed robotic container handling system will be the MacGregor GLE crane outfitted with an active rotation control swivel and a Bromma spreader. Also, the crane and the spreader will be outfitted with an advanced sensor suite enabling 3D image creation, to detect obstacles, possible unsafe situations as well for positioning the spreader relative to the container or a container stack, based on computer vision and object recognition algorithms. The created world model serves as input for the container handling process and provides the necessary situation awareness concerning the location of the container relative to the ship, object avoidance, the container ID, the position of the doors, and other relevant operational features. Optimization strategies will enable the system to perform optimal real-time path planning in dynamic and unknown environments and to maintain safety at the desired level.

The proposed operational concept also includes a human operator supervising the container handling. The operator is remote and works from a Shore Control Station (SCS). Besides performing test procedures and assessing safety critical situations, the function of the operator is to supervise the operations and to intervene when issues occur that are beyond the autonomous control scope of the crane itself e.g., the crane cannot move a truck standing in the way. This kind of situations can only be solved through direct communication with local port authorities, for instance a harbour master. For this, the remote operator needs to be able to understand the local situation and must be able to judge upon appropriate interventions. This example makes clear, that the overall operational safety and performance of the robotic container handling system depends on the collaboration between the (autonomous) robotic crane and the remote operator. The operator situation awareness concerning the container handling operation and local circumstances is build-up using visual information and other data sources. So, the sensor-based world model does not only feed the robotic crane but also provides the SCC the necessary visual information.

The expectation is that several operators will supervise several feeder vessels each and, therefore, several container handling operations (for cost effectiveness). A software component based on Artificial Intelligence (AI) will support all operators present. This entails assigning container handling operations to operators, monitoring the progress of each, and support the situation awareness. This AI component's role is to facilitate the human-robot collaboration between operator and the robotic crane. It receives all data from the crane if bandwidth permits and performs a continuous risk assessment and performance estimation. Furthermore, this AI component will relay any information requests or control signals to the robotic crane.

3.1.3 AutoDock (Autonomous Tugboats and AutoMoor)

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, as addressed in deliverable D5.1, 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. 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.

3.1.4 MOSES Recharging Station

MOSES aims to significantly enhance the SSS component of the European container supply chain by addressing the vulnerabilities and strains that relate to the operation of large containerships. For stimulating the use of SSS feeder services to small ports (hub and spoke traffic) that have limited or no infrastructure, MOSES project has developed container feeders specifically designed for meeting the requirements of Spanish and Greek business cases as defined in deliverable D2.3.

Based on the route and the current cargo volumes, deliverable D3.1 concluded that, for the Greek case, it is technically possible to design a hybrid powered solution, consisting of a methanol fueled ICE in combination with a battery, which enables partly zero emission operation of the feeder vessel. For the Spanish case both a methanol hybrid powered solution and a battery electric solution were found to be feasible from a technical and operational point of view.

The MOSES project conceptually designed and conducted a technical feasibility and life-cycle cost study for an automated shore side station fully integrated in the port energy management system, which will be used for powering the MOSES innovative feeders and tugboats while berthed. The work conducted within MOSES addressed design needs and operational constraints of the port infrastructure and ship-to-shore interface. The aim of MOSES is to provide a charging system, instead of just a power supply, which meets the operational requirement of vessels in terms of berthing time and autonomy.

Considering the operational profile of container feeder vessels and tugboats, and the SoA of the recharging technologies in the market or under development, MOSES analyzed and compared the following technologies:

- Hybrid propulsion configuration charging the batteries on board while sailing by using a shaft generator.
- Battery-buffered transfer configuration where the incoming grid power is transformed to a lower voltage and used to charge a terminal battery bank, which is subsequently used to charge the vessel. Power from the batteries may be supplemented with grid power, as requested, when the vessel is connected to shore power.
- Charging the batteries through an inductive wireless power transfer to allow fully automated operations.

- Batteries swapping using a crane.

The aim is to achieve full charging of electric powered vessels during the vessel call at the port or during idle times of the tugboats.

3.1.5 MOSES Logistics 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

3.2 To-Be call process concept

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 Gandía. 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 Gandía 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 Gandía, 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.

MOSES innovations do not seek to alter the current legal and regulatory framework of vessel calls in various ports but rather to automate and improve the efficiency of current operations and improve the overall environmental footprint of ports. Thus, all the documentation and time constraints for delivering information and regulations regarding arrival times and delays will remain unchanged from the AS-IS processes described in Chapter 2 of this document. However, it does affect the legal framework for loading unloading operations with the introduction of the Robotic Arm.

Whereas, 20 years ago, industrial robots were almost solely used for high volume manufacturing, today can be used for manufacturing, logistics, rehabilitation, or even agricultural applications. The use of MOSES robotic arm can lead to uncertainty with respect to safety and applicable standards, especially due to the domain-specific organization of international safety standards, through two specific ways. On the one hand, in situations where innovations occur faster than standardization, there are not always relevant domain specific standards for the application in question. On the other hand, combinations of device types can lead to conflicting issues from different safety standards. The forces specified during contact are different when considering an industrial manipulator (in the ISO/TS 15066) or an autonomous truck (ISO 3691-4). Further challenges arise when considering what separation distances to apply, as the ISO/TS15066 also specifies that the approach speed of humans needs to be taken into account, whereas the ISO 3691-4 does not. While adherence to standards is not legally binding, they do represent the state of the art and can be extremely helpful for considering the safety of collaborative robotics applications. A streamlined approach that offers robotics stakeholders the means to conceptually talk about the safety of their system, regardless of the specific domain, would be helpful here. Furthermore, it would be extremely helpful to the robotics community if the same approach were to extend to methods for validating the implemented risk reduction measures.

MOSES Innovations come into play with the arrival of a vessel within the area of interest of each port (Figure 8). The vessel's captain or an authorized representative of the shipping line will have access to the Shore Control Station module that shows the availability of tugboats. Upon selection of the number and type of tugboats required to maneuver the vessel to the docking place, the port authority, the coastal guard, the tugboat operator, the vessel operator, the vessel captain and the shipping agent will be notified about the initiation of the berthing process. The trajectory of the approach of the vessel to the docking place will be calculated and presented at the relative module of the Shore Control Station. MOSES automated tugboats swarm will be dispatched to meet the vessel at a set rendezvous point. Tugboats will lead the vessel to the docking place following the predetermined trajectory. In case there is deviation from the predefined trajectory that exceeds a pre-set limit, a warning message will be dispatched to involved parties and the tugboat operator will be given options to switch to remote control operation or even switch to manual operation. Situational awareness will be provided at all times using the sensor network and cameras on board the tugboat.

The tugboat maneuvering process will continue so that it can lead the vessel in a position parallel to the docking place, with zero speed and at most six meters away from the auto-docking system. When these conditions are met, the autodocking system will take over and try to dock the vessel safely. Upon safe docking, the autodocking system will alert the tugboats via the SCS to disengage.

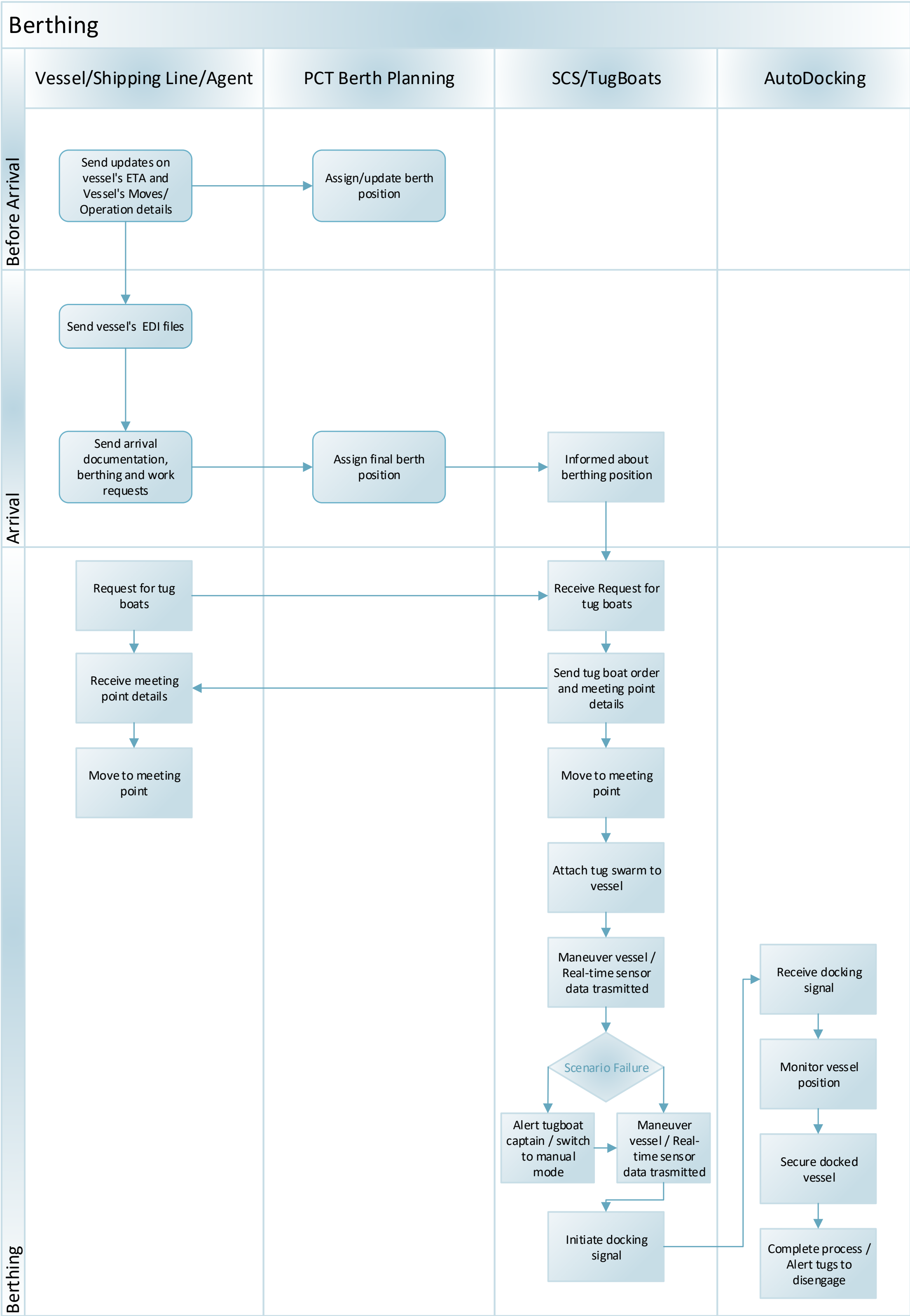

Figure 8: MOSES berthing process

Upon successful docking of the vessel, all relative parties will be notified and the stevedorage process will be initiated. Ports with automated or manual infrastructure to handle container loading/discharging will have the option of using their own equipment or the MOSES robotic arm. Ports that are lacking this infrastructure, will have to rely on the MOSES Robotic Container Handling System.

The onboard robotic crane is designed to operate autonomously, thus it does not need an onsite or an onboard crane driver, nor a safety officer on deck. The camera's, mounted on the robotic crane, are able to detect obstacles and possible unsafe situations, based on an accurate 3D-world model of the local situation and object recognition algorithms. The created and maintained world model also provides the robotic crane with the necessary location coordinates, distance to objects, container ID, the position of the doors, and other relevant operational directives. The container optimizing algorithm provides real-time crane sequence planning to optimize the efficiency of the (off)loading.

Despite the high level of self-sufficiency of the robotic crane, the loading and offloading process is supervised by a remote operator using the Shore Control Station located at a remote location. Remote supervisory control is necessary because during the operation it might be inferred that safety is compromised due to unauthorized people or vehicles (e.g. a bystander) within the offloading area. The remote operator will have access to communication with which to contact the local port authority and ask to take action to direct the object out of the way. As soon as the last container has been put on board, the robotic crane resets to its seagoing position and the feeder vessel leaves port and heads towards its next destination.

Upon completion of the stevedorage operations, all involved parties are notified and the unberthing process initiates. The autodocking system unlocks the vessel which will either sail with its own means or following the same process for booking tugboats as the berthing process.

Discharged cargo owners or authorized logistics service providers will be able to make use of the MOSES Logistics Matchmaking Platform to move their cargoes either to the hinterland or to a vessel to continue to their final destination.

In the case of electric powered vessels, connection of the vessel with the On-Shore Power Supply will be required. In general, the sequence for connecting a vessel to shore power starts upon completion of the autodocking process with the connection of the required power and control cables and the last running engine is synchronized with the landside power grid. After the shore connection circuit breaker is closed, the generator is offloaded, and the engine is stopped. Before the vessel departs, the first engine is restarted and synchronized with the onshore power grid. Once the load has been transferred to the generator, the shore connection reopens, power and control cables are disconnected, and the vessel is ready for departure.

4. Conclusions

This document has described the current vessel call process in the MOSES ports by using workflow diagrams that provide details of the steps that need to be followed to enable the berthing of a container vessel in a container terminal. MOSES applications related to vessel calls have been described along with the relative MOSES business cases.

The documentation of the current process and the description of MOSES applications related to these processes have enabled the description of the TO-BE process that will be followed once MOSES innovations have been adopted.

Adopting MOSES Innovations during container vessel berthing can provide several benefits, including:

- **Increased efficiency**: Automation can streamline the berthing process by reducing the time it takes for the vessel to dock, unload and load containers, and depart. This can help improve the overall productivity of the port and reduce waiting times for other vessels.
- **Improved safety**: Berthing a large container vessel and carrying out stevedoring activities can be a complex and hazardous operation, involving multiple vessels, tugs, and personnel. Automation can help reduce the risk of accidents and injuries by allowing vessels to be guided and maneuvered with greater precision and control.
- **Reduced costs**: Automating the berthing process can help reduce labor costs, as fewer personnel may be needed to guide the vessel and handle containers. Additionally, automation can help reduce maintenance costs by minimizing wear and tear on equipment and infrastructure.
- **Increased capacity**: Automation can help increase the capacity of a port by allowing vessels to be docked and unloaded more quickly, allowing more vessels to be serviced in a given time period.
- **Improved environmental performance**: Automated berthing systems can help reduce emissions and noise pollution by enabling vessels to dock and depart more quickly, reducing the time they spend idling in port or at anchorage waiting to enter the port.

Overall, the adoption of automation during container vessel berthing can help ports and shipping companies operate more efficiently, safely, and sustainably.