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D2.2 – SEAMLESS REFERENCE LOGISTICS ARCHITECTURE, STANDARDS, AND SIMPLIFIED ADMINISTRATIONAL PROCEDURES

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EXECUTIVE SUMMARY

Documenting the finding of the tasks T2.3 and T2.4 of the SEAMLESS research project, this report presents the SEAMLESS Reference Logistics System Architecture and the simplification potential of complex administrational procedures in the planning and execution processes of a multimodal transport chain using autonomous vessels.

Originating from a detailed analysis of the current practices and processes both in short-sea shipping and inland waterway transport within a holistic “cargo story” from origin to destination, a consistent and coherent reference process architecture in its current form has been developed and analysed. Thereby, a proper understanding of the underlying logistics system architecture including its logistics process flows, the actors and stakeholders involved in it, the communication and interactions patterns, and the systems used has been developed before applying prospective technical innovations from the SEAMLESS research project to the case. As a results, a plethora of activity and sequence diagrams document the details of each process phase, individual processes, and selected sub-process steps.

Increased transparency on process implications of automation technology allows stakeholders to better evaluate the compatibility with its current process organization. Therefore, the changes have been identified by consulting the SEAMLESS research consortium working on the different SEAMLESS innovations and their utilisation in a (hybrid) Logistics Redesign workshop. The pertaining analysis yielded some key findings: process change induced by technological innovation, new supervisory roles of the staff replacing operational tasks, and a shift to more systems and less persons involved were the four key categories of expected change. Apart from these generic changes from automation, a series of changes specifically related to the SEAMLESS research project and the cases examined therein came to light.

Next, the precise definition of the modus operandi of each SEAMLESS innovation in terms of logistics process flow has been collected with the help of (online and on-site) workshops with the heads of the development teams and regular iterations with the development teams. In this way, a clearer understanding of the SEAMLESS innovations, its functional scope, and its im-pact on system and process architecture including the process change induced by each of them is provided.

Eventually, the individual processes of the SEAMLESS innovations were then integrated into the original cargo story of a door-to-door transport process from the consignor (origin) to the consignee (destination) via multiple transport legs using various transport modes. Thereby, the SEAMLESS Reference Logistics System Architecture – with its logistics process flows, its actors and stakeholders involved, its business information systems and communication means used, and the communication and interaction patterns between them – has been developed and is available as a base for the subsequent development and analysis work streams. Derived from the new system architecture, the simplification potential of administrational procedures has been determined.

REFERENCES TO THIS DOCUMENT – ACKNOWLEDGEMENTS

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ACHS	Autonomous Cargo Handling System
ADN	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
ADR	European Agreement concerning the International Carriage of Dangerous Goods by Road
AIS	Automatic Identification System
APERAK	Application Error and Acknowledgement Message
API	Application Programming Interface
APICS	Antwerp Port Information and Control System
AVSPM	Autonomous Vessels' Smart Port Manager
B/L	Bill of Lading
B2B	Business-to-Business
BERMAN	Berth Management
BICS	Binnenvaart Informatie & Communicatie Systeem, Barge Information and Communication System
BPML	Business Process Management Lifecycle
BPMN	Business Process Modelling Notation
BPR	Business Process Reengineering
BRM	Bridge Resource Management
CC	Centralised Clearance
CCNR	Central Commission for the Navigation of the Rhine
CEERIS	Central and Eastern European Reporting Information System
CESNI	European Committee for drawing up Standards in the field of Inland Navigation
CFR	Cost and Freight
CHE	Cargo Handling Equipment
CIF	Cost Insurance Freight
CII	Carbon Intensity Indicator
CIM	Uniform Rules concerning the Contract of International Carriage of Goods by Rail
CMNI	Budapest Convention on the Contract for the Carriage of Goods by Inland Waterway
CMR	Contract for Carriage of Goods by Road
CSW-CERTEX	Customs Single Window Certificates Exchange System
DA	Delegated Act
DAVID	Danube Navigation Standard
DCS	Data Collection System
DCSA	Digital Container Shipping Association
DDP	Delivered Duty Paid
DNL	Do Not Load
DNV	Det Norske Veritas
DUC	Demonstration Use Case
eBL	electronic Bill Of Lading
ECDIS	Electronic Chart Displays
eCMR	electronic Consignment Note
EDI	Electronic Data Interchange
EEA	European Economic Area
EFTA	European Free Trade Association
eFTI	electronic Freight Transport Information
EMPA	European Maritime Pilots Association
EMSA	European Maritime Safety Agency
EMSWe	European Maritime Single Window environment
ENC	Electronic Navigational Charts
ENIGMA	Electronic Network for Information in the Ghent Maritime Area
ENS	Entry Summary Declaration, Entry Summary Notification
EPI	Environmental Port Index

ERI	Electronic Reporting International
eRIBa	electronic Reporting for Inland Barges, Electronic Reporting for Inland Barges
ERINOT	ERI notification message
ERP	Enterprise Resource Planning
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
EU	European Union
EUCU	European Union Customs Union
EXS	Exit Summary Notification
FAL	Convention on Facilitation of International Maritime Traffic, Facilitation Committee
FAS	Free Alongside Ship
FEPORT	Federation of European Private Port Companies and Terminals
FIATA	International Federation of Freight Forwarders Associations
FOB	Free On Board
FTTE	Faculty of Transport and Traffic Engineering of the University of Belgrade
GEF	Global Environment Facility
GHG	Greenhouse-Gases
GIA	Global Industry Alliance
GISIS	Global Integrated Shipping Information System
GNC	Guidance, Navigation, and Control
GPS	Global Positioning System
HVCC	Hamburg Vessel Coordination Center
IA	Implementing Act
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICS2	Import Control System
ICT	Information and Communications Technologies
IFTDGN	International Forwarding and Transport Dangerous Goods Notification
IFTSAI	Forwarding and transport schedule and availability information
IMO	International Maritime Organization
Incoterms	International Commercial Terms
ISL	Institute of Shipping Economics and Logistics
ISPS	International Ship and Port Facility Security Code
ISSC	International Ship Security Certificate
IWMS	Inland Waterway Management System
IWT	Inland Waterway Transport
JSON	JavaScript Object Notation
KPIs	Key Performance Indicators
LEG	Legal Committee
LSP	Logistics Service Provider
MARSEC	Maritime Security Level
MASS	Maritime Autonomous Surface Ships
MMSI	Maritime Mobile Service Identity
MRO	Maintenance, Repair, and Overhaul
MRV	Monitoring, Reporting and Verification
MS	Member States
MSC	Maritime Safety Committee
NaMIB	Nachfolgeanwendung des bestehenden Melde- und Informationssystems für die Binnenschifffahrt
NCTS	New Computerised Transit System
NMC	Norwegian Maritime Code
NSW	National Single Window
NtS	Notices to Skippers
OCR	Optical Character Recognition
PAXLST	Public Authorities and Water Police
PCS	Port Community System
PEMA	Port Equipment Manufacturers Association

RAINWAT	Regional Arrangement on the Radiocommunication Service for Inland Waterways
RFI	Request for Information
RFID	Radio Frequency Identification
RFP	Request for Proposal
RFQ	Request for Quotation
RIS	River Information Services
ROC	Remote Operation Centre
RTLS	Real-Time Locating System
SEEMP	Ship Energy Efficiency Management Plan
SME	Small and Medium-sized Enterprises
SMGS	Agreement on International Freight Traffic by Rail
SOLAS	International Convention of Safety of Life at Sea
SSNN	SafeSeaNet Norway
SSS	Short-Sea Shipping
TIC4.0	Terminal Industry Committee 4.0, Terminal Industry Committee
TMS	Transport Management System
TOS	Terminal Operating System
UCC	Unions Customs Code
UN/EDIFACT	United Nations rules for Electronic Data Interchange for Administration, Commerce, and Transport, United Nations Directories for Electronic Data Interchange for Administration, Commerce and Transport
UNDP	United Nations Development Program
VCOP	Voyage and Container Optimisation Platform
VELI	Voyage En Ligne
VGM	Verified Gross Mass
VHF	Very High Frequency
VTS	Vessel Traffic Service
XML	Extensible Markup Language

1 INTRODUCTION

1.1 PROBLEM STATEMENT

The pursuit of increased sustainability is often cited as the main motivation for seeking higher levels of automation and autonomy in waterborne freight transport. This not only relates to the environmental sphere of shipping but also to the domains of social and economic sustainability (Purvis et al., 2019). From an environmental perspective, increasing levels of automation may serve as a catalyst to develop and implement greener propulsion technologies and, thus, reduce the GHG footprint of waterborne transportation. Social implications may be related to relieving shortage of labour, making jobs in waterborne transportation more interesting, or improving worker safety. To analyse the implications on the economic level, one must revisit automated and autonomous waterborne transport services as part of the greater picture: supply chains and pertaining logistics systems in which waterborne transportation may take a central role.

In order to create viable business cases, automation technologies must allow for at least the same logistics performance level or even help attain higher levels and/or stable or ideally more favourable cost conditions – and, thereby, comparative advantage. This implies that the highly automated transport services must be able to better address existing transport demands in terms of “costs, convenience, speed or reliability” (Rodrigue, 2024, p. 157). As waterborne transport is mostly dependent on additional transport legs and thus part of multimodal chains, the ability of a waterborne transport service to seamlessly integrate with other transport modes is another important characteristic in terms of competitiveness – particularly against unimodal road transportation.

These considerations are central to the SEAMLESS project, which not only strives to further develop technological automation capabilities but to showcase innovative ways to bring autonomous waterborne transportation concepts into practice. Therefore, the research and innovation project deploys two demonstration use cases, which are used to validate and verify the projects building blocks and logistical concepts. Geographically placed in Norway, one demonstration use case focuses on a short-sea shipping haulage which will be part of transportation flows to and from Central Europe. The other demonstration use case considers inland waterway transportation as part of the seaport hinterland transportation services between Antwerp, Belgium, and Duisburg, Germany, and Lille, Northern France, respectively. The detailed setup of these demonstration use cases can be accessed in deliverable D2.1 of the SEAMLESS project (Jungen et al., 2024).

In general, any technology-based optimization should be taken into account only after the process is clearly defined and well-understood. Regardless of its manual or automated character, optimizing a poor process or applying novel technologies to it is not reasonable. Therefore, a proper understanding of the underlying logistics system architecture including its logistics process flow, the actors and stakeholders involved in it, and the systems used are of utmost significance before applying prospective technical innovations to the case. The present work addresses the subsequent task T2.3[1] of defining a reference logistics system architecture which will be used for the careful integration of a series of technological innovations and is to result in the definition of a new (to-be) reference logistics system architecture involving the various SEAMLESS innovations. Based on the reference

[1] T2.3: Reference logistics system architecture and standards

logistics system architecture, the list of requirements from the logistics practice of the SEAMLESS innovations can be completed and considered for their further development. Furthermore, the present work addresses the task T2.4[2] of mapping existing administrative processes and their complex interdependencies.

Therefore, the SEAMLESS reference logistics system architecture refers to a holistic and coherent "cargo story" from origin, i. e., the consignor sending the consignment, to destination, i. e., the consignee receiving the consignment, which includes a multimodal transport chain with transport legs by land, sea or air (theoretically) and – in future – engages highly automated and autonomous technologies within the supply chain. Moreover, the reference system architecture includes potential for simplification of the administrational procedures surrounding the freight transport and analyses their impact on the reference logistics system architecture and the pertaining performance levels.

To conclude, this report aims to generalize current practices within these use cases in an inductive manner, to subsequently assess how the SEAMLESS building blocks are compatible with existing logistics practices and to identify the requirements and opportunities to induce a logistics system redesign.

1.2 Objectives

The present report includes the combined results of the analyses of the tasks T2.3 and T2.4 of the SEAMLESS project. Based on the findings of the preceding deliverable D2.1 and the details of the two demonstration use cases and six transferability use cases contained therein, a reference logistics system architecture was to be developed which acts a framework for the subsequent development work on the SEAMLESS building blocks and innovations.

More precisely, this report documents the logistics process flows before and after deployment of the SEAMLESS innovations, the communication and interaction patterns throughout the flows, the involved actors and stakeholders, and the business information systems (and automated units) used therein.

So, with the help of the SEAMLESS Reference Logistics System Architecture, a framework is created to describe any current logistics system architecture, including the SEAMLESS Demonstration Use Cases and the SEAMLESS Transferability Use Cases. Combined with the SEAMLESS innovations, different visions of future waterborne logistics, such as automated feeder loops along coastal areas and automated seaport hinterland transport in the hinterland of large European seaports, are to be developed.

In addition, a clearer understanding of the SEAMLESS innovations, its functional scope, and its impact on system and process architecture is provided as the process change induced by each of them is emphasised before eventually integrated into the future SEAMLESS Reference Logistics System

[2] T2.4: Simplification of complex administrational procedures

Architecture. In that sense, the report is to yield functional and institutional automation barriers, identify potential to simplify administrational procedures, and to streamline transport and logistics operations.

1.3 Link to other work streams

This report foots on the findings about the demonstration and transferability use cases worked out in task T2.1[3] and described in the deliverable D2.1. Particularly, the demonstration use cases are in the focus of the efforts of integrating the SEAMLESS innovations into existing logistics processes. Therefore, the present reports refer to the same demonstration use cases and presents a generic reference logistics system architecture which is able to accommodate both SEAMLESS Demonstration Use Cases.

Besides, the work in task T5.1[4] has yielded detailed descriptions of the SEAMLESS innovations as part of a baseline analysis. This report refers to the system and function descriptions of the pertaining deliverable D5.1. For each of the SEAMLESS innovations apart from ModalNET, the functional specifications and users have been determined and described. In the case of ModalNET, a use case view of its system architecture is provided - apart from a functional view, a process view, and a development view. All of this has been incorporated in the work documented in this report.

Another link is evident to task T2.5[5] which describes the technical functionality of the respective SEAMLESS innovations and their interaction in the context of the actual demonstrations of the two use cases. Whereas task T2.5 focuses on the functional and non-functional requirements of the SEAMLESS Building Blocks and their interaction within the considered process, task T2.3 focuses on the logistics process flow and pertaining communication and interaction patterns between different process participants. More precisely, the SEAMLESS Reference Logistics System Architecture and contains the logistics process and communication flows along a complete “cargo story”, i. e., the planning and execution of a door-to-door transport process from the consignor (origin) to the consignee (destination) via multiple transport legs using various transport modes. Within this cargo story, the context of operation of the SEAMLESS innovations within both demonstrators is situated. As both work streams ran in parallel over several months in which the respective teams have aligned regularly, the pertaining documents contain complementary information and avoid contradictory statements.

Moreover, the report is connected with the work in task T3.4[6] as the port processes for cargo handling and storage are to be optimised in the way that the SEAMLESS innovations are integrated seamlessly. Particularly, the interaction with the port assets and facilities is designed in such a way that a safe and efficient terminal operation is safeguarded. By aligning with the SEAMLESS Reference Logistics System Architecture, it is further ensured that the future logistics processes in the

3 SEAMLESS Use Cases
4 Specifications, systems architecture, and design
5 Concept of Operations and requirements for SEAMLESS Building Blocks
6 Concepts for automated port interfaces and intermodal cargo forwarding to the hinterland

terminals are streamlined and match with the processes in other terminals and the ones of adjacent transport legs.

Similarly, the SEAMLESS Reference Logistics System Architecture provides a framework for the work in task T3.5[7] in order to ensure safe and secure processes with the SEAMLESS innovations while interacting the existing port assets and facilities and complying with the requirements of the future logistics processes and interactions which again are provided in this report. Likewise, the work in task T4.3[8] can be supported by the SEAMLESS Reference Logistics System Architecture as it provides a base for a more general system approval approach footing on a typical application scenario.

Furthermore, the SEAMLESS Reference Logistics System Architecture represents a good base to measure the performance and beneficial impact of the SEAMLESS innovations. In that sense, the work conducted in task T6.1[9] and documented in the deliverable D6.1 can be combined with the results of this report. In order to measure the KPIs), specific points along the logistics process flow and particular interactions between any two systems can be monitored and scrutinized in order to collect and process the relevant performance indicators.

Similarly, the evaluation of the SEAMLESS Transferability Cases, which is the content of task T6.6[10], foots on the findings of the SEAMLESS Reference Logistics System Architecture as it is supposed to assess impact of the SEAMLESS innovations on the different cases. By identifying certain operating principles of a particular SEAMLESS innovation on a particular performance indicator, the evaluation of the various transferability cases can be streamlined and detailed according to the respective nature of the case. For instance, a transferability case with multiple stops of a vessel sees the elevated significance of (innovative) remote operation, stowage planning, cargo handling, and mooring whereas another transferability case with a multimodal transport chain requires a greater focus on ModalNET supervising the transport process and orchestrating the different parties involved.

Last but not all least, the tasks T7.3[11] and T7.4[12] are closely linked to the SEAMLESS Reference Logistics System Architecture because its underlying cargo story combines the two demonstration use cases in an abstract (and transferable and scalable) manner. The demonstrations represent excerpts from the holistic reference architecture and follow the same process flows and system interactions so that further developments in the two demonstration cases can be matched with the reference architecture. It is important to note though that the details of the technical interaction are not predetermined by the SEAMLESS Reference Logistics System Architecture.

Eventually, the SEAMLESS Reference Logistics System Architecture posts the operational framework and surrounding in which the SEAMLESS innovations are supposed to operate. This report may confirm already known requirements and induce new ones which the individual innovations

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[7] Operational safety and security assessment
[8] Simplification of risk-based approval procedures
[9] Identification and development of the Key Performance Indicators (KPIs)
[10] Evaluation of the SEAMLESS Transferability Cases
[11] Northern European Demo Case: Planning, Integration Activities, and Implementation
[12] Central European Demo Case: Planning, Integration Activities and Implementation

need to meet in order to perform effectively in the future logistics processes. Therefore, the report features a general link to the technical development work conducted in work packages 3, 4, and 5.

1.4 Scope acc. to SEAMLESS Logistics Model Taxonomy

Logistics encompasses not only the spatiotemporal transformation of goods through physical transportation and handling processes but also value-adding activities such as packaging, finishing or tracking shipments. In addition, the organizational and planning activities for the preparation and follow-up of the flow of goods are also relevant. These activities are oftentimes not provided by one single entity but by a network of various actors that are connected and interdependent among each other. For this reason, the term “logistics system” is used to highlight the complexity of relationships and activities.

A tool or concept to allow to analyse isolated or common cargo flows within the system, the concept of a “logistical chain” (or “logistics network”) is deployed. This model makes use of the SEAMLESS logistics model taxonomy (see Figure 1), a multi-dimensional taxonomy approach which has been proposed in SEAMLESS D2.1 and which builds on the Industry Blueprint by the Digital Container Shipping Association (DCSA).

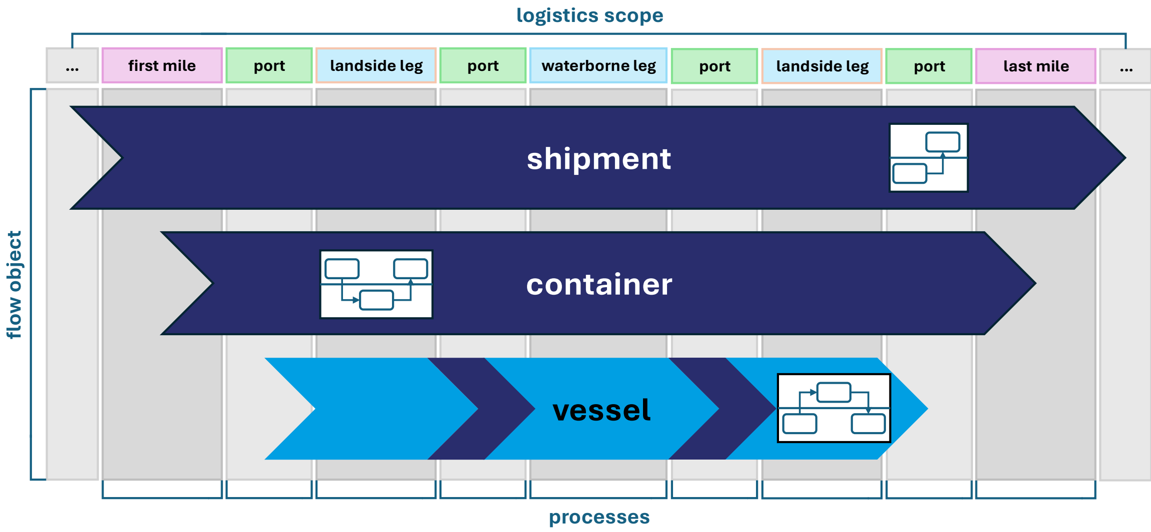


Figure 1. SEAMLESS logistics model taxonomy (Jungen et al., 2024)

The SEAMLESS logistics model taxonomy comprises three dimensions, i. e., the logistics scope, the flow object, and the processes.

The first dimension, the logistics scope, defines the part of the logistical chain considered in the respective case and can vary between an extensive end-to-end view of the entire logistical chain between consignor and consignee of a particular consignment and a focused consideration of a particular transport leg and its interfaces to the preceding and subsequent legs only. The second dimension refers to the flow object considered, i. e., the consignment, the loading equipment, or the transport vehicle used, for instance. In case of research and innovation projects centring around waterborne transportation, the flow object of interest is oftentimes the vessel. The third dimension considers the processes with the parties involved as well as the activities, the events, and the interactions, e. g., in the form of messages or artifacts. Naturally, the process level involves the flow objects and is embedded in the logistics scope defined earlier.

As part of the present report, the logistics scope of the SEAMLESS refers to the entire so-called “cargo story”, i. e., the planning and execution of the physical movement of a consignment sent from the consignor to the recipient, the consignee, including all logistics processes between the goods issue by the consignor over the various transport legs involved to the goods receipt by the consignee. This end-to-end consideration is significant for the later integration of the SEAMLESS innovations - and the evaluation of their impact on performance and cost at a later stage in the project. Despite the taxonomy facilitates flexible designs of the transport chains, the default transport case includes a first-mile transport leg from the consignor to a port, followed by a landside leg which may involve transportation via road, rail, or inland waterway, a waterborne leg in the form of a short-sea shipping transport leg or an intercontinental ocean carrier haulage, and another landside leg using road, rail, or inland waterway transportation, prior to a last-mile transport leg to the consignee eventually. Thereby, the two demonstration cases, consisting of a waterborne transport leg with a subsequent last-mile transport in the Northern European demonstration use case and – in the Central European demonstration use case – a waterborne transport leg combined with a landside transport leg using inland waterway transportation and a transport leg on the first mile in the export case and on the last mile in the import case, respectively, can be derived from the default design of the taxonomy.

Accordingly, the flow objects of interest primarily include the commissioned consignment, the transported containers, and the vessels and trucks moved. In the latter case, this refers to the short-sea vessels in the Northern European demonstration use case and the inland vessels in the Central European demonstration use case, respectively. Apart from the physical movement, the information flow is of pivotal importance in this dimension.

Ultimately, the processes considered as part of the definition and set-up of the SEAMLESS reference logistics system architecture do not confine to the ones related to the vessels but extend over the entire cargo story. Consequently, the numerous parties involved in the multiple stages of the end-to-end process, their activities, their interaction with one another, and the events throughout the course of the process need to be taken into account when defining and determining the processes within the SEAMLESS architecture. The process representation used in this deliverable is a simplified version of the Business Process Modelling Notation (BPMN) 2.0.

In essence, the SEAMLESS Logistics System Architecture foots on the process organization including parties involved, activities, events, and interaction among one another. By focusing on the logistics process flows, the respective roles and responsibilities of each party, the physical and digital systems and resources used, and the communication and interaction patterns with other parties of the logistical chain network, a holistic picture of the entire logistics system becomes visible. Particularly, the integration of the SEAMLESS innovations into the underlying logistics processes and the determination of the extent of change of the logistics processes induced by those innovations is a crucial part of the report as it may generate additional technical and non-technical requirements towards those innovations, impact the precise definition of both demonstration use cases, and provide the base for a profound evaluation of the impact of the SEAMLESS innovations by means of meaningful key performance indicators pre-defined in an earlier report[13] and their before-after comparison in the underlying reference processes.

However, neither the exact description of the technical interaction of the different systems involved (including their operators and addressees) nor the precise definition of the technical and non-technical requirements of the SEAMLESS innovations are not part of the consideration of this report but will be explicitly dealt with in a subsequent report[14]

1.5 Evolution of the Report

1.5.1 Course of action

For the collection of the work, the information from the SEAMLESS deliverable D2.1 formed the base and the starting point. Out of the synopsis of both the Demonstration Use Cases and the Transferability Use Cases, a first impression of the existing and available information on the logistics system architecture was gained.

After an initial alignment with the team working on T2.5 (led by SINTEF Ocean) and delineating the respective scopes of both tasks, the development leads of the SEAMLESS innovations (i. e., MacGregor Finland, AWAKE.AI, Kongsberg Maritime, Fundación ValenciaPort, and NTUA/ICCS) have been consulted in order to comprehend the functional scopes of the individual SEAMLESS innovations.

In the following, a holistic view of the waterborne logistics was developed which led to the decision that a generic reference logistics system architecture is required with which the multiple potential configurations can be represented and which can act as a blueprint for the respective system and process environment in which any individual SEAMLESS innovation needs to be integrated into. Hence, the reference logistics system architecture was composed of the details of the two SEAMLESS Demonstration Use Cases and complemented to a consistent door-to-door cargo story by closing the gaps between the two.

For that purpose, as much information as possible has been collected about the cargo story. While the information was abundantly available for SEAMLESS Demonstration Use Case 1 and documented in D2.1, the individual processes along the residual transport chain had to be collected in close cooperation with the fellow consortium members Duisburger Hafen AG, Terminal Industry Committee 4.0 (TIC4.0), Institute of Shipping Economics and Logistics (ISL), the Faculty of Transport and Traffic Engineering of the University of Belgrade (FTTE), and further consortium members engaged in the IWT sector. Particularly, the consultation of many stakeholders from the environment

[13] SEAMLESS deliverable D6.1 - Outlook on Key Performance Indicators for Use Cases
[14] SEAMLESS deliverable D2.3 - Concept of Operations and Requirements for SEAMLESS Building Blocks

of the Port of Duisburg has benefited the data collection and information mapping processes significantly so that a clear picture of the as-is situation could be developed. Both the process flows and the actors and systems involved have been collected diligently.

Next, the SEAMLESS innovations were to be analysed in terms of implications for the logistics process flow, the actors and stakeholders involved, the communication and interaction patterns, and the business information systems used. To commence that work stream, a (hybrid) Logistics Redesign workshop has been conducted in which all consortium members were asked about their expectations about each SEAMLESS innovation and its respective impact on logistics operations. This exercise was of importance in order to understand at an early stage whether any particular impacts are foreseen or even planned by the engineers and developers – apart from "typical" effects of automation, such as modified process flows due to new (technical) parties involved, new roles of operators (gradually shifting from operational tasks to supervisory tasks), more technical systems and less humans involved which may rise technical complexity in orchestration but lower exposition to danger but less influence. In addition, the workshop confronted the technical members of the SEAMLESS project team with the potential impact of their respective innovations on the pertaining logistics process flows, which possibly might have led to modifications and adaptations of the requirements.

With the collected information and the deep understanding of both the current logistics system architecture and the SEAMLESS innovations, the precise definition of the modus operandi of each SEAMLESS innovation in terms of logistics process flow was the next task. With the help of (online and on-site) workshops with the heads of the development teams (i. e., MacGregor Finland, AWAKE.AI, Kongsberg Maritime, and Fundación ValenciaPort) and regular iterations with the development teams, the typical logistics process flow and communication and interaction pattern has been worked out for each SEAMLESS innovation. These typical logistics process flows will also be used as a reference and explanation base as part of the performance evaluation in WP 6, particularly for the individual assessment of each SEAMLESS innovation and for before-after comparisons.

In the following, this knowledge on the innovation has been combined with the current logistics system architecture in order to define a future reference logistics system architecture that encompasses the two Demonstration Use Cases and employs all SEAMLESS innovations while remaining applicable to many other multimodal transport chain configurations including autonomous vessels. The logistics process flows and communication patterns of the SEAMLESS innovations have been integrated into future cargo story in order to build the SEAMLESS Reference Logistics System Architecture which is applicable to the two Demonstration Use Cases and further transport cases.

Eventually, the resulting SEAMLESS Reference Logistics System Architecture has been validated with the team leads of the two SEAMLESS Demonstration Use Cases (SINTEF Ocean, ZULU Associates), the technical development leads (e. g., Fundación ValenciaPort), and various interested stakeholders, such as VNF or Port of Antwerp-Bruges.

1.5.2 Structure of the report

After this introductory section in which the problem statement, the objectives of the work stream, and its link to other work streams and tasks of the SEAMLESS project have been presented and the scope of the analysis set, this report provides an understanding of the as-is situation with its institutional arrangements, its typical logistics process flows, the pertaining administrational procedures, and communication and interaction patterns in chapter 1.5. Also, the chapter provides basic terminology and concepts that will be used within the course of this deliverable and are required to fully understand the lines of argumentation.

In the subsequent chapter 2.5.2, the potential for change is determined as the individual SEAMLESS building blocks innovations are described in order to provide a clearer understanding of their functional scope and their respective modus operandi. Following that, the change induced by each of the innovation is considered from a process- and system-oriented perspective.

Chapter 3.3 provides a reference architecture of the future SEAMLESS logistics system incorporating the SEAMLESS innovations and providing new responsibilities, interactions and process flows resulting from their deployment. The reference architecture is also tailored to the SEAMLESS Demonstration Use Cases in order to provide a clearer vision of a to-be process to be achieved.

Apart from the findings of the preceding analyses, some research gaps as potential aspects of future research have been identified in chapter 5. Eventually, the results are revisited in the in light of the upcoming activities within the SEAMLESS research project and beyond before summarising the finding and providing an outlook (chapter 6).

2 REFERENCE LOGISTICS SYSTEM ARCHITECTURE (AS-IS)

2.1 INSTITUTIONAL ARRANGEMENTS OF WATERBORNE LOGISTICS

While the focus of this deliverable concerns the organisation and deployment of logistics flows, this section shall provide some background on institutional arrangements in international waterborne logistics. As the SEAMLESS demonstration covers containerized transports, the following section mainly refers to intermodal contexts. The institutional arrangements typically originate from a contract of sale[15], which establishes the legal and commercial foundation for the movement of goods from the seller (also called vendor) to the buyer (also called purchaser). As such, the contract of sale specifies the goods being sold (e. g., quantity, quality, and price) but also governs the terms of delivery, including the allocation of shipping costs and the transfer of risk from seller to buyer.

The delivery terms are typically expressed in the form of widely accepted International Commercial Terms (Incoterms). In its latest 2020 version, the Incoterms represent a spectrum of eleven responsibility modes, which range from full responsibility for the transportation chain on the seller’s side to full responsibility on the buyer’s side on the contrary. As an example, the Incoterm EXW (“ex works”) requires the seller to provide the goods at its premises or another named place of delivery while the buyer has the obligation to organize and compensate for the whole transport to his or her own premises. On the opposite, the term DDP (“delivered duty paid”) places all obligations to the seller’s side to deliver the goods to a named place and cover all costs and ensure customs’ clearance in the country of destination. For waterborne transport chains, the framework furthermore includes specific terms such as FAS (“free alongside ship”), FOB (“Free On Board”), CFR (“cost and freight”) as well as CIF (“cost, insurance & freight”) which relate to a transition of responsibility either in the port of origin (FAS / FOB) or in the port of destination (CFR / CIF).

While the terms "seller" and "buyer" emphasize commercial transaction aspects, another terminology used in transport logistics and especially transport contracts is "consignor" and "consignee", respectively. The consignor is the party that sends goods and is responsible for arranging the transportation of goods to the consignee as the recipient of goods. Therefore, in many cases, the seller is represented by the consignor, and the buyer represents the consignee. However, depending on the characteristics and Incoterms governing the shipment, these roles may vary. An example represents a transaction which involves the EXW incoterm and thus has no logistical involvement of the seller and requires the buyer or a party acting on behalf of the buyer to act as the consignor. Other examples may involve a third-party logistics provider or goods that are sold while in transit (e. g., in bulk shipping). Another term for the party that arranges the transport of goods is the “shipper”. Considering the roles introduced above, it may be used interchangeably with the “consignor” in most cases. For example, a freight forwarder may be hired to take care of all logistics operations on behalf of the consignor. On the international waterborne freight service market, the shipper can choose from a variety of different transport products, depending on the configuration of the chain. This can range from door-to-door products, which include the full transport chain, from door-to-port, which may be

[15] Even if an international transport is not subject to a trade relationship between independent entities but between entities belonging to one organisation, international trade regulation and taxation laws require an “arm’s length principle”, which represents a concept that the transaction between affiliated parties must be carried out as if in a market-like setting.

used to carry out part or the whole hinterland transport over to port-to-port products, which only include a waterborne haulage.

Within containerized maritime transport chains (which typically involve one maritime and two inland legs), a common concept used to indicate the organizing party for inland transportation is the differentiation between merchant's haulage and carrier's haulage. While in carrier's haulage, the ocean carrier takes care of organizing the maritime as well as one or both hinterland legs, the exporting and/or importing party (or a party acting on behalf) are responsible for organizing the inland transport.

It is important to note that in intermodal transportation, the interaction between the waterborne transport carrier and the port terminal operator almost always happens on a contractual basis, which includes an agreement for serving a specific vessel or service. On the other hand, while the terminal interacts with inland carriers, this interaction does not necessarily happen within a contractual relationship between both parties. This situation may also be referred to as "intermodal disintegration" (Jaffee, 2016).

2.1.1 Phases of a Transport Process

A business process is a collection of related, structured activities or tasks performed by people or equipment in which a specific sequence produces a service or product for a particular customer or customers (Weske, 2012, p. 5). As logistics in companies encompasses the planning, management, coordination, implementation, and monitoring of all internal and external flows of goods and information per definition, a typical business process in transport logistics includes the planning, the execution, and monitoring of the activities and tasks in order to plan the transport chain and to execute the various transport legs including transshipment and further cargo handling activities.

Consequently, the logistics system architecture features a transport planning layer and a transport execution layer. While the earlier acts as a reference for the latter, e. g., by means of service level agreements between the contractual parties and pertaining performance indicators, the latter is used for monitoring purposes and encompasses the stimulation of re-planning activities in case of critical deviations from the original planning.

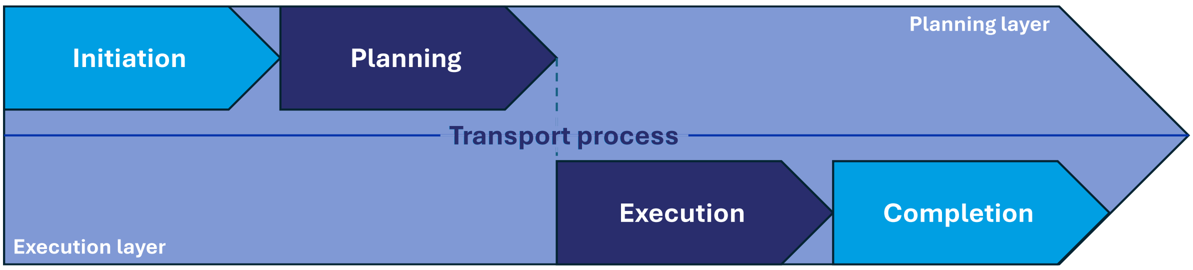


Figure 2. Transport process with two layers and four phases

Classically, the transport process can be subdivided into four major phases ranging from a primary business *initiation* phase over a *planning* phase and an *execution* phase to a *completion* phase at the end. Figure 2 shows the position of each of the four phases in the transport process (FInest, 2011b, 2011g, 2011i, 2011k; Fjørtoft et al., 2010; Platz & Klatt, 2017, pp. 51–52; Zahlmann et al., 2011, pp. 15–18).

Transport planning is a process in which a consignor (or freight forwarders on their behalf) determines which goods will travel a certain route by which means of transport and at what time. The underlying goal to pursue is the composition of a transport chain in such a way that allows the best service performance at the lowest cost. Transport planning comes in many different forms and degrees of complexity. They range from simple route planning to the planning of international flows of goods using various modes of transport. At the operational level, transport planning involves the planning of routes and the compilation of optimised tours and requires close coordination with production, warehousing, and distribution planning. Whereas the *business initiation* includes marketing and sales activities, tender procedures, collection of market information, and the coordination between contractor (consignor or consignee) and client (logistics planner). The *actual planning* refers to the set-up of a multimodal transport chain and includes the composition of the legs of the transport chain, the selection process of the transport provider per leg depending on the collected information on availability and price, and the pre-announcement at the terminals involved. Eventually, the process is completed with the preparation of the customs process and the documents issue and the notification of the consignor and other involved parties. Transport execution, on the contrary, includes the actual and physical *execution* of the different transport legs and related preparatory and follow-up steps. The underlying goal to realise the transport chain according to the plan previously determined and agreed and to meet performance and cost objectives. In a multimodal transport chain, transport execution may include the physical execution of the main leg, typically with an ocean-going vessel, a cargo airplane, or an inland vessel, and the pre- and post-haul legs, mostly carried out with trucks, trains, or inland vessels. In addition, preparing operational transport details to the vehicle operators, such as drivers and shipmasters, providing the customs and transport documents, and taking final preparatory steps belongs to transport execution. So does the *completion* of the transport processes by determining the fees due and invoicing them after carrying out the respective service.

In the SEAMLESS project, the definition of the quantities, routes, and times, as well as the selection of the transport modes per transport leg are considered as exogenous variables that are to be complied with when planning the actual transport. Hence, the initiation of the transport planning, the conceptual design of the transport chain, the planning of its transport legs and pertaining transport modes, the selection of the precise operators per transport leg, and the preparation of the transport documents remain part of the considered transport planning process level.

On the subsequent transport execution level, the final preparation of the transport regarding both physical and administrative topics is followed by the realization of all transport, transshipment, and cargo handling operations as well as the related administration procedures forms the core of the logistics system architecture. Each of the transport legs needs to be executed and synchronized with its predecessor and its successor legs while being closely monitored with respect to its cost and service level performance. In its completion phase, the transport process is eventually completed with invoicing each service provider and settling those invoices while the performance may be evaluated immediately after completion or with a particular time lag.

2.1.2 Actors and Flow Objects Involved

Before elaborating on the actual processes of transport planning and transport execution, the actors and flow objects need to be introduced in order to facilitate optimal understanding of the complex process flows. Some potential actors, such as railway carriers and other railway undertakings, are not considered in this list although they may have been considered as parties potentially involved. However, the list is mainly aligned with the SEAMLESS Demonstration Use Cases.

Transport and logistics processes are simple to comprehend and at the same time complex to carry out. On the superior level, operations primarily involve moving and storing goods which suggests simplicity. On the levels below, however, the diversity of goods to be moved and stored, the variations in country infrastructure and logistics maturity, border and customs differences, modal operating variations, differing customer requirements and expectations, differing customs within the various regions of operation, different governmental regulations in the countries through which goods pass, and a host of other operating factors need to be taken into account while organizing and performing the precise logistics process flow. One of the reasons causing the complexity is the multitude of actors and stakeholders involved in the different phases of a typical transport process. (FInest, 2011f)

In the following, a series of terms is defined in close alignment to scientific theory. However, some minor deviations may occur in the scope of this report and the SEAMLESS project.

• **Shipment**: A shipment encompasses the complete customer order to transfer cargo, i. e., a single container, trailer, or other transport unit or a set of several units, from an enterprise (or individual) sending the cargo to another enterprise (or individual) receiving the cargo. Therefore, a shipment consists of several individual processes or process steps involving both internal and external interfaces. Although it predominantly refers to the planning and execution of the related transport process, it may also include processes of transport document preparation, administrational procedures (including customs), and accounting.

• **Consignment**: A consignment is a collection of cargo items that are transported from one enterprise (or individual) to another. The term can be used to cover a consolidated cargo to be moved by a carrier contracted by the freight forwarder as the consignor (master level), by the freight forwarder himself (house level), or even by a carrier (e. g., an ocean shipping line) behalf of another carrier, such as a road haulier (subcontract level).

• **Consignor and consignee**: The *consignor* is an enterprise (or individual) that ships goods, or gives goods to another for care. The consignor (or his agent) is usually the exporter in international trade. Accordingly, the *consignee* is an enterprise (or individual) that receives goods. In the same context, the consignor is also called the shipper, the sender, or the merchant whereas the consignee is also known as the receiver or the beneficiary. Being the contractual partner of the consignor in a sales contract, the consignee's responsibilities, costs, and liabilities are defined in the agreed terms of delivery. While the consignee is not required to provide transport documents for the shipment, they may be required to provide a letter of credit before the shipment can be released by the shipper. (FInest, 2011c, 2011d; Platz & Klatt, 2017, p. 50; Rodrigue, 2020, p. 425)

The consignor is the start point of a logistics chain whereas the consignee is the end point of a logistics chain. The consignor is the source of a transport while the consignee represents the sink (SCM EDU, 2023b, 2023c). Both the consignor and the consignee can be the client of the entire transport or parts of a transport chain depending on the terms used in the contractual agreement between consignor and consignee. Both the consignor and the consignee can be the involved party responsible for providing and delivering the goods related to the shipment. (Schieck, 2008, pp. 324–325).

With respect to invoicing and shipment completion, it is the accountant of the involved party responsible for providing and delivering the goods who is responsible for checking the received invoices from other parties and initiating the pertaining payment.

• **Carrier**: A carrier performs the physical transport tasks in the shipping process and can be a shipping company, airline, railway company, trucking enterprise, or any other transport service provider. While most carriers own their own transport equipment, some carriers act as non-vehicle operating entities, performing all functions of an asset owning carrier while being free to contract with any third party who owns assets for actual carriage of the goods. Non-vehicle operating entities must obtain special certification and authorization from local authorities to operate in this manner (FInest, 2011a; Langford, 2007, pp. 356–360; Rodrigue, 2020, p. 423).

• **Logistics service provider**: The logistics service provider (LSP) provide different logistics services to the customer, i. e., the consignor or the consignee, such as transport and storage of goods, freight forwarding and consolidation services, contracting services, planning services, customs brokerage and clearance services, visibility to freight movements, and a host of other services to buyers and sellers of goods (Blanchard, 2004, pp. 95–96; FInest, 2011h; Platz & Klatt, 2017, p. 50).

• **Logistics planner**: The *logistics planner* (or transport planner) can be an employee of the consignor, the consignee, a carrier, or any other company involved in the shipment process, respectively, but the most common case is that the transport planning role resides with the logistics service provider (LSP). The logistics planner is responsible for the development of the transport plan and decides about which modes of transport will be used for the various legs of the shipment. He will lay out the different legs and reconvene with the consignor or consignee to confirm the transport plan before arranging the required transports.

The *accountant* (in the same organisation as the logistics planner) is responsible for issuing and transmitting invoices to parties their company was contracted by or for checking the received invoices from other parties and initiating the pertaining payment.

• **Shipping company**: A shipping company is an enterprise main engaged in owning and operating ships. Mainly, the shipping companies are differentiated between one another by the type of waterway they serve, i. e., inland waterway transport, coastal shipping, or ocean shipping, and the type of cargo they haul, i. e., break-bulk cargo, bulk cargo, containers, oil (or other liquid bulk cargo), passengers, or special cargo. (Nijdam & van der Horst, 2018, p. 12)

• **Short-sea shipping company / Ocean carrier**: The ocean carrier (or ocean shipping company) is an enterprise company that organizes and operates maritime transport with their self-owned and operated fleet of cargo vessels. In the case of container transport, the ocean carriers typically operate their vessels in fixed liner services which form the most rigid part of the transport chain. Ocean carriers usually contract with consignors (or consignees) to transport their cargo on a particular route and for a certain price. Similarly, coastal carriers (or short-sea shipping operators) operate in areas along the coast of a country or continent. Coastal shipping companies play an important role in the transport and logistics domain as they take over a large portion of the global freight volume and are pivotal to the transport of goods to and from coastal ports. (SCM EDU, 2023a, 2023e)

The *dispatcher* of the ocean carrier is responsible for the planning and monitoring of the voyages of the ocean-going vessels and has the task of coordinating the incoming transport orders with the best possible voyage from the perspective of the ocean carrier, e. g., by matching them with the vessel schedule.

The *shipmaster* is the highest in command aboard a sea-going vessel. He holds the ultimate responsibility for the vessels and its crew. "[The] Master is in charge of safety of the crew, vessel and Cargo. He is charged with ensuring that all international and local laws are followed properly, and that all management policies are fully complied with. Master also ensures compliance with the vessel's security plan […]." (EduMaritime) In the role, the shipmaster is the contact point on board the ocean ship in the communication between vessel and shoreside entities.

The *accountant* of the ocean carrier is responsible for issuing and transmitting invoices to parties their company was contracted by or for checking the received invoices and initiating the payment.

• **Inland shipping company**: Whereas the term 'inland carriers' describe a transport company operating in the cargo transport overland between an origin point and a destination point, an inland shipping company refers to an enterprise company that organizes and operates inland vessels. Hence, inland shipping companies are the providers of inland waterway transport services. (SCM EDU, 2023d) In inland shipping, different types of transport service providers are to be distinguished. A typical inland shipping company owns several vessels and operates shoreside offices to organize and process the transport orders. They fulfil the transport orders with their own vessels or contracted shipping capacity. Larger inland shipping companies oftentimes operate as multimodal operators providing additional transport services beyond the inland waterway transport, such as pre- and post-haul transports, or stuffing and stripping services. As a particularity of inland waterway transport, another type of service providers is represented by independent ship owners who also operate the vessels themselves. These companies are called (independent) owner-operators or masters sometimes. An owner-operator in inland shipping operates with his own equipment, e. g., his (up to three) inland vessels, only. Typically, they are organized in cooperatives or have contracts with larger inland shipping companies to acquire cargo. (Schieck, 2008, pp. 324–325)

The *dispatcher* of the inland shipping company is responsible for the planning and monitoring of the voyages of the inland vessels and has the task of coordinating the incoming transport orders with the best possible voyage from the perspective of the inland shipping company, e. g., by matching them with the vessel schedule. In case of an owner-operator, the dispatcher for the Inland Waterway Transportation (IWT) shipping company is the same person as the vessel owner and operator.

In an inland shipping company, a *vessel operator* as the person in charge oversees every individual vessel operation. Accordingly, he is in charge of stowage planning, secure mooring of the vessel, maintenance and repair works during transit, and other aspects of vessel operation. The term is the counterpart from inland waterway transport of the term 'shipmaster' in the short-sea shipping and ocean transport realms.

The *accountant* of the inland shipping company is responsible for issuing and transmitting invoices to parties their company was contracted by or for checking the received invoices and initiating the payment.

Due to the prevalence of owner-operators in the IWT sector, the vessel operator may be his own dispatcher and accountant

• **Road carrier**: A road carrier is a provider of road-borne transport services with the help of a fleet of trucks, possibly even heavy-duty trucks. A road carrier can vary in size from a small local business with only a single truck to a large operation with multiple depots and an equally large size of fleet. Road transport is the most used mode of transport for hinterland transport. (Nijdam & van der Horst, 2018, p. 13)

The *dispatcher* of the road carrier is in charge of receiving and processing transport orders and planning the itinerary of both vehicles and drivers.

The *truck driver* is the main actor from the road carrier who is operationally engaged in the execution phase. He fulfils the transport order and may also be tasked with transporting the empty equipment to the consignor's point of loading (or returning it to the container depot after the post-haul transport leg).

The *accountant* of the road carrier is responsible for issuing and transmitting invoices to parties their company was contracted by or for checking the received invoices and initiating the payment.

• **Port**: A port is an area on a seacoast or on the banks of a river, lake, or canal at which ships can berth and tranship cargo. Whereas a harbour represents any sheltered water body at which ships can moor or anchor, a port includes the facilities built for loading and unloading such ships. (FInest, 2011j; Talley, 2018, pp. 1–2)

• **Port authority**: The port authority is the organization owning and possibly operating the port or responsible for providing the basic infra- and superstructure for port operations, such as wharf and dock investments. It is tasked with controlling and managing the port operations and providing terminal facilities and services to terminal operators. Moreover, it acts as a regulator and ensures the compliance of operations with existing rules and regulations. A port authority can be governed in different ways. As a so-called service port, the land and all assets are owned by the government and managed by the port authority including all operations on site. In case some of the operations are carried out by private enterprises, the port is a so-called tool port. The landlord port concept includes public ownership of the port and management of all port operations by a private terminal operator, leaving merely the management of the infra- and superstructure and the vessel traffic coordination to the port authority. The landlord port concept is very common among seaports and increasingly prevalent among inland ports. A port which is completely owned by a private enterprise is called a private port. (Nijdam & van der Horst, 2018, p. 13; Platz & Klatt, 2017, p. 50; Talley, 2018, pp. 182–183)

The *harbour master* is the figurehead for a port authority acting as a landlord. The harbour master enforces the local maritime (or fluvial) rules and regulations within the port area, registers vessels entering and leaving the port, e. g., for the purpose of the invoicing port dues, coordinates the vessel movements inside the port basin, and ensures navigational safety by means of security instructions, traffic and pilotage directions, operational and technical integrity of port facilities, and environmental protection. (Burns, 2015, p. 107)

The *accountant* of the port authority is responsible for issuing and transmitting invoices for the incurred fees by other parties or for checking the received invoices and initiating the payment.

• **Terminal**: A terminal is a place that links different modes of transport and acts as a transshipment point in order to merge or separate shipments, e. g. for a long-haul transport leg or the final delivery. Moreover, it can act as a storage point with warehousing capacities or a distribution centre from which customers or connected distribution warehouses are served. Such terminals be accommodated in seaports and inland ports but also in airports, railway stations, or trucking hubs. Several terminals can belong to one sea or inland port so that the transfer of cargo arriving at one terminal and departing from another requires the inter-terminal transfer of cargo as part of the terminal operations. However, the topic of inter-terminal transfer is excluded from the consideration of the example of the SEAMLESS Demonstration Use Cases and the SEAMLESS Reference Logistics System Architecture (FInest, 2011l).

• **Terminal operator**: The terminal operator is the organization that performs transshipment operations within a port. Terminal operators can have different owner structures, ranging from being completely independent as a third party to fully carrier-owned, e. g. by an ocean carrier. In the case of terminals in smaller inland ports, they are oftentimes co-owned by the local port authority and supported in daily operations by it (Nijdam & van der Horst, 2018, pp. 11–12; Pettit & Beresford, 2018, pp. 70–76).

The *terminal planner* is responsible for planning the terminal operations, including the preparation of the work orders for the crane operators. (Burns, 2015, p. 107)

Sitting in a cabin at the top of the crane tower or controls the crane by remote control from the ground control centre, the *crane operator* is responsible for offloading cargo, e. g., ISO containers, from the incoming transport vehicle onto the terminal compound or – in the opposite case – loading the cargo from the terminal onto the transport vehicle. With respect to ocean-going and inland vessels, the crane operator moves the cargo from the quayside to the terminal compound or vice versa. The task is performed in correspondence with the planning provided by the terminal planner and the stowage plan provided by the shipmaster or inland vessel operator.

The *accountant* of the terminal operating enterprise is responsible for issuing and transmitting invoices to parties their company was contracted by or for checking the received invoices and initiating the payment.

• **Container depot**: An empty container depot is a storage space for idle loading equipment of the ocean carrier. Such depots inspect, clean, maintain and repair, and store containers for shipping companies and leasing enterprises. Typically, the depot provides the empty loading equipment to a consignor on the discretion of the owner of the equipment (most typically the ocean carrier). The empty equipment can be picked up by the consignor or somebody on his behalf, e. g., a road carrier, from a designated depot up to 15 days prior to the actual start of the transport process and must be returned to a different designated depot shortly after reaching its destination. (Hofmann & Schmidt, 2018, pp. 119–124)

• **Customs agent**: A customs agent (or customs broker) is appointed by an economic operator (e.g. a consignor, freight forwarder or logistics company) to clear goods on his behalf. Precisely, he advises importers on technical requirements for foreign cargo to enter a country or customs union, takes care of the complicated customs documents, and prepares the necessary paperwork and payment for the import or export of cargo to or from a country or customs union before he arranges for the delivery of the cargo to the importer's location. In essence, he takes care of the administrative handling of the customs procedure and negotiates directly with the customs authority on behalf of his contractor. (Talley, 2018, p. 62) In order to avoid misunderstandings, it should be noted that this role is called 'customs broker' in many literature sources written in US-American English.

• **Customs office**: The customs office is an institution of the customs administration that is responsible for processing customs transactions in a particular port or area that are not directly related to the import or export of goods. The office decides which goods may be imported into or exported from a country or customs union. They can also determine when and where certain shipments must be presented for customs clearance. A customs office may be located in or in the vicinity of a seaport, on an international border, or elsewhere within the territory of a country, e. g., near an inland port. In the import case, it is the location at which the consignment is available for inspection. In the export case, an inland customs office is the customs office responsible for the sender of goods. Typically, the customs office of export (e.g., at the location of the consignor or at the inland port) responsible for the export declaration whereas the cargo is physically presented at the customs office of exit prior to leaving Union waters. In many cases, the customs office of exit is co-located with the border control point (FInest, 2011e; pureprogress.ch; Thoma et al., 2021, pp. 151–153). In order to avoid misunderstandings, it should be noted that this role is called 'customs agent' in many literature sources written in US-American English.

• Border Control Point: The border control point is the checkpoint on an international border at which travellers, vehicles (or vessels), and goods are inspected and granted (or denied) passage through. Such a border control point can be located along an inland waterway as well. The Danube, for instance, accommodates 49 border control points. A border control point may accommodate various authorities, such as border police, tax and customs control, water police, governmental public health service, disaster management (for dangerous goods transport), governmental directorate for food chain safety and animal health. For instance, the border control point in Mohács, Hungary, is located approximately ten kilometres upstream of the trilateral state border of Hungary, Croatia, and Serbia, which thus is Schengen external border, and facilitates so-called complex border inspections involving all concerned authorities. These authorities are located in one building and jointly conduct on-board checks in mixed teams – either in the border port or at designated spots along the Danube (Hartl et al., 2023).

• **Waterway authority**: A waterway authority (or navigation authority) is the national, regional, or local authority responsible for the maintenance and management of waterways, including maritime waters like coastal waterways and estuaries and inland waterways like rivers and canals, in an area, e. g., a country or a part of a country. Moreover, it is entitled to regulate and standardise inland navigation through legislative measures. Further, it ensures a safe, efficient and barrier-free traffic flow and maintains, operates, and improves the pertaining waterway infrastructure, such as riverbeds, locks, weirs, turning basins, and (partly) bridges. An inland vessel operator travelling within the jurisdiction of a waterway authority must register its voyage with the respective authority. The waterway authority acts as a regulator and network manager in the typical waterborne transport process. (Platz & Klatt, 2017, pp. 50–51)

The *lock operator* (or lock keeper) is an employee of the waterway authority who has the task of monitoring the operation of a particular lock, controlling vessel traffic through the lock assigned to him, and organizing its maintenance in case of need.

2.1.3 Systems Involved

The SEAMLESS project – and the digital platform ModalNET as part of it – will rely on different kinds of systems supporting the transport and logistics process using automated units ashore and on the water. The ModalNET logistics network pursues the goal of organizing the entire transport chain, generating all pertaining bookings and shipment orders for the various transport legs, compute the related fees and charges, and manage administrative procedures linked to the shipment. In addition, the ModalNET platform will be federated to any other third-party platform that will take part of the ecosystem where SEAMLESS business and logistics models will be implemented, including the SEAMLESS innovations to be developed in the course of the research project.

Due to the large number of actors and stakeholders involved in the processes of planning and carrying out a multimodal transport process, a (nearly) equally number of systems involved in the process flow can be expected. Each of the systems used is linked to mainly one actor involved in the process (at least) and offers a particular functionality to that actor. Some systems may be denoted with the same term but actually represent different systems of the same type as they are owned, operated and used by different organizations. A transport management system (TMS), for instance, may be used by any major transport service provider, regardless of the particular mode of transport used. However, a TMS of an inland shipping company may differ significantly from the one of a road haulier – despite both belong to the same category of systems.

It should be noted though that a large part of the planning and execution of a multimodal transport process takes place with no particular system based on information and communication technologies in place or with conventional communication methods like e-mails, phone calls, fax messages, or radio communication.

• **Enterprise Resource Planning Systems**: Until the 1990s, Enterprise Resource Planning (ERP) systems, which provided functionality for several business areas, was primarily found in large enterprises. Small and medium-sized enterprises (SME) worked with expert systems for production, inventory management, warehousing, and financial accounting. However, as the cost of hardware and software has fallen, fully integrated ERP systems has also become affordable and profitable for SMEs. ERP systems have undergone significant further development in recent years due to continuous functional expansion and the integration of expert systems. Nowadays, an ERP system is an integrated software system for the comprehensive planning and coordination of business tasks, especially business management tasks. The benefit here lies in the most efficient possible utilisation of the resources available in an enterprise (e. g. capital, personnel, information). In addition to logistics applications (e. g. inventory management or scheduling), the system offers programmes for almost all of an enterprise's tasks, from financial management to accounting, controlling, production and product development. Modern ERP systems must be able to easily follow dynamic business processes and have therefore been developed into flexible software solutions with open technical standards. (Bundesvereinigung Logistik, 2012, p. 11)

Important business functions covered ERP functionalities include production planning, inventory management, project management, financial reporting, controlling, sales and marketing planning, procurement, human resources, as well as customer relationship management, master data administration, and multi-site and multi-company management. Thereby, an enterprise using an ERP system can integrate its finance, human resources, supply chain and account management departments into a single system. This means that when a new order is received, the system automatically updates stock levels, initiates production, manages invoicing and tracks dispatch status in real time. The availability of up-to-date information for all relevant parties minimises the occurrence of errors, delays, and misunderstandings. The utilization of an ERP system can be of significant advantage to enterprises operating in a multitude of industries, leading to improvements in efficiency and productivity, decision-making capabilities, customer satisfaction, and the realisation of a streamlined supply chain management strategy. (Pallathadka et al., 2024)

Within the SEAMLESS Reference Logistics Systems Architecture, ERP systems are mainly engaged in issuing, checking, and paying invoices for the different services provided, such as transport or customs brokerage.

• **Transport Management System**: Prior to the use of IT-based transport management systems, transport-related external logistics was usually covered by freight forwarding software from the transport and logistics service provider. With the increasing complexity of global and closely interlinked logistics chains, the need for comprehensive systems to manage these complex transport chains with all their functional requirements developed around the turn of the millennium – on the side of the consignors (and logistics service providers). A Transport Management System (TMS) generally enables the planning, control, monitoring and optimisation of transport networks and logistics chains. Elementary functional areas of a TMS include order management, scheduling, transport planning and optimisation, tracking and tracing as well as fleet and resource management. Hence, a TMS is used to plan, execute and optimize transport processes in external transport. In addition to trucks and other road-borne transport vehicles, the transport vehicles planned for use can also include ships, freight trains, or aircrafts (Bundesvereinigung Logistik, 2012, p. 13).

The use of TMS offers enterprises numerous advantages, particularly in terms of increased efficiency, cost savings and customer loyalty. This results in shorter lead times, faster deliveries, and an overall improvement in service quality. Moreover, a TMS can enable enterprises to reduce their transport costs by optimising the use of resources, reducing empty runs and negotiating better conditions with suppliers. In addition, enterprises can minimise their fuel costs through efficient route planning and freight optimisation. Enterprises can track the status of their shipments in real time and inform customers about the status. This helps to strengthen customer confidence and increase customer satisfaction (Wittenbrink, 2014).

The shipping and logistics industry is particularly reliant on the efficient organisation and control of transport processes. TMS therefore play a decisive role in the optimisation of logistics processes in enterprises operating in this sector. To improve their order management, the TMS allow users to efficiently record, manage, and coordinate transport orders. This encompasses the planning of sea transport, the booking of freight space, the tracking of shipments, and the invoicing of transport services. They even support enterprises in planning and optimising their sea routes by taking into account factors such as sea weather, sea conditions, port conditions and fuel consumption, enterprises can optimise their routes to achieve time and cost savings (Nettsträter et al., 2015).

Within the SEAMLESS Reference Logistics Systems Architecture, TMS are mainly involved in booking of transport carriers, information exchange with terminals, document issue, container provision, transport data provision, as well as shipment monitoring and status reporting.

Within the SEAMLESS Reference Logistics Systems Architecture, freight forwarding systems are included as the booking system of the waterborne carriers, i. e., the ocean and inland shipping companies, which the logistics planner uses to book the transport leg and transmit potential amendments of the booking.

- **Terminal Operating Systems**: A Terminal Operating System (TOS) is used for the planning and operational support of the tasks and activities of a terminal in a seaport or inland port. It is the core information system of a port terminal and influences the performance of a terminal directly as it manages and controls its operational processes. Primarily a TOS fulfils five major tasks: planning the terminal operations, monitoring the operations related to cargo handling, managing the resources including terminal assets and equipment, controlling the terminal berth and yard, and managing the interactions with different stakeholders, such as consignors, shipping lines, truckers, port authority, or customs, through defined interfaces including the ones for Electronic Data Interchange (EDI). Being the core software of a terminal, its functions include the planning, management, and monitoring of all the processes carried out in the terminal (e. g., loading, unloading, transport, storage processes developed by the equipment of the terminal) and its surroundings (e.g., arrivals and departures of transport vehicles like vessels or trucks, truck queue at the gate). This includes planning and controlling the flow of goods into, within, and out of a terminal as well as their storage. Further, a TOS is used for the real-time allocation of resources like space, personnel, and equipment to the different processes, ensuring their efficient use, and may even optimise the use of available resources (Heilig & Voß, 2018, pp. 242–243; Jahn et al., 2021, pp. 16–19; Ullrich & Baumert, 2018, pp. 157–159).

By using TOS, terminals can automate and streamline terminal operations, achieve faster turnaround times, reduce waiting times, and increase throughput capacity. Further, TOS help shipping companies and consignors (and consignees, respectively) meet delivery deadlines and improve customer satisfaction by reducing delays and improving cargo handling efficiency. Thirdly, TOS provide real-time visibility into the status and location of cargo within the terminal, enabling better tracking and monitoring of shipments and facilitating transparency to the stakeholders involved in the shipment process. A TOS often utilises different information and communication technologies, such as optical character recognition (OCR), Global Positioning System (GPS) and other satnav systems, real-time locating systems (RTLS), and radio frequency identification (RFID), and can be connected to ERP systems, TMS of the different transport service providers, and other third-party systems. It is important to note though that there is no standardised TOS as no port is like another, implying that operational procedures, technologies at hand, and interconnection among systems may vary. Thus, it is essential to anticipate this variability in the processes and allow for it in the functional design of the system. Furthermore, it should be acknowledged that there may be instances in which port terminals lack computerised support for operational processes. Nowadays, the various software solutions generally have a modular structure and cover different areas of operational application. Whereas the typical modules of a TOS include those from the areas of incoming and outgoing cargo flows, internal transport, storage, as well as administration, management, and IT. Advanced TOS offer features for optimised processes, e. g., optimised scheduling, container stacking, and resource allocation. (Heilig & Voß, 2018, pp. 237–241; Hervás-Peralta et al., 2019; Ullrich & Baumert, 2018, pp. 157–159).

Within the SEAMLESS Reference Logistics Systems Architecture, TOS are involved in the interaction with the vessels as well as with the arriving and departing trucks in the realm of determining cargo handling fees and invoicing service charges. Moreover, the incoming and outgoing vessels are in contact with the respective TOS of the different terminals in order to allow them to record the dwell time in the port and to request and book the services to be provided, particularly related to loading and unloading of cargo and bunkering. The arriving and departing trucks interact with the different TOS – albeit in an indirect manner – during their respective cargo collection and delivery processes, e. g., for the provision of a pick-up reference number.

- **Port Community Systems**: A Port Community System (PCS) provides a digital platform connecting all stakeholders of a port community of a seaport, airport, or inland port, and facilitating document and information exchange among them. By connecting various Information and communications technology (ICT) systems of the different organisations involved to the platform, it provides a single point of contact for many different stakeholders and connects the multiple parties involved in the cargo movement of the respective port. Provided by a PCS operator and used by a port authority, a PCS typically enables information exchange between transport operators in the port and for hinterland connections, the port users, Customs, port and other authorities, electronic exchange of customs declarations and responses, electronic handling of all information regarding import and export of cargo and other declarations. (EPCSA, 2011, p. 2; Heilig & Voß, 2018, pp. 241–242; Kaup et al., 2021; Sahu et al., 2023, pp. 9–11)

By offering a neutral and open electronic platform for smart and secure exchange of information between public authorities and private stakeholders, ports can improve their competitive position as it enables optimized and even automated processes by providing a portal for a single submission of data which is then provided to all required recipients. Thereby, it reduces duplication of effort, saves time, and improves communication quality among all stakeholders (Pettit & Beresford, 2018, p. 21; Ullrich & Baumert, 2018, pp. 160–163; UNECE, 2023, pp. 9–13).

PCS are common among seaports, such as like Rotterdam (PortBase), Antwerp (NextPort), Hamburg (DAKOSY), Valencia (ValenciaportPCS) and Piraeus (HPCS), in Europe and elsewhere. Among inland ports, however, it is a trend recently begun. With RiverPorts Planning and Information System (RPIS), the inland ports of Duisburg and Basel have joined forces to set up a so-called multi-port community system and put into service along the Rhine-Alpine Corridor (Schweizerische Rheinhäfen, & Duisburger Hafen AG, 2024).

The main difference between a PCS and a TOS is that each of them supports completely different kinds of processes. While a TOS supports terminal operations on site, a PCS mainly connects various stakeholders at a port, enables communication and exchange of documents and information, and provides a basis for administrational procedures with public authorities and officials.

Within the SEAMLESS Reference Logistics Systems Architecture, PCS are involved in the entry and exit of inland and sea-going vessels in the port. Further, they are used by the port authorities to communicate and exchange information with the vessels and charge them port fees for their dwell times in the respective ports.

- **Customs Procedure Management System**: A Customs Procedure Management System (or customs software in short) refers to an application for the simplified issue of import and export documents in cargo handling and features specific versions for different countries, like ‘Douaneaangiften Management Systeem’ (DMS) in the Netherlands, ‘Automatisiertes Tarif- und Lokales Zoll-Abwicklungs-System’ (ATLAS) in Germany, PaperLess Douane en Accijnzen (PLDA) in Belgium, and Déclaration en douane (DELTA) in France, for instance. It is designed to assist enterprises in managing the intricate process of cross-border and international trade by identifying customs requirements, engaging customs service providers, and efficiently handling tasks of customs clearance and compliance. Moreover, it assists the user in guiding through the whole process of customs declarations, ensuring adherence to regulations, and monitoring the customs process. In order to do so, a Customs Procedure Management Systems utilises trade data from customs authorities, freight forwarders, other participants of the supply chain, and different other sources. Many Customs Procedure Management Systems offer the interfaces provided by the customs administration to the in-house ERP software of an enterprise (AEB SE, 2024; Generalzolldirektion, 2024; Long, 2009; Maersk).

Within the SEAMLESS Reference Logistics Systems Architecture, the Customs Procedure Management System is the entity processing export declarations and – in the import case – the system with which a shipping company and the customs office exchange documents, information, and declarations.

• **Inland Waterway Management System**: An Inland Waterway Management System registers the cargo vessels travelling on and using the respective waterway network, as well as the cargo they are carrying as inland shipping companies must submit their load and empty transport declarations for every journey. Nowadays, such declarations are to be submitted no longer in paper form but via online declaration portals provided through the inland waterway management system. The waterway authority uses the data collected to compile usage statistics of the waterway stretches, manage usage intensities and associated maintenance and repair work, and make decisions on further measures to increase the attractiveness of inland navigation for consignors like traffic reorganisation or infrastructure investments. In addition, tolls and invoices for various services are issued and billed and data about the inland vessels using the network is kept via the inland waterway management system. Following the specifications of Electronic Reporting International (ERI), there exists a series of EDIFACT messages for different types of message content, such as notification of arrival (ERI-NOT), data exchange between the shipmaster (as the vessel operator) and public authorities and water police (PAXLST), or berth management (BERMAN). The different waterway authorities operate different systems, such as Binnenvaart Informatie & Communicatie Systeem (BICS) in the Netherlands, Voyage En Ligne (VELI) in France, electronic Reporting for Inland Barges (eRIBa) in the Belgian region of Flanders, and (NaMIB) in Germany, whereby the latter provides the relevant information to the responsible emergency and rescue services in the event of emergencies, accidents or accidents involving inland waterway vessels. On the Rhine, both inland container vessels and inland tank vessels are subject to reporting obligations. On the Danube (and the Elbe), the so-called CEERIS system has been implemented in 2023 as a reporting portal allowing shipmasters to fulfil all reporting requirements for a specific inland waterway transport in the Danube riparian countries and Czechia by reporting only once with single entering of data with the help of standardised forms, the so-called DAVID forms (BAG, 2018, pp. 19–22; CCNR; CESNI, 2021; CESNI & CCNR, 2015; De Vlaamse Waterweg N.V.; Ninnemann et al., 2019, pp. 19–20; Platz & Klatt, 2017, pp. 50–53; viadonau, 2019, pp. 204–215, 2024a, 2024b; Voies Navigables de France, 2019). Within the SEAMLESS Reference Logistics Systems Architecture, the Inland Waterway Management System is the system that inland vessels need to register at in particular traffic situations, e. g., when entering a new waterway network or approaching a lock for passage. Further information on River Information Services (RIS) is provided in later sections of this report.

• **Vessel Traffic System**: A Vessel Traffic Service (VTS) is a shore-side systems and a service to support navigation in maritime shipping. It is used to secure and coordinate vessel traffic within a limited geographical traffic area and/or for areas that are particularly challenging to navigate. In accordance with a UN convention, a member state is obliged to set up VTS if certain conditions are met in order to ensure the safety of shipping and environmental protection in the controlled area. Not only does a VTS provide simple information messages to ships, such as position of other traffic or meteorological hazard warnings, it also coordinates and manages complicated traffic within a port area or particular waterway stretches. Accordingly, ships entering a VTS area report to the authorities, usually by radio, and may be tracked by the VTS control centre. Vessels must keep watch on a specific frequency for navigational or other warnings, while they may be contacted directly by the

VTS operator who warns the vessel in case of risk of an incident or advises it on when to proceed in areas and times of regulated traffic flow (BSH, 2024; IMO, 2019).

Within the SEAMLESS Reference Logistics Systems Architecture, VTS are involved in the arrival and departure processes of ocean-going and short-sea shipping vessels entering and leaving the seaport.

• **Booking systems of shipping companies**: Shipping companies utilise booking systems to manage the scheduling and booking of cargo shipments. Coming as digital platforms or software solutions, these systems allow shippers, vendors, and booking agents to arrange shipments directly with carriers or logistics service providers. The booking process involves specifying shipment details, such as origin, destination, cargo type, and desired departure date. Such booking systems help streamline the booking process, providing visibility to the users and a single point of contact for all parties involved in the shipment process. Further, they play a pivotal role in the transport and logistics domain, facilitating the efficient and cost-effective movement of goods across the globe. Booking systems of shipping companies are designed to integrate seamlessly with other logistics and supply chain management systems, thereby facilitating seamless communication and collaboration between all parties involved in the shipment process. By providing a centralized platform for booking and managing shipments, these systems facilitate coordination and collaboration across the entire supply chain (Cargoo, 2024; e2open, 2024; Maersk)

Within the SEAMLESS Reference Logistics Systems Architecture, these systems are used for the booking the shipping companies both for short-sea shipping and inland waterway transport.

2.2 Logistics Process Flows

2.2.1 Preliminary Remarks

In the following, a Reference Logistics System Architecture has been developed along a fictional but realistic “cargo story”, i. e., the planning and execution of a door-to-door transport process from the consignor (origin) to the consignee (destination) via multiple transport legs using various transport modes. Thereby, a realistic setting is prepared both for the matching of the SEAMLESS innovations and the business needs from the stakeholders’ sides and for the technical interaction of the SEAMLESS innovations among one another and with the surrounding process and system landscape. Therefore, the Reference Logistics System Architecture contains the logistics process flows, the actors and stakeholders involved, the business information systems and communication means used, and the communication and interaction patterns between them. By providing these aspects at one, a holistic view of the business setting in which the SEAMLESS innovations are to operate effectively and perform efficiently is given. This setting can be used for refining requirements, synchronising intermediate results of the respective development processes, and validating the functional principles in their future operational (process and system) environment.

Given the structure of typical flows coming into and going out of the large European seaports, the multimodal transport chain of an export case or an import case can be used as relevant cargo story.

In both cases, the consignors and consignees, respectively, are typically located in the European hinterland so that their usual import or export transport chain may exceed a pure maritime transport chain and require additional legs from and to the seaports, typically operated by truck or train. In the following, a common export case from continental Europe to a destination in extra-Union territory is being used as the underlying cargo story. Such a case may reside in the Hauts-de-France region the north of France using the inland port of Lille, France, and the waterway connection to Antwerp, Belgium, or in the Ruhr area in the west of Germany using the largest European inland port of Duisburg, and the Rhine to the same seaport. The subsequent transport leg may lead from Antwerp to Valencia, Spain, or Bergen, Norway – or even an intercontinental destination. Thereby, it can be safeguarded that the two demonstration use cases of the SEAMLESS project are represented in the Reference Logistics System Architecture (see Figure 3). In most of the cases, the process flows, interaction patterns, and system involvements presented as part of the export case can be used for an import case as well. The only major deviation stems from the customs handling procedure which will be addressed separately in a later section.

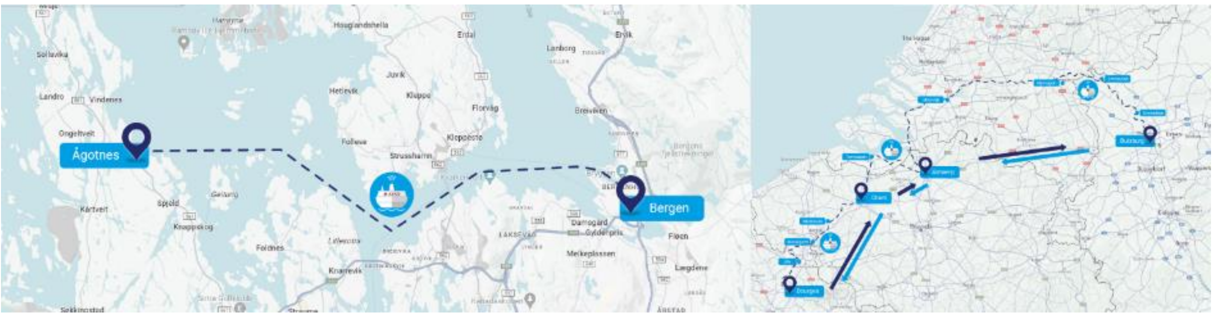


Figure 3. SEAMLESS Demonstration Use Cases in northern Europe (left) and central Europe (right)

Footing on typical freight transport chains in maritime shipping from scientific literature, the ocean- or sea-going leg is considered as the main leg. However, as the transport leg covered by the inland vessel is considered the main leg in inland waterway transport, particularly in continental transport in Europe, the Reference Logistics System Architecture is built in a way that both transport cases are integrated in one joint transport chain, enhancing the multimodal chain. The Reference Logistics System Architecture represents one of the most prevalent forms of seaborne container transport as it includes a representative logistics process flow, usual actors and stakeholders involved, and prevalent systems in use. At the same time, the Reference Logistics System Architecture is characteristic for a typical inland waterway transport case. Moreover, the cargo type considered in the following is unitized cargo in containers which is also represented in the set-up of the reference architecture by means of the related transport chain composition and logistics process flows. Ultimately, the Reference Logistics System Architecture features both an IWT leg and a SSS leg, complemented by a pre-haul and a post-haul transport leg as the SEAMLESS project includes both one demonstration use case focusing on short-sea container shipping and another demonstration use case on inland waterway container transport. Although the pre-haul and post-haul legs may include railway transport, the more likely variant is road-borne transport as the more prevalent transport modes. (Kummer et al., 2010, pp. 275-276, 280-284, 292-294, 324-325; Schieck, 2008, pp. 183–187).

As presented earlier, the SEAMLESS Reference Logistics System Architecture comprises the logistics process flows, the actors and stakeholders involved, and the business information systems used – all of which are represented in an activity or flowchart diagram presented in a simplified form of the widely prevalent BPMN representation form – and the communication and interaction patterns represented in a sequence diagram. In addition, the administrational procedures centred around the logistics process flow are also considered as an integral part of the system architecture. Correspondingly, the next sub-chapters refer to the logistics process flows, the administrational procedures, and the communication and interaction patterns, respectively, which are presented one after the other in the following.

A business process represents a sequence of operational activities for achieving a business objective. It clarifies the process structure by assigning tasks to different actors and connect them to depict prevailing relationships (Chinosi & Trombetta, 2012, p. 126). In order to facilitate easy and swift comprehension and to avoid misunderstanding, the represented business processes within this deliverable are modelled in a particular notation based on the BPMN standards. BPMN is a specification language for the modelling and representation of business processes and already widely used in many different areas, including software development, business process management, and research and development. that is but owns adjustments for the specific application. With respect to the notation used in this work, it has to be emphasized though that the large set of BPMN elements represented by a plethora of icons have been reduced to a small subset of the original in order to allow non-experts follow the process diagrams easily and intuitively (Silver, 2011, pp. 33-34, 40, 48, 54-56, 60, 101).

As in BPMN, different actors in a process are separated from each other by using graphical bordered fields called *pools*. Those pools can be sub-divided in different *swim lanes* when different organizational units (sub-actors) of one actor should be shown side by side. The diagrams use solid bordered fields as pools (for an actor) and swim lanes with a dashed border (for a sub-actor), e. g., when a new established SEAMLESS innovation participates in the process as a part of one of the actors, e. g., a remote operation centre as part of a shipping company.

Main elements of a process are *tasks* that specify an activity within the process. Tasks are assigned to the responsible actor by drawing a rectangular shape with rounded corners in the respective pool or swim lane. Depending on the selected level of aggregation, a task can be either a single order or a summary of several steps. The rectangle for a task may contain a plus symbol in case there is an *associated subprocess* for an individual task in an own process diagram.

Sequences of tasks are indicated by either solid or dashed arrows. Unlike BPMN, the presentations in this document do not differentiate between material flows and information flows in order to reduce complexity. The main interaction patterns are illustrated by arrows whereas as the precise physical flow is not always visible in the diagram. If a sequence takes place within a single pool, the arrows are solid. As soon as an interaction takes place between different pools (and, thus, different actors), it is represented with dashed arrows.

The purpose of the activity diagrams is to show the logistics process flows along the cargo story. According to the cargo story, there is only one common start event within a process which is clearly and unambiguously defined. Therefore, it was deliberately decided not to use additional start events for each pool. A sequence may lead to more than one end though, allowing alternative ends to the cargo story. The *beginning* and the *end* of a sequence are represented by corresponding symbols taken from BPMN standards. Processes can be considered starting from an empty circle with a green border as a start symbol. Within a process, individual strands can branch off and thus lead to separate end for different actors, shown as red circles around a black dot.

The *interactions* between two actors, i. e., two different pools, consist of either a direct contact between two actors, e. g., during the flow of materials, or a communication by means of message exchange which is illustrated by a letter symbol and labelled with the content of the message. Deviating from the BPMN standard, the simple envelope symbol is used for every form of communication and interaction between actors.

For a clear interpretation, *logical gateways* are inserted where several arrows leave an element or enter another element. A plus symbol in an upright diamond symbolizes that all incoming arrows must enter in parallel before the subsequent process step can take place. In case of several outgoing arrows, the parallel gate triggers the sequences of all outgoing arrows simultaneously. In contrast to those, a cross in an upright diamond may represent a decision or consolidation node, respectively. A decision node is represented by one arrow entering the gateway and several arrows leaving it. Typically, a decision node is labelled with a question and the leaving arrows with the different possible option alternatives, e. g., ‘yes’ and ‘no’. A consolidation node, on the contrary, is represented by several arrows entering and exactly one leaving the gateway – which means that any of the preceding paths may lead to the subsequent step. It is noteworthy to emphasize that gateways may have multiple entering and leaving arrows whereas an activity (with or without an associated sub-process), a message, a signal, and any type of event require exactly one entering and/or one leaving arrow.

Additional *event symbols* have also been used in the illustration to describe the process in more detail. A clock in a green circle serves as a simplified symbol for a waiting event in order to represent an interruption due to possible waiting times or deadlines. In contrast, two yellow circles indicate that a particular state has occurred (or changed) because of the previous sequences. These events or status updates do not have any delaying effect on the course of the process. The use of a triangle in a green circle represents machine-based (and partly automated) communication between the systems involved. A system-based message exchange can contain status messages as well as additional information.

As part of the reference processes with a focus on the cargo story, no further BPMN elements are used. In addition, deviations in the use of BPMN standards as described above have been deliberately chosen.

The typical phases of a transport process explained in section 2.1.1 are used for the structural subdivision of the logistics process flows on the transport planning and transport execution layers. With respect to the actors and stakeholders involved, all relevant roles appearing in the transport planning and execution layers have been described in section 2.1.2. Similarly, all relevant business information systems and communications that are used at some point in the course of the transport planning and execution processes have been introduced and briefly explained in section 2.1.3. Next to the systems used, Figure 4 shows the legend of the notation used in the following activity diagrams presenting the logistics process flows.

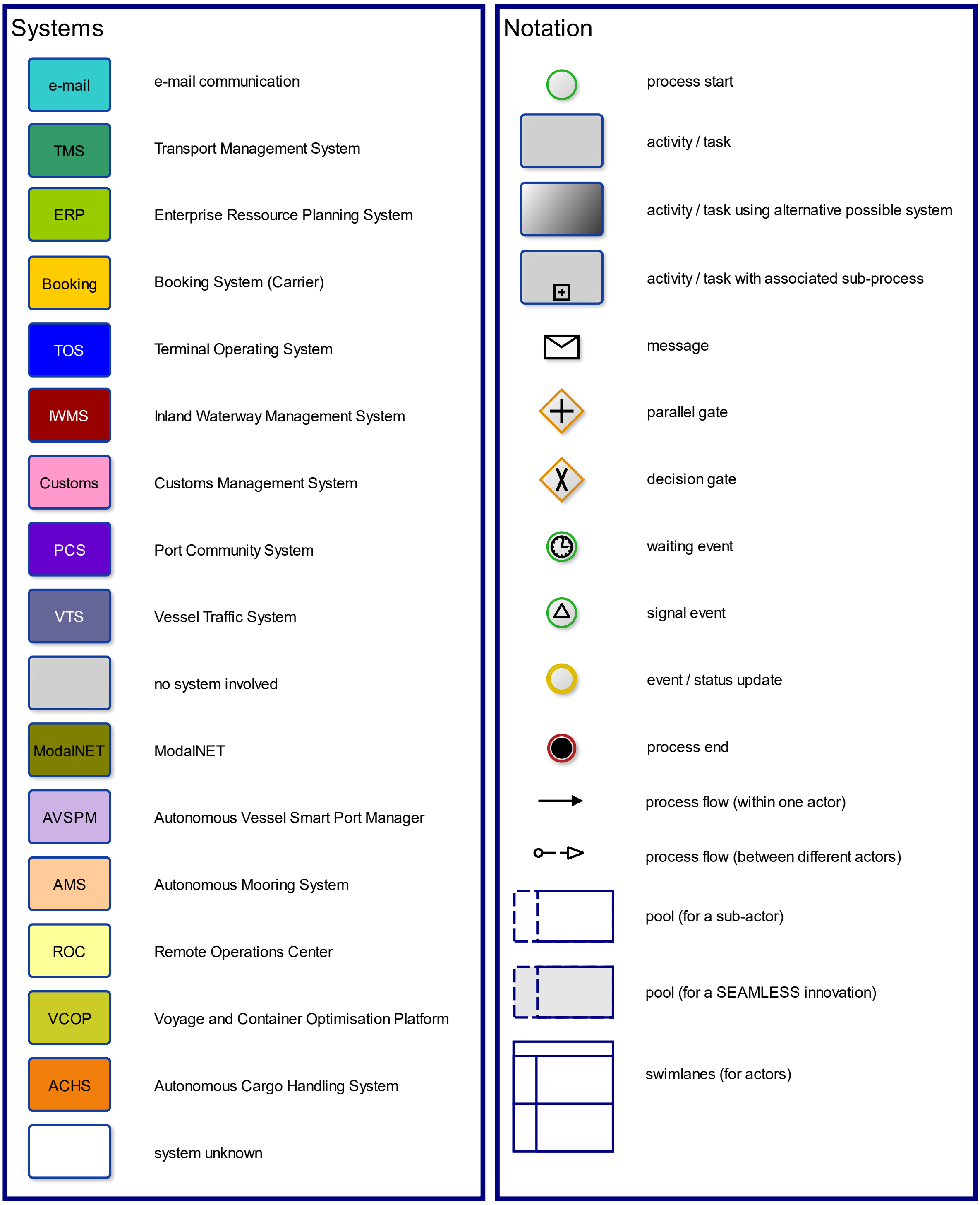


Figure 4. Legend of the notation used in the logistics process flows

The SEAMLESS Reference Logistics System Architecture consists of a planning layer – with an initiation and a planning phase – and an execution layer including an execution phase and a completion phase. Whereas the planning layer encompasses the business initiation and several booking and preparation steps concerning the transport chain and its different legs, the execution phase covers the realisation of the respective transport legs, the customs and administrational procedures, and their follow-up, particularly from a financial perspective. Therefore, the planning layer and the execution layer are shown as different parts (see Figure 5 and Figure 6). The main reason for the separation is the absence of physical activities in the earlier, the difference of systems involved in the two layers, and the number and position of the persons involved.

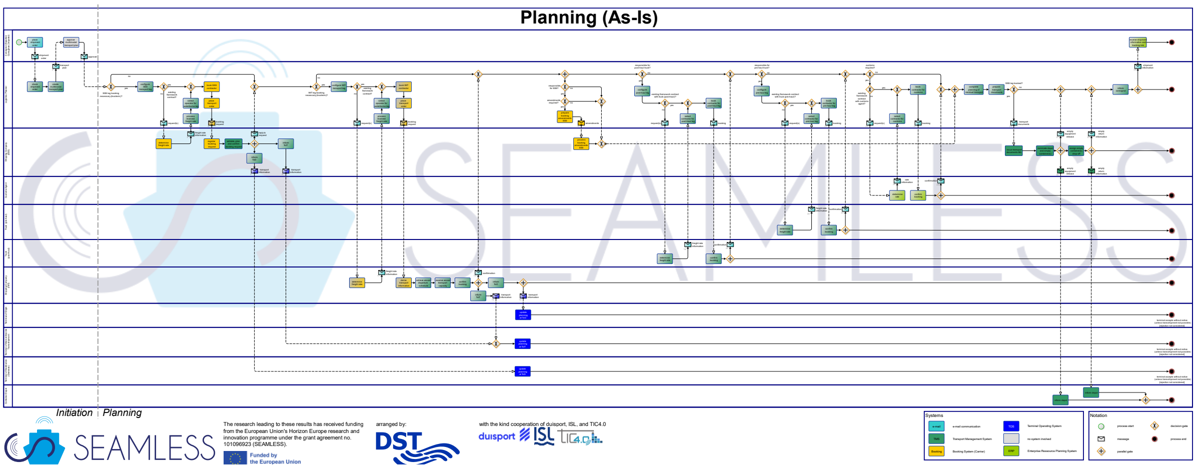


Figure 5. Planning layer of the Logistics Reference System Architecture

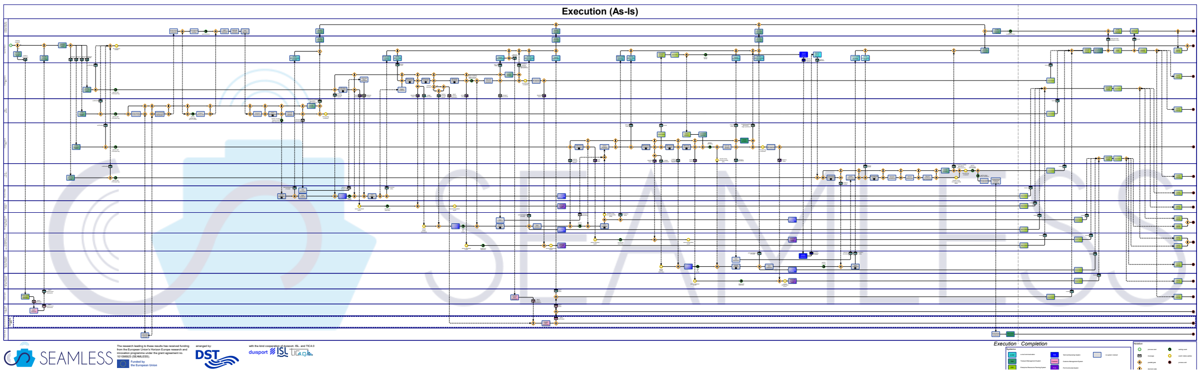


Figure 6. Execution layer of the Logistics Reference System Architecture

In order to be able to show the interplay of the elements within the underlying Reference Logistics System Architecture more clearly, the two layers will be presented and explained separately in the following. The transport planning layer consists of two phases, i. e., initiation and planning, and includes the following eight sub-phases:

- planning initiation,
- SSS leg planning,
- IWT leg planning,
- SSS planning amendments,
- post-haul leg planning,
- pre-haul leg planning,
- customs preparation, and
- planning completion.

The transport execution layer consists of two phases as well, i. e., execution and completion, and encompasses the following six sub-phases:

- shipment preparation,
- pre-haul transport leg,
- IWT leg,
- SSS leg,
- post-haul transport leg, and
- shipment completion and invoicing.

The different phases of the two layers are represented with alternating-coloured backgrounds in the respective figure. Moreover, some of the process steps can be subdivided into sub-processes which are part of the respective phase and sub-phase, respectively.

In the following, each of the eight process phases of the transport planning layer and the six process phases of the transport execution layer is presented by briefly presenting the main purpose, introducing the main parties and systems involved, and explaining the process flow in detail.

2.2.2 Transport Planning Layer

Initiation phase, planning initiation sub-phase

The planning initiation is the only sub-phase of the initiation phase of a transport process and the first of eight process sub-phases of the transport planning layer. As shown in Figure 7, it is centred around the actual business initiation of the shipment and the engagement of a professional logistics planner by the consignor or consignee, respectively. Depending on the specific form of the freight contract concluded in maritime and inland shipping, the consignor may have to reach out directly to some of the parties, use a ship broker or a chartering company, or rely on the service of a logistics service provider. In general, all of these options are possible and can be found on the market but in the case of the SEAMLESS Reference Logistics System Architecture, a logistics planner from a logistics service provider company is commissioned to take over the planning on behalf of the consignor. Theoretically, the logistics planner could be an employee of the consignor as well.

Disregarding the process searching and selecting a capable logistics planner, the process starts with the consignor (or consignee, respectively) placing a shipment order at the logistics planner of the logistics service provider who checks the incoming shipment order and creates a multimodal transport plan to accomplish the request of the consignor. That transport plan includes trade details like international commercial terms (Incoterms) which specifies aspects like the transfer of responsibility and costs as well as insurance, liability, and risk between the contractual trade partners, i. e. consignor and consignee. Depending on the precise Incoterm agreed, the planning responsibility for certain transport legs may reside with either party. On checking the proposed transport plan, the consignor has the opportunity to ask for modifications before eventually approving (or dismissing) the final transport plan. Thereby, the sub-phase is completed.

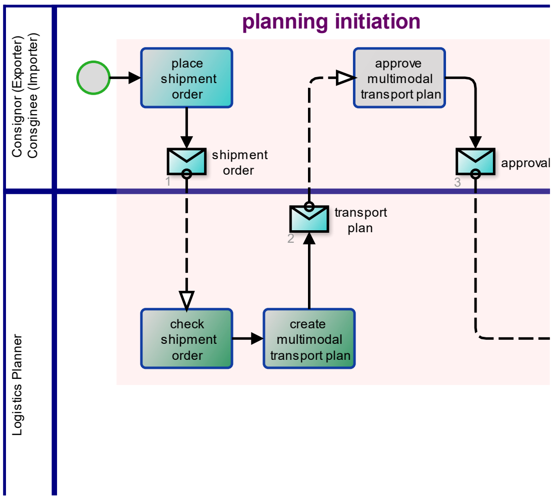


Figure 7. Logistics process flow in the planning initiation sub-phase (initiation phase)

Despite the partial sophistication among consignors and the evolution of systems in the transport and logistics domain, it cannot be assumed that every consignor, every logistics service provider, or every transport service provider has access to these sophisticated tools. Hence, the communication is assumed to be mainly based on conventional e-mail messages and telephone calls, while larger logistics service provider will already be used to work internally with a Transport Management System to align and coordinate with the consignor.

Planning phase, SSS leg planning sub-phase

After the initiation phase follows the planning phase of the transport process. The first transport leg planned by the logistics planner is the main leg, in the present case the sea-going transport leg using short-sea shipping vessels – in case the agreed Incoterm foresees the main leg not to be organized by the opposite party. In the present case, the planning of the Short Sea Shipping (SSS) leg marks the first sub-phase of the planning phase. This sub-phase comprises the entire process from initial configuration to final notification of the origin and destination terminals (see Figure 8). Apart from the logistics planner, the short-sea shipping company providing the SSS transport service, the terminal of intercontinental transshipment (in Antwerp) and the terminal in the port of destination are actors in the SSS leg planning.

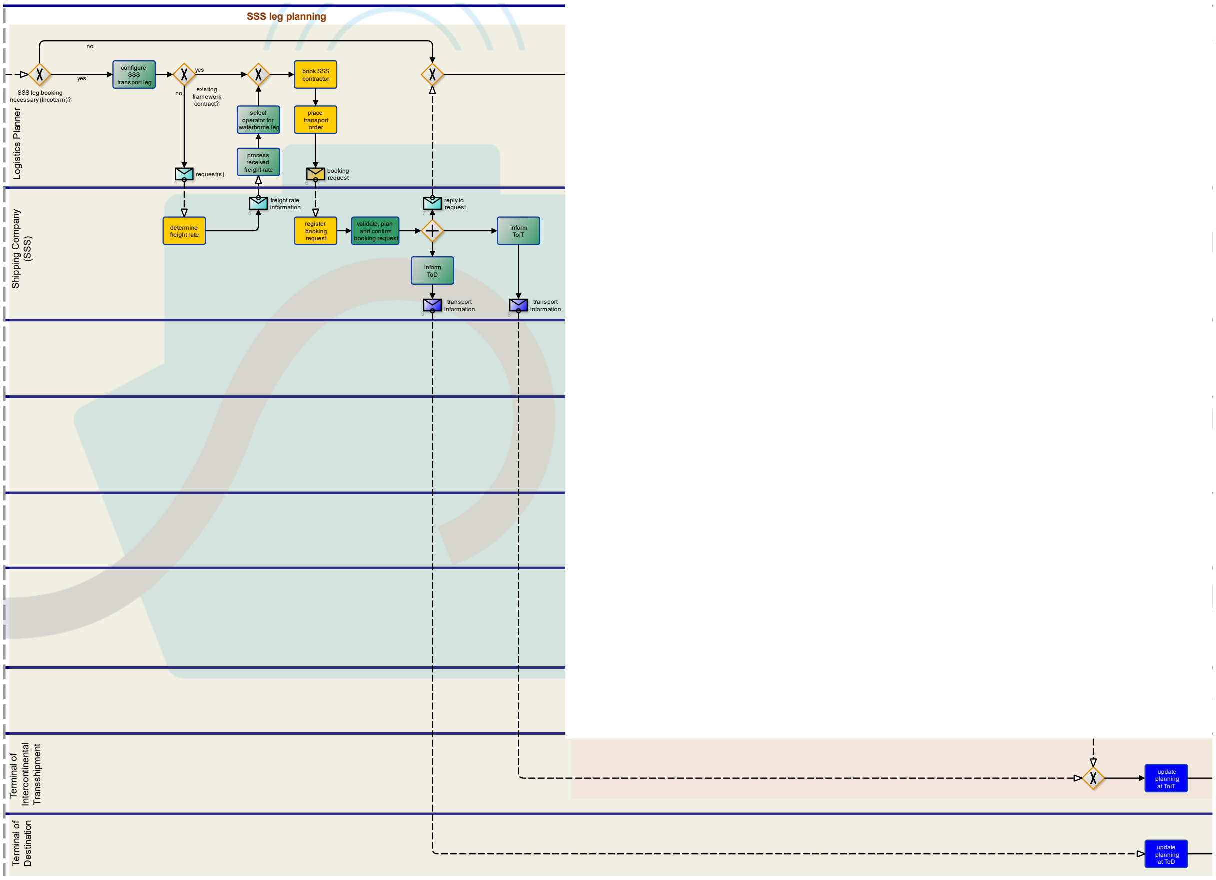


Figure 8. Logistics process flow in the SSS leg planning sub-phase (planning phase)

Once the multimodal transport plan has been approved by the consignor or consignee, respectively, the logistics planner starts the process by configuring the SSS transport leg, i. e., scanning the available options and identifying potential service providers. In case the logistics service provider (or the consignor or consignee, respectively) have a valid framework contract in place, a further selection of a service provider is not required. However, if such a framework contract does not exist, the planner needs to retrieve the required information, e. g., with the help of a request for information (RFI), a request for proposal (RFP), with which potential service providers are invited to propose solutions reflecting the required goals and service levels and proving the capabilities of the applicant, and eventually a request for quotation (RFQ), which aims at obtaining concrete offers for the defined transport service. On processing the incoming offers and comparing costs and other significant performance indicators, the operator of the waterborne main leg is selected. With the help of the booking system of the short-sea shipping company, a booking of the contractor and the transport service is placed which is mirrored by the registration of the booking on the side of the carrier, i. e., the shipping company. Subsequently, the booking received is processed in the internal TMS of the shipping company and – after validation and planning update – confirmed to the logistics planner and passed on as notifications to the terminals in Antwerp and the final destination via portals connected to their respective TOS (or via e-mail, alternatively). The terminals update their respective operations planning accordingly. With these notifications, the sub-phase of SSS leg planning is finished.

Both the logistics planner and the shipping company use their respective TMS for managing the selection process and processing the booking whereas the formal requests are usually transmitted via e-mail. The booking itself is placed in the booking system of the short-sea shipping company. The notification takes place with the help of the respective TOS of the involved terminals.

Planning phase, IWT leg planning sub-phase

The next sub-phase is the IWT leg planning sub-phase in which the IWT leg is planned and which spans from the initial configuration to the final notification of the origin and destination terminals (see Figure 9). Involved parties are the logistics planner, the inland shipping company, and the terminals of origin and destination, e. g., one terminal in Duisburg as the starting point of the IWT leg and another one in Antwerp as its end point.

Similar to the planning process of the SSS leg, the IWT leg planning process starts with the check whether valid framework contracts exist. If so, the detailed planning is cancelled, and the transport leg is booked before the involved terminals are notified. If there exists no framework contract for IWT services though, a similar carrier identification and selection as in the case of SSS leg planning commences. By collecting information on available services and operators as well as their respective capacities and prices in iterative interaction with multiple candidates, the information obtained is processed and a decision is made regarding the service provider to be selected. With the confirmation of the booking by the inland shipping company sent to the logistics planner and the notifications of the involved terminals of origin and destination, respectively, who then update their operational planning, the IWT leg planning sub-phase comes to an end.

As in the preceding sub-phase of SSS leg planning, the ICT systems involved in the IWT leg planning sub-phase are TMS (of the logistics planner and the inland shipping company), the booking system of the inland shipping company, the TOS of the two terminals, and e-mail communication.

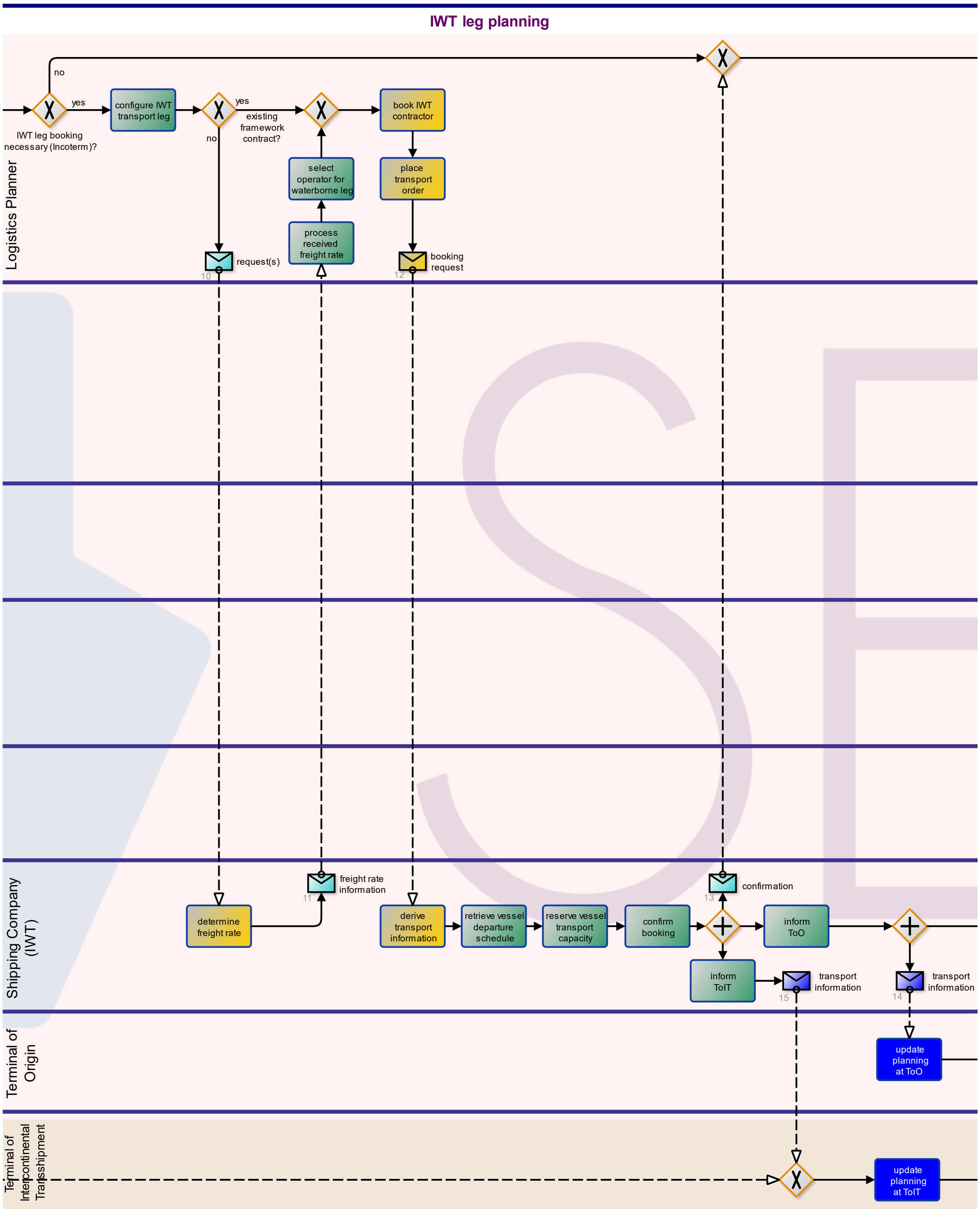


Figure 9. Logistics process flow in the IWT leg planning sub-phase (planning phase)

Planning phase, SSS leg planning amendments sub-phase

The next sub-phase is the one of SSS leg planning amendments which may become necessary in case the selected service for the IWT leg does not perfectly match the selected service for the SSS leg. For instance, the available IWT leg may arrive later than the closing date of the SSS service provider in the seaport. In such cases, an amendment of the booking may appear necessary and are negotiated and processed between the logistics planner and the short-sea shipping carrier. Figure 10 shows the corresponding process flow.

Concerning the logistics process flow, the logistics planner prepares the booking amendments following another iteration of planning the SSS leg, transmits the amendments to the short-sea shipping company, and awaits its processing. It is to be noted that the so-called “happy case” case is considered – without serious changes to the transport plan or without premature cancellation, both of which would involve notifying the shipper.

The entire planning amendment is processed in the booking system of the short-sea shipping company even though it is an interaction between the logistics planner and transport service provider.

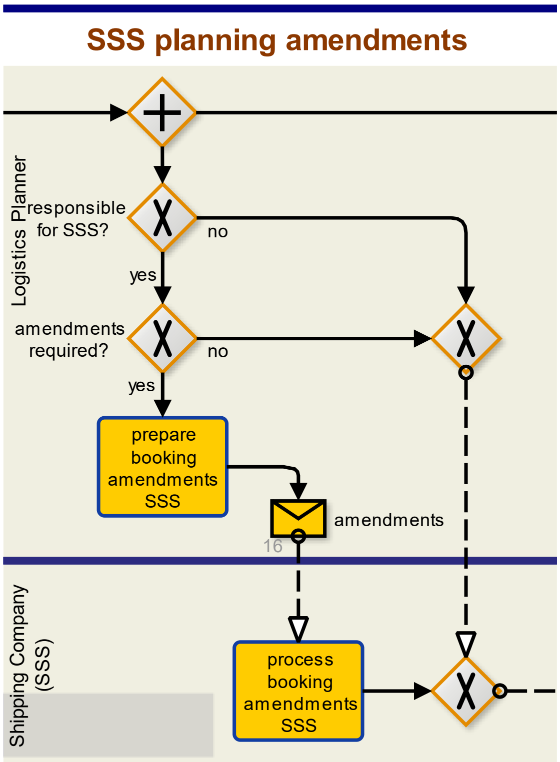


Figure 10. Logistics process flow in the SSS leg planning amendments sub-phase (planning phase)

Planning phase, post-haul transport leg planning sub-phase

The subsequent transport leg to be planned is the post-haul transport leg. Technically, the pre-haul transport leg can be brought forward so that the pre-haul leg is planned before the post-haul leg. The sub-phase begins with the initial configuration and ends with the booking confirmation and involves the logistics planner and the road haulier selected to conduct the service (see Figure 11).

If there is no framework agreement with a road transport service provider, the logistics planner obtains the necessary information from the various candidates, on the basis of which he makes a decision in favour of a transport service provider. As soon as the service provider has confirmed the booking to the logistics planner, the planning of the transport section is considered complete.

The entire planning process is carried with the respective TMS on both sides and e-mail communication between the two.

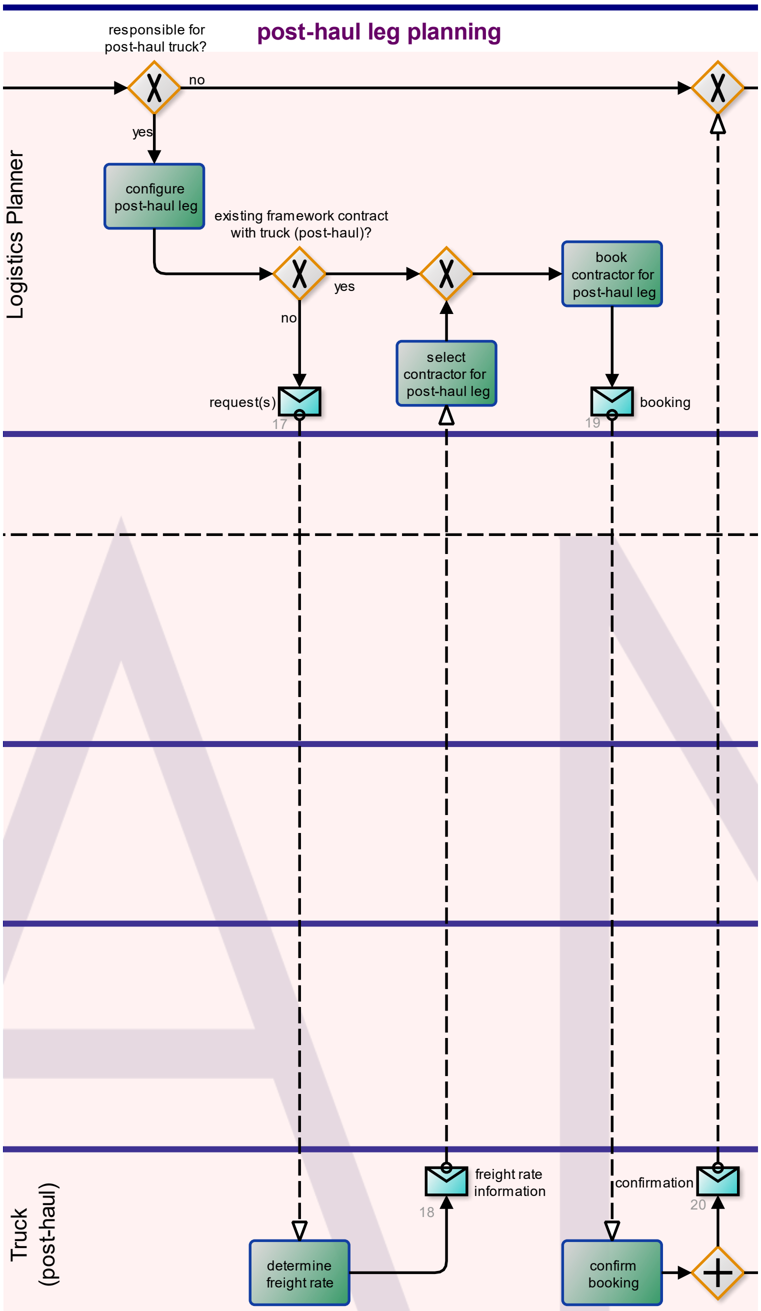


Figure 11. Logistics process flow in the post-haul leg planning sub-phase (planning phase)

Planning phase, pre-haul transport leg planning sub-phase

Similar to the post-haul transport leg, the pre-haul transport leg planning sub-phase ranges from the initial configuration and to the booking confirmation and involves the logistics planner and the road haulier of the pre-haul transport leg (see Figure 12).

Analogous to the post-haul transport leg planning, the pre-haul transport leg planning refers to the same planning routine as with the other legs, including information collection, carrier selection, order placement, and booking confirmation. Again, the booking conformation sent from the road haulier to the logistics planner marks the end of the sub-phase.

The entire planning process is carried with the respective TMS on both sides and e-mail communication between the two.

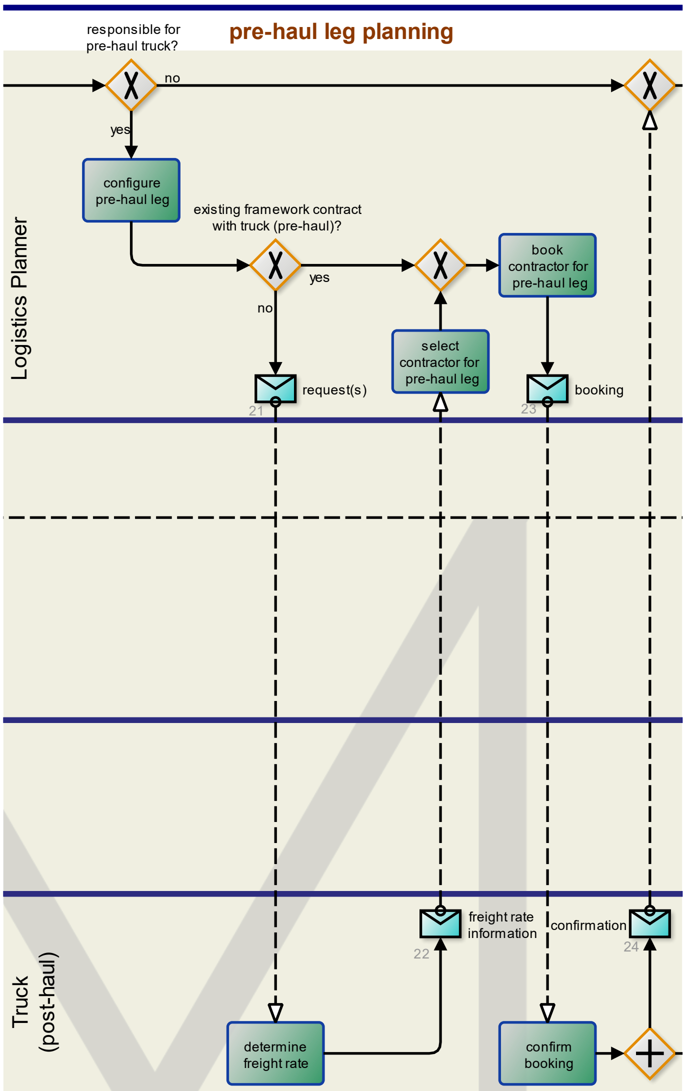


Figure 12. Logistics process flow in the pre-haul leg planning sub-phase (planning phase)

Planning phase, customs preparation sub-phase

Once the different transport legs, the subsequent sub-phase of customs preparation follows next (see Figure 13). The sub-phase contains the selection and booking of a customs broker and is negotiated and processed between the logistics planner and the customs agent.

In case there is no existing framework contract with a customs broker in place, the logistics planner reaches out to various service providers, asks for information and offers in order to select a service provider and book his service. To do so, the order booking is sent via e-mail to the customs agent who confirms the booking and informs the logistics planner accordingly.

The entire sub-phase is carried out with the help of the TMS on the side of the logistics planner, the ERP system on the side of the customs agent, and e-mails for the communication between the two.

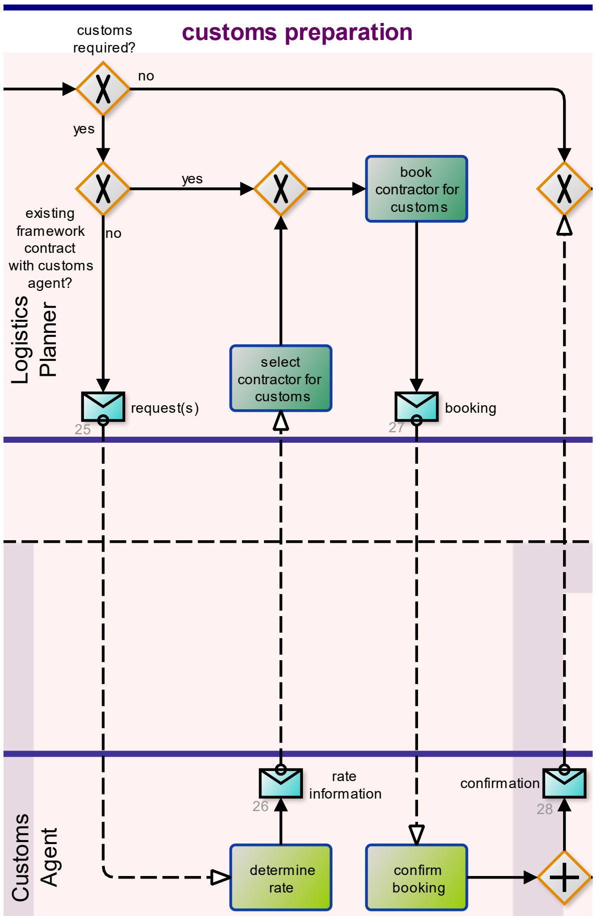


Figure 13. Logistics process flow in the customs preparation sub-phase (planning phase)

Planning phase, planning completion sub-phase

The planning completion sub-phase is the last sub-phase of the transport planning layer. As illustrated in Figure 14, it begins after every planning and booking process has been completed and, thus, the planning of the multimodal transport chain is finalized. The sub-phase ends with the different threads led to their respective end. Apart from the logistics planner who is actively completing the transport planning process, it is the consignor (or consignee, respectively), the short-sea shipping company, and the empty container depot who are involved in the final sub-phase of this layer.

The sub-phase begins with the formal completion of the planning of the residual transport, e. g., by collecting and complementing missing information about the respective transport legs booked earlier. Next, the issue of the transport documents is prepared by the logistics planner consolidating the required information to do so and transmitting them to the short-sea shipping company which issues the transport documents over time, nominates the empty container depot and reserves the required empty equipment, and assigns the depot to drop off the empty containers in the wake of the completed transport execution. Accordingly, the empty container depot is informed about the reservations and assignments. In the meantime, the logistics planner informs the consignor (or consignee, respectively) about the completion of the planning process and provides the final version of the multimodal transport plan and pertaining details as well as and a weblink to access a tracking and tracing portal.

The completion of the planning process is conducted with the TMS of the logistics planner and the short-sea shipping company, and e-mails for the communication with consignor.

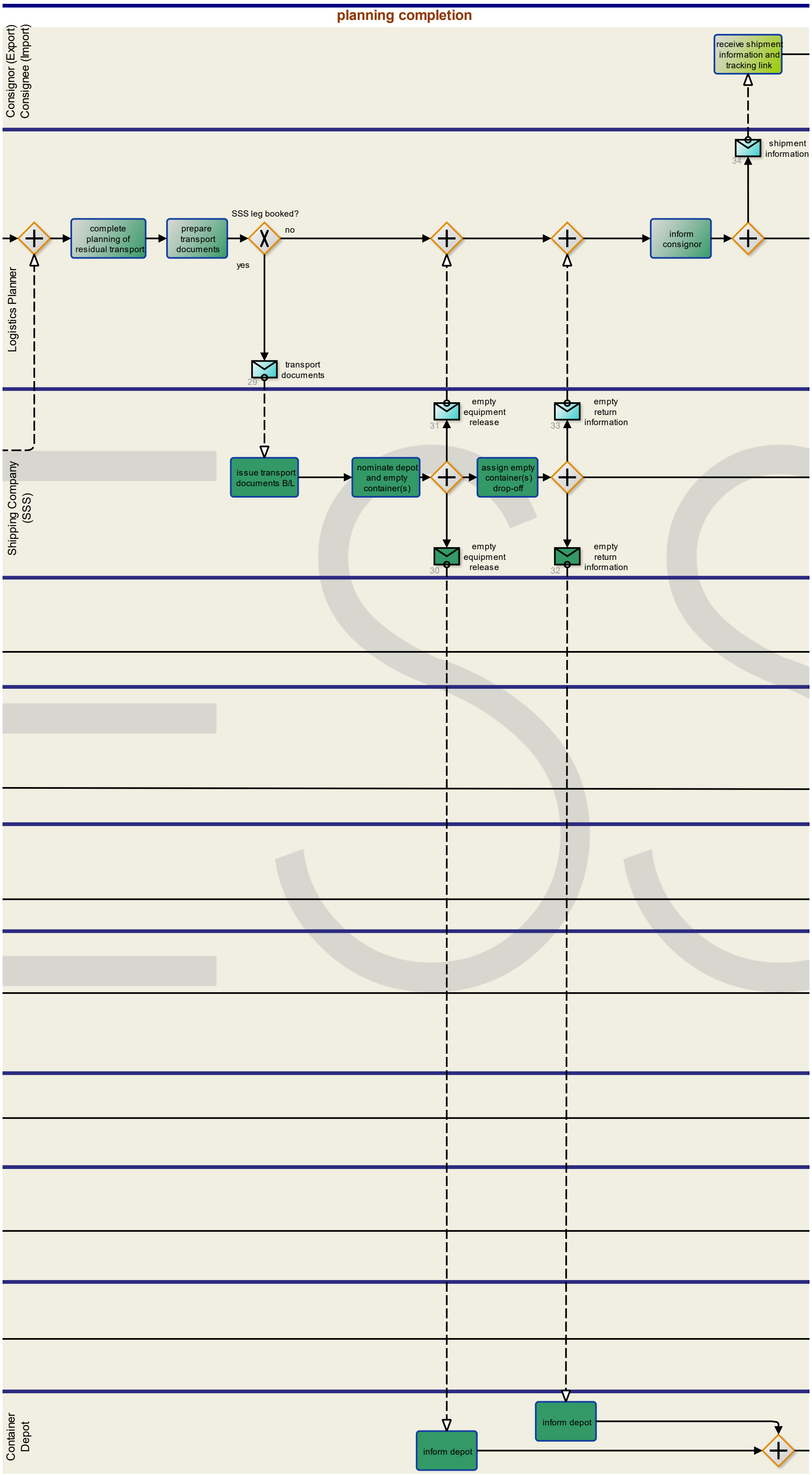


Figure 14. Logistics process flow in the planning completion sub-phase (planning phase)

2.2.3 Transport Execution Layer

Execution phase, shipment preparation sub-phase

After having completed the transport planning layer with the initiation and planning phases and their sub-phases, the transport execution phase begins next with the shipment preparation sub-phase (see Figure 15). By using the term shipment, the entire customer order to transfer cargo from one enterprise to another is meant, including the actual transport process as well as the surrounding document flow and administrational procedures. The sub-phase begins with the transmission of customs details and ends with the completed briefing of all service providers involved. Actively in the sub-phase engaged are the logistics planner, the four transport service providers, i. e., the short-sea shipping company, the inland shipping company, and the two road hauliers responsible for the pre- and post-haul transport leg, respectively, as well as the customs agent.

At the beginning of the process the logistics planner will approach the customs agent if customs are required along the transport chain, otherwise the planner will directly move on with the transmission of the transport details. If customs process is required, the logistics planner will provide all the customs details to the customs agent who will use the information to prepare the export summary declaration. Once transmitted the customs office of export will process the declaration and clear the cargo for exit. This process might involve the cargo being required to be presented at the customs office to receive the clearance. However, for this process flow it is assumed that the consignor is a pre-approved exporter of the respective cargo which allows receiving the customs clearance and related documents without presenting the cargo at the customs office of export. The export clearance and documents will be provided to the customs agent, who in turn will send the information and documents onward to the logistics planner. The logistics planner will integrate the customs document with the remaining transport details. Next, the logistics planner submits data to the four transport service providers individually which is to be confirmed by each of them to reach a state where all contracted parties are briefed with up-to-date information prior to the actual beginning of the first leg. The time to elapse between the briefing and the first leg commencing can vary depending on the precise case and transport chain composition. Same applies to the subsequent legs as it would only be their turn afterwards.

Concerning the business information systems involved, the logistics planner and the service providers use their respective TMS whereas communication is done via e-mail. The customs agent processes the transport details in his ERP system before returning them to logistics planner.

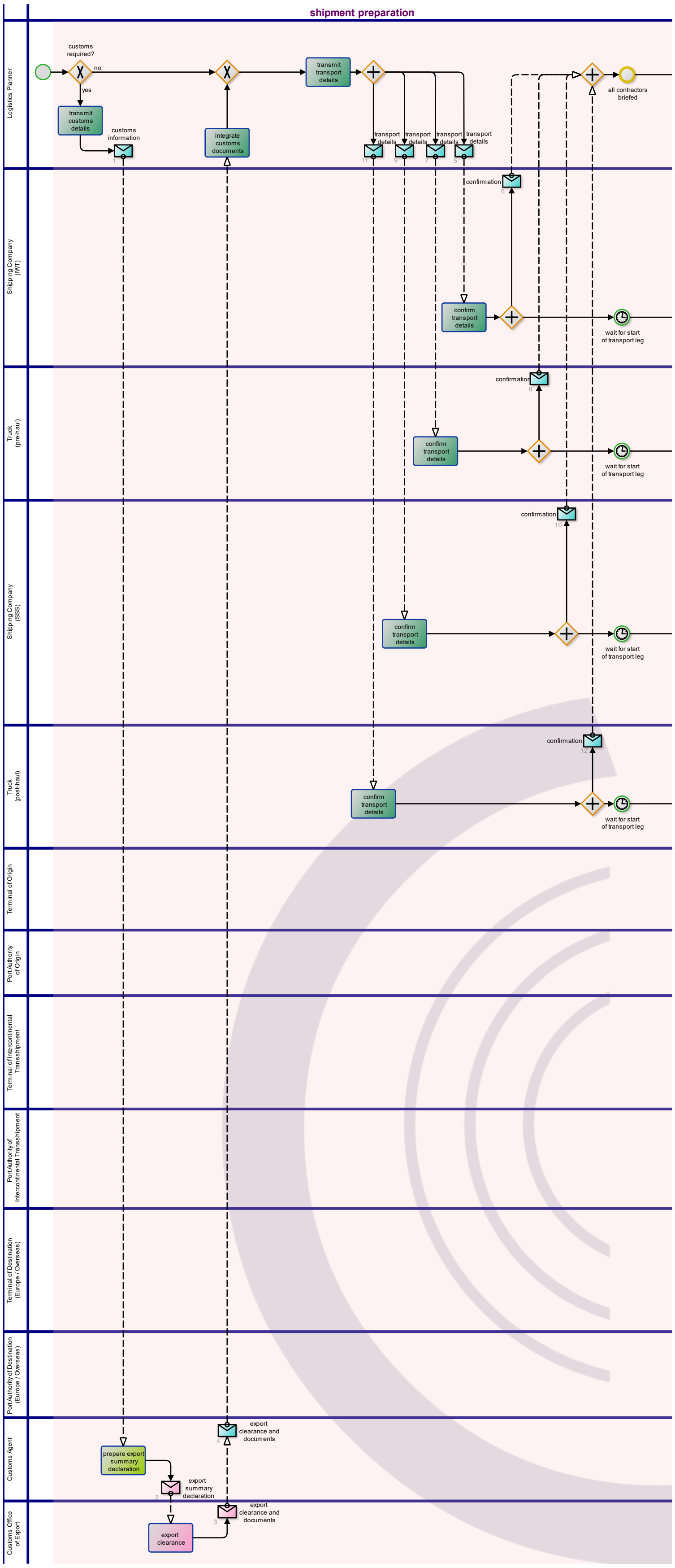


Figure 15. Logistics process flow in the shipment preparation sub-phase (execution phase)

Execution phase, pre-haul transport leg sub-phase

The following sub-phase is the first one executing a transport leg, the road-borne pre-haul transport leg including the collection of empty containers from the depot (see Figure 16). The sub-phase begins with the arrival of a truck at the empty container depot and ends with the completion of the transport leg following the delivery of the containers at the terminal of origin and their storage in the container storage area. Participants of the sub-phase are the consignor (or consignee, respectively), the logistics planner, the road haulier responsible for the pre-haul transport leg, the container depot, and the operator of the terminal, from which the IWT leg is supposed to commence.

The process starts with the arrival of the truck at the empty container depot as the initial journey from its previous location to the depot is disregarded here. On arriving at the depot, the truck picks up the empty container(s) and drives it to the agreed pick-up point, e. g., at the consignor's premises. There, the truck is received and the container unloaded at the ramp before the container stuffing process takes place. The truck may leave and return at a later stage or – in case of swift stuffing processes of a few hours' duration only – wait on site before being loaded onto the truck again. The related transport documents are handed over to the driver prior to the departure of the truck. The containers are transported to the terminal where the truck arrival process takes place on time, i. e., prior to the cut-off date of the inland port with respect to the departing inland vessel.

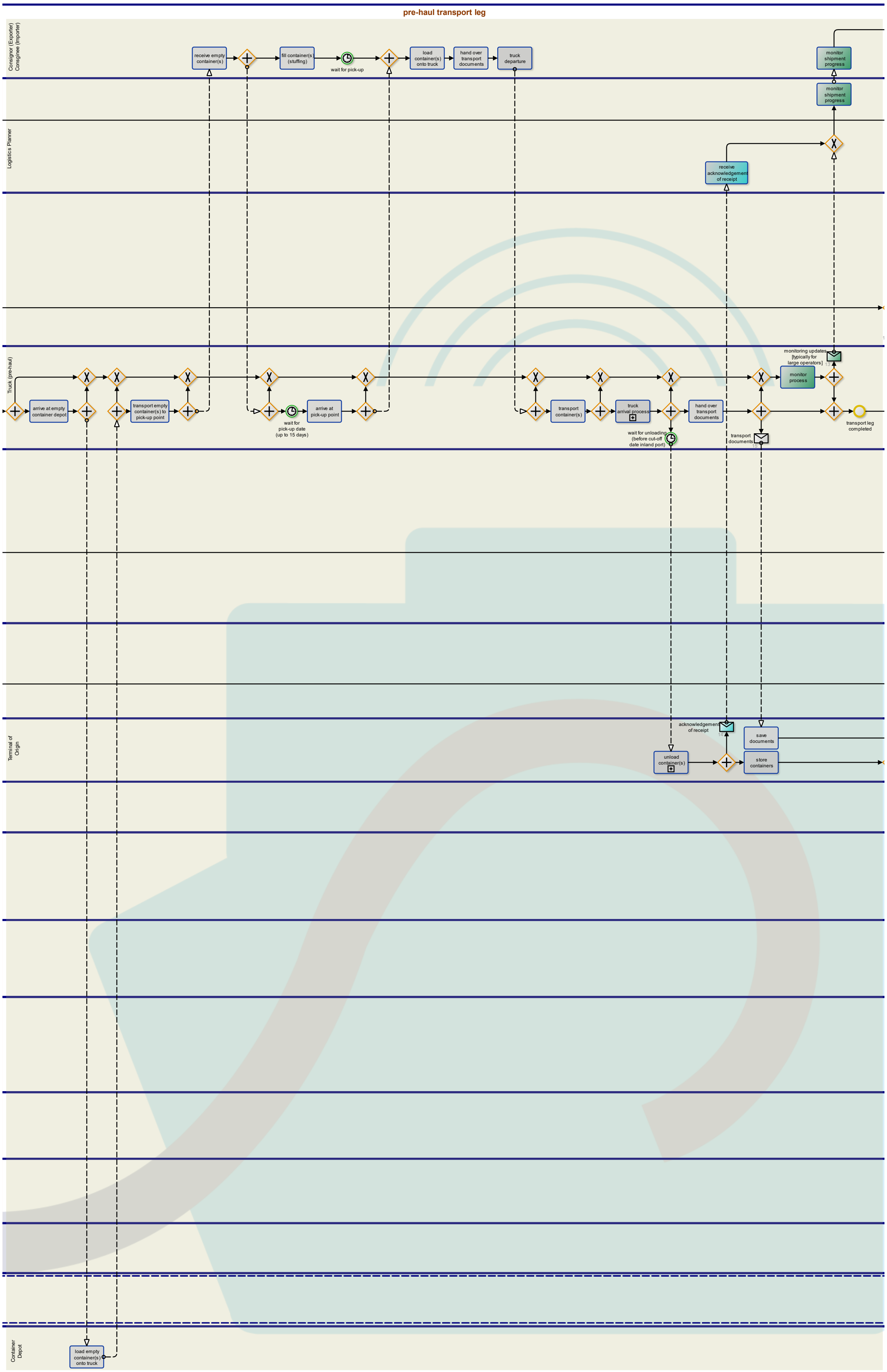


Figure 16. Logistics process flow in the pre-haul transport leg sub-phase (execution phase)

The arrival of a truck at a terminal follows a particular pattern which is described in the following (see Figure 17 and Figure 18): The truck moves to a so-called OCR gate at which the relevant information of the truck, such as the truck licence plate number and the container ID, are retrieved before it moves to the weighbridge in order compute the container weight. The weight has to be determined in order to comply with the latest Safety of Life at Sea (SOLAS) regulation which requires Verified Gross Mass (VGM) information about each packed container in order to be loaded on board the vessels. Both the transport service provider and the port terminal involved in the process require the VGM information. The collected information on truck, container, and weight are submitted to the terminal operator who forwards the container data to the inland shipping company destined to take over the following leg. Meanwhile, the truck checks in at the terminal, transfers the container(s) to a container unloading station, and is parked in its vicinity.

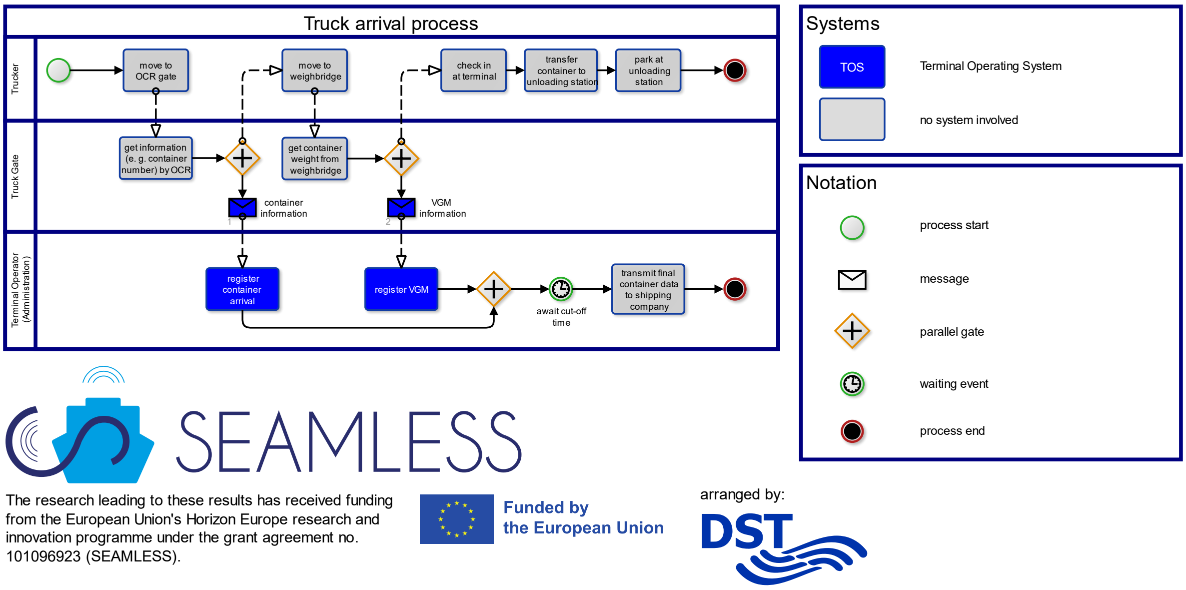


Figure 17. Logistics process flow in the truck arrival sub-process

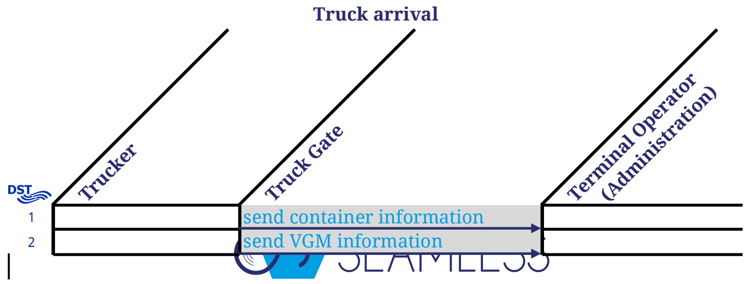


Figure 18. Communication/interaction pattern in the truck arrival sub-process

After the truck arrival, the truck driver submits the transport documents to the terminal, and the containers are unloaded at the terminal. As can be seen in Figure 19 and Figure 20, the truck unloading process begins with a pre-planning by the terminal operator who provides the pertaining plan to the crane operator. Once the truck driver has unsecured the container(s), the crane operator can unload the container(s), complete the process step, and inform both the truck driver and the terminal administration.

Finally, the containers are stored in the container storage area of the terminal, and the terminal operator acknowledges the receipt of the containers to the logistics planner.

The entire process flow in this sub-phase is monitored by the logistics planner who reports to the consignor as his client in case of his enquiries or emergencies.

In the pre-haul transport leg sub-phase, various partners use their TMS – and e-mails for communication and occasionally for the management of transport documents. In the sub-processes, the TOS of the concerned terminal (at the port of origin) is also involved.

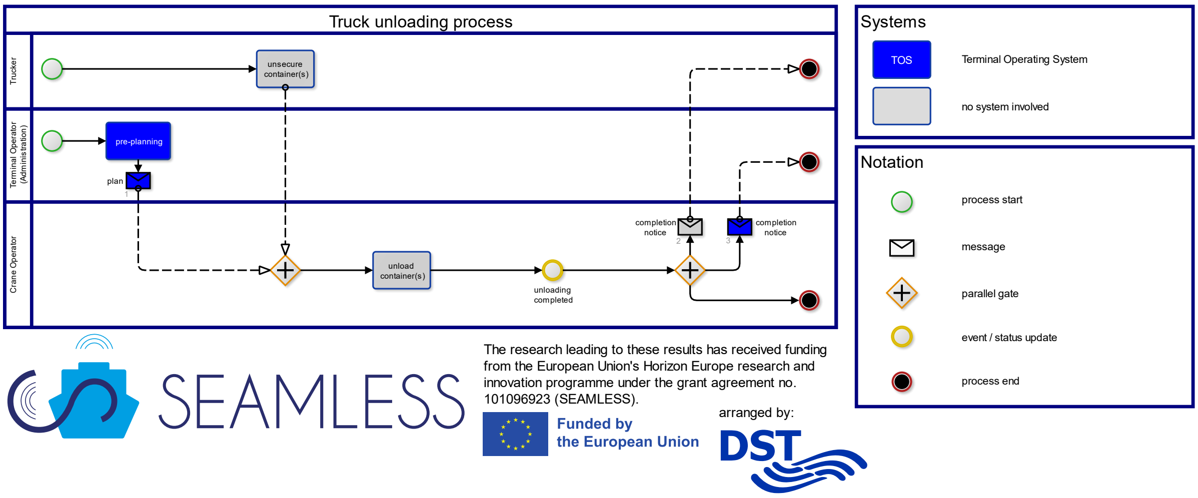


Figure 19. Logistics process flow in the truck unloading sub-process

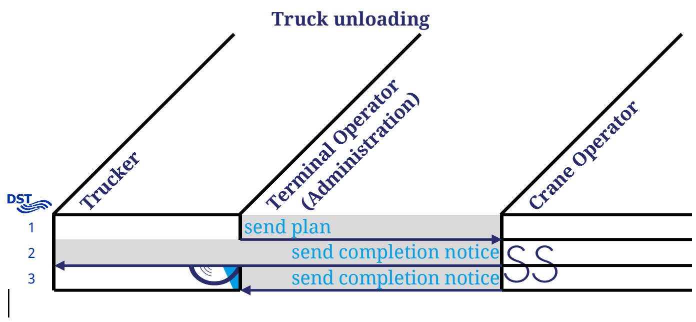


Figure 20. Communication/interaction pattern in the truck unloading sub-process

Execution phase, IWT leg sub-phase

The next sub-phase of the transport execution phase is the IWT leg which begins with the arrival process of the inland vessel at the port of origin and ends with the completion steps in the wake of the transport leg ending (see Figure 21). Apart from the logistics planner and the consignor, the two port authorities and the two terminal operators at the port of origin and the port of intercontinental transshipment, respectively, and – last but not least – the inland shipping company participate in the sub-phase. Additionally, if a customs procedure or a border crossing of the inland vessel is required the customs agent along with the customs office of export and customs office of exit (as part of the border control point) are involved.

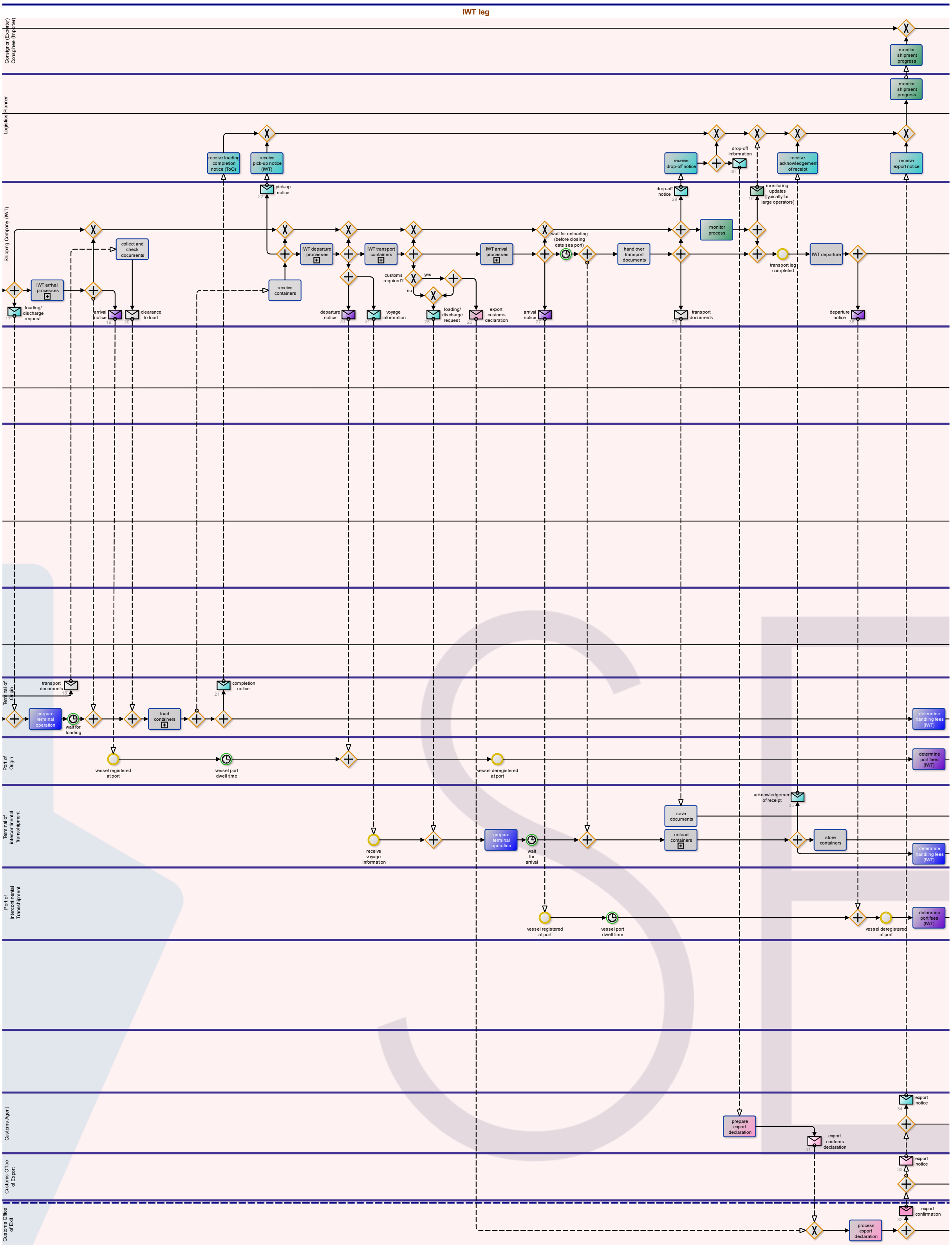


Figure 21. Logistics process flow in the IWT leg sub-phase (execution phase)

By transmitting the loading and discharge request to the terminal operator in the port of origin, the inland vessel announces its arrival prior to its actual arrival process. The loading and discharge request is used by the terminal for operational preparation whereas an arrival notice[16] is sent to the port authority when the vessel arrives at the port.

The arrival process, which is illustrated in Figure 22 and Figure 23, starts with the registration of the inland vessel at the authority by the vessel operator. The port authority receives the registration as arrival notice and allows the inland vessel to arrive at the port of origin in which the vessel operator coordinates the precise arrival procedure in the port basin and at the berth with the terminal operator. On receiving the berth request, the terminal operator assigns a berth at his terminal to the newly arrived inland vessels, checks its current occupancy status, and sends out a readiness notice. In the case of a currently occupied berth, the port authority (instead of the terminal operator) assigns a waiting position which the terminal operator has requested at the port authority following a berth occupied notice. The port authority replies with an assigned waiting berth to which the inland vessel can sail and at which it can wait until berth readiness has been signalled by the terminal operator. As soon as the signal has been given, the inland vessel can sail to the terminal and moor at the terminal.

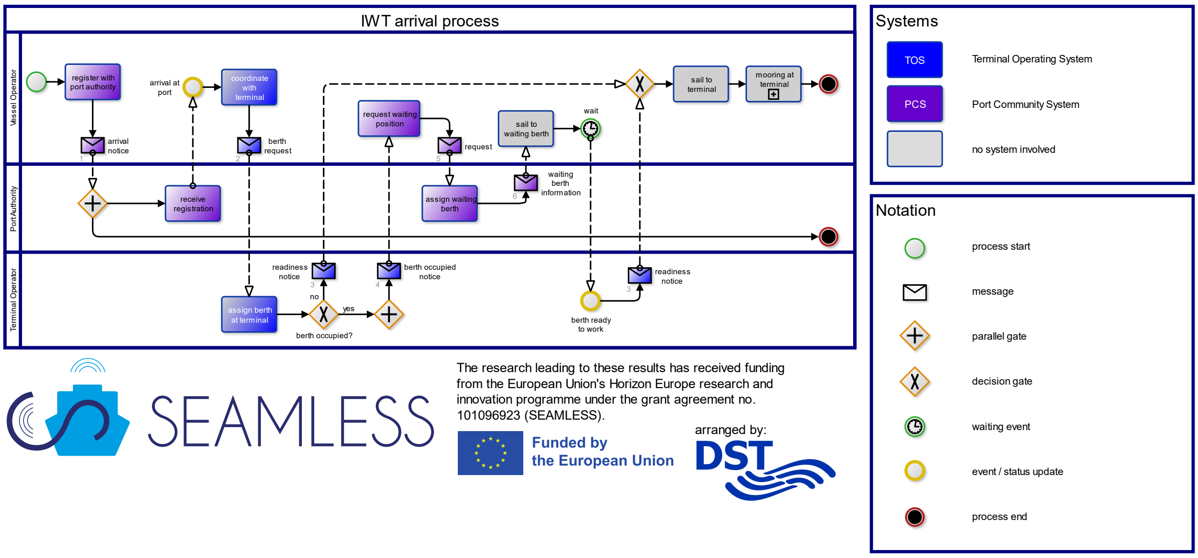


Figure 22. Logistics process flow in the IWT arrival sub-process

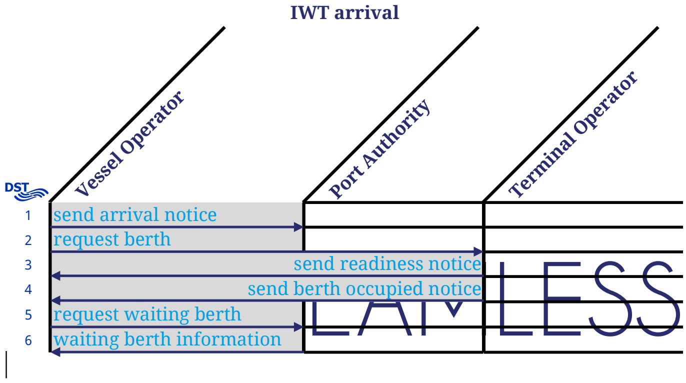


Figure 23. Communication/interaction pattern in the IWT arrival sub-process

The conventional process of a vessel mooring at a terminal is shown in Figure 24 and Figure 25. The inland vessel arrives at the berth and picks up the mooring line. As inland vessels typically do

16 Formally, this is the same arrival notice as in the following IWT arrival sub-process. In order to highlight the link to the port vessel dwell time, the same message has been duplicated and integrated to keep it visible in both diagrams (although only one exists in reality).

not use a mooring service, it remains a purely manual work exclusively on the side of the vessel crew and to place the mooring lines on the bollards and fasten them with the winches aboard.

With the mooring of the inland vessel and, thereby, its arrival completed, the transport documents related to the transport leg are handed over to the inland vessel operator who collects and controls the documents and signals the clearance to load to the terminal operator who start loading containers onto the inland vessel in the following.

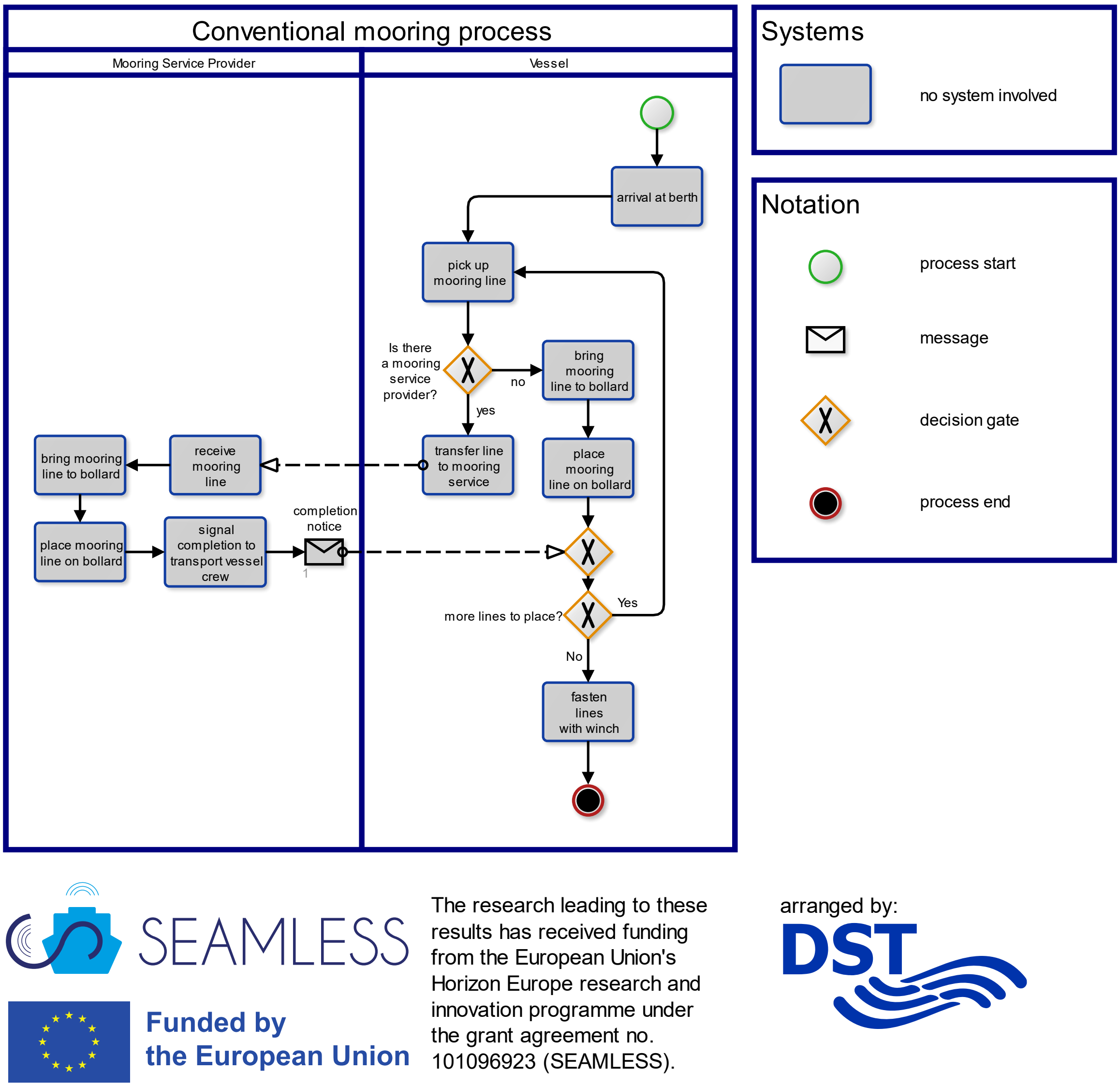


Figure 24. Logistics process flow in the conventional mooring sub-sub-process

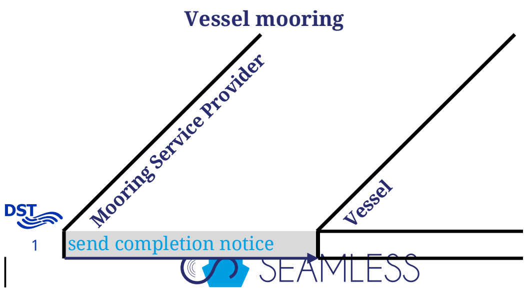


Figure 25. Communication/interaction pattern in the conventional mooring sub-sub-process

As shown in Figure 26 and Figure 27, the vessel loading sub-process starts with a terminal operator conducting his pre-planning and the vessel operator providing a final stowage plan to the terminal operator.

The stowage planning sub-sub-process is initiated by the vessel operator (see Figure 28 and Figure 29). For stowage planning taking place on the landside, e. g., in larger inland shipping companies, the stowage plan is provided by an office staff member to the vessel operator who checks the stowage plan diligently as the vessel operator is the formally responsible party. If the stowage plan appears acceptable to the vessel operator, the final version of the stowage plan is signed and kept ready for transmission to the terminal side.

The final stowage plan is then sent to the crane operator in order to load the containers while the vessel operator secures the loaded container on board the vessel. Once the loading is completed according to the stowage plan, the crane operator notifies both the terminal administration and the vessel operator.

At the same time, the inland shipping company confirms the receipt of the containers and informs the logistics planner. Along with the loading completion notice sent from the terminal operator to the logistics planner, the container reception can be considered as completed. The next step is the departure of the inland vessel.

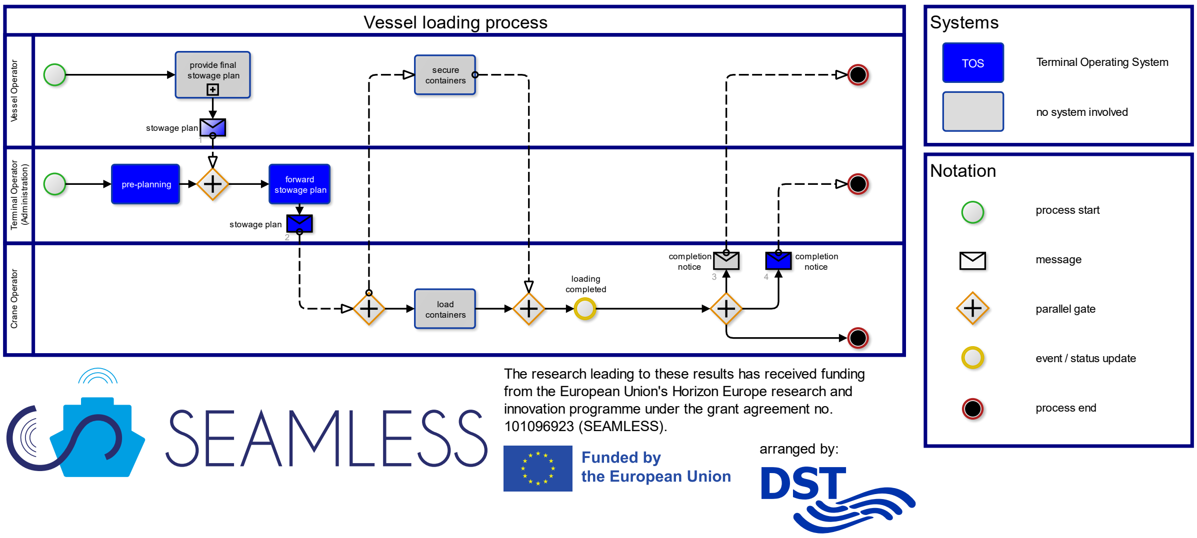


Figure 26. Logistics process flow in the vessel loading sub-process

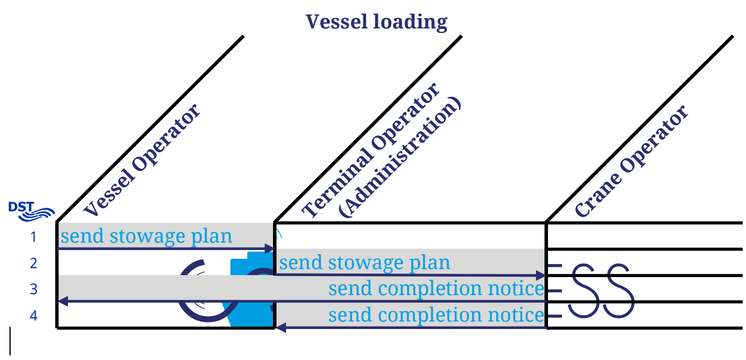


Figure 27. Communication/interaction pattern in the vessel loading sub-process

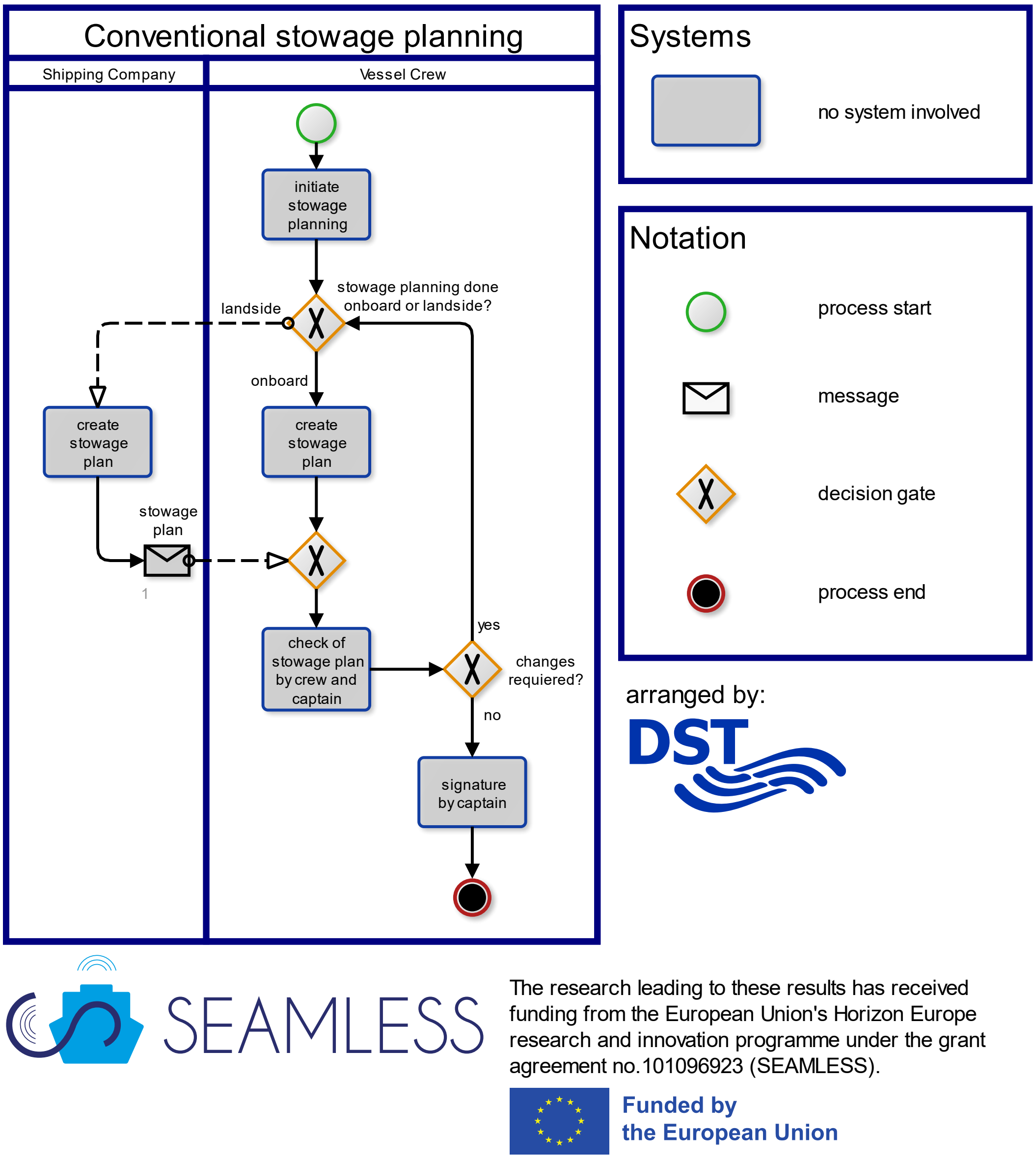


Figure 28. Logistics process flow in the conventional stowage planning sub-sub-process

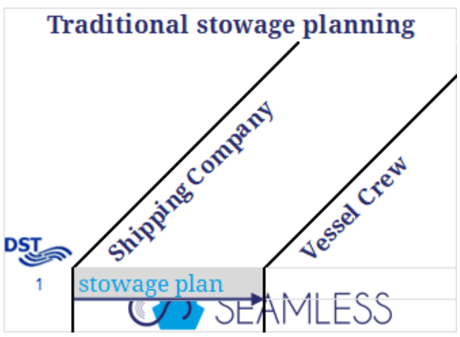


Figure 29. Communication/interaction pattern in the conventional stowage planning sub-sub-process

The departure of the inland vessel begins with a fuel check by the vessel operator (see Figure 30 and Figure 31). In case of insufficient fuel level aboard, a bunkering request is sent to the port authority and forwarded to the bunkering service provider who first confirms the booking request and then provides the service, before comparing quantities before and after the bunkering process. After completing the service and detecting the amount of fuel bunkered, the related invoice is issued by the bunkering service provider and checked by the vessel operator (or the inland shipping company) and the pending amount paid. After the fuel check and (possibly) bunkering, the unmooring process at the terminal takes place before unberthing and departing from the terminal. While sailing to the port exit, a departure notice[17] is transmitted to the port authority prior to actually departing from the port.

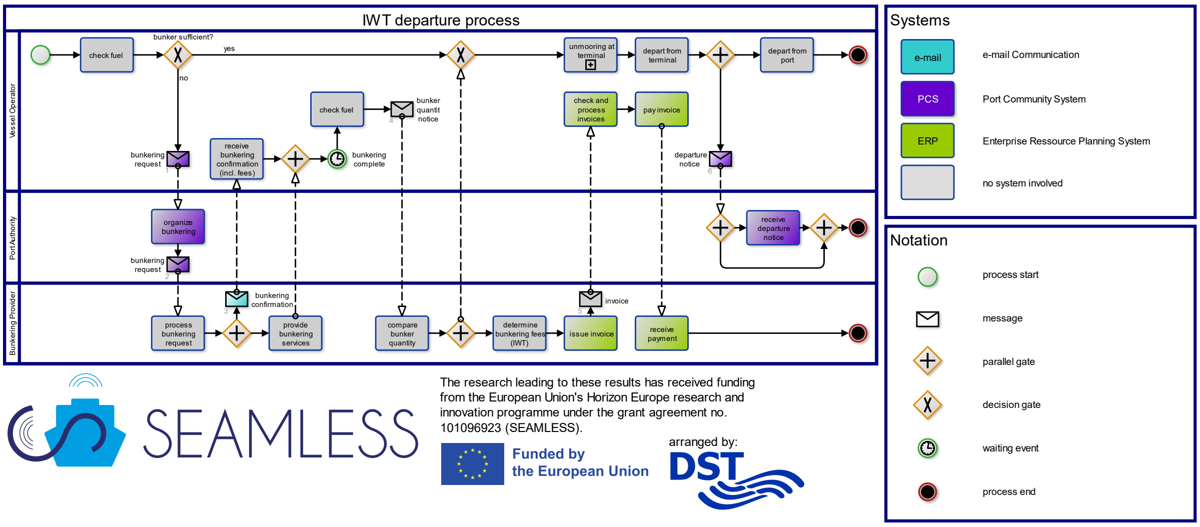


Figure 30. Logistics process flow in the IWT departure sub-process

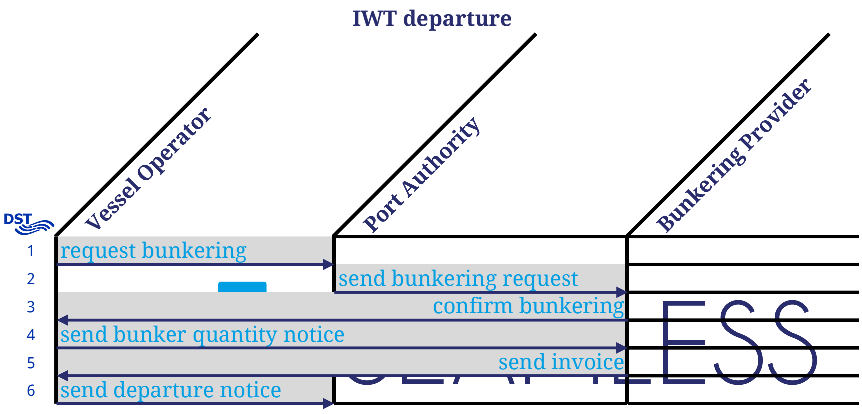


Figure 31. Communication/interaction pattern in the IWT departure sub-process

The conventional unmooring process is illustrated in Figure 32 and Figure 33 and begins with the vessel loosening the lines with the winch. As mooring service providers are unusual in IWT, the mooring line is retrieved manually from the bollard and returned to the inland vessel, which accommodates the mooring line safely and securely on board. Once all lines are unmoored in this way, the process is considered completed.

The departure of the inland vessel from the port of origin is followed by a departure notice provided by the vessel operator to the port authority upon departure. The port authority issues the fees for cargo handling and sends the corresponding invoice to the inland shipping company. Shortly after the departure notice, the inland shipping company approaches the terminal operator at the port of

17 Formally, this is the same departure notice as in the following IWT departure sub-process. In order to highlight the link to the port vessel dwell time, the same message has been duplicated and integrated to keep it visible in both diagrams (although only one exists in reality).

destination and places his loading and discharge request. Thereby, the terminal operator receives a voyage information at an early stage.

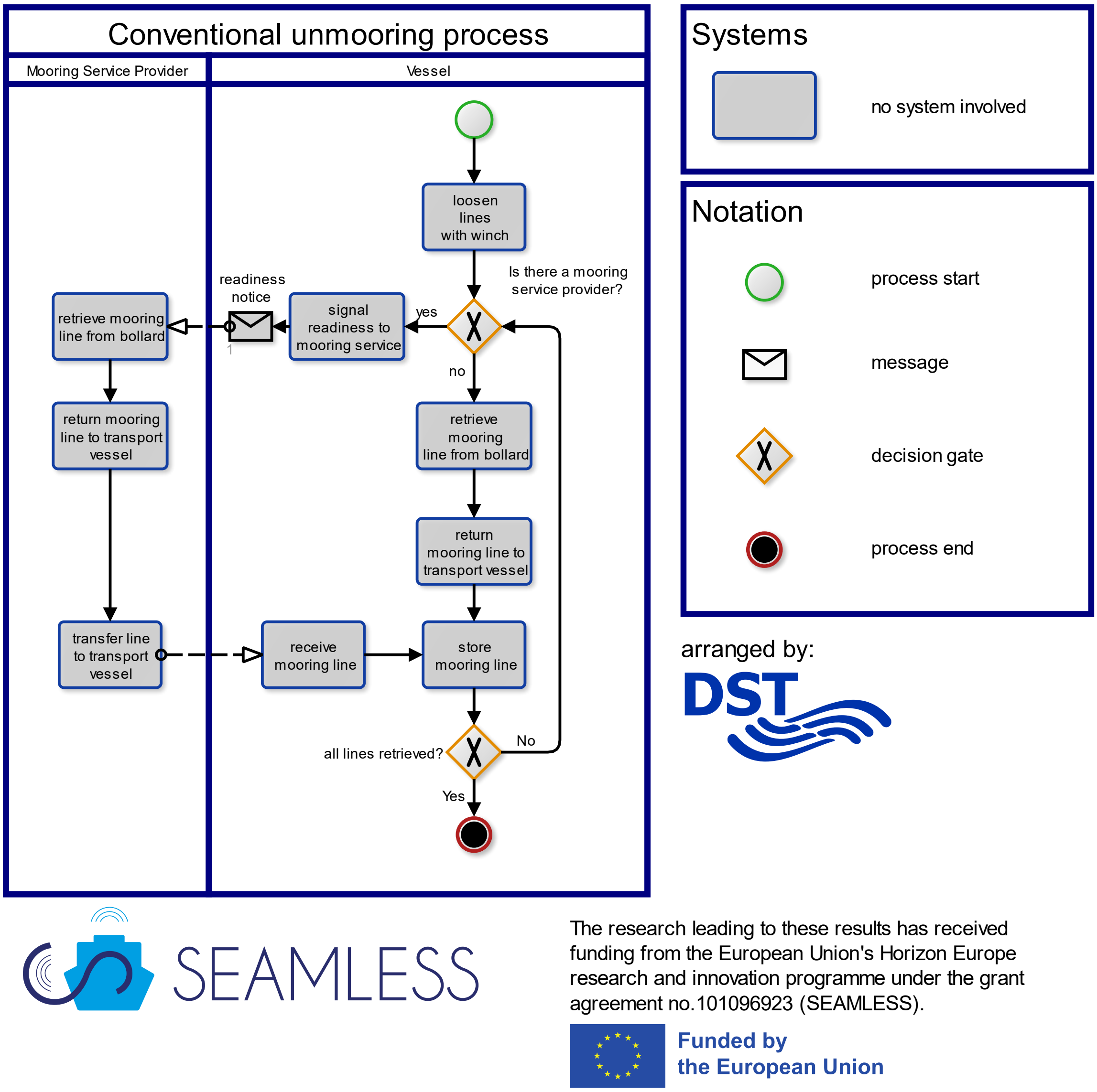


Figure 32. Logistics process flow in the conventional unmooring sub-sub-process

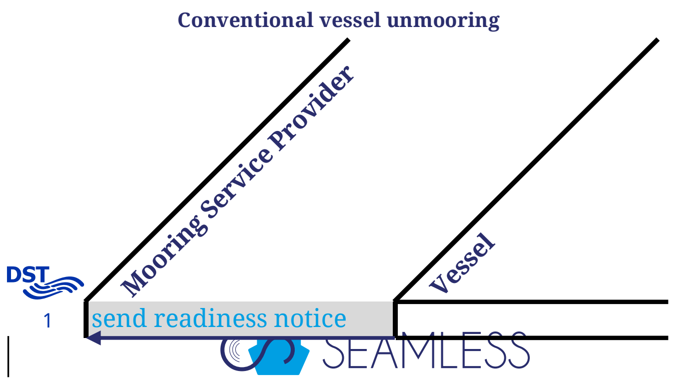


Figure 33. Communication/interaction pattern in the conventional unmooring sub-sub-process

Then, the actual inland vessel transit on the waterway with the container transport takes place (see Figure 34, Figure 35, Figure 162, Figure 163, Figure 164, and Figure 165). Whereas the actual sailing process is a negligible process step within the logistics process flow, there may occur various situations in which a situation requiring an interaction between the vessel operator and miscellaneous other parties. In case a registration with the inland waterway authority is required, such a registration is placed with the help radio communication (or a phone call or via app, alternatively) by the vessel operator and processed by the waterway authority. Additionally, to the registration with an inland waterway authority the vessel might cross border that is relevant to the customs process. In this case the vessel will have to stop at a border control point and announce its arrival. The vessel crew operator will have to go through the border control process and on-board checks in order to proceed. Furthermore, if the vessel is not in transit through the country it is about to enter or it is at the final border of the country or trade union from where the cargo originates the vessel will also need to declare the export at the customs office of exit. This export declaration will be revisited in the main process diagram. In case of a lock passage, the vessel operator informs the lock operator about the requested lockage service ahead of the arrival at the respective lock, whereupon the lock operator indicates the occupancy status of the lock. Once arrived at the lock, the inland vessel might sail to the access channel, possibly wait for access, enter the lock chamber, and moor the inland vessel inside the lock, while the lock operator closes the lock chamber, adjusts the water level (manually or automatedly), and reopens the lock gate. The vessel unmoors and leaves the lock in order to continue sailing. It should be noted though that waiting times at a lock may also depend on the sailing regime pursued in order to make use of driving time breaks in an optimal manner. Similar procedures are in place for passing critical waterway stretches, such as shallow-water stretches or narrow fairway sections, in which a coordination of the inland vessel with the oncoming traffic according to existing traffic regulations on the respective waterway is required. The same applies to overtaking procedures. Both procedures are included in Figure 34 but left out of the textual description of the cargo transport process. It is important to mention that the vessel operator engages in maintenance and repair works during transit and that the logistics planner is able to monitor the entire sailing process and to inform the consignor (or consignee, respectively) as well.

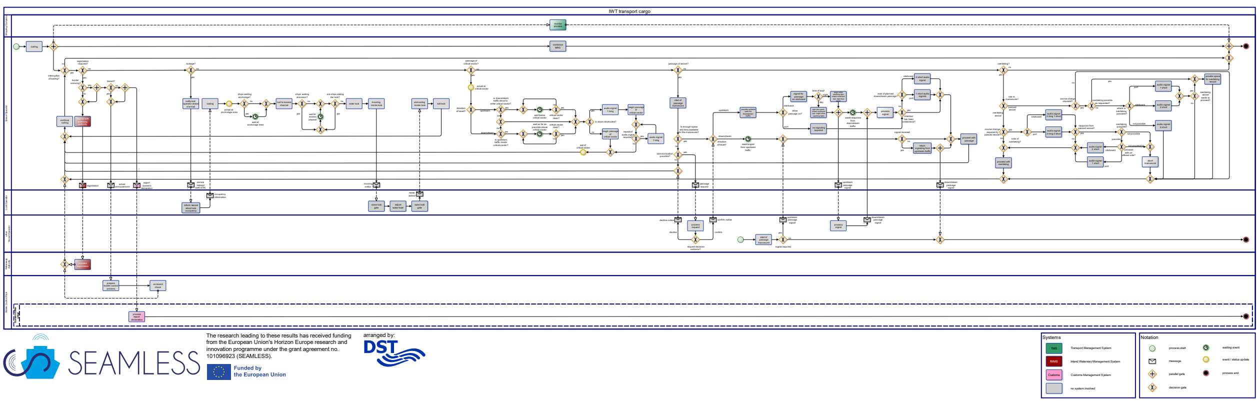


Figure 34. Logistics process flow in the IWT transport cargo sub-process

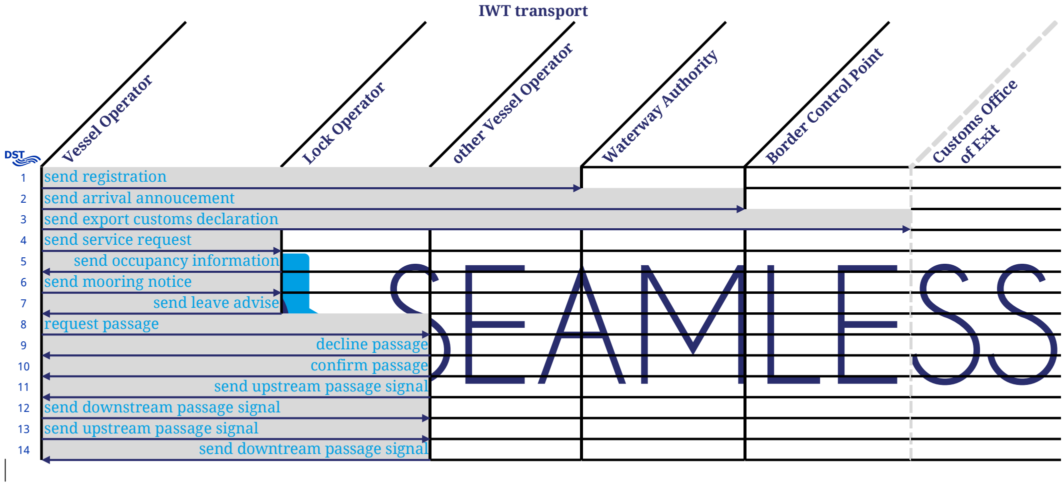


Figure 35. Communication/interaction pattern in the IWT transport cargo sub-process

In the main process diagram from the IWT transport cargo sub-process originates the export customs declaration where it is required. If this is the case the export customs declaration will be processed by the customs office of exit where the cargo will be validated and confirmed for export. The customs office of exit will transmit the export confirmation to the customs office of export which will in turn notify the customs agent. The customs agent will relay the export notice to the logistics planner to let them know the customs procedure is completed. The export notice will be used in the monitoring process of the logistics planner. Prior to the arrival at the port of intercontinental transshipment, the vessel operator sends a loading and discharge request to the terminal operator who then knows about the upcoming arrival of the inland vessel beforehand and can prepare on-site operations at the terminal while awaiting the arrival. When the inland vessel physically approaches the entry of the port of intercontinental transshipment, an arrival notice is exchanged between the vessel operator and the port authority who receives it as the port call. Another arrival process of the inland vessel takes place, following a pattern similar to the one explained above and shown in Figure 22. That arrival includes another conventional mooring step again, as illustrated in Figure 24. The vessel operator hands over the transport documents to the terminal operator who saves the documents while the container unloading sub-process is initiated in the meantime.

Similar to the vessel loading sub-process, the vessel unloading sub-process begins with the pre-planning of the terminal operator and the final stowage plan of the vessel operator before the crane operator receives a final stowage plan according to which the inland vessel is to be unloaded after the vessel operator has unsecured the containers (see Figure 36 and Figure 37). When the crane operator has completed the unloading process, both the terminal administration and the vessel operator are informed. The logistics planner receives a drop-off notice from the inland shipping company and an acknowledgement of receipt from the terminal operator, while the terminal operator stores the containers recently unloaded at the container storage area. With the drop-off notice by the inland shipping company the logistics planner will also initiate the export process for the cargo at the seaport and inform the customs agent about the drop-off at the terminal. The customs agent will prepare and lodge the export customs declaration which will also be processed by the customs office of exit. Once finished the customs office of exit will send the export confirmation to the customs office of export who will notify the customs agent. He will as before relay the export notice to the logistics planner who utilizes it in his monitoring process. The transport leg is considered as completed, and the inland vessel either stays in the port for a follow-up order or leaves the port for that and informs the port authority about the departure whereupon the port authority issues the port fees for its port vessel dwell time and used services. The port authority charges the port fees and sends the corresponding invoice to the inland shipping company.

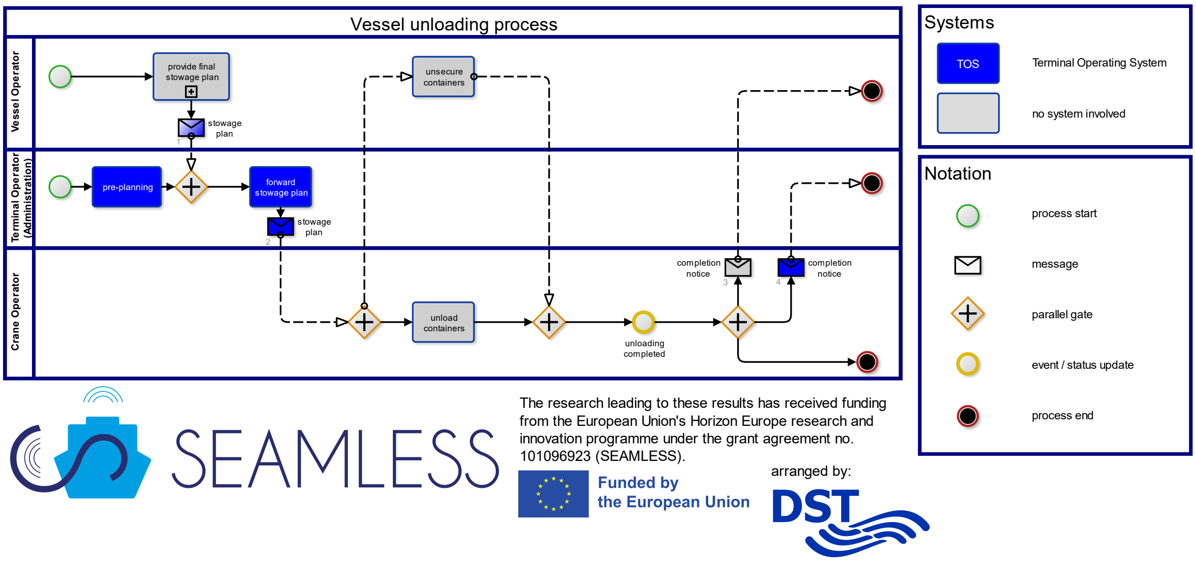


Figure 36. Logistics process flow in the vessel unloading sub-process

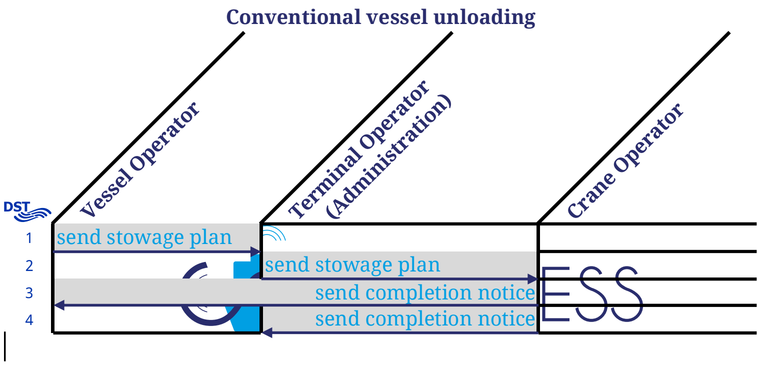


Figure 37. Communication/interaction pattern in the vessel unloading sub-process

The entire process flow in this sub-phase is monitored by the logistics planner who reports to the consignor as his client in case of his enquiries or emergencies.

The business information systems involved in the sub-phase are TMS, TOS, and PCS as well as ERP systems and Inland Waterway Management Systems (on the level of the sub-processes) while communication takes place via e-mail, radio communication, or even app (of the inland waterway authority).

Execution phase, SSS leg sub-phase

After the IWT leg, the multimodal transport chain of the underlying Reference Logistics System Architecture foresees a SSS leg, which starts with the arrival of the vessel at the port and ends with the final steps following the transport leg ending (see Figure 38). Besides the consignor and the logistics planner, the short-sea shipping company, the two port authorities and the two terminal operators at the port of intercontinental transshipment and the port of destination, respectively, participate in the sub-phase.

The process begins with the loading and discharge request transmitted to the terminal operator in the port of intercontinental transshipment by the short-sea vessel while still in transit on its way to the port. While the terminal prepares its operations, an arrival notice[18] is sent to the port authority when the vessel arrives at the port.

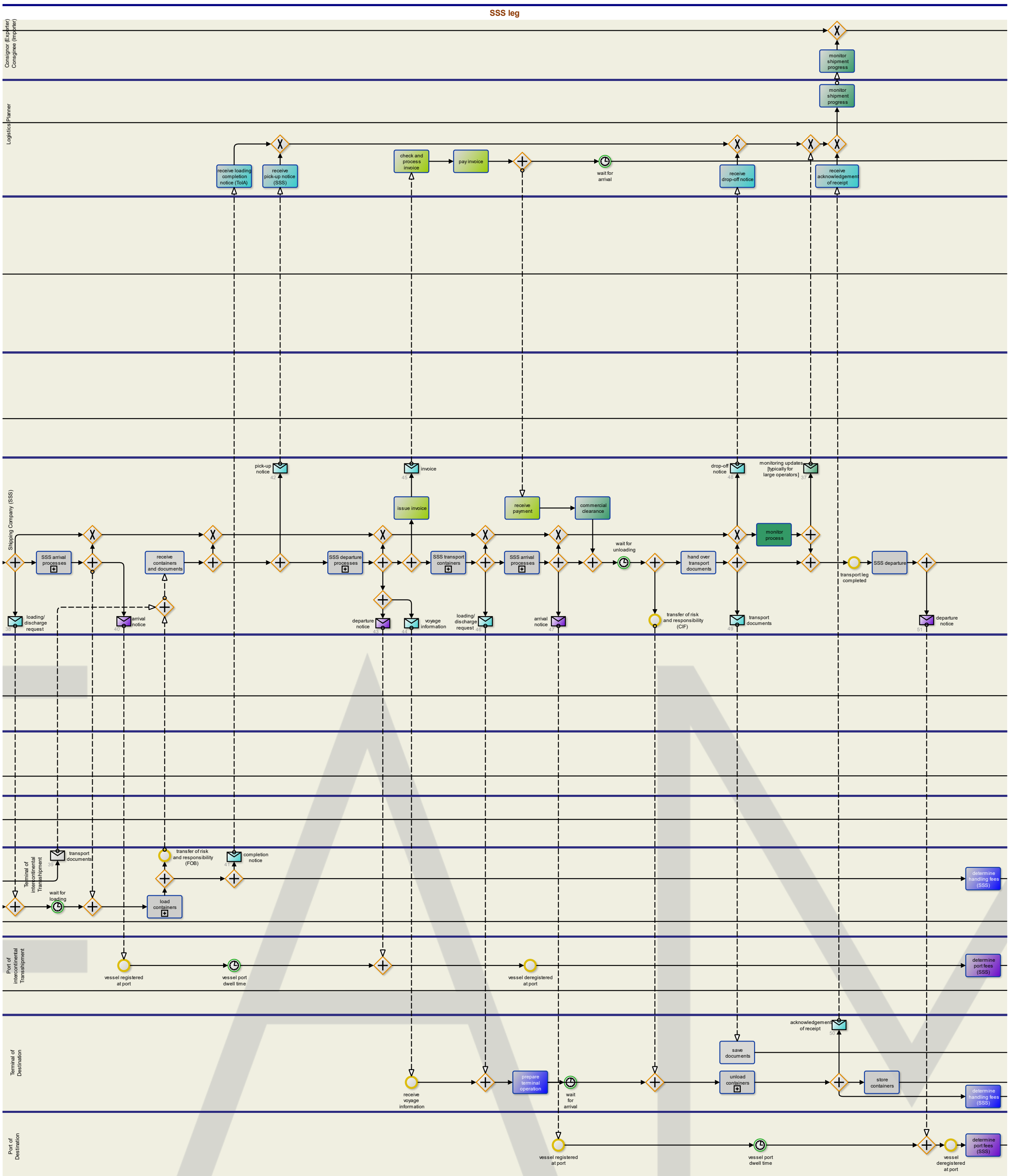


Figure 38. Logistics process flow in the SSS leg sub-phase (execution phase)

18 Formally, this is the same arrival notice as in the following SSS arrival sub-process. In order to highlight the link to the port vessel dwell time, the same message has been duplicated and integrated to keep it visible in both diagrams (although only one exists in reality).

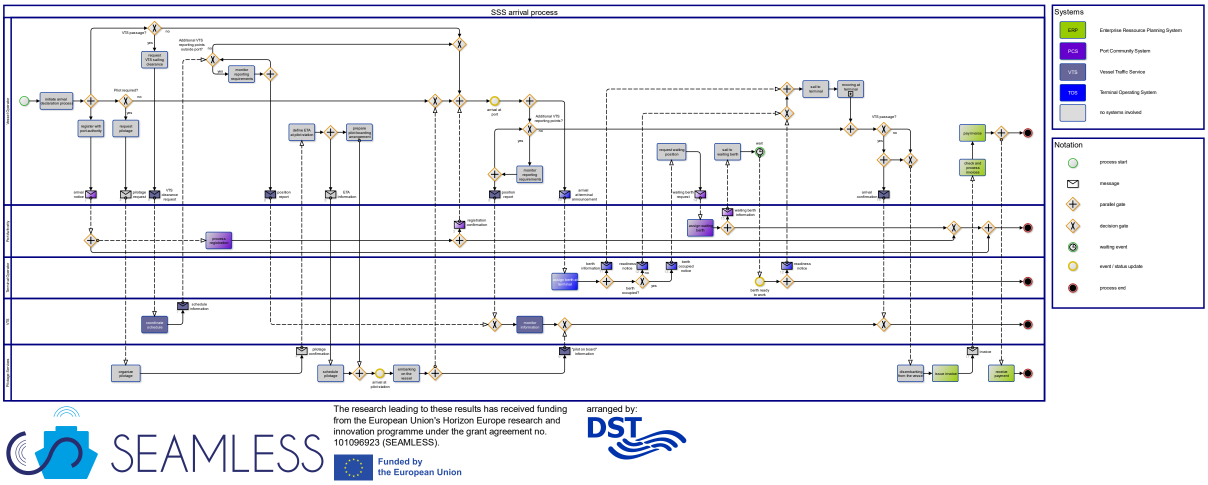


Figure 39. Logistics process flow in the SSS arrival sub-process

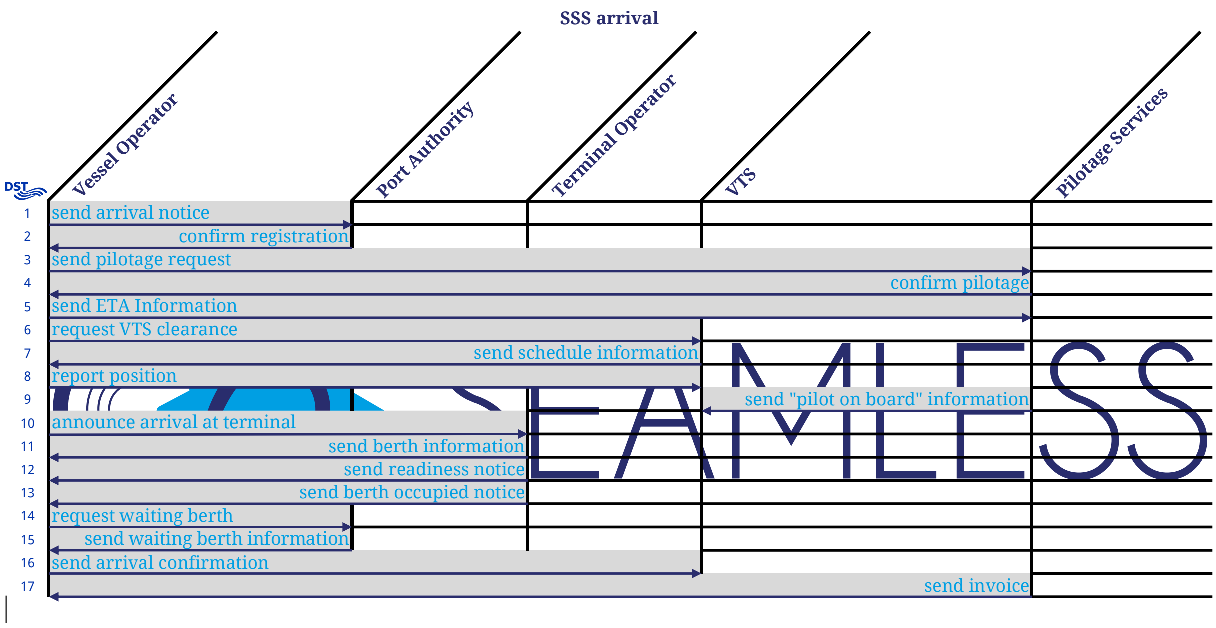


Figure 40. Communication/interaction pattern in the SSS arrival sub-process

As shown in Figure 39, Figure 40, Figure 166, and Figure 167, the arrival process of the short-sea vessel starts with the arrival declaration process of the vessel operator, followed by the registration with the port authority who process that registration and confirm it to the vessel operator. At the same time, the vessel operator decides whether or not to use VTS passage. If yes, he is to request sailing clearance from the VTS who coordinate their schedule and send relevant schedule information back. In case there are additional VTS reporting points outside the port, the position is to be reported to the VTS. Also, the vessel operator needs to decide whether a pilot is required. If so, the vessel operator needs to request pilotage which the pilotage service provider would organize accordingly before informing the vessel operator about the confirmation. The vessel operator defines the estimated time of arrival (ETA) at the pilot station, informs the pilotage service provider about that prospective arrival time, and makes arrangements on board for the pilot boarding process. Once the vessel has arrived at the pilot station, the pilot embarks the vessel, and the pilotage service provider sends a “pilot-on-board” information to the VTS. Regardless of whether a pilot is aboard and whether VTS passage has been used or not, the vessel arrives at the port, sends out an announcement about its arrival at the terminal, and is assigned a berth of the destined terminal by the VTS upon request.

Moreover, it releases a readiness notice according to TIC4.0 standards once the terminal and the berth are ready. Should it not be ready, a waiting position is requested by the vessel operator and assigned by the terminal operator, before it sails to its temporary waiting location and waits there until the terminal readiness is given. Should it have become ready, a new readiness notice is sent out from the terminal operator to the vessel operator, and the vessel moves to the final destination in order to berth and moor there. The conventional mooring step is shown in Figure 24. In case of VTS passage, the information was monitored throughout the entire process steps which ends with the arrival notification. Next, the pilot disembarks the vessel and the pilotage service provider issues an invoice which the vessel operator (or the inland shipping company) checks and processes before initiating the payment.

When the arrival process of the short-sea vessel is completed, the next step is the vessel loading sub-process which has been described earlier as part of the IWT leg phase and presented in Figure 26. With the loading of the containers on board, the point of transfer of risk and responsibility for the Incoterm "Free On Board" (FOB) is achieved. The documents and containers are received by the short-sea shipping company while the terminal sends a loading completion notice to the logistics planner. Parallelly, the short-sea shipping company sends a pick-up notice to the logistics planner, confirming the receipt of the containers.

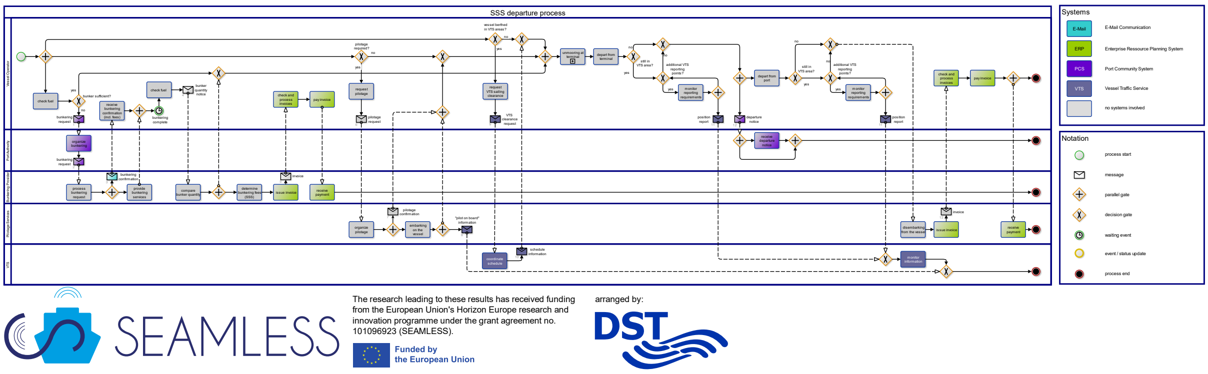


Figure 41. Logistics process flow in the SSS departure sub-process

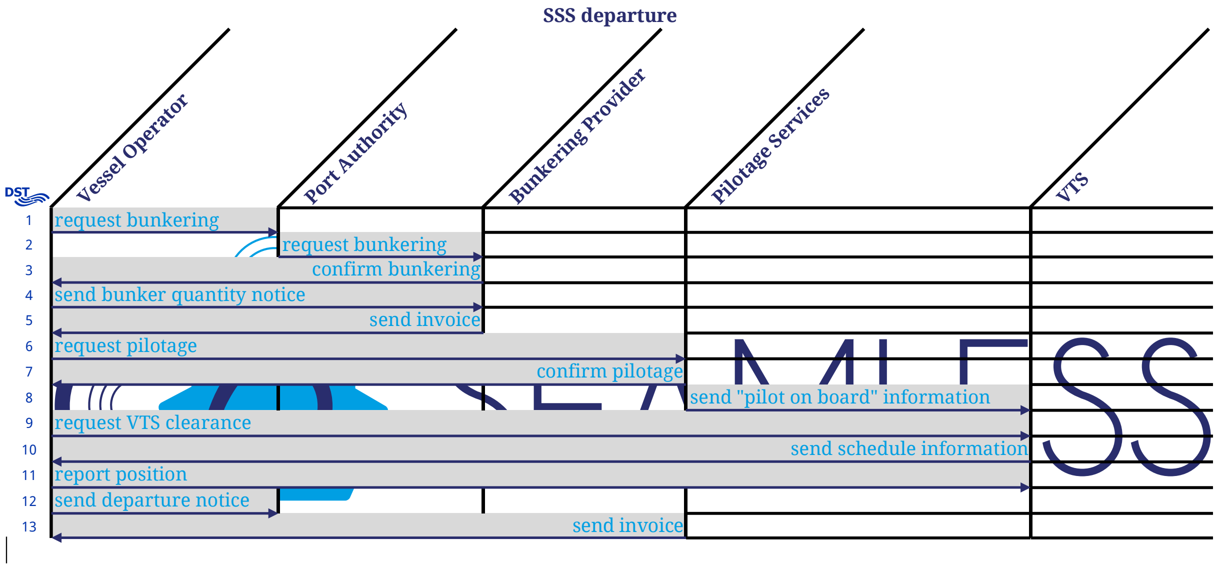


Figure 42. Communication/interaction pattern in the SSS departure sub-process

The departure of the short-sea vessel is illustrated in Figure 41, Figure 168, Figure 169, and Figure 42. The sub-process starts with a fuel check and foresees a bunkering request from the vessel operator to the bunkering service provider which is processed and confirmed before the actual bunkering provided by the service provider takes place. Once finished and the bunker quantity determined, the related fees are computed and the invoice issued. With the payment of the invoice amount, the bunkering service is competed. The next decision refers to the need of a pilotage service which would be requested and organized between the vessel operator and pilotage service provider before a pilot embarks the vessel until leaving the port. Also, the VTS is informed by a "pilot on board" message. In case the vessel is berthed in a VTS surveillance area, sailing clearance has to be requested at the VTS which coordinates the schedule and informs the vessel operator about the assigned time window. The vessel is unmoored, following the description of the IWT departure sub-process and the corresponding illustration in Figure 32, sends out a departure notice[19] to the port authority, and departs from the terminal. The next step is the departure from the port. In case the vessel is still in the VTS area and there are additional VTS reporting points, the vessel monitors the reporting requirement and transmits a position report to the VTS, which monitors the information about the departure process until the vessel has eventually left. On its way to the exit, the pilot disembarks from the vessel before the pilotage service is invoiced to the inland shipping company and the corresponding payment made by them.

In international trade and export to extra-Union destinations, it is important that the invoice is issued and sent to the logistics planner who checks, processes, and pays the invoice prior to the unloading of the container. This may imply the arrival of the vessel at the port of destination. The payment is a prerequisite to generating and transmitting a container reference number which is used for the pick-up reference for the road carrier responsible for the post-haul transport leg.

After the departure of the vessel, the cargo transport by short-sea vessel follows next (see Figure 43, Figure 44, Figure 170, and Figure 171). The vessel is in sailing mode and requires activity from the vessel operator in particular situations. In the case of lock passage, the lock operator is informed about the requested lock passage and the corresponding time ahead of arrival via radio or phone message who checks the designated lock status at the ETA and either assigns clearance to enter or – in case of occupancy – sends a waiting notice so that the vessel would navigate to waiting area until the message to enter the lock would arrive. Then, the vessel enters the lock and moors inside the lock chamber before the lock gate is closed, the water level adjusted as part of the lockage process, and the gate re-opened. The unmoored vessel exits the lock and continues sailing. In situations in which the vessel needs to request sailing clearance from the VTS who coordinates the schedule and provides schedule information when the VTS clearance is to be processed. In situations in which the vessel is to leave VTS area, the vessel operator is supposed send a leaving notice to the VTS which monitors the reporting requirements while the vessel leaves the port. There are further procedures for COLREG situations and additional VTS reporting points which are illustrated in Figure 43 but are disregarded at this point. It is important to mention that the vessel operator engages in maintenance and repair works during transit and that the logistics planner is able to monitor the entire sailing process and to inform the consignor (or consignee, respectively) as well.

[19] Formally, this is the same departure notice as in the following SSS departure sub-process. In order to highlight the link to the port vessel dwell time, the same message has been duplicated and integrated to keep it visible in both diagrams (although only one exists in reality).

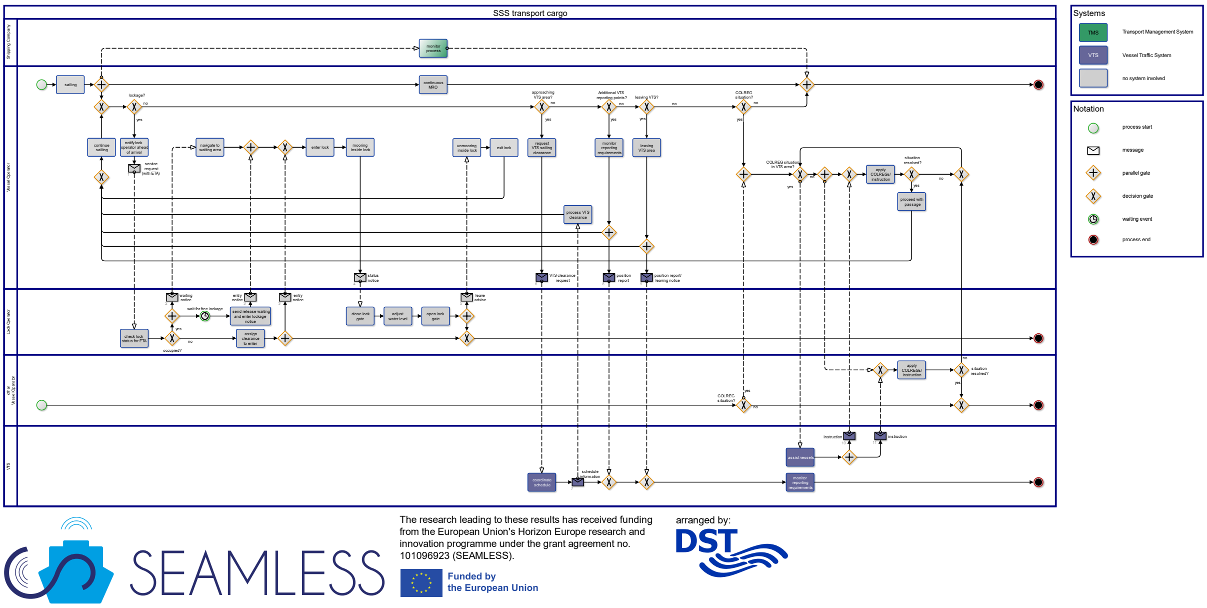


Figure 43. Logistics process flow in the SSS transport cargo sub-process

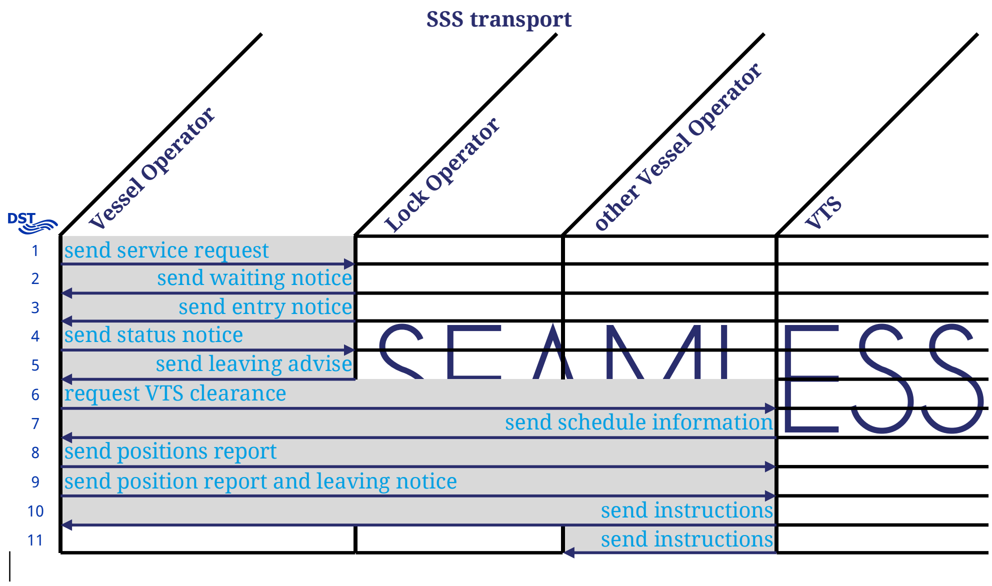


Figure 44. Communication/interaction pattern in the SSS transport cargo sub-process

The cargo transport sub-process is succeeded by the arrival of the short-sea vessel in the port of destination, following a pattern similar to the one explained above and shown in Figure 39. That arrival includes another conventional mooring step again, as illustrated in Figure 24. By arriving at the port of destination, the point of transfer of risk and responsibility for the Incoterm CIF is achieved. While the vessel operator hands over the documents to the terminal, the process of container unloading from the vessel begins. The container unloading sub-process has been already described earlier and is shown in Figure 36, so that a repeated elaboration has been omitted. After unloading the cargo, the logistics planner receives a drop-off notice from the short-sea shipping company and an acknowledgment of receipt from the terminal operator. On the terminal itself, the containers are stored in the container storage area while the terminal administration issues an invoice for the handling fees incurred. The transport leg is considered as completed, regardless of whether the short-sea vessel stays in the port for a follow-up order or leaves the port for that and informs the port authority about the departure. Upon departure, the port authority charges the short-sea shipping company the port fees for its port vessel dwell time and used services and invoices the incurred fees to the carrier.

The entire process flow in this sub-phase is monitored by the logistics planner who reports to the consignor as his client in case of his enquiries or emergencies.

The business information systems involved in the sub-phase are TMS, TOS, and PCS as well as ERP systems, and VTS (on the level of the sub-processes) while communication takes place via e-mail, phone, or radio communication.

Execution phase, post-haul transport leg sub-phase

With the arrival of the containers at the port of destination, the final transport leg begins. Precisely, the post-haul transport leg sub-phase begins with the request of pick-up references by the logistics planner and ends with the empty container returned to the depot defined as drop-off location (see Figure 45). Involved in the final sub-phase are the road haulier responsible for the post-haul leg, the terminal of destination, and the empty container depot as well as the logistics planner and the consignor (or consignee, respectively).

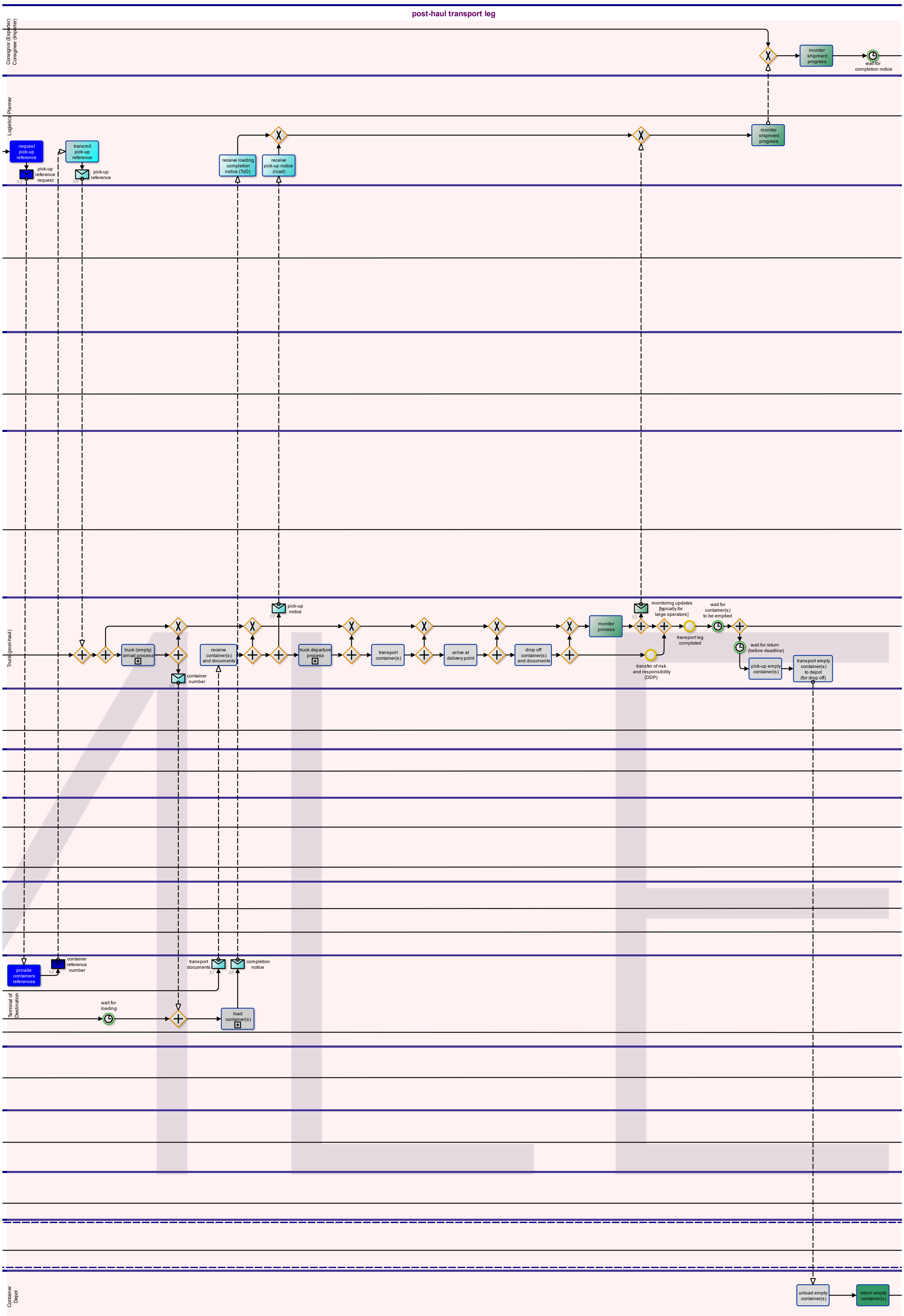


Figure 45. Logistics process flow in the post-haul transport leg sub-phase (execution phase)

The container pick-up reference is requested from the terminal of destination by the logistics planner in order to be retrieve and transport the container off the terminal. The terminal provides the requested container references to the logistics planner who forwards these to the road carrier via e-mail. The road carrier arrives at the port of destination with an empty truck in order to retrieve and collect the containers for the post-haul transport leg.

The arrival of the empty truck is shown in Figure 46 and Figure 47 and begins with the arriving truck moving to the OCR gate which detects licence plate and name. Afterwards, the OCR information is sent to the terminal operator for the purpose of truck arrival registration. The trucker checks in at the terminal and parks at the loading station in order to take over the final transport plan.

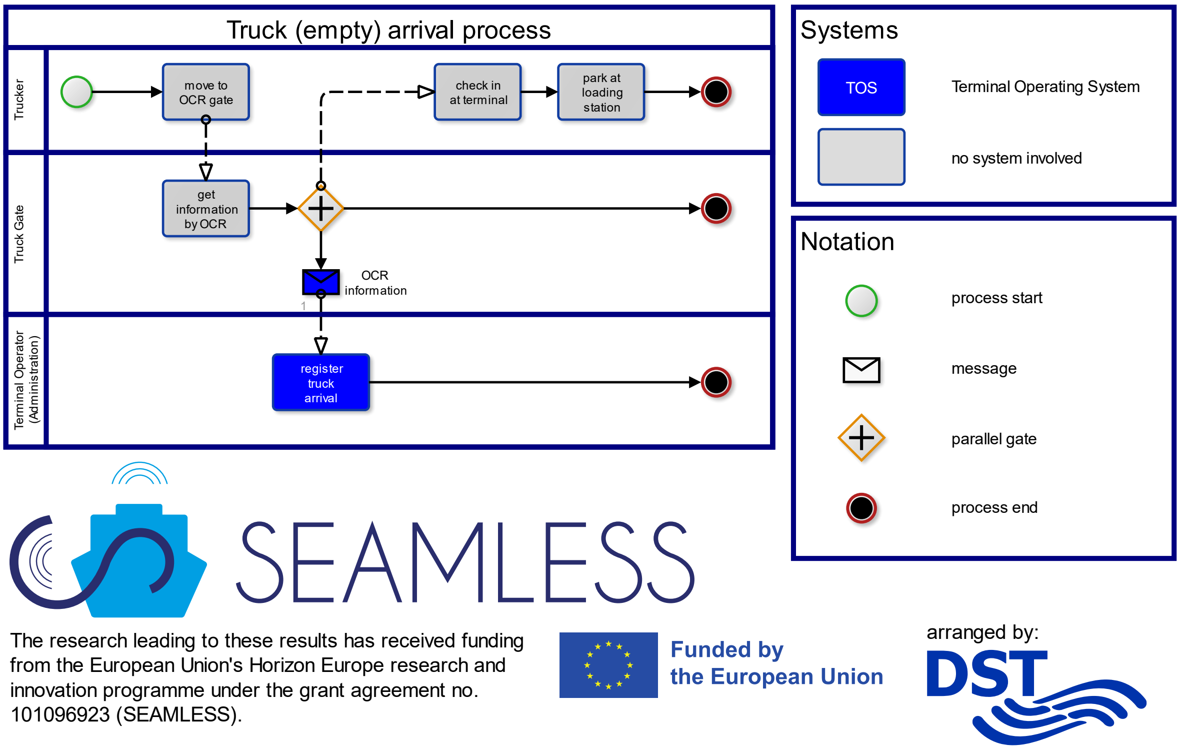


Figure 46. Logistics process flow in the empty truck arrival sub-process

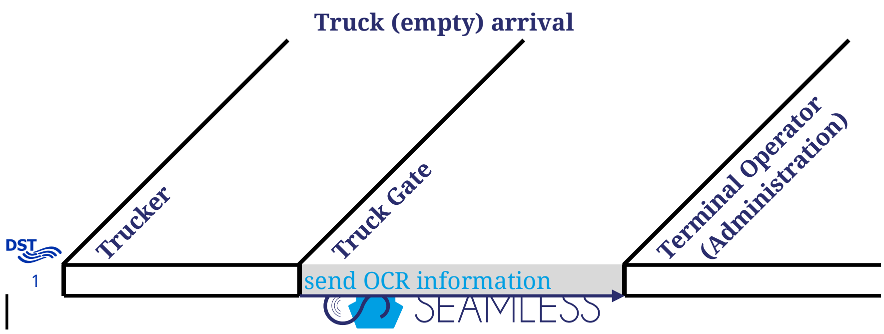


Figure 47. Communication/interaction pattern in the empty truck arrival sub-process

With the subsequent transmission of the container numbers, the truck driver receives the transport documents, and the terminal of destination starts to loading the container(s) onto the truck. The truck loading sub-process is shown in Figure 48 and Figure 49 and foots on the pre-planning of the terminal operator. The corresponding plan is provided to the crane operator who loads the containers onto the truck and informs both truck driver and terminal administration about completion. The truck driver secures the containers eventually.

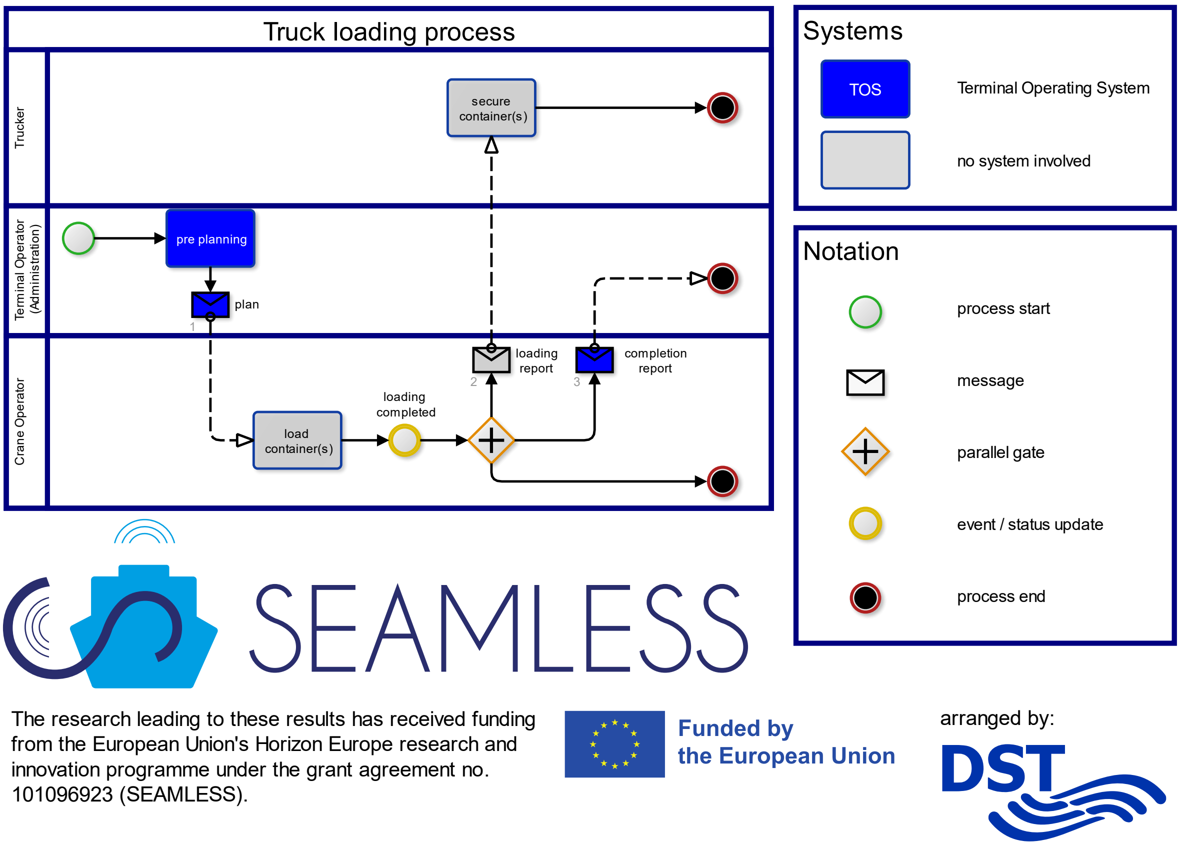


Figure 48. Logistics process flow in the truck loading sub-process

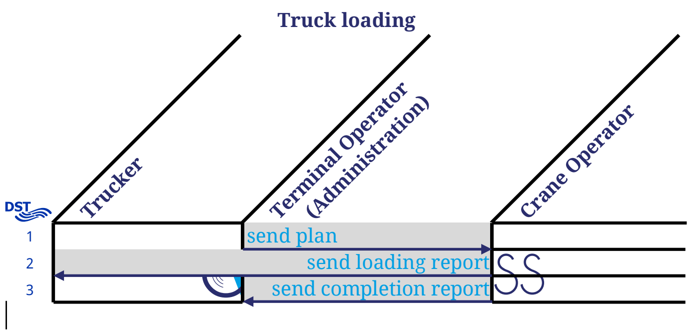


Figure 49. Communication/interaction pattern in the truck loading sub-process

After the loading process, the logistics planner receives a loading completion notice from the terminal operator and a pick-up notice from the truck driver. In the following, the truck can leave the terminal. The corresponding truck departure sub-process is shown in Figure 50 and Figure 51. The truck moves to the container unloading/loading station, arrives at the exit gate, moves to the OCR gate which records licence plate, container ID, and possibly other information automatically, which again is transmitted to the TOS of the terminal operator. The truck leaves the gate, and transports the container(s) to the consignee.

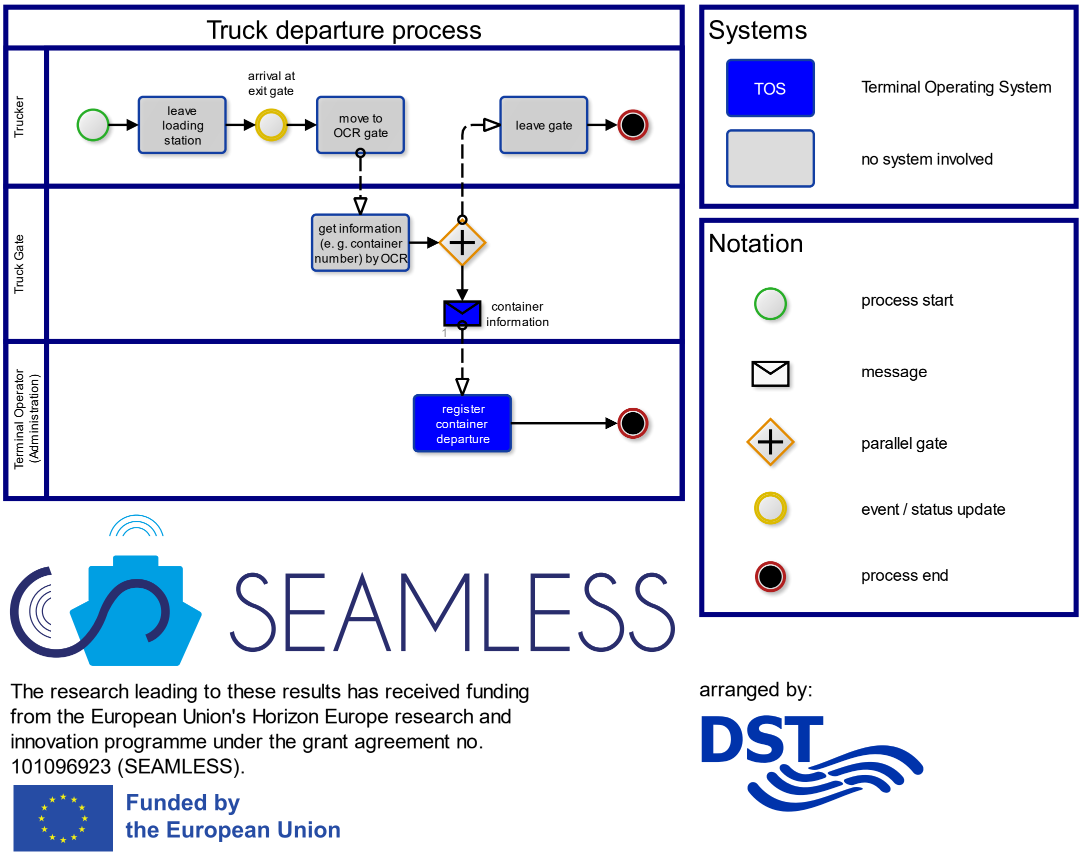


Figure 50. Logistics process flow in the truck departure sub-process

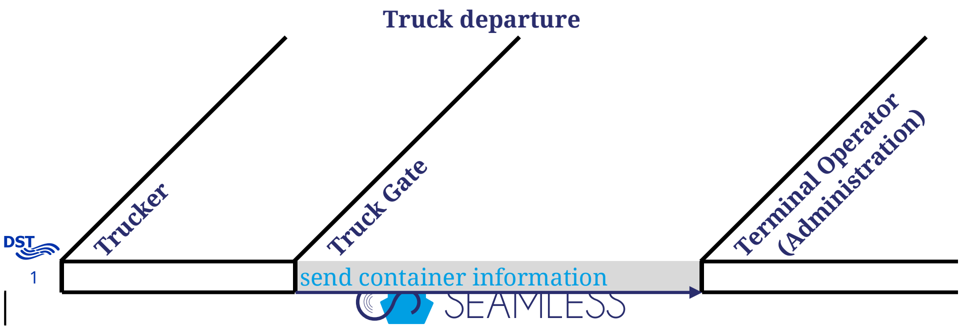


Figure 51. Communication/interaction pattern in the truck departure sub-process

On arrival at the delivery point, the truck drops off the container(s) and hands over the documents to the consignee. By doing so, the point of transfer of risk and responsibility for the Incoterm “Delivery Duty Paid” (DDP) is achieved, and the transport leg is considered as completed. It can sometimes take some time for the delivered containers to be opened and emptied at the consignee 's premises. Once emptied, the empty containers are picked up and hauled to the empty container depot for drop-off, at which the containers are unloaded and, thereby, returned.

The entire process flow in this sub-phase is monitored by the logistics planner who reports to the consignor as his client in case of his enquiries or emergencies.

In the post-haul transport leg sub-phase, some partners use their TMS while other work with the TOS of the terminal of destination – and e-mails for communication and occasionally for the management of transport documents. In the sub-processes, the TOS of the concerned terminal (at the port of origin) is also involved.

Completion phase, shipment completion and invoicing sub-phase

After completing the business initiation, transport planning, and transport execution with the four transport legs, the final phase of transport completion follows next. As can be seen in Figure 52, the shipment completion and invoicing sub-phase consists of invoicing and payment activities and the final notification of the consignor (or consignee, respectively) about the completion of the shipment order. In this phase, nearly all actors and stakeholders involved in some sub-phase of the transport execution layer is involved here as well. It has to be noted though that the respective invoice may be issued immediately after the service has been rendered. So, the shipment completion and invoicing sub-phase does not necessarily imply that the entire shipment needs to be completed before individual payments are made.

The services of the inland shipping company, the road carriers responsible for the pre- and post-haul legs, and the customs agent are remunerated. Similarly, the cargo handling services at the terminal of origin, the terminal of intercontinental transshipment, and the terminal of destination for both container loading and unloading are paid here. Likewise, the port fees based on the respective port vessel dwell times and used services in the port of origin, the port of intercontinental transshipment, and the port of destination are settled by the short-sea shipping company and the inland shipping company, respectively, depending on the precise service used.

Last but not least the logistics planner, who receives, checks, and processes the various invoices of the service providers he has commissioned, informs his client, i. e., the consignor (or consignee, respectively), about the successful completion of the shipment order before he pays each contractor and issues his own invoice which he transmits to and is settled by his client.

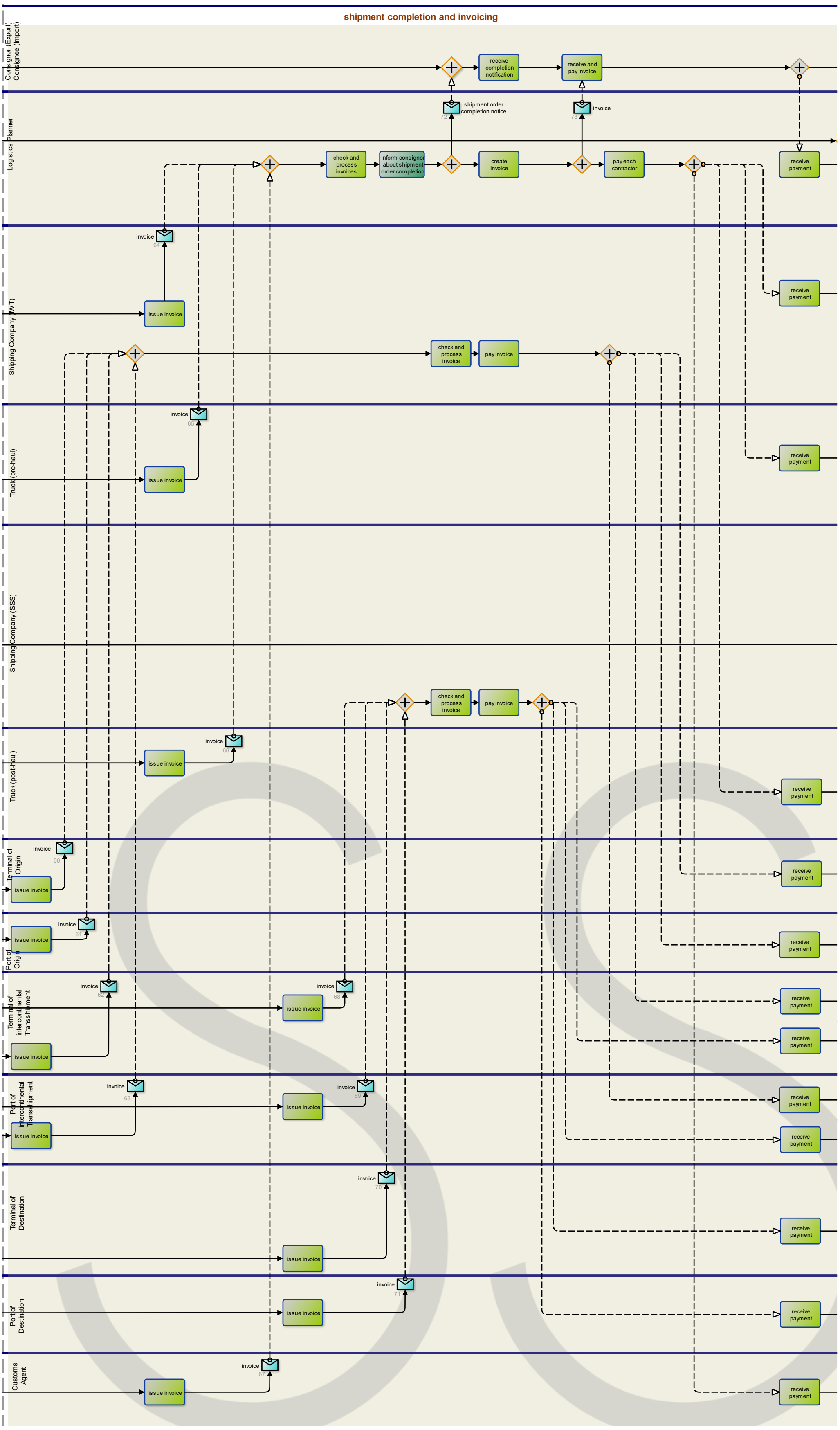


Figure 52. Logistics process flow in the shipment completion and invoicing sub-phase (completion phase)

In this phase, the ERP systems of nearly all partners are used for the invoicing and payment monitoring tasks whereas the TMS is used for the formal completion of the shipment order and its individual transport legs. E-mails are widely prevalent for the distribution of the invoices issued by the different ERP systems.

Execution phase, customs (import) process

Although the underlying cargo story foots on an export case, the presented logistics process flows, the actors and stakeholders involved, the business information systems and communication means used, and the communication and interaction patterns can also be used for an import case. One major difference, however, is the customs handling procedure in the import case. Figure 53 shows the process flow in such a case whereas Figure 54 illustrates the related communication and interaction pattern. Depending on the precise case, one or two shipping companies, one or two terminals, and the cargo owner as the importer or a representative a customs agent acting on his behalf are involved in the project.

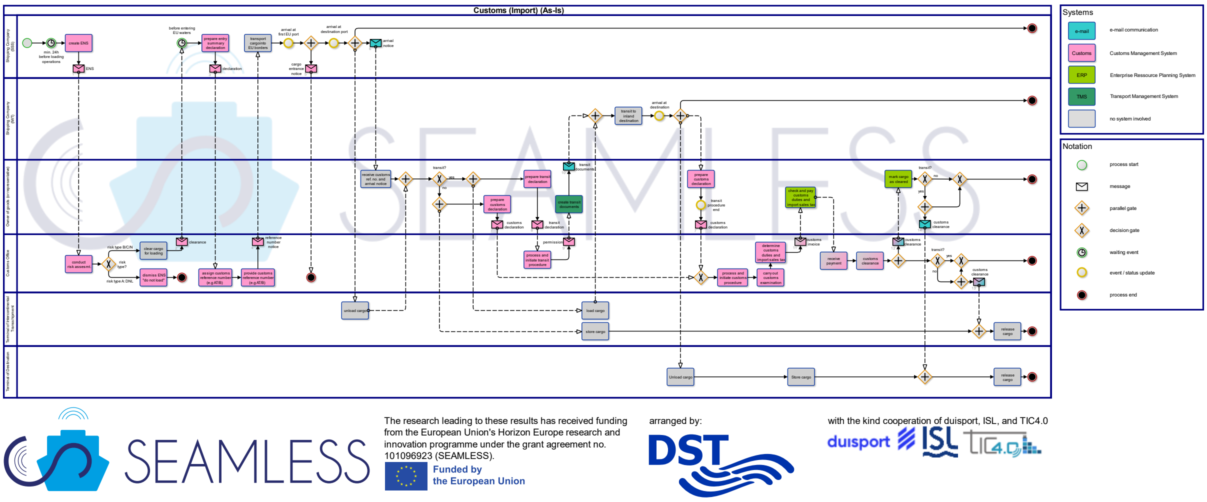


Figure 53. Logistics process flow in the customs handling process (import case)

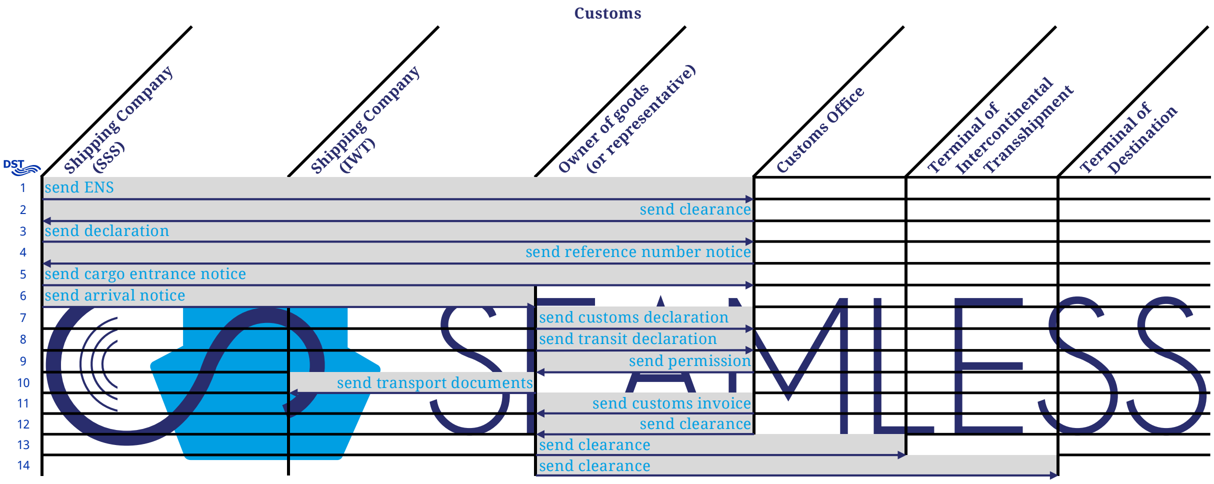


Figure 54. Communication/interaction pattern in the customs handling process (import case)

As part of the shipment preparation or latest within the SSS leg of the import case, the process starts 24 hours before loading operations in the port of origin, e. g., in Shanghai, China, with the short-sea shipping company creating an Entry Summary Declaration (ENS) and sending it to the customs office. The customs office conducts a risk assessment. According to EU regulations, “the customs office will issue a risk type A message, which will result in a so-called "Do Not Load" (DNL) message" (ECSA, 2016, pp. 9–10) when the customs serious risks regarding safety and security related to the cargo to be loaded onto the vessel. Although subject to different procedures upon arrival in the European Union, cargoes of the types B, C, and N can be loaded onto the vessel though. Then, the cargo is cleared for loading, the pertaining clearance is provided to the short-sea shipping company which loads the cargo onto the vessel, departs and is in transit. Before entering waters of the European Union, the Entry Summary Declaration needs to be prepared and submitted to the customs office who then assign a customs reference number and provide that to the short-sea shipping company. Afterwards, the cargo can be transported in the EU borders. With the arrival at the first port in the European Union, the cargo entrance notice needs to be sent to the customs office. When the vessel arrives at its destination port, an arrival notice is sent to the owner of the goods (or his representative), who, thereby, receives the reference number, while the cargo is unloaded off the vessel at the port of intercontinental transshipment, i. e., the seaport terminal.

In case it is not a transit process, the cargo is stored at the seaport terminal, the owner as the importer of the cargo prepares a customs declaration and submits it to the local customs office, which again processes the declaration, initiates the customs procedure, and carries out a customs examination before determining customs duties and import sales taxes. The resulting customs invoice is sent to the inland shipping company who check the invoice and pay the amounts due. Upon payment receipt, customs clearance is considered complete. After the completion of customs clearance has been signalled to the seaport terminal, the cargo can be released.

In case it is a transit process, a transit declaration has to be prepared and transmitted to the local customs office who process the declaration and initiate the transit procedure. When the customs office replies with a permission, the cargo owner (or his representative, respectively) creates the transit documents and provides them to the inland shipping company which transports the cargo to the inland destination, i. e., the inland port, at which the cargo is unloaded and stored while the same customs declaration procedure as in the seaport terminal commences – with declaration submission, customs examination, customs invoice issue, payment receipt, and customs clearance. As in the case of the seaport, the cargo can be released with the cargo owner signalling a completed customs clearance to the inland terminal.

The entire process is largely covered in the Customs Management System, which – in many cases – is linked to the customs procedure management systems or portals of the national customs authorities. The cargo owner uses his ERP system and his TMS as well. Moreover, parts of the document transmission are carried out with e-mail communication.

2.3 Administrational Procedures

2.3.1 Vessel reporting

Vessel reporting relates to the provision of information on a journey and related port calls to competent authorities. In 1965, the International Maritime Organisation (IMO) has provided general provisions and recommendations to streamline and harmonize the information exchanges before, during and after port stays within its Convention on Facilitation of International Maritime Traffic (FAL). This includes the declaration of cargo and ship's stores, it's crew and passengers, dangerous goods, but also incorporates the maritime declaration of health, ship sanitation control, security as well as waste delivery to ports.

Within the EU, vessel reporting procedures in maritime navigation are currently governed by Directive 2010/65/EU which states reporting formalities for ships arriving in and/or departing from ports of the EU Member States. It builds upon the internationally recognized principles set by the IMO and sets the requirement for electronic data exchange. As such, it mandates Member States to implement electronic information exchange via centralised platforms, so called “national single window” (NSW). To improve international responses to incidents and dangerous situations as well as to improve the capabilities to prevent and detect ship pollution, these reports have to be partially made accessible to other Member States by means of the vessel traffic monitoring platform “SafeSeaNET”, which is operated by the European Maritime Safety Agency (EMSA). Among the data provided through the mandatory ship reporting systems, SafeSeaNET processes Automatic Identification System (AIS) messages collected by coastal base stations.

In the domain of inland navigation, the EU has defined the concept of River Information Services within its Directive 2005/44/EC, which is commonly known as the “RIS-Directive”. With the goal to provide a framework for interoperable and harmonized information systems and exchange of information between actors in the context of inland navigation, it mandates the EU member states to assign competent authorities and implement a set of technologies. In specific, the directive defines the four core technologies “Automatic Identification System” (AIS), “Electronic Chart Displays” (ECDIS), “Notices to Skippers” (NtS) as well as “Electronic Reporting International” (ERI). While the former mainly concern navigational aspects, the ERI concept sets the foundation for electronic exchange of voyage-related information between authorities and vessel operators.

Even though the RIS directive aims at harmonizing the way digital services are being deployed across the EU, a recent evaluation of the RIS directive has pointed out that "not all RIS technologies have reached the same level of implementation and maturity” and “slow and fragmented deployment of RIS”. This is especially true in the field of ERI, which is supposed to reduce the number of resubmissions of vessel reports during international voyages. While most EU member states have adopted a dialect of the ERINOT message via national systems, the respective datasets are “not always exchanged” between these systems.

For this reason, “the fragmented technical, procedural, organisational and regulatory environment” still requires barge operators to report part of the information several times.

2.3.2 Traffic Management and Navigational Safety

In order to allow for safety and security, maritime vessels are required to communicate with different authorities and bodies or private organisations with mandate to perform sovereign tasks when approaching, arriving and departing ports. These communications usually follow strict guidelines that not only define how communication is to be carried out but also specifies the requirements that need to be met to ensure the communication from the landside. In this section, the communication between vessels with Vessel Traffic Services (VTS) and Pilotage as examples for the most common authorities which whom vessels communicate ahead of a port call, is discussed in detail. As presented earlier, such communication is considered as part of the current reference logistics system architecture (see section about the Transport Execution Layer)

Vessel Traffic Service

Vessel Traffic Services comprise different services towards maritime vessels within a specified VTS area. These services are provided by the VTS provider, an entity, which holds an authorization by the respective national Government. The focus of VTS is laid on traffic management with the aim to ensure the compliance of the vessel traffic with the according rules (e. g., COLREGS) and the prevention of dangerous situations developing. By interaction of the VTS personnel with individual vessels within the VTS area and them reacting to critical situations, safety of life at sea as well as safety and efficiency of navigation are improved (Resolution A.1158(32), 2021). VTS are generally located within the approaches to ports or in areas that have a particular high traffic density, such as the Dover Strait (Maritime & Coastguard Agency, n.d.). VTS is also considered as an important measure of navigational safety in Chapter V of the International Convention of Safety of Life at Sea (SOLAS), where contracting Governments are suggested to implement VTS in places, “where, in their opinion, the volume of traffic or the degree of risk justifies such services” (International Maritime Organization, n.d.-b).

VTS personnel mitigates potentially unsafe situations by providing information to the vessels to assist their crews in their navigation and decision-making processes. These factors may include but are not limited to positions and movements of other ships, limitations of vessels within the VTS area (e. g., limited manoeuvrability), safety information or reporting formalities. Further VTS includes the monitoring of any vessel traffic within the VTS area and plotting ships movements in advance. In case of arising unsafe situation VTS are advised to respond to vessels being unsure of its route or position, vessels deviating from their routes or requiring guidance and upon detecting risks of collision or grounding (Resolution A.1158(32), 2021).

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) recommends, that relevant authorities, VTS providers and training facilitations to implement standardized operating procedures making use of standardized communications phrases to improve the efficiency of communication between VTS and vessels (International Association of Marine Aids to Navigation and Lighthouse Authorities, 2022a). Communication between VTS and vessels is to be done with marine Very High Frequency (VHF) radio. IALA also adds precise details, on how VHF messages are to be structured, which marker words are to be utilized and how certain information is to be expressed (International Association of Marine Aids to Navigation and Lighthouse Authorities, 2022b).

When a vessel is entering the VTS area, a first exchange of general information is exchanged via VHF to announce the vessels intention, verify the vessels' identity and confirm any additional requirements. This first exchange can also include additional information e. g., on crew, cargo and voyage details. Although the IALA recommends certain communication patterns, reporting procedures between different VTS do not necessarily follow the same procedure and can differ from each other. The vessels crews can find information on how to contact VTS all over the world in Admiralty List of Radio Signals Vol 6 or in the Admiralty Sailing Directions (The Nautical Institute, 2018).

The establishment of VTS in the EU is made compulsory by Directive 2002/59/EC of the European Parliament and of the Council. Article 8 states that each member state must undertake every effort to ensure that ships comply with the IMO rules for VTS. Thereby it is irrelevant which flag the ship flies or in whose territorial area the VTS is located. Article 9 lays out that member states have to deploy coastal stations by the end of 2007 that are able to fulfil these tasks. It must be ensured that the coastal stations entrusted with the task have suitably qualified personnel and the necessary equipment at their disposal (Directive 2002/59/EC, 2019).

Pilotage

Pilotage is a common concept on maritime vessels. Maritime vessels often are employed on different routes calling different ports. The navigation through waterways such as narrow channels or canals, port accesses and the port area itself can pose a challenge to the ship management due to unknown local characteristics and dangers of these waterways. To tackle this challenge, maritime pilots serve as an aid towards the ship management to ensure the safe and efficient navigation of vessels in and or in the vicinity of ports. Pilots are highly specialized professionals, often former mariners that have an extensive knowledge of local conditions of the waterways which includes tidal patterns, currents, depths, underwater hazards and navigational aids. Additionally, they are skilled with handling different types and sizes of vessels and are familiar with local regulations, port procedures and traffic management rules. Although pilots are never a member of the vessels crew their advisory role is integrated into the Bridge Resource Management (BRM), which is a concept comprised of procedures and skills that is aimed to prevent accidents at sea.

While the European Maritime Pilots Association (EMPA) promotes a common culture of improving pilotage within Europe and boost safety and efficiency, Article 23 of Directive 2009/16/EC of the European Parliament and of the Council expects pilots on board vessels to report any anomalies found to be present on board vessels to relevant authorities (Directive 2009/16/EC, 2019), there is no known EU-legislation making pilotage compulsory. However, with reference to Resolution A.960 of the IMO it is acknowledged in Regulation (EU) 2017/352 of the European Parliament and of the Council that pilotage is made compulsory and regulated by each Member State independently, making it a sovereign task (Regulation (EU) 2017/352, 2020; Resolution A.960(23), 2003).

Such as the decision, whether a pilotage is compulsory or not and if exemptions from pilotage may apply, the procedures, how pilots are requested may vary. According to Resolution A.960 of the IMO it lies within the competent pilotage authority, which may be a national or regional government, or any other corporate body authorized by law or tradition, to set up pilot boarding points and procedures for requesting pilots. The IMO suggests that contact between the vessel and the pilot station is made as early as possible with frequent updates (Resolution A.960(23), 2003). How pilotage is requested, and which means of communication can be used, can be accessed in the Admiralty Sailing Directions, that provide important information when entering a port and being engaged in coastal navigation.

2.3.3 Customs Procedures

The domain of customs includes all activities which are related to the determination and collection of customs as well as to the control of the flow of goods into and out of a customs area. It is therefore both a fiscal and a security function.

Within the European Union Customs Union (EUCU)[20], the legal foundation set by the Unions Customs Code (UCC) is laid down in Regulation (EU) No 952/2013. It implies that within the EUCU, no tariffs or non-tariff barriers are applied so that customs-related border controls within the customs territory of the Customs Union (Regulation (EU) No. 952/2013, 2013, art. 4) are only applied occasionally. Externally, common external customs tariffs, which are negotiated by the European Commission, apply for the whole union. Each EUCU member provides its own customs authority in order enforce the UCC within its own territory. While a description of all customs related aspects is out of scope for this deliverable, this section will highlight some of the most important concepts.

The first case to be considered within freight transportation is the physical transfer of “non-union goods” (Regulation (EU) No. 952/2013, 2013, art. 5 (24)) into the customs territory, which is furthermore referred to as an “import”. In containerised waterborne trade, the carrier of an import shipment is responsible for notifying a shipment to the customs authority at least 24 hours before loading the cargo onto the vessel. This process is referred to as the “entry summary notification” (ENS) and may be carried out electronically. As this phase is related to avert danger (e. g., counter-terrorism or smuggling), a risk assessment is carried out by the customs authority (Regulation (EU) No. 952/2013, 2013, art. 128).

After full or semi-approval[21], the cargo may be loaded onto the vessel. Once arrived at EUCU territory, the carrier must further carry out a notification of arrival (Regulation (EU) No. 952/2013, 2013, art. 133). After discharging the cargo at the port, the still non-union goods are kept in temporary storage until a “customs declaration” is lodged and thus the goods transferred into one of the “customs procedures” (Regulation (EU) No. 952/2013, 2013, art. 5 (16)). These procedures may have different purposes: The most common is to change the status to Union goods and thus to receive clearance for free circulation of the goods (Regulation (EU) No. 952/2013, 2013, art. 201). Other option is to declare the goods for special procedures which includes “specific use” (e. g., temporary admission), “processing”, “storage” or “transit” (Regulation (EU) No. 952/2013, 2013, art. 210). Electronic import reporting formalities are carried out using the Import Customs System (ICS).

Until the goods have received their customs status, they are under “customs supervision” and therefore be subject to physical or documental examinations (Regulation (EU) No. 952/2013, 2013, art. 134). These examinations mainly relate to proof the appropriateness and correctness of the declaration's information.

If Union goods are intended to be moved out of the customs territory and thereby changing their status to non-Union goods, it can be referred to as an export. While the normal procedure relates to a permanent export, there are special procedure for temporary export and the re-export of non-Union goods. To start the customs procedure, the declarant is required to lodge an export declaration to the customs authority at the point of exit. Under certain conditions, the carrier is also obliged to file an Exit Summary Notification (EXS). Export cannot be done unless clearance for export has been received which is bound to the payment of export refunds and duties, as well as the application of

[20] The EUCU is represented by the EU Member States as well as Monaco, and the British Overseas Territory of Akrotiri und Dhekelia, Guernsey, Isle of Man and Jersey.

[21] Customs may decide to conduct border control upon arrival at first union port or port of destination.

prohibitions and restrictions posed upon export goods (Regulation (EU) No. 952/2013, 2013, art. 267). Electronic export and exit formalities are carried out using the Automatic Export System (AES).

Lastly, goods may enter the territory of the EUCU either for a destination within another territory within the Union or for transit to non-Union territory (Regulation (EU) No. 952/2013, 2013, art. 226). In this case, customs transit procedures may be applied. Transit formalities are carried out using the New Computerised Transit System (NCTS) system.

2.3.4 Transport Documentation

Transport documentation as understood in this document refers to the structured collection of electronic and physical information on cargo that needs to be available during transit. As such it may serve different functions such as the presentation towards authorities (police, customs, veterinary inspection, etc.) in order to establish transparency and evidence of a transportation contract. Also, it may provide evidence or acknowledgement of receipt when taking over cargo by a respective party. Lastly, some documentation may constitute a title such that the party in possession has ownership of the goods being transported.

In practice, different and often mode-specific types of documentation can be found. In the maritime domain, a “bill of lading” (B/L) may be issued by the carrier, which - among others – may serve as a title of goods. This is preferable in cases in which goods are sold during transit or financing of the trade is required. Thus, the bill of lading is considered as “negotiable”. If the ownership of cargo during transport is fixed, a “shipping waybill” may be used alternatively to provide evidence of the transportation contract. Within cross-border inland waterway transportation, a bill of lading that represents title may be issued in accordance to the Budapest Convention on the Contract for the Carriage of Goods by Inland Waterway (CMNI). Other commonly used documents are consignment notes that do not represent securities. For international rail and road transportation, relevant documents that are used as receipt for the transportation contract are the Uniform Rules concerning the Contract of International Carriage of Goods by Rail (CIM) and Agreement on International Freight Traffic by Rail (SMGS) consignment note in rail transportation as well as the Contract for Carriage of Goods by Road (CMR) consignment note. For national transports, national legislation may be applicable. In case of multimodal transport chains, a negotiable International Federation of Freight Forwarders Associations (FIATA) multimodal bill of lading or non-negotiable multimodal transport waybill may be used by FIATA members.

Even though digital forms of transport receipts are available in principle, paper-based documentation is still very present in most cases. Especially in cases, in which a document represents a title, the “original” version is often requested by the respective parties. However, especially in the container transportation domain, major players strive for the transition towards electronic bills of lading (eBL). Therefore, the Digital Container Shipping Association has announced the goal to achieve 100% electronic transport document by 2030. Similar commitments can be observed in other sectors, such as bulk shipping.

Besides documentation that represents evidence of the transportation contract and is primarily based on commercial law requirements, supporting documents or information such as ADN information, certificates of origin, veterinary certificates may be prepared, and held for presentation or actively lodged to authorities.

2.3.5 Emission Reporting

With nearly 200 states expressing their ambition in limiting climate change to below 2°C greenhouse gases from various sectors by adopting the Paris Agreement in 2015 and it entering into force in November 2016 (Paris Agreement, 2016; UNFCCC, n.d.) greenhouse gas emissions from shipping are receiving increased international attention. In line with the Paris Agreement, the International Maritime Organization (IMO) has set ambitious targets for the shipping industry. By 2050, the IMO aims to reduce total greenhouse gas emissions from shipping by at least 50% compared to 2008 levels and eventually achieve net-zero emissions. To reduce the greenhouse gas intensity of shipping, it is an important requirement, that emissions are recorded. With the EU Monitoring, Reporting and Verification (MRV) System and the IMO Data Collection System (DCS) two monitoring systems are discussed, that are important towards maritime shipping. Besides these two monitoring systems there is also the possibility that ports or individual countries set up their own emission reporting duties. However, there is no general approach to those. Whether such a proprietary emission reporting system applies in the context of the SEAMLESS use cases, is discussed in the corresponding sections of this document.

EU MRV System - Monitoring, Reporting and Verification

The EU MRV system is a system that has been set up by the EU with the aim of monitoring, reporting and verifying the annual CO2 emissions of maritime shipping within the boundaries of the EU. It is intended, that the reported emissions from maritime transport are included in the EU's ambition in reducing greenhouse gases along with the greenhouse gas emissions from other sectors. The corresponding regulation 2015/757 of the European Parliament and of the Council is in force since 1st of July 2015, with the first reporting period starting on the 1st of January 2018 (Regulation (EU) 2015/757, 2024).

The EU MRV is a mandatory reporting process for cargo and passenger vessel exceeding 5,000 GT on any EU related voyage (travelling from/to or between EU ports). Beginning 2025, the rules will also apply to offshore vessels (> 5,000 GT) and smaller general cargo vessels of at least 400 GT. There are also some vessel types – among others e. g., warships, fishery vessels and government vessels, if they don't transport cargo or passengers – that are exempted from the EU MRV.

The emissions are calculated via emission factors that are applied to the total consumption of different fuels that need to be reported per voyage. An exemption from the "per voyage" reporting is only possible, if all voyages take place in the European Economic Area and the vessel performs more than 300 voyages in a calendar year (Regulation (EU) 2015/757, 2024). The delegated Regulation (EU) 2016/2071 of 22 September 2016 lists three different methods of monitoring the fuel consumptions that are accepted as a base for calculating the emissions. Besides that, a direct measurement of CO_2 emissions is tolerated as well:

- Bunker Delivery Note and periodic stocktakes

- Bunker fuel tank monitoring on board
- Flowmeters for combustion processes
- Direct CO2 emission measurement (Commission Delegated Regulation (EU) 2016/2071, 2016)

A monitoring plan must be created for each vessel stating the planned monitoring method and how it is applied. Besides that, the monitoring plan needs to take basic data, activity data, data gaps, information on the management and any other seemingly important info into account. Monitoring plan and emission reports are verified by accredited verifiers to ensure, data is correct and compliant with the corresponding regulations (Regulation (EU) 2015/757, 2024). The verified emission reports must be uploaded on the electronic version of THETIS MRV, which is a software maintained and supervised by European Maritime Safety Agency (EMSA) (Commission Implementing Regulation (EU) 2016/1927, 2016). Emission data is made available to the public via THETIS MRV in aggregated form, which is also intended to remove market barriers.

IMO DCS – Data Collection System

The IMO Data Collection System (IMO DCS) is a regulatory mechanism introduced by the International Maritime Organization (IMO) to gather and report data on fuel consumption and other relevant information from ships as part of its efforts to address greenhouse gas emissions from ships. It was adopted by the resolution MEPC.278(70) on the 28th of October 2016, which requires vessels to record and report their annual fuel oil consumption. By which means data is collected is documented for each individual vessel in its Ship Energy Efficiency Management Plan (SEEMP). From the 1st of January 2019, every vessel of at least 5,000 GT must submit verified reports to their flag administrations, which are then forwarded to the IMO. These reports include information on the following six topics:

- IMO number to identify the vessel
- Period for which the data is submitted
- Technical information on the vessel such as the vessel type, its tonnage, power of main and auxiliary drives
- Consumption in tons and by fuel type
- Travelled distance
- Travel time in hours

Collected data is stored in the IMO Ship Fuel Oil Consumption Database. The DCS serves different purposes (Resolution MEPC.278(70), 2016). First, it enables the monitoring and assessment of the maritime overall greenhouse gas emissions and by this helps to identify trends and areas for improvement. Second, the development of informed policies and regulations aimed at reducing emissions from ships is supported. For example, the operational Carbon Intensity Indicator (CII), which has to be reported since 2023 (Resolution MEPC.328(76), 2022), is calculated by using the collected data from the DCS (International Maritime Organization, n.d.-a). Lastly, by creating annual reports of the reported fuel consumptions, the IMO promotes transparency within the maritime sector by making data on fuel consumption and emissions publicly available.

2.4 Communication and Interaction Patterns

Apart from the logistics process flows and the administrational procedures elaborated upon in the previous sections, the communication and interaction patterns within the reference logistics system architecture are of interest. This is related to the significance of the information flow accompanying the actual material flow, i. e., in our case the information transmitted along the multimodal transport chain next to the physical flow of containers and documents. For the proper understanding it is significant to comprehend the amount and content of message exchange throughout the logistics process flows. Correspondingly, the communication and interaction patterns presented in the following foot on the logistics process flows to ensure the same underlying base while presenting two different views of the very same matter. The logistics process flow has already been described in detail on the previous pages, including all sub-processes and sub-sub-processes. As a supplement, the communication and interaction patterns of each of the processes, sub-processes and sub-sub-processes need to be screened in order to fully understand the current mode of operation and to identify and underline the change induced by the various SEAMLESS innovations at a later stage. Whereas the logistics process flows are visualised in the form of activity diagrams, the communication and interaction patterns are shown in the form of sequence diagrams indicating the messages and signals exchanged any two parties during the entire process considered. Belonging to the category of interaction diagrams, sequence diagrams are typically used to describe how and in what order a group of actors and possibly systems works together and widely used among process analysts and software engineers to document an existing process and to derive requirements for a new system. In our case, it is used by a team researchers and developers to document the current situation of a reference logistics system architecture and to show the potential change to the logistics process flows by introducing the various SEAMLESS innovations. Each actor involved is represented by one of the parallel vertical lines, the so-called lifelines, standing next to each other while each message exchanged between them is represented by horizontal arrow. Typically, the messages exchanged are shown in the order in which they occur. In case of parallel threads though, it is important to note that the notation in the following diagrams may differ from the actual sequence of messages exchanged in reality. Each line in the sequence diagram represents a new message, with “1” being the first message to be exchanged according to the logistics process flow.

For the transport planning layer of the underlying cargo story, Figure 55 shows the logistics process flow across the eight sub-phases whereas Figure 56 shows the pertaining communication and interaction diagram, both displaying the multiple actors and stakeholders involved throughout the entire planning process. At first sight, it becomes evident that the individual sub-phases, that are easily visible in Figure 55, are hardly detectable in Figure 56 as the focus of the diagram lies on a different topic. On a closer look, the individual sub-phases can be detected though: The messages exchanged in the planning initiation sub-phase are represented in lines 1 to 3, the ones of the SSS leg planning in 4 to 9, and the ones of the IWT leg planning in 10 to 15. The planning amendments sub-phase is represented in line 16 whereas the post-haul leg planning is to be found in lines 17 to 20 and the pre-haul leg planning in lines 21 to 24. Eventually, the customs preparation sub-phase is shown in lines 25 to 28 while the planning completion sub-phase is represented in lines 29 to 34. By comparing the messages displayed in Figure 56 with description of logistics process flows in the transport planning layer with its initiation and planning phases, it becomes evident that the same messages described there can be found in the sequence diagram.

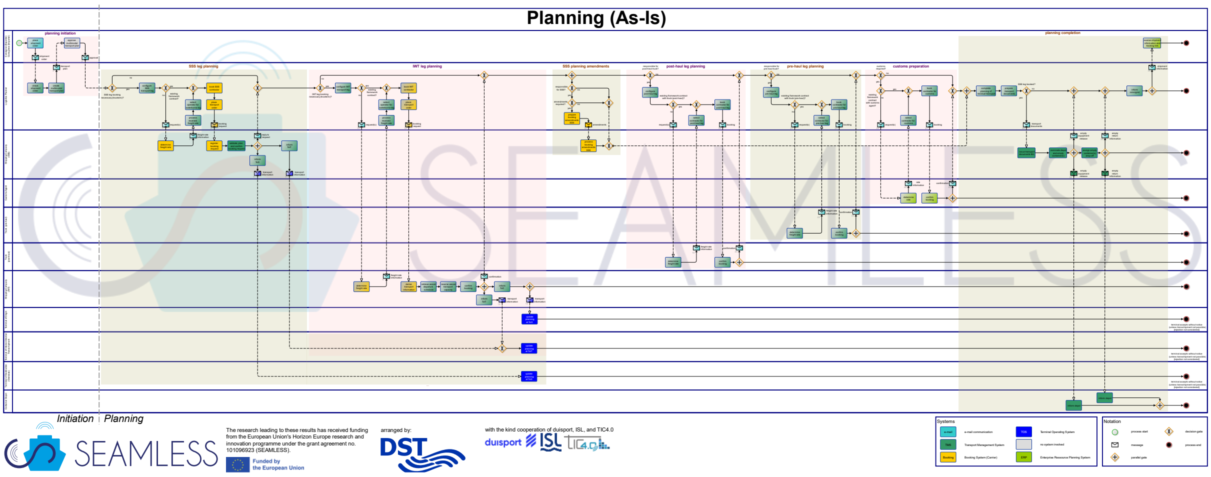


Figure 55. Logistics process flow (including sub-phases) in the transport planning layer

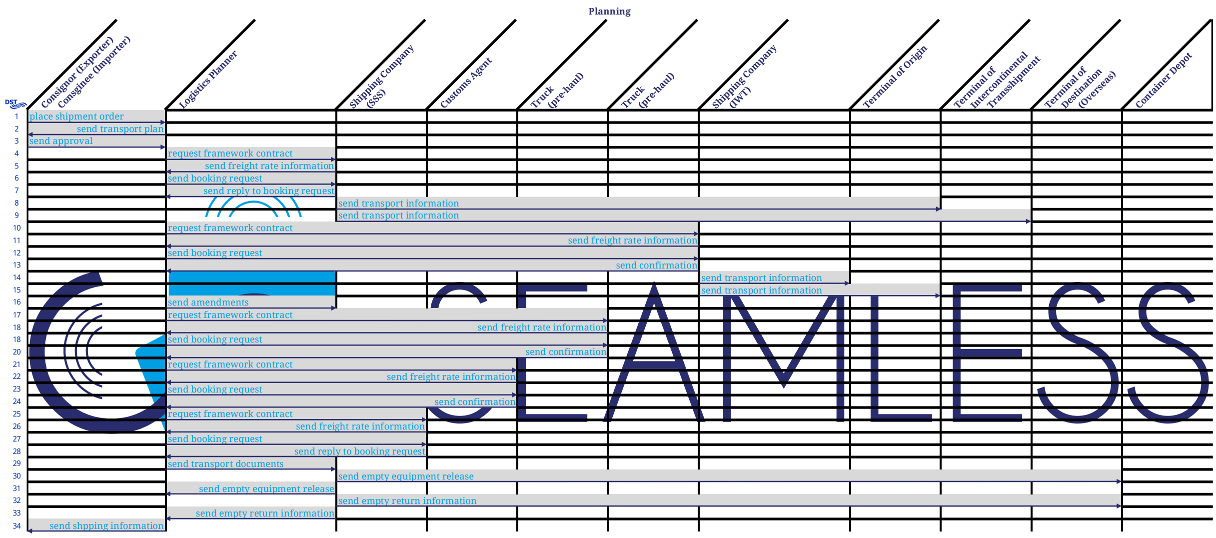


Figure 56. Communication/interaction pattern in the transport planning layer

Moreover, the central role of the logistics planner becomes evident as he is the actor with the most messages exchanged with (sending and receiving). Corresponding to the logistics process flow in the transport planning layer, the logistics planner interacts with the consignor at first before reaching out to the carriers on the respective transport legs of the multimodal transport chain, i. e., the short-sea shipping company, the inland hipping company, and the road-borne carriers responsible for the pre- and post-haul legs. Eventually, the customs agent is booked and the final planning items completed with individual actors involved. In this view, the logistics planner and the two shipping companies are the only parties interacting with more than one other party. A potential system-based support should therefore be directed towards their role in the transport planning layer and their precise planning activities.

Similarly, Figure 57 shows the logistics process flow in the transport execution layer which encompasses six different sub-phases from the execution and completion phases. Figure 58 presents the corresponding communication and interaction diagram throughout the transport execution layer. The same sub-phases shown in Figure 57 can also be recognised in Figure 58 as the shipment preparation sub-phase (lines 1 to 12), pre-haul transport leg (lines 13 to 15), IWT leg (lines 16 to 36), SSS leg (lines 37 to 51), post-haul transport leg (lines 52 to 59) and shipment completion and invoicing (lines 60 to 73) are all represented in the sequence diagram – corresponding to the descriptions of the execution and completion phases.

For the sake of completeness, the communication and interaction patterns of each of the multiple sub-processes within the transport execution player have been developed as well. They have been positioned in the preceding section on logistics process flows (see section 2.2.3), next to the corresponding activity diagram showing the respective logistics process flow. Most of those interaction diagrams present a few interactions only as the respective sub-process is defined as a small and self-contained process. The sub-processes describing the arrival, transit, and departure of a vessel, however, feature eleven or more message exchanges each in the case of short-sea shipping and between five and twelve messages each in the case of inland waterway transport. In both cases, the messages exchanged in the sub-sub-processes have not been counted.

The communication and interaction pattern of the transport execution layer reveals that the central role of the logistics planner is less pronounced than in the planning case. Whereas the coordinating role prevails in the shipment preparation sub-phase, the involvement during the sub-phases related to the individual transport legs is limited to monitoring activities. In these sub-phases, the individual carrier takes over the coordinating role and interacts with the residual actors and stakeholders involved in the respective transport leg. This holds particularly true for the carriers on the main legs, i. e., the SSS leg and the IWT leg. During the shipment completion sub-phase, however, the logistics planner and the main leg carriers are pivotal to the settlement of the various invoices and the closure of the entire shipment order.

Furthermore, the strong interaction between vessel operator and landside actors, i. e., the port authority or the terminal operator, becomes visible. In the SSS leg, the short-sea shipping company needs to exchange a multitude of messages with the terminal and port of intercontinental transshipment and later the terminal and port of destination, respectively. In the IWT leg, the inland shipping interacts with the terminal and port of destination as well as the terminal and port of intercontinental transshipment. Apart from the discrete-time notifications about a particular milestone achieved, e. g., containers unloaded at the port of intercontinental transshipment, there is no active interaction involving the logistics planner, let alone the consignor (or consignee, respectively). The logistics planner can gain insight to the progress status of the execution of the multimodal transport process but is not actively involved in it in a direct manner.

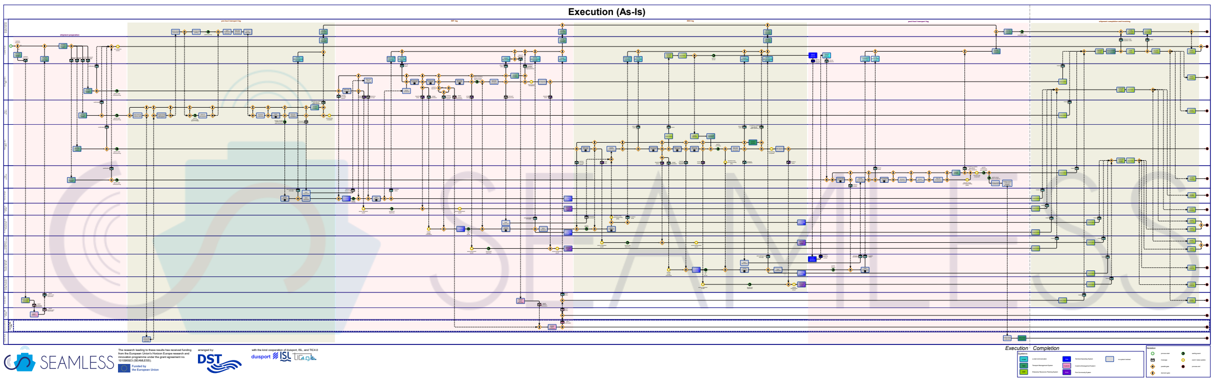


Figure 57. Logistics process flow (including sub-phases) in the transport execution layer

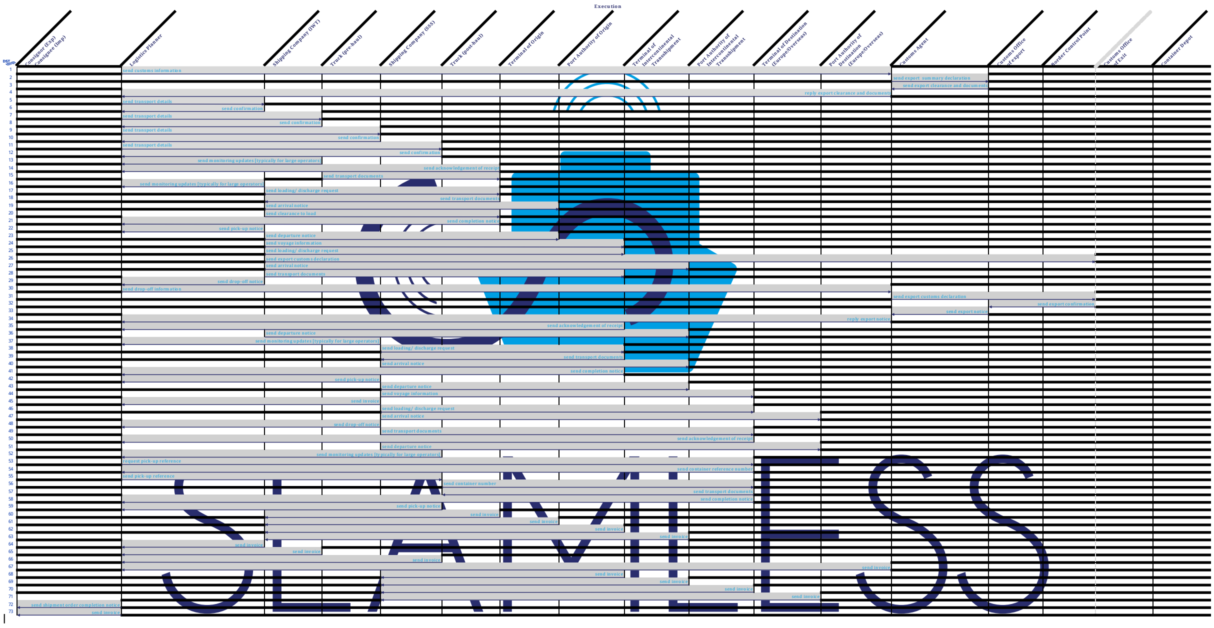


Figure 58. Communication/interaction pattern in the transport execution layer

In a nutshell, the central role in the planning layer remains with the logistics planner whereas this role moves to the carriers of main legs, the short-sea shipping company and the inland shipping company, in the execution layer.

On taking a look at the business information systems involved, further peculiarities become evident (see Table 1). In the initiation and planning phases, it is mainly the respective TMS of the various actors involved in the different planning activities. A large part of the communication is carried out with the help of e-mails and other forms of conventional and non-digital communication. Further, the different service providers are booked via dedicated portals. The systems in the ports are not involved in the entire process on the transport planning layer while the ones in the terminals are only for the planning and booking of the waterborne transport legs.

In the execution and completion phases, on the contrary, the role of the TMS is largely diminished as it focuses on tasks of monitoring the process and reporting to the consignor (or consignee, respectively). E-mail communication as well as other forms of conventional communication including phone calls, radio messages and the like occur occasionally along the project but large parts of the communication and message exchange happens with the help of systems in place and – presumably

– in a (largely) standardized manner. Particularly, in the interaction with the ports and terminals, the role of the related business information systems, TOS and PCS, is outstanding as can be seen in Table 1. Whereas the booking systems does not appear in the execution phases anymore, both VTS and ERP are extensively used in particular sub-phases. Inland Waterway Management System (IWMS) and Customs Procedure Management Systems have their role at specific points along the logistics transport flow and need to be considered when contemplating about the digital data flow along the multimodal transport chain. However, their involvement confines to a small set of interactions.

To conclude, whereas it is the different TMS and e-mails that dominate communication and interaction in the transport planning layer, the systems at the ports and terminals, the different TOS and PCS, are the crucial entities in the transport execution layer.

Table 1. Systems involved in the transport planning and execution layers

Variant	Part	Phase	Sub-phase	Subprocess	E-Mail	ERP	TMS	Booking	TOS	IWMS	Customs	PCS	VTS	*(none)*
As-Is					X	X	X	X	X	X	X	X	X	X
	Customs				X	X					X			X
	Planning				X	X	X	X	X					X
		planning initiation			X		X							X
		SSS leg planning			X		X	X	X					
		IWT leg planning			X		X	X	X					
		SSS planning amendments						X						
		post-haul leg planning			X		X							
		pre-haul leg planning			X		X							
		customs preparation			X	X	X							
		planning completion			X		X							X
	Execution				X	X	X		X	X	X	X	X	X
		shipment preparation			X	X	X				X			X
		pre-haul transport leg			X		X							X
			truck arrival process						X					X
			unload container(s)						X					X
		IWT leg			X		X		X		X	X		X
			IWT arrival process						X			X		X
			IWT arrival process	conventional mooring process										X
			load containers						X					X
			load containers	traditional stowage planning										X
			IWT departure process		X	X						X		X
			IWT departure process	conventional unmooring process										X
			IWT transport containers				X			X	X			X
			IWT arrival process						X			X		X
			IWT arrival process	conventional mooring process										X
			unload containers						X					X
			unload containers	traditional stowage planning										X
		SSS leg			X	X	X		X			X		X
			SSS arrival process			X			X			X	X	X
			SSS arrival process	conventional mooring process										X
			load containers						X					X
			load containers	traditional stowage planning										X
			SSS departure process		X	X						X	X	X
			SSS departure process	conventional unmooring process										X
			SSS transport containers				X						X	X
			SSS arrival process			X			X			X	X	X
			SSS arrival process	conventional mooring process										X
			unload containers						X					X
			unload containers	traditional stowage planning										X
		post-haul transport leg			X		X		X					X
			truck (empty) arrival process						X					X
			load container(s)						X					X
			truck departure process						X					X
		shipment completion and invoicing			X	X	X							

2.5 SEAMLESS DEMONSTRATION USE CASES

2.5.1 Demonstration Use Case 1

2.5.1.1 Logistics Process Flow

As has been described in deliverable D2.1, the SEAMLESS Demonstration Use Case (DUC) 1 is situated in southwestern Norway, more precisely in the fjord of Bergen, and encompasses a domestic short-sea shipping service to transport cargo from the port of Ågotnes to the port of Bergen and further locations in the area. In terms of the logistics taxonomy, it falls between the feeder system to Bergen and the hinterland system of the port of Bergen. Figure 59 shows the scope of the SEAMLESS Demonstration Use Case 1 within the SEAMLESS logistics model taxonomy. In essence, it consists of the domestic leg in the wake of the (waterborne) main leg, e. g., from overseas or from continental Europe to the port of Ågotnes, and covers the transport leg from port to port. In some case variants, it is also conceivable that the transport leads to the point of destination directly, e. g., to a consignor with a private quay at which transshipment may take place.

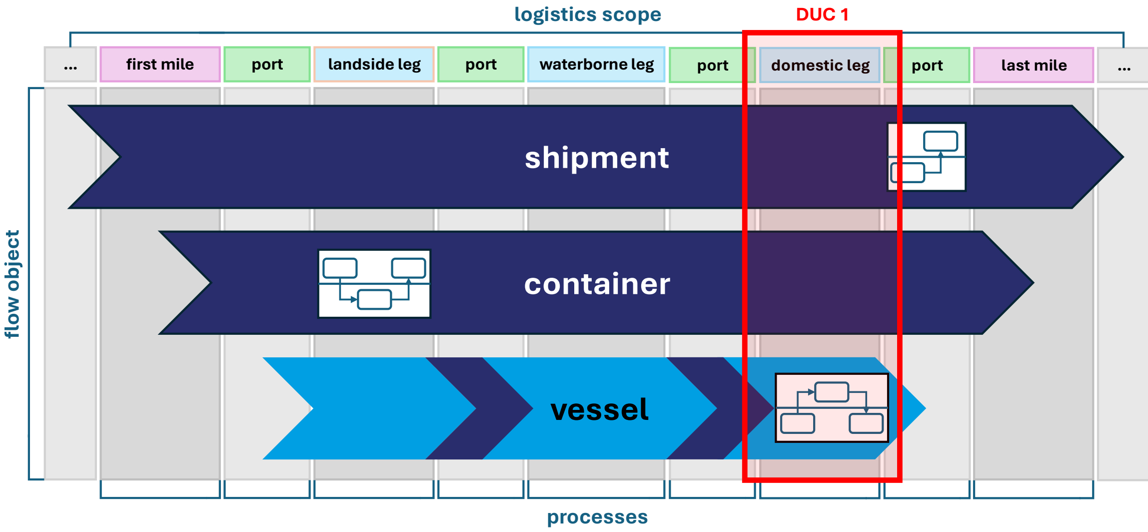


Figure 59. Domestic short-sea shipping (Demonstration Use Case 1) within SEAMLESS logistics model taxonomy

In order to show a typical reference process focusing on short-sea shipping, the reference logistics system architecture (as-is) needs to be reduced to a pure SSS-focused multimodal transport process which includes the short-sea shipping leg as the waterborne main leg, a pre-haul leg to the port of origin of the short-sea shipping vessel, and a post-haul leg from the port of destination to a subsequent port or the consignee, respectively. This typical reference process can further be differentiated between a domestic case and an international one. The domestic case corresponds to a national transport within a single country like Norway, in which cities and municipalities can be supplied more easily by using short-sea shipping services, or to a waterborne transport inside the European Free Trade Association (EFTA) zone including the European Union, Norway, Iceland, Switzerland, and Liechtenstein. The international SSS process refers to short-sea shipping routes across customs borders, e. g. between the European Union and the United States of America, the United Kingdom, China PR, or the Russian Federation.

As DUC 1 builds on a domestic short-sea shipping service, the related reference process flow will act as the base for the development of a to-be reference system architecture utilising the SEAMLESS innovations. Hence, the planning and execution layers need to be tailored to the reduced case of a domestic short-sea shipping service.

The planning process of a domestic short-sea shipping transport case follows the same planning routine as the full reference process (see section 2.2.2 and Figure 6) but results in less sub-phases. While the planning initiation, the planning of the SSS leg, the pre-haul leg and the post-haul leg, and the planning completion remain part of the new focus, the sub-phases of IWT leg planning, SSS planning amendments, and customs preparation have been excluded in the focused reference process of the domestic short-sea shipping case though as neither a IWT leg nor a customs declaration occur there. Accordingly, the three related actors, i. e., the inland shipping company, the intermediate terminal of intercontinental transshipment formerly connecting the IWT leg with the SSS leg, and the customs agent, have been omitted from the process as there is no IWT leg foreseen, no inland port involved, and no customs declaration required anymore. In case the domestic short-sea shipping scenario follows an international freight transport to import cargo, the pre-haul is obsolete while the international vessel transport is considered beyond scope of consideration. As a result of booking each leg of the transport chain individually and sequentially, SSS planning amendments generally become relevant for the alignment of the transport chain and the update on transport- or cargo-related information. While such alignments are unlikely to be needed, the opportunity of updating is still required. The adapted planning process of the domestic short-sea shipping service is on display in Figure 60.

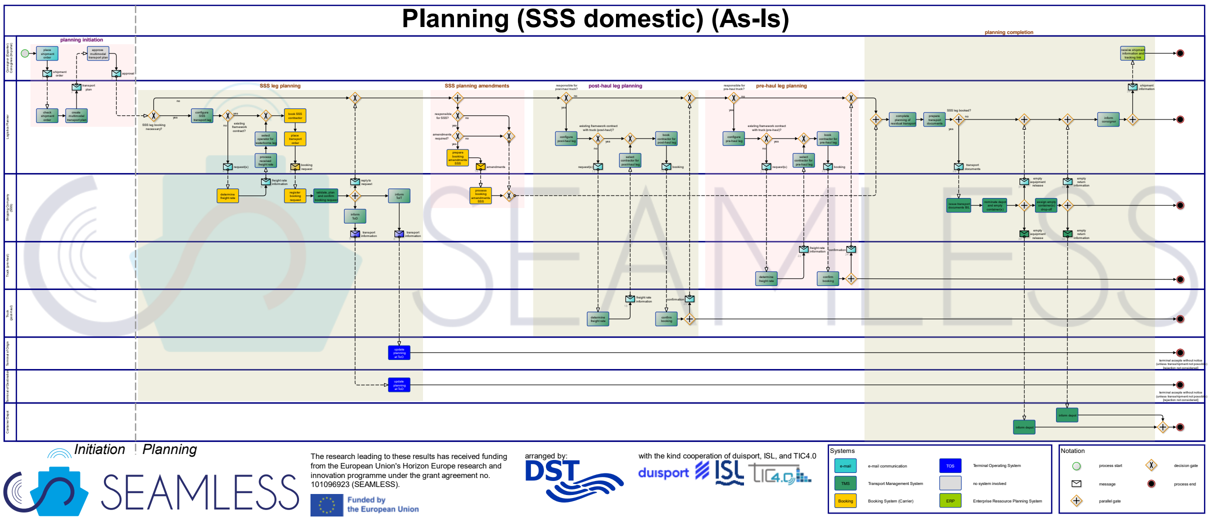


Figure 60. Planning layer of the Logistics Reference System Architecture of the domestic short-sea shipping case (as-is)

Similarly, the execution process illustrated in Figure 61 includes the sub-phases of shipment preparation, pre-haul, short-sea shipping, post-haul leg and shipment completion and invoicing, leaving the execution layer of the new focused reference process of the domestic short-sea shipping case reduced by one sub-phase. The preparatory steps in the first sub-phase of the execution layer exclude those process steps related to the inland shipping company, the customs agent, and the customs office of export. The pre-haul leg remains unchanged with the same drop-off and arrival routines at the terminal of origin. The leg now connects directly to the subsequent SSS leg with the same arrival and pick-up routines at the terminal of origin. As the IWT leg has been skipped, the IWT transport sub-phase and the embedded processes of customs border crossing and customs declaration are removed as well as the pertaining actors, such as the border control point and the customs office of export. The process flows of the remaining transport legs, i. e., the SSS leg, the pre-haul leg, and the post-haul leg, are largely unchanged. Only the customs declaration process is not required in a domestic scenario. As already mentioned above for the planning process, the execution process excludes the terminals and port authorities of intercontinental transshipment as the transport comprises on short-sea shipping vessel travelling between two seaports only. In total the execution process pf the domestic SSS transport case reduces the number of actors involved by six. Due to this reduction and the removal of the IWT transport leg, the complexity of invoices in the final sub-phase of the execution process diagram is significantly reduced while the actual processes of invoicing and transport completion have not been changed in any other way.

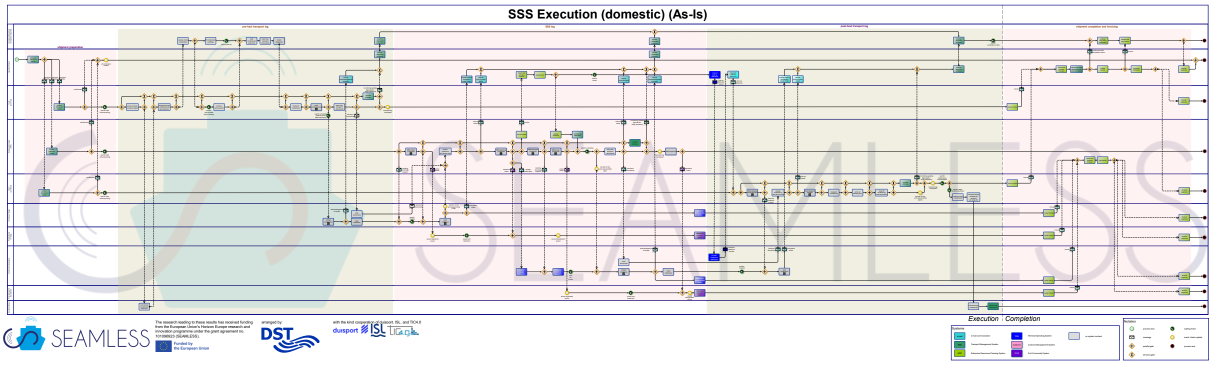


Figure 61. Execution layer of the Logistics Reference System Architecture of the domestic short-sea shipping case (as-is)

A variation of the Demonstration Use Case 1, which focuses on domestic short-sea shipping scenario, includes the relocation of the short-sea shipping leg from a domestic route to an international one. Within the SEAMLESS logistics model taxonomy, the focus is on the classic (waterborne) main leg, e. g., between Antwerp, Belgium, and Bergen, Norway, or between Valencia, Spain, and Piraeus, Greece (see Figure 62). In such a case, the pre-haul and post-haul legs may involve road-based and waterborne transport legs, e. g., by using feeder services to Antwerp or truck services from the Spanish mainland to Valencia.

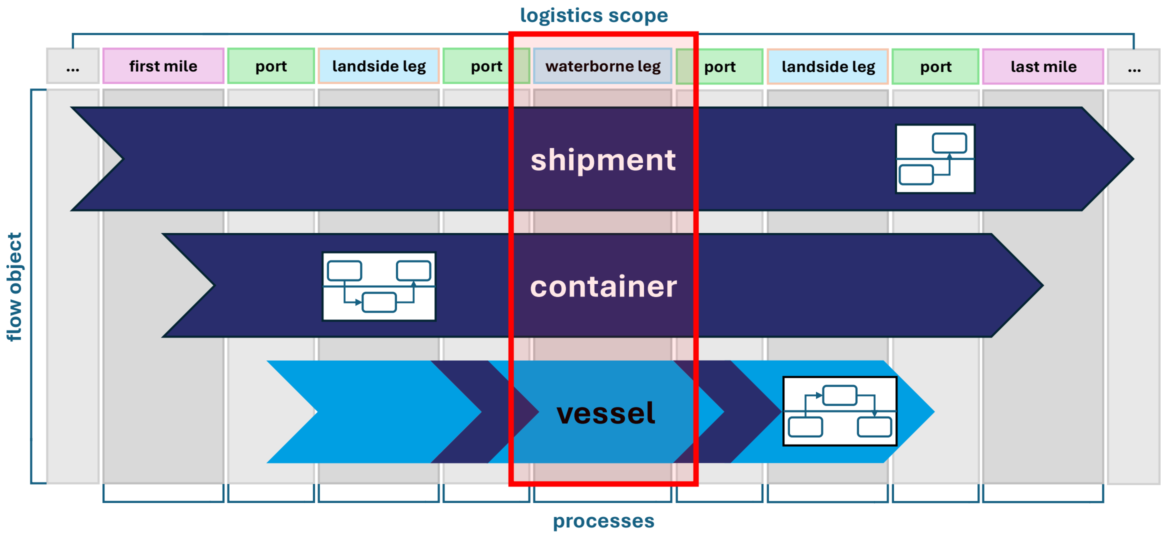


Figure 62. International short-sea shipping within SEAMLESS logistics model taxonomy

In the focused reference process of the international short-sea shipping case, the planning phase is identical to its domestic counterpart – except for the fact that for an international cargo transport (across customs borders), the customs process is applicable again, thus requiring the customs preparation sub-phase included in the planning process in order to book a customs agent. The other previously mentioned changes, esp. the omission of the IWT leg planning, remain valid for this variant.

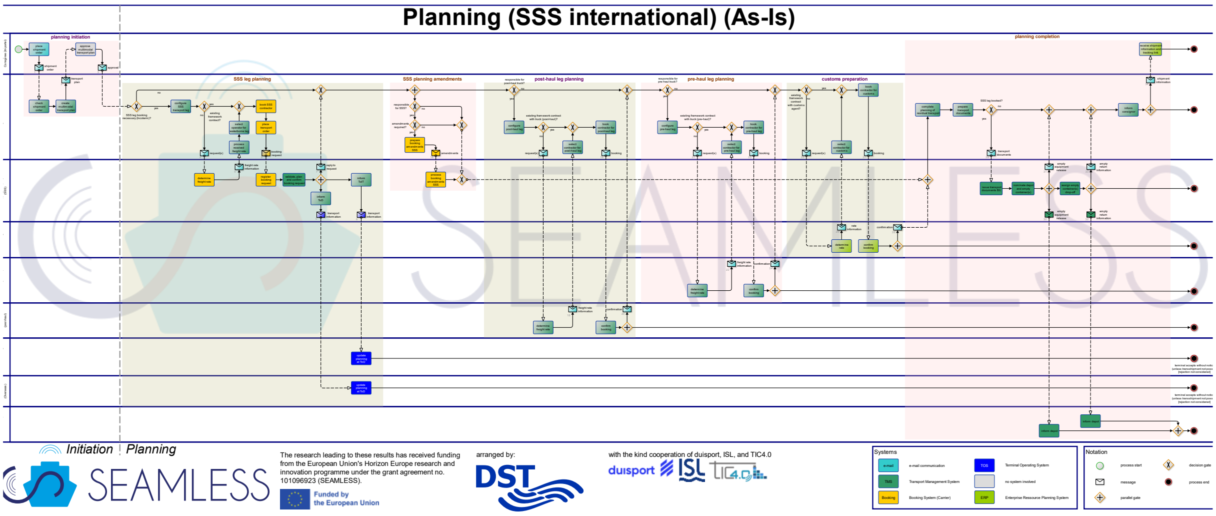


Figure 63. Planning layer of the Logistics Reference System Architecture of the international short-sea shipping case (as-is)

Similarly, the execution phase in the focused reference process of the international short-sea shipping case needs to be extended by the customs-related aspects (see Figure 64). Therefore, the shipment preparation sub-phase includes the relevant actors for the customs process and sees the logistics planner starting the process by submitting the customs details to the customs agent. One change in the focused reference process of the international short-sea shipping case compared to the full reference process is that the steps of the export customs procedure is shifted from the no longer included IWT leg to the pre-haul leg as the process of submitting the export declaration has to be performed after the truck delivers the containers directly to the port from which they are to be exported via short-sea shipping vessel. Thus, the customs agent needs to be informed by the logistics planner when the container arrives at the port of origin in order to finalize the export custom process.

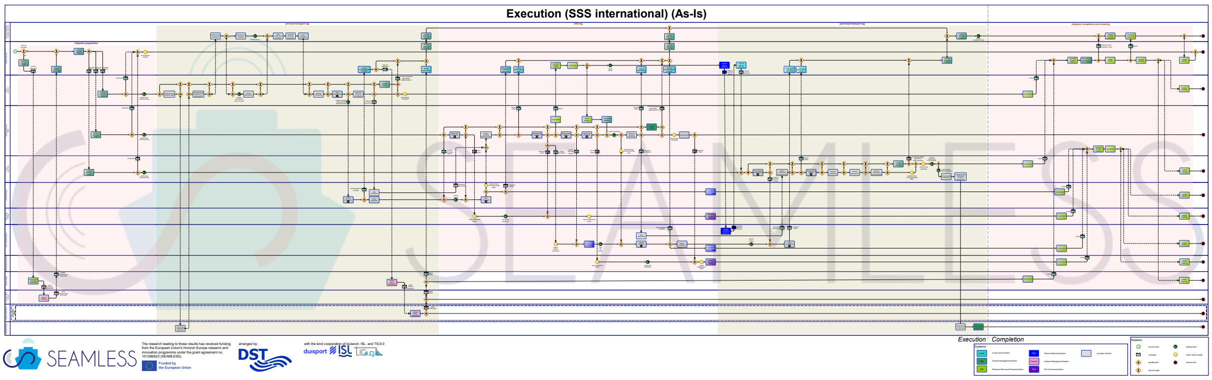


Figure 64. Execution layer of the Logistics Reference System Architecture of the international short-sea shipping case (as-is)

2.5.1.2 Administrational Procedures

Customs Procedures

It is assumed that Demonstration Use Case 1 is embedded into continental or intercontinental cargo flows. As Norway is not part of the EUCU, cargo being loaded or unloaded from feeder vessels at

Ågotnes is thus subject to customs procedures according to Norwegian customs legislation. Specifically, this includes the "Customs Duty Act" and "Customs Duty Regulation" as well as the "Movement of Goods Act" and "Movement of Goods Regulation" which have been revised in 2023 Enforcement of Norwegian customs is carried out by the Norwegian Customs Service (nor: "Tolletaten"). Norway is part of the EU security zone, which implicates that the Norwegian Customs Law applies similar principles as the EU Customs Code as outlined in section 2.3.3. As a consequence of this, the movement of goods between Norway and the EU are exempted from the prenotification (Entry and Exit Summary Declaration) requirement. Technically, customs declarations can be lodged using the customs clearing system "TVINN". Since 2024, the system is connected to the EU Import Control System (ICS2).

Vessel reporting

Norway, despite not being a member state of the European Union (EU), participates in the European Economic Area (EEA) agreement, which extends the European Union's (EU) single market rules to non-EU member countries in Europe, including Norway, Iceland, and Liechtenstein. The agreement allows these countries to participate in the EU's internal market, which encompasses the free movement of goods, services, capital, and people. As part of the EEA agreement, Norway is obliged to adopt certain EU legislation related to the single market, including directives such as the Directive 2010/65/EU on reporting formalities for ships arriving in and/or departing from ports of the Member States. The decision to incorporate Directive 2010/65/EU into the EEA Agreement was made in 2013 (*Annex XIII (Transport) to the EEA Agreement*, 2013) by the EEA Joint Committee. Norway incorporated the directive into national law by the "Regulation on vessels' notification obligations under the Harbour and Fairways Act" in December 2015 (Regulation on Vessels' Notification Obligations under the Harbour and Fairways Act, 2015).

To meet requirements of the European Union Directive 2010/65/EU Norway implemented a system called SafeSeaNet Norway (SSNN). SSNN aligns with the objectives of this directive by serving as Norway's implementation of a National Single Window (NSW) system for maritime reporting and serves as internet-based centralized platform where all relevant information related to a ship's arrival, departure, and cargo can be submitted once and then made available to relevant stakeholders and authorities, such as the Norwegian Coastal Administration, the Norwegian Maritime Authority, the Police, Norwegian Customs, the Norwegian Armed Forces, the Norwegian Environment Agency and ports. The System is administered by the Norwegian Coastal Administration (Kystverket, n.d.-a).

The reporting requirements of SSNN can be found in the mentioned "Regulation on vessels' notification obligations under the Harbour and Fairways Act" (Regulation on Vessels' Notification Obligations under the Harbour and Fairways Act, 2015). The website of the Norwegian Coastal Administration gives a very good summary about those requirements by showing them in an FAQ-style (Kystverket, n.d.-b). If sections are stated within this summary, the text refers to the just mentioned regulation:

> ***"Who needs to report arrival at a port?***
>
> *All vessels with a gross tonnage of 300 or more must report ports of call in Norway. Exceptions apply to vessels under military command, non-commercial official vessels*

and fishing vessels, recreational craft and historic vessels that are less than 45 metres in length. This means that fishing vessels, recreational craft and historic vessels of 300 GT or more, AND that are 45 metres in length or more, must report in accordance with this provision.

Vessels in regular service may be exempt from the duty to report.

What details should be included in the report?

Sections 4 and 8 must be viewed in conjunction with each other here. The report must contain the following information:

Identification of the vessel (name, call sign, IMO identification or Maritime Mobile Service Identity (MMSI) number) Port of destination Total number of people on board Gross tonnage of vessel Length of vessel Volume of cargo Total load volume Expected time of arrival at port of destination Expected time of departure from port of destination

Who needs to report hazardous or noxious cargo?

All vessels carrying hazardous or noxious cargo must report their arrival/departure. There is no lower size limit for vessels reporting under this provision. Definitions of hazardous and noxious cargo are given in Section 2 d) and e) of the regulations on the duty to report.

In addition, all vessels with a gross tonnage of more than 1000 carrying bunker fuel or lubricating oil for use on board, must report hazardous or noxious cargo. In practice, this means that all vessels with a gross tonnage of more than 1000 must report hazardous or noxious cargo.

Exceptions apply to vessels under military command, non-commercial official vessels and fishing vessels, recreational craft and historic vessels that are less than 45 metres in length. This means that fishing vessels, recreational craft and historic vessels that are 45 metres in length or more, and are carrying hazardous or noxious cargo, must report in accordance with this provision.

Vessels in regular service may be exempt from the duty to report.

Who needs to report International Ship and Port Facility Security Code (ISPS) ports of call?

In international waters, all passenger ships (including high-speed passenger craft) and cargo ships (including high-speed vessels) with a gross tonnage of 500 or more, and mobile offshore drilling units with their own propulsion, must report their ports of call in Norway.

All ships with an International Ship Security Certificate (ISSC) are regarded as being in international waters at all times.

What details should be included in the report on ISPS ports of call?

The report must include the details requested in the Maritime Security Level (MARSEC) form. The form itself should not be used – it is only used here to show what information needs to be provided by the vessel.

When should notification be given?

Notice must be given at least 24 hours prior to arrival at the port of destination. If the voyage is expected to last less than 24 hours, notice of arrival must be given before the vessel leaves the previous port.

Where a vessel does not know the port of destination, this must be reported as soon as this information becomes available. This will typically apply to fishing vessels.

How should the report be sent?

Reports to port authorities and the Norwegian Coastal Administration are to be sent via SafeSeaNet Norway. (Kystverket, n.d.-b)*"*

The regulation refers several times to a possible exemption from the duty to report under the Harbour Act, relevant to ships in regular service. How and under what conditions such an exemption is granted can also be found in the "Regulation on vessels' notification obligations under the Harbour and Fairways Act". Here too, the Norwegian Coastal Administration provides a clear summary on its website:

*"**Which obligations can we be exempted from?***

Exemptions may be granted from reporting ports of call and hazardous and noxious cargo as stipulated in Sections 8 and 11 of Regulation no. 1790 of 21 December 2015 on vessels' reporting obligations under the Harbour Act.

Vessels in regular service that have been granted an exemption from the duty to report ISPS ports of call under Article 7 of the Regulation (EC) No 725/2004 of the European Parliament and of the Council of 31 March 2004 on enhancing ship and port facility security, are also exempt from the duty to report pursuant to Regulation no. 1790 of 21 December 2015 on vessels' reporting obligations under the Harbour Act.

How is the exemption granted?

When the vessel is included in the aforementioned lists and the 'Is Approved' column shows 'Yes', the exemption is considered granted. The shipping company is required to enter vessels and routes in SafeSeaNet Norway (SSNN) in line with the regulations. In addition, the Norwegian Coastal Administration carries out spot compliance checks.

How should deviations in the expected time of arrival at the port of destination be reported to the Norwegian Coastal Administration?

Delays of more than three hours must be registered in SSNN. Consequently, all vessels or shipping companies that are exempt from the duty to report still need to create a user account in SSNN.

What is meant by the stipulation that the operator responsible must set up an internal system that enables this information to be sent to the Norwegian Coastal Administration?

The shipping company must have an electronic system or work routines that enable them to have the relevant information available for sending to the Norwegian Coastal Administration.

What is meant by the stipulation that it must be possible to send information to the Norwegian Coastal Administration in electronic format at any given time?

The contact point registered by the shipping company in the list must be able to provide information around the clock, 365 days a year. Electronic format refers to the sending of information by email or submitting a port of call or HAZMAT report in SSNN.

How should the operator list vessels covered by the provisions, update the list and send it to the Norwegian Coastal Administration?

The vessels are to be listed in the new exemption module in SSNN."

Traffic Management and Navigational Safety

To grant the safety of navigation, regular communication between vessels and authorities, mainly VTS and pilots, is carried out, when approaching and departing the port of Bergen.

Vessel Traffic Service

Any vessel traffic to or from the port of Bergen falls under the responsibility of the Fedje Vessel Traffic Service (Fedje VTS). Fedje VTS is managing and organizing any vessel traffic within its area of responsibility. Any vessel navigating within the area must participate in the reporting if certain circumstances apply to the vessel (length overall >= 24m, carrying dangerous or polluting cargo in bulk, vessels engaged in towing operations). The vessel, which is planned to be used within the scope of DUC 1 is exceeding a length of 24m by far and therefore is required to participate in the mandatory reporting process. At least one hour before arriving at the VTS area, vessels wishing to navigate within have to request sailing clearance. This applies as well to vessels intending to leave a port, berth or quay within the area of the VTS. The request has to include information on the vessels identification, its sailing plan estimated time of arrival (ETA) and estimated time of Departure (ETD) at/from the VTS area as well as any other information requested by Fedje VTS. Besides requesting sailing clearance vessels in the VTS area have to send position reports. E.g. this has to be done, when passing the limits of the VTS area, when changing VTS channels or if the vessel is in difficulties. Fedje VTS is available by phone, mail or VHF. Navigational communication between a vessel and Fedje VTS has to be done in a Scandinavian language or in English via VHF (National Geospatial-Intelligence Agency, 2022, p. 100). Besides the 2nm before and after the berth, the routes intended within DUC 1 completely lie in the area of the VTS. Therefore the vessel has to perform reporting processes with Fedje VTS within the demonstration of DUC 1 (Jungen et al., 2024, p. 40 ff.).

Pilotage

Pilotage in Norway is controlled by the Ministry of Fisheries and is compulsory when operating within the baseline of Norway and therefore compulsory when entering the port of Bergen, if no exemptions apply to a vessel. Compulsory pilotage and its exemptions are defined within the Compulsory Pilotage Regulations (National Geospatial-Intelligence Agency, 2020, p. 145ff, 2022, p. 87; Regulations on Compulsory Pilotage and the Use of Pilot Exemption Certificates (Compulsory Pilotage Regulations), n.d.). According to the port of Bergen the majority of masters of container vessels do hold such exemptions.

The booking of a pilotage should preferably be done via the SafeSeaNet, which has been described in section 2.3.1 but can also be done via the Kvitsoy Pilot Booking Center via Telephone, E-Mail or VHF. Pilotage should be requested at least 24 hours prior to arrival at the baseline by providing details about the vessel which include, but are not limited to its name, call sign, cargo and bunker fuels. The request shall be confirmed five hours prior to arrival at the baseline. Two hours prior arrival at the pilot station or departure from port contact with the pilot station is to be established via VHF channel 16 (National Geospatial-Intelligence Agency, 2020, p. 146ff.).

Transport Documentation

Specific regulations on transport documentation, which are applicable for maritime transports in Norway can be found within chapter 13, section VII of the Norwegian Maritime Code (NMC).

As Norway is party of the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR), the same documentation obligations on dangerous goods as in the European Union are applicable for road transportation.

Emission Reporting

EU MRV System - Monitoring, Reporting and Verification

Although Norway, where DUC 1 is situated, is not a member state of the European Union (EU), the EU MRV also applies in Norway. This is due to ports of calls in Norway fall under the jurisdiction of a member state, as the MRV regulation, among others, is incorporated into the EEA Agreement (*Annex XIII (Transport) to the EEA Agreement*, 2013).

Since the EU MRV is only mandatory for vessels above 5,000 GT, it does not apply for the Northern European Demonstration Use case, where the expected vessel size will have a gross tonnage of about 879 GT (Regulation (EU) 2015/757, 2024). However, it cannot be ruled out, that the regulation won't be amended to smaller vessels in the future; beginning 2025, the EU MRV will also apply to general cargo vessels and offshore vessels with a size exceeding 400 GT (*EU MRV Extended to Ships from 400 GT - Start Preparing Now*, 2024).

IMO DCS – Data Collection System

The obligation for the reporting of emissions within the scope of the IMO DCS is tied to the size of the vessel and only mandatory for vessels above 5,000 GT (Resolution MEPC.278(70), 2016). Since the vessel size for the Northern European Use Case will have a gross tonnage of about 879 GT, emissions reporting within the framework of the IMO DCS does not apply.

Environmental Port Index

The Environmental Port Index (EPI) is a shareholding company that has been developed in cooperation by the Port of Bergen. Det Norske Veritas (DNV) and other Norwegian ports and is currently owned by ports and municipalities that operate ports. The core of EPI is a reporting tool that is intended to collect information about the operations of a vessel while being in port. The system was introduced in 2019 and is currently implemented in 37 ports that are mostly Norwegian (*Ports*, 2023; *Vessel's Environmental Impact in Port Measured by New Index*, 2020). Upon leaving the port, various data about the port stay is shared by the vessels. The data collected includes info on fuel consumption, usage of onshore power supply, and the emissions of CO_2, NO_x and SO_x. The collected data is then used to assign a score to each vessel that ranges from 0-100. Vessels fully meeting the authorities requirements that have low emissions in port, receive a high score; vessels with high emissions receive a lower score. The attained score can then be used as a base for incentives towards the shipping companies. In the port of Bergen shipping companies need to pay additional port fees for vessels attaining a score considerably lower than 30. For vessels with a high score on the other side they receive a reduction of their port fees (*How It Works*, 2023). In the port of Bergen it was observed in cruise ships, that the incentive system via the EPI seemed to gain traction with the scores of the vessels increasing over time (*Green Ports*, 2022).

2.5.2 Demonstration Use Case 2

2.5.2.1 Logistics Process Flow

Whereas DUC 1 focuses on short-sea vessels in a domestic setting in Norway, the SEAMLESS Demonstration Use Case 2 involves a waterborne seaport hinterland transport from Antwerp, Belgium to its hinterland destinations, such as Lille, France, and Duisburg, Germany. As the largest seaports of continental are situated at the Rhine-Meuse-Scheldt delta, the waterways in their hinterland are typical cargo transport corridors with the Rhine being considered as Europe's most important cargo highway. Typically, such a seaport hinterland case is an international transport, albeit rarely on crossing customs borders. Along the Rhine-Alpine Corridor, Switzerland is the only country for which the customs regulations apply. Accordingly, the full reference process needs to be tailored to a focused reference process of the seaport hinterland IWT case in the realm of DUC 2. As a variation of this, it is also conceivable that the multimodal transport entirely runs on the continent without any involvement of a seagoing vessel. Such multimodal transports may occur between two seaports, two inland ports, or one seaport and one inland port, possibly including their respective pre- and post-haul legs. It is to be noted that merely the considered scope of planning and execution refers to the seaport hinterland part of the intercontinental and multimodal transport whereas its actual scope may encompass the transport legs overseas and involving ocean transport as well. Figure 65 illustrates this aspect vividly as the considered scope refers to a portion of the entire transport chain only. Such a transport may occur in reality as an export of containers from a consignor's premises over the inland waterways to the seaport, from which they are to be transported to a destination overseas, or as an import of cargo via a European seaport and the European inland waterways to the consignee. Such a confined view of the European part of the transport chain only leads to the fact that only one of the two road-based legs need to be considered for planning and execution monitoring, i. e., the pre-haul leg in the export case and the post-haul leg in the import case, respectively.

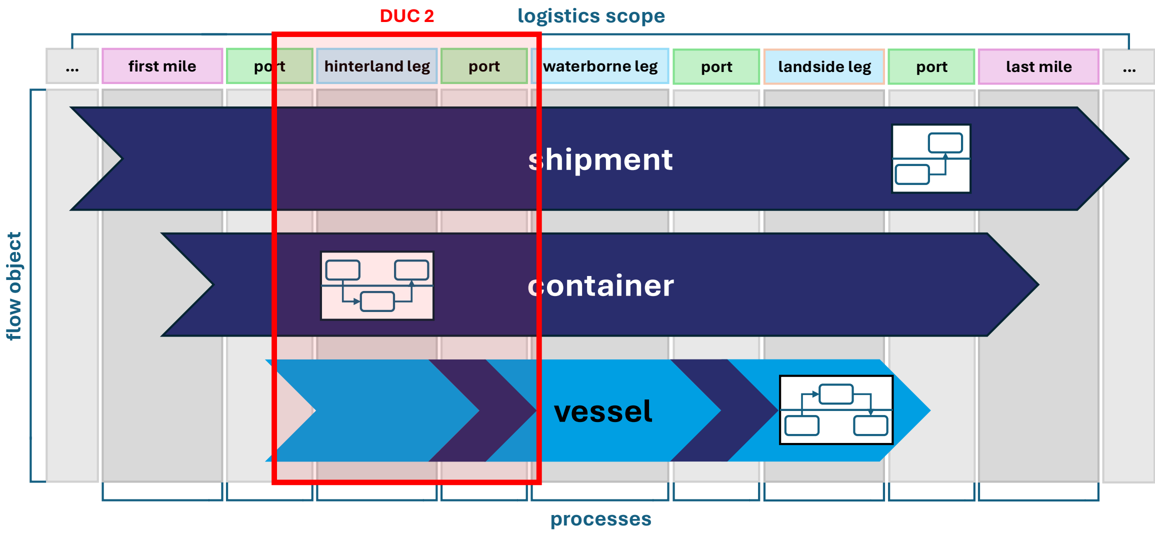


Figure 65. Waterborne seaport hinterland transport (Demonstration Use Case 2) within SEAMLESS logistics model taxonomy

The focused reference process of the seaport hinterland IWT case typically sees a planning process flow reduced by three sub-phases, i. e., the SSS planning leg, the SSS planning amendments, and the planning of one of the truck legs. In Figure 66, the planning of a multimodal transport related to an export case is displayed with a pre-haul leg planning included. As a reaction to the reduction of the transport chain by one waterborne transport leg, the related terminals are no longer required. More precisely, the port of origin and the one of intercontinental transshipment are sufficient for a focus on the hinterland transport in an export case, whereas the port of destination remains out of scope. The very same applies to the terminals. After the unchanged planning initiation sub-phase, the next task is the IWT leg planning because the IWT leg is considered as the main leg of the focus transport process. The planning of the IWT leg and the pre-haul leg are the remaining two legs to be planned sequentially within the scope of the focused reference process of the seaport hinterland IWT case. The same applies to the customs preparation sub-phase which is important as the main export of cargo happens in the seaport and, thus, lies outside the scope of a seaport hinterland transport on inland waterways like in DUC 2. Hence, the customs preparation is included into the scope of the focused reference process of the seaport hinterland IWT case as seaport hinterland transports in Europe occasionally require additional customs procedures, for example, in transports in which Serbia, Moldova, and Ukraine are involved as country of origin or destination or just as part of a transit. The SSS planning amendments are omitted as no SSS leg is included in the multimodal transport chain anymore. The reference process concludes with the planning completion which lacks the nomination and notification of a container depot. As the seaport hinterland transport is always part of a lager transport case using ocean-going or short-sea shipping vessels, it is assumed that the responsible carrier of those main legs is the party providing the container and, thus, nominating the pick-up and drop-off depots of the container. Since the nomination of these depots takes place outside of the considered scope, it is assumed that the information about the depot is provided to the logistics planner within the shipment order and will be supplied to the pre-haul trucker as part of the transport details (at the beginning of the execution phase). Likewise, the issue of the Bill of Lading by the short-sea shipping company (or another maritime transport service provider responsible for a waterborne main leg) remains beyond scope of consideration. In total, the focused reference process of the seaport hinterland IWT case includes only seven actors, equalling four actors removed from the full reference process. To the removed actors belong the short-sea shipping company, the trucking company responsible for the post-haul leg, the terminal of destination, and the container depot.

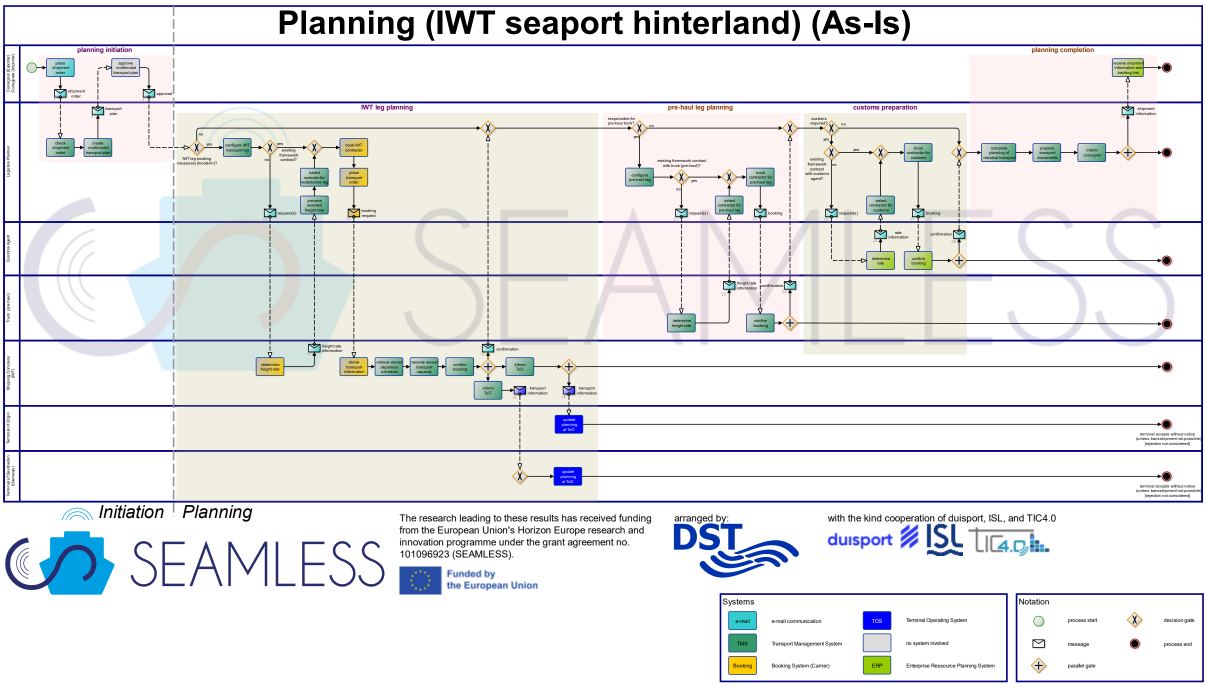


Figure 66. Planning layer of the Logistics Reference System Architecture of the waterborne seaport hinterland transport case (as-is)

The execution layer of the seaport hinterland transport on inland waterways begins with the usual shipment preparation, minus providing the transport details to those transport companies that have been excluded. In the pre-haul leg sub-phase, the process remains unchanged. Although the organisation of an empty container is not explicitly part of the considered planning process, the road haulier still picks up the assigned empty container at the depot in the process flow, as it is required for the process. In an alternative process flow, the container might already be stuffed at the consignor's premises and stand ready for pick-up which would eliminate the requirement of an empty container pick-up and the waiting time for the container to be stuffed by the consignor until the road haulier can start his travel to the port of origin. In the following sub-phase, the inland waterway transport leg is carried out with the same steps as in the full reference process. However, it ends with the delivery of the container to the seaport terminal – and the acknowledgement of receipt by the terminal. Since the export customs procedure in the seaport does not fall within the scope of this focus view, the only possible starting point for an export customs procedure is the inland vessel passing a customs border during transit from the inland port to the seaport. Finally, the process flow for the sub-phase of shipment completion and invoicing remains unchanged, apart from the reduction in the total number of players who have to send or settle invoices. Figure 67 presents execution layer of the focused reference process in the seaport hinterland IWT case

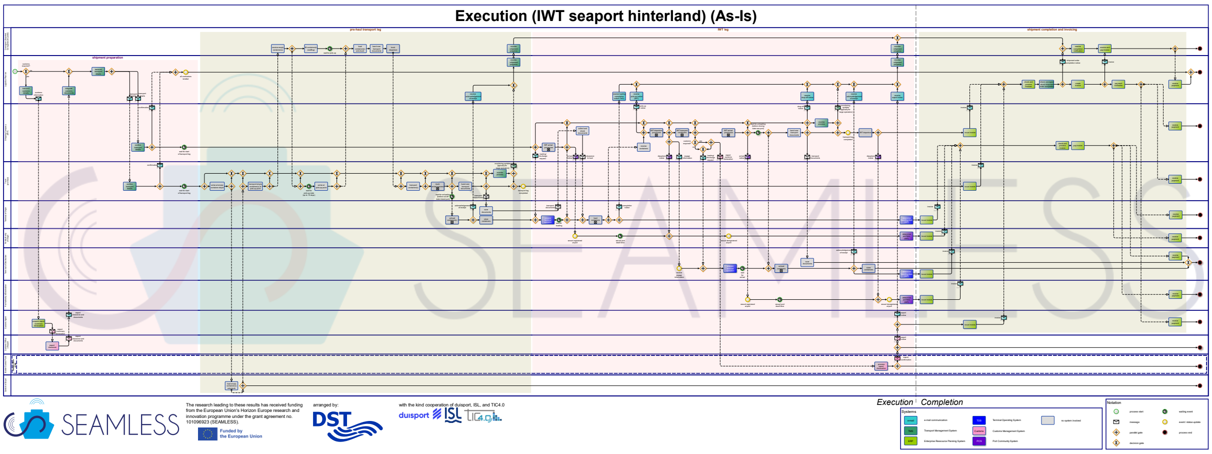


Figure 67. Execution layer of the Logistics Reference System Architecture of the waterborne seaport hinterland transport case (as-is)

A variation of the seaport hinterland transport on inland waterways is the case of continental transport on European inland waterways (see Figure 68). By this, multimodal transports between a consignor and a consignee, both situated on the continent and accessible via inland waterways, are meant, not seaport hinterland transports in which the original consignor or consignee, respectively, are possibly located outside the European inland waterway network. However, it is to be emphasized that a continental transport of containers is a more an exception than the norm. In continental IWT, semi-trailers and swap bodies onboard the inland vessel or bulk cargo are much more common. The most typical goods include liquid and dry bulk cargo, while piece goods and breakbulk cargo are less prone to IWT albeit cargo volumes are rising. Furthermore, a slow trend towards the transport of containerized bulk cargo is expected for the Danube or other longer waterway stretches. Moreover, non-ISO containers might also be used as loading unts in continental transport as ISO containers.

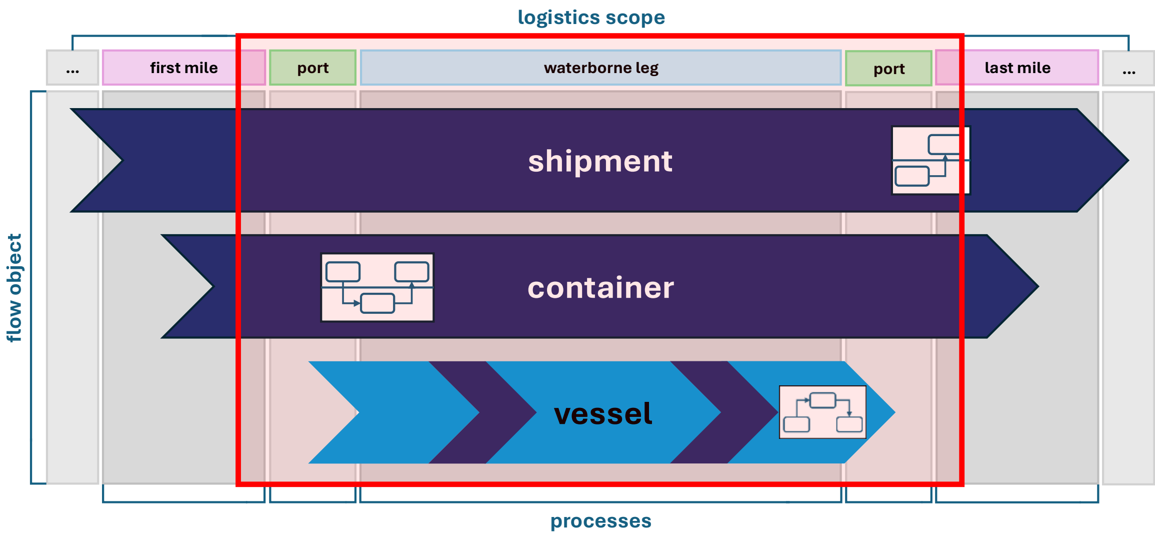


Figure 68. Waterborne continental transport within SEAMLESS logistics model taxonomy

Since it is an exceptional scenario, the typical workflow might differ from the underlying planning and execution processes in this particular case. As a result, is it assumed that any party can be the organizer of the empty equipment as it is not a default case. Furthermore, the process of organising empty equipment is considered out of scope of the depicted transport process and therefore assumed as given. The residual planning phase is not affected by this difference to the seaport hinterland transport on inland waterways case. One important difference between the seaport hinterland transport variant and the continental transport variant lies in the second road-based transport leg included in the focused reference process of the continental IWT case. In the export case, the post-haul leg is part of the multimodal transport chain, and the pre-haul leg in the import case, respectively. Thereby, the resulting planning layer of the focused reference process of the continental IWT case consists of an IWT leg, a pre-haul and post-haul leg, besides the sub-phases of planning initiation, customs preparation, and planning completion. The planning phase of the focused reference process in the continental IWT case is presented in Figure 69.

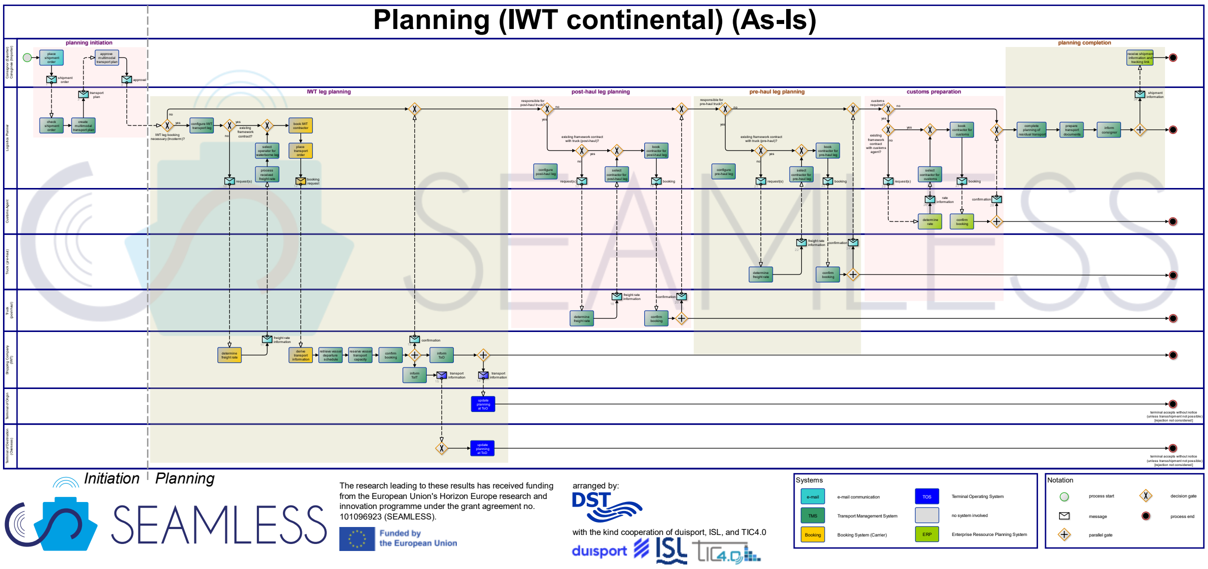


Figure 69. Planning layer of the Logistics Reference System Architecture of the continental IWT case (as-is)

For the pertaining execution process shown in Figure 70, both road-haul legs are included on either end of the IWT leg. Additionally, the continental transport does not require any of the ports to be a seaport. The continental transport between two seaports is covered in the earlier part of this section about seaport hinterland transport on inland waterways. For intra-Union transport relations, no customs process is required. Across Europe, there are a few exceptions though in which customs declaration is required, e. g., for continental transports on the Danube when shipping to, from, or through Serbia, Moldova, and Ukraine.

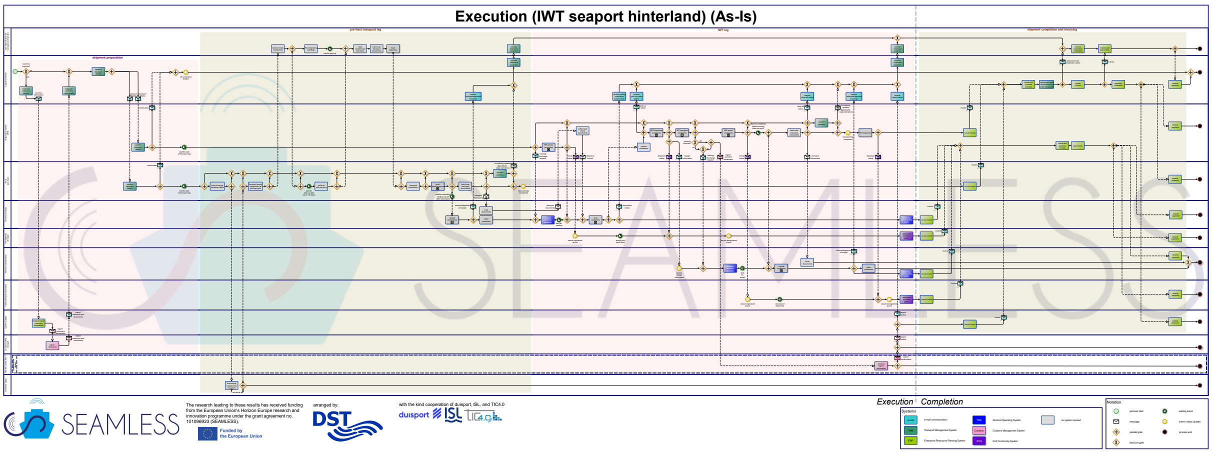


Figure 70. Execution layer of the Logistics Reference System Architecture of the continental IWT case (as-is)

2.5.2.2 Administrational Procedures

Customs Procedures

Whether customs procedures are relevant for the use case will depend on the customs status of goods as well as the choice for procedures. In the case of imports coming into the Port of Antwerp and being moved by inland waterway transport, most goods will already have received Union-goods status within the seaport. Also, it is also possible to lodge for a specific use or transit customs procedure, so that the transported goods via inland waterways are still considered non-Union goods. In addition to the common transit procedure, the UCC allows to use the procedures according to the Rhine Manifest for transport of goods via the Rhine. However, according to EU customs authorities, this procedure is no longer adopted by IWT players and is therefore being replaced by the NCTS procedure.

Vessel Reporting

The European Union has significantly advanced its inland waterway transport system by implementing electronic vessel reporting systems. This development aims to enhance the efficiency, safety, and reliability of inland navigation, contributing to the overall sustainability and competitiveness of the transport sector. The purpose of the standards for Electronic Reporting in Inland Navigation is to enable electronic data interchange (EDI) for reporting purposes to and between competent authorities and to facilitate electronic data interchange among partners in inland navigation as well as with partners in the multi-modal transport chain involving inland navigation. The standards describe the messages, data items, codes, and references to be used in electronic reporting for the different services and functions of River Information Services (RIS). These standards contain the basic and most important recommendations for electronic reporting, with some procedures and recommended practices expected to be revised upon empirical experience. The standards address the relationships between private parties (shippers, skippers, terminal operators, fleet managers) and public parties (waterway authorities, public ports), but do not cover relationships between private parties without the involvement of public partners (Central Commission for the Navigation of the Rhine (CCNR), 2015).

This endeavour of harmonisation and facilitation of standards in electronic inland ship reporting in Europe is known as **Electronic Ship Reporting International (ERI)** (Central Commission for the

Navigation of the Rhine (CCNR), 2015). Key legislative measure for ERI is the so called RIS-Directive 2005/44/EC (Directive 2005/44/EC, 2019) on harmonized river information services on inland waterways in the Community. This directive laid the foundation for the systematic deployment of electronic reporting systems, ensuring interoperability and data exchange between different national RIS platforms. Over time, several technical specifications for RIS and ERI, so called RIS Guidelines (*RIS Guidelines*, n.d.), have also been implemented, some of which build on each other. The Regulation (EU) 2019/1744 (Commission Implementing Regulation (EU) 2019/1744, 2019) on technical specifications for electronic ship reporting in inland navigation is currently the newest regulation to further harmonize and standardize these reporting systems across member states. In addition, European standards for River Information Services in general and for Electronic Ship Reporting in Inland Navigation in specific, are published and continuously updated by the European Committee for drawing up Standards in the field of Inland Navigation (CESNI) (European Committee for drawing up Standards in the field of Inland Navigation (CESNI), 2023).

Electronic reporting systems enable vessels to report voyage-related data electronically and facilitate efficient communication between vessels and port authorities. This includes pre-departure notifications, cargo information, and arrival updates. Messages within these systems are based on United Nations rules for Electronic Data Interchange for Administration, Commerce, and Transport (UN/EDIFACT) (United Nations Economic Commission for Europe, n.d.), and customized for inland navigation purposes. The primary message types include:

- **(Dangerous) Goods Reporting Message — ERINOT:** This message is a specific use of the UN/EDIFACT 'International Forwarding and Transport Dangerous Goods Notification (IFTDGN)' message and shall be used for the reporting of voyage related information on dangerous and non-dangerous cargo carried on-board vessels sailing in inland waterways.

  The ERINOT message encompasses the following types:

a) transport notification from vessel to authority

b) transport notification from carrier to authority

c) passage notification (identifier 'PAS' in both Extensible Markup Language (XML) and UN/EDIFACT formats), from authority to authority

- **Passenger and Crew Lists Message (PAXLST):** The PAXLST message is a specific use of the UN/EDIFACT message with the same name and shall be used for reporting the lists of passengers and crew on board between captain/skipper or carrier and relevant authorities such as customs, immigration, police or terminals falling under the ISPS Code.

- **ERI Response Message (APERAK) — ERIRSP:** Originally derived from the UN/EDIFACT Application Error and Acknowledgement Message (APERAK) and acknowledges the receipt of ERINOT messages.

- **Berth Management Port Notification Message (BERMAN):** This message is a special use of the UN/EDIFACT message with the same name and shall be sent by vessels before arriving at or departing from a berth or port. The message provides details about the time of arrival or departure and required services.

- Additionally, the **ERIVOY message** can be used to report voyages involving multiple stops or changes in convoy configuration, though it is not part of the official standard. The message is based on the United Nations Directories for Electronic Data Interchange for Administration, Commerce and Transport (UN/EDIFACT) Forwarding and transport schedule and availability information (IFTSAI) (Transport Scheduling and Information) message). According to CESNI the ERIVOY message shall be sent from a carrier, its agent or a ship to the responsible waterway authority (European Committee for drawing up Standards in the field of Inland Navigation (CESNI), 2023).

As of today, Electronic Reporting International (ERI) has been adopted by most EU Member States and integrated into policing regulations. Competent authorities have established a set of backend systems to support these reporting requirements, including:

- **CBS-SRK:** The Central Broker System used in the Zeeland region for various shipping authorities in the Netherlands and Belgium.

- **BICS:** Developed by Rijkswaterstaat, BICS (Barge Information and Communication System) is the name for both, backend and frontend system for electronic ship reporting in the Netherlands.

- **eRIBa:** Electronic Reporting for Inland Barges, used in Flanders, developed by De Vlaamse Waterweg nv, Port of Antwerp-Bruges, North Sea Port, Port of Ostend, Agency for Maritime and Coastal Services and the Joint Nautical Management

- **ENIGMA:** The Electronic Network for Information in the Ghent Maritime Area.

- **APICS:** Antwerp Port Information and Control System.

- **IVS-Next:** Integrated Traffic Management System.

- **NaMIB (Germany):** Nachfolgeanwendung des bestehenden Melde- und Informationssystems für die Binnenschifffahrt (Successor application of the existing reporting and information system for inland navigation) (*ERI - Status Implementation*, n.d.).

- **VELI:** Launched in October 2011 by the French authorities (Central Commission for the Navigation of the Rhine (CCNR), 2015) is both, backend and frontend system only to be used in France (de Lijster, 2009).

Vessel operators can choose from a set of different software solutions readily available on the market. These software solutions work as frontend systems that communicate with the linked backend systems mentioned above (de Lijster, 2009; *RIS Guidelines*, n.d.).

- **BICS (Rijkswaterstaat):** Developed by Rijkswaterstaat, BICS (Barge Information and Communication System) is widely used in Europe for electronic reporting of voyage and cargo information.
- **ContainerPlanner (Autena):** A system by Autena that supports container planning and reporting, enhancing operational efficiency and compliance with reporting requirements.
- **NAVIGIS (Tresco):** NAVIGIS by Tresco provides integrated navigation solutions, including electronic chart display and information system (ECDIS) capabilities for inland waterways.
- **Inland ECDIS Viewer (Periskal):** Developed by Periskal, this viewer supports the display and interaction with inland electronic navigational charts (ENC), aiding in navigation and reporting.
- **RiverGuide (Teqplay):** RiverGuide by Teqplay offers a comprehensive tool for voyage planning, navigation, and reporting, tailored to the needs of inland navigation.
- **UAB-Online (UAB):** A system designed for various reporting tasks, UAB-Online facilitates the electronic submission of voyage and cargo information.
- **Vemasys (Blue Century):** Vemasys by Blue Century is used for electronic reporting and management of vessel operations, supporting compliance with regulatory requirements.

Implementation Status

Figure 71 shows the local implementation of the various systems that are relevant for the DUC 2. While in the VTS Scheldt (striped area), reporting via VHF is still mandatory, various systems for purely electronic reporting are installed on the inland waterways.

Starting from France, the skipper must first report his voyage via the French VELI system. The information available on linking VELI with other systems is not uniform. While data transmission between VELI and the Belgian system should take place via email in the direction from Flanders to France, but not vice versa, data transmission between the systems of other countries seems to be possible via the German NaMIB system as an intermediary (*ERI - Status Implementation*, n.d.; *ERI Status Overview Implementation*, n.d.). It is not known why this connection between Flanders and France does not seem to be possible.

The eRIBA system set up in Flanders is a pure backend solution that is also used for data exchange between the Netherlands and Belgium. For electronic reporting in Belgium, all of the named software solutions on page ... are compatible with eRIBA. However, the BICS software appears to be the standard here, as the intercompatibility between eRIBA and BICS is explicitly emphasized on the eRIBA-Website. For border crossings between Flanders and the Netherlands, additional electronic reporting is no longer necessary and the information is exchanged in the backend between IVS-Next and eRIBA (*Digital Sailing?*, n.d.).

According to the BICS-Website, BICS is linked to the Systems of the Netherlands, Flanders, Germany and the Central & Eastern European Reporting Information System CEERIS, i.e. the System of the states bordering the Danube (Rijkswaterstaat, n.d.). Here, it is also stated that the German system NaMIB serves as intermediary to inter alia France, but also to Luxembourg and Switzerland (Rijkswaterstaat, n.d.). The form of reporting in Wallonia (red area in Figure 71) is not clear. A leaflet on electronic ship reporting from the Central Commission for the Navigation of the Rhine (CCNR) from 2015 describes that a system called GINA (Gestion intégrée de la Navigation) can be used in Wallonia (Central Commission for the Navigation of the Rhine (CCNR), 2015). It is unclear whether this system is still in use, as no information can be found on the internet.

Due to the explicitly mentioned intercompatibility of the BICS software with all reporting systems mentioned on the DUC 2 route (with the possible exception of Wallonia), this solution seems to fulfil the requirements of DUC 2. Other user systems mentioned may also fulfil these requirements, but the documentation provided leaves room for doubt.

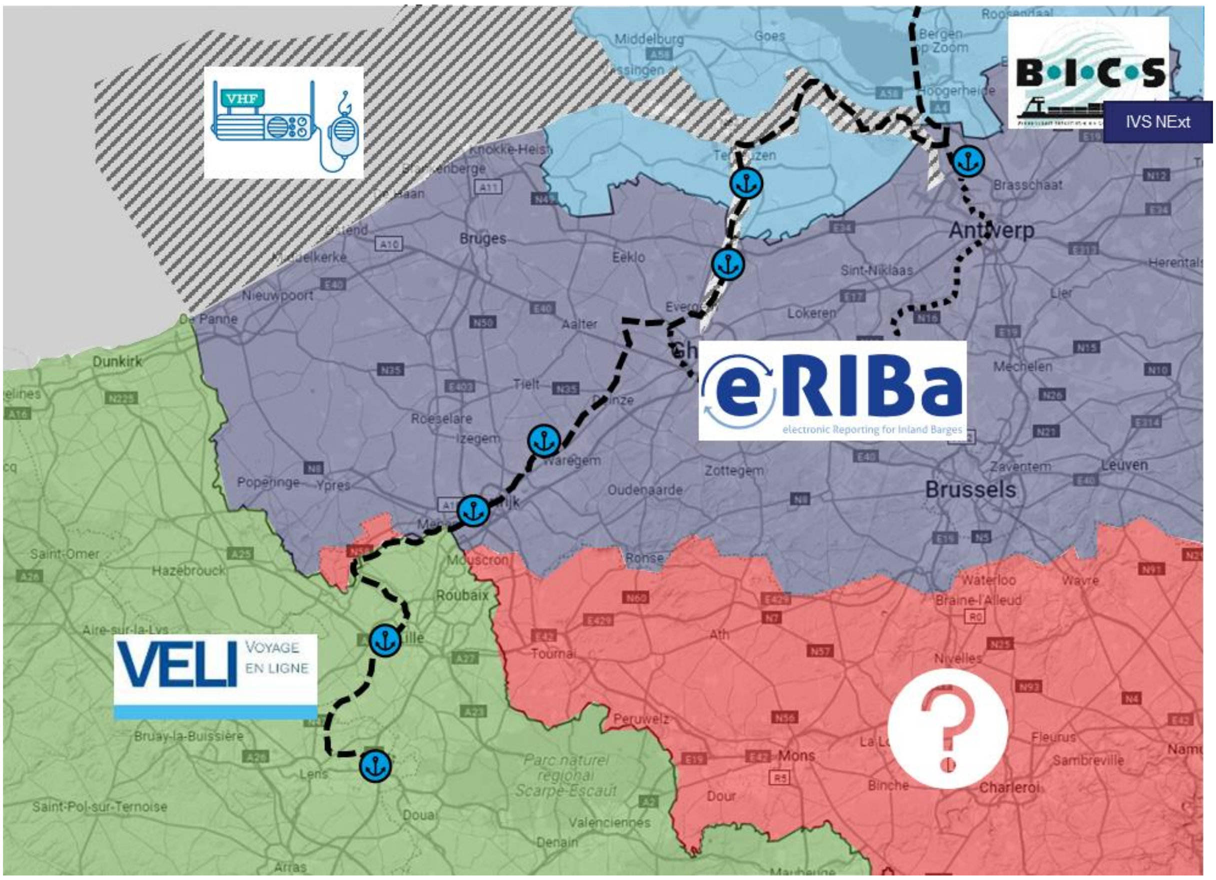


Figure 71. Different vessel reporting systems in DUC 2

Electronic Reporting Obligation

France

River freight vessels are required to make loading and empty transport declarations for each trip (art. R 4461 of the French Transport Code).

Article 9 of Ordinance no. 2021-409 of April 8, 2021, "relative au transport fluvial et à la navigation intérieure" ("on river transport and inland navigation") in Chapter V, "dispositions relatives au contrôle du transport fluvial" ("provisions relating to the control of river transport"), generalizes the obligation to declare the journeys of commercial vessels, whether empty or loaded, in electronic form, throughout the entire navigable network entrusted to Voies Navigables de France.

Any loading declaration that is not made by electronic means is treated as a failure to declare and will be subject to automatic invoicing of the toll due, plus a 100% penalty (*VNF*, n.d.-b).

Flanders

In Flanders the general obligation to report electronically is only valid for ships carrying dangerous goods as mentioned in the "Decree of the Flemish Government on the electronic reporting of data by ships and amending the decision of the Flemish Government of 25 May 2018 adapting the regulations regarding the transport of dangerous goods on inland waterways to scientific and technical progress." The method of reporting is similar to that in the Netherlands and the information to be reported can be found in the relevant regulation (Belgische Federale Overheidsdiensten, 2022).

Netherlands

The Dutch "Communication regulations and dimensions of national inland waterways" (Koninkrijksrelaties, n.d.) state that the skipper or captain of inter alia ships that transport containers shall report electronically before entering certain sections named in the regulation. The sections "Terneuzen locks + bridges Sluiskil and Sas van Gent" and the River Scheldt are relevant for DUC 2 (see also the following section VTS Scheldt). The Information that this notification shall state can be found in Article 2 of the "Regeling communicatie en afmetingen rijksbinnenwateren" (Koninkrijksrelaties, n.d.). The regulation further states that if navigation is interrupted for more than two hours, the skipper or captain of a ship shall report the beginning and end of this interruption to the nearest IVS -post.

VTS Scheldt

Although the DUC 2 is an inland waterway use case, it is also intended to use some sea routes, including the Scheldt. The Scheldt will be monitored by a Vessel Traffic Service (VTS), which will intervene in critical traffic situations and communicate with the vessels involved if necessary. In addition, the VTS transmits relevant information about the sea area and can warn skippers promptly. The VTS Scheldt is operated jointly by Flanders and the Netherlands under the organization "Gemeenschappelijk Nautisch Beheer".

To ensure safe and smooth navigation in the Scheldt area, there are clear "VHF procedures" that must be followed when navigating the Scheldt. With regard to DUC 2, first report to channel 03 when leaving the Terneuzen lock on the way to Antwerp. After that, the messages are sent according to Figure 72 on the corresponding channels (VTS-Scheldt, 2024).

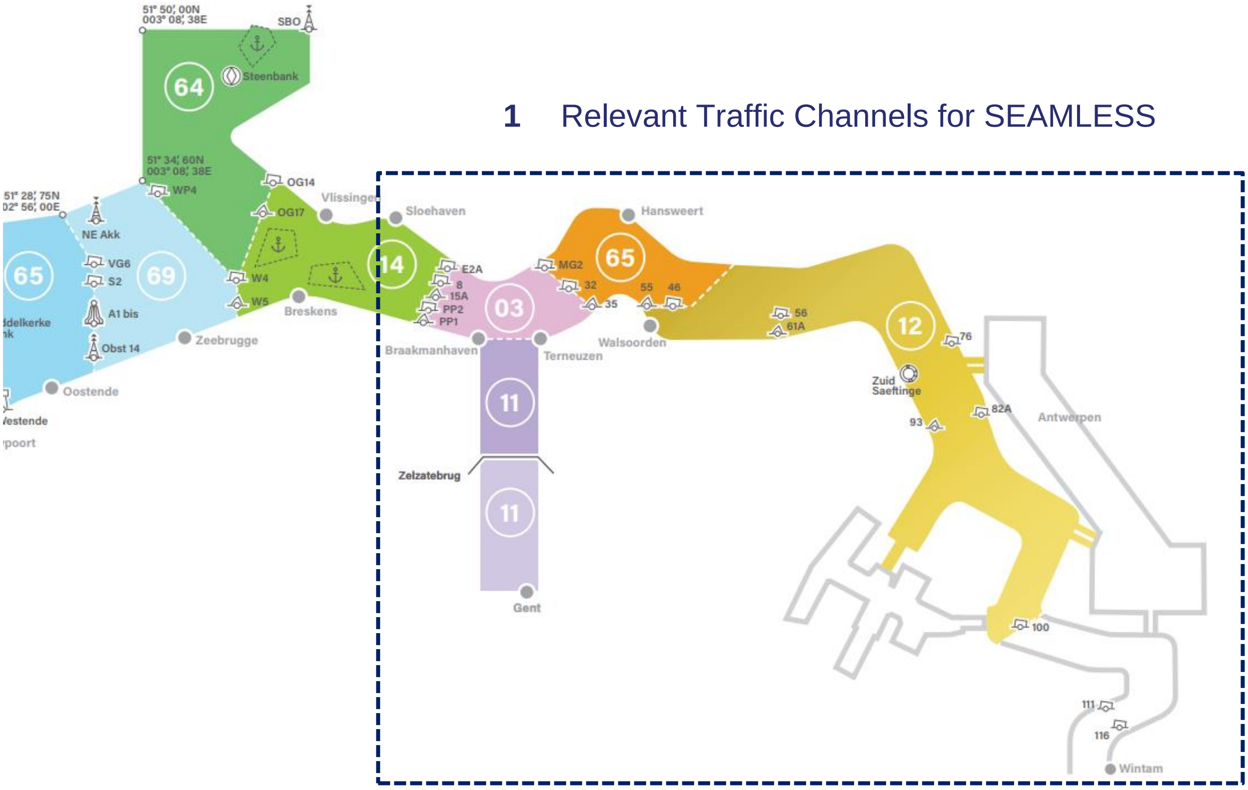


Figure 72. Relevant Traffic Channels for DUC 2 in VTS Scheldt

Traffic Management and Navigational Safety

Inland water shipping is a vital component of the transportation network, offering a cost-effective and environmentally friendly mode of transporting goods and passengers. Ensuring traffic management and navigational safety on these waterways is crucial for preventing accidents, maintaining efficient flow, and protecting the environment. Unlike maritime short sea traffic, the concept of Vessel Traffic Services (VTS) is not directly applied in inland water shipping, because of its limited application. Inland waterways, especially in rural areas, often lack the infrastructure and density of traffic that justifies the full implementation of VTS. Instead, traffic management in these areas relies on simpler and more localized systems. In areas with dense and especially with mixed traffic, such as the Westerscheldt or the port of Antwerp, inland vessels are required to consult VTS centres in addition to using vessel-to-vessel communication. This ensures a higher level of traffic management and safety in complex navigational environments where both inland and maritime vessels operate. General information or conditions related to changes in navigational rules on certain waterway areas are usually published by the national waterway authority using the Notices to Skippers (NtS) River Information Service. These can be retrieved on the websites of the national authority, on some ECDIS viewers as well as using the EuRIS platform.

VHF communication

In rural areas, traffic coordination is primarily done by VHF which is one of the traditional RIS technologies as the CCNR calls it (Central Commission for the Navigation of the Rhine, n.d.). To harmonize and optimize the use of radio telecommunication on inland waterways the respective administrations of several European Countries, including France, Belgium, the Netherlands and Germany, in 2000 agreed upon the “Regional Arrangement on the Radiocommunication Service for Inland Waterways (RAINWAT)” (*Regional Arrangement on the Radiocommunication Service for Inland Waterways (RAINWAT)*, 2013). The primary objectives of RAINWAT are to establish uniform communication protocols for vessels on inland waterways, enhance navigational safety through consistent and reliable communication, streamline traffic management and coordination to prevent delays and congestion, and facilitate international cooperation to ensure seamless communication across borders.

Key components of RAINWAT include the designation of specific VHF channels for different types of communication, such as distress, safety, and operational messages. For instance, VHF channel 22 is commonly used for reporting entrance into certain areas and coordinating movements in restricted sections. Standardized communication protocols are another crucial element, ensuring vessels follow predefined procedures when reporting their positions, intentions, and navigational status. Vessels are required to maintain a continuous listening watch on designated channels to ensure they can respond promptly to any communication.

In addition to international harmonisation attempts such as RAINWAT, there are numerous national regulations governing the use of VHF. An example is provided by the policing regulation within the Nord Pas-de-Calais region in France, which states a passing and crossing restriction on the Deule Canal near Lille. In this case, the entrance of this area needs to be reported via VHF (*VNF*, n.d.-b, pp. 11, 27).

In addition to the harmonization in VHF communication a further integration of technologies like AIS or advanced digital communication technologies has already been established by some authorities and administrations. An example for a digital communications system is APICS.

Ship Reporting System – APICS Barge:

The APICS Barge system is a system used in the port of Antwerp, to report vessel arrivals and departures. This system also facilitates additional services such as coordinating locks, mooring/unmooring operations, onshore power supply points, or waste collection centres. In addition, APICS Barge gives barge operators or skippers the possibility to receive a digital overview of the situation in the port of Antwerp, such as the position of locks and bridges, tides and the current wind force and wind directions. APICS Barge can be accessed via an app or a website, making it convenient for operators to manage their interactions with port authorities (C-Point, n.d.-a).

Vessel-to-Lock Interaction

Communication between vessels and lock operators is crucial for managing the passage through locks, which are often choke points in inland waterways. The process of coordinating with lock operators is usually done via VHF radio. However, this process is not harmonized across different regions, leading to variability in procedures and communication protocols.

The lack of standardized procedures for vessel-to-lock interaction can lead to inefficiencies and delays. Efforts to harmonize these processes could significantly improve traffic flow and safety. In the VNF network however, the crossing of locks is performed with a specialized remote control that is used, to register with a lock and to request a locking. The navigation lights on the remote control guide the vessel through the lockage (VNF, n.d.-a). As already discussed above, in areas, where mixed traffic with inland vessels and maritime vessels sharing infrastructure, occurs, inland vessels have to comply with the VTS scheme, as discussed in section 2.3.2. Also in the area of Port of Antwerp-Bruges a digitalized solution for lock passages is given; as hinted in the previous paragraph on “Ship Reporting System – APICS Barge”, APICS Barge can be utilized to guide the skipper through the process of a lockage. A lockage can be booked in advance. The lockage plan and any changes towards the process of the lockage are made available to the skipper via the application (C-Point, n.d.-b).

Conclusion

Traffic management and navigational safety in inland water shipping rely heavily on vessel-to-vessel communication, particularly on rural stretches where infrastructure for VTS is not feasible. VHF radio communication plays a pivotal role in ensuring safe navigation, reporting to port authorities, and coordinating with lock operators. Systems like APICS Barge in the port of Antwerp demonstrate how technology can enhance these interactions, although there remains a need for harmonization in procedures, especially concerning lock operations. By adopting standardized communication protocols and leveraging technological solutions, the inland water shipping industry can enhance safety, efficiency, and operational coherence.

Transport Documentation

For international transport using inland shipping, a freight letter or consignment note may be used according to the Convention on the Contract for the International Carriage of Goods by Inland Waterways (also known as Budapest Convention).

For inland waterway transport within Europe, the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN) is applicable for dangerous goods. This implies, that all information required by ADN must be available to the barge operator either in paper or electronic form.

Emission Reporting

EU MRV and IMO DCS are directed towards maritime vessels and do not apply to inland waterway shipping. Currently, no legislation requiring emissions reporting in inland waterway shipping is in force in the countries, in which DUC1 takes place (France, Belgium, Netherlands, Germany). Also, the ports envisioned for DUC1 currently do not have any mandatory emissions reporting of any kind. Therefore, there is no emissions reporting within the scope of DUC1.

3 IDENTIFYING THE POTENTIAL FOR CHANGE THROUGH SEAMLESS INNOVATIONS

3.1 SEAMLESS BUILDING BLOCKS AND INNOVATIONS

Within the SEAMLESS research project, a series of innovations are being researched, developed, and tested in order advance future waterborne logistics. These individual innovations have been consolidated to so-called SEAMLESS building blocks which again act as technical enablers of a fully automated, economically viable and cost-effective, waterborne freight feeder loop service. These building blocks relate to different aspects of logistics management and logistics execution, such as supply chain and transport planning and vessel- and port-related matters of waterborne transport and logistics.

Precisely, the SEAMLESS research project features three building blocks:

1. Automated Port Interface (DockNLoad)
2. Modular Vessel and Operations Concepts
3. Integrated Supply Chain Support (ModalNET)

The building blocks refer to the port side including berthing, mooring, stowage planning, and cargo handling as well as the vessel side with the remote operation centre in the focus and supporting functions and features like rapid prototyping green machinery and propulsion, risk-based safety assessment, and a guidance, navigation, and control (GNC) scheme. Likewise, the integration into the supply chain – by means of a collaborative framework of logistics platforms, digitalized administrational procedures, and support in voyage planning, navigational and operational aspects – belongs to the focus areas of the SEAMLESS building blocks. Each of the SEAMLESS building blocks is supposed to work as a plug-and-play module in the respective transport use case, including the two Demonstration Use Cases and the six Transferability Use Cases of the SEAMLESS research project. Consequently, the building blocks apply equally to both short-sea shipping and inland waterway transport.

The SEAMLESS building block #1, Automated Port Interface (DockNLoad), considers the port side including berthing, mooring, stowage planning, and cargo handling and includes four SEAMLESS innovations. To these belong a system handling port calls of automated vessels including communications and operational assistance during port dwell time of the vessels, an autonomous container crane to load and discharge cargo while place on board or ashore, a robotic arm on board the vessel facilitating automated mooring by grabbing mooring lines and placing them on conventional bollards, and a system for the purposes of stowage planning and coordinating the loading and unloading sequences on automated vessels.

The SEAMLESS building block #2, Modular vessel and operations concepts, considers the vessel side including the control centre ashore that enables remote operation and shore-side control of vessel transit and manoeuvres, the technical aspects of remotely operated and autonomous vessels including the GNC scheme and connectivity and cyber-security aspects, as well as the design aspects of autonomous vessels including their evaluation and a method for safety assessment for risk-based approval. While the latter two do not actively influence the transport planning and execution processes (as they are supposed to have happened before the vessels entered into service), the earlier one is integrated in the modi operandi of both the autonomous vessels and the remote operation centre.

The SEAMLESS building block #3, Integrated supply chain support (ModalNET), considers the supply chain planning perspective as part of which autonomous vessels are to conduct the waterborne leg(s) of the end-to-end multimodal transport chain. ModalNET allows the transport customer, e. g., a logistics planner, to search for suitable transport chain configurations including different legs and potential service providers, as well as to take over proposed plans, modify those, and book them via the portal. During the execution phase, it is also supposed to allow reporting to authorities, such as port and waterway authorities and customs, and give insight into the respective progress status of the multimodal transport process.

As some of the innovations are functions and modules of others, the focus will be laid on six representative innovations that appear explicitly in the SEAMLESS Reference Logistics System Architecture and participate as individual system in the logistics process flows of the transport planning and execution layers. These encompass

A. Autonomous Cargo Handling System (from SEAMLESS building block #1),
B. Autonomous Mooring System (from SEAMLESS building block #1),
C. Autonomous Vessels' Smart Port Manager (from SEAMLESS building block #1),
D. Voyage and Container Optimisation Platform (from SEAMLESS building block #1),
E. Remote Operation Centre (from SEAMLESS building block #2), and
F. Integrated supply chain support (ModalNET) (from SEAMLESS building block #3).

In the following, each of these six SEAMLESS innovations will be described briefly – in close alignment with the remarks from other deliverables of the SEAMLESS project, such as D2.3 and D5.1.

3.1.1 SEAMLESS Building Block #1: Automated Port Interface (DockNLoad)

Autonomous Cargo Handling System

Typically, cargo handling of autonomous vessels is foreseen with shoreside infrastructure or manually (and sometimes remotely) operated on-board crane systems whereas the SEAMLESS innovation follows the concept of an automated on-board crane system.

The Autonomous Cargo Handling System (ACHS) can be positioned on board the vessel or ashore and used with short-sea vessels as well as inland vessels. This mainly depends on the precise use case, i. e., the availability of a crane on the shoreside, and the size of the vessel. The purpose of the ACHS is the transshipment of containers with human operation of the loading equipment and, thus, can be used for loading and unloading operations (nearly) at any port or transshipment point visited along the transport route.

The ACHS employs the design of a triple-joint crane and uses a winch to lift the container from the stack, the floor on terminal compound, or the loading bay of a vessel. In order to receive work orders, the ACHS features an interface with which the positions for lifting and dropping the container are transmitted and provided and through which entire sequences of loading and unloading operations according to the stowage plan of the vessel can be realized. Moreover, the respective status of the container, such as “idle”, “loading in progress”, or “unloading step completed”, can be retrieved for the individual container and the entire stowage plan. By utilising digital maps of the quay side and the loading bay of the vessel as well as information on real-time position and orientation of the vessel, the ACHS has its own situational awareness and autonomous control. It scans the surrounding working area of the crane by means of object detection and collision avoidance in order to ensure secure operation of the crane. While the movement from the parking position to the container is realised with the entire triple-joint crane, the fine positioning of the spreader once the crane is positioned in the immediate vicinity of the container is carried out with the help of the autonomous controller. The precise position of the container and the motion trajectories of the crane movement are computed with the situational awareness. Also, it can read container IDs to ensure that the correct container has been retrieved in order to be moved. Once the correct container has been identified and is ready to be grabbed, the crane positions the spreader, locks on to the container, and lifts the container in order to move it to the destined location on board the vessel or ashore, place it securely in the position, and release the container. The container crane also confirms the completion of the loading step and reports the position. It is important to note that the operation of the ACHS can be aborted manually in case of an emergency.

Autonomous Mooring System

While autonomous navigation takes the lion’s share of attention of both research and industry when dealing with autonomous navigation, mooring – just like other tasks and functions on board – remains an open question of subordinate importance. However, as autonomous vessels are to be deployed, the residual tasks apart from autonomous navigation remain to be addressed effectively and – from a technical and/or economic perspective – efficiently.

The Autonomous Mooring System (AMoS) is another SEAMLESS innovation, allowing autonomous vessels without crew on board moor at berths without human intervention. Apart from various solutions based on land-based installations which require (sometimes high) capital expenditure, e. g. from the port authority or the terminal operator, and, thus, are not very prevalent unless they are to assist regular and high-frequency services like ferry services, on-board solutions appear as a promising path.

With the help of the AMoS system, which is placed on board the vessel and supposed to cope well with miscellaneous types of bollards on the quayside, any autonomous (or remotely operated) vessel can moor at any berth, (largely) regardless of the precise port, terminal, or waterway – and is independent of human labour for the working step. Same applies to unmooring, which is also facilitated by the AMoS system. The AMoS system features an interface to external systems to incorporate external command signals, e. g., coming from a remote operation centre or a remote controller.

The AMoS system consists of a robotic arm, a series of winches, and an autonomous control system. Typically, a vessel needs four mooring lines and one or – in case of larger vessels – several robotic arms.

In order to conduct the mooring process automatically, the mooring arm detects both the quay and the bollards with the help of its sensors and, possibly, a digitalized map of the quay side with coordinates of the bollards. Next, it verifies that the destined bollard is not in use already, and calculates the motion trajectories of the arm and the mooring line to the bollard, and initiates the physical movement. Then, the robotic arm takes the mooring line, detects the bollard, and places the mooring line on the bollard. In order to safeguard safe and secure operation, object detection and anti-collision system are in place and avoid any crash into an object or structure. Once the bollard is put on the bollard, the winches tighten the mooring line, while the robotic arm returns to its parking position.

The winches are supposed to control the tension of the mooring line automatically. One winch is used per mooring line, leading to a total of four winches in a typical case. The autonomous control system comprises the mooring arm controller and dedicated winch controllers, with the earlier serving as the overall system controller. With the help of the winches, roll stability during cargo handling and position correction, e. g., during draft and tide changes can be equalised.

In the case of an automatic unmooring process, the robotic arm moves from the parking position to a position above the bollard on which the mooring has been placed on. Next, it detects the mooring line and the corresponding gripping position before it approaches the mooring line and grabs it. In case of unknown mooring lines detected on the bollard, the robotic arm stops operation and returns to the parking position. It is important to note that the operation of the AMoS system can be aborted manually in case of an emergency.

Autonomous Vessels' Smart Port Manager

Port calls belong to the typical and central tasks of a vessel while operating. While the process is largely manual in many cases, autonomous vessels need an automated system for assistance during port calls.

In order to address the matter in the SEAMLESS research project, the Autonomous Vessels' Smart Port Manager (AVSPM) acts as an intermediate between port authority and vessel operator (or supervisor, respectively). The AVSPM plans and conducts port calls, takes over negotiations with traffic management bodies, exchanges messages and data with authorities and other vessels, and ensures real-time safety and security monitoring.

The AVSPM plans port calls in the long term, i. e., weeks or months ahead of the port call, and confirms the planning in the short term, i. e., days or hours prior to the prior call. The long-term port call planning includes a pre-reservation of a berth and the transmission of related information about terminal, berth, and bollards. The short-term port call planning includes a negotiation in order to confirm allocations of terminal, berth, and bollards, arrival and departure times, and other booking details. Moreover, the route of the (autonomous and remote operated) vessels while sailing within the port area

During port call execution, the AVSPM confirms the berth readiness while approaching the berth and prior to initiating autodocking manoeuvres. Further, it transmits key information on traffic, such as position information, environmental data, such as wind and current information, and port notices to other parties involved in the port manoeuvres. Likewise, the AVSPM provides information on events occurred and achieved during the port manoeuvre phase, so that the vessel operator (or supervisor, respectively) is able to monitor the vessel movement. To this port call monitoring feature belongs a user interface in order to allow traffic managers like VTS a means to monitor and control the manoeuvres. Moreover, the AVSPM monitors the safety state of the autonomous vessel by constantly checking on its navigational and communication status.

Voyage and Container Optimisation Platform

Like other aspects affecting vessel stability, stowage planning belongs to the responsibilities of the shipmaster. He takes responsibility for the safety of the vessel, which might be affected by containers being loaded onto and unloaded from it. Accordingly, the plan how to tranship the cargo – more precisely, which containers in which sequence to load and unload – is traditionally made by the shipmaster or the administrational office of the shipping company. With autonomous vessels, the entire process needs to be redesigned as the manual (system-supported and, possibly, semi-automated) stowage planning process and the provision of the final stowage plan to the terminal operator in order to inform the crane operator – or alternatively to an automated crane unit like the ACHS – needs to be replaced with a new process using automated stowage planning and automated transmission of the plan to subsequent parties such as terminal operators welcoming autonomous vessels or autonomous crane units carrying out the loading and unloading sequences.

In the SEAMLESS research project, the Voyage and Container Optimisation Platform (VCOP) is developed in order to close this gap and, thereby, turn waterborne logistics using autonomous vessels into reality. As indicated above, its main function is the automated generation of the stowage plan and the corresponding loading and unloading sequences. Moreover, it acts as a high-level controller of the ACHS as the VCOP send work instructions to ACHS and monitors their execution.

The VCOP operates in terms of automated stowage plan generation while taking care of vessel stability, sailing schedule, cargo route (with respective origins and destinations) and other relevant boundary conditions. Next, the loading and unloading sequences are derived from the generated stowage plan which again can be transmitted to the ACHS as work orders. Also, the VCOP is the interface towards the terminal when to communicate the sequences for better planning and preparation on the terminal side.

3.1.2 SEAMLESS Building Block #2: Modular Vessels and Operations Concepts

Remote Operation Centre

The higher the automation level of a vessel, the bigger the scope of functions and responsibilities located in the shore control centre. Starting from mere monitoring and coordination tasks like in traffic control centres over remote operation and navigation like in remote control centres to shore-based supervision of automatedly operating vessels like in remote operation centres, the specific characteristics of the shore control centre depends on the level of automation and the vessel-operating functions that are subject to automation, such as navigation or berthing, for instance.

In the SEAMLESS research project, a Remote Operation Centre (ROC) is to be developed. The ROC encompasses remote operation workstations providing information and control to the vessel operators, server and computation infrastructure for data processing, and network and power management systems. Footing on previously developed technology in a preceding research and development project, the focus lies with the definition and design of high-attention modes, the determination of the conditions and requirements, and the development of procedures for handing over vessels between two operators or ROCs.

With respect to the low-attention mode, an operator of the ROC is supposed to be able to monitor three vessels by monitoring the navigational status and system health of the vessels and receiving detected issues potentially requiring a change of the attention mode. During the high-attention mode, the ROC operator is supposed to monitor the autonomous vessels more closely by accessing the information provided like in a remote-control centre. In this way, the operator has better situational awareness and faster reaction possibilities. To the tasks and duties of the operator belong the active control input to vessels, the interaction with other vessels, and the active decision-making in manoeuvring and navigation.

3.1.3 SEAMLESS Building Block #3: Integrated Supply Chain support

ModalNET

In order to integrate autonomous vessels in multimodal transport chains and international supply chains, their integration into existing transport management practices and end-to-end supply chain concepts is vital as the decision-making logistics planners from consignors or logistics service provider want to ensure safe, reliable and comfortable planning and execution of the multimodal transport. Hence, any new transport service, such as one using autonomous vessels, needs to safeguard that these conditions are met and yield an additional benefit with respect to logistics costs and service quality.

Typically, the ModalNET platform from the SEAMLESS research project is to provide features like transport chain planning, transport booking and shipment ordering, monitoring of vehicle, vessel and shipment, cargo handling and storage, and electronic vessel reporting. Existing solutions are combined and federated in such a way that only the missing links need to be closed to achieve the above-mentioned goal of providing a powerful and efficient transport management tool to plan and execute the related multimodal transport process.

ModalNET is supposed to facilitate matchmaking in the business initiation and booking phases of multimodal transport planning by means of the so-called computational engine for resilient logistics. Thereby, optimised schedules of multimodal transport service combinations are provided and presented to the user by retrieving information on individual transport services per leg from a database. When the logistics planner selects one transport chain and confirms the booking, the corresponding transport legs are booked via ModalNET. All subsequent steps can be managed within the ModalNET environment so that other actors and stakeholders can also complement supplementary data there. ModalNET features a cargo handling and storage component as an interface to the terminal to register cargo entries and an automated port interface for gate-in and gate-out orders via the TOS. Likewise, loading and discharging operations can also be managed within ModalNET, providing a bridge to the TOS. With the help of the vehicle, vessel and shipment monitoring component, the respective progress status of the object of interest can be retrieved and provided to interested parties like the consignor (or consignee, respectively) via status reports. The electronic vessel reporting component ensures compliance with reporting requirements of autonomous vessels when arriving at and departing from ports.

In case of existing solutions for any of the above-mentioned functions, ModalNET will incorporate them by federating the respective solution platform with it. With the help of APIs and connectors, ModalNET can be used with other platforms, systems, and formalities.

In addition, cybersecure communication with diligent and secure management of access, identity, and stakeholders is a prerequisite of the SEAMLESS innovation. The solutions are developed and deployed in cloud computing while the communication and external access is made possible by secure REST APIs.

3.2 Expectations of Logistics Redesign

Typically, existing analyses of automation within inland waterway transportation tend to focus on the technical aspects exclusively, whereas changes to the process flow are rarely considered. Combined with a focus on particular vessel-operating functions, like navigation, this may limit the possibilities to fully utilise the logistics benefits of IWT automation and to foster adoption. Increased transparency on process implications of automation technology allows stakeholders to better evaluate the compatibility with its current process organization. This enables informed decision-making and selection of solutions supplementing each other rather than implementing non-complementary systems that reduce the effectiveness of the overall process while increasing its complexity. By putting an emphasis on the process view, well-fitting solutions can be designed better, making the implementation effortless and, therefore, more attractive.

The approach of analysing business processes in detail and modifying them in order to obtain better performance or lower costs is not new. Developed by Hammer and Champy (1995), business process reengineering (BPR) intended to bring about a fundamental change in all business processes. To the motives for using BPR belong competitive pressure, customer satisfaction improvement, and product and service quality improvements. In its original form, BPR is supposed to undergo four phases, i. e., renewing, revitalizing, reframing, and restructuring (Hammer & Champy, 2003). As part of the renewal phase, the processes are recorded as they were organized and carried out before the BPR. After a precise analysis of the process organization, the core business processes are redefined. In the subsequent phase of revitalisation, the company uses the quantitative and qualitative data to evaluate the business processes. In the third phase of reframing, the development of new business processes is generated by inserting the existing processes and sub-processes into a process model. The modified measures are then implemented in the real workflow in the final phase of restructuring. Among the methods of classic process redesign, BPR belongs to the transformational methods.

Another approach is presented by business process management lifecycle (BPML) (Dumas et al., 2018). As a discipline, BPML is systematically concerned with how to examine, identify, optimize and monitor business processes to ensure that they lead to the right results over time. Technically, the BPM lifecycle consists of five stages including design, model, execute, monitor, and optimize – and pursues the goal of systematically and continually improving business processes. Starting with ‘design’ step in which the as-is process is thoroughly analysed and comprehended and the subsequent ‘model’ step encompassing a visual representation of the (as-is and to-be) process steps at stake, the third step ‘execute’ involves the expected change when the new model is put to the test in order to deploy the new (to-be) process. In the following ‘monitor’ step, the new business processes are carried out and data is acquired for the purpose of performance evaluation. The fifth and final step ‘optimize’ foresees the removal of bottlenecks and improvement of the performance.

An adapted method blended from the BPML and BPR methods was used to investigate process changes in the course of implementing innovations in automated IWT. The basic features of this method are the structuring of processes that define individual work steps and assign them to the actors, organizations or IT components involved individually. Following a cyclical step-by-step approach, the procedure ranges from the creation to the optimization and permanent monitoring of the documented processes. Based on a case-specific system definition, the (to-be) process organization of the individual innovations was examined. Subsequently, the actual processes of the workflows in inland waterway transportation, which are still highly manual today, were created in accordance with the model phase of BPML. The know-how required for this was gained through process observations and collaborative workshops and discussion panels with the engineers and future users. The as-is process descriptions served as the basis for the development of to-be processes, taking into account the IWT innovations examined. The process-related effects of the technical solutions were interpreted from logistics actor's perspective and integrated into the new overall to-be process.

In the context of the SEAMLESS research project, this aspect is to be addressed by systematically determining the scope of change induced by the SEAMLESS innovations. To start with, the entire consortium – consisting of consignors, logistics service providers, shipping companies, port authorities, technology providers, and maritime and waterway authorities as well as researchers and developers from various fields of the waterborne logistics domain – has been confronted with the scope of the innovations and asked to provide their expectations regarding the change to be expected from each of the SEAMLESS innovations. Afterwards, the replies have been consolidated, analysed and scrutinised for critical, surprising, or particularly noteworthy expectations. On the basis of the replies, the technical development teams of each SEAMLESS innovations have been consulted (once or several times, depending on the complexity of the matter) in order to identify the process change induced by the respective innovation. Once validated, the respective logistics process flow has been integrated into the to-be logistics process flows of the transport planning and execution layers – in accordance with the above-mentioned blended approach from BPR and BPML.

During a General Assembly meeting of the SEAMLESS consortium in Rome, Italy, in December 2023, the consortium underwent a hybrid one-hour workshop in which the group of 42 persons (with 27 participants on site and 15 online) has been divided into three groups and an online whiteboard tool has been set up as a digital collaborative platform. The whiteboard presented the leading question (“How do you expect processes, interactions, administrative procedures, etc. to change from SEAMLESS?”) and three dedicated fields for the three SEAMLESS building blocks, i. e., DockNLoad, Modular Vessel & Operation Concept, and ModalNET. Each of the three groups was assigned to one of the three building blocks and instructed to contribute their respective views on expected process changes through the innovations of the respective building block. Whereas the first group discussed ACHS, AMoS, AVSPM, and VCOP, the second one focused on the ROC and its innovative functions, and the third group elaborated on ModalNET and its different features. The participants were able to provide their views by writing a digital sticky note and posting it in the right field. The sticky notes did not reveal any information about the person who posted the note nor his affiliation. Parallelly, the discussion was ongoing as the participants were commenting their own and others' sticky notes and their remarks.

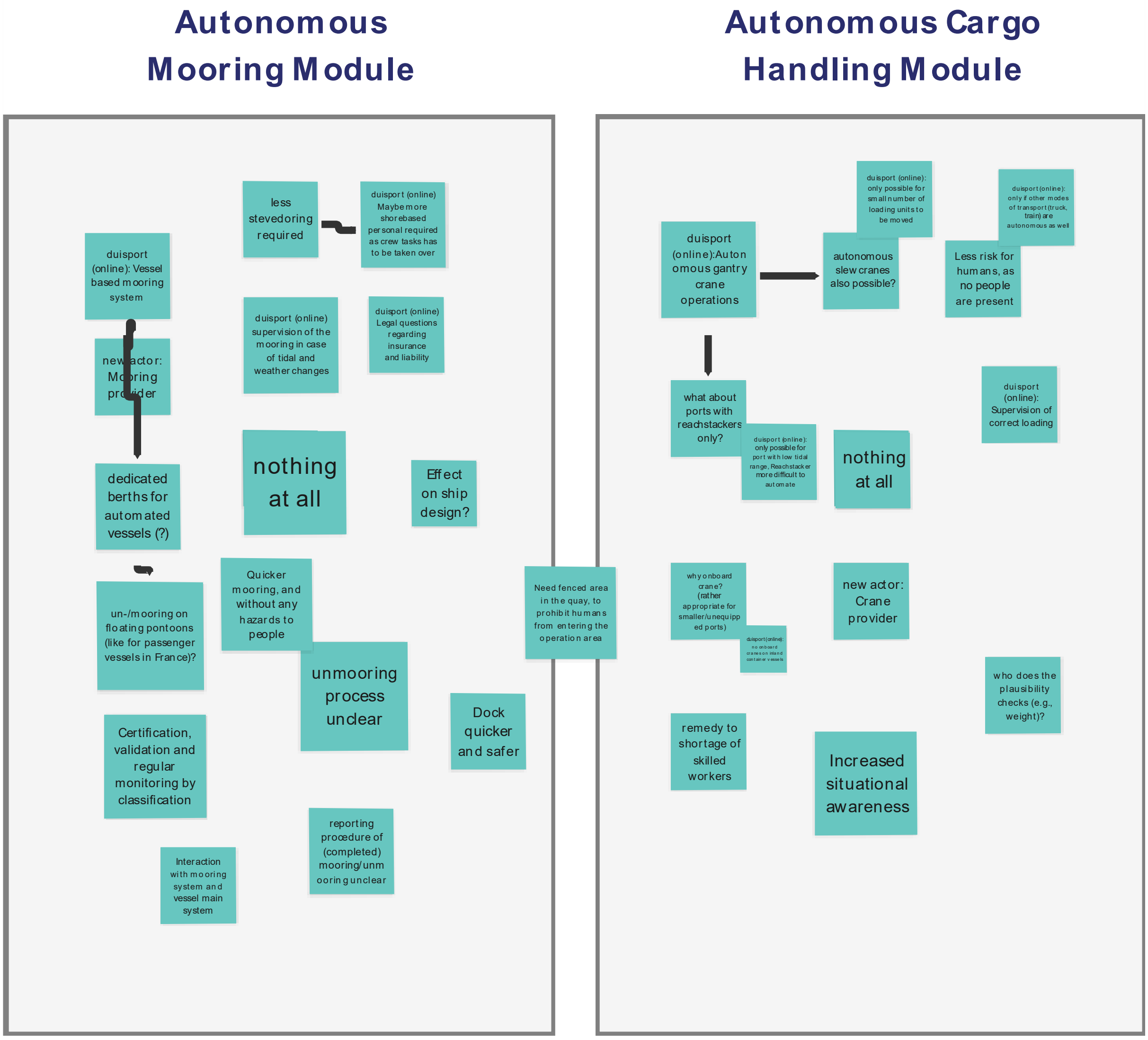


Figure 73. Results of Logistics Redesign workshop on SEAMLESS building block #1 innovations

The results of the discussion about SEAMLESS building block #1 is shown in Figure 73 and Figure 74. Due to the fact that four different SEAMLES innovations have been discussed, a large number of comments and remarks have been collected. The innovations address vessel-operational functions that have their respective conventional counterpart which again were familiar to the participants.

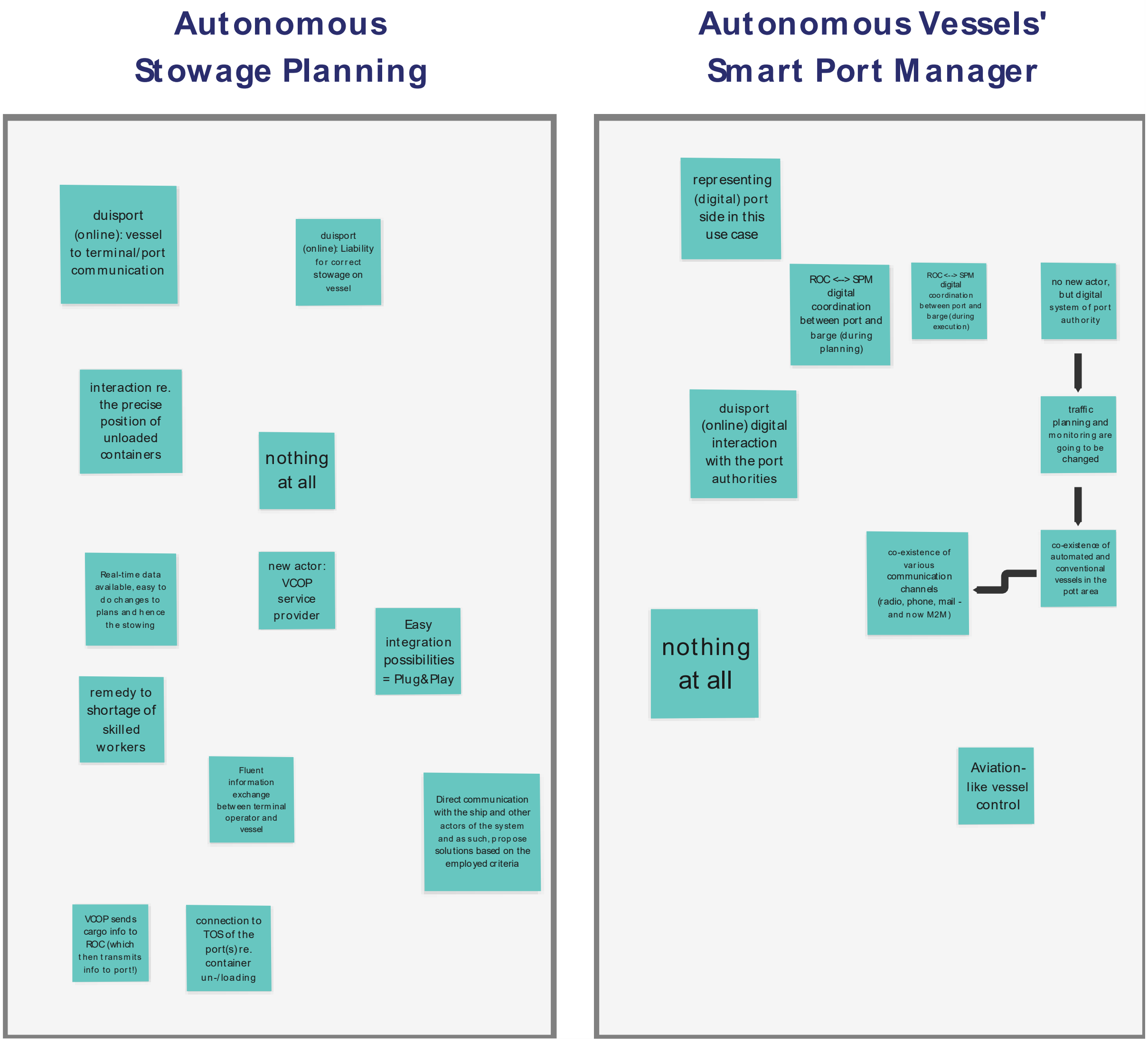


Figure 74. Results of Logistics Redesign workshop on SEAMLESS building block #1 innovations

Similarly, the discussion about the ROC stimulated a series of replies from the workshop participants, not least because of its numerous different functions. By comparing the current modus operandi with the different functions envisioned for the ROC, the remarks clarify the expected change. Figure 75 and Figure 76 illustrate the workshop results about SEAMLESS building block #2.

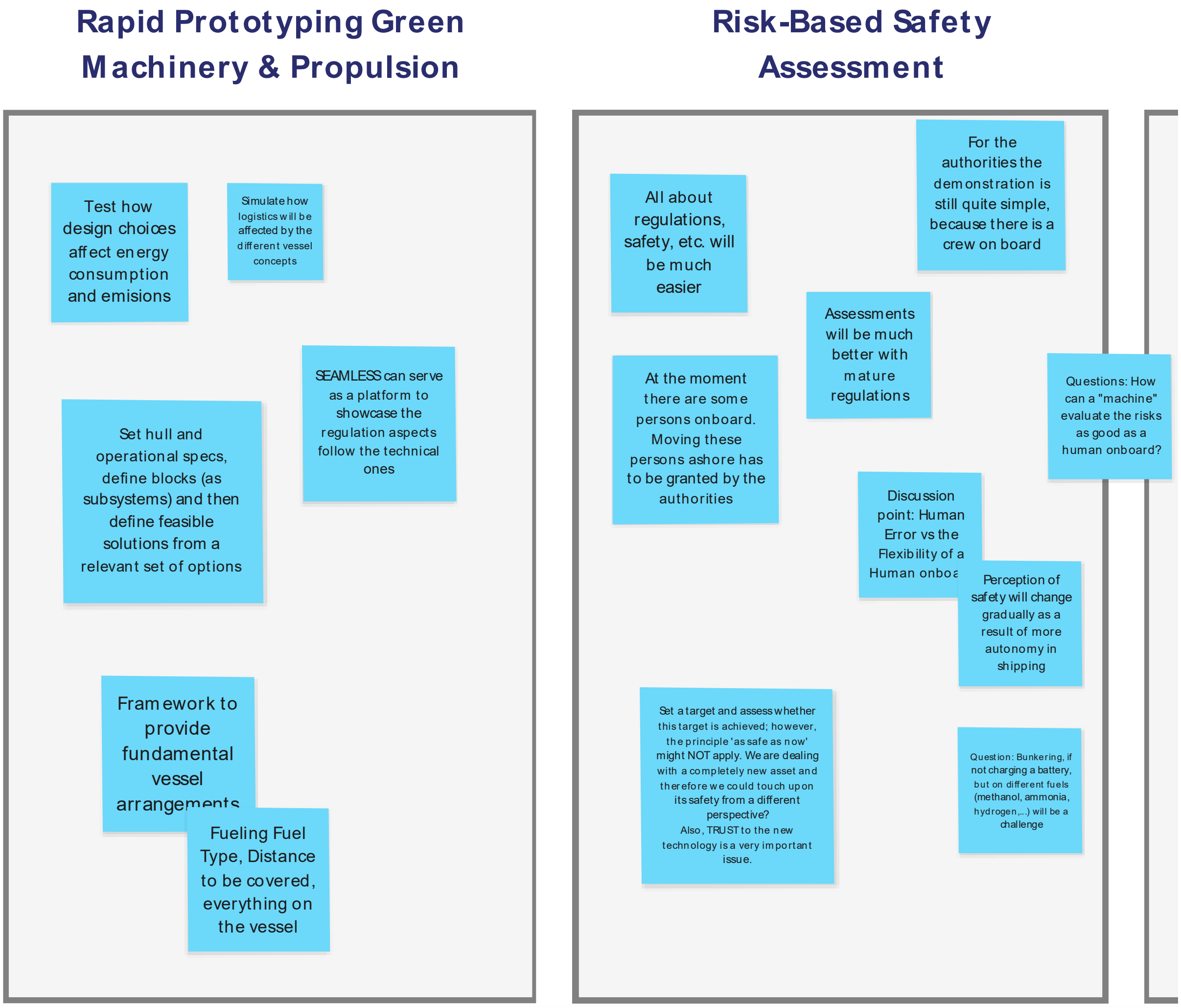


Figure 75. Results of Logistics Redesign workshop on SEAMLESS building block #2 innovations

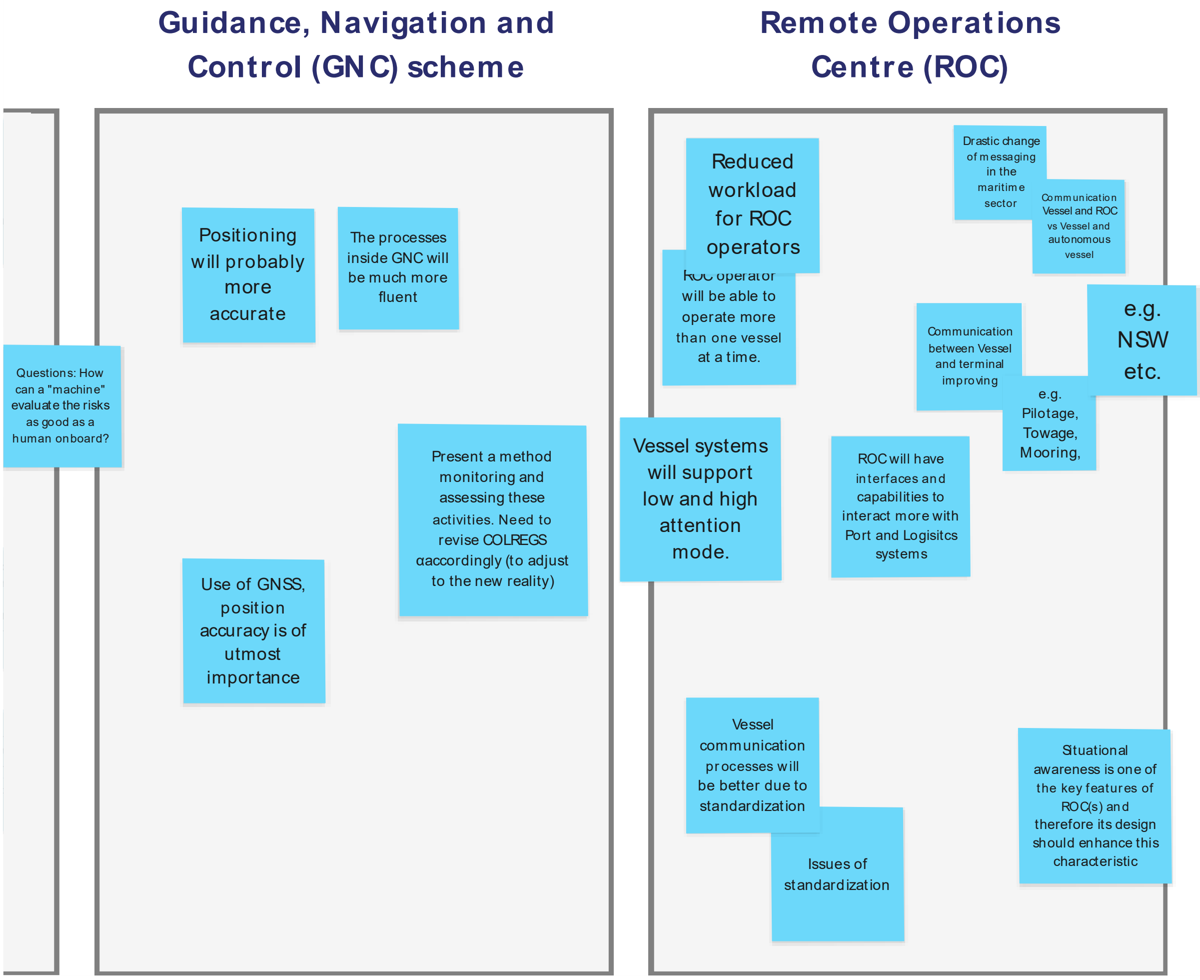


Figure 76. Results of Logistics Redesign workshop on SEAMLESS building block #2 innovations

The views of the workshop participants about the process changes caused by SEAMLESS building block #3 are presented in Figure 77. In contrast to the preceding building blocks, the functional scope of ModalNET spans over the entire cargo story and goes beyond the vessel movement which again makes it difficult to spot the precise changes beyond generic expectations.

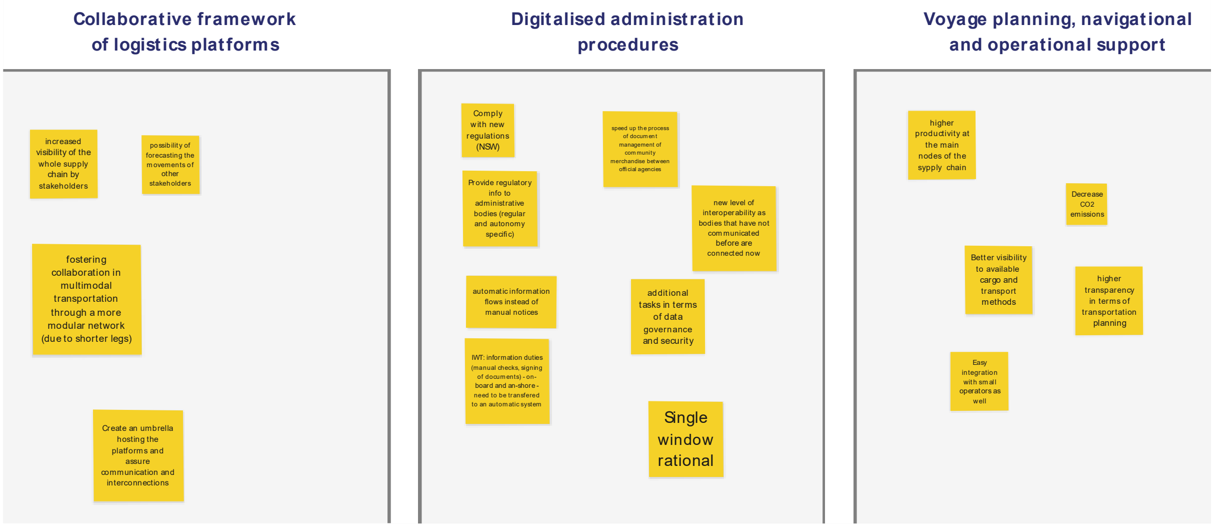


Figure 77. Results of Logistics Redesign workshop on SEAMLESS building block #3 innovations

The replies of the workshop participants have been clustered according to the SEAMLESS innovations and analysed regarding their content.

With respect to ACHS, the replies were categorized into nine major effects that are expected in the wake of deployment of the innovation. Obviously, the main change expected is the change of the process and the underlying task as a formerly operation-oriented job undergoes a transition to a supervisory role. Compared to conventional on the shoreside, the crane itself works differently in terms of technical operation. Due to the lack of humans in close vicinity of the ACHS, an increased safety level is expected. Moreover, the ACHS is supposed to introduce new actors and stakeholders as the vendors and service providers of the ACHS are expected to enter the stage. Using the ACHS is expected to have an impact on operational performance and, possibly, the technical equipment of terminals. Even the layout of ports could change as the larger shoreside cranes are replaced with on-board cranes. Further, the market structure is supposed to change as smaller ports can prospectively be called at by the introduction of ACHS. Hence, the ACHS is considered to be a game-changer as ports whose port operations are endangered can preserve their operation by being able to welcome autonomous vessels and handle cargo automatedly. Figure 78 shows the clustered workshop results on ACHS.

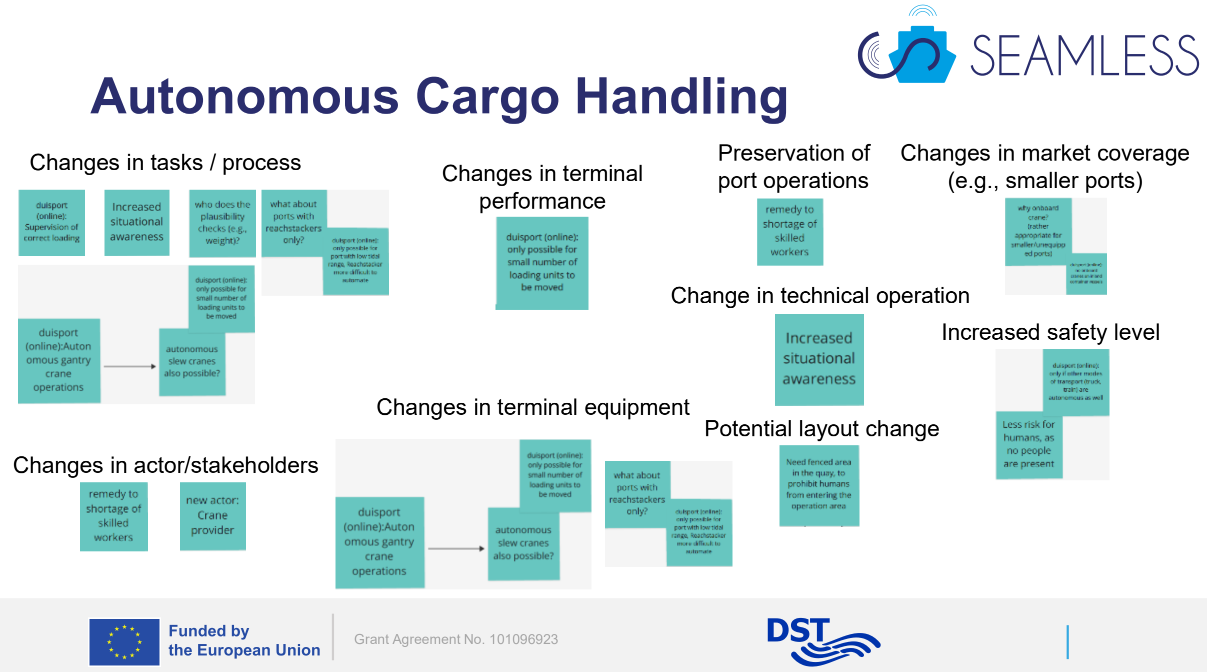


Figure 78. Clustered results from the Logistics Redesign workshop on ACHS

Similar to the ACHS, the discussion on the AMoS system yielded a multitude of replies with respect to expected changes of the mooring and unmooring processes (see Figure 79). Among the eight change effects in total, the immediate change of the process and the related tasks appeared most evident. In particular, the question of whether more personnel can be expected on land was discussed in detail during the workshop. Also, the evolution of new actors and stakeholders providing the asset or the service belongs to the expected effects in the wake of deploying autonomous mooring systems on board the vessels. The AMoS system works differently concerning its technical operation as the process today is fully manual. As in the case of ACHS, an increased safety level is expected due to the absence of humans in the working space. On a more abstract level, the introduction of AMoS systems is expected to lead to layout changes on the terminal side as well as changes in vessel design. Related to that, new or extended classification requirements and modifications to the insurance coverage are awaited as well.

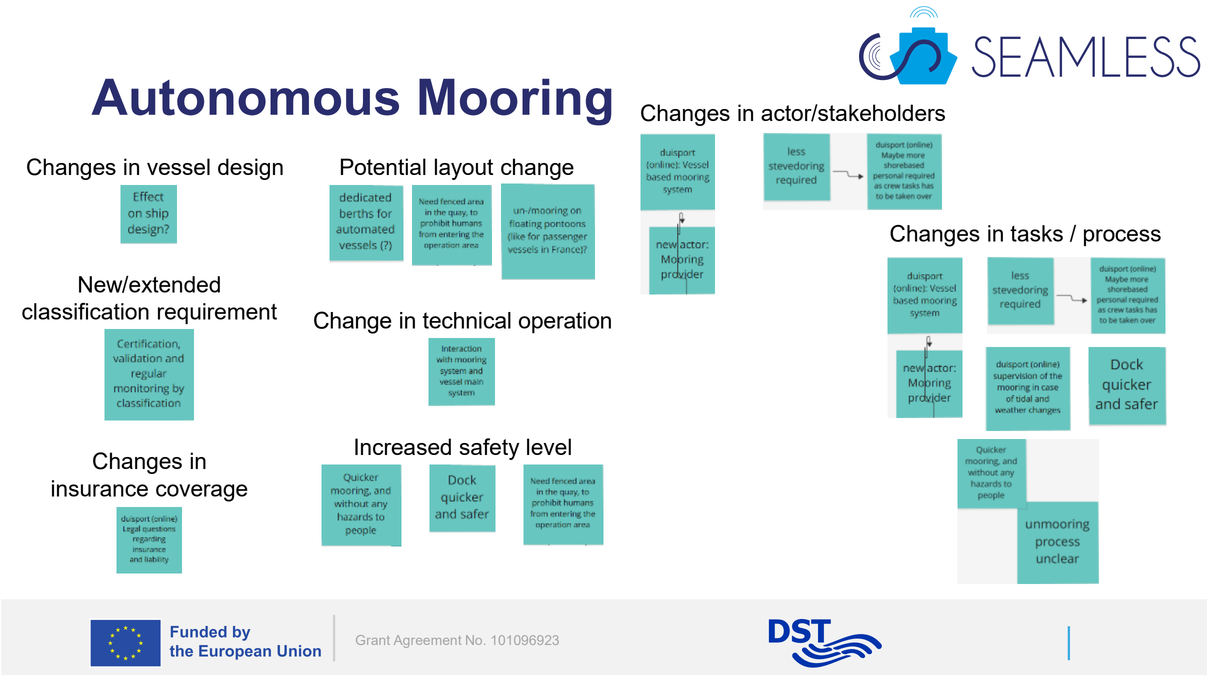


Figure 79. Clustered results from the Logistics Redesign workshop on AMoS

The discussion on the AVSPM featured three main effects to be expected. The process of the port calls of (automated) vessels is subject to change as the technical operation is different from today's practice. Accordingly, new actors and stakeholders are awaited for the AVSPM case. Particularly the expectation of the co-existence of conventionally operated vessels and the ones with remote control or autonomous function on board was expressed by one noteworthy comment. Figure 80 shows the workshop results on AVSPM.

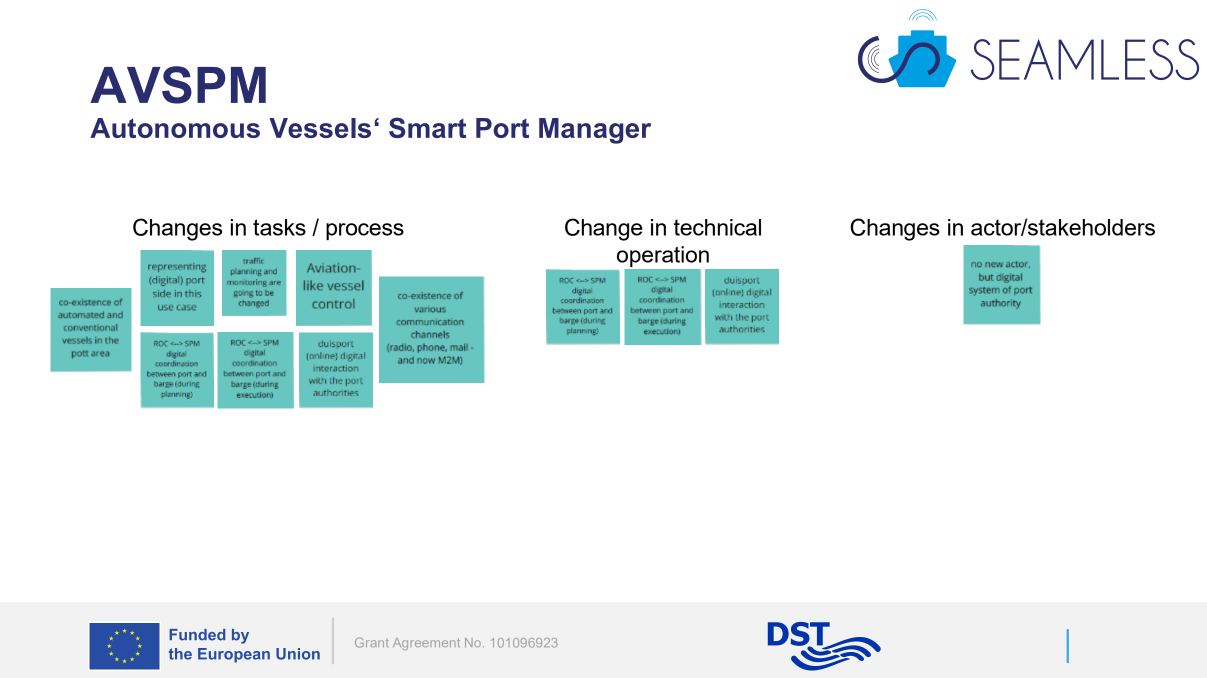


Figure 80. Clustered results from the Logistics Redesign workshop on AVSPM

The automation of stowage planning with the help of VCOP changes the stowage planning process due to technical and organisational reasons. Consequently, the process flow and the role of the actors alter. One single remark expressed the expectation that fluent exchange of information between vessel and terminal will be possible in the future. Likewise, the market participants are supposed to change because new actors and stakeholders will enter the stage. With the help of VCOP, smaller and less busy ports are expected to be able to preserve their port operations while the employment of VCOP is awaited to cause changes in liability coverage. Figure 81 presents an overview of the results on VCOP.

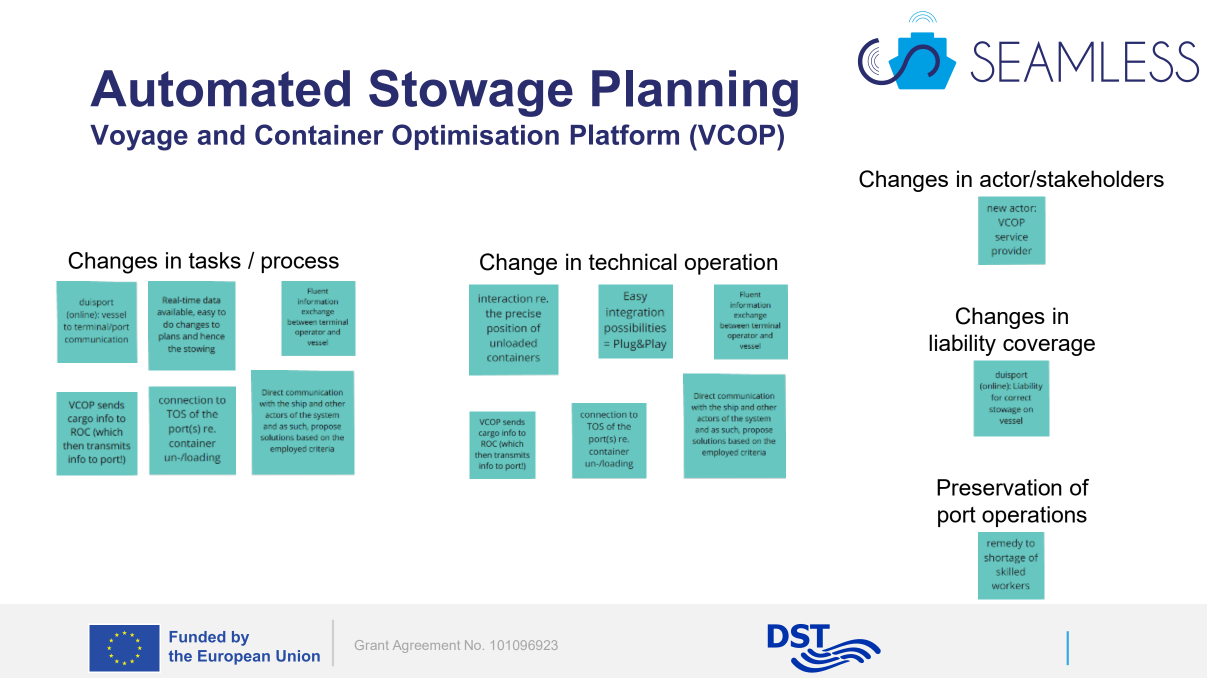


Figure 81. Clustered results from the Logistics Redesign workshop on VCOP

The Remote Operation Centre belongs to the most renowned SEAMLESS innovations which was mirrored by the quantity and quality of the remarks during the Logistics Redesign workshop. The vessel operator is expected to take new role as a reaction to the presumably changed process flow and modified technical operation behind navigation and manoeuvring. One single remark to point out referred to the drastic change of messaging that is expected in the maritime sector due to the introduction of autonomous vessels. Overall, a reduced workload is expected as the ROC is supposed to switch between low- and high-attention mode. Furthermore, the ROC vendors and providers are considered as prospective new actors in the scene. With different ROC with diverse backgrounds entering the market, the market structure might change as well. Figure 82 presents the workshop results on ROC and the other parts of the SEAMLESS building block #2 which are to be incorporated in the design and development process of the ROC or as part of its functional scope.

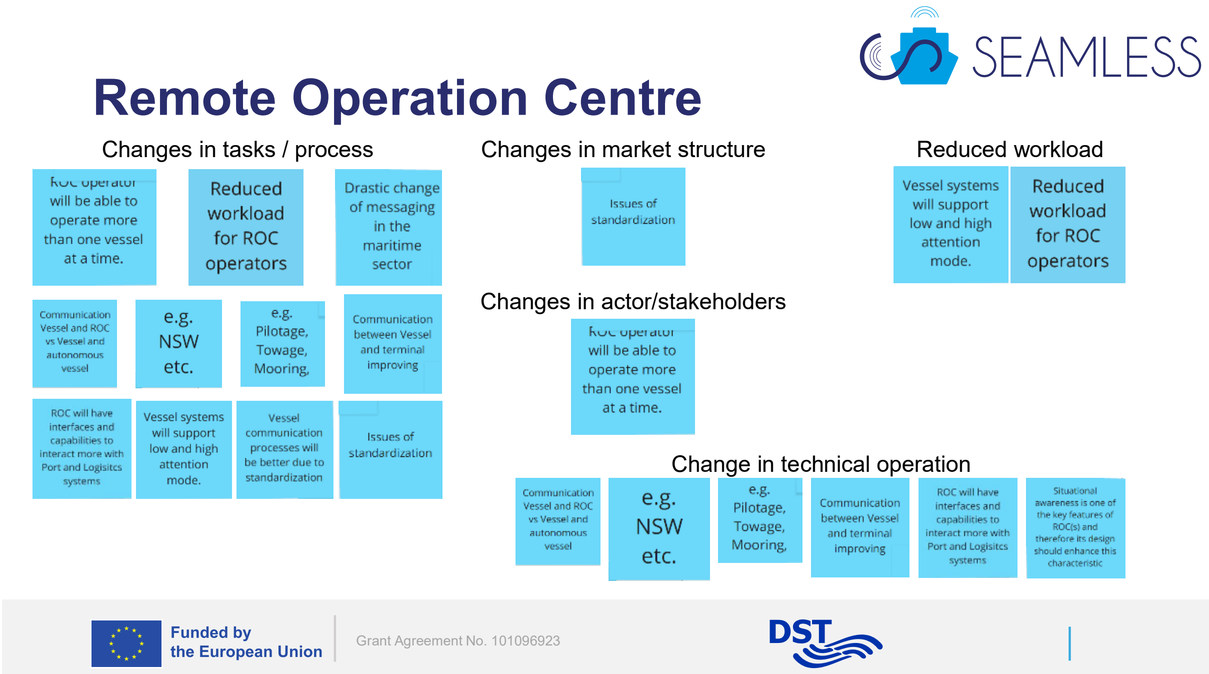


Figure 82. Clustered results from the Logistics Redesign workshop on ROC

As can be seen in Figure 83, the integrated supply chain support provided by ModalNET has produced many assessments regarding expected changes. ModalNET is expected to act as tool for enhanced supply chain collaboration and a means to provide end-to-end supply chain visibility. Both are expected to facilitate users to act in an improved manner, e. g., taking better decisions, reacting swifter and more efficiently, and improving performance levels. The expected automation of information flows is a single remark on expected changes due to ModalNET that deserves special mention. Moreover, its one-stop-shop approach and its built-in features like automated communication with authorities and a convincing data governance and data security policy, for instance, are expected with the introduction of the ModalNET solution. Even related effects like CO_2 emission reduction are linked to ModalNET.

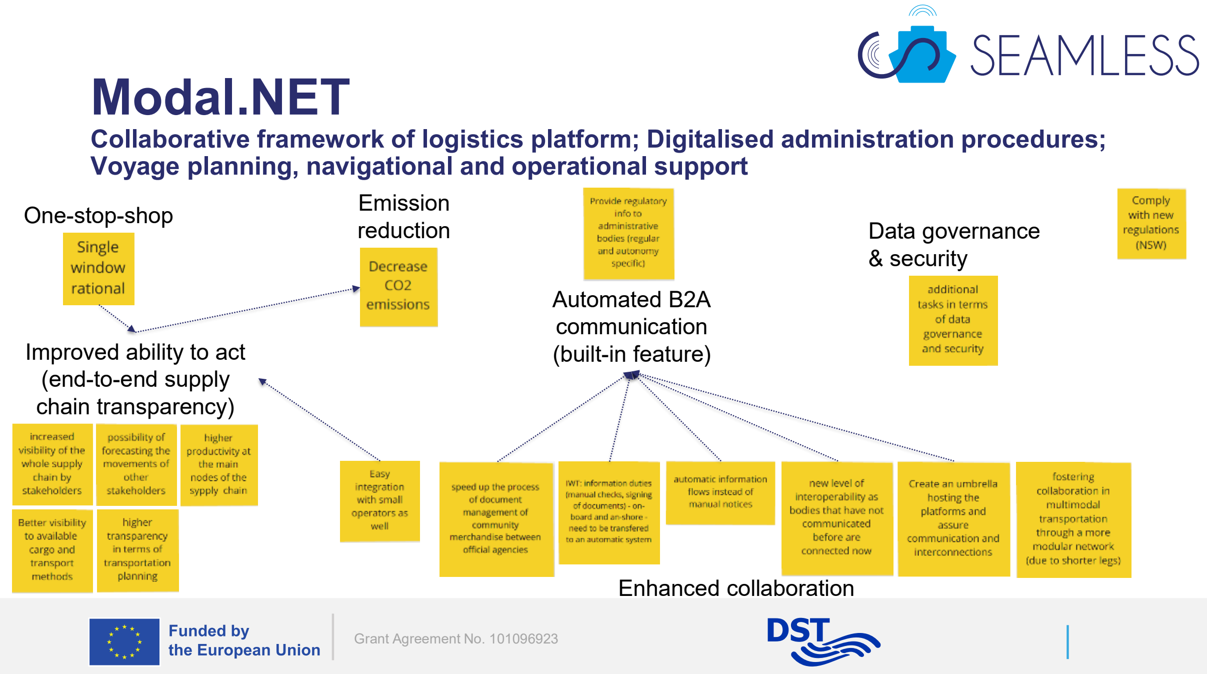


Figure 83. Clustered results from the Logistics Redesign workshop on ModalNET

The main results of the workshop and its subsequent analysis comprise some key findings. The main change expected by the SEAMLESS consortium is the obvious one: Due to the envisioned introduction of technological innovation, the existing practices of transport and logistics management as well as vessel operation are going to be affected. Existing processes will be subject to change as the innovations need to be incorporated and their respective functioning principle respected from a technical perspective. Moreover, the job profiles of the humans currently involved in various processes will undergo a transition process as operational roles with manual work will slowly be replaced with supervisory roles monitoring robots, machines, and computers taking over formerly manual process steps. With the introduction of ever new technological innovations, the sheer number of systems involved rises, leading to increased technical complexity in their orchestration and growing need for a strict and diligent management of interfaces to external parties and systems. Eventually, the gradual automation of various manual process steps makes humans obsolete in the operational setting so that less persons involved in the immediate vicinity of the vehicles, facilities and assets are exposed to danger, on the one side, but partly can take less influence, on the other.

Next to the obvious change of processes and tasks, a couple of noteworthy change expectations are highlighted here. Some of the innovations are expected to save the operations and the underlying business model of smaller and less busy ports – which means a certain level of hope is linked the automation of waterborne logistics and the use of autonomous vessels therein.

The smaller an innovation with respect to scope and impact on the entire process, the clearer and more pin-pointed were the uttered change expectations. In comparison with ACHS and AMoS which featured many comments on numerous topics related to expected change, the number of different categories discussed in the cases of AVSPM, VCOP, and ROC dropped significantly. The discussion about ModalNET's impact on the future system architecture again brought forth a number of realisations which is probably linked to its vast coverage, i. e., from origin to destination in a door-to-door cargo story.

While changes of technical nature or directly caused by such have been discussed in detail, changes of market conditions and the regulatory framework were less discussed. In opposition to the general approach of starting from a validated demand as the problem to solve and the derived business and technical requirements of the solution including its various modules which again are reflected in the technical development work, the workshop revealed that individuals submitted comments which implied a technical focus on the innovation presented as a solution which later needs to find its counterpart problem. However, it is important to emphasize the composition of the workshop group which consisted of a large number of engineers operatively active in the project whereas the number of superior managers, research group leads, and other decision-makers was low. This is one explanation for the earlier verdict. This report acts as a remedy to the danger of developing innovations without taking market needs into account. In that sense, the workshop was a first awareness-building measure to remind every member of the SEAMLESS team that the business requirements as well as the (technical, organisational, and economic) compatibility of each SEAMLESS innovations with the surrounding logistics system architecture needs to be safeguarded.

Moreover, the individual replies and the results of their consolidated analysis formed a base for the subsequent steps of focusing on each of the six SEAMLESS innovations and developing a comprehensive understanding of their technical functioning and their individual logistics process flow. For that purpose, each head of the development team has been consulted once or – for more complex topics – several times in order to discuss and develop a common understanding of the respective SEAMLESS innovation and a vision of its process flow. Particularly, the comparison with the existing process flow, if existing, helped to outline the system boundaries and the procedural changes. As a result, the common understanding of a to-be process was the result of each discussion thread with a development team head. These to-be processes per SEAMLESS innovation, which are presented and described in the subsequent section, were then integrated into the cargo story of a door-to-door transport process from the consignor (origin) to the consignee (destination) via multiple transport legs using various transport modes. In this way, the individual perspective of each SEAMLESS innovation was expanded in the direction of compatibility with the surrounding environment and the residual processes beyond the scope of the individual innovation.

Ultimately, the new cargo story forms the base of the SEAMLESS Reference Logistics System Architecture – with its logistics process flows, its actors and stakeholders involved, its business information systems and communication means used, and the communication and interaction patterns between them.

3.3 CHANGE INDUCED BY SEAMLESS INNOVATION

3.3.1 SEAMLESS Building Block #1: Automated Port Interface (DockNLoad)

Autonomous Cargo Handling System

The ACHS is a triple joint crane which can be placed on board a vessel or on the quay side for cargo handling operations and belongs to the SEAMLESS building block #1.

The initiator of the cargo handling process with the help of the ACHS is the ROC which will send out a signal to start the cargo operations. Once initiated, the VCOP will provide the loading and unloading sequence to the TOS and the ACHS. The terminal operator will use the received stowage plan and (un-)loading sequence to plan the terminal operations and will start to provide the needed containers at the quay in case container loading is required. As soon as the container is placed, a signal is sent to inform VCOP about the container and its position on the quayside. As soon as the VCOP has provided the (un-)loading sequence to the ACHS, the latter will be initialized and perform a security scan of the surroundings in order to ensure safe operations. Afterwards the ACHS starts the cargo movements while making use of object detection and collision avoidance procedures. In case the following movement is a loading operation, the ACHS will require the confirmed container position on the quay side which will be received from the VCOP after the TOS has transmitted it.

The cargo movement itself consists of six process steps. The first step is the pre-positioning of the cargo crane near the container location to verify the correct container ID in step two. The crane then calculates the exact target position for the spreader and the required motion trajectories. Once the spreader is positioned, the cargo crane will lock on the container with the help of the twist locks in the corner castings, lift it, and move it to a predefined position at which the container will finally be placed before release. After the movement of cargo, the ACHS will send the container ID and position, at which the container was finally placed, to the VCOP for monitoring purposes. The further distribution of these updates can be seen in the VCOP process description (see section about VCOP). The cargo movement process and subsequent report will be repeated until the cargo handling sequence is completed. After all cargo handlings have been completed, the ACHS controller will return the crane to the parking position. By the end of the whole cargo operations, the system will also terminate the object detection and collision avoidance procedures. Lastly, the ACHS will send out the completion report to the VCOP and end the process.

Despite a new technological innovation in place, the new process with the ACHS does not differ from the conventional cargo handling significantly – except for the fact that the transshipment task is executed by an autonomous system. The system itself follows the same steps as a crane operator in order to ensure a safe operation mode and that the correct container is handled. However, whereas the as-is process foots on manual (or system-supported) transmission of data and information, the to-be process features an automated transmission of the required data in order to enable the other parties and systems involved to complete the subsequent steps. From originally three humans (i. e., vessel operator, terminal operator, and crane operator) involved, only the terminal operator remains in the to-be process as VCOP and ROC take over the tasks of the vessel operator and ACHS replaces the crane operator. In addition, the to-be logistics process flow shows more activities and more interaction than the previous configuration.

It is obvious that the expectations mentioned in the Logistics Redesign workshop in Rome, Italy, in December 2023 have been confirmed regarding modified technical operation, altered logistics process flow, and changed task profiles of the humans involved. Figure 84 shows the to-be logistics process flow of the ACHS and allows a comparison with the conventional cargo handling process which was part of the container loading and unloading processes described in the section about the as-is situation.

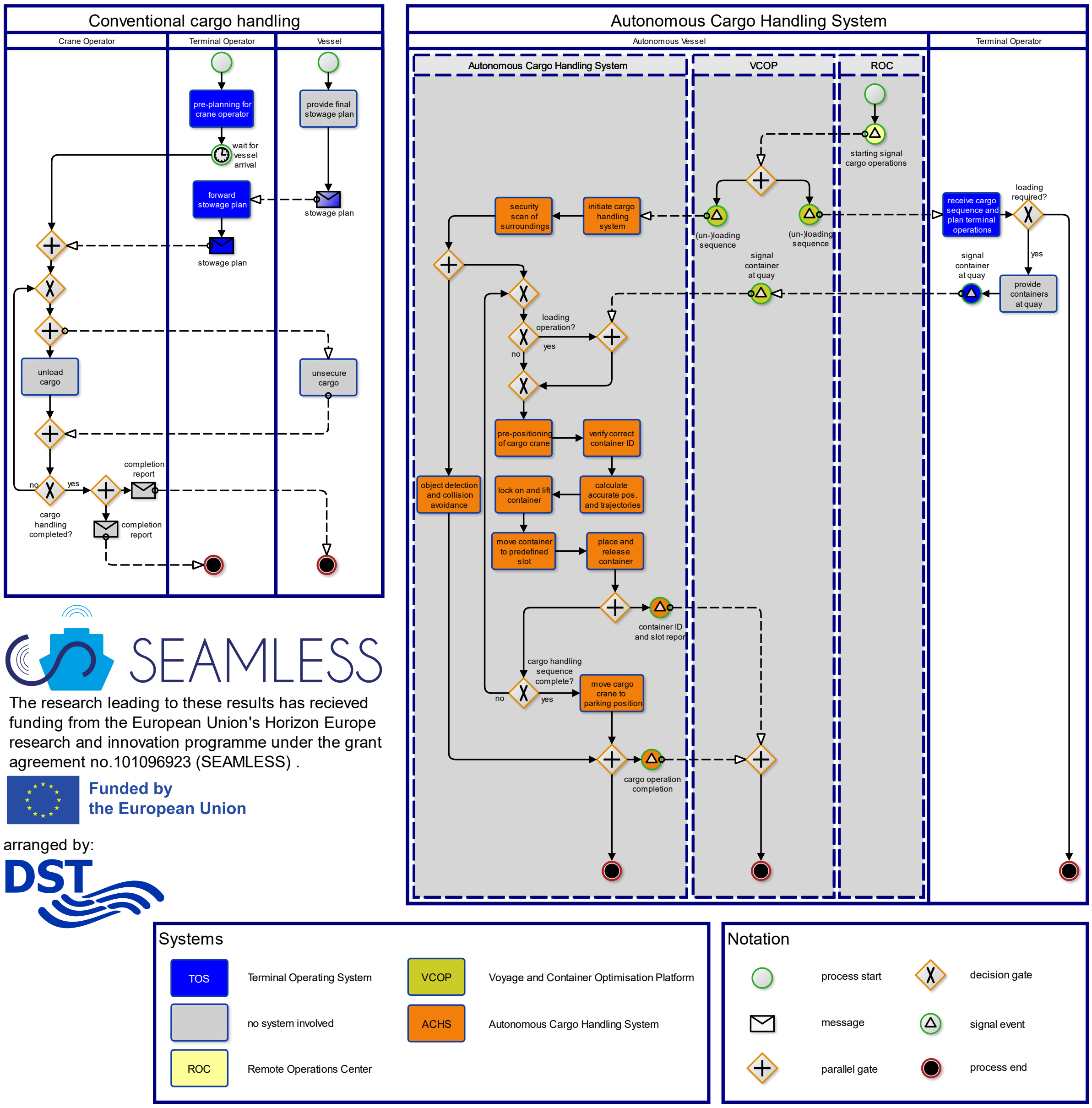


Figure 84. Logistics process flow of Autonomous Cargo Handling System

Autonomous Mooring System

The AMoS system consists of a robotic arm to pick, move, and place the mooring line, several winches to tighten and loosen the mooring line and ensure the correct tension, as well as a related control architecture. It is considered as a part of the SEAMLESS building block #1.

The AMoS system involves two parties only: the (remotely operated or autonomous) vessel and the AMoS system. The process begins with the vessel arriving at the berth and sending a signal to start the mooring (or unmooring, respectively) sequence via ROC and VCOP. The mooring sequence is initiated on the side the AMoS system, which then detects the quayside and identifies the bollards. It may also utilise additional digital maps of the quayside, the exact geo-positions of the bollards, and the loading bay of the vessel in order to accelerate the process further. In case the destined bollards are idle and free, the object detection and collision avoidance procedures are employed while the actual mooring (or unmooring, respectively) sequence begins with the robotic arm picking the mooring line, computing the motion trajectory towards the target bollard before eventually moving the line to the position. Once the mooring line has been placed on the bollard by the robotic arm, the latter is retracted while tensioning the lines with automated winches. As soon as the line placing tasks are completed, the robotic arm is moved back to the parking position, and a mooring completion signal sent to the vessel.

In the opposite process of unmooring, the corresponding signal comes from the vessel which allows the AMoS system to initiate the unmooring sequence. The robotic arm is placed above the bollard, the mooring line detected, identified, and located before it is loosened with the help of the automatic winches. The mooring lines are picked up from the bollard and retrieved and returned to the vessel. Throughout the operational process of the AMoS system, the object detection and collision avoidance procedures will be active. After completing the unmooring sequence, the robotic arm is retracted and returned to the parking position, and a completion signal provided to the vessel.

As in the case of ACHS, the AMoS system features the same procedure as the manual steps conducted by human operators at the moment. The big difference lies in the use of an automated robotic arm instead of a crew member on board the vessels. Even at first glance, you can see in Figure 85 that the number of steps and interactions has increased. A process that is conducted with the involvement of the vessel crew and the mooring service provider is to change towards one with ROC and VCOP representing the vessel operation management and the AMoS system as the executional entities. In the case of IWT, the number of involved roles has doubled as conventional mooring is an on-board duty without further interaction with external parties after the organisational aspects are settled.

With respect to the results of the Logistics Redesign workshop, the major change expectations of the AMoS system referred to process change, task and role change, and modification of technical operation – and have been confirmed.

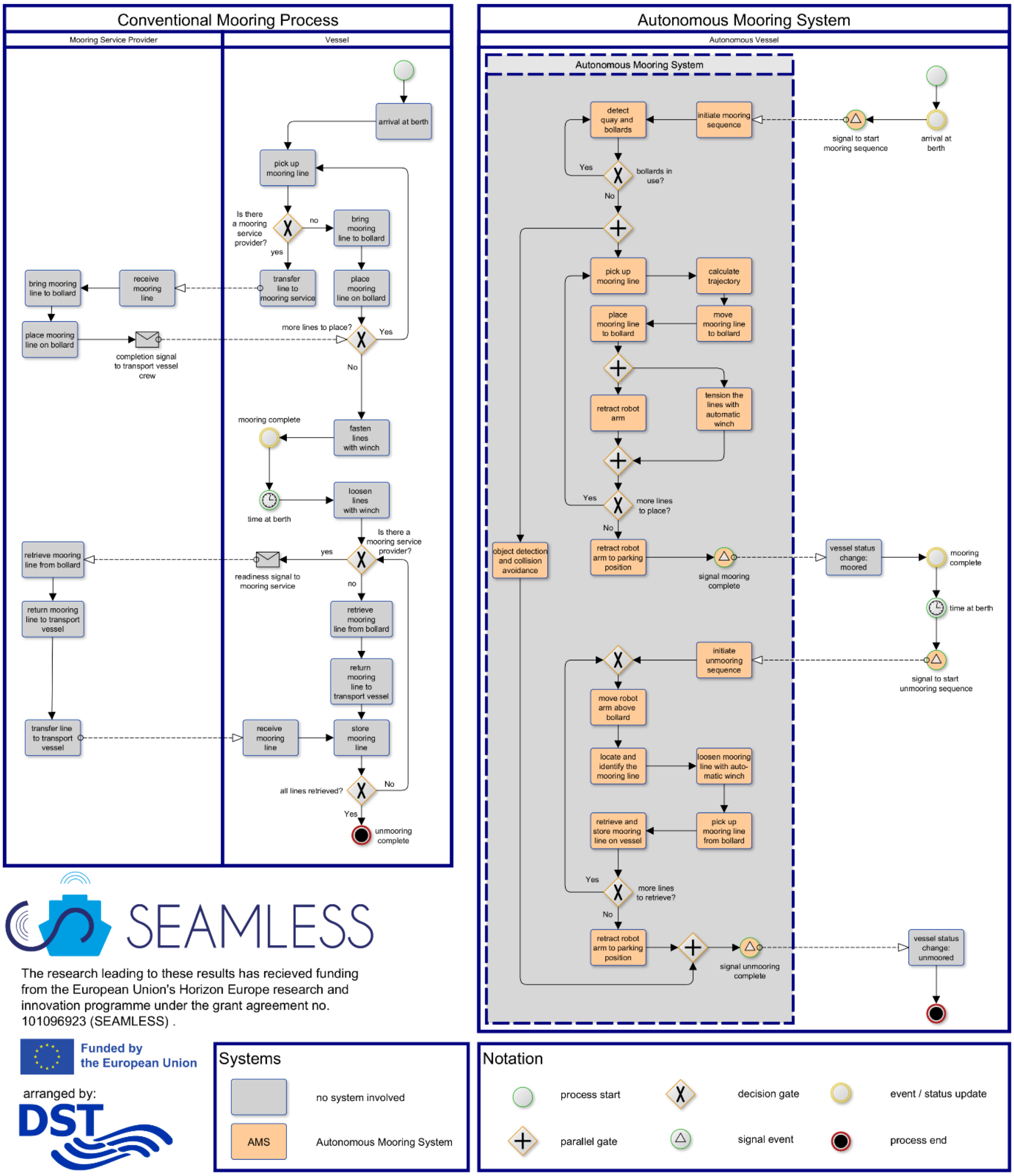


Figure 85. Logistics process flow of Autonomous Mooring System

Autonomous Vessels' Smart Port Manager

The AVSPM is set to be the link between a port and an autonomous vessel during port calls as it will be linked internally to the PCS of the port authorities and take over communications between autonomous vessel and the terminal through its TOS. The tasks of an AVSPM are separated into two phases: the long-term port call planning and the short-term port call planning, with the latter being complemented by the port call execution (see Figure 86).

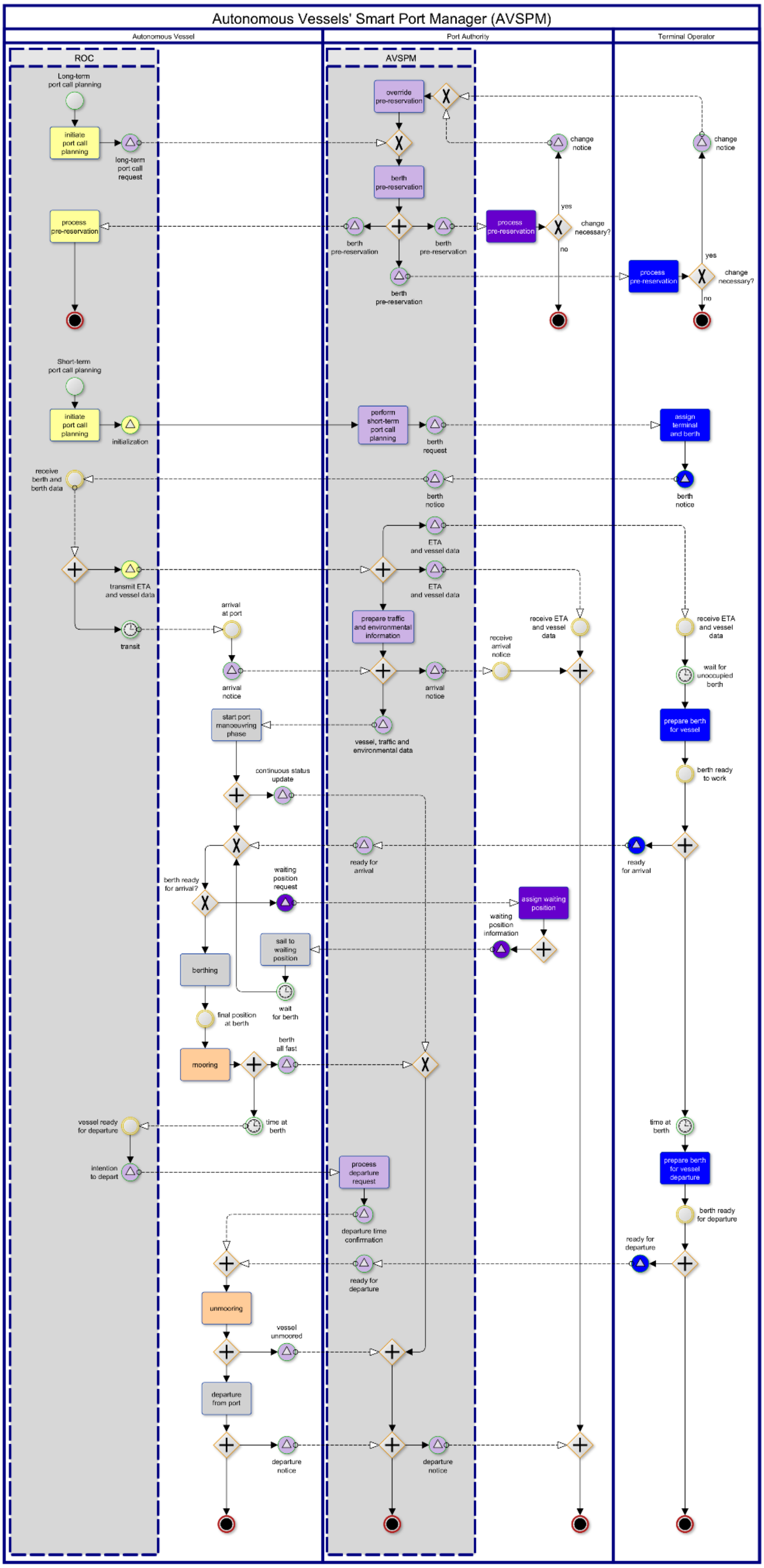
The long-term port call planning is initiated by the ROC which needs to be aware of a planned port call in order to start the entire planning process. It will submit a request for the long-term port call planning to the AVSPM which will perform a pre-reservation of a berth at the requested terminal and provide the ROC, the port authority, and the terminal operator with a berth pre-reservation. All three parties process the pre-reservation by feeding into their respective schedules. After placing the pre-reservation, the port authority and terminal operator can request a change to an already placed pre-reservation via AVSPM at any time through the PCS and TOS respectively, e. g. due to maintenance requirements or infrastructure failures. The AVSPM will then override the earlier pre-reservation, perform a new one under the changed conditions, and re-send the pre-reservation to all three parties. If there is no change of the pre-reservation required, the process is completed.

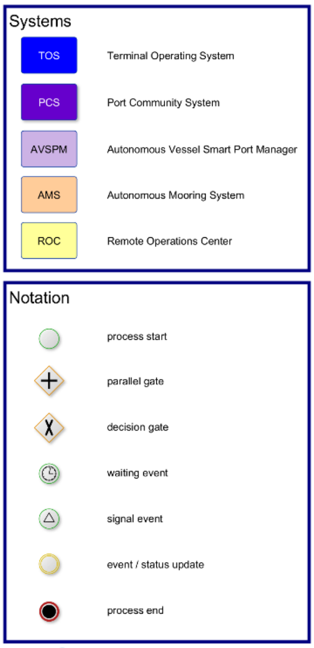
In the short-term port call planning, the ROC will initialize the planning when the vessel is getting close to the port of call. As part of the planning, the AVSPM will send a berth request to the specific terminal to get the final berth information and data. The terminal will assign the final berth for the vessel based on the status and availability of the terminal and send a berth notice to the AVSPM and further to the ROC. Once the ROC receives the final berth notice and corresponding berth data, it will transmit the ETA and the vessel data that is required for the port call to the AVSPM, which again will relay this message to the port authority and the terminal operator. Further, the AVSPM prepare the route, traffic information, and weather data for the vessel. Once the port is reached, the autonomous vessel will send an arrival notice to the AVSPM. The arrival notice will be forwarded to the port authority for the registration of the vessel and the determination of the port fees at a later stage. The AVSPM will also send out the route, traffic information, and weather data to the vessel for safe navigation within the port. The vessel can now start its port manoeuvring phase. During the phase, the vessel will constantly send status updates and safety pulses to the AVSPM for traffic monitoring purposes within the port. Meanwhile, the terminal will prepare the berth for the arrival of the vessel and send out a “ready for arrival” signal to the AVSPM once the berth is ready, which in turn passes the signal to the vessel. If the vessel reaches the berth prior to receiving the “ready for arrival” signal from the terminal, it will request a waiting position from the port authority through the PCS. The port authority will assign a waiting position for the vessel and send the corresponding information to the vessel. The vessel will now wait at the designated location until the message “ready for arrival” signal is provided by the terminal. Once the berth is ready for arrival, the vessel will begin the berthing progress und subsequently initiate the autonomous mooring system upon reaching the final position and berth. After completing the mooring process, the vessel will send one more signal, the berth all fast signal, to the AVSPM.

In the following, the vessel will dwell at the berth until the vessel is ready for departure. Then, the ROC will signal the vessel departure intention to the AVSPM which will process the departure request and confirm a departure time to the vessel. Parallelly, the terminal will be made ready for vessel departure itself and send a “ready for departure” signal to the AVSPM. The signal will be forwarded to the vessel. For the terminal and the port, the process comes to an end at this point. Once the physical unmooring process is completed, the corresponding notice is sent to AVSPM, confirming the completion. When the vessel has a confirmed departure time and the terminal is ready for the vessel departure, the unmooring process is initiated and the completion reported to AVSPM. The vessel will start is departure from the port and send a departure notice to the AVSPM. Finally, the AVSPM will send a final departure notice to the AVSPM which will be forwarded to the port authority one last time before the process ends.

Although the to-be port call execution resembles today's process with the vessel operator, the port authority, and the terminal operator involved, the main change lies in the technical operation of the new port call. Moreover, the modified process flow and the elevated level of automated message and information exchange are remarkable. Instead of the vessel operator manually coordinating with the port authority and the terminal operator before finally berthing and mooring, the to-be process flow includes more participants, more systems, many more messages exchanged among one another, and less activity of the involved parties other than message exchange.

All in all, the changes in the underlying technical operation and the logistics process flows have been confirmed as derived from the Logistics Redesign workshop in Rome. Particularly, the direct connection between vessel and other actors via AVSPM allows a better and swifter arrangement.





The research leading to these results has received funding from the European Union's Horizon Europe research and innovation programme under the grant agreement 101096923 (SEAMLESS).

Funded by the European Union

arranged by:

Figure 86. Logistics process flow of Autonomous Vessels' Smart Port Manager

Voyage and Container Optimisation Platform

The fourth and final SEAMLESS innovation as part of the SEAMLESS building block #1 is the Voyage and Container Optimisation Platform (VCOP). It pursues the task of preparing the stowage plan and overseeing the cargo handling of autonomous vessels. Acting as the higher-level controller of the ACHS, the VCOP is also directly responsible for carrying out the cargo handling (see section about ACHS). In Figure 87, the process flow of the VCOP can be compared with the conventional stowage planning process described earlier.

The process of the VCOP is initiated every time it receives a booking transmitted from ModalNET. Initially, the VCOP will compute a possible stowage plan under consideration of the newly received and previously placed bookings. This stowage plan is transmitted to the ROC for review purposes, as the stowage plan has to be approved by the shipmaster. If the ROC is dissatisfied with the provided stowage plan, it will request changes to the stowage plan from the VCOP. This will initiate a loop until a stowage plan is finally approved by the ROC. Once the stowage plan is approved by the ROC, the VCOP will provide the necessary cargo data for the ROC to create a ballast plan for the vessel in accordance to the agreed upon stowage plan. Meanwhile, the VCOP will determine the optimal loading and unloading sequence for the containers. These sequences will be transferred to the ACHS and the TOS. The TOS will use the cargo sequence to prepare terminal operation and to provide the necessary containers at the quayside for the ACHS, if loading is required. Once the terminal has placed a container on the quayside, it will send a signal to the VCOP with the container location on the quayside which is relayed by the VCOP to the ACHS.

The ACHS will initiate operation upon receiving the cargo handling sequence from the VCOP. It will then perform the loading and unloading sequence. This requires the container position at the quay for loading operations which has been provided earlier by the TOS and the VCOP. After each cargo movement, the ACHS will send a container ID and the drop position to the VCOP for monitoring purposes. The VCOP sends them further to the ROC and the TOS. Once the ACHS has finished its cargo handling sequence and ceased operation, it will notify the VCOP about the completion of cargo operation. The VCOP transmits the signal to the ROC, the terminal operator, and ModalNET before terminating the VCOP process.

Compared with the conventional stowage planning process, the VCOP takes on more monitoring and reporting tasks during the actual transshipment process – not least because it acts as the controller of the cargo handling system. As far as the actual stowage planning is concerned, the process remains the same and the stowage plan still has to be approved by the shipmaster via the ROC. What has changed is the proposal to change the stowage plan on the part of the terminal operator. As the VCOP is deciding on the loading and unloading sequence automatically, the terminal operator has to accept the predetermined sequence in which the ACHS intends to move the cargo.

Again, the expectations from the workshop in Rome have been confirmed with regard to modified technical operation behind the stowage planning procedure and changes to the process flow and the roles involved. The central role of VCOP as the controlling unit of ACHS and acting independently of the terminal side, however, was not foreseen by the workshop participants.

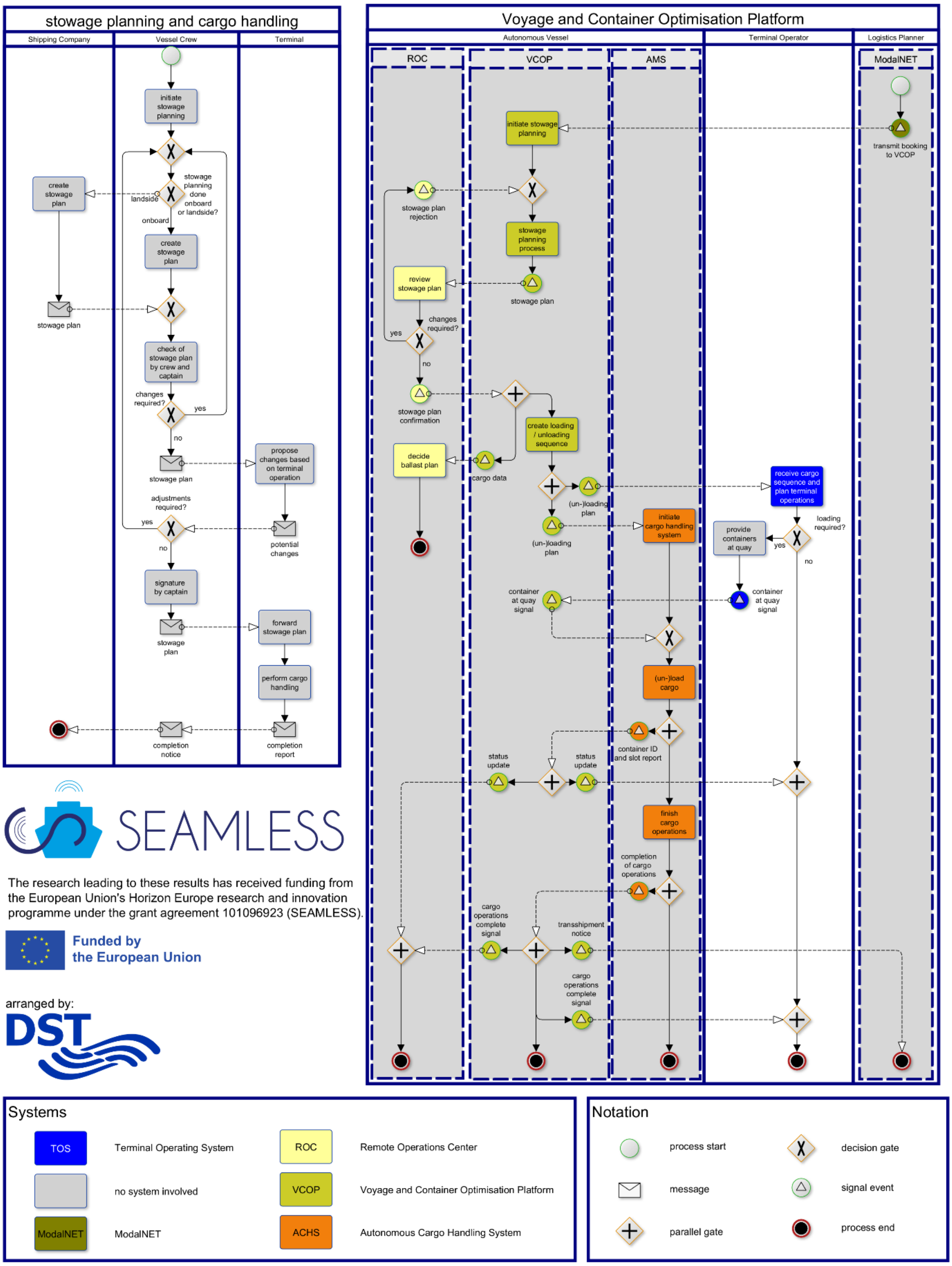


Figure 87. Logistics process flow of Voyage and Container Optimisation Platform

3.3.2 SEAMLESS Building Block #2: Modular Vessels and Operations Concepts

Remote Operation Centre

The ROC is the supervising and coordinating element of automated vessel operation which takes over mission planning and transit monitoring and belongs to SEAMLESS building block #2. The ROC process is split into two parts, i. e., a planning and port call phase and a transit phase.

The process involving the ROC begins way ahead of the actual journey of a vessel with the shipping company providing the vessel schedules to the ROC. With this information, the ROC will be able to begin the voyage planning for a vessel and provide the vessel data and schedule to ModalNET and VCOP. Through ModalNET, a matchmaking will take place by a logistics planner who identifies potential service providers for the different transport legs and selects one per leg. The respective bookings initiated by the logistics planner and executed in the ModalNET platform will be transmitted to the VCOP which will then perform the stowage planning and send it to the ROC for approval. If the stowage plan needs changes, the ROC will reject the stowage plan, and a replanning will be done by the VCOP until the loop ends with a confirmation of the final stowage plan by the ROC. After receiving the confirmation, the VCOP will provide cargo data to the ROC to prepare a ballast plan for the vessel based on the agreed stowage plan. Parallel to this, the ROC will initialize the long-term port call planning with the AVSPM whose typical process flow is described in a preceding section (see section on AVSPM). Once the long-term port call planning is completed, the AVSPM will return a pre-reservation to the ROC. After the different threads are completed, the voyage can start. As its next task, the ROC needs to initialise the short-term port call planning with the AVSPM as described before. The AVSPM will return a notice including the terminal and berth information for the port call of the vessel. When this notice has been received, the ROC will return the ETA and further relevant vessel information to the AVSPM as part of its port call monitoring process. Lastly, the ROC will signal the intention to depart to the AVSPM once the vessel is ready for the departure. The AVSPM will process the departure request as the process is terminated.

During the transit of a vessel, the ROC has the task of monitoring the individual vessel or a fleet. This process starts with the vessel going in transit. The ROC acts in the so-called low-attention mode as it monitors multiple vessels from one ROC operator seat ashore. If the conditions around the voyage change and a particular care of a matter happens to be required (with elevated attention of the operator), the vessel will decide on the basis of predefined criteria whether a switch to the high-attention mode is useful. If so, the vessel will request the high-attention mode from the ROC which will then switch to a one-to-one monitoring regime so that the ROC operator can focus on the respective monitoring and control task. If necessary, the ROC will move away from one-to-one monitoring, take over (remote) control, and further operate the vessel. Should a switch to high-attention mode not be useful, the vessel will perform an emergency fallback action and alert the ROC. From here, the ROC will automatically assume control and perform fallback recovery actions. If no intervention is required, the ROC will just remain in high-attention mode performing one-to-one monitoring. Once the surrounding conditions changed in such a way that allows automated sailing in low-attention mode, the ROC will switch back to low-attention mode performing one-to-many monitoring. Once this switch has occurred, the vessel will resume travel in low-attention mode. Eventually, the transit part of the ROC process ends as the vessel will go into a port call.

The change both from conventional vessel operation (with the shipmaster on board) and from remote control (with the shipmaster ashore) to remote monitoring of autonomously sailing vessels is immense. The ROC operator switches between low- and high-attention mode and has no proxy on board the vessel to perform certain operations or correct certain malfunctions directly. Other parts of the process remain similar, especially during the planning and preparation phases in which stowage plan and ballast plan need to be developed, reviewed, and approved.

On-board functions like securing cargo or performing maintenance and repair works are omitted from the list of tasks of the ROC while the new supervisory role mentioned during the workshop on Logistics Redesign is visible at multiple points along the process flow.

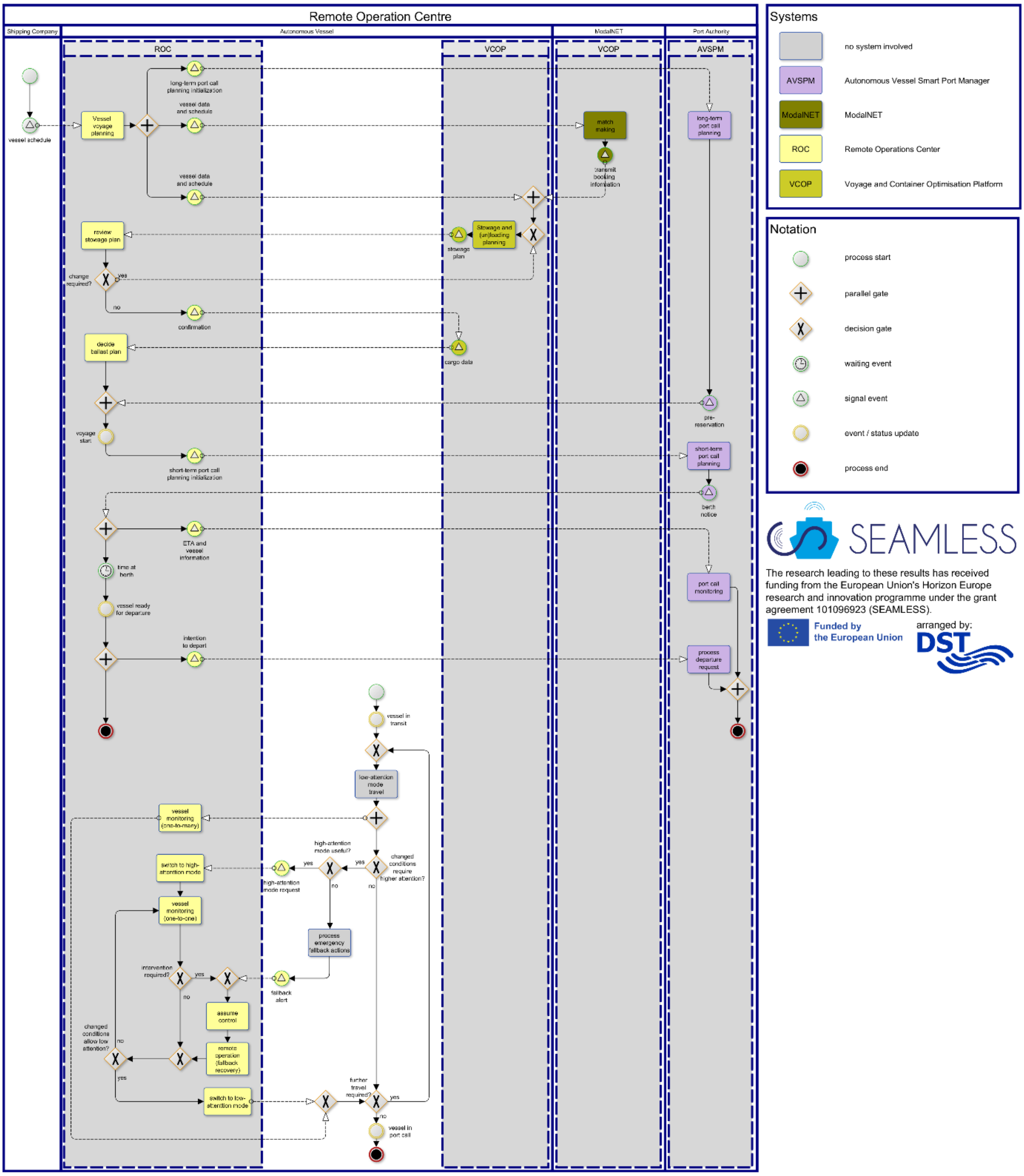


Figure 88. Logistics process flow of Remote Operation Centre

3.3.3 SEAMLESS Building Block #3: Integrated Supply Chain support

ModalNET

As can be seen in Figure 89 showing the typical process flow, ModalNET is a platform for transport planning, carrier booking, execution monitoring and data management related to multimodal transport chains and belongs to the SEAMLESS building block #3.

Following the preceding interaction between consignor (or consignee, respectively) and logistics planner, the ModalNET process starts with the logistics planner submitting a transport order into the ModalNET user interface. This transport order is forwarded to the computational engine for resilient logistics within ModalNET, which comprises a matchmaking platform for multimodal transport chains and which will use its database to determine feasible transport options for the transport order. The order will then be transmitted to the logistics planner afterwards, who reviews the transport chain option selected and confirms the chosen option in ModalNET. Following the confirmation, ModalNET will generate individual bookings with the selected operators required for the respective transport chain. Each of the transport service providers operating on any of the legs, i. e., the short-sea shipping company, the inland shipping company, and the trucking companies for the pre-haul and post-haul legs, will receive its individual booking and complement any missing transport information required to send a booking confirmation back to ModalNET. With the booking confirmation, the pure planning process is completed for the road transport enterprises. For the waterborne legs, however, ModalNET will then send a notice of the booking confirmation to the logistics planner before it transmits the booking information to the respective VCOPs of the two shipping companies involved for their respective stowage planning. Afterwards, the planning phase is completed for all parties involved.

Next, the monitoring task of ModalNET commences. In this phase, ModalNET receives a series of updates regarding the transport process starting with the monitoring updates of the pre-haul leg. The first terminal interaction is the acknowledgement of receipt from the terminal of origin. The terminal of origin will later also send a loading completion notice[22] to ModalNET. Following this, ModalNET will receive updates of the IWT leg from the inland shipping company such as the pick-up and drop-off notices as well as any further monitoring updates provided by the vessel operator. Subsequently, the terminal of intercontinental transshipment will provide an acknowledgement of receipt and later a loading completion notice[23]. From the short-sea shipping company, notifications similar to the IWT leg, such as pick-up and drop-of notices, are provided, next to additional monitoring updates. The terminal of destination will also provide the acknowledgement of receipt and the loading completion notice[24] before finally the operator on the post-haul leg will transmit a final pick-up notice and further monitoring updates to ModalNET. During the monitoring phase, the consignor (or consignee, respectively) and the logistics planner have the option to request a status report from ModalNET and gain insight in the status of their transport. Once such a request has been submitted to ModalNET,

[22] This is an assumption that requires validation in the course or in the wake of the SEAMLESS research project.
[23] This is an assumption that requires validation in the course or in the wake of the SEAMLESS research project.
[24] This is an assumption that requires validation in the course or in the wake of the SEAMLESS research project.

it will generate the status report based on the monitoring updates collected up to the time of request of the status report – and send it out to the requesting party.

ModalNET will provide a significantly shortened process of planning a multimodal transport as the logistics planner neither has to create a multimodal transport plan himself nor is he required to individually book the transport legs sequentially after one another. Instead, ModalNET provides a one-stop shop for the multimodal transport chain and offers multiple coherent monitoring options – compared to isolated and varying updates from each individual operator.

With regard to the expectations expressed during the Logistics Redesign workshop, the main change between the existing and the future process is the facilitation of a single access point to plan the entire shipment order. This matches the expectation of the single window rationale in transport planning and management. Moreover, the transparency throughout the multimodal transport chain due to improves decision-making quality and collaboration intensity.

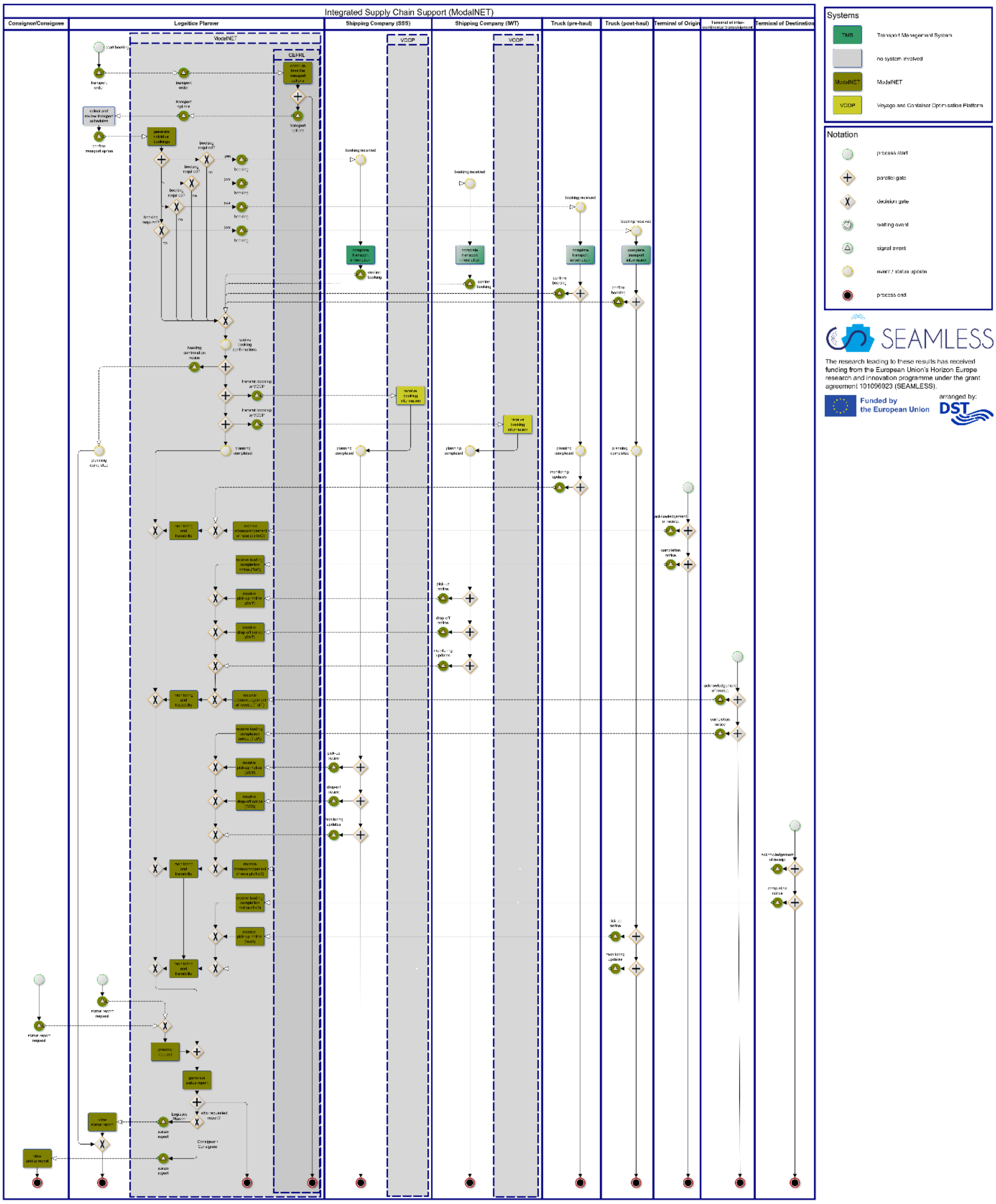


Figure 89. Logistics process flow of ModalNET

4 SEAMLESS REFERENCE LOGISTICS SYSTEM ARCHITECTURE

4.1 COMPLIANCE WITH DCSA AND TIC4.0 PROCESS STANDARDS

The challenging objective of the project, in its aspiration to achieve a level of autonomous operations among the various stakeholders that make up this extensive system of interrelations, such as maritime port operations, presents significant challenges. One of the most important is that these close relationships, which currently develop in an unstructured environment, need to be rethought to transition from this fragmented scheme to one where communications and interactions occur as harmoniously as possible, achieving the highest level of homogeneity that existing tools allow. Undoubtedly, achieving these objectives requires the collaboration of all parties, seeking the greatest possible functionalities within known technical capabilities. As discussed throughout the deliverable, the fundamental change between traditional processes and the autonomous processes proposed by SEAMLESS lies in the shift from an environment where planning, execution, and decision-making are based on human actions to one where systems are responsible for most new processes. Consequently, the interaction between systems will be crucial to ensure proper compliance with the process as designed.

One of the main challenges currently acting as barriers to system interaction is the heterogeneity in the various technologies, formats, and communication protocols in which these systems are developed. Additionally, the different semantics used by each system and person in understanding various concepts and definitions also need to be considered. Faced with this problem, standardization is probably the fundamental tool to ensure that the transition between both schemes is as smooth as possible and to facilitate the interconnection between different systems to achieve the necessary interoperability.

Seeking to shed light on these topics, SEAMLESS will consider two initiatives dedicated to promoting digitization through the development of various standards, references, and definitions. Their complementary approach provides the opportunity to interconnect the different systems present in port logistics through the standardized exchange of digital data. These two entities are DCSA and TIC4.0, two international associations composed of leading companies in their respective sectors, with DCSA covering the maritime sector and TIC4.0 covering activities of port terminals. The following sections will describe the nature of these two initiatives, how SEAMLESS can align with them, and the opportunities provided by the standards of both associations.

4.1.1 Compliance with TIC 4.0 standards to be presented

The Terminal Industry Committee (TIC4.0) is a global initiative spearheaded by the port industry to promote the creation of unified digital standards. Founded in 2018, it is backed by the Federation of European Private Port Companies and Terminals (FEPORT) and the Port Equipment Manufacturers Association (PEMA). Its primary objective is to establish a common standard that facilitates objective comparisons of equipment and systems and defines a format for electronic data interchange. The committee's members include port operators, digital service providers, suppliers, terminal equipment manufacturers, Terminal Operating Systems (TOS) suppliers, and media partners. Additionally, TIC4.0 collaborates regularly with recognized international standardization bodies, aiming to achieve the status of an "international standard" over time. As of April 2024, the association comprises 58 active members and has published 10 Technical Releases.

At the heart of TIC4.0's standard are a Data Model and a common semantics, both continuously updated by internal Task Forces that discuss, refine, and develop them based on members' experiences and needs. The semantics follow a "Subject-Object-Concept-Observed Property-Value" format, closely resembling human language. To fully grasp the technical potential of TIC4.0's language for just-in-time port arrivals and port call optimization, a detailed description of the data model and semantics is provided in the following sections.

TIC4.0 Internal Workflow

The association's daily operations are managed by two decision-making entities: the Executive Council and the Operations Council. The Executive Council handles high-level management and external representation, making decisions that affect the institution's overall goals and targets. Meanwhile, the Operations Council oversees more technical tasks, including the technical development roadmap, the functioning of various working groups, and the Review Board. These working groups, known as "Task Forces," consist of experts appointed by members to discuss and define the various concepts supporting TIC4.0's Data Model and Semantics. Any member can join an existing Task Force or propose and sponsor a new one in an area of interest, subject to the Operations Council's approval. Participation is voluntary.

Similar to an ISO/CEN committee, these bodies include a Task Force Leader and a group of expert collaborators. They meet regularly to discuss and define concepts for new releases and to revise existing content as needed. Once a consensus is reached, the content is reviewed and edited by the Review Board before being distributed to the general public.

Semantics

The main innovation of TIC4.0 is the common language and semantics, designed to model the physical flow and reality of port operations. This is achieved by using harmonised definitions and an ontology that combines five main elements: a “Subject”, a “Concept”, an “Observed Property”, a “Measurement Point” and a “Value”.

A typical TIC4.0 message is structured as follows:

- Header: It identifies the message in its origin (or destination), time of reference for the message and a unique identifier/reference;
- Subject: Who or which entity is executing an object (object as per TIC4.0’s semantics) or embodying a concept;
- Concept: Refers always to a particular subject (or subject-subsystem) specifying what the subject is (status) or does (action-event);
- Observed Property: How much is the magnitude of the concept (status, pieces, length, volume weight, energy, time, speed, power, duration, acceleration, etc.) represented in the value;

- Point of Measurement: Defines where in place and time (past, present and future) the value representing the concept of observed property of the subject is measured and represented;
- Value: A "value" in TIC4.0 is defined as "the actual measured result for a specific combination of the TIC4.0 semantic items "time of measurement", "subject, concept and observed property", and "point of measurement. The same value can be represented in several units.

The figure below shows the structure of TIC4.0's semantics in a graphical way:

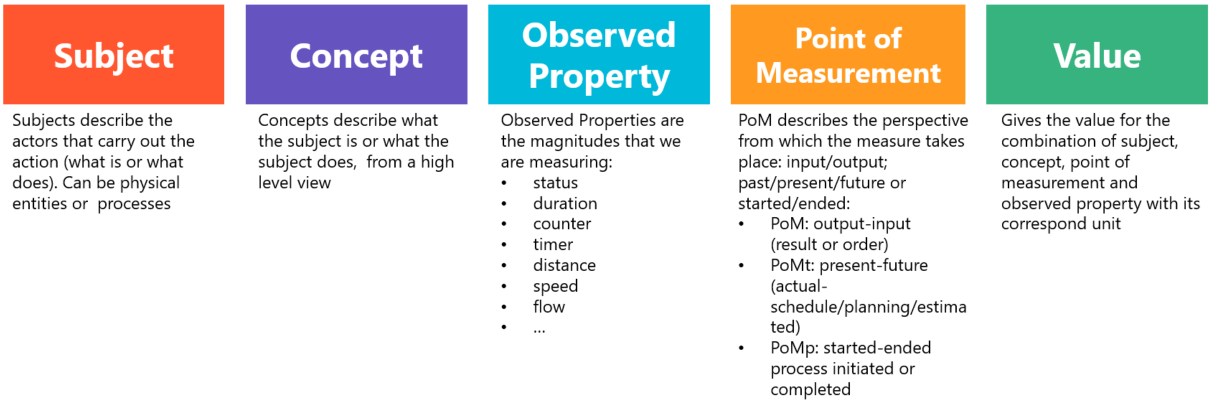


Figure 90. TIC4.0 semantics (source: TIC4.0)

By combining these five elements in a single sentence, it is possible to represent any reality in the port logistics environment. This semantics is currently represented in a digital data format. The data model in which the standards are published is JavaScript Object Notation (JSON) because it allows representing different hierarchical levels. However, it is also possible to use alternative formats such as XML or FLAT, among others. This is one of the main attributes of this language, as it can be adapted to the most commonly used data formats today.

TIC4.0 in the context of SEAMLESS research project

As previously mentioned, TIC4.0 standards have been developed to represent the reality of operations carried out in the context of a container port terminal. To achieve this representation, TIC4.0 has had to address two major categories of standards: those related to the processes performed in a terminal, and those standards that make visible the reality of Cargo Handling Equipment (CHE). These two sets of standards have been consolidated into two different data models: the TOS Data Model, related to the representation of processes, and the CHE Data Model, which captures everything related to CHE. By combining both, it is possible to digitally represent the various activities that occur in container port terminals.

Since the scope of SEAMLESS covers almost all stages of port logistics operations, from booking creation to cargo dispatch to the hinterland, the applicability of TIC4.0 can play a significant role in all operations and processes that occur in the port environment. If we directly link it to the different Building Blocks that make up the project, the most natural connection is found in Building Block #1: Automated Port Interfaces (DockNLoad), especially in tasks such as the autonomous cargo handling system, automated cargo voyage planning and stowage execution platform, and concepts for automated port interfaces and intermodal cargo forwarding to the hinterland. Additionally, there is a possible connection in Building Block #3: Integrated Supply Chain Support (ModalNET) related to specifications, systems architecture, and design.

Building Block #1: Automated Port Interfaces (DockNLoad):

This Building Block aims to lay the foundations for defining the resources needed to autonomously perform operations related to the activities closely connected with the vessel-cargo-port interaction. It seeks to establish a direct link between the possibilities of TIC4.0 and the needs of the Building Block.

Autonomous Cargo Handling System:

Regarding the requirements outlined in this task, aimed at developing an autonomous cargo handling system, the potential application of TIC4.0 standards involves digitally representing the system's operations. The use of the CHE Data Model is crucial in this context, as it is designed to accurately portray the primary states and various actions performed by Cargo Handling Equipment (CHE) within a container terminal.

Table 2. List of Concept in the TIC4.0 CHE Data Model

CONCEPTS		
location	idle	stability
powered	onlydriving	warning
on	notonlydriving	fault
off	working_and_notdriving	interlock
standby	slowdown	energy
notstandby	healthy	energytank
working	error	control

TIC4.0 has defined the different subjects (Who) and concepts (What a subject is or what it is doing) as seen in Table 2 and Table 3. This information reveals the types of realities being represented. The current level allows for representing a general level of activity of a CHE. However, if there is a need to represent new concepts or subjects not currently covered by the standards, they should be able to be incorporated after a process of creation and validation within the TIC4.0 working structure.

Table 3. List of Subjects & Sub-Subjects in the TIC4.0 CHE Data Model

SUBJECTS & SUB-SUBJECTS		
health	firefighting	lubrication
powersource	cabin	auxiliary
drive	cycle	containerbe-low
spreader	trip	ambient
hoist	inverter	user
trolley	lights	userprofile
boom	hydraulic	permission

In addition to the digital representation of CHEs, TIC4.0 standards can be used for communication between operational management systems and machines to execute operations. In this intercommunication, the TOS Data Model serves as a reference to specify the container movements that equipment must perform, as this data model digitally captures the various loading and unloading processes as mentioned earlier. Based on the definition of Subjects such as "Cycle", "Move", “Job instructions”, “Order” and “Location,” all the necessary information to instruct a crane on what and how to perform tasks will be included.

Automated cargo voyage planning and stowage execution platform:

The task at hand is divided into two distinct types of processes. On one side, we have those related to planning, and on the other, those related to execution. In this regard, as we have seen so far, the primary function of the TIC4.0 standards is to represent processes and their executions. Therefore, the current definitions are aligned with this need, which is mainly coordinated between VCOP as the entity responsible for issuing loading and unloading orders, the automatic crane control system, and finally, the TOS as the entity responsible for yard activities. As we saw in the previous section, the two data models include the processes and definitions necessary to exchange the required information for the fulfilment of these processes.

However, in the context of stowage planning, no standards capable of representing this reality have yet been defined. This absence represents an opportunity to explore the creation of a set of definitions to be added to the data model, following the particularities of planning activities. By doing so, using the same information exchange system, it would be possible to intercommunicate these three links without needing interfaces to transform the information into each system’s formats. To endow TIC4.0 standards with this capability, it is necessary to understand the stowage planning process and the possible physical characteristics related to the location of containers on the vessel to digitally represent the ship’s stowage.

Concepts for automated port interfaces and intermodal cargo forwarding to the hinterland:

We have already seen how the TIC4.0 standards can intercommunicate systems in the loading and unloading processes between vessel and port, acting as the information conduit between planning systems (VCOP) and execution systems (TOS and the autonomous crane control system). What remains is to understand how these standards connect port terminals with their hinterland. This phase of operations is primarily administrative, so it is necessary to incorporate all the required data to admit a load and a carrier into a port/terminal and to be able to dispatch the load and the corresponding carrier.

In this regard, TIC4.0 has defined two major processes to represent the passage of a carrier and cargo through a terminal. These two processes are called Carrier Visit and Cargo Visit. Both incorporate the most important data enabling the entry or exit of a load. In addition to including the data, these two processes also define the gate-in and gate-out procedures for the terminals.

Building Block #3: Integrated Supply Chain Support (ModalNET)

In the previous section, we examined how TIC4.0 standards can interconnect systems responsible for loading, unloading, and dispatching operations to the hinterland within the port terminal environment. This section focuses on describing how TIC4.0 interconnects logistics coordination systems across the entire supply chain. Although this approach exceeds the scope on which TIC4.0 primarily focuses, there are still certain information needs for which TIC4.0 provides various definitions. These definitions standardize and eliminate ambiguity, making the meaning of events and processes more comprehensible for stakeholders.

In previous chapters, various diagrams have illustrated the role of ModalNET and its interactions with different systems, which are summarized as a set of reports and orders exchanged between systems to control and monitor the initially defined logistics sequence. Among the various reports, those involving systems such as VCOP and TOS can be addressed by the standards developed by TIC4.0, with the necessary modifications, to meet those information needs.

4.1.2 Compliance with DCSA standards to be presented

The Digital Container Shipping Association (DCSA) is an independent, non-profit organization established in 2019 by nine of the largest container shipping companies. Its primary goal is to set IT standards that enable interoperability of technology solutions across the container shipping industry. The purpose is to facilitate digital interconnectivity and seamless data communication that anyone involved in the industry can leverage.

DCSA focuses on creating standardized messages and documentation, as well as practical adoption solutions such as standardized APIs and data models. One key aspect of DCSA's work is the development of comprehensive frameworks that address various facets of the shipping process. These frameworks support efficient and transparent communication, operational efficiency, and optimal resource utilization.

DCSA's standards cover several critical areas, including:

- Across Journeys:
    - Track & Trace
- Shipment Journey:
    - Booking
    - Bill of Lading
- Equipment Journey
    - Commercial Events
- Vessel Journey
    - Just In Time Arrival
    - Load List and Bay Plan
    - Commercial Schedules
    - Operational Vessel Schedule

By establishing these standards, DCSA aims to support the transition towards autonomous logistics. The standardized APIs, data models, and communication protocols enable different systems to interact seamlessly, reducing the need for manual intervention and allowing for more automated processes.

For example, DCSA's frameworks facilitate real-time data exchange between shipping companies, port operators, and other stakeholders, which is crucial for autonomous logistics. The standards ensure that all parties have access to accurate and timely information, enabling automated decision-making processes. This reduces delays, optimizes shipping routes, and enhances overall efficiency.

The comprehensive set of standards developed by DCSA thus lays the groundwork for a more automated and interconnected logistics ecosystem. By promoting interoperability and clear communication, these standards help the industry move towards future where autonomous logistics can thrive, resulting in more efficient, sustainable, and reliable shipping operations.

DCSA in the context of SEAMLESS research project

Seeking to link the analysis of DCSA standards with the project's needs, Building Blocks 1 and 3 are identified, similar to the case of TIC4.0. The implications of Building Block #1: Automated Port Interfaces will be analysed first, due to its possible implementations regarding port arrival operations and the way events are communicated to coordinate port activities.

Building Block #1: Automated Port Interfaces (DockNLoad)

As mentioned in the description of DCSA, its standards are focused on harmonizing operations in the maritime sector and their interactions with ports and terminals. This is why, within the various tasks developed in Building Block number 1, the part of Autonomous Vessels Smart Port Manager can be particularly useful.

Specifically, the four sub-groups of the process stage that DCSA calls Vessel Journey are pertinent. Whether it is through the use of definitions of the 112 most important events in the process or the Just in Time Port Call operational specifications, these standards are useful for exchanging information from platforms such as smart port systems or any platform that serves as an information exchange hub. The same applies to standards like the Operational Vessel Schedule and the Commercial Schedule. The former enables the automatic sharing of vessel schedule data and exception-related information between carriers, operational partners (i.e., terminals), and their solution providers. The latter provides a common way for carriers to communicate vessel schedule information to customers.

Building Block #3: Integrated Supply Chain Support (ModalNET)

Regarding the applicability of DCSA standards to improve the efficiency levels of platforms like MODALNET, and everything related to the logistics side of the supply chain, the creation of eBookings and eBill of Lading is a significant step towards standardized digitalization. Both standards digitize the two central documents of all logistics operations. These documents are shared by many different stakeholders, so being able to exchange and share them in reliable digital formats increases the potential for deploying autonomous processes that can include administrative tasks.

As seen, both TIC4.0 and DCSA share a high degree of similarity in the problems they aim to solve and the challenges SEAMLESS faces when establishing operational links between the various systems involved in the processes at different levels of involvement and responsibility. It is important to highlight that both are oriented towards digitalization and, crucially, they offer solutions such as Application Programming Interface (API) references and data models, which make the implementation of both standards more feasible and viable. Another important point to consider is that both initiatives represent the largest international companies in their respective sectors, so the standards developed by these organizations are validated by industry leaders.

4.2 Logistics Process Flows

4.2.1 Preliminary Remarks

Based on the logistics system architecture in its as-is configuration and a comprehensive understanding of the SEAMLESS building blocks and innovations and their respective logistics process flows, the SEAMLESS Reference Logistics System Architecture combines the findings of both streams while incorporating the six SEAMLESS innovations into the cargo story with its four typical transport legs.

While the individual logistics process flows and interaction patterns of each SEAMLESS innovation has been elaborated upon in the preceding section, their respective integration into the reference logistics system architecture is yet to be proven. Thereby, it can be safeguarded that not only the functional fitness of the innovation is given but also the applicability on a real-world logistics scenario, such as a multimodal transport chain.

The following section presents the results of an iterative exchange of the lead authors over several months, in which (online and on-site) workshops with the heads of the development teams (i. e., MacGregor Finland, AWAKE.AI, Kongsberg Maritime, and Fundación ValenciaPort) were held and regular iterations with the development teams have taken place. Originating from the remarks of the Logistics Redesign workshop, a first understanding of the SEAMLESS innovations was used to identify the process areas, actors, and communication instances prone to change.

As in the case of the existing logistics reference system architecture described in section 2.1.1, the entire cargo story is divided into the four typical phases on two transport layers. Therefore, the planning layer and the execution layer are shown as different parts (see Figure 91 and Figure 92) as the first part includes mainly preparatory steps whereas the second one includes the physical execution of the transport process and related processes.

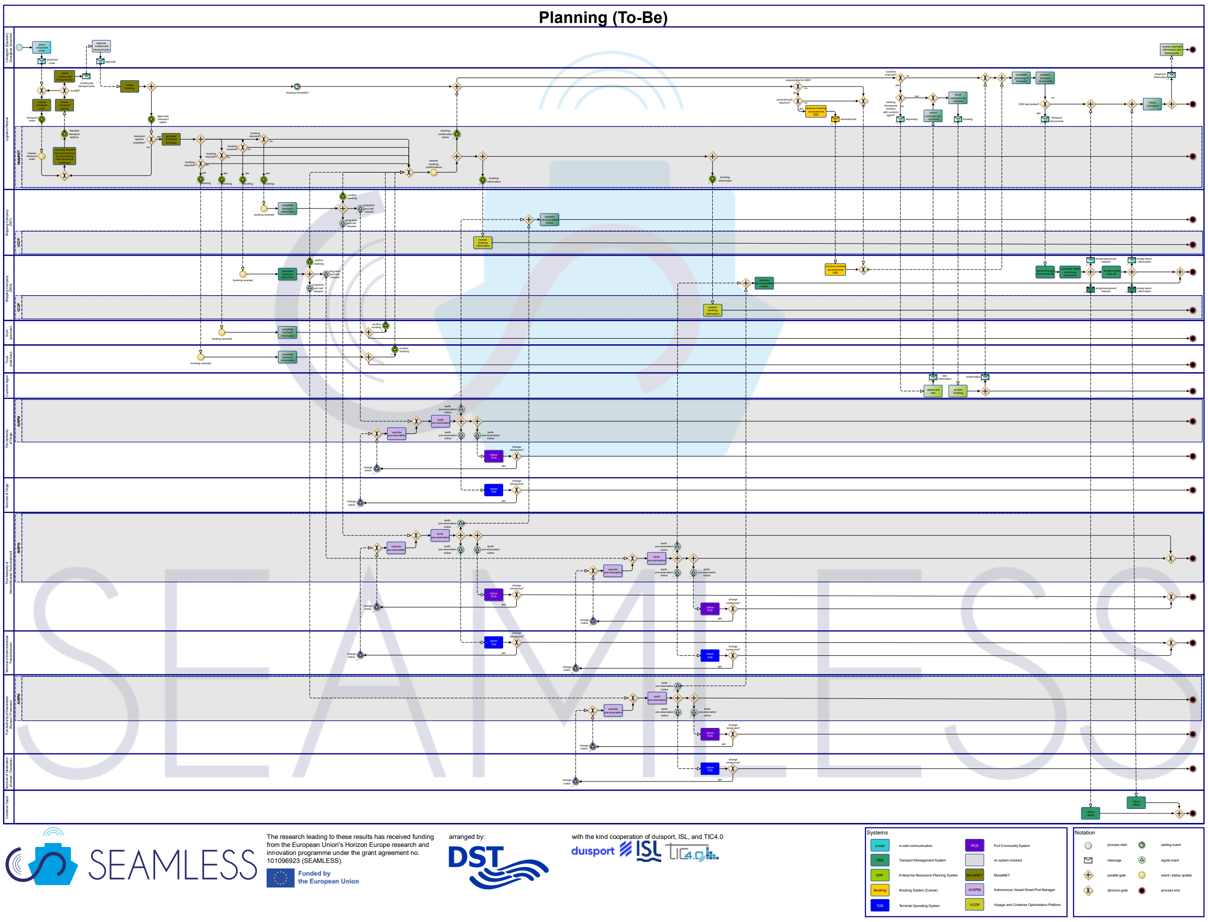


Figure 91. Planning layer of the SEAMLESS Logistics Reference System Architecture (to-be)

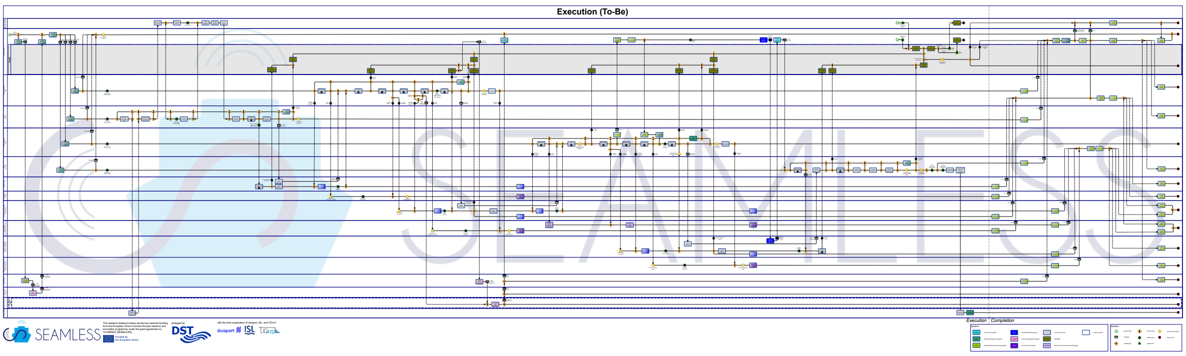


Figure 92. Execution layer of the SEAMLESS Logistics Reference System Architecture (to-be)

Both layers will be presented and explained separately in the following. The transport planning layer consists of the initiation and planning phases and includes the following five sub-phases:

- planning initiation,
- transport chain planning,
- SSS planning amendments,
- customs preparation, and
- planning completion.

The transport chain planning sub-phase can be subdivided into four sub-sub-phases which represent the formerly individual transport leg planning tasks, i. e., SSS leg planning, IWT leg planning, and post-haul leg planning, and pre-haul leg planning. These four sub-sub-phases were formerly individual sub-phases but have been subsumed in the new transport chain planning sub-phase. The reasons for the decision are explained in a later section.

The transport execution layer consists of two phases as well, i. e., execution and completion, and encompasses the following seven sub-phases:

- shipment preparation,
- pre-haul transport leg,
- IWT leg,
- SSS leg,
- post-haul transport leg,
- progress supervision, and
- shipment completion and invoicing.

In the respective figures, the different sub-phases of the two layers are represented with differently coloured backgrounds. As before, the different processes have been subdivided into sub-processes within the different phases and sub-phases, respectively.

For each of the five process sub-phases of the transport planning layer and the seven process sub-phases of the transport execution layer, the respective logistics process flows, the actors and stakeholders involved, and the systems used are presented and explained. Particularly, the differences between the as-is reference logistics system architecture and the SEAMLESS reference logistics system architecture and the changes induced by the SEAMLESS innovations are emphasized there.

4.2.2 Transport Planning Layer

Initiation phase, planning initiation sub-phase

The planning initiation sub-phase focuses on the business initiation of the shipment. The main differentiating factor between the as-is and to-be logistics process flow in this sub-phase is the use of ModalNET by the logistics planner, who receives the usual shipment order from the consignor or consignee, respectively. Instead of checking and planning the multimodal transport chain himself though, the logistics planner will feed the information to ModalNET which will plan and create multiple multimodal transport plan options. Then, the logistics planner only needs to select a pre-designed transport plan from the different options presented by ModalNET and receive the authorisation from the consignor or consignee, respectively. the to-be logistics process flow for the planning initiation can be seen in Figure 93.

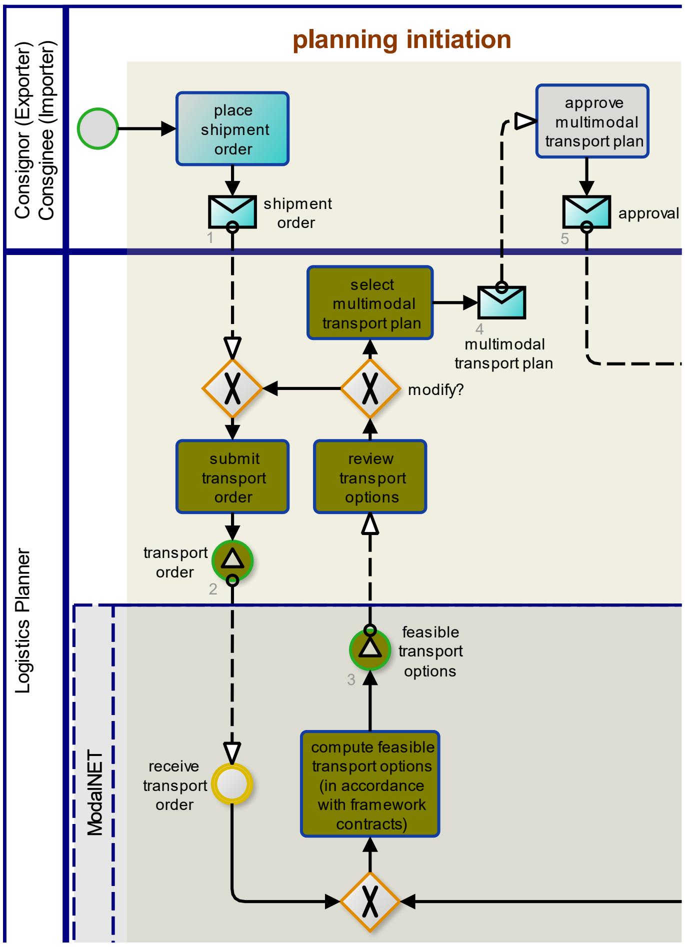


Figure 93. Logistics process flow in the planning initiation sub-phase (initiation phase) (to-be)

Planning phase, transport chain planning sub-phase

After completing the initiation phase, the subsequent planning phase begins with transport chain planning sub-phase which again sees the most significant changes in comparison with the as-is logistics process flow. As ModalNET has already configured several feasible multimodal transport chains of which one has been selected, the individual booking processes can now be performed in parallel. The is no need for the logistics planner to book each contractor individually in order of importance to the transport chain anymore. Likewise, there is no need to check for framework contracts separately as these are supposed to be considered in ModalNET's search for potential transport chain configurations and pertaining operators per leg and, thus, in the transport chain configuration process. The new transport chain planning in its entirety is presented in Figure 94. Instead of four individual sub-phases for the booking of different carriers, one joint sub-phase including all four transport legs is conducted. Upon receiving the booking request from ModalNET, the various shipping and trucking companies will complete their respective transport information and confirm the booking (in the ideal case). Once the bookings for all actors are confirmed, ModalNET will send the booking information to the VCOP for stowage planning and long-term port call planning purposes.

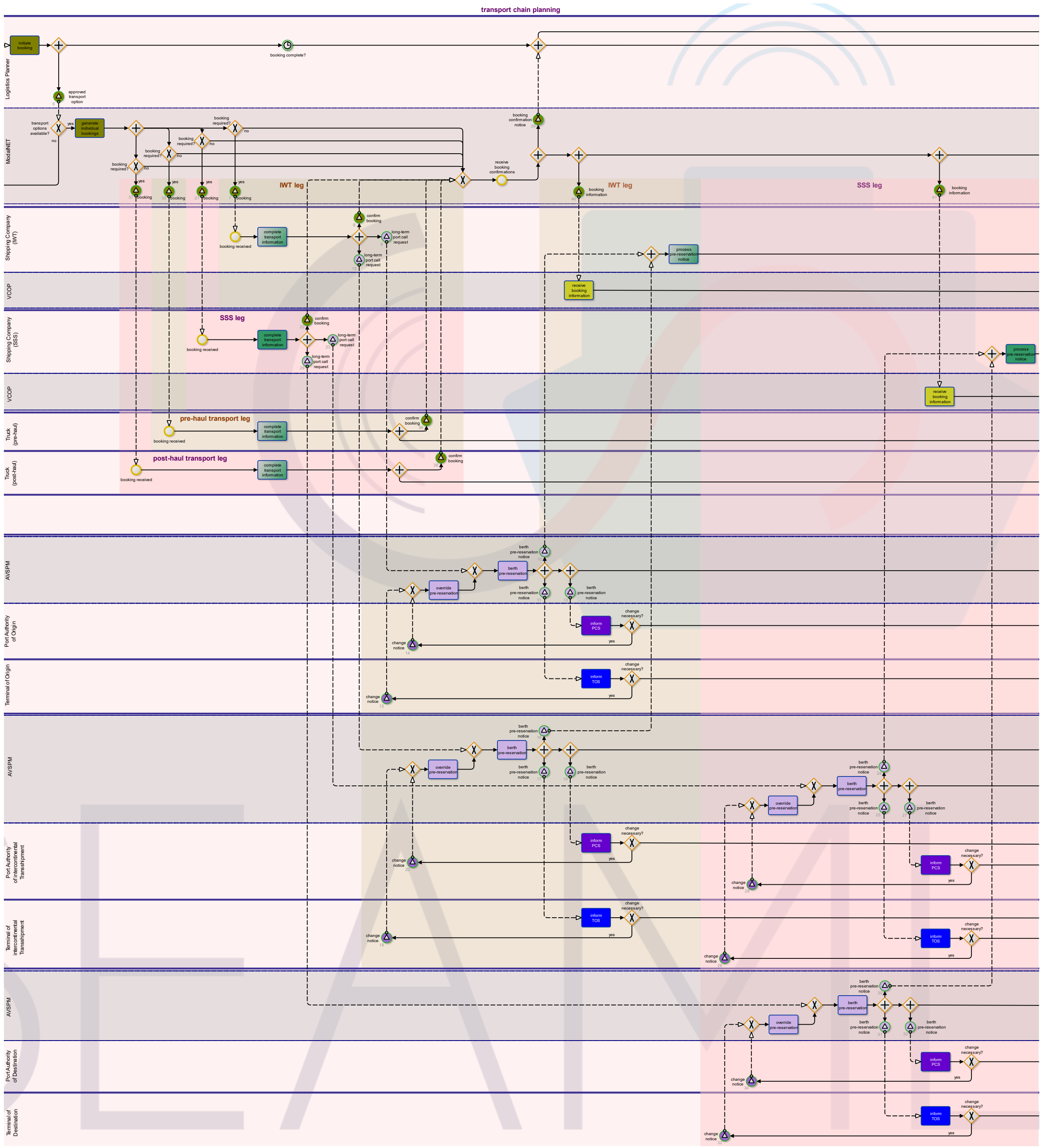


Figure 94. Logistics process flow in the transport chain planning sub-phase (planning phase) (to-be)

Another novelty in the to-be booking process is the inclusion of the long-term port call planning through AVSPM. Here, AVSPM takes over the notification of the terminal in order to pre-reserve a berth for the vessel. In addition, AVSPM communicates this pre-reservation with the involved parties, i. e., the shipping company, the terminal operator, and the port authority. Both the terminal operator and the port authority have the opportunity to request a change to the pre-reservation at any point after its creation by AVSPM, e. g., for reasons such as unavailability due to maintenance and repair. The logistics process flow of the SSS leg planning as part of the transport chain planning sub-phase can be seen in Figure 95 and Figure 96. For the SSS leg planning as part of the transport chain planning sub-phase, the logistics process flow is shown in Figure 97 and Figure 98 wherein the second figure includes the AVSPM process for both the SSS and IWT process flows. The respective logistics process flow illustrations of pre-haul and post-haul transport leg planning can be seen in Figure 99 and Figure 100, respectively.

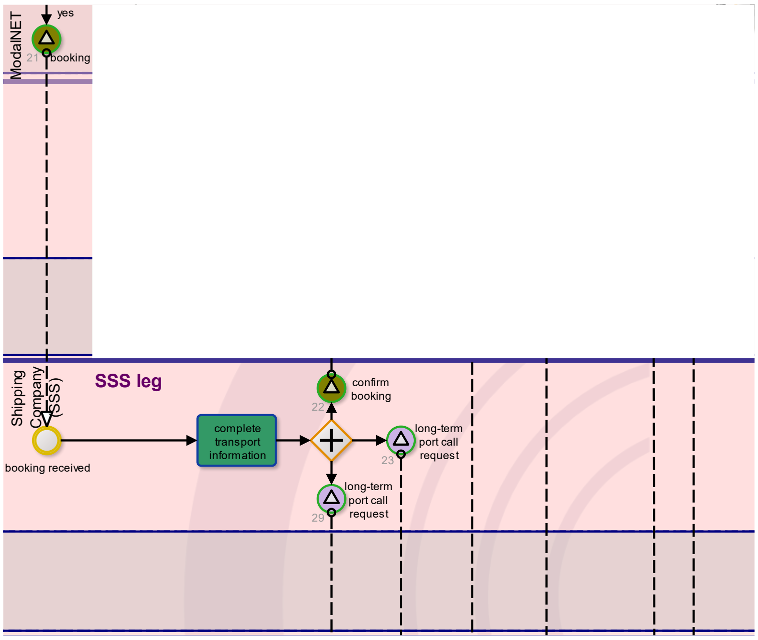


Figure 95. Logistics process flow in the transport chain planning sub-phase / SSS leg (1/2) (planning phase) (to-be)

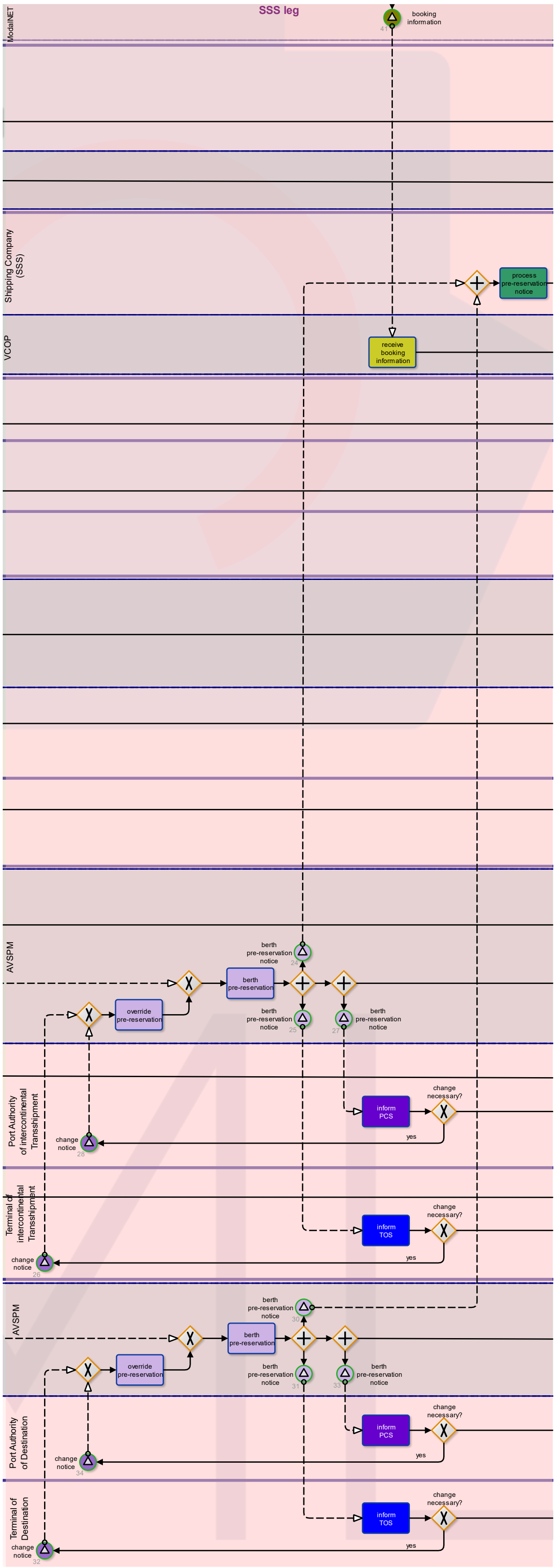


Figure 96. Logistics process flow in the transport chain planning sub-phase / SSS leg (2/2) (planning phase) (to-be)

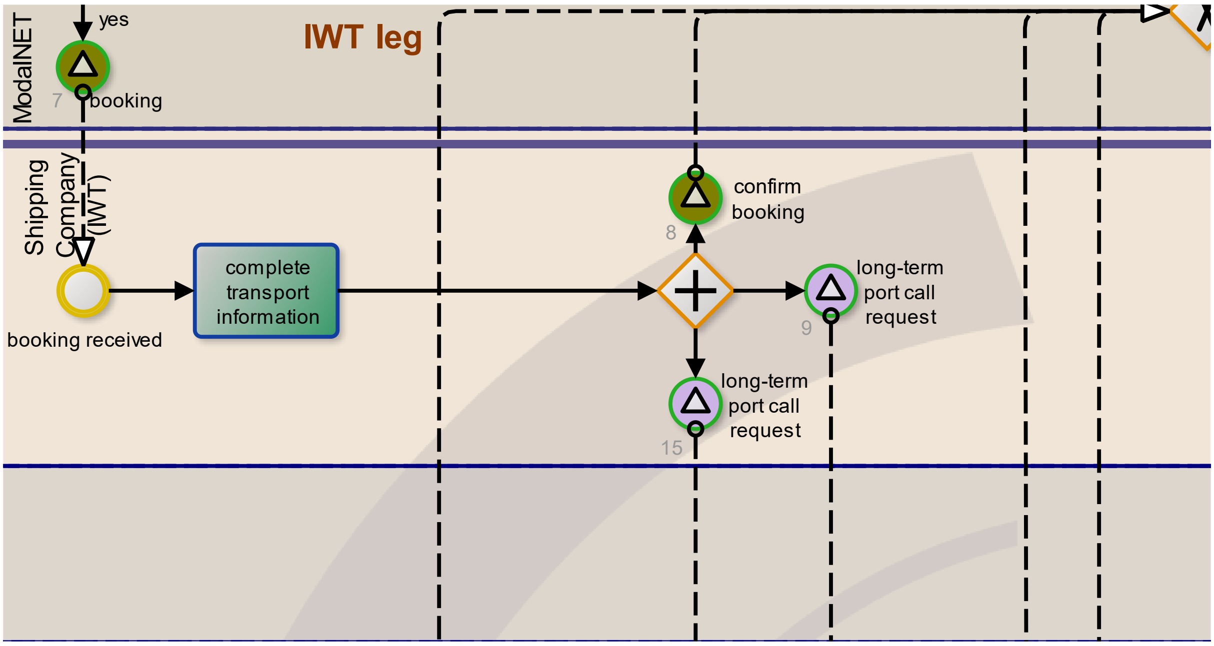


Figure 97. Logistics process flow in the transport chain planning sub-phase / IWT leg (1/2) (planning phase) (to-be)

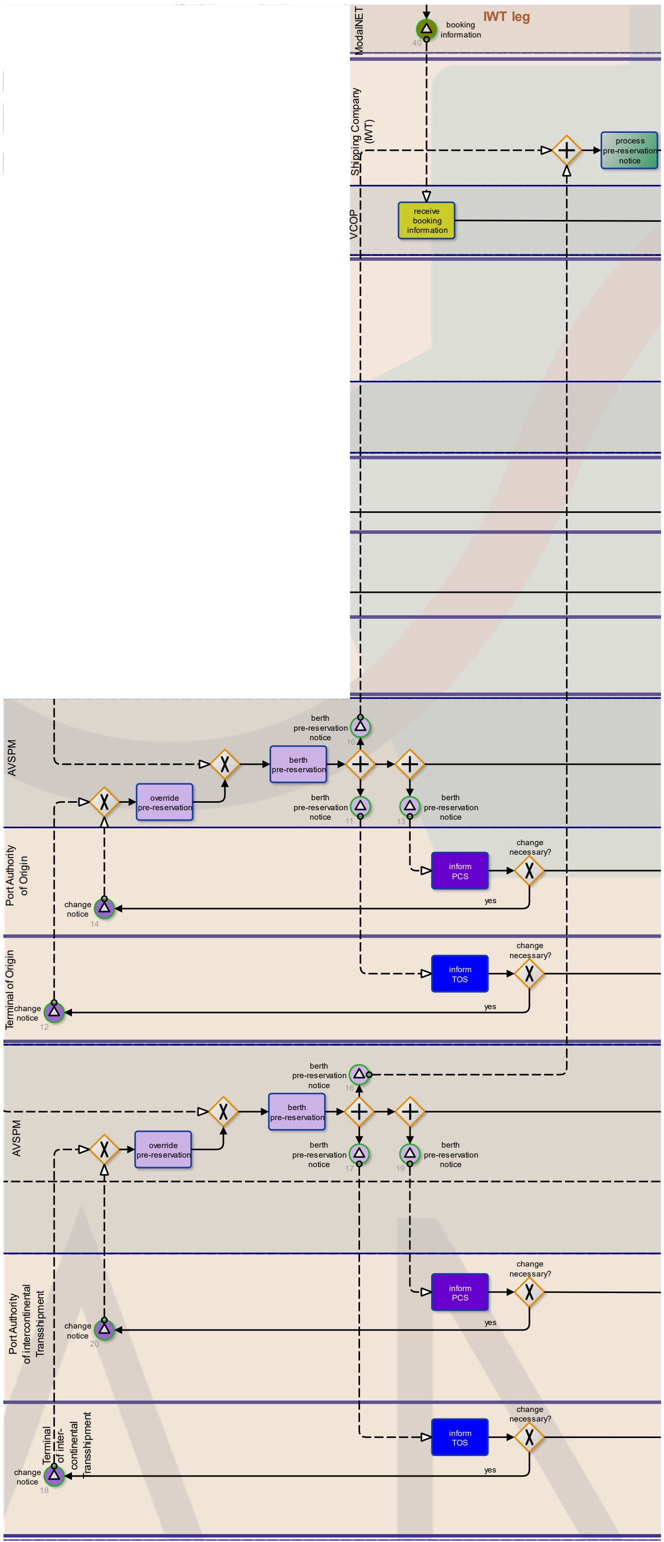


Figure 98. Logistics process flow in the transport chain planning sub-phase / IWT leg (2/2) (planning phase) (to-be)

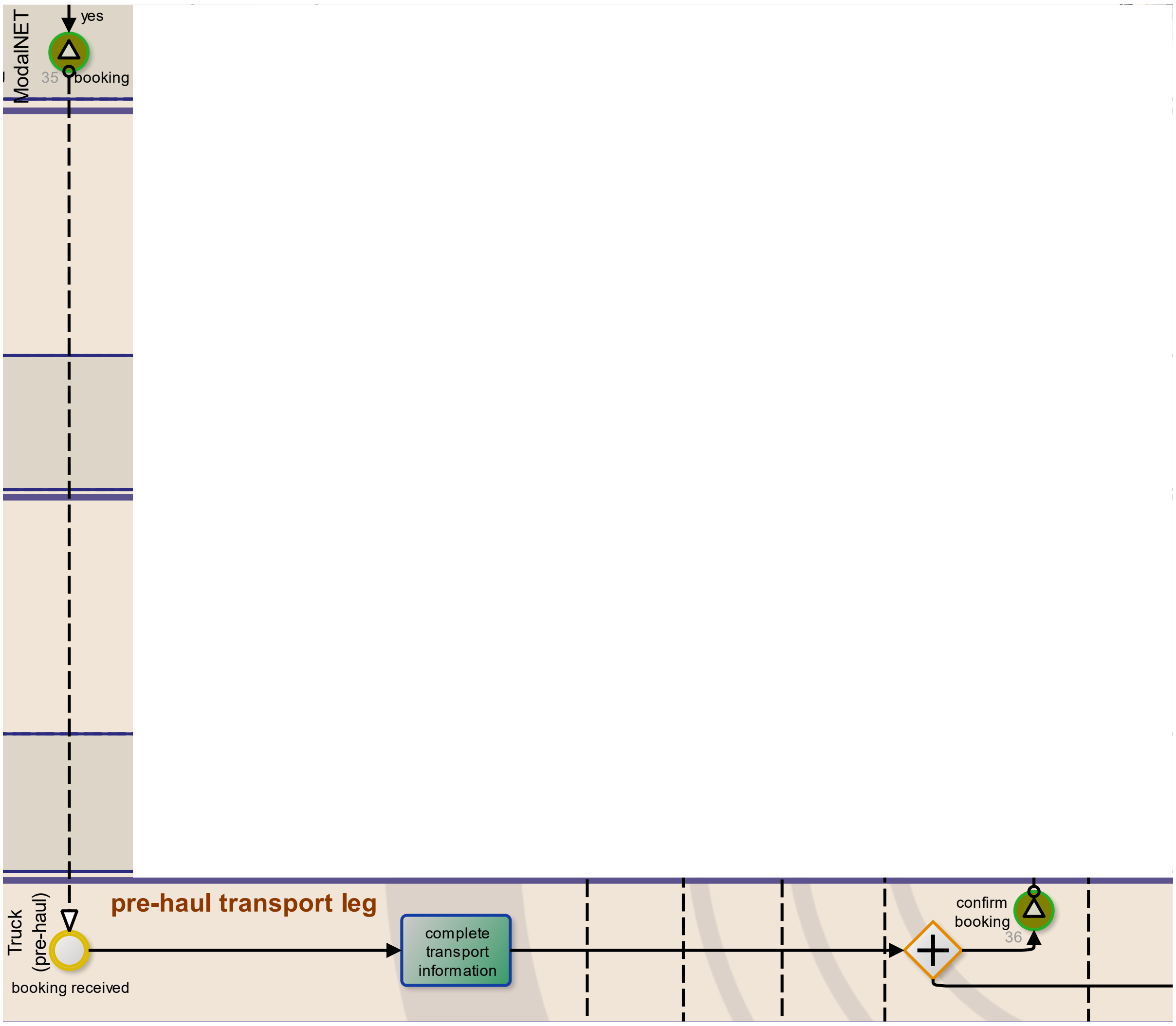


Figure 99. Logistics process flow in the transport chain planning sub-phase / pre-haul leg (planning phase) (to-be)

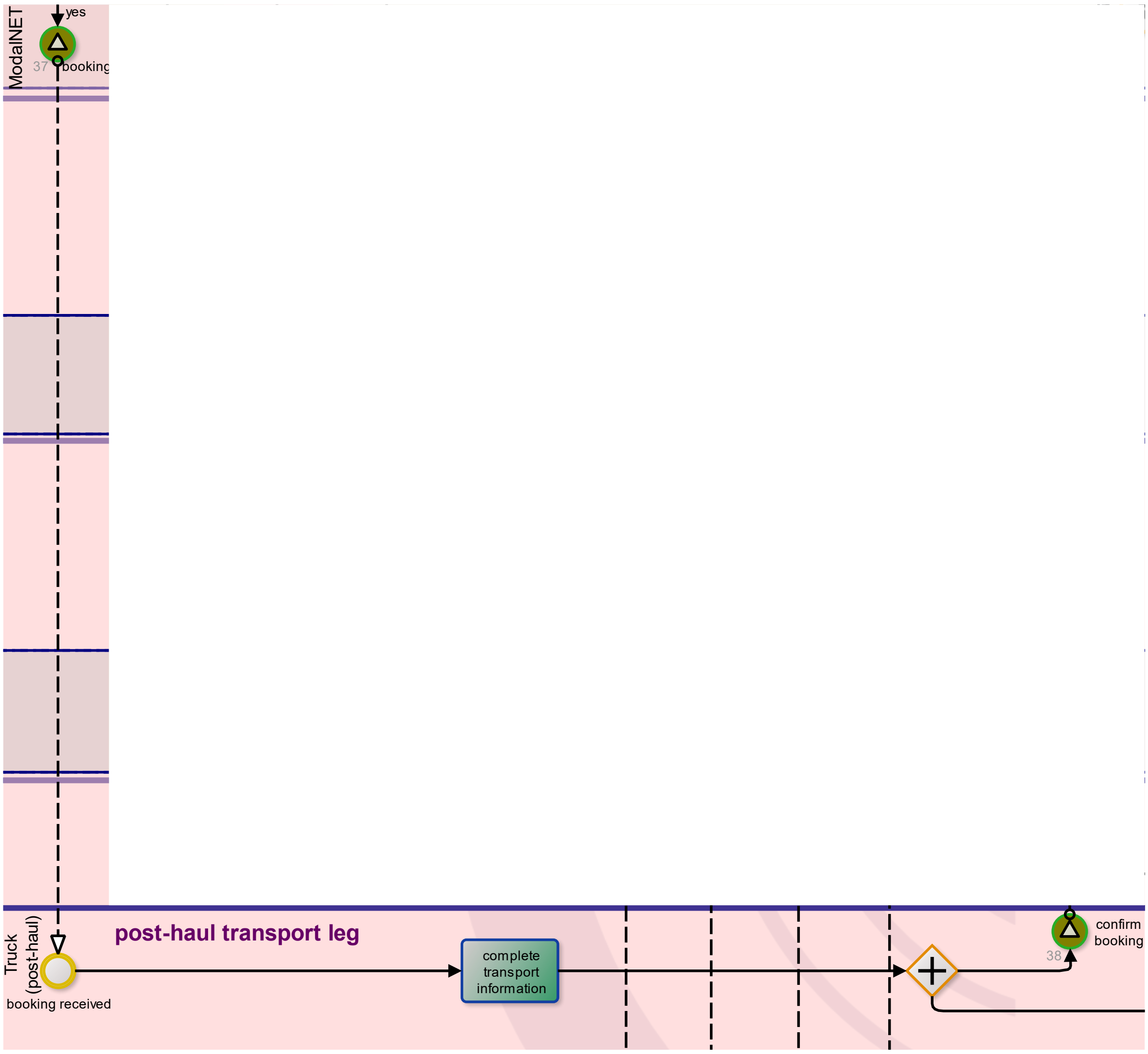


Figure 100. Logistics process flow in the transport chain planning sub-phase / post-haul leg (planning phase) (to-be)

Planning phase, SSS leg planning amendments sub-phase

The SSS planning amendments sub-phase has not been affected by the SEAMLESS innovations stemming from the SEAMLESS project (see Figure 101) and remains a bilateral exchange between logistics planner and SSS shipping company, provided he that is responsible for organizing the SSS leg and that any booking amendments are required. However, as the bookings are now parallelized in the to-be process, the amendments have to be made after all bookings are completed.

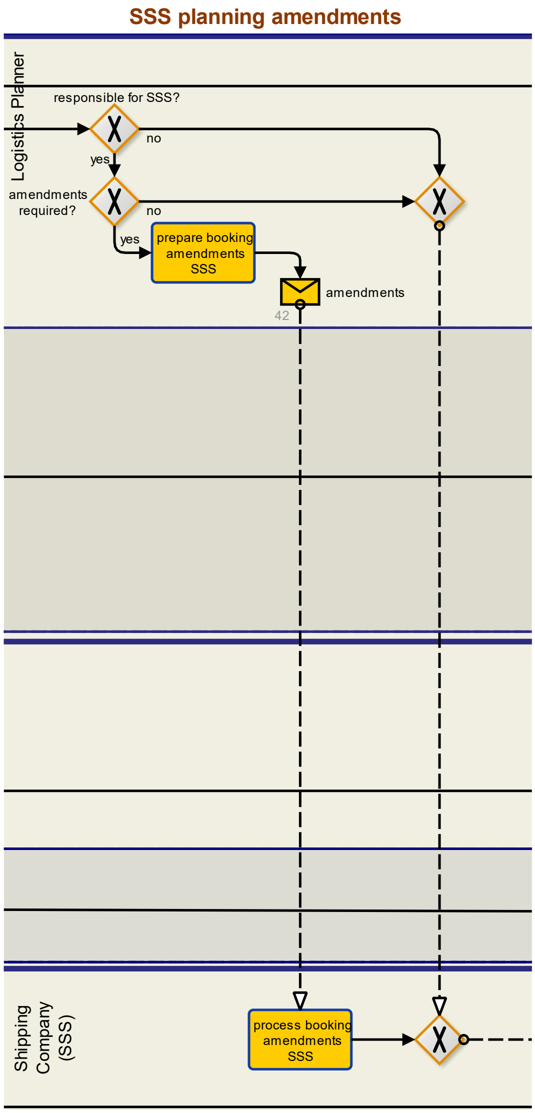


Figure 101. Logistics process flow in the SSS leg planning amendments sub-phase (planning phase) (to-be)

Planning phase, customs preparation sub-phase

The customs preparation is another sub-phase that has not changed from as-is to the to-be process and remains exactly the same between the two processes. It can be seen in Figure 102.

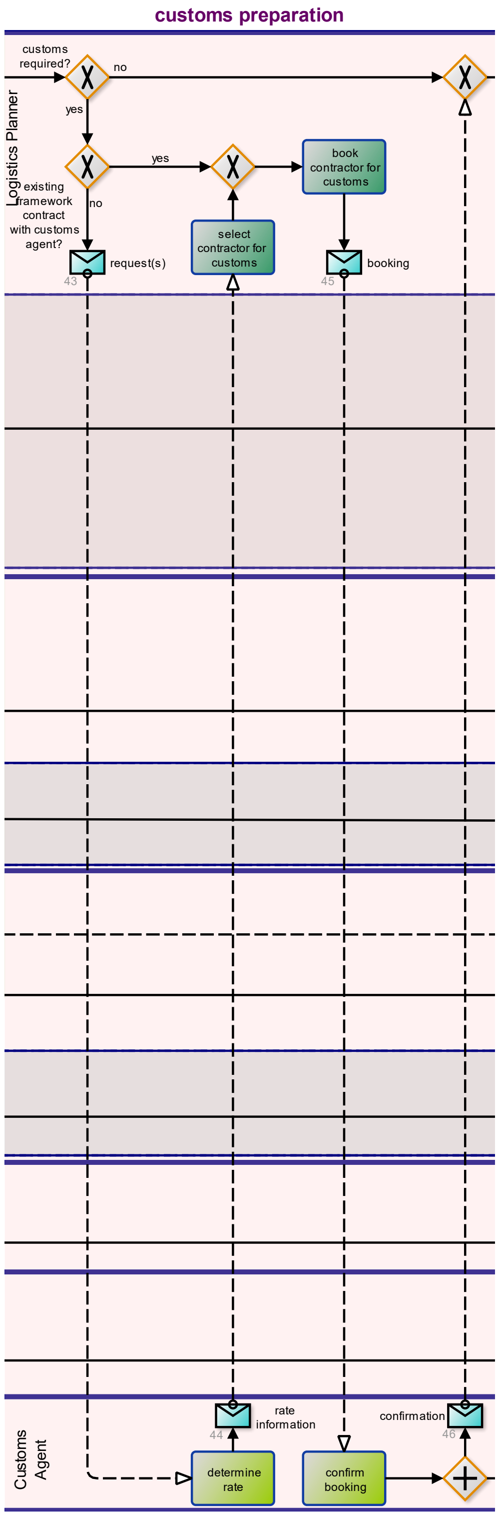


Figure 102. Logistics process flow in the customs preparation sub-phase (planning phase) (to-be)

Planning phase, planning completion sub-phase

Like the preceding sub-phases, the planning completion sub-phase remains unaffected by the SEAMLESS innovations as none of those influence the planning completion steps. The logistics process flow can be seen in Figure 103.

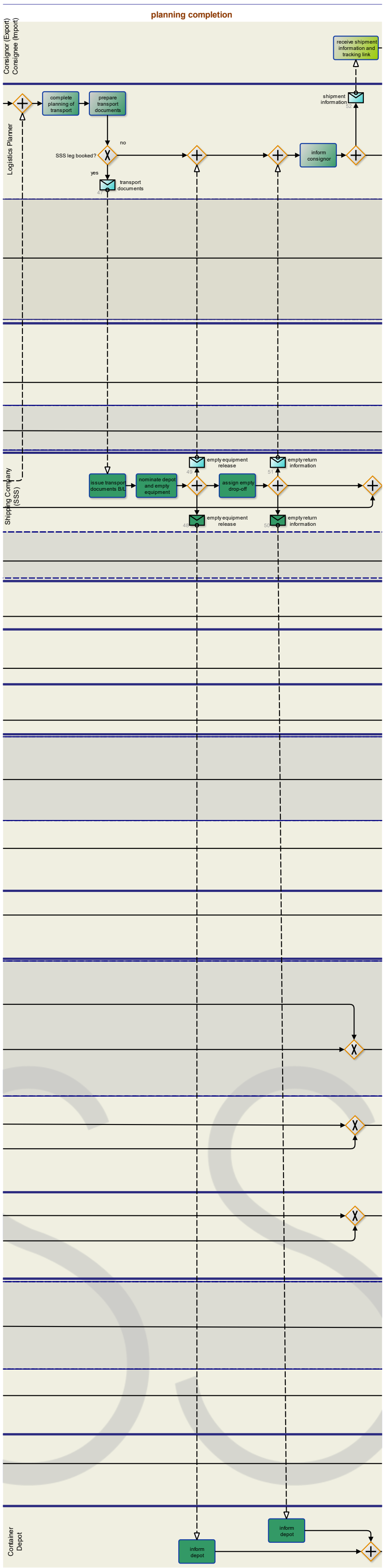


Figure 103. Logistics process flow in the planning completion sub-phase (planning phase) (to-be)

4.2.3 Transport Execution Layer

Execution phase, shipment preparation sub-phase

After completing the planning phase, the execution phase begins with the with its first sub-phase, the shipment preparation sub-phase, whose logistics process flow does not change through the implementation of the SEAMLESS innovations. The customs process is entirely untouched by the innovation and as such, just as the booking process for the customs agent the exchange of details and customs documents between the logistics planner and customs agent remain the same. The transmission of transport details to the different transport service providers follows the same logic like in the as-is process. Any final details required by the vehicle and vessel operators still have to be provided to them by the logistics planner. The unchanged process flow is presented again in Figure 104.

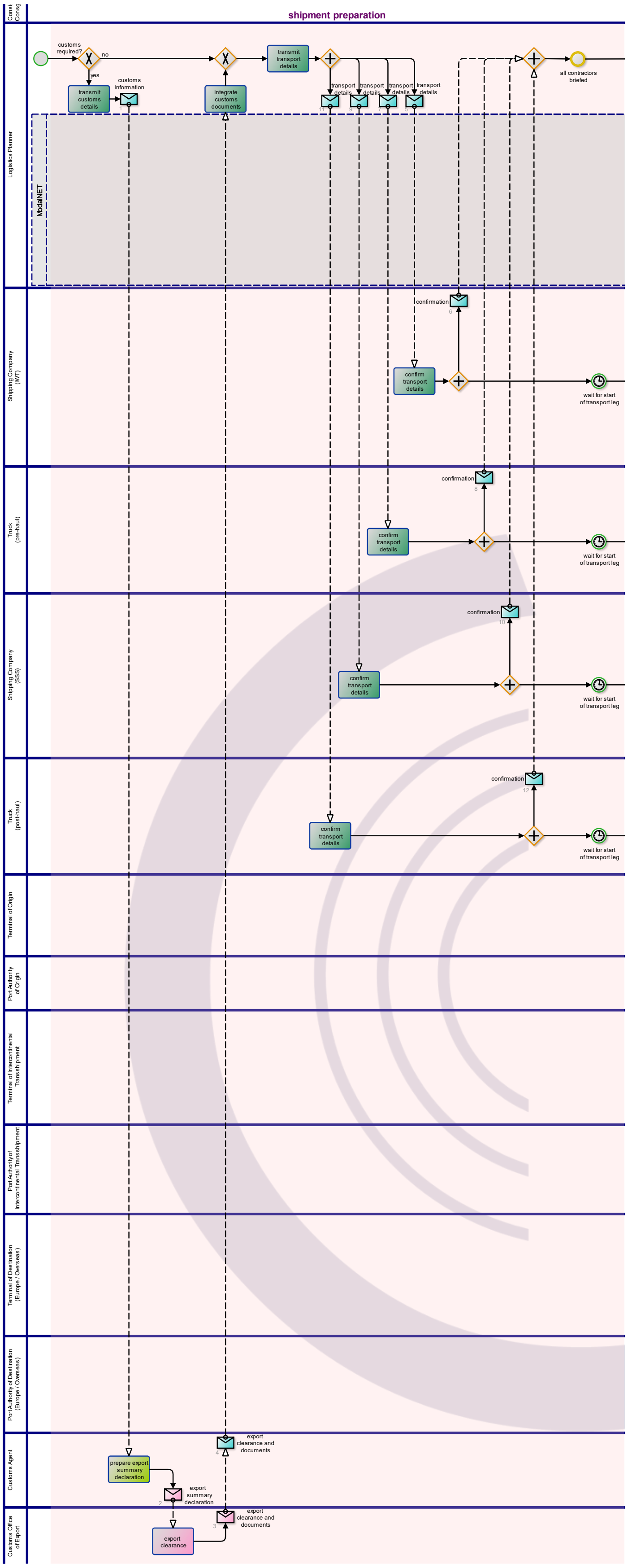


Figure 104. Logistics process flow in the shipment preparation sub-phase (execution phase) (to-be)

Execution phase, pre-haul transport leg sub-phase

The multimodal transport chain of the underlying cargo story begins with the road-based first-mile leg from the consignor’s premises to the first port of embarkation. In the to-be process, the pre-haul leg of the transport chain has not changed largely on an operative level as the SEAMLESS innovations are focused on waterborne transport and, thus, only affect the waterborne transport legs in the multimodal transport chain (see Figure 105).

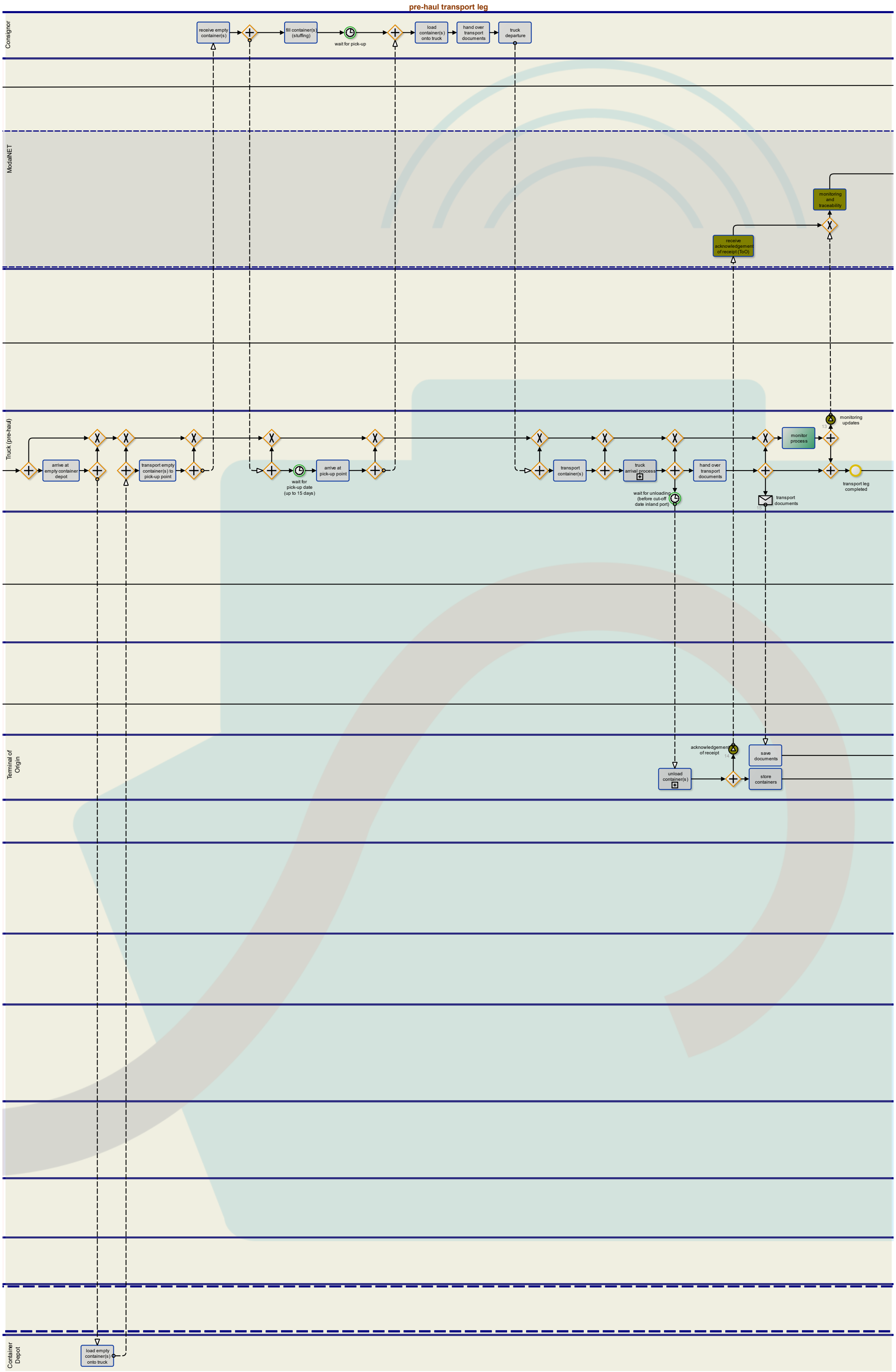


Figure 105. Logistics process flow in the pre-haul transport leg sub-phase (execution phase) (to-be)

The monitoring aspect, however, is affected by the implementation of ModalNET which acts as the new monitoring instance. Therefore, the monitoring updates of the pre-haul leg are now sent directly from the road haulier to ModalNET. The same is true for the acknowledgement of receipt sent by the terminal operator via ModalNET after the truck has been unloaded. It should be emphasized though that some of the messages are now generated and transmitted automatically (as opposed to the manual confirmations in the as-is process, for instance). For the sub-processes of the road pre-haul sub-phase, i. e., the truck arrival sub-process and the truck unloading sub-process, there are no further changes to be expected as the technical changes caused by the SEAMLESS innovations affect waterborne transport only. The logistics process flows for these sub-processes are displayed in Figure 106 and Figure 108, while the corresponding communication diagrams are shown in Figure 107 and Figure 109, respectively.

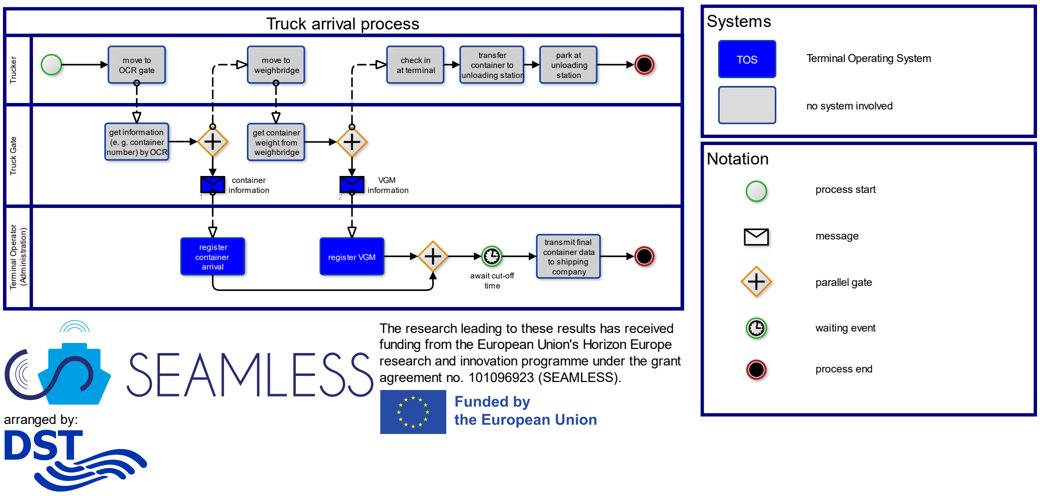


Figure 106. Logistics process flow in the truck arrival sub-process (to-be)

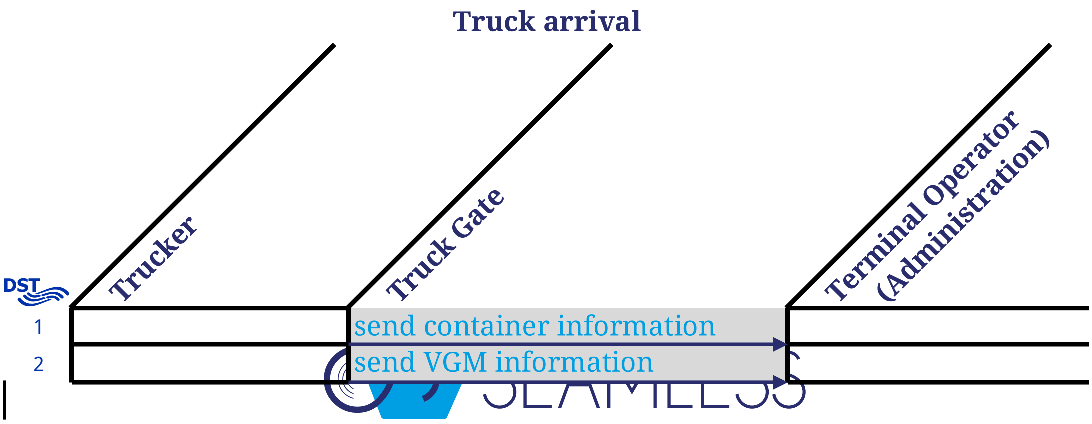


Figure 107. Communication/interaction pattern in the truck arrival sub-process (to-be)

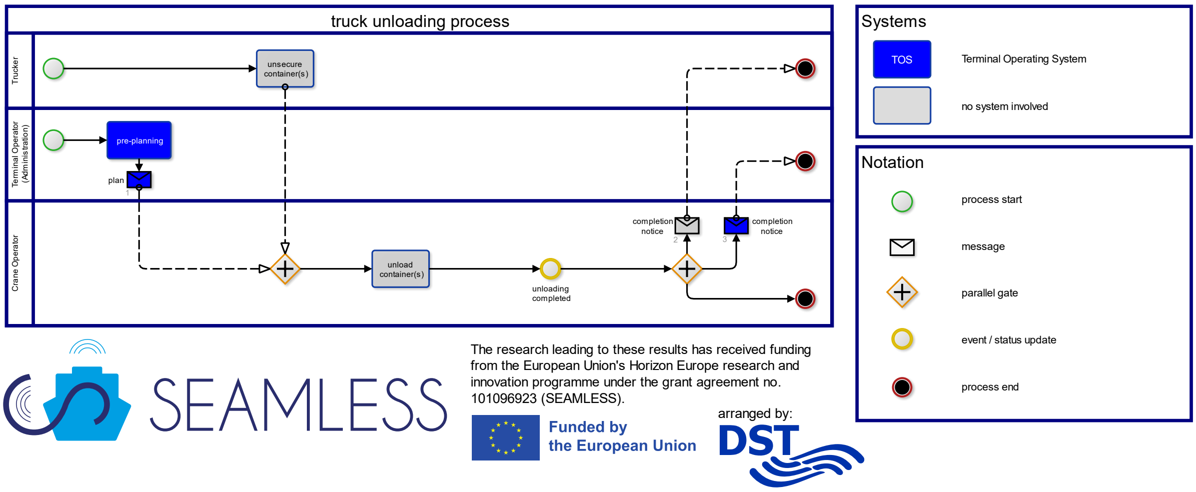


Figure 108. Logistics process flow in the truck unloading sub-process (to-be)

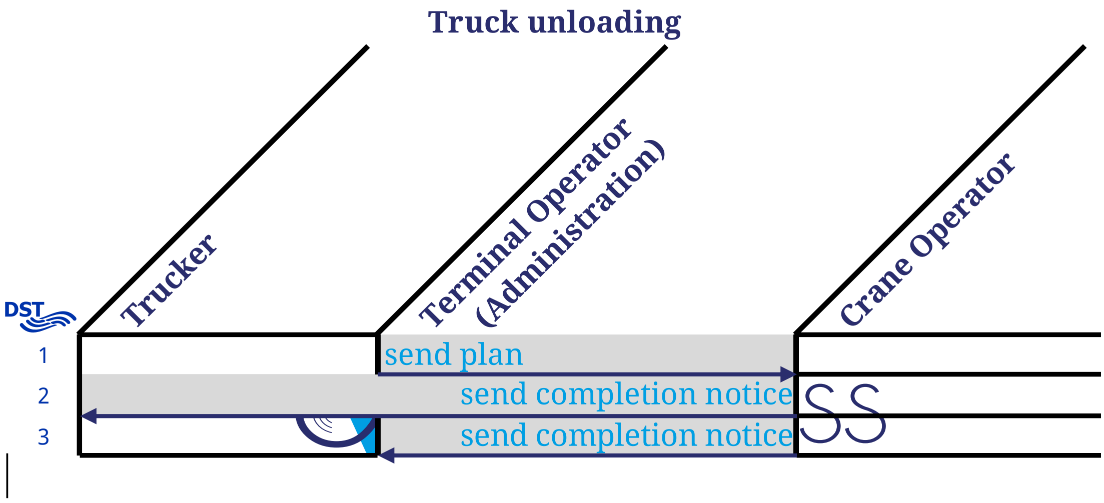


Figure 109. Communication/interaction pattern in the truck unloading sub-process (to-be)

Execution phase, IWT leg sub-phase

In the third sub-phase of the execution phase, the first waterborne transport leg of the multimodal transport chain involves inland vessels. The changes in this leg are manifold as all SEAMLESS innovations, i. e, VCOP, ROC, AVSPM, ACHS, AMoS, and ModalNET, co-create a new logistics process flow together.

The main difference in the logistics process flow is the transfer of responsibility for the task of cargo loading and unloading from the terminal operator to the inland shipping company. This is related to the on-board Autonomous Cargo Handling System which is considered as the default system for the transhipment of cargo from the vessel to shoreside and vice versa. This has shifted the tasks be-tween the players. Due to the shift in responsibility for the transshipment the notice about loading and unloading completion which was formerly sent from the terminal to the logistics planner, and the message signalling clearance to load, which was transmitted to the terminal by the inland shipping company, are both no longer required. Moreover, it is unclear how the new unloading process flow is going to affect the underlying business model of the terminal and the handling fees due for cargo transshipment.

Moreover, the majority of information exchanges, such as the arrival and departure notices, as well as loading and discharge requests have been converted from messages to signals sent to, from and between the different SEAMLESS innovations. The interaction between vessel and port/terminal is handled almost exclusively via the AVSPM while the monitoring information is transmitted to Modal-NET.

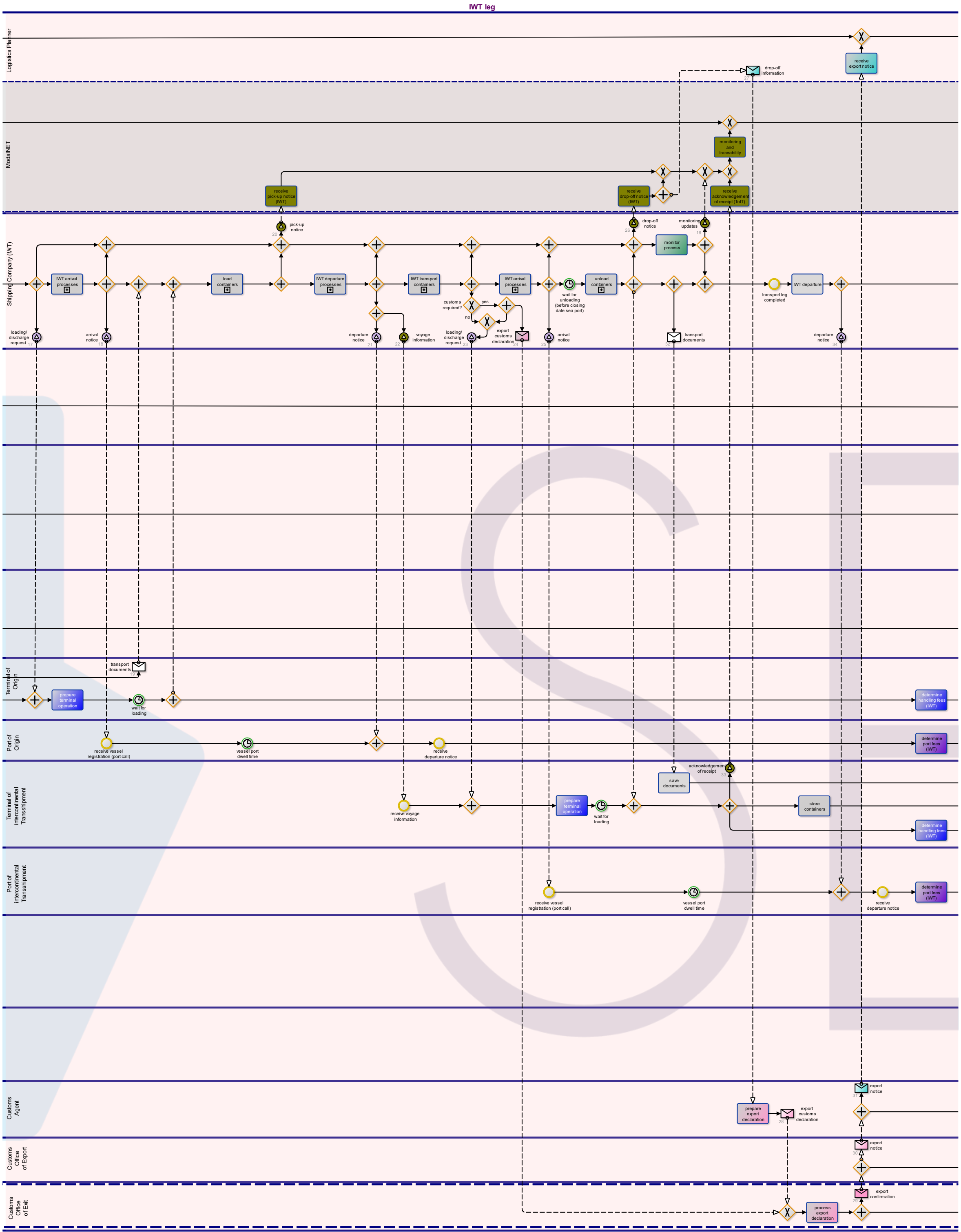


Figure 110. Logistics process flow in the IWT leg sub-phase (execution phase) (to-be)

Similarly, one of the most important gaps visible in the activity diagram of this sub-phase is the handling of cargo documents. While the physical exchange of documents is the rule in the as-is situation, this will no longer be possible with the use of autonomous vessels. This also applies to the tasks of collecting and checking the transport documents and handing them over at the terminal of origin or the terminal of intercontinental transshipment. Currently, it is unclear how and from where the information will be received and how the check of the transport documents will look like. This problem is not addressed by any of the SEAMLESS innovations and, thus, lies outside the scope of the research project. Hence, this was omitted as there have already been standards developed that focus on the digital exchange of transport documents, such as eFTI (see section about eFTI). The new logistics process flow including the above-mentioned changes can be seen in Figure 110.

Apart from the general process level with its changes to the logistics process flow, bigger changes compared to the as-is process are visible within the sub-processes of this sub-phase as these describe those logistics process flows in which most of the SEAMLESS innovations are active and induce change. As illustrated in Figure 111, the arrival process of inland vessels has been almost completely redesigned to accommodate all SEAMLESS innovations. Within the arrival process the vessel operator has been replaced by the autonomous vessel, the ROC (including its operator), and the AMoS system. The three systems now split the tasks originally performed by the vessel operator among them. Further, the process now includes the AVSPM and, thereby, the port authority – along with the terminal operator. With regard to communication, the only notices remaining from the original as-is process are the arrival notice of the inland vessel and the readiness notice by the terminal after loading. However, these notices are not directly transferred to their respective recipient anymore but are communicated through the AVSPM of the port authority instead. The communication and interactions patterns are displayed in the Figure 112.

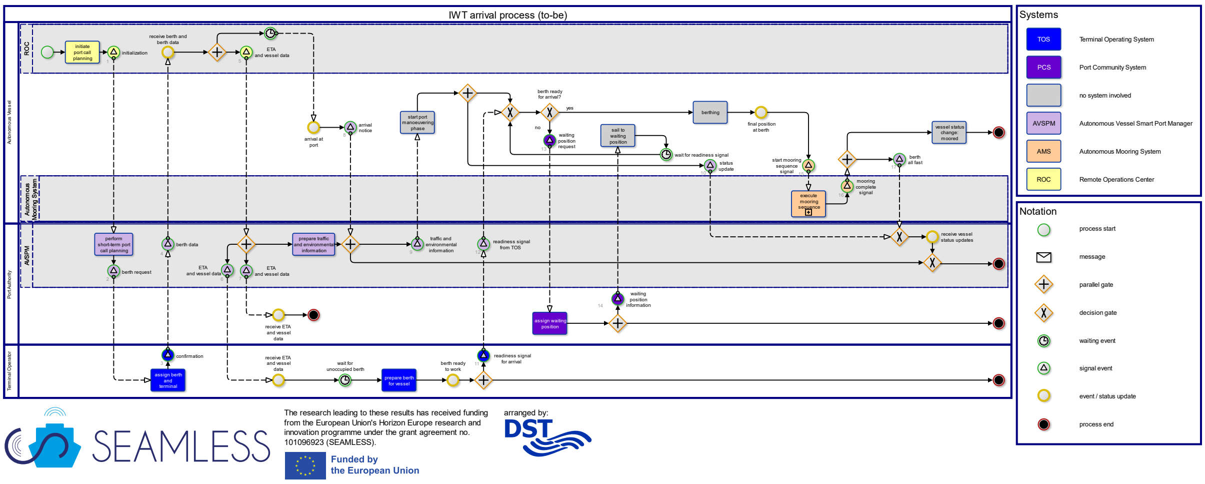


Figure 111. Logistics process flow in the IWT arrival sub-process (to-be)

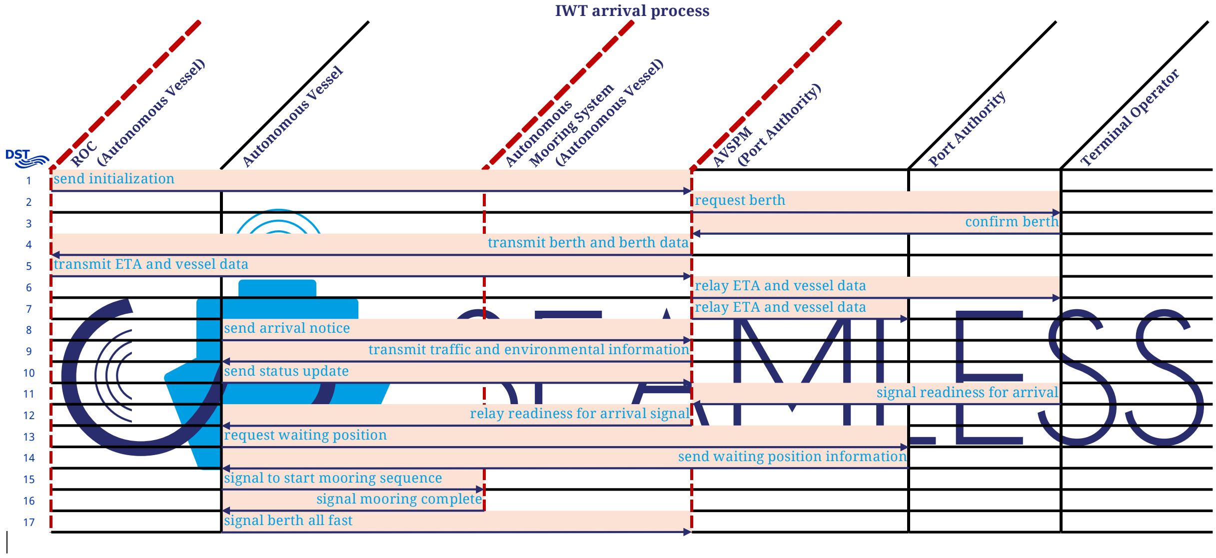


Figure 112. Communication/interaction pattern in the IWT arrival sub-process (to-be)

The arrival process begins with the ROC initializing the short-term port call planning. The pertaining initialization signal is sent to the AVSPM which will submit a final berth request to the terminal operator and receive a confirmation after the final assignment of the berth. This confirmation may include various berth-related information and will be sent back to the ROC which then then will respond by sending the ETA of the inland vessel as well as further vessel-related data to the AVSPM. The AVSPM uses this information to prepare the traffic and environmental information to be provided to the vessel on arrival and communicates the ETA to the terminal operator and forwards the ETA and vessel data to the port authority. Once the assigned berth is vacant, the terminal operator will start to prepare the berth for vessel arrival. Upon arrival, the autonomous vessel will send the arrival notice to the port (more precisely, to the AVSPM) and receive the traffic and environmental data required to start the port manoeuvres. After entering the port area, the vessel will send updates of its position and status continuously to the AVSPM for the purpose of traffic monitoring inside the port. When the autonomous vessel approaches the assigned berth, the vessel will check whether the berth is ready for arrival. If no readiness signal has been received, the vessel will request a waiting position from the port authority which in turn assigns the waiting position and informs the vessel about it. The vessel will then sail to the assigned position and wait for the readiness signal of the terminal berth. When the readiness signal has been received prior to or during the waiting process, the autonomous vessel will start berthing. After the final position at berth has been reached, the autonomous vessel will start the mooring sequence with the help of the AMoS system. This sequence is described in detail in the section about the Autonomous Mooring System and is displayed in Figure 113, while the related communication diagram is shown in Figure 114. When the AMoS system signals the completion of the mooring sequence to the autonomous vessel, the latter will send the final signal of the arrival process, the so-called ‘berth all fast’ signal, to the AVSPM and change its status to ‘moored’.

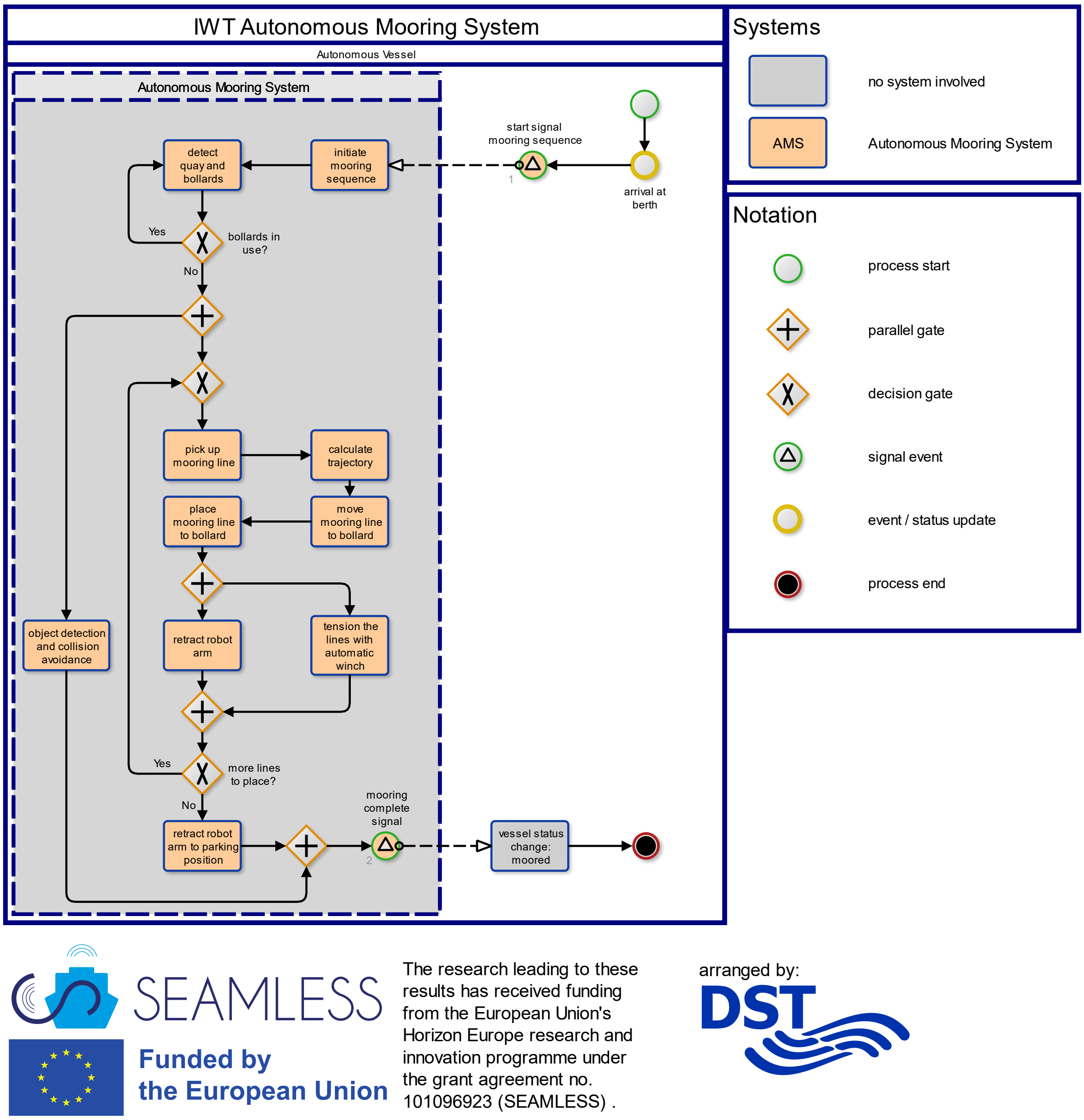


Figure 113. Logistics process flow in the autonomous mooring system (IWT) sub sub-process (to-be)

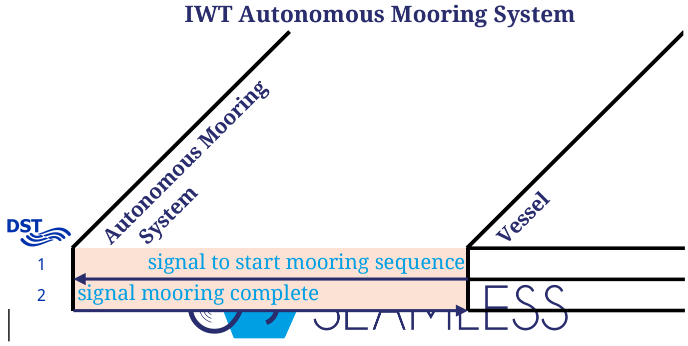


Figure 114. Communication/interaction pattern in the autonomous mooring system (IWT) sub-sub-process (to-be)

Similar significant changes have occurred in the loading and unloading process, next to the shift of responsibility of the task of cargo handling from the terminal to the inland shipping company. The logistics process flow now comprises the autonomous vessel including the ROC, VCOP, and ACHS, the terminal operator, the logistics planner with the monitoring of ModalNET, and another actor who still needs to be determined as the responsible party for the task of securing and un-securing cargo on the vessel, if required. As this task is currently still undefined, it represents another gap in the entire to-be process of a multimodal transport chain. As indicated briefly earlier, the crane operator is removed from this sub-process as his duties are taken over by ACHS on board the vessel. Another significant variation in the sub-process is the stowage planning which is now handled by the VCOP exclusively – compared to the options in the as-is process of being executed on board the vessel by the shipmaster or on the shoreside by the inland shipping company. The final stowage plan still needs to be confirmed by the ROC (or its operator, respectively) acting as the shipmaster. The final stowage plan is also affected by the missing ‘clearance to load’ message as this could influence the IDs, number, and sequence of containers to be loaded or unloaded. The processes of vessel loading and vessel unloading now both follow the same logistics process flow, leading to one universal activity diagram (see Figure 115) and one universal sequence diagram (see Figure 116).

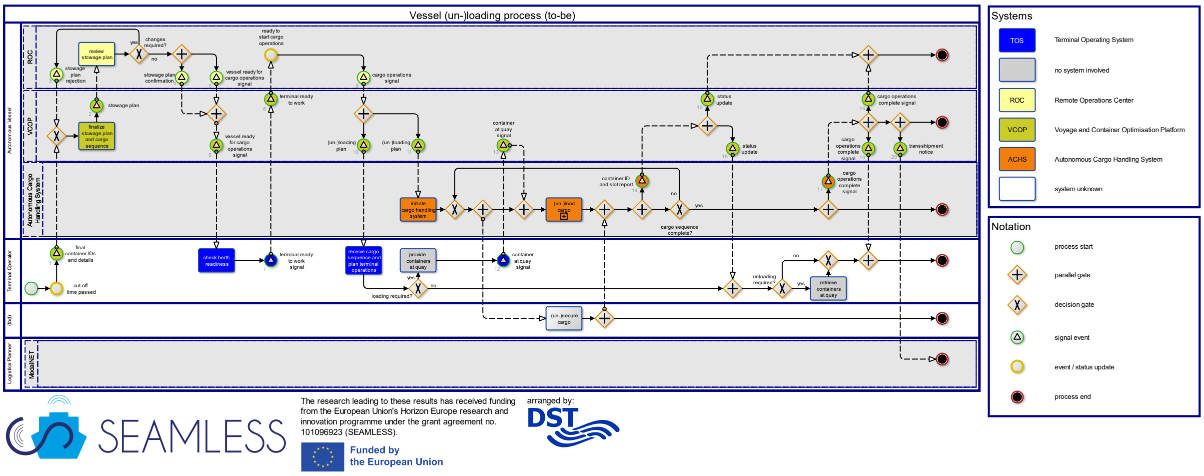


Figure 115. Logistics process flow in the vessel (un-)loading sub-process (to-be)

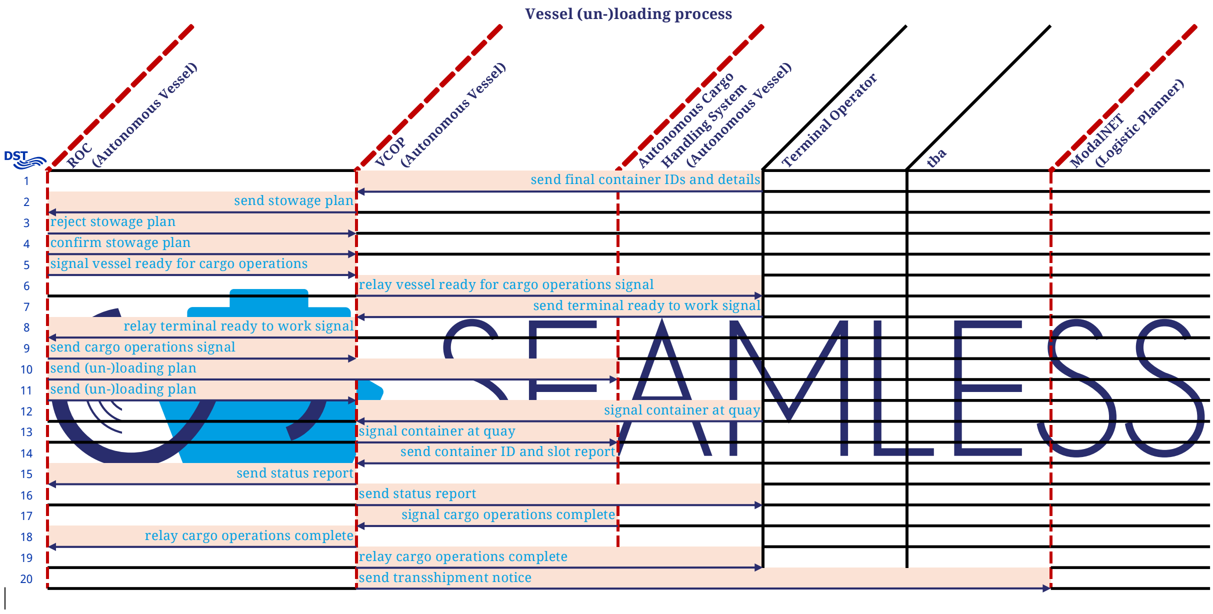


Figure 116. Communication/interaction pattern in the vessel (un-)loading sub-process (to-be)

The vessel loading or unloading sub-process is started by the terminal operator, who will provide the final container IDs and details such as weight to the VCOP after the cut-off date has passed. In this way, the VCOP can finalize the stowage plan with the data of all containers available to load. The stowage plan is sent to the ROC for review and will be accepted or rejected. A rejection of the stowage plan will lead to the VCOP creating a new stowage plan for approval by the ROC. When the stowage plan suffices the expectations of the ROC, the latter will confirm the stowage plan and later send out the signal that the vessel is ready for cargo operations back to the VCOP. The VCOP will check with the terminal operator whether the berth is ready to work and forward the ready-to-work signal from the terminal to the ROC, which prompts the ROC to initiate cargo operations with the VCOP. Upon receiving the signal, the VCOP will send the loading or unloading plan to both the terminal operator and the ACHS. The ACHS will initiate the cargo handling system, whereas the terminal will use the cargo sequence received and start to provide the containers at the quay side (in the loading case). Once a container is provided at the quay, the terminal operator will signal this to the VCOP (via the TOS) which in turn will send a signal to the ACHS which will then execute the container transhipment sequence. Parallel to this, the securing or un-securing of cargo on board the vessel needs to happen. The cargo handling process was described previously in the section about ACHS but is also displayed in Figure 117 along with the corresponding communication pattern in Figure 118. After the containers have been moved, the ACHS will send a report to the VCOP transmitting the container ID and slot on board or quay side, respectively, in which the containers have been placed. This report will be provided as a status update to the ROC and the terminal operator. In case of an unloading process, the terminal operator will use this information to retrieve the containers from the quay. These steps (from the initiation of the cargo handling system onwards) will be repeated for each container until the container sequence provided is complete. As soon as this is done, the ACHS stops operating the loading crane and sends a final signal to the VCOP that the loading process is complete. This signal of completed cargo operations will be provided to the ROC and terminal operator to inform both parties about the sub-process completion. Lastly, the VCOP will also send a transshipment notice to ModalNET about all the containers moved in the cargo handling sequence.

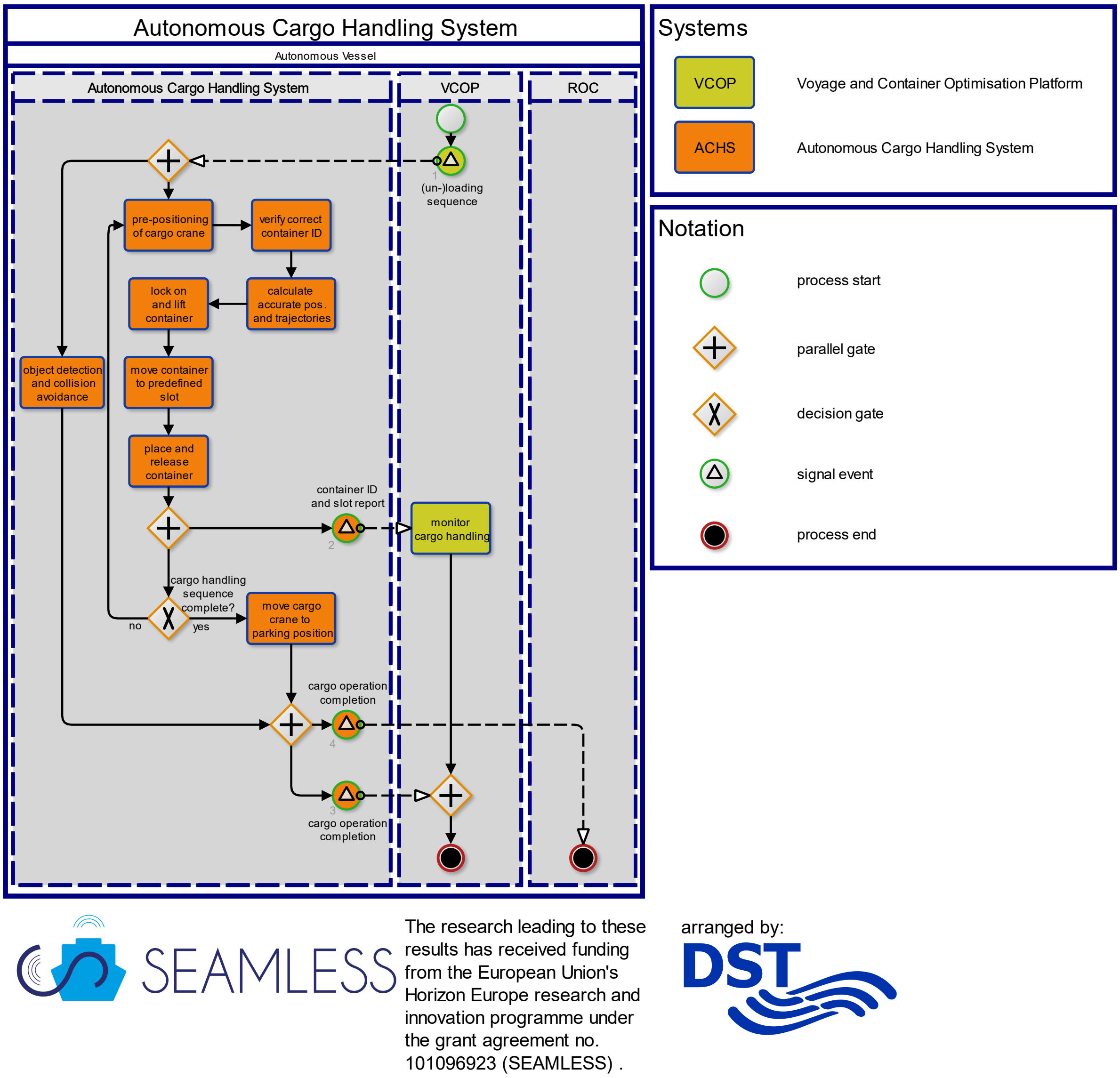


Figure 117. Logistics process flow in the autonomous cargo handling sub-sub-process (to-be)

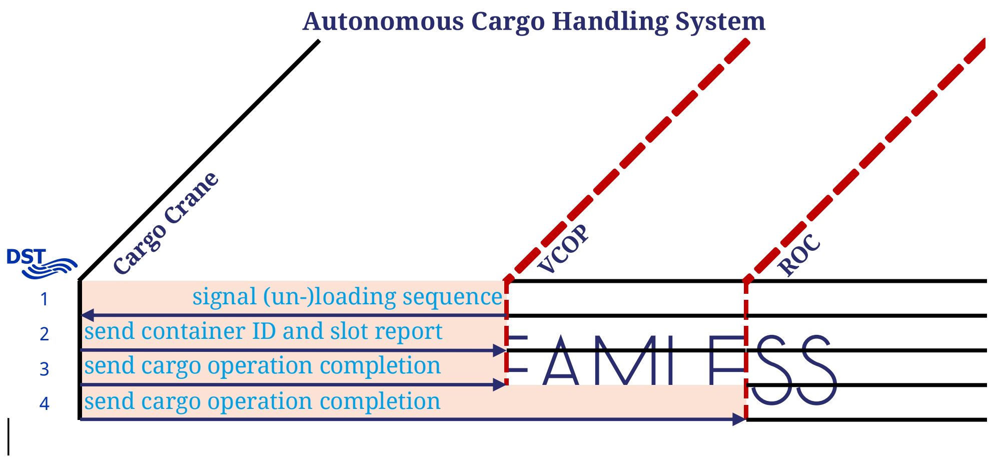


Figure 118. Communication/interaction pattern in the autonomous cargo handling sub-sub-process (to-be)

The departure process of inland vessels, displayed in Figure 119, has undergone significant changes with respect to the logistics process flow. Just as in the arrival process, the departure process now includes the ROC, the AMoS system, and the AVSPM in its to-be version. Further, the inland vessel is envisioned to potentially be electrically powered by means of swappable battery containers. Thus, a battery provider is required for the process equivalent to recharging or the former refuelling. The related communication diagram can be seen in Figure 120.

The departure process of inland vessels commences with a check for a fuel- or battery-powered inland vessel. The responsibilities per working step in the bunkering process have changed as the autonomous vessel will perform the fuel check. If it is determined that there is not enough fuel available, the ROC operator sends a bunker request to the bunker provider, who then responds to the ROC as in the as-is process. The ROC will receive the confirmation and the fees. After the bunkering is completed, the autonomous vessel will perform another fuel check before the ROC will supply the bunker quantity notice to the bunker provider who will proceed as previously described in the as-is process. In case of a battery-powered inland vessel, the battery swap process is similar to the bunkering process. If required, the ROC will send a request to the battery provider who will process the request and send a confirmation to the ROC. The ROC will receive the confirmation including the fees, and the battery provider will execute the battery swap. As soon as these possible refuelling operations have been completed, the inland vessel waits for the departure time. As soon as the vessel is ready to depart, the ROC notifies the port authority of the intention to depart via the AVSPM, which will process the departure request and supply the vessel with a confirmation of the departure time. Parallel to this, the terminal will prepare the berth for the vessel departure. Once the confirmed departure time is reached and the berth readiness for departure has been signalled to the vessel via the AVSPM, the vessel will start the unmooring sequence. The unmooring sequence will once again be performed by the AMoS system (as described in section about the Autonomous Mooring System and shown in Figure 121 and Figure 122), and the process is terminated with a completion signal sent to the autonomous vessel which will change its status to unmoored and notify the AVSPM about it. Afterwards, the vessel will begin the departure from the port and finally send a departure notice to the AVSPM upon leaving the port area.

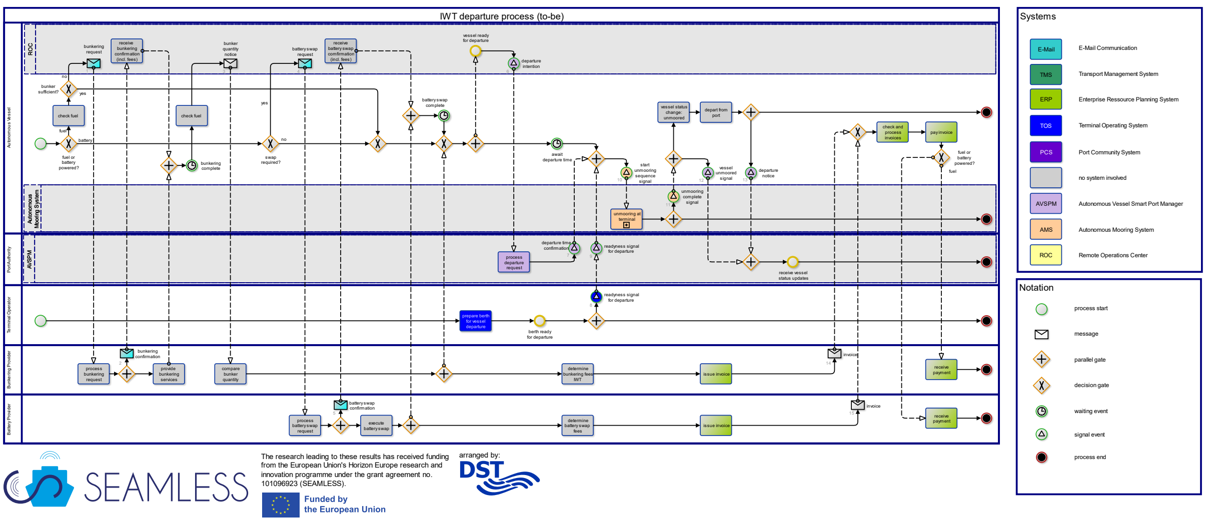


Figure 119. Logistics process flow in the IWT departure sub-process (to-be)

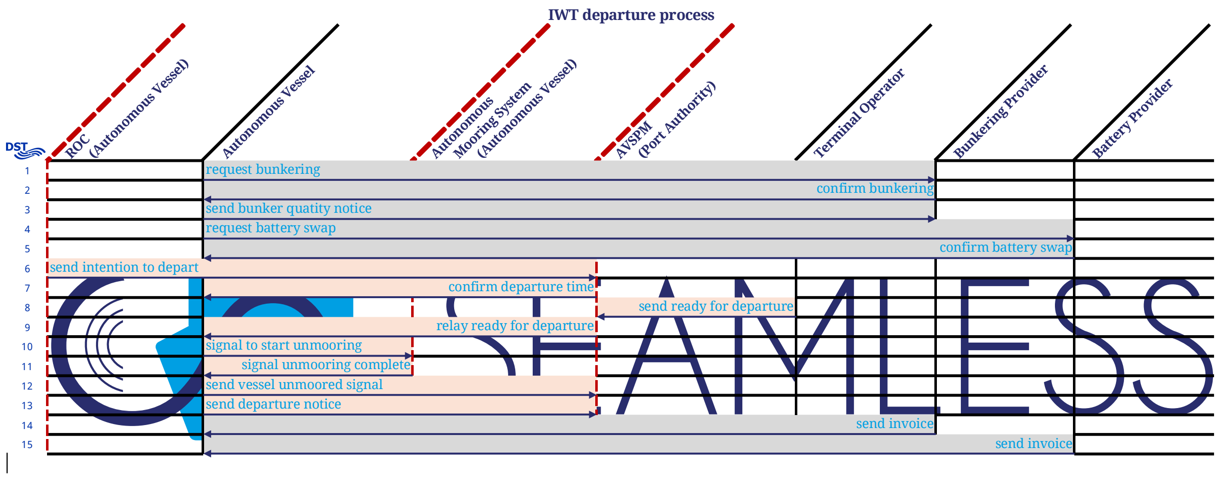


Figure 120. Communication/interaction pattern in the IWT departure sub-process (to-be)

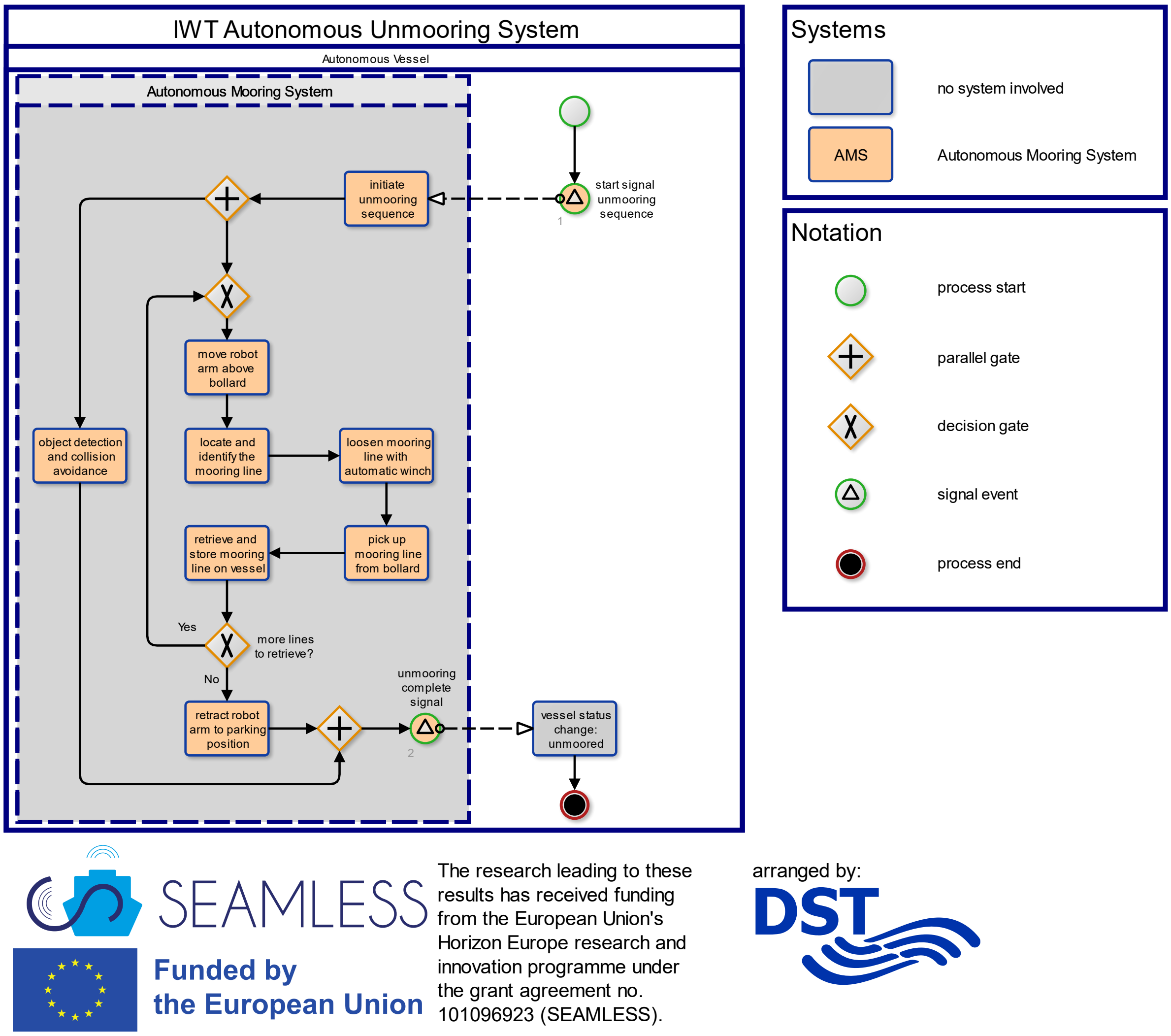


Figure 121. Logistics process flow in the autonomous unmooring (IWT) sub-sub-process (to-be)

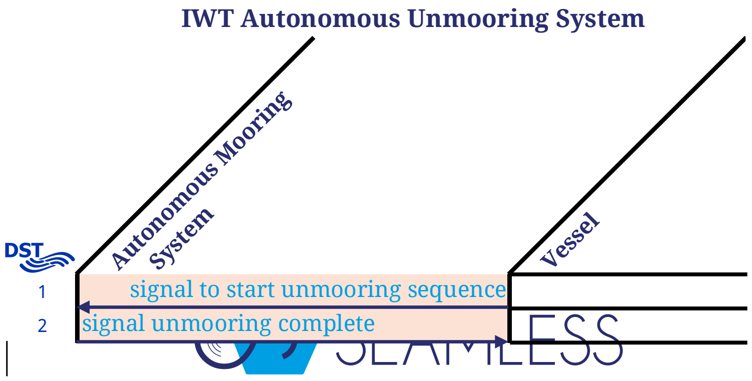


Figure 122. Communication/interaction pattern in the autonomous unmooring (IWT) sub-sub-process (to-be)

The to-be transport cargo process is highly related to the development of autonomous vessels and, thereby, a major difference to the as-is counterpart. The processes of registering with an inland waterway authority, crossing a customs border, passing a critical stretch on the inland waterway, passing an oncoming vessel, and overtaking another vessel are not illustrated in the to-be scenario as they have not been considered as core content of the SEAMLESS research project. Hence, this leaves a research gap for the operation of autonomous inland vessels. Potentially, some of these gaps will be addressed at other points within or outside the research project. However, it should already be noted that all these situations require a switch from low-attention to high-attention mode of the of the ROC operator – at least, for the time being and as long as the precise to-be process has not been defined. The process of monitoring the autonomous vessel during transit and switching between high- and low-attention mode is explained in the section about the ROC. The ROC will carry out the monitoring process instead of the inland shipping company, which has been removed from the transport cargo process. Similarly, other vessel operators and the waterway authority have also been removed from the process diagram here as they play no active role in the depicted process (due to the undefined logistics process flows). Consequently, only a potential process for the lockage procedure has been designed. It includes the ROC as the connector between the autonomous vessel and the lock operator. Therefore, the ROC will need to be operated in high-attention mode when it will take over all communication tasks. Once the vessel has switched to high-attention mode for the upcoming lockage procedure, the ROC will notify the lock operator ahead of the arrival of the vessel and adjust the vessel's course according to the lock occupancy information received from the lock operator. The vessel will perform the entry into the lock automatedly and moor inside the lock with the help of dynamic positioning. Then, the ROC will communicate with the lock operator so that the latter can start the lockage process. After the normal lock operation, the lock operator will send the leave advise to the ROC which signals the autonomous vessel to follow the leave advise, unmoor, and exit the lock. After the lock operation (or any of the other interruptions of the regular transit), the ROC will return to low-attention mode. The logistics process flow of the cargo transport sub-process can be seen in Figure 123, and the communication diagram in Figure 124.

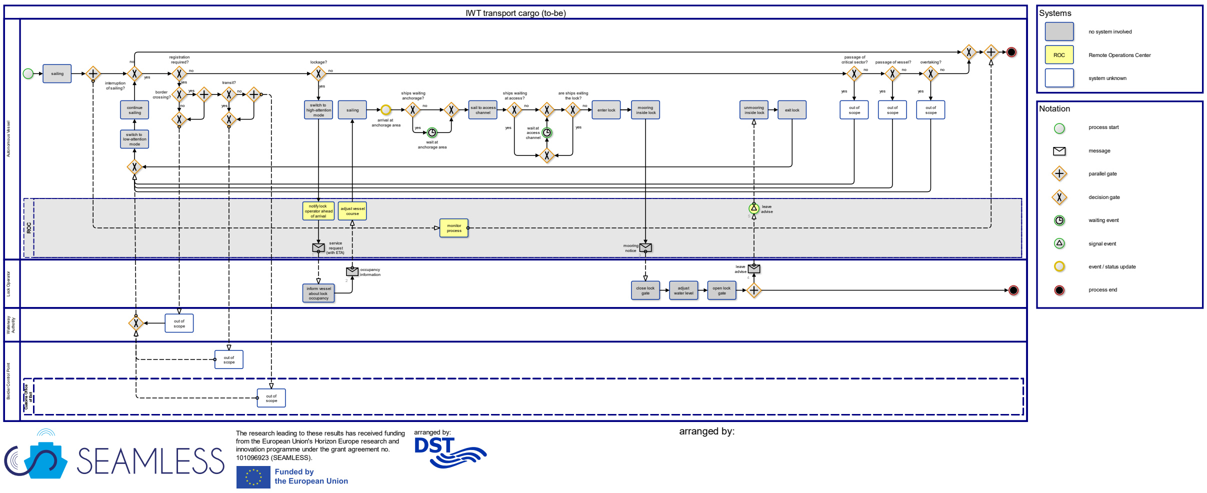


Figure 123. Logistics process flow in the IWT transport cargo sub-process (to-be)

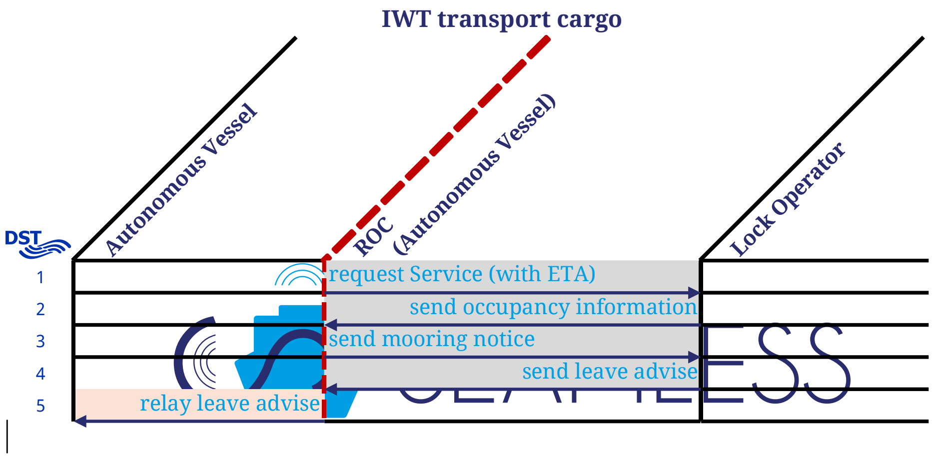


Figure 124. Communication/interaction pattern in the IWT transport cargo sub-process (to-be)

Execution phase, SSS leg sub-phase

For the fourth sub-phase of the execution phase, the SSS leg sub-phase, the same changes apply as in the previous IWT leg sub-phase as the SEAMLESS innovations address waterborne transport in total. Consequently, all SEAMLESS innovations affect the to-be SSS leg with VCOP, ROC, AVSPM, ACHS, AMoS, and ModalNET included at different points along the process.

As in the IWT leg, the responsibility for the loading and unloading operations has been moved from the terminal operator to the inland shipping company due to the ACHS. Most of the communication has been transformed to system-to-system interaction, oftentimes between the SEAMLESS innovations and other business information systems in place or among two SEAMLESS innovations. The precise transfer of transport documents again represents a gap in the logistics system architecture, while the customs process remains unchanged as in the as-is counterpart. Likewise, the process of invoicing the logistics planner by the short-sea shipping company remains unchanged as the payment is required before unloading operations can commence as part of the commercial clearance. The entire sub-phase is shown in Figure 125.

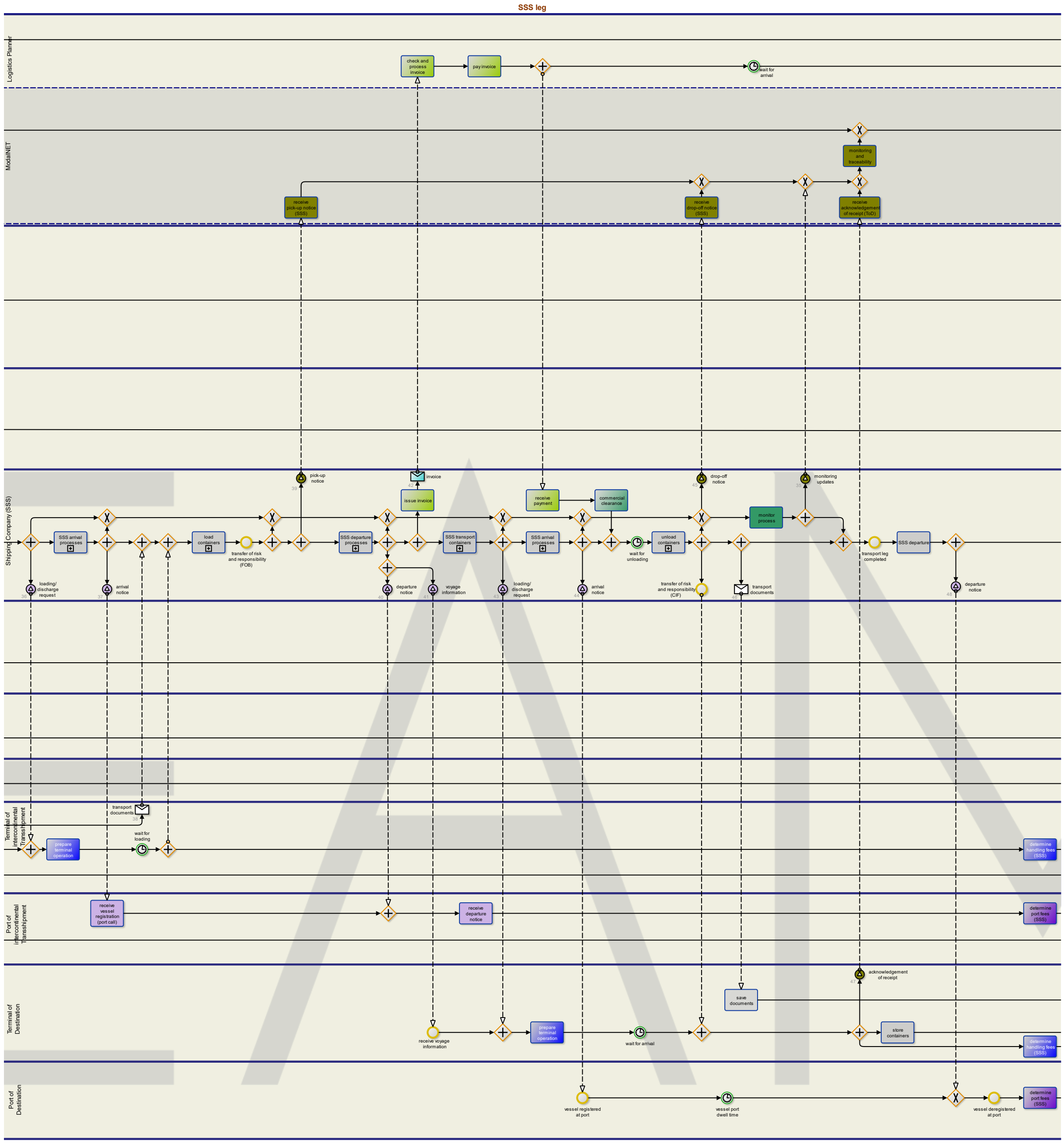
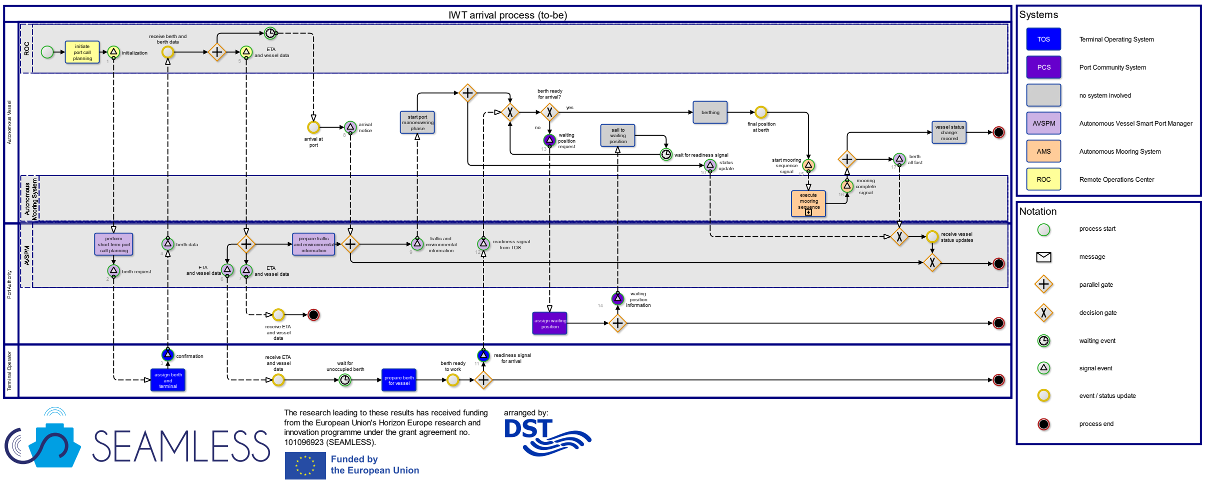


Figure 125. Logistics process flow in the SSS leg sub-phase (execution phase) (to-be)

With the adoption of the SEAMLESS innovations, the sub-processes for the IWT leg and the SSS leg have been harmonized significantly. As a result, the arrival and departure processes for SSS vessels differ very little from their IWT counterparts. The only significant change to the processes is that the SSS-based SEAMLESS Demonstration Use Case 1 involves electrically powered vessels that need to be recharged when empty, unlike the swappable battery containers in the IWT-based SEAMLESS Demonstration Use Case 2.

The departure process of the SSS vessels does not include any refuelling, recharging, or battery swap as it is assumed that the autonomous mooring system connects and disconnects a charging solution as the last or first step of the mooring sequence – in addition to the normal mooring sequence described in the section on the Autonomous Mooring System and also reflected in the mooring (see Figure 128 and Figure 129) and unmooring (see Figure 136 and Figure 137) sub-sub-processes.

Nonetheless, the above-mentioned harmonization and the switch from conventional to autonomous SSS vessels caused a change of actors involved in the process. The VTS as well as the pilotage services have been removed from the to-be versions of the arrival and departure processes as both are no longer required for autonomous vessels. A pilot on board would bring no benefit as the vessel can be provided with the necessary data to navigate through difficult stretches. The duties of the VTS are taken over by the AVSPM in the case of autonomous vessels. Still, a co-existence of VTS and AVSPM is expected as conventional and autonomous vessels need to share space in the traffic system and exchange information between the two systems. The logistics process flow of the SSS arrival process is presented in Figure 126 while Figure 127 shows the pertaining communication pattern. The logistics process flow and the interaction pattern of the SSS departure process can be found in Figure 134 and Figure 135, respectively.



The research leading to these results has received funding from the European Union's Horizon Europe research and innovation programme under the grant agreement no. 101096923 (SEAMLESS).
Funded by the European Union

Figure 126. Logistics process flow in the SSS arrival sub-process (to-be)

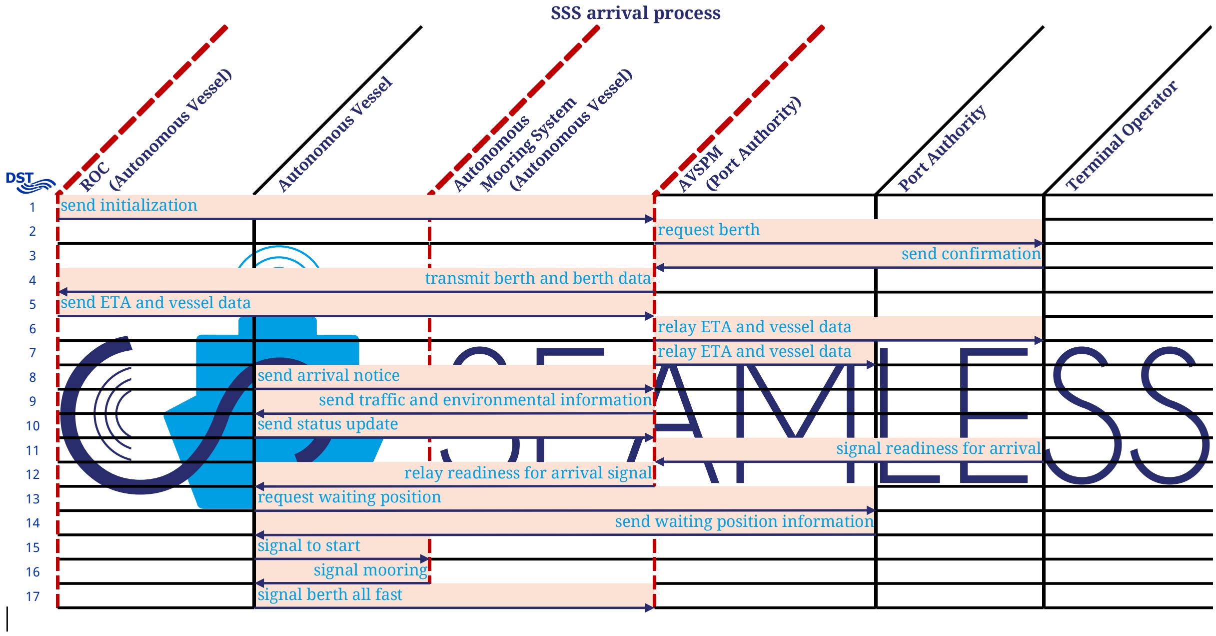
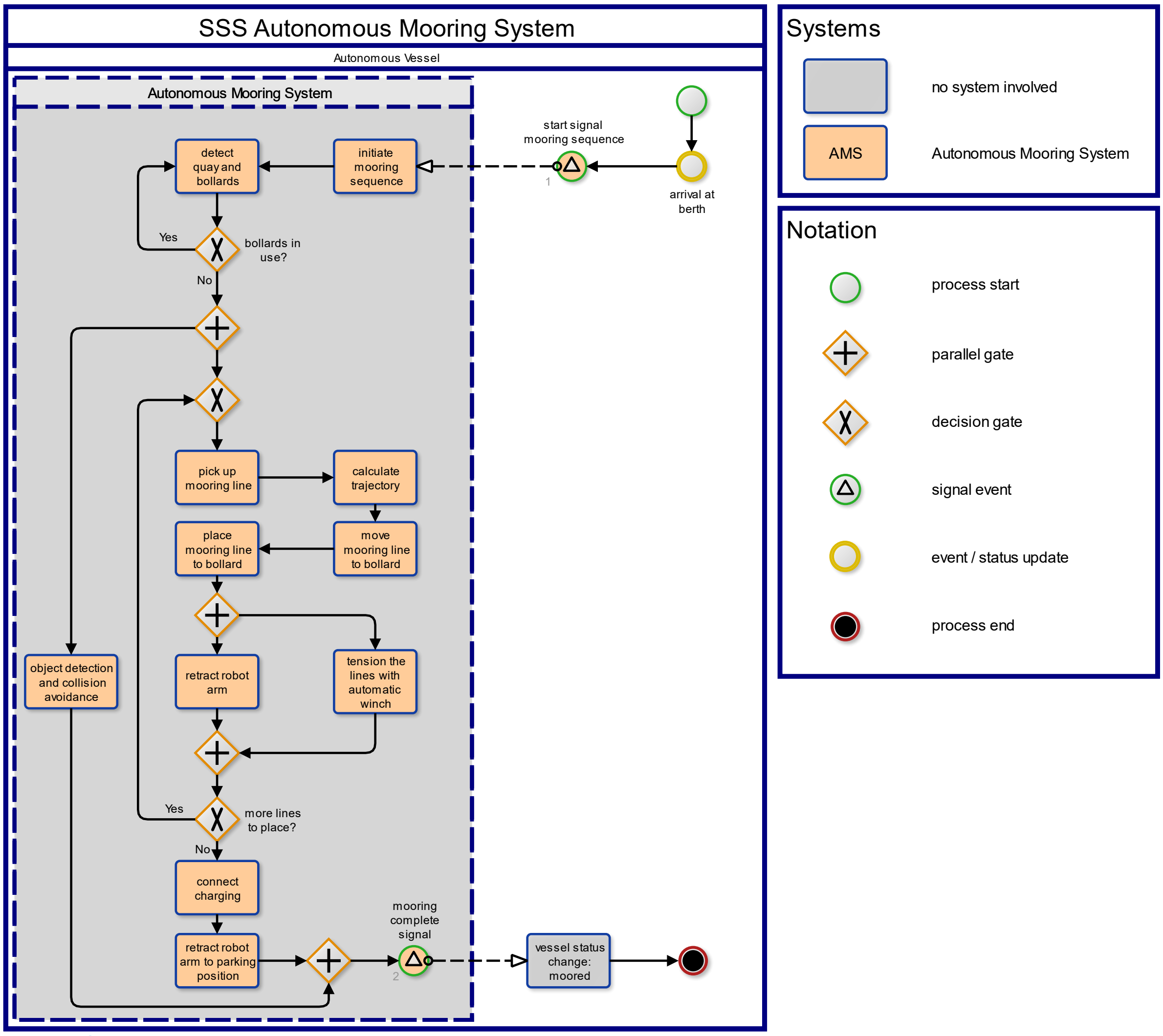


Figure 127. Communication/interaction pattern in the SSS arrival sub-process (to-be)



SEAMLESS

Funded by the European Union

The research leading to these results has received funding from the European Union's Horizon Europe research and innovation programme under the grant agreement no. 101096923 (SEAMLESS) .

arranged by:

Figure 128. Logistics process flow in the SSS autonomous mooring sub-sub-process (to-be)

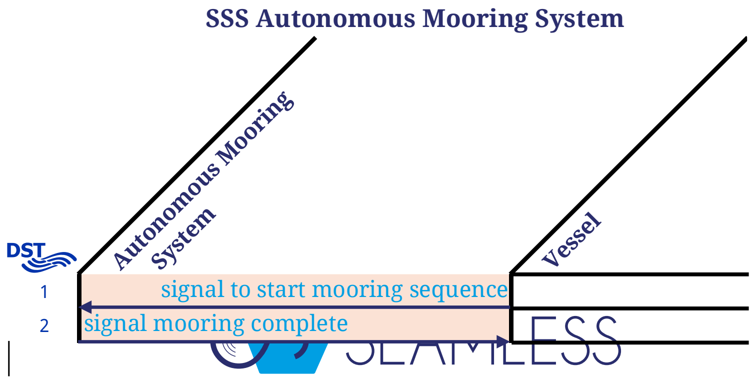


Figure 129. Communication/interaction pattern in the SSS autonomous unmooring system sub-sub-process (to-be)

For loading and unloading the process is equivalent to the IWT process as described in the section about IWT leg with the cargo handling system operating as described in the section about ACHS. The activity diagram for the vessel (un-)loading process is presented in Figure 130 with the communication diagram following in Figure 131. Next, the cargo handling process flow using the ACHS is displayed in Figure 132, while the related interaction pattern can be found in Figure 133.

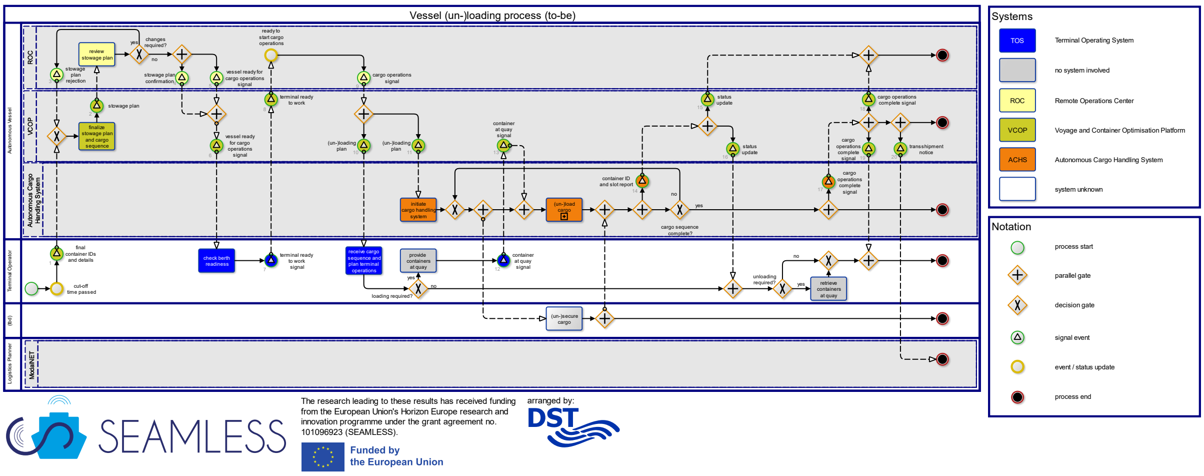


Figure 130. Logistics process flow in the vessel (un-)loading sub-process (to-be)

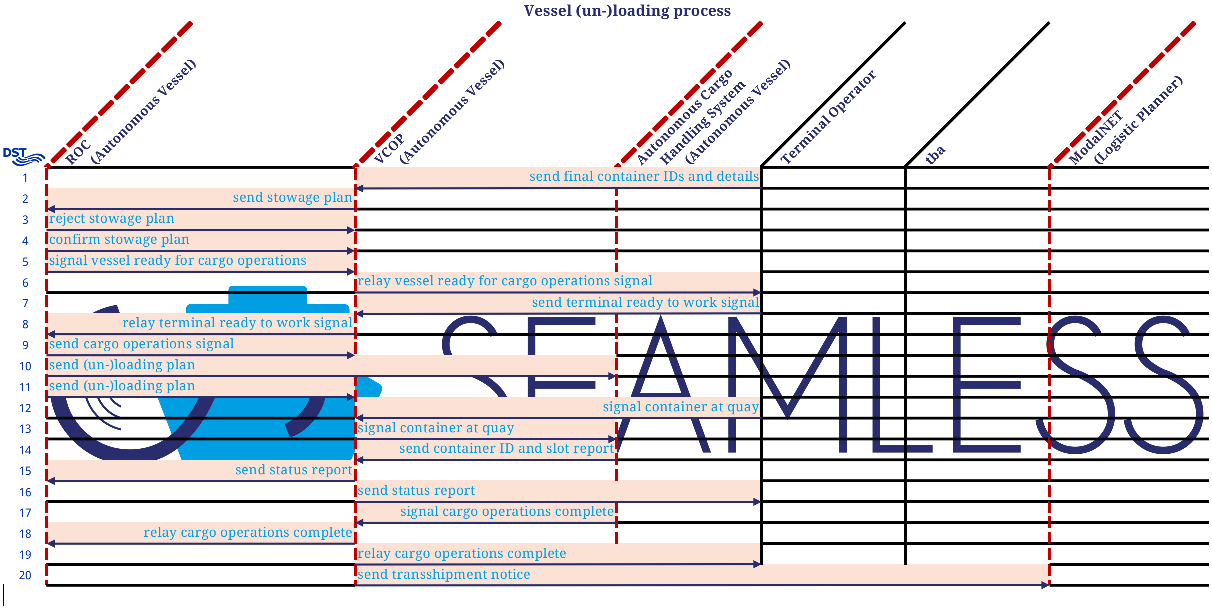


Figure 131. Communication/interaction pattern in the vessel (un-)loading sub-process (to-be)

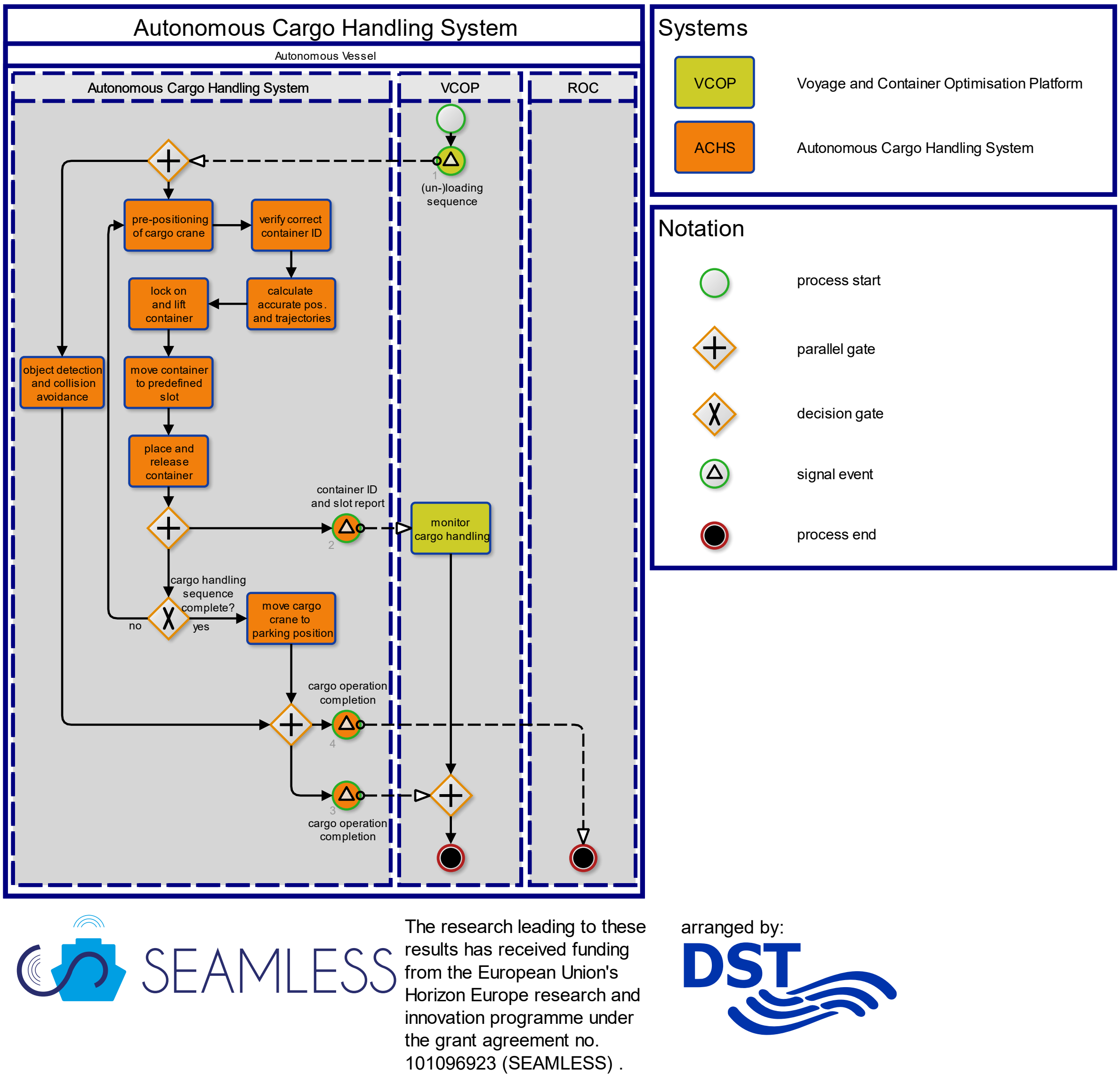


Figure 132. Logistics process flow in the autonomous cargo handling sub-sub-process (to-be)

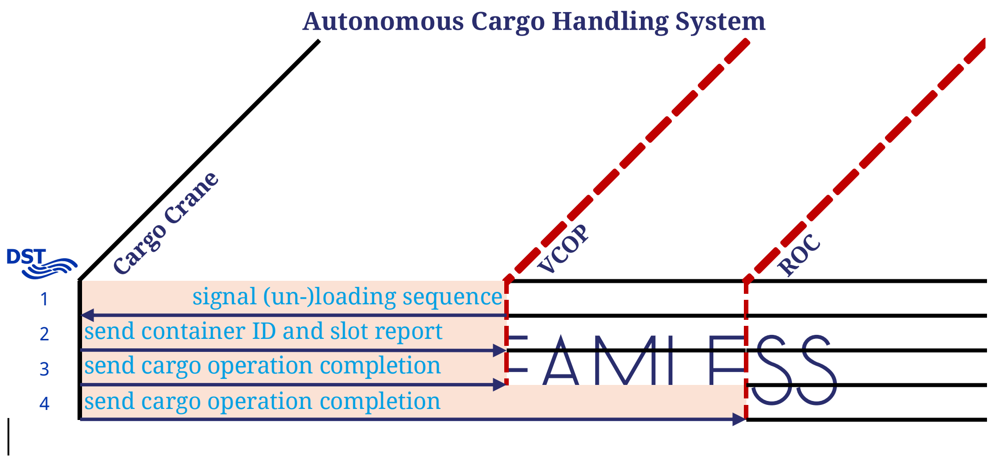


Figure 133. Communication/interaction pattern in the autonomous cargo handling sub-sub-process (to-be)

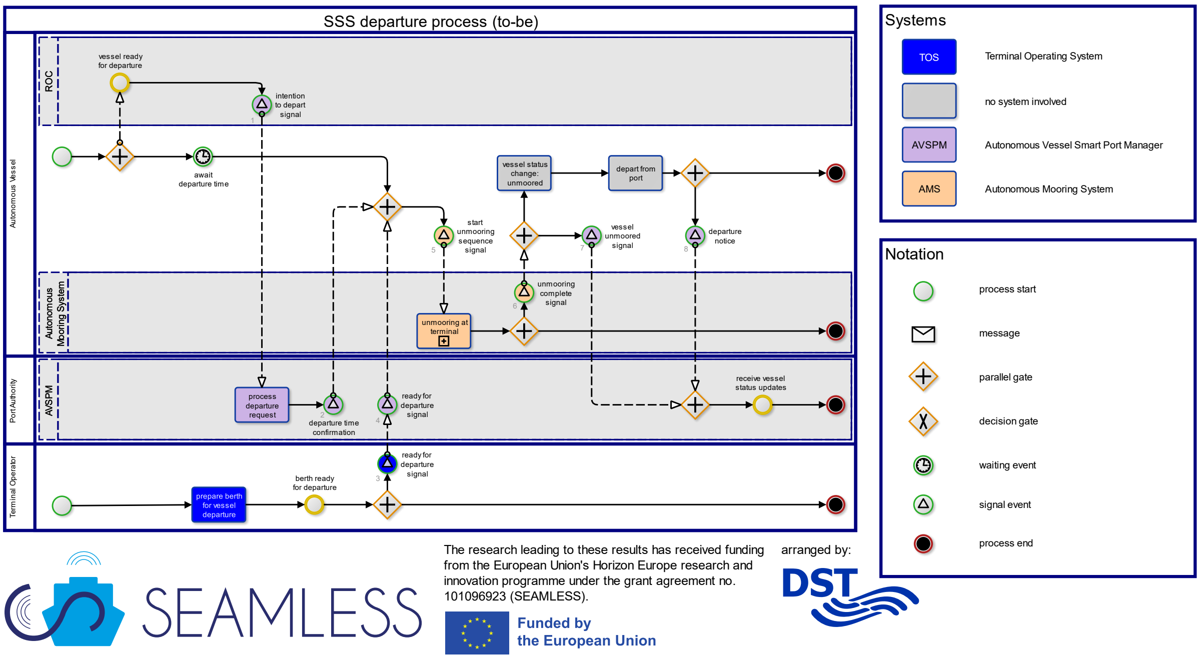


Figure 134. Logistics process flow in the SSS departure sub-process (to-be)

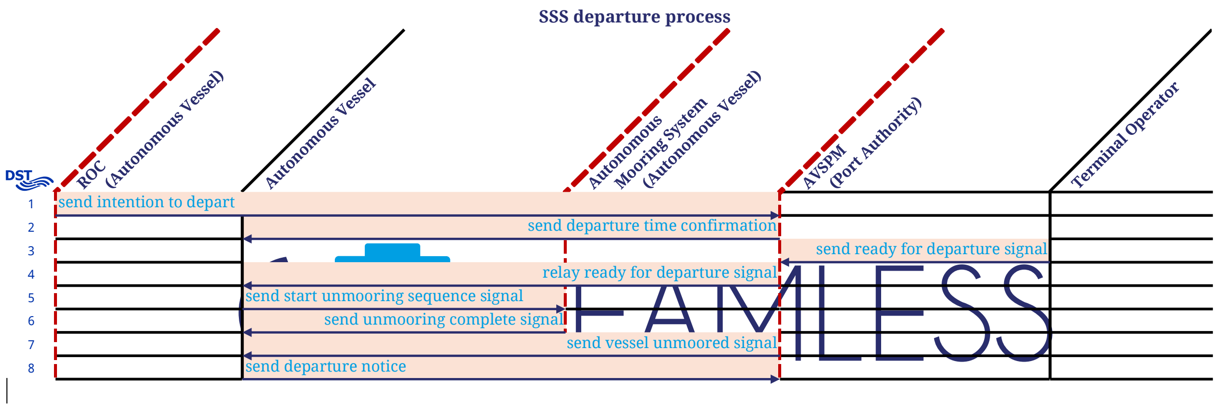


Figure 135. Communication/interaction pattern in the SSS departure sub-process (to-be)

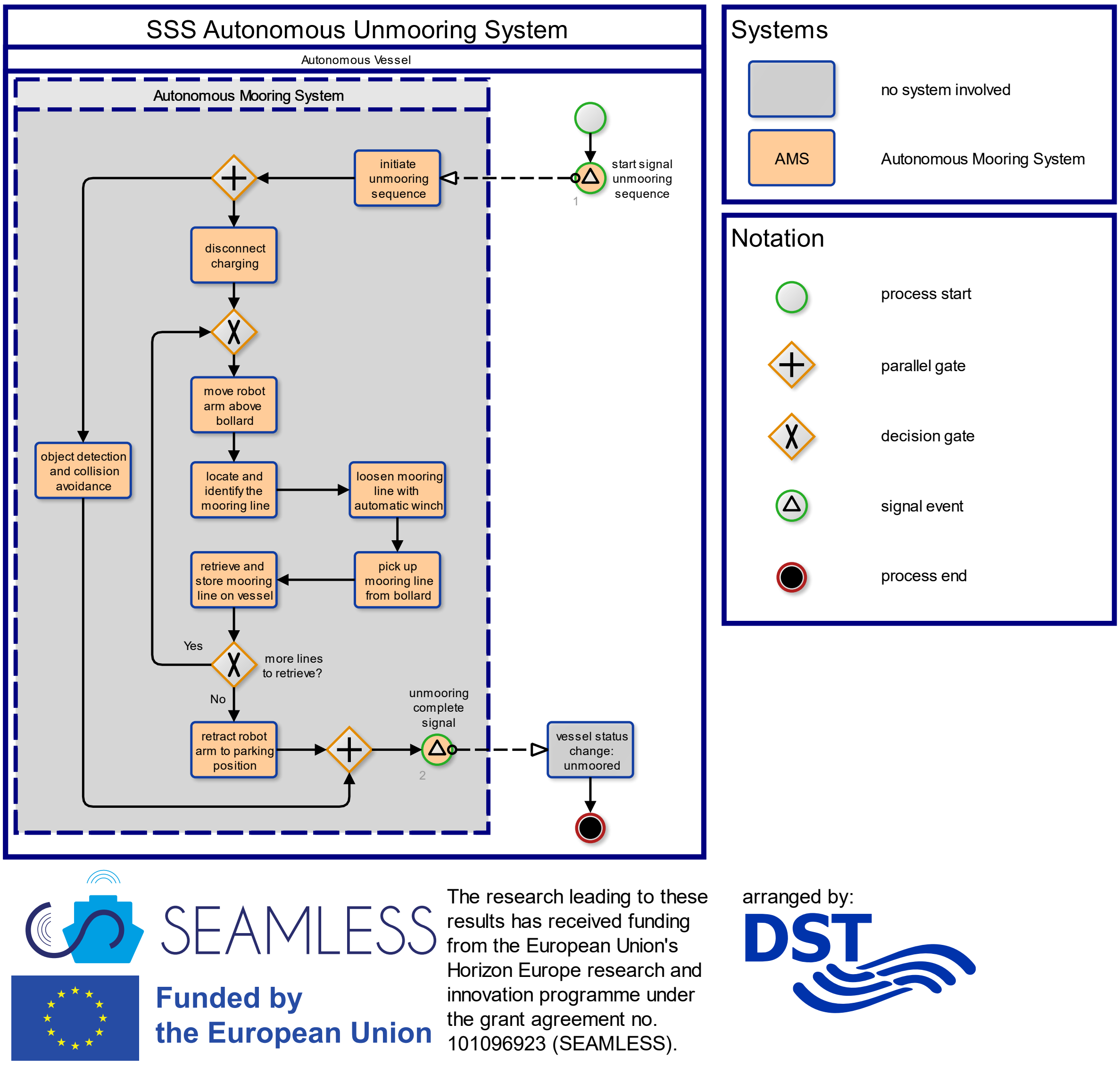


Figure 136. Logistics process flow in the SSS autonomous unmooring sub-sub-process (to-be)

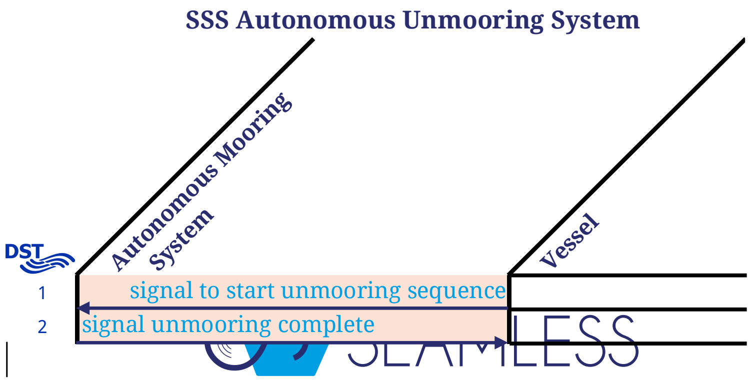


Figure 137. Communication/interaction pattern in the SSS autonomous unmooring sub-sub-process (to-be)

Many parts of the cargo transport sub-process within the SSS leg are largely out of scope as those have not been defined for autonomous vessels. As such, the process steps related to VTS, such as approaching VTS area, passing VTS reporting points, and leaving the VTS area, are not covered in this process illustration. The same is true for the process flow of a COLREG situation. Therefore, both the VTS and other vessels are removed as actors as they are not relevant to the depicted in this process description. But the same assumptions as in the IWT leg apply, so that for each situation arising, it can be assumed that the autonomous vessel will need to be monitored in high-attention mode by the ROC. The part of the SSS cargo transport sub-process that has been defined is the lockage process which will run slightly differently as the ROC will act as the intermediate entity in communication between the vessel and the lock operator. In addition, the ROC carries out the monitoring process instead of the short-sea shipping company which is why the enterprise has been removed as an actor from the process. The described logistics process flow and the related communication patterns are visible in Figure 138 and Figure 139, respectively.

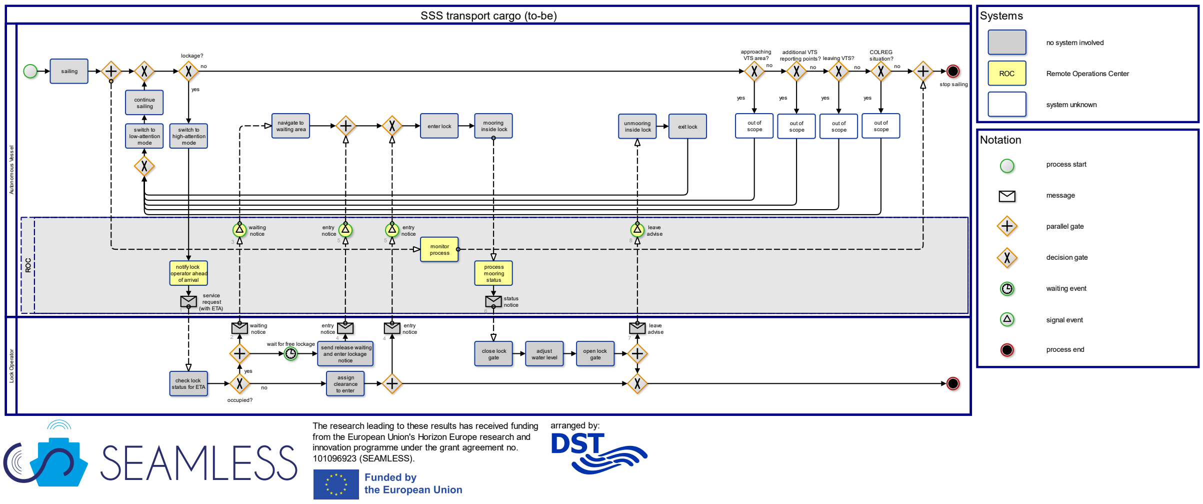


Figure 138. Logistics process flow in the SSS transport cargo sub-process (to-be)

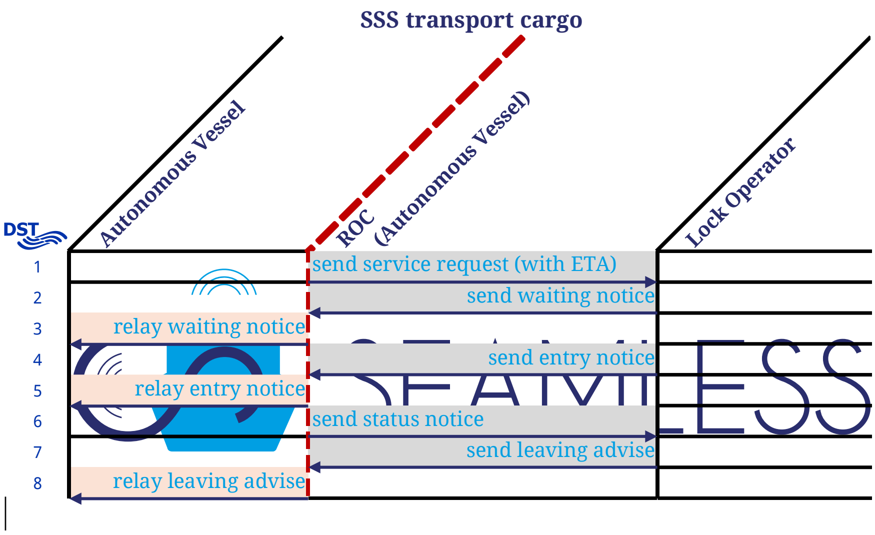


Figure 139. Communication/interaction pattern in the SSS transport cargo sub-process (to-be)

Execution phase, post-haul transport leg sub-phase

The post-haul leg sub-phase, which represents the road-based last-mile leg from the final port of disembarkation to the consignee's premises and is shown in Figure 140, is not largely affected in their operational processes. The processes of arrival of the empty truck at the port (see Figure 141 and Figure 142), loading of the truck (see Figure 143 and Figure 144), and departure of the truck (see Figure 145 and Figure 146) remain unchanged in comparison with the as-is process. However, the post-haul leg sub-phase does see a change caused by a SEAMLESS innovation as it includes ModalNET into the monitoring tasks. At the end, ModalNET will send a completion notice to both the logistics planner and the consignor or consignee, respectively, upon detecting the completion of the transport chain.

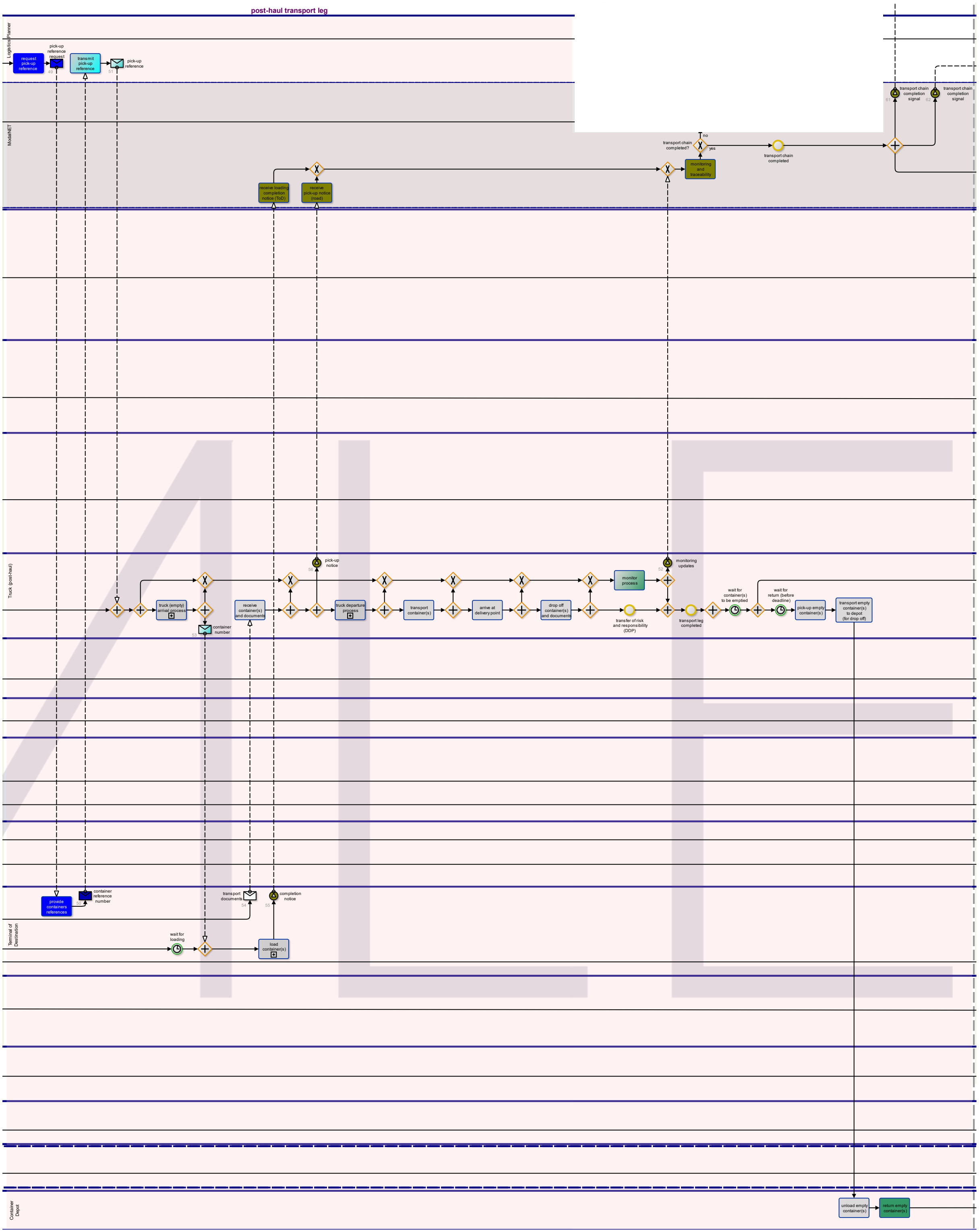


Figure 140. Logistics process flow in the post-haul transport leg sub-phase (execution phase) (to-be)

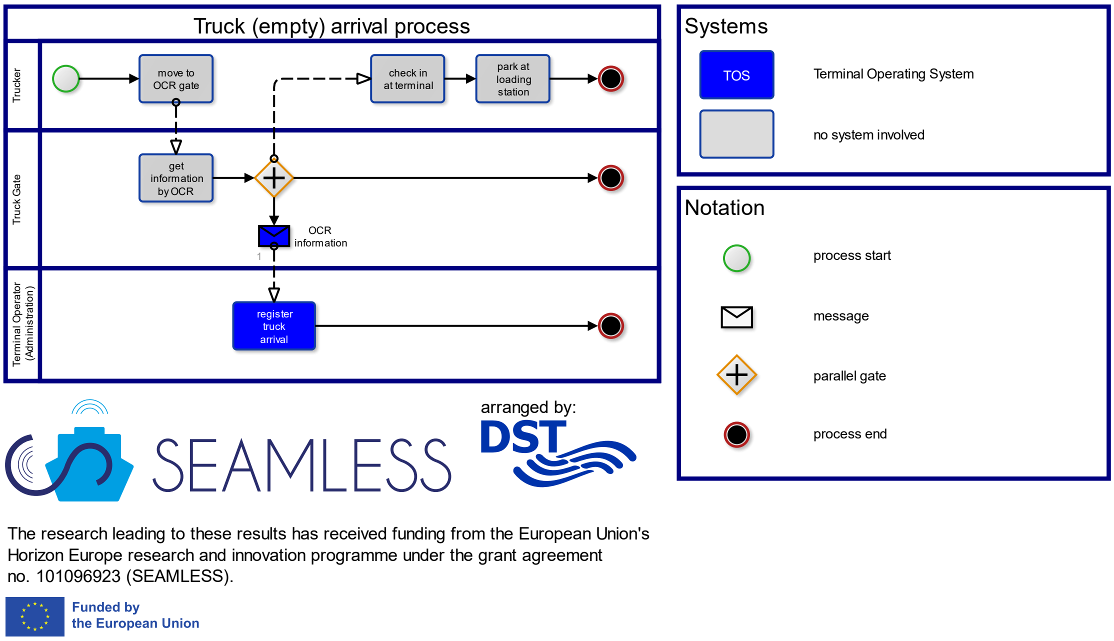


Figure 141. Logistics process flow in the empty truck arrival sub-process (to-be)

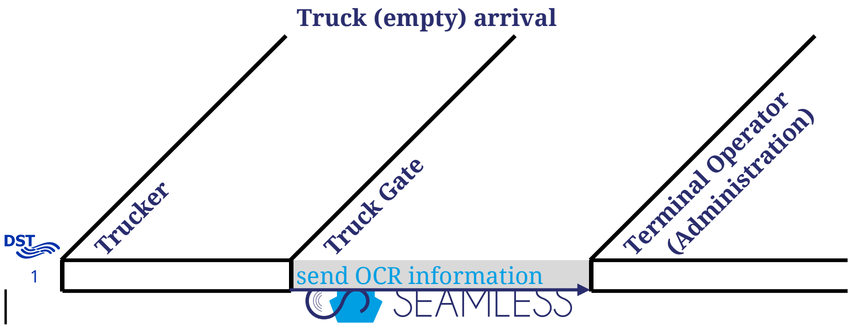


Figure 142. Communication/interaction pattern in the empty truck arrival sub-process (to-be)

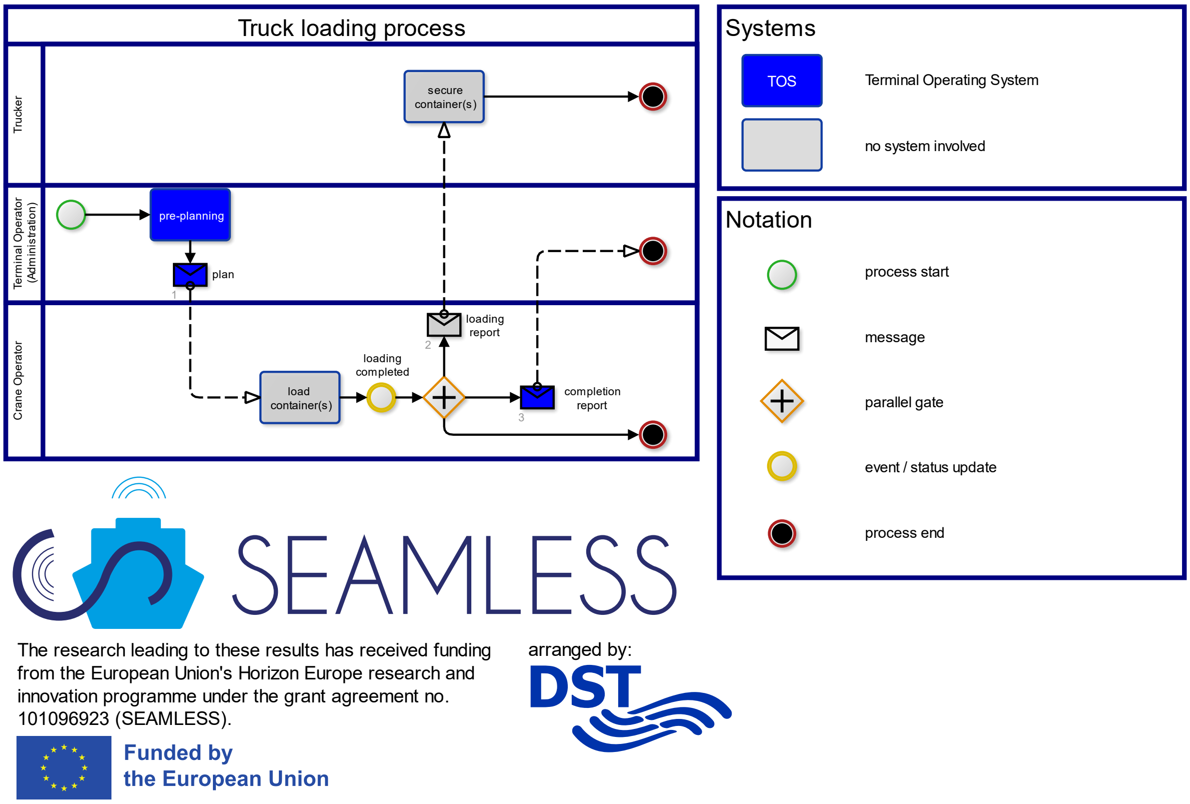


Figure 143. Logistics process flow in the truck loading sub-process (to-be)

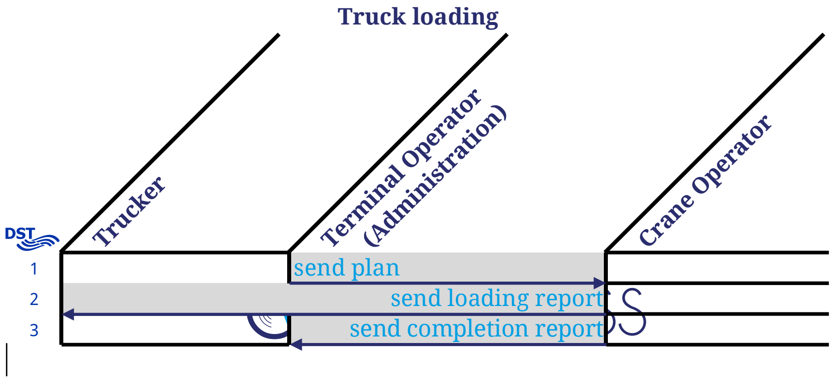


Figure 144. Communication/interaction pattern in the truck loading sub-process (to-be)

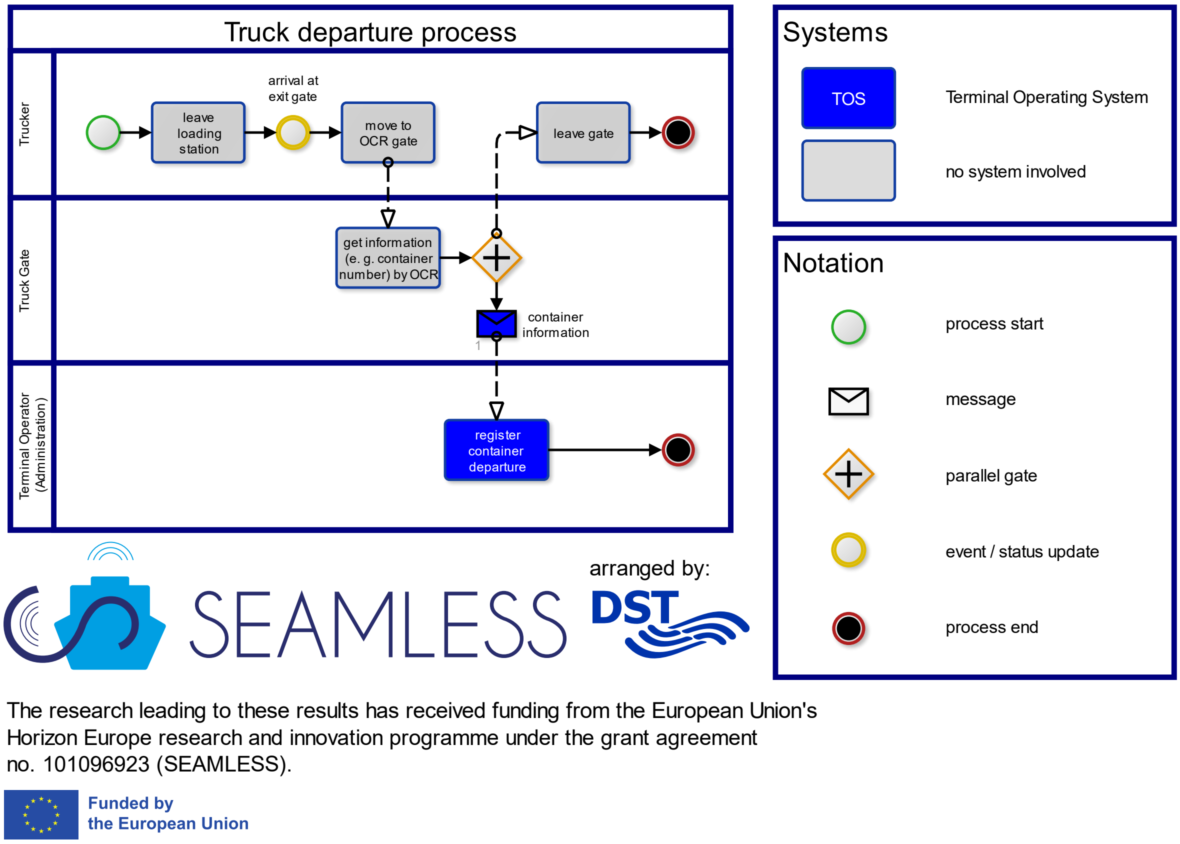


Figure 145. Logistics process flow in the truck departure sub-process (to-be)

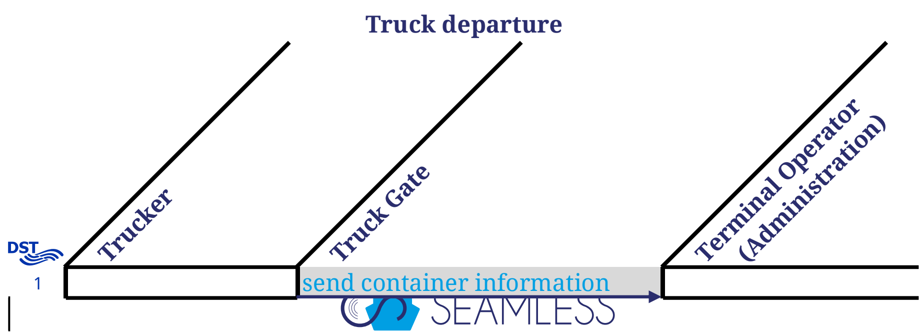


Figure 146. Communication/interaction pattern in the truck departure sub-process (to-be)

Execution phase, progress supervision sub-phase

The progress supervision sub-phase is another addition to the sub-phases of the to-be execution process. It is designed to lie transversally to the sub-phases of the four individual transport legs and involves ModalNET, the logistics planner, and the consignor or consignee, respectively. The progress supervision sub-phase includes the status reporting about the progress of the transport process at any point along the entire the transport chain. The logistics process flow of this sub-phase is displayed in Figure 147.

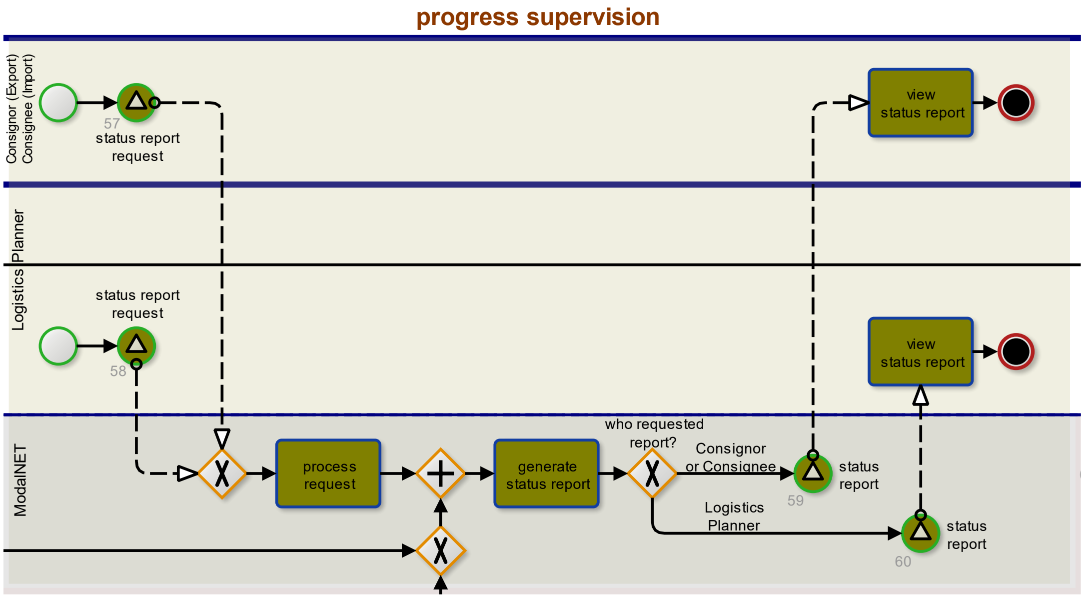


Figure 147. Logistics process flow in the progress supervision sub-phase (progress supervision phase) (to-be)

The supervision process can be initiated at any point during or even after the execution phase of the multimodal transport. Both the consignor or consignee, respectively, and the logistics planner have the option to request a status report with a reference for their transport order via ModalNET. Once either actor has sent a status report request to ModalNET, the latter will process the request and fetch the relevant updates of the requested transport or transport leg from the accompanying monitoring database in order to compile the requested status report.

Completion phase, shipment completion and invoicing sub-phase

Finally, the completion phase with the shipment completion and invoicing sub-phase concludes the multimodal transport process. Here, no major changes have been made between the as-is and to-be process as the SEAMLESS innovations do not appear in this phase. As the final determination of the handling fees due in the respective terminals is still pending, the overall logistics process flow has been left matching the as-is process, assuming that the terminals will pursue a configuration in which the loss of revenue will be covered effectively by new revenue streams. Hence, the logistics process flow of the final sub-phase includes the exact same actors as before (and as described previously in section about the shipment completion and invoicing sub-phase of the as-is process) and is illustrated in Figure 148.

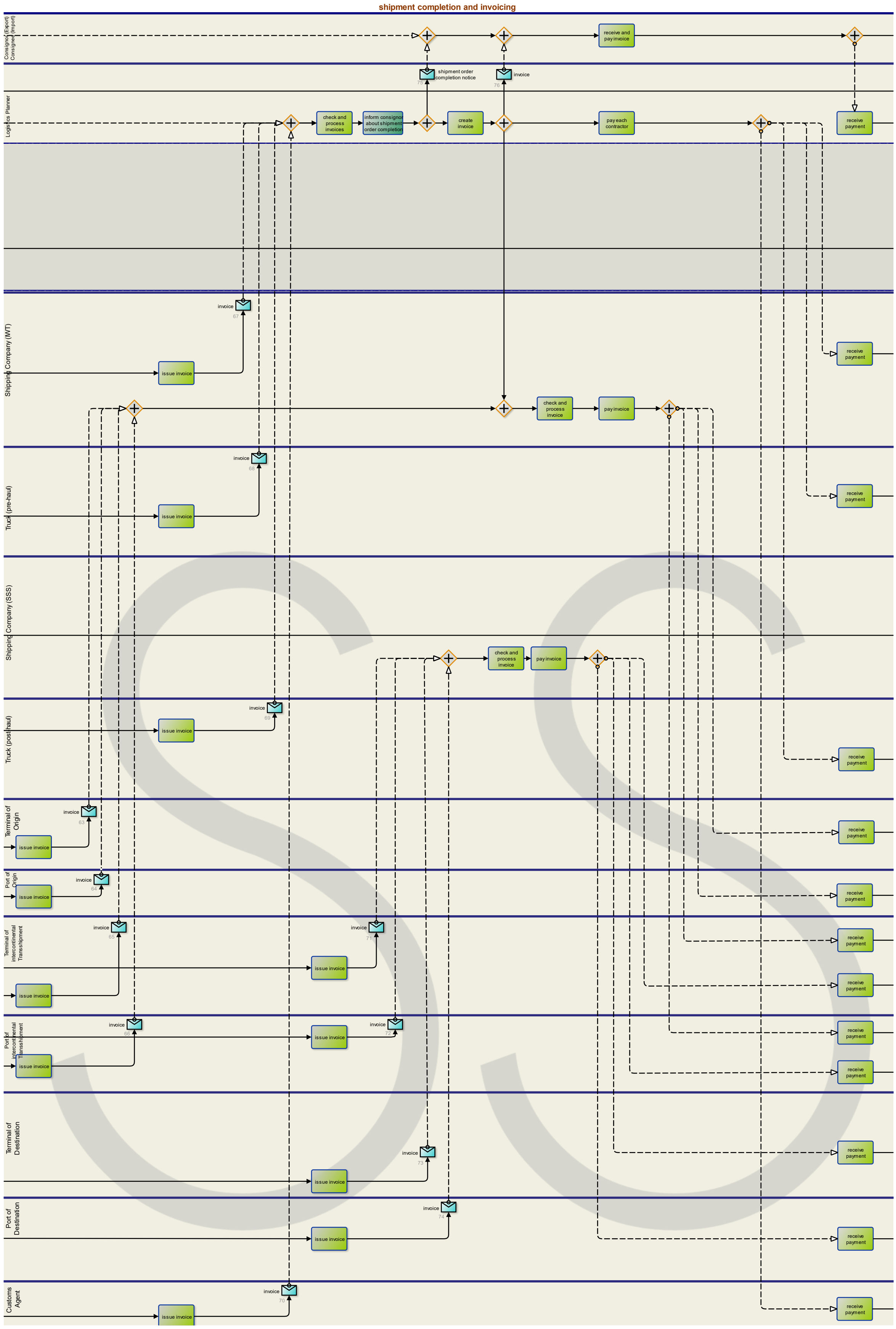


Figure 148. Logistics process flow in the shipment completion and invoicing sub-phase (completion phase) (to-be)

4.3 Administrational Procedures

4.3.1 Customs Procedures

Within the European customs landscape, a variety of digitalization and harmonisation initiatives are currently underway.

By the end of 2025, the transitional use of means other than the electronic data-processing techniques provided for in the Union Customs Code will no longer be applicable, thus finalizing the transition to fully electronic customs. From this point on, national as well as trans-national systems such as NCTS, AES and ICS2 will become fully operational (REGULATION (EU) 2019/632 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, n.d.). Also, centralised clearance (CC) of export and import (CCE/CCI) declarations will become possible, which will allow economic operators to lodge customs declarations to any customs office (and not necessarily where goods are presented) and thus streamline its internal processes. Furthermore, to ensure improved data sharing between EU customs systems and non-customs authority systems (s.a. TRACES, OD, an EU Single Window Environment for Customs (CSW-CERTEX) will be implemented from 2025 on to automate non-customs related conformity checks during customs processing.

Strategically, the EU Commission has proposed a major EU Customs Reform that may invoke dramatic changes to current customs practices. As part of this reform, the Commission plans to establish a central “EU Customs Data Hub” which will be managed by an EU Customs Authority. This hub is meant to gradually replace the existing customs systems in the EU Member States and thus serves as a single window for all EU customs declarations. By deploying advanced machine learning algorithms, it is meant to minimize human intervention within customs procedures without compromising safety, security and anti-fraud requirements. Also, a new group of “Trust and Check” trader, which represents an improved version of the current AEO concept, will be introduced and shall be able to release goods into the union without any customs intervention The Commission’s current planning foresees first e-commerce users to join the EU Data Hub by 2028 in a limited operational phase. After migration of already centralized IT systems and later on national customs systems, other traders may use the hub from 2032 on. Obligatory use of the EU data hub is foreseen from 2038 on.

The Norwegian Customs Service is currently following aligned or compatible approaches. As part of Norway’s “digitoll” concept, notifications and declarations will become mandatory in digital form from April 2025 onwards. This is planned to facilitate “Smart Border Crossings” so that customs formalities can be carried out before or after goods cross border.

For the SEAMLESS Demonstration Use Case 1, in which Ågotnes takes over the role as the maritime gateway from the port within Bergen, it is expected that customs activities will be moved there as well. Goods transported on the feeder connection between Bergen and Ågotnes will therefore already have been assigned a customs status.

4.3.2 Vessel Reporting

In section 2.5.1.2, the Safe Sea Net Norway system was presented as the so-called National Maritime Single Window of Norway, where ship operators and agents in maritime shipping can fulfil their reporting obligations electronically via a central national system. As the various authorities have access rights to this system, there is no need for duplicate reporting, which means a considerable reduction in administrational work.

However, as soon as a ship leaves the borders of an individual state and becomes active in international traffic, a separate reporting obligation continues to apply in each individual state with often very different reporting obligations between the individual countries. To further reduce the administrational burden in the EU and to simplify communication in maritime transport in the internal market, the European Maritime Single Window environment (EMSWe) was established under the underlying Regulation (EU) 2019/1239. The idea behind the EMSWe is to harmonise reporting obligations so as to ensure that the same data sets are reported in the same way for each Maritime National Single Window. The system is also intended to facilitate the exchange of information between all stakeholders in the maritime supply chain, such as port operators, ship operators and authorities.

The EMSWe is planned as decentralised environment which is based on a network of the different Maritime National Single Windows of the member states of the EU. Each member state has to ensure that the data elements of the EMSWe data set provided at departure from a port in the Union are made available to the declarant for the purpose of fulfilling the reporting obligations at arrival to the next port in the Union. The underlying principle is that the declarant needs to report only once. At the centre of the EMSWe is the SafeSeaNet system, which has been established at both the national and Union levels. The SafeSeaNet at the EMSA shall serve as central system for the data exchange between the national MNSWs. Figure 149 shows a simplified overview of the EMSWe in Europe.

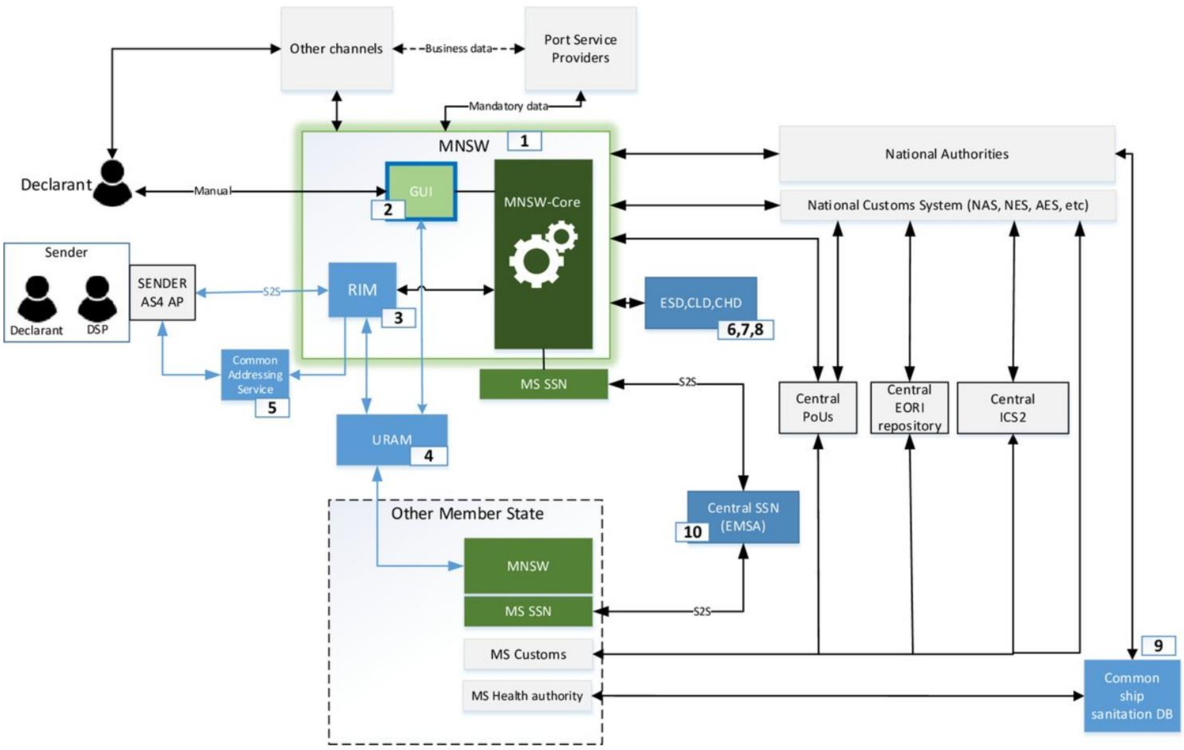


Figure 149. High-level EMSWe architecture around one maritime national single window

A harmonized reporting system within the EU is invaluable for a smooth and accurate data exchange and the EMSWe is a big step in this direction. In addition, a harmonized system like EMSWe supports the development and operation of autonomous supply chains by providing a consistent, efficient, and integrated framework for data exchange and regulatory compliance, ultimately enhancing the overall performance and reliability of the supply chain.

As the inland waterway counterpart to the EMSWe, section 2.3.1 gave a brief introduction to Electronic Reporting International (ERI). While both ERI and EMSWe aim to streamline reporting processes and enhance efficiency, EMSWe offers a more standardized and advanced framework. While ERI is purely a system for the exchange of data from vessel/operator to authority, the EMSWe is also intended for other stakeholders, e.g. port service providers like terminal operators what means a higher level of transparency and an improved data quality over the whole maritime supply chain. Since autonomous systems depend on high-quality data for decision-making, navigation, and operational efficiency, this means a huge improvement over the status quo. Here, the inland shipping sector certainly lacks behind.

4.3.3 Traffic Management and Navigational Safety

Traffic management and navigational safety in inland water shipping rely heavily on vessel-to-vessel communication, particularly on rural stretches where infrastructure for VTS is not feasible. VHF radio communication plays a pivotal role in ensuring safe navigation, reporting to port authorities, and coordinating with lock operators. Systems like APICS Barge in the port of Antwerp demonstrate how technology can enhance these interactions, although there remains a need for harmonization in procedures, especially concerning lock operations.

The provision of digital vessel reporting information, which as explained in the previous section is mandatory on some corridors but mainly used for tactical purposes by waterway authorities may be extended to more operational use cases.

Tracking of vessels may be carried out on a more detailed level, and trip information then shared with respective lock operators as well as terminal operators. Also, while the flow of information is unidirectional now, a feedback channel is needed, e. g., to pass navigational requests towards the vessel (e. g., to provide requested times of arrival at locks or berths).

The requirement for electronic and standardised information exchange rather than VHF communication is also important to allow lock and port operators with autonomous navigation systems. In general, by adopting standardized communication protocols and leveraging technological solutions, the inland water shipping industry could heavily enhance safety, efficiency, and operational coherence.

Even though the communication protocols in maritime shipping are more harmonized and standardised than in inland shipping, mainly due to its international character, also in short- and especially in deep-sea shipping you still see many inefficiencies in everyday operations. Ships travelling full steam across the world's oceans so that they can keep to their so-called berthing windows in ports, only to find that the berth is still occupied, are not uncommon. In such cases, these ships often have to wait many hours or even days at the anchorage. This practice results in unnecessary fuel consumption and increased Greenhouse-Gas (GHG) emissions.

In 2020 the IMO together with the Global Environment Facility (GEF), the United Nations Development Program (UNDP) and members of the Global Industry Alliance (GIA) introduced a Just in Time Arrival Guide for ships aiming to optimize the arrival process and by that reducing greenhouse gas emissions in the maritime industry. The JIT Arrival Guide promotes the concept of ships adjusting their speed to ensure that they arrive at their destination port when their berth is actually available and cargo operations can commence, rather than arriving early and waiting idly (GEF-UNDP-IMO GloMEEP Project and members of the GIA, 2020).

There are already coordination centres that provide ship operators with real-time information about, for example, berth availability and expected waiting times, so that unnecessary waiting times can be effectively avoided. One such entity is the HVCC (Hamburg Vessel Coordination Center) that offers the 24/7 handling of the operational coordination of ship arrivals and departures, as well as the coordination of ship rotations within the Port of Hamburg. The close collaboration with shipping companies, terminals and pilots, contributes to a better communication during the whole process from arrival to departure (*HVCC Hamburg Vessel Coordination Center*, n.d.).

In the future, systems like APICS Barge but also coordination services like the HVCC could be further optimised and made more efficient by increasing the degree of automation, transparency and data availability of the whole maritime supply chain.

The integration of autonomous ships into traffic management and VTS could be a major challenge in the future. This issue has already been touched during the discussion within the second session of the Maritime Safety Committee (MSC), Legal Committee (LEG) and Facilitation Committee (FAL) (MSC-LEG-FAL) Working Group on Maritime Autonomous Surface Ships (MASS). During the session it was acknowledged that "the interaction of MASS with Vessel Traffic Services (VTS) needs to be considered when defining an ROC" (Maritime Safety Committee, 2023, p. 6). It is important to note that the outcomes of the session are not subject to any binding resolution or regulation and can include a subjective slant of any individual members of the working group.

4.3.4 Transport Documentation

The missing obligation for authorities to accept relevant freight transport information in electronic form was identified as main reason for the lack of progress towards digital information exchange. Therefore, EU has set out to establish a framework for the digital exchange of electronic freight transport information (eFTI) between member state authorities and companies. The regulatory framework is set by the Regulation (EU) 2020/1056 of the European Parliament and of the Council, commonly known as the **eFTI-Regulation**, which entered into force on 20 August 2020.

The eFTI-Regulation establishes a legal obligation for authorities to accept all regulatory information of all transport modes made available electronically whenever economic operators are obliged (by relevant legal acts) to make information available. Although eFTI does not mandate the digitalisation of private-sector transport documents such as an electronic consignment note (eCMR), it is expected that common specifications and the acceptance of electronic information exchange by authorities will have a positive effect in developing a uniform and simplified business-to-business (B2B) electronic communication across the Union. If companies choose to make information available electronically to authorities, they must:

- Use data processed on a certified eFTI platform and, if applicable, by a certified eFTI service provider;
- Make data available in machine-readable format via an authenticated and secure connection to an eFTI platform's data source;
- When data is requested for inspection, communicate to the authorities a unique identification link to that data;
- Provide data in a human-readable format when requested by the competent authority on-site, on the operator's equipment.

For digital transport information to be exchanged securely between authorities and logistics companies, a harmonised and trustworthy ICT environment is required. One of the most important technical design principles here is that the data from companies always remain with them (“shared by source) and are only made accessible to the authorities for the specific query (via a unique identification link). Because related work is still in progress, no final statements can be given about the eFTI elements in details or the proposed systems as a whole. From publicly available information, the core concept can be described as follows:

- The eFTI-architecture consist of a "company domain" for **Economic Operators** and a "government domain" for the **Competent Authorities**. Such a company domain could belong to one company or a collaboration of companies.
- Within the "company domain" part, a company makes itself known, via an authorisation mechanism, to an **eFTI platform**. The eFTI platform can be operated by the Economic Operator itself or by an **eFTI Service Provider**, a company that offers eFTI-related services to one or more Economic Operators. Different eFTI platforms are also able to communicate with each other, in order to establish B2B communication.
- The “government domain” will include so called **eFTI-Gates** (National Access Points), which will be used by public administrations to retrieve information available within the “company domain”. These eFTI-Gates can also communicate with each other, so that the desired data can always be requested within EU Member States.

Among the system, its architecture and the exchange-rules and -mechanisms, content and structure of exchanged data needs to be defined according the following terms of the eFTI Regulation:

- A **data element** is defined as the smallest unit of information with a unique definition and precise technical characteristics. An **eFTI data subset** is a structured data set, related to one of the regulatory pieces of information being covered by the eFTI-Regulation and consists of the corresponding data elements. The **eFTI data set** is a comprehensive structured data set and can be seen as sum of all subsets, where data elements that are common in two or more subsets are included only once.
- The eFTI data set will be profiles of the UN/CEFACT Multimodal Transport Reference Data Model (MMT RDM).

The detailed elaboration of the eFTI platform and eFTI data set will be part of work by the Commission and selected experts before they can finally be adopted by the Commission in form of several implementing and delegated acts. The following table shows the actual timetable (eFTI4EU).

Table 4: eFTI Time table

Date	Activity
Aug 2020	**Entry into force Reg EU 2020/1056**
2020-2023	**Preparatory work**: DTLF, **DA** expert group, **IA** committee
Aug 2021	**Notification** by **MS** of national legislation
Feb 2024	**Adoption** • **DA** on eFTI data set & national requirements • **IA** on common rules for authorities (Adopted 19.12.2023)
Jul 2024	**Adoption** • **IA** on eFTI platforms & service providers specification
Aug 2024	**Application start date** (except for the obligation of MS authorities to accept eFTI data)
Sep 2024	**Adoption** • **DA** on rules for certification of eFTI platforms & service providers
Dec 2026	**Full Application** (start of obligation of MS authorities to accept eFTI data)
Feb 2029	**Review** • need for obligation for economic operators • interoperability with other e-enforcement systems

MS – Member States
DA – Delegated Act (Commission Regulation)
IA – Implementing Act (Commission Regulation)

Currently, the Regulation leaves economic operators free to choose whether they use the electronic or the paper-based version to submit the regulatory information. This may change in the future as the Commission has assessed possible initiatives to establish an obligation for economic operators to make regulatory information electronically available (in accordance with the 'digital by default' principle).

4.3.5 Emission Reporting

Both reporting systems discussed in section 2.3.5 offer comparable methods to report fuel consumption data as a base for calculation emissions. Corresponding data is submitted via web interfaces exclusively in a digital format. In the case of the IMO DCS, data is to be submitted via the platform Global Integrated Shipping Information System (GISIS) either by the administration of a member state or by any other organization being authorized by the member state (International Maritime Organization, n.d.-a). Data to be submitted on the EU MRV has to be submitted as *.xml-files through the electronic version of THETIS MRV (Commission Implementing Regulation (EU) 2016/1927, 2016; THETIS MRV, 2018). It is not stated explicitly, whether an API exists to transfer sensor data directly from the vessel into either GISIS or THETIS MRV. However, authorized organizations seem to offer a "system-to-system connection" to transfer all relevant data between the vessel and the portal of the authorized connection (DNV, n.d.-a, n.d.-b). Therefore, and due to the digital format only reporting it is assumed, that the relevant systems can be set up to also work with automated reporting from automated vessels.

4.4 Communication and Interaction Patterns

As in the case of the existing reference logistics system architecture, the logistics process flows and administrational procedures of the SEAMLESS Reference Logistics System Architecture are complemented with the pertaining communication and interaction patterns (see section 2.4). Again, this is of elevated significance as the information flow is of equal importance to logistics systems as the material flow. While the physical flow and the related activities are described in the multitude of activity diagrams illustrating the logistics process flows throughout the entire transport process, the communication and interaction patterns are represented with sequence diagrams showing the interaction between the different actors and stakeholders – and SEAMLESS innovations involved. With the help of these sequence diagrams, the number of messages and signals exchanged throughout the respective logistics process flows becomes visible. Next to the process view, the same system is visible in terms of interaction, presenting two different views of the very same matter thereby. While the logistics process flow in the SEAMLESS Reference Logistics System Architecture including all sub-processes and sub-sub-processes has already been described, the communication and interaction patterns of each of the processes, sub-processes and sub-sub-processes were scrutinised in order to identify and emphasize the change induced by the various SEAMLESS innovations.

Apart from the black lifelines, i. e., the parallel vertical lines representing the different actors, and the horizontal arrows with the grey shading representing the messages exchanged between any two actors, there are also red lifelines, which stand for the different SEAMLESS innovations, and arrows with a rose shading, which symbolise the signals and messages from or to a SEAMLESS innovation. As in the preceding cases, the messages are shown in the order of occurrence.

While the logistics process flow of the transport planning layer is shown in Figure 150 with its five sub-phases, the related communication and interaction pattern can be seen in Figure 151. The messages exchanged in the planning initiation sub-phase are represented in lines 1 to 5 and the ones of the transport chain planning in 6 to 41. More precisely, after initiating the transport chain planning (line 6), the SSS leg planning is visible from line 7 to 20, followed by the IWT leg planning from line 21 to 34, the pre-haul leg planning in lines 35 and 36, and the post-haul leg planning in lines 37 and 38. Then, after another message related to the entire transport chain planning phase (line 39), the planning of the individual legs of IWT (line 40) and SSS (line 41) is completed. Next, the SSS leg planning amendments are visible in line 42, the customs preparation from line 43 to 46, and the planning completion from line 47 to 52. The messages displayed Figure 150 feature an ID which again serves as a key to the exact position of that message within the sequence diagram in Figure 151.

It is obvious that the formerly grey-shaded arrows have turned rose. The diagram shows a clear dominance of rose colour which means that the SEAMLESS innovations are centrally involved in the planning process steps. The traditional actors are still involved though – albeit in the initiation sub-phase and the sub-phases subsequent to the transport chain planning only.

Next, the central entity sending and receiving messages is ModalNET. In the current (as-is) configuration, it is the logistics planner who takes over the central role and coordinates the individual planning routines and, thereby, composes the multimodal transport chain. In the SEAMLESS Reference

Logistics System Architecture, this is a role taken over by ModalNET which will also conduct all planning and booking routines at once as opposed to the sequential approach nowadays. Thereby, the burden ion the logistics planner is much alleviated.

In addition, the number of participants sending and receiving messages has increased as the SEAMLESS innovations are represented as individual entities belonging to a particular actor in the project. It has to be noted though that some of the innovations are represented more than once as each instance belongs to another actor in the SEAMLESS Logistics System.

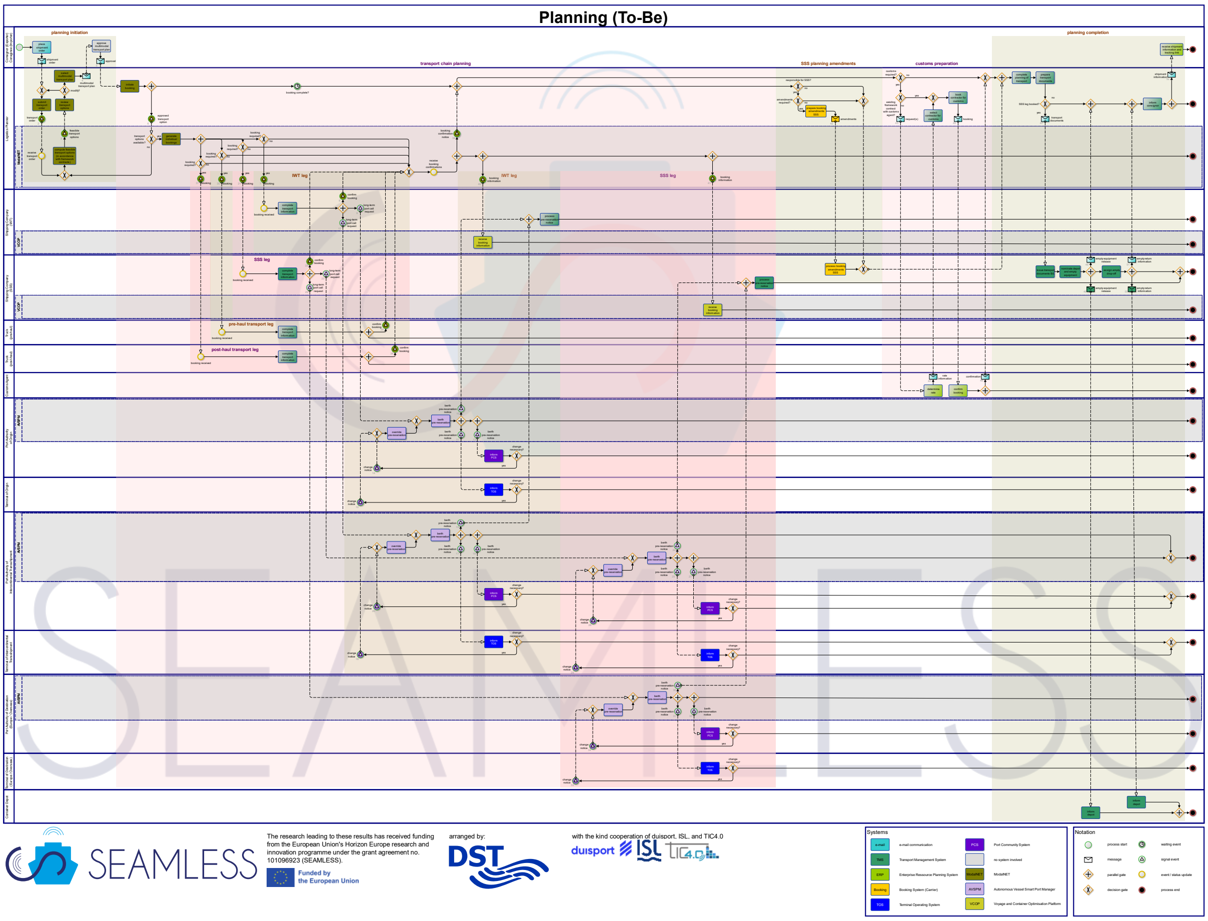


Figure 150. Logistics process flow (including sub-phases) in the transport planning layer (to-be)

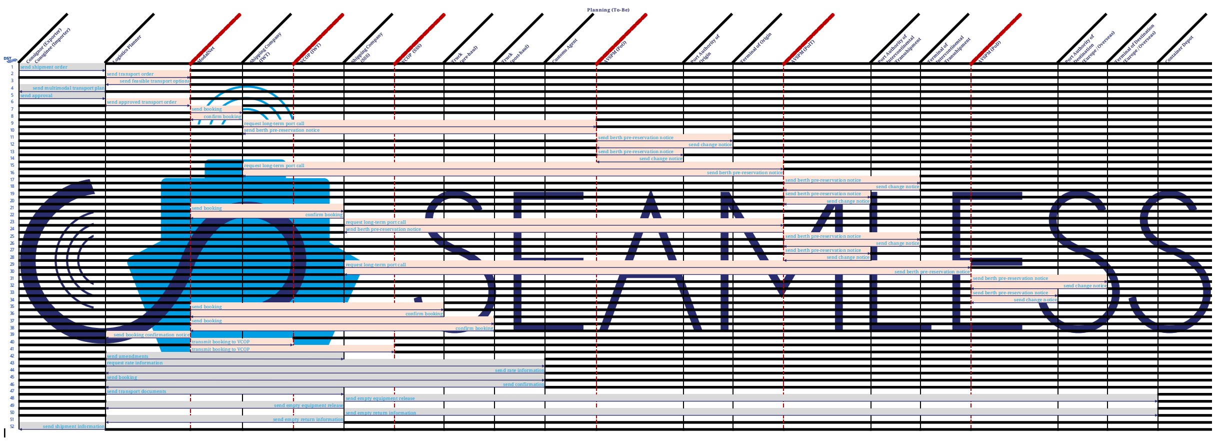


Figure 151. Communication/interaction pattern in the transport planning layer (to-be)

For the phases of the transport execution layer, Figure 152 shows the logistics process flow in the execution and completion phases encompassing seven different sub-phases. Correspondingly, Figure 153 shows the related communication and interaction diagram. In the sequence diagram, the different sub-phases can be tracked as the shipment preparation sub- phase is represented from line 1 to 12 whereas pre-haul transport leg is shown in line 13 to 15. The IWT leg is next and can be found in the lines from 16 to 34, while SSS leg is described in the lines 35 to 48. Messages from the post-haul leg is visible from line 49 to 56 and from 61 to 52. Situated in between and positioned transversally to the entire actual execution process, the progress supervision sub-phase can be found in line 57 to 60. The shipment completion has brought up many different, mainly invoice-relevant messages which can be seen in Figure 153 from line 63 to 76.

With respect to the communication and interaction pattern, the dominance of the rose colour holds true for the transport execution layer as much as for the preceding transport planning layer. The SEAMLESS innovations are directly involved in the execution phases and influence the operations immediately.

As in the current system architecture, the prominent position of the logistics planner is downgraded in favour of the individual carriers, particularly the waterborne transport service providers. Depending on the transport leg, the respective carrier is the central entity communicating with several fellow actors involved and coordinating the progress of the transport process. By combining the sequence diagram with the activity diagram, it becomes clear that although it is the shipping companies who take the leading role in the execution sub-phases, the tool used to manage and coordinate the processes and roles is ModalNET. So, the SEAMLESS innovation takes a pivotal position in the system architecture, being the central assistance system in the planning tasks of the logistics planner and - simultaneously – the main coordination systems for the execution task of the individual carriers and service providers. The logistics planner merely takes a supervisory role during the physical transport but is highly involved in shipment preparation, progress supervision, and shipping completion and invoicing.

It is to be noted that other SEAMLESS innovations do play an important role in the SEAMLESS Reference Logistics System Architecture but rather in the various sub-processes than in the main logistics process flow shown in Figure 152. This holds particularly true for AVSPM and VCOP but is also applicable to ROC, ACHS, and the AMoS system.

As in the case of the current reference logistics system architecture, the communication and interaction patterns of each of the multiple sub-processes of both the transport planning and the transport execution layer can be seen in the various sections on different logistics process flows, positioned closely to those. In most of the cases, the communication and interaction diagrams represent small and self-contained processes and sub-processes and, thus, feature a few interactions only.

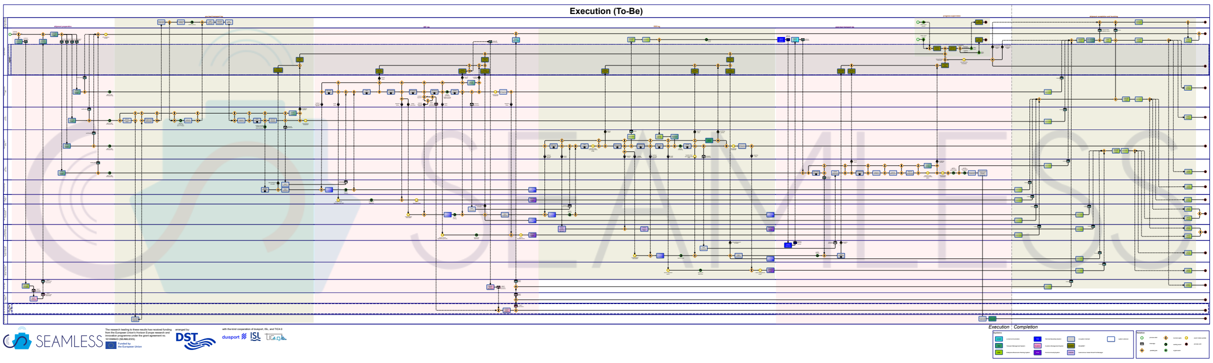


Figure 152. Logistics process flow (including sub-phases) in the transport execution layer (to-be)

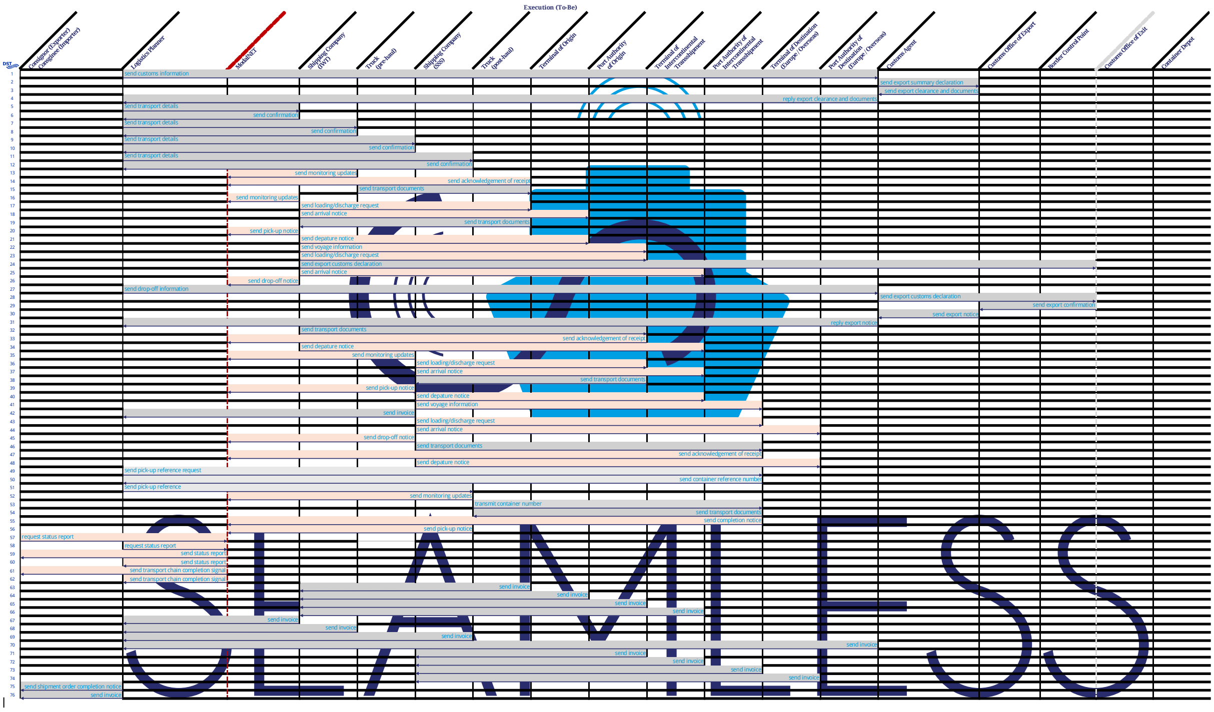


Figure 153. Communication/interaction pattern in the transport execution layer (to-be)

Eventually, a look at the business information systems involved reveals a significantly larger number of systems involved and some modifications of their respective involvement in the different phases and sub-phases (see Table 5). The role of e-mails has diminished whereas ModalNET is present in (nearly) all planning sub-phases and throughout all four transport legs. It takes a central role in co-ordinating and monitoring the progress in each phase and collects the data and information required to initiate the subsequent steps and to monitor monitors compliance with the service levels and quality objectives of a transport process. The PCS is involved in many processes because it is directly linked to AVSPM which again is involved both in the planning phase (for long-term port call planning purposes) and the execution phase. Even VCOP appears in the planning phase as it is directly linked to AVSPM as well.

Table 5. Systems involved in the transport planning and execution layers (to-be)

Variant	Part	Phase	Sub-phase	Subprocess	E-Mail	ERP	TMS	Booking	TOS	IWMS	Customs	PCS	VTS	(none)	ModalNET	AVSPM	AutoMoor	AutoCH	ROC	VCOP
To-Be					X		X	X	X			X			X	X				X
	Customs				X	X					X			X						
	Planning				X		X	X	X			X			X	X				X
		planning initiation			X									X	X					
		transport chain planning					X		X			X		X	X	X				X
			SSS leg				X		X			X			X					X
			IWT leg				X		X			X		X	X					X
			pre-haul transport leg				X							X						
			post-haul transport leg				X							X						
		SSS planning amendments						X												
		customs preparation			X	X	X													
		planning completion			X	X	X													
	Execution																			
		shipment preparation			X	X	X				X			X						
		pre-haul transport leg					X							X	X					
			truck arrival process	Truck arrival process					X					X						
			unload container(s)	truck unloading process					X					X						
		IWT leg					X		X		X	X		X	X	X				
			IWT arrival process						X			X		X		X	X		X	
			IWT arrival process	Autonomous Mooring System										X			X			
			load containers						X					X	X			X	X	X
			load containers	Autonomous Cargo Handling System														X	X	X
			IWT departure processes		X	X	X		X			X		X		X	X		X	
			IWT departure processes	Autonomous Unmooring System										X			X			
			IWT transport containers											X					X	
			IWT arrival process						X			X		X		X	X		X	
			IWT arrival process	Autonomous Mooring System										X			X			
			unload containers						X					X	X			X	X	X
			unload containers	Autonomous Cargo Handling System														X	X	X
		SSS leg			X	X	X		X			X		X	X	X				
			SSS arrival process						X			X		X		X	X		X	
			SSS arrival process	Autonomous Mooring System										X			X			
			load containers						X					X	X			X	X	X
			load containers	Autonomous Cargo Handling System														X	X	X
			SSS departure process						X					X		X	X			
			SSS departure process	Autonomous Unmooring System										X			X			
			SSS transport containers											X					X	
			SSS arrival process						X			X		X		X	X		X	
			SSS arrival process	Autonomous Mooring System										X			X			
			unload containers						X					X	X			X	X	X
			unload containers	Autonomous Cargo Handling System														X	X	X
		post-haul transport leg			X		X		X					X	X					
			truck (empty) arrival process						X					X						
			load container(s)						X					X						
			truck departure process						X					X						
		progress supervision													X					
		shipment completion and invoicing			X	X	X													

On the execution layer, the roles of e-mails, TMS and ERP systems have further diminished whereas the TOS of the terminals involved remain central to the entire multimodal transport process. When looking closer at the individual sub-phases, it becomes clear that ModalNET provides support to the transport execution throughout the process. Little surprisingly, the ACHS, AMoS system, AVSPM, ROC, and VCOP appear in the two waterborne transport legs only.

It is unclear which particular role dedicated systems like the IWMS and the Customs Procedure Management System will play in the future. Despite their role in the current reference logistics system architecture, their new role in the SEAMLESS counterpart has not been defined finally.

4.5 SEAMLESS Demonstration Use Cases

4.5.1 Demonstration Use Case 1

The SEAMLESS Demonstration Use Case 1 pursues the vision of **automated regional freight feeder loop services** distributing the cargo delivered to the port of Ågotnes on ocean-going and short-sea shipping vessels to the surrounding ports of the region including the port of Bergen. Instead of trucks distributing the arriving cargo on the road, automated vessels are supposed to take over the distribution job and, thereby, offer a 24/7 waterborne freight feeder loop service in the region. This automated regional freight feeder loop is expected to manage cargo flows from the main hub for maritime cargo within the region, which is expected to shift from Bergen to Ågotnes, use dedicated vessels for serving one or several transshipment points in the fjord, and helps to reduce congestion on the roads of the region. Originating from the vision, the SEAMLESS Reference Process Architecture is to be broken down for DUC 1 and to offer a focused to-be reference process of the domestic short-sea shipping case. This focused to-be reference process is expected help realise the above-mentioned vision of an automated regional freight feeder loop and guide the related technical development as well as the organisational and regulatory adaptation effectively.

With respect to the planning layer of the domestic short-sea shipping case (see Figure 154), the planning layer exhibits its main changes following the introduction of ModalNET as an actor and tool involved in the planning steps and the parallelisation of the leg bookings provided by ModalNET, which is used during the planning initiation sub-phase to generate transport chain options for the logistics planner instead of carrying out individual planning and booking processes manually. The next transport legs, i. e., the SSS leg, the post-haul leg, and possibly the pre-haul leg, are consolidated in one joint transport chain planning sub-phase and are booked with the help of ModalNET at once. Within the individual planning sub-sub-phases, new steps have emerged with the long-term port call planning conducted through AVSPM in order to pre-register the vessel at the terminals and ports that it is supposed to call. Similarly, the booking information is also provided to the VCOP of the short-sea shipping company for stowage planning purposes. Due to this consolidation of the individual leg bookings, the sub-phase of SSS planning amendments has been moved to a later rank in the sequence, i. e., after all leg bookings have been completed. The planning completion sub-phase remains unchanged.

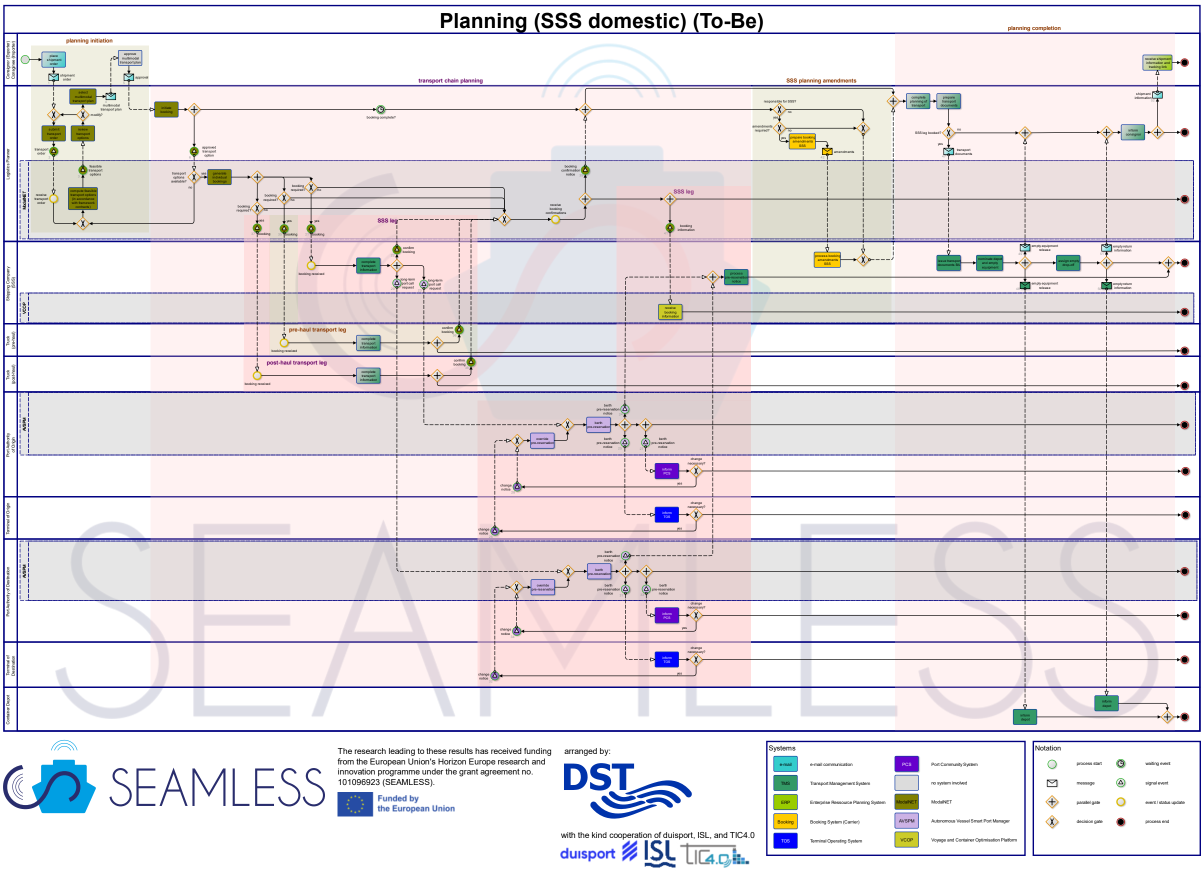


Figure 154. Planning layer of the Logistics Reference System Architecture of the domestic short-sea shipping case (to-be)

The first sub-phase in the execution phase of the domestic short-sea shipping case, the shipment preparation sub-phase, is mostly identical to its as-is counterpart (see Figure 155). Merely the customs preparation steps and preparatory steps for the IWT leg have been eliminated. Here, the transport-related documents and further information are handed over to the transport service providers involved. Afterwards, the process flow exhibits the same changes as presented in the reference process case: the monitoring and traceability task is handled by ModalNET for all actors, and the information exchange between the actors is mainly based on system-to-system interaction of the

SEAMLESS innovations and further systems in place, replacing conventional forms of communication like e-mails and phone calls. In some cases, this leads to new interactions as some messages and signals are sent directly to ModalNET instead of notifying an intermediate party like the logistics planner. With respect to the transport legs, the waterborne main leg using the short-sea shipping vessel is surrounded by two road-based legs to and from the ports. Analogously to the changes presented as part of the SEAMLESS Reference Logistics System Architecture and the individual sub-processes, the same changes that were described for the sub-processes (as described in section 4.2.3) are true for the domestic short-sea shipping case. This includes the arrival and departure processes of the short-sea shipping vessel (including the interaction with the shoreside), the transit phases of the vessel, and the cargo handling processes in the ports. The responsibility for cargo loading and unloading is transferred from the terminal operating a shoreside crane to the vessel operator using an automated on-board cargo handling system. Similarly, a large portion of the communication is covered by signals used for the interaction with ModalNET, while the communication with the port authority runs via AVSPM only. As part of the integration of ModalNET, the progress supervision sub-phase is added here as well. Finally, the completion and invoicing sub-phase remains unaltered by the SEAMLESS innovations.

A complete walk-through of the domestic short-sea shipping case can be found in Annex B. As it is underlying base for the SEAMLESS Demonstration Use Case 1, it foots on the SEAMLESS Reference Logistics System Architecture and serves as the reference process for vision of an automated regional freight feeder loop service.

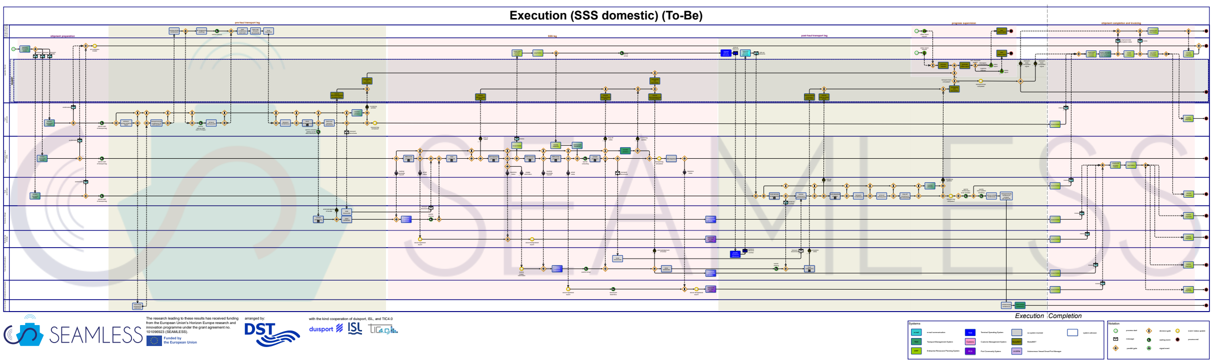


Figure 155. Execution layer of the Logistics Reference System Architecture of the domestic short-sea shipping case (to-be)

As a variation case, the international short-sea shipping case has also been investigated regarding its change following the deployment of SEAMLESS innovations. The planning process of the case variant exhibits the same changes as for the domestic case but includes the customs preparation sub-phase which again remains untouched by the SEAMLESS innovations (see Figure 156).

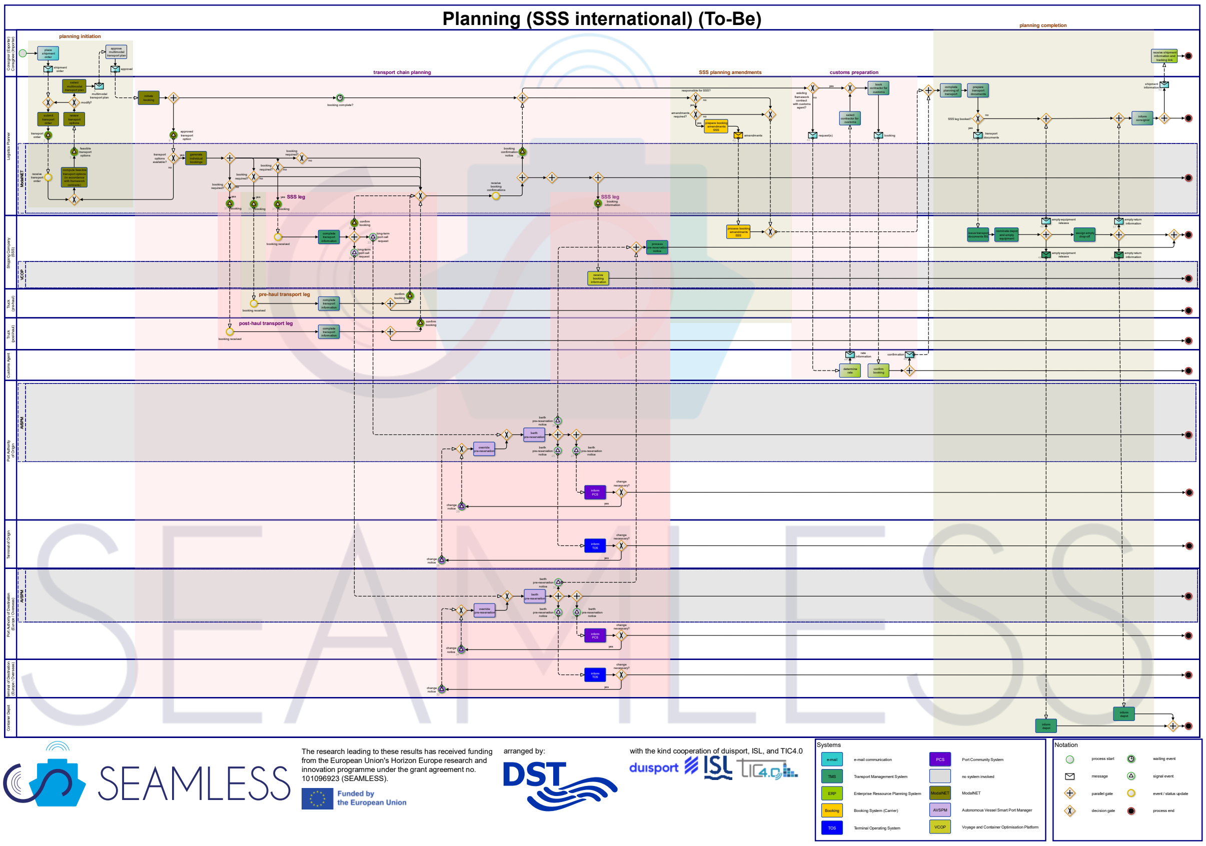


Figure 156. Planning layer of the Logistics Reference System Architecture of the international short-sea shipping case (to-be)

In the execution phases of both the domestic and the international short-sea shipping cases, the only changes are the ones caused by from the SEAMLESS innovations, as can be seen in Figure 157. The differences between the domestic and the international case lies in the customs-related processes, such as customs preparation on the shipment preparation sub-phase and customs declaration prior to the departure of the short-sea shipping vessel. Again, the most obvious change is the addition of a new sub-phase, the progress supervision sub-phase, in which the request of information from the ModalNET system is presented.

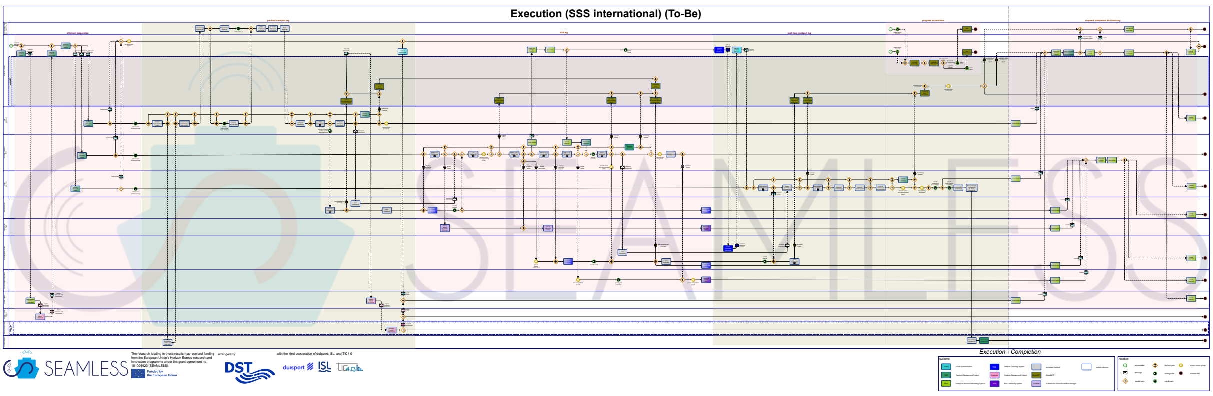


Figure 157. Execution layer of the Logistics Reference System Architecture of the international short-sea shipping case (to-be)

4.5.2 Demonstration Use Case 2

In the SEAMLESS Demonstration Use Case 2, the involved actors and stakeholders aim at utilising autonomous inland vessels for the **automated waterborne seaport hinterland transport** from and to seaports in continental Europe. In the precise case, the port of Antwerp-Bruges acts as the focal point of the underlying scenario from which hinterland transport corridors both to northern France and to western Germany are served. The corresponding inland ports between which and Antwerp the transports are envisioned are Lille, France, and Duisburg, Germany, respectively. Although it is also conceivable to facilitate continental waterborne cargo flows between the two regions, the scenario centring the seaport in Antwerp is considerably more likely. The reason for this assessment is the strong modal split of IWT in the hinterland transport of the largest seaports of Belgium and the Netherlands, particularly when executed along the Rhine-Alpine Corridor. The large number of operators engaged on this route increases the likelihood that innovations will be introduced to further increase the profitability of operations, provided they are sufficiently wealthy to make the investment. In addition, the leverage effect of such innovation introduced on this route is significantly higher than in a smaller use case. As has been elaborated in the deliverable D2.1, the distances of approximately 213 kilometres from Antwerp to Dourges, France, and 282 kilometres to Duisburg are to be covered in DUC 2. While France-bound route features ten locks, the one to western Germany only has two locks to pass. Similarly, the number of bridges to pass on the route to Dourges exceeds 100, whereas only around 20 bridges are to driven through in the case of the Duisburg route. Hence, DUC 2 offers sufficient variety of operational conditions to achieve a credible level of reliability of a transport service (Jungen et al., 2024, pp. 67–92).

Analogous to the short-sea shipping case variants presented in the preceding section, the IWT-related case variants have been confronted with the SEAMLESS innovations. As presented earlier, the case involves a pre-haul leg on the road and a main leg on the inland waterway, involving one seaport and one inland port. Although the empty containers are part of the overarching process of intercontinental export cargo flow, it is not considered in the focus view on the waterborne seaport hinterland transport. The same holds true for the preparation of the transport documents. The waterborne seaport hinterland case sees the same changes caused by the integration of ModalNET into the planning process both during the sub-phases of planning initiation and transport chain planning. Once again, the transport chain planning reduces the individual planning sub-phases into one phase and parallelizes the individual bookings performed in this case. Moreover, the long-term port call planning of the AVSPM performed for the ports of origin and destination is initiated while VCOP is also informed during this sub-phase. The customs preparation sub-phase as well as the planning completion sub-phase remain unchanged compared to the current practice of waterborne seaport hinterland transport. The entire process flow is depicted in Figure 158.

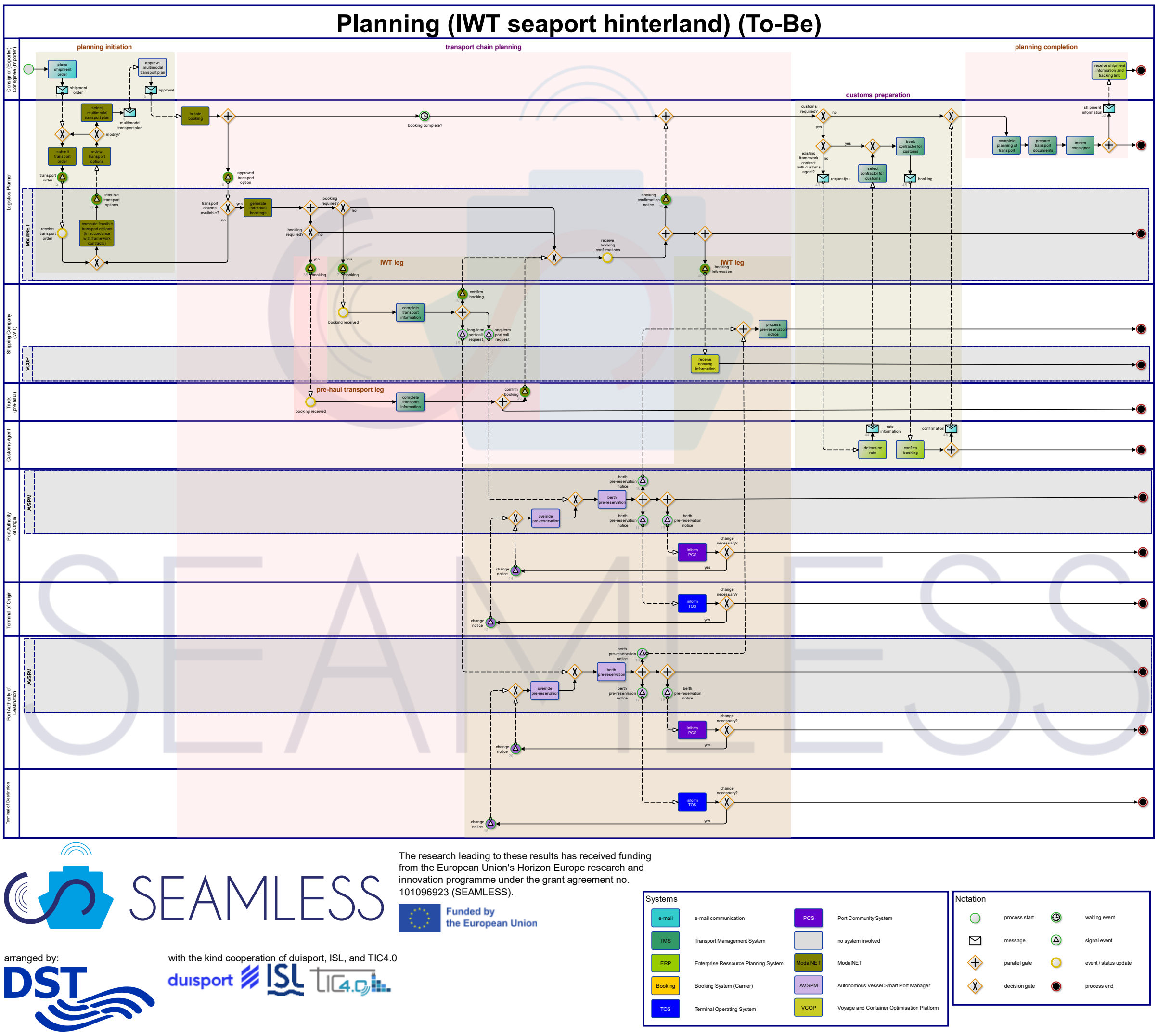


Figure 158. Planning layer of the Logistics Reference System Architecture of the waterborne seaport hinterland transport case (to-be)

With respect to the execution layer and the physical operations prior to, during, after the transport services, the changes to the process flow are manifold (see Figure 159). During shipment preparation, the first subphase of the execution phase, no particular changes are observed though (compared to the as-is process flow described in section 2.5.2). A potential change may arise from the fact that the hinterland transport is supposed to run within the area of the European Union as the customs preparations becomes is no longer necessary. In other cases, it remains pivotal though. In the subsequent two sub-phases, i. e., the pre-haul to the inland port and the waterborne main leg to the seaport, multiple changes are expected (compared to current practice). Consequently, the related port authorities and terminal operators are involved in the process. The interaction with ModalNET sending and receiving automated messages and signals replaces the manual exchange of conventional messages, the cargo handling is controlled from the vessel side and taken away from the responsibility of the terminal operators, and the interaction between the automated vessel and the port authority is channelled through AVSPM. The sub-processes of arrival and departure of the vessel as well as the further vessel-related operations of berthing, mooring, cargo transshipment, and battery swap (instead of bunkering) have undergone change as well. As some parts of vessel transit have not been defined yet, they remain topics of future research. The progress supervision task running transversal to the residual sequential process flow can be found in the automated waterborne seaport hinterland transport case as well. Figure 160 shows the related process flow of the execution layer.

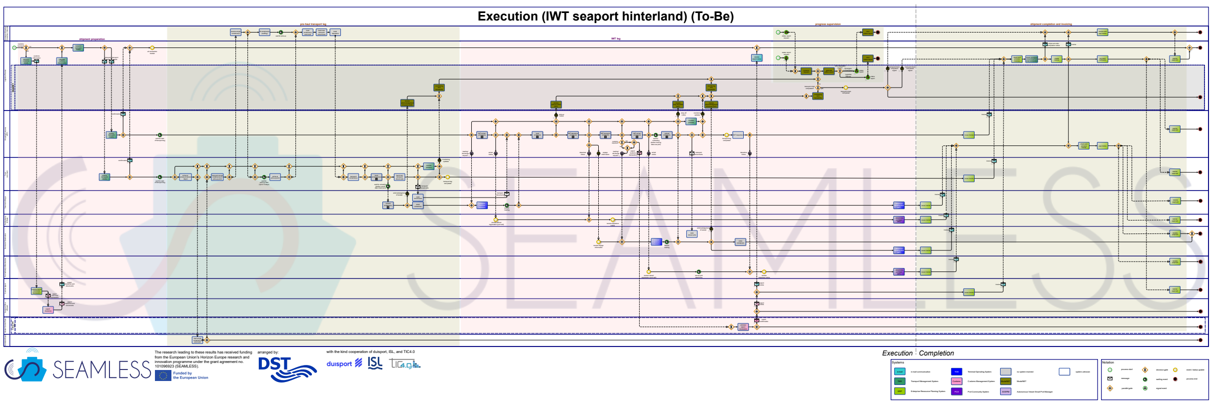


Figure 159. Execution layer of the Logistics Reference System Architecture of the waterborne seaport hinterland transport case (to-be)

A complete walk-through of the domestic short-sea shipping case can be found in Annex C. As it is underlying base for the SEAMLESS Demonstration Use Case 2, it foots on the SEAMLESS Reference Logistics System Architecture and serves as the reference process for vision of an automated waterborne seaport hinterland transport service.

Similarly to the short-sea shipping case, the continental IWT case represents a variant case of the formerly presented waterborne seaport hinterland transport case. On investigating into the changes of the system architecture induced by the SEAMLESS innovations, the changes in the planning and execution processes in the continental IWT case are similar to the in other case variants. Regarding the planning process, the same parallelisation of the booking processes as in the SEAMLESS Reference Logistics System Architecture is present in this case. It is to be noted though that the continental IWT case features two road-based legs and one waterborne main leg all of which require individual bookings of the related transport service providers. The waterborne main leg consists of a transport relation between two inland ports. The new role of ModalNET in configuring the multimodal transport chain options is obvious and does not differ from the other case variants. The same is true for the long-term port call planning with AVPSM and stowage planning with VCOP. The planning phase for the continental IWT case is shown in Figure 160.

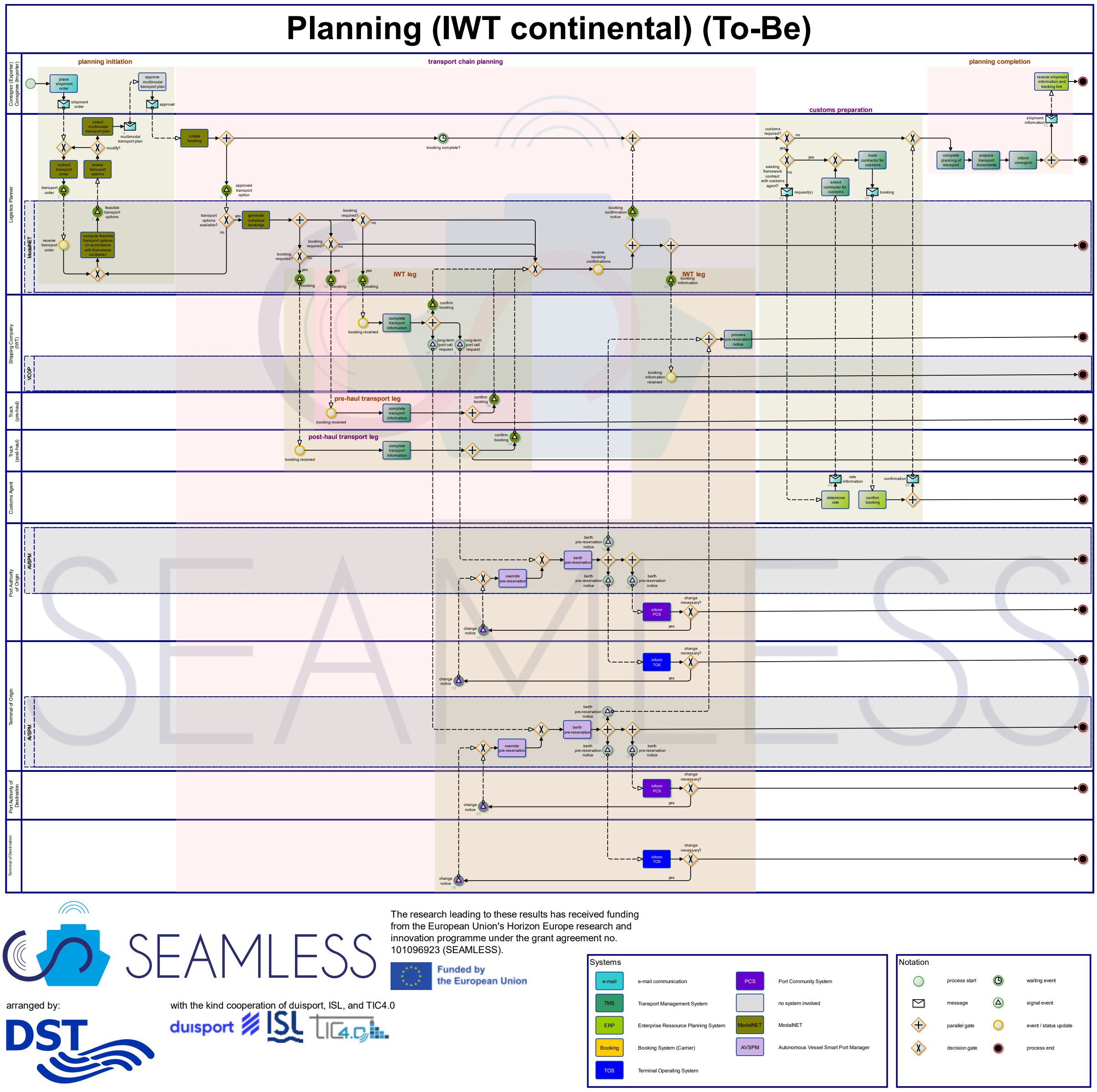


Figure 160. Planning layer of the Logistics Reference System Architecture of the continental IWT case (to-be)

The execution phase of the continental case encompasses six sub-phases, i. e., the IWT leg, the pre-haul and post-haul legs, the shipment preparation, the progress monitoring, and the shipment completion and invoicing sub-phases. The shipment preparation sub-phase may encompass the customs preparation tasks, in case the transport relation involves a port outside the customs union or transits such an area. Apart from that, the central role of ModalNET collecting the status information of each leg and the completion notices about various process milestones remains valid in this case variant. Likewise, the changes during vessel arrival, transit, and departure as well as mooring and cargo transshipment are represented in the case variant. It is once again emphasized that waterborne continental container transport is not the rule and appears exceptionally only, making the ACHS less relevant for this case variant than other SEAMLESS innovations. While the sub-phases encompassing transport operations may rarely differ from their counterparts in other case variants, the shipment completion may differ to a bigger extent. Despite the similarity in structure and sequence, the processes related to continental transport are considerably different from those of intercontinental transport so that other requirements apply and other artefacts, e. g., transport documents, are produced. The process flow of the execution phase can be seen in Figure 161.

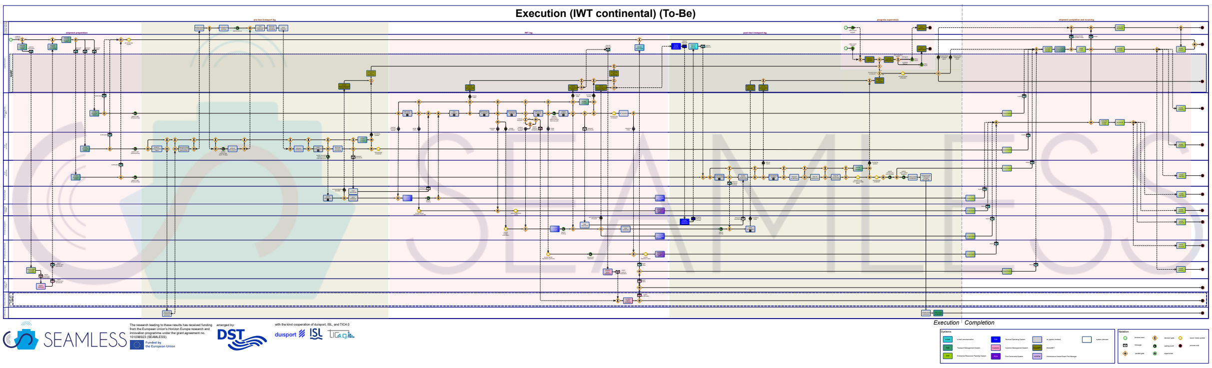


Figure 161. Execution layer of the Logistics Reference System Architecture of the continental IWT case (to-be)

5 CONSOLIDATION OF RESEARCH AGENDA

After comparing the current reference logistics system architecture with the SEAMLESS Reference Logistics System Architecture, it has become clear that some major changes are to be expected, particularly in the form of an optimized and coherent transport planning process and various efficiency gains on the operational layer due to the introduction of automation- and digitalisation-based solutions, such as automated physical processes like mooring or cargo transshipment and automated information exchange between AVSPM and PCS.

Despite the ambitious and holistic nature of the SEAMLESS project, there are particular points along the process flows of planning and executing a multimodal transport that remain undefined. The majority of these refer to the execution layer of the transport as most of the SEAMLESS innovations come into play there.

On the planning layer, the issues around handling problems outside the functional scope of ModalNET, such as planning amendments and customs matters, are to be mentioned here. In the wake of the transport chain planning step, in which multiple potential configurations of a multimodal transport chain are identified and designed in order to find the most efficient and economic transport chain configurations between a predetermined origin and destination are to be presented by ModalNET and from which one multimodal transport plan selected by the logistics planner and approved by the consignor or consignee, respectively, amendments and modifications of the very same transport cannot be handled in ModalNET. In order to accommodate those, the concerning transport service provider needs to be approached via TMS or even more conventional methods like via e-mail or phone. Since the entire transport chain is planned and booked at once, potential changes incur a change and, possibly, a re-planning of the entire transport chain because amendments and modifications can only be considered after the transport chain planning step. Formerly, the particularly impactful changes to the main (waterborne) legs could be considered earlier and before the road-borne legs are planned and booked. In addition, the responsibility of handling amendments and modifications is unclear as ModalNET does not provide any function for that. Apparently, the logistics planner needs to address such amendments and modifications outside ModalNET and, therefore, needs to run a parallel transport management solution like a TMS. Ideally, such a function is integrated into the scope of ModalNET so that the parallel use of both systems can be omitted.

Similarly, the integration of the entire customs handling process into ModalNET is not foreseen as part of the SEAMLESS research project. Instead, corresponding interfaces will be provided in order to facilitate information exchange between the two sides.

As part of the execution layer, several aspects of vessel operation are still undefined. This includes various aspects of vessel transit, port manoeuvres, and interaction with the shoreside. For instance, the registration process of autonomous vessels with inland waterway authorities upon entering their area of responsibility and jurisdiction has not been defined yet. Therefore, neither the precise logistics process flow nor the role of the IWMS is clear. The possibility of transmitting data either digitally or with conventional means by a ROC operator appear as potential options but a reliable solution has not been defined.

Similarly, the regulation and routine of autonomous vessels crossing (customs) borders while entering and leaving Union territory remains an unspecified area. As the current process involves particular manual interactions and physical steps, e.g., of checking vessel, cargo, and documents, the counterpart for autonomous vessels without any crew member on board needs to be determined. It is unclear which regulations will apply to autonomous vessels and whether dedicated regulations are to be expected which the autonomous vessels or ROC operators will need to comply with.

Likewise, the processes of passing oncoming vessels, overtaking vessels in the front, and overcoming critical stretches ahead need to be re-defined as the current processes include a multitude of manual interactions with fellow vessels on the waterway and other parties involved as well as a series of physical steps to be carried out by the crew on board. In the case of uncrewed, autonomously operating vessels, the applicable rules and regulations still need to be defined and agreed. The same holds true for COLREG situations as COLREG regulate the applicable steering and sailing rules, lights and shapes, sounds and light signals, and exemptions. Furthermore, the typical vessel operations on board, such as activities of maintenance, repair, and overhaul (MRO), inspections, and entrepreneurial tasks of the shipmaster and the crew on board the vessel need to be redesigned. Because the MRO-related tasks have not been assigned to a particular party involved in the logistics process flow, the task remains unassigned in the process descriptions and illustrations of the cargo transport process steps. Out of the multitude of options, such as moving the task to the shoreside either to fellow co-workers or to external service providers or automating the entire task with the help of technical facilities, an effective and efficient solution needs to be selected or developed per task.

Apart from vessel transit, some aspects of port manoeuvres and other activities of the vessel during port dwell time will need to undergo change. The equivalent of VTS activities for autonomous vessels, such as approaching the VTS area, passing VTS reporting points, and leaving the VTS area, needs further refinement, despite the initial allocation of these task areas to the AVSPM. Particularly, the interaction between the VTS, which will remain responsible for conventional vessels, and the AVSPM responsible for autonomous vessels is still a gap to be closed. Moreover, VTS and AVSPM need to coordinate with one another to accommodate hybrid traffic situations with conventional and autonomous vessels involved, e. g., during the arrival of vessels at and their departure from the port.

Next, a redesign of the formerly physical flow of transport document remains a pending issue. For instance, it has not been defined yet which transport documents are to be provided by which party, e. g., the terminal operator, in order to enable vessel departure. The format also remains undefined, so that both physical letters and digital messages can be considered for the various transport legs. In some cases, certain assumptions have been made as a final and formal decision is not available. For example, the ‘clearance to load’ signal is required to be submitted by the autonomous vessel as a prerequisite for the terminal to serve it and start loading operations. However, it is unclear how the signal is to be submitted from the vessel side to the shoreside, i. e., the terminal operator. It can be transmitted automatically via the ROC or manually released by the ROC operator. As details of this process step have not been specified, a suitable process flow has been assumed. As a third example, the flow of documents and information prior to, during, and after the operation of the ACHS needs to be defined in order to clarify the process steps around loading and unloading containers. With the crane operator of the terminal operation enterprise being omitted from the process and the cargo transshipment taken over by an on-board crane, the former responsibilities of document provision do not apply anymore. An alternative process configuration is required in order to safeguard a legal and economic equivalent to its as-is counterpart.

With respect to the completion phase and concerning the economic perspective of the multimodal transport, it needs to be defined how the omitted landside cargo transshipment can be covered by replacement fee as on-board cranes take over the cargo transfer task from the terminal operator. Furthermore, it needs to be determined how and according to which tariff structure the fees are to be charged. This again affects the processes of determining the fees due, invoice issue, and payment settlement. The same applies for novel services, such as the monitoring and supervision of the mooring process, which is currently under the responsibility of the shipmaster regardless of the automation level of his mooring aides. In case of an uncrewed vessel with the AMoS system on board, the duty of care must be observed in an alternative manner.

6 SUMMARY AND OUTLOOK

Documenting the finding of the tasks T2.3 and T2.4 of the SEAMLESS research project, this report presents the SEAMLESS Reference Logistics System Architecture and the simplification potential of complex administrational procedures in the planning and execution processes of a multimodal transport chain using autonomous vessels.

Originating from a detailed analysis of the current practices and processes both in short-sea shipping and inland waterway transport within a holistic "cargo story" from origin to destination, a consistent and coherent reference process architecture in its current form has been developed and analysed. Thereby, a proper understanding of the underlying logistics system architecture including its logistics process flows, the actors and stakeholders involved in it, the communication and interactions patterns, and the systems used has been developed before applying prospective technical innovations from the SEAMLESS research project to the case. As a results, a plethora of activity and sequence diagrams document the details of each process phase, individual processes, and selected sub-process steps.

Increased transparency on process implications of automation technology allows stakeholders to better evaluate the compatibility with its current process organization. Therefore, the changes have been identified by consulting the SEAMLESS research consortium working on the different SEAMLESS innovations and their utilisation in a (hybrid) Logistics Redesign workshop. As consignors, logistics service providers, shipping companies, port authorities, technology providers, and maritime and waterway authorities as well as researchers and developers from various fields of the waterborne logistics domain are members of the group, a sufficiently heterogenous composition of the group and, hence, a largely unbiased assessment of the expected changes caused by each SEAMLESS innovation was ensured. The pertaining analysis yielded some key findings: process change induced by technological innovation, new supervisory roles of the staff replacing operational tasks, and a shift to more systems and less persons involved were the four key categories of expected change. Apart from these generic changes from automation, a series of changes specifically related to the SEAMLESS research project and the cases examined therein came to light. The individual results of the consolidated analysis formed a base for the subsequent focus on each of the six SEAMLESS innovations in order to develop a comprehensive understanding of their technical functioning and their individual logistics process flow.

Next, the precise definition of the modus operandi of each SEAMLESS innovation in terms of logistics process flow has been collected with the help of (online and on-site) workshops with the heads of the development teams and regular iterations with the development teams. In this way, a clearer understanding of the SEAMLESS innovations, its functional scope, and its im-pact on system and process architecture including the process change induced by each of them is provided. Thereby, a clearer picture of the functional principle and its precise process flow is developed – and an explanation base of a potential impact on various performance measures provided.

Eventually, the individual processes of the SEAMLESS innovations were then integrated into the original cargo story of a door-to-door transport process from the consignor (origin) to the consignee (destination) via multiple transport legs using various transport modes. Thereby, the SEAMLESS

Reference Logistics System Architecture – with its logistics process flows, its actors and stakeholders involved, its business information systems and communication means used, and the communication and interaction patterns between them – has been developed and is available as a base for the subsequent development and analysis work streams. Derived from the new system architecture, the simplification potential of administrational procedures has been determined.

During the work on the above-mentioned results, it has become clear that some major changes are well-defined and integrated into the process flows of the SEAMLESS Reference Logistics System Architecture whereas others represent gaps and remain still to be defined, possibly even outside the SEAMLESS research project.

The technical development teams and the ones working on the conceptualisation and operationalisation of the SEAMLESS Demonstration Use Cases are expected to base their follow-up work on the SEAMLESS Reference Logistics System Architecture in order to ensure consistency between technical operation and envisioned performance evaluation and analysis.

Together with the deliverable D2.3 presenting the technical functionality of the respective SEAMLESS innovations and their interaction in the context of the SEAMLESS Demonstration Use Cases, the SEAMLESS Reference Logistics System Architecture will act as input to the technical development work conducted in work packages 3, 4, and 5 as well as the manifold evaluation tasks in work package 6. Moreover, the SEAMLESS Reference Logistics System Architecture will be used as a reference base for the design and conceptualisation of both SEAMLESS Demonstration Use Cases.

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ANNEX A

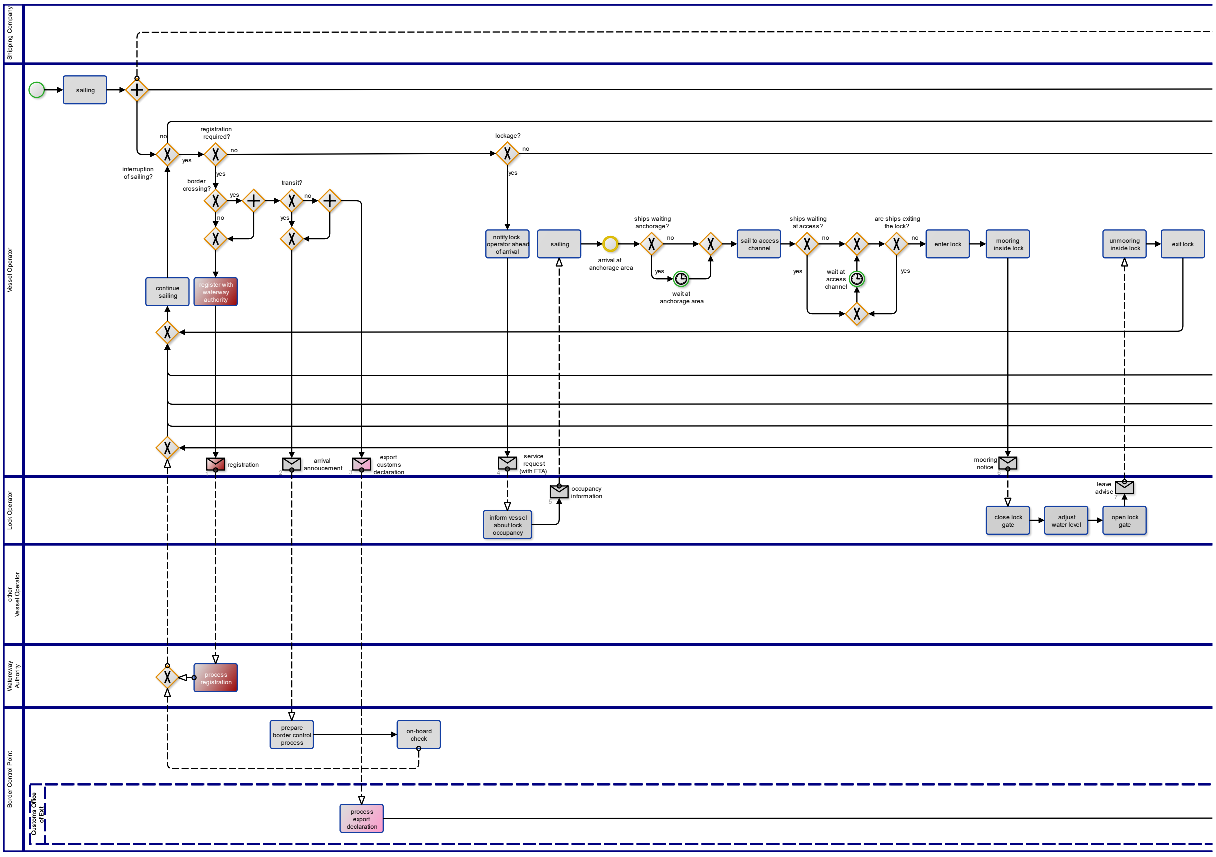

Figure 162. Logistics process flow in the IWT transport cargo sub-process (waterway registration and lockage)

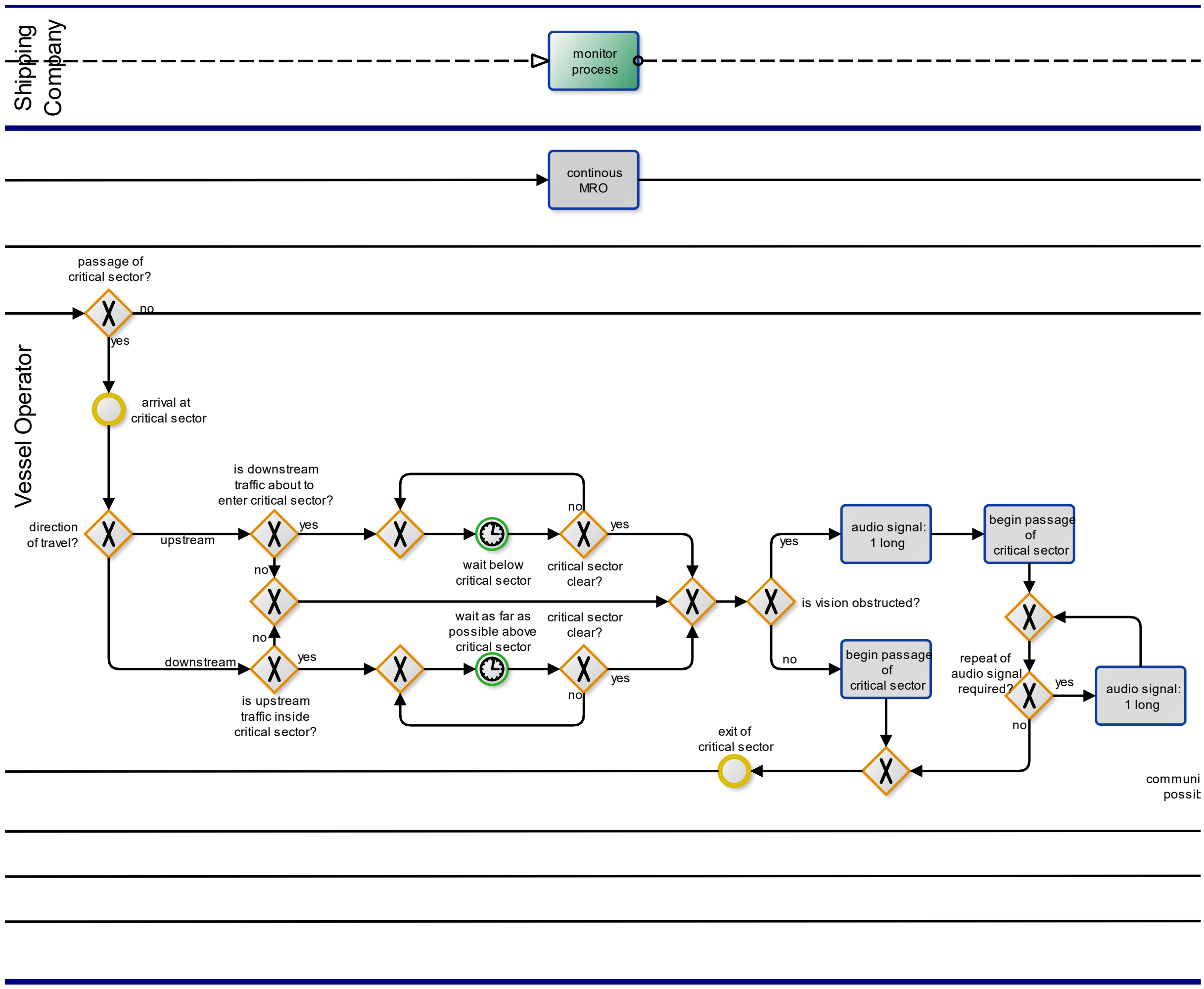

Figure 163. Logistics process flow in the IWT transport cargo sub-process (passage of critical stretch)

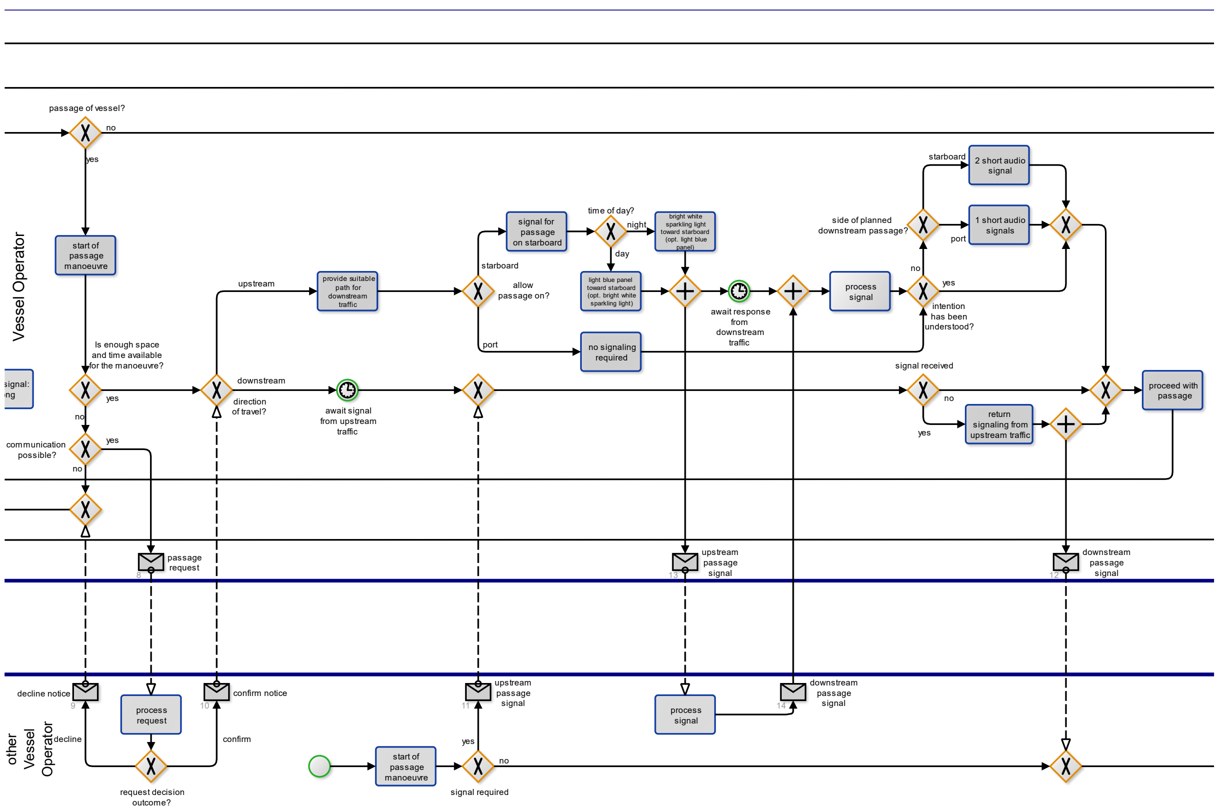

Figure 164. Logistics process flow in the IWT transport cargo sub-process (vessel passage)

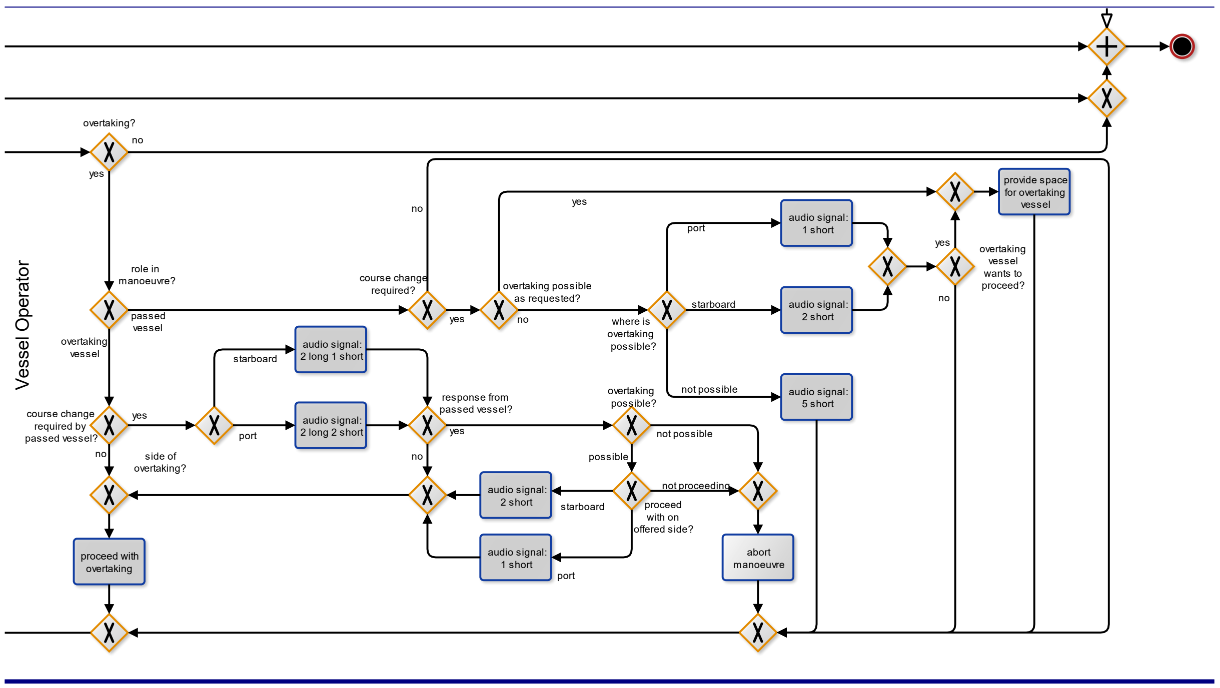

Figure 165. Logistics process flow in the IWT transport cargo sub-process (vessel overtaking)

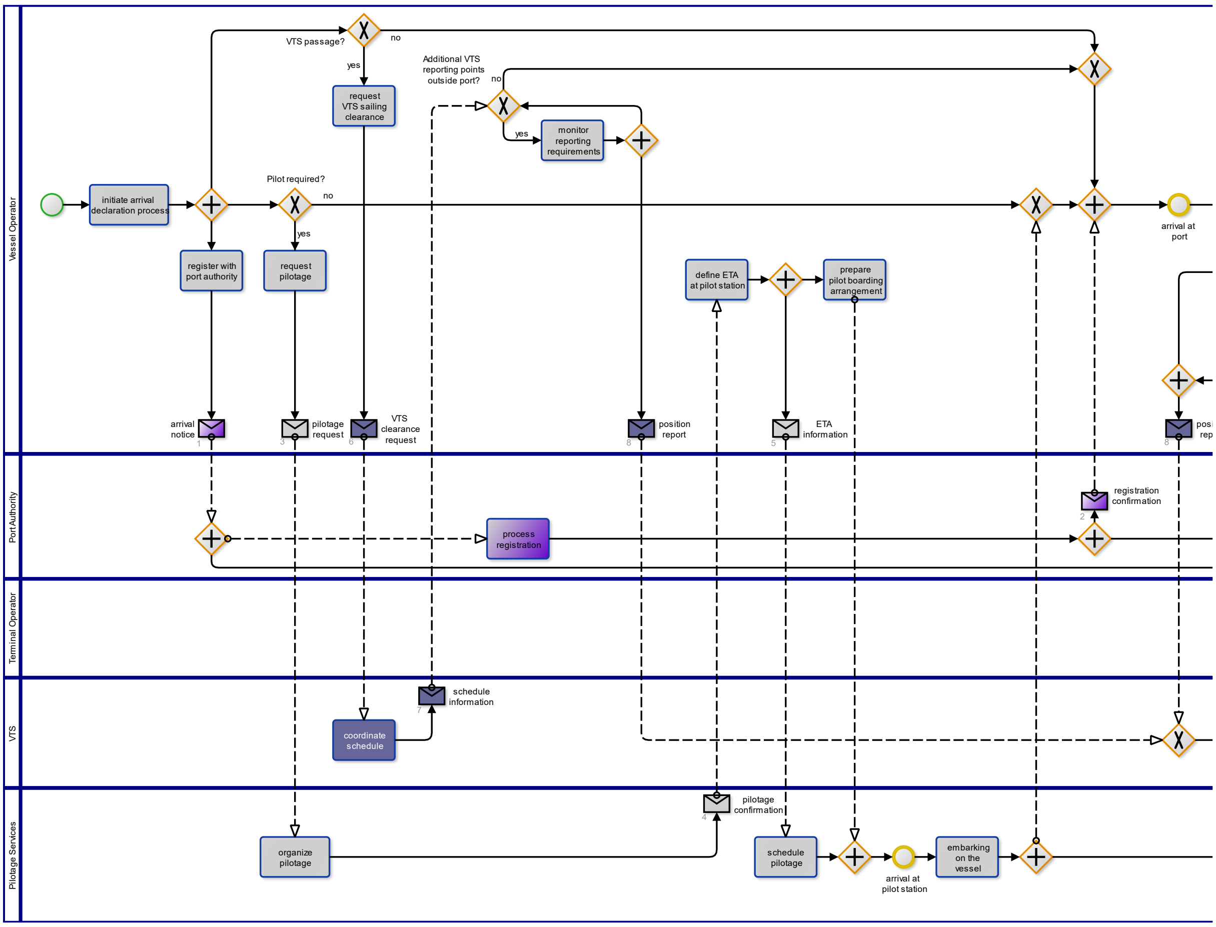

Figure 166. Logistics process flow in the SSS arrival sub-process (outside port)

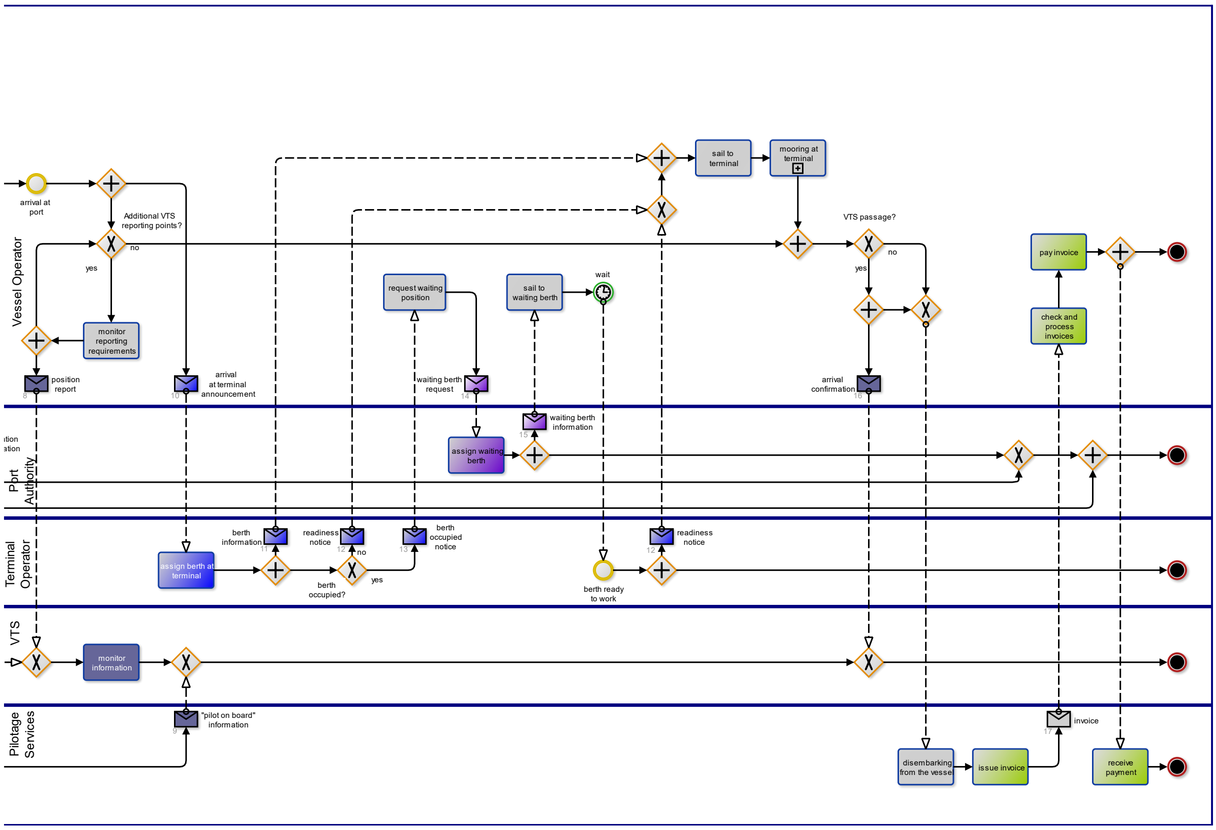

Figure 167. Logistics process flow in the SSS arrival sub-process (inside port)

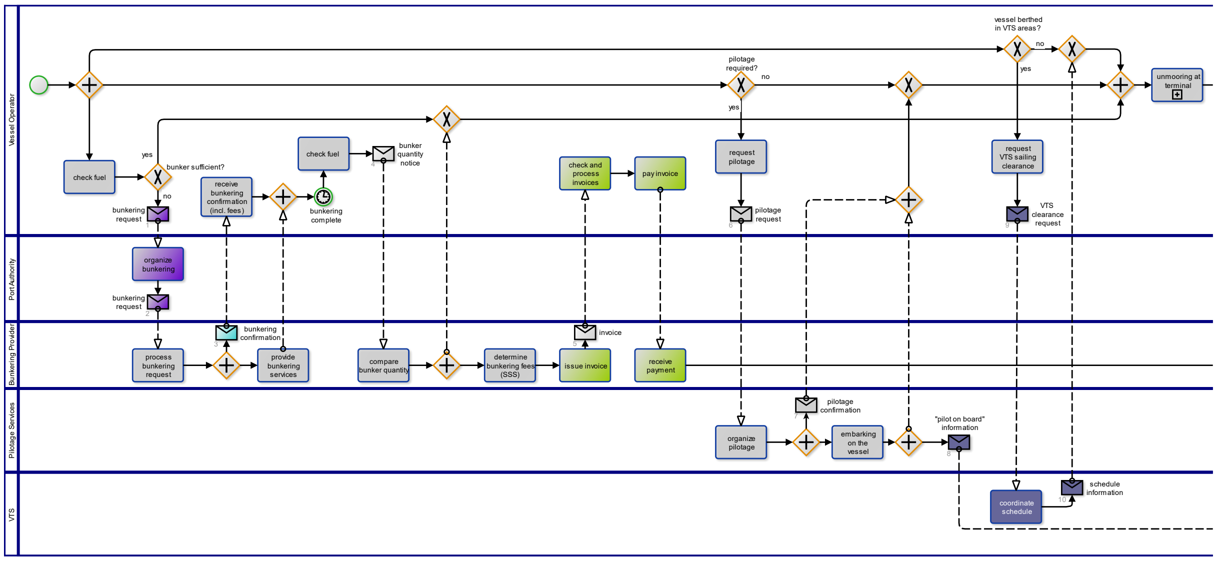

Figure 168. Logistics process flow in the SSS departure sub-process (at berth)

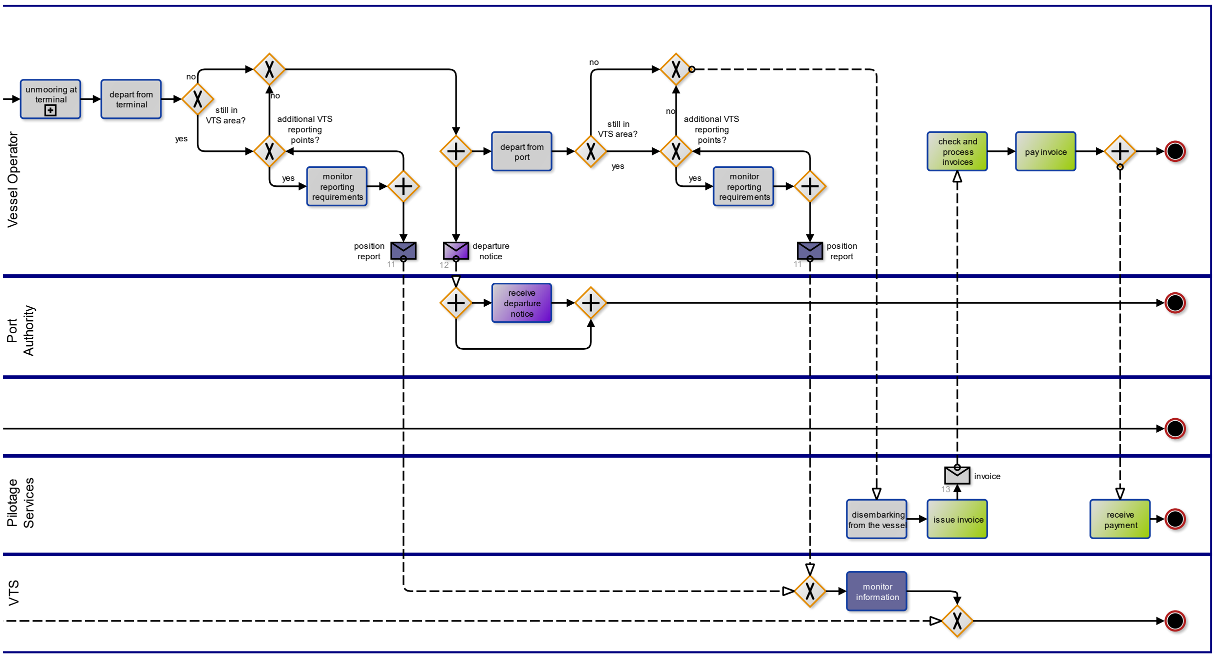

Figure 169. Logistics process flow in the SSS departure sub-process (leaving the port)

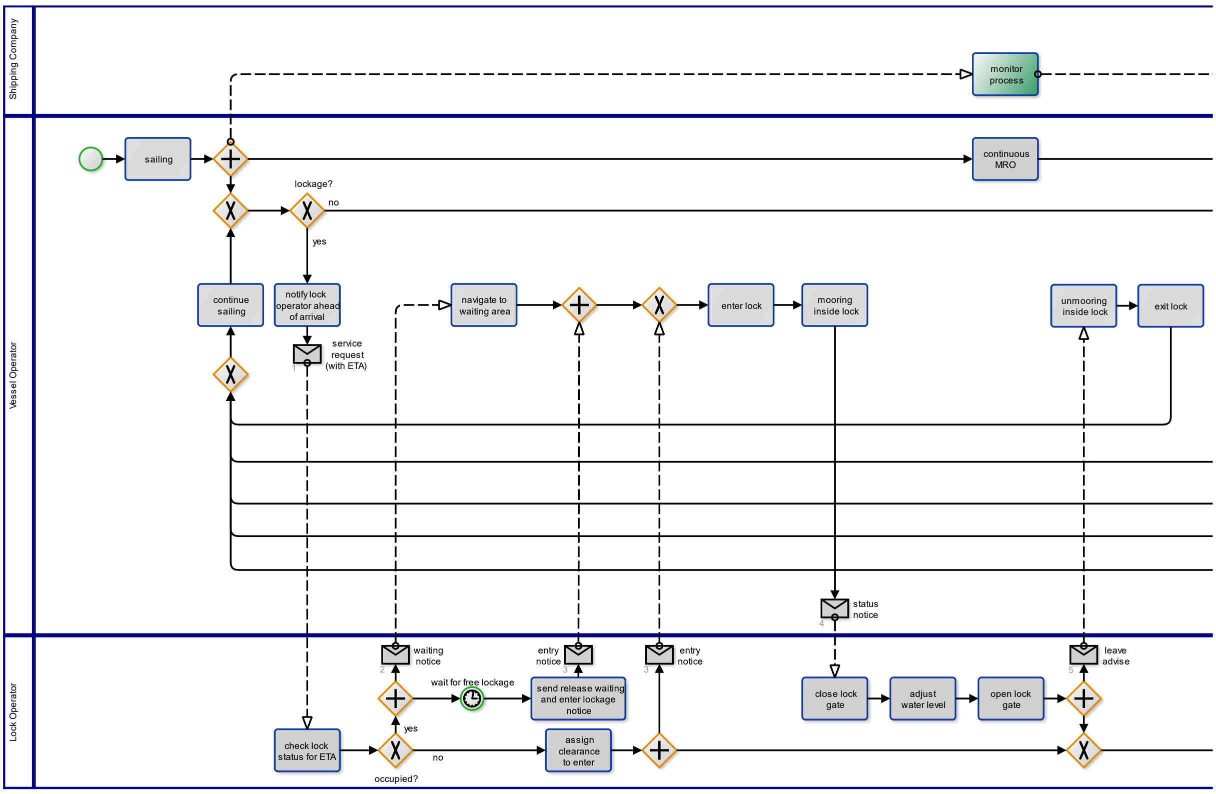

Figure 170. Logistics process flow in the SSS transport cargo sub-process (lockage)

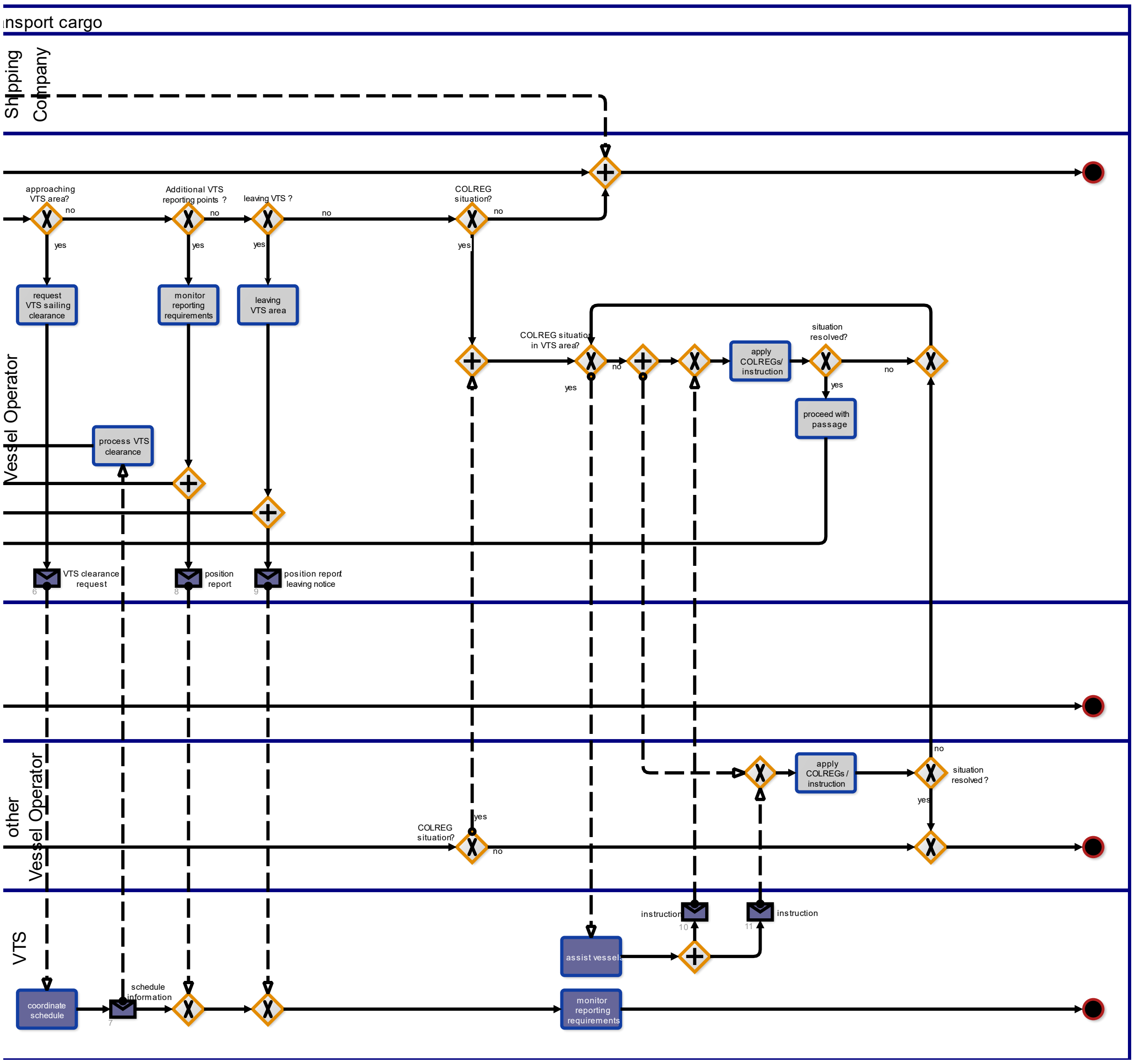

Figure 171. Logistics process flow in the SSS transport cargo sub-process (other manoeuvres)

ANNEX B

AUTOMATED REGIONAL FREIGHT FEEDER LOOP SERVICE

Planning layer

Phase 1: Planning initiation

- consignor sends shipment order, log. Planner feeds data to ModalNET, ModalNET responds with feasible transport options, log. Planner transmits multimodal transport plan to consigner for approval.
  - shipment order (consignor -> log. planner)
  - transport order (log. planner -> ModalNET)
  - feasible transport options (ModalNET -> log. planner)
  - multimodal transport plan (log. planner -> consignor)
  - approval (consignor -> log. planner)

Phase 2: Transport chain planning

- Log. Planner initiates booking through ModalNET, ModalNET creates and sends individual bookings to transport required transport companies
  - approved transport plan (Log. Planner -> ModalNET)
- Truck (post-haul) receives the booking, completes the transport information and confirms the booking
  - booking (ModalNET -> Truck (post-haul))
  - confirm booking (Truck (post-haul) -> ModalNET)
- Truck (pre-haul) receives the booking, completes the transport information and confirms the booking
  - booking (ModalNET -> Truck (pre-haul))
  - confirm booking (Truck (pre-haul) -> ModalNET)
- Shipping company (SSS) receives the booking, completes the transport information and confirms the booking, shipping company requests long-term port call planning through AVSPM at both ports, AVSPM performs berth pre-reservation and informs port authority, terminal operator and shipping company (SSS), port authority and terminal operator can submit change request to pre-reservation
  - booking (ModalNET -> Shipping Company (SSS))
  - confirm booking (Shipping Company (SSS) -> ModalNET)
  - long-term port call request (Shipping Company (SSS) -> AVSPM (Port Authority of Origin and Destination)
  - berth pre-reservation notice (AVSPM -> Port Authority, Terminal Operator, Shipping Company (SSS))
  - change notice (Port Authority, Terminal Operator -> AVSPM)
- ModalNET receives all booking confirmations and send confirmation notice to log. planner, ModalNET send booking information to VCOP of shipping company

  - booking confirmation notice (ModalNET -> Log. Planner
  - booking information (ModalNET -> VCOP)

Phase 3: SSS planning amendments

- if applicable the log. planner prepares any amendments required to the SSS booking, log. planner sends the amendments to the SSS shipping company, SSS shipping company processes the amendments
  - amendments (Log. Planner -> Shipping Company (SSS))

Phase 4: Planning completion

- log. planner completes the planning process, prepares transport documents to send to the SSS shipping company, the shipping company (SSS) issues the bill of lading and nominates a depot and the empty equipment, shipping company (SSS) sends an empty equipment release to the log. planner and container depot, SSS shipping company assigns a drop off depot and sends the empty return information to the log. planner and container depot, the log. planner informs consignor about the completion of the planning phase.
  - transport documents (Log. Planner -> Shipping Company (SSS))
  - empty equipment release (Shipping Company (SSS) -> Log. Planner, Container Depot)
  - empty return information (Shipping Company (SSS) -> Log. Planner, Container Depot)
  - shipment information (Log. Planner -> Consignor)

Execution Layer

Phase 1: Shipment preparation

- log. planner will transmit all required transport details to respective transport companies, transport companies confirm reception of transport details and wait for the start of their transport leg
  - transport details (Log. Planner -> Shipping Company (SSS), Truck (pre-haul), Truck (post-haul))
  - confirmation (Shipping Company (SSS), Truck (pre-haul), Truck (post-haul) -> Log. Planner)

Phase 2: Pre-haul transport leg

- the truck (pre-haul) provides monitoring updates to ModalNET during the transport, the truck starts his transport, picks up the container at the empty depot and delivers the container to the consignor for stuffing, the truck picks up the loaded container and transports them to the terminal of origin
  - monitoring updates (Truck (pre-haul) -> ModalNET)
- [truck arrival process] upon arrival truck passes OCR gate and weighbridge when entering the terminal, truck checks into terminal of origin and transports container to the unloading station at the terminal
  - container information (Truck Gate -> Terminal Operator)

  - VGM information (Truck Gate -> Terminal Operator)
- [unload container(s)] the terminal operator provides pre-planning information to the crane operator, the trucker unlocks the container and crane operator unloads the container, crane operator notifies trucker and terminal operator about completion
  - plan (Terminal Operator -> Crane Operator)
  - completion notice (Crane Operator -> Tucker, Terminal Operator)
- the trucker hands over the documents and terminal operator acknowledges the receipt to ModalNET, terminal operator saves documents and stores container
  - acknowledgement of receipt (Terminal Operator -> ModalNET)
  - transport documents (Truck (pre-haul) -> Terminal Operator)

Phase 3: SSS leg

- the SSS shipping company provides monitoring updates to ModalNET, inland vessel sends a loading and discharge request to the terminal, terminal of origin prepares terminal operations and transfers documents
  - monitoring updates (Shipping Company (SSS) -> ModalNET)
  - loading / discharge request (Shipping Company (SSS) -> Terminal of Origin
  - transport documents (Terminal Operator -> Shipping Company (SSS))
- [SSS arrival processes 1/2] ROC initiates port call planning with AVSPM, AVSPM performs short term port call planning request final berth position, terminal operator confirms berth, AVSPM transmits berth data to ROC, ROC returns ETA and vessel data, AVSPM relays ETA and vessel data to port authority and terminal operator, inland vessel send arrival notice and AVSPM provides traffic and environmental data, after arrival vessel transmits continuous status updates to AVSPM, terminal has to provide readiness signal for vessel arrival through AVSPM, otherwise vessel requests waiting position from port authority, once at berth the vessel starts the autonomous mooring sequence
  - initialization (ROC -> AVPSM)
  - berth request (AVSPM -> Terminal Operator)
  - confirmation (Terminal Operator -> AVSPM)
  - berth data (AVSPM -> ROC)
  - ETA and vessel data (ROC -> AVSPM; AVSPM -> Port Authority, Terminal Operator)
  - arrival notice (Auton. Vessel -> AVSPM)
  - traffic and environmental data (AVSPM -> Auton. Vessel)
  - status update (Auton. Vessel -> AVSPM)
  - readiness signal for arrival (Terminal Operator -> AVSPM)
  - readiness signal from TOS (AVSPM -> Auton. Vessel)
  - waiting position request (Auton. Vessel -> Port Authority)
  - waiting position information (Port Authority -> Auton. Vessel)
  - start mooring sequence signal (Auton. Vessel -> AMS)

- [execute mooring sequence] vessel signals AMS to start, AMS initiates and detects surroundings, AMS performs mooring process and connects the vessels' charging, AMS returns to parked position, AMS signals completion to vessel
  - Start signal mooring sequence (Auton. Vessel -> AMS)
  - mooring complete signal (AMS -> Auton. Vessel)
- [SSS arrival processes 2/2] AMS signals mooring completion, vessel notifies AVSPM of status all fast
  - mooring complete signal (AMS -> Auton. Vessel)
  - berth all fast (Auton. Vessel -> AVSPM)
- vessel registers with port authority
  - arrival notice (Shipping Company (SSS) -> Port Authority)
- [load containers 1/2] terminal operator provides final container IDs and details to VCOP, VCOP finalizes stowage plan and transmits to ROC for approval, ROC rejects (causing a replanning) or confirms the stowage plan, ROC signals vessel ready for cargo operation to VCOP, VCOP relays the signal to terminal operator, terminal operator signals terminal ready for work to VCOP (relays to ROC), ROC starts cargo operations, VCOP send (un-)loading plan to terminal operator and ACHS, for loading terminal provides cargo at quay side and informs VCOP
  - final container IDs and details (Terminal Operator -> VCOP)
  - stowage plan (VCOP -> ROC)
  - stowage plan rejection (ROC -> VCOP)
  - stowage plan confirmation (ROC -> VCOP)
  - vessel ready for cargo operation signal (ROC -> VCOP; VCOP -> Terminal Operator)
  - terminal ready to work signal (Terminal Operator -> VCOP; VCOP -> ROC)
  - cargo operations signal (ROC -> VCOP)
  - (un-)loading plan (VCOP -> ACHS, Terminal Operator)
  - container at quay signal (Terminal Operator -> VCOP; VCOP -> ACHS)
- [(un-)load cargo] ACHS receives (un-)loading sequence, ACHS moves containers to planned positions at quay or on board, ACHS sends a report for each movement to VCOP, ACHS return cargo crane to parked position, ACHS sends completion signal
  - (un-)loading sequence (VCOP -> ACHS)
  - container ID and slot report (ACHS -> VCOP)
  - cargo operation completion (ACHS -> VCOP, ROC)
- [load containers 2/2] VCOP receives container and slot report, VCOP updates ROC and terminal operator, ACHS signals cargo operations complete, VCOP relays signal to ROC and terminal operator, VCOP send transshipment notice to ModalNET
  - container ID and slot report (ACHS -> VCOP)
  - status update (VCOP -> ROC, Terminal Operator)

  - cargo operations complete signal (ACHS -> VCOP; VCOP -> ROC, Terminal Operator)
  - transshipment notice (VCOP -> ModalNET)
- shipping company (SSS) sends pick-up notice to ModalNET
  - pick-up notice (Shipping Company (SSS) -> ModalNET)
- [SSS departure processes 1/2] once the vessel is ready for departure the departure intention is signalled by the ROC to the AVSPM which replies with a confirmation of the departure time for the vessel, once the terminal has signalled ready for departure through the AVSPM the vessel starts the unmooring sequence
  - Intention to depart signal (ROC -> AVSPM)
  - departure time confirmation (AVSPM -> ROC)
  - ready for departure signal (Terminal Operator -> AVSPM; AVSPM -> Auton. Vessel)
  - Start unmooring sequence signal (Auton. Vessel -> AMS)
- [unmooring at terminal] vessel signals AMS to start, AMS disconnects charging and removes all mooring lines, AMS moves robot arm to parking position, AMS signals unmooring compete
  - start signal unmooring sequence (Auton. Vessel -> AMS)
  - signal unmooring complete (AMS -> Auton. Vessel)
- [SSS departure processes 2/2] AMS signals mooring complete, vessel updates status unmoored with AVSPM, Vessel departs from port and sends departure notice to AVSPM, bunkering or battery provider create and issue invoice for their services
- unmooring complete signal (AMS -> Auton. Vessel)
  - vessel unmoored signal (Auton. Vessel -> AVSPM)
  - departure notice (Auton. Vessel -> AVSPM)
  - invoice (Bunkering Provider, Battery Provider -> Auton. Vessel)
- vessel deregisters with port authority, vessel informs next terminal about voyage
  - departure notice (Shipping Company (SSS) -> Port Authority of Origin)
  - voyage information (Shipping Company (SSS) -> Terminal of Destination)
- [SSS transport containers] vessel requires lock passage and switches to high-attention mode, ROC notifies lock operator, lock operator checks lock status and provides waiting or entry notice, vessel navigates to waiting area or moves to enter lock, vessel is moored inside lock, lock operator performs lockage and provides leave advise afterwards, vessel unmoors and exits lock, vessel switches to low-attention mode and continues journey
  - service request (with ETA) (ROC -> Lock Operator)
  - waiting notice (Lock Operator -> ROC; ROC -> Auton. Vessel)
  - entry notice (Lock Operator -> ROC; ROC -> Auton. Vessel)
  - status notice (ROC -> Lock Operator)
  - leave advise (Lock Operator -> ROC; ROC -> Auton. Vessel)

- Shipping company sends loading / discharge request to terminal of destination, if required shipping company submits export customs declaration, customs office of exit processes export declaration and sends export confirmation to customs office of export, customs office of export transmits an export notice to customs agent, customs agent informs log. planner
  - loading / discharge request (Shipping Company (SSS) -> Terminal of Destination)
  - export customs declaration (Shipping Company (SSS) -> Customs Office of Exit)
  - export confirmation (Customs Office of Exit -> Customs Office of Export)
  - export notice (Customs Office of Export -> Customs Agent; Customs Agent -> Log. Planner)
- [SSS arrival processes 1/2] identical to description above
- [execute mooring sequence] identical to description above
- [SSS arrival processes 2/2] identical to description above
- vessel registers with port authority
  - arrival notice (Shipping Company (SSS) -> Port Authority)
- [unload containers 1/2] identical to load containers described previously
- [(un-)load cargo] identical to description above
- [load containers 2/2] identical to load containers described previously
- shipping company (SSS) sends drop-off notice to ModalNET, terminal operator acknowledges receipt, shipping company provides transport documents to terminal operator, transport leg is complete, SSS vessel departs from port and deregisters from port of destination, terminal operators and port authorities determine fees
  - drop-off notice (Shipping Company (SSS) -> ModalNET)
  - acknowledgement of receipt (Terminal Operator -> ModalNET)
  - transport document (Shipping Company (SSS) -> Terminal Operator)
  - departure notice (Shipping Company (SSS) -> Port Authority of Destination

Phase 4: Post-haul transport leg

- log. planner requests container pick-up reference from terminal of destination, log. planner sends provided reference number to post-haul trucker, truck (post-haul) sends monitoring updates to ModalNET
  - pick-up reference request (Log. Planner -> Terminal of Destination)
  - container reference number (Terminal of Destination -> Log. Planner)
  - pick-up reference (Log. Planner -> Truck (post-haul))
  - monitoring updates (Truck (post-haul -> ModalNET)
- [truck (empty) arrival process] tucker moves to the OCR gate, the truck gate gets the truck information and sends it to the terminal operator, trucker checks in at terminal and parks at loading station
  - OCR information (Truck Gate -> Terminal Operator)

- Truck (post-haul) transmits container number to terminal of destination, terminal of destination provides transport documents
  - transmit container number (Truck (post-haul) -> Terminal of Destination)
  - transport documents (Terminal of Destination -> Truck (post-haul))
- [load container(s)] the terminal operator provides pre-planning information to the crane operator, crane operator loads the container onto the truck and provides loading report to the trucker, trucker secures the container, crane operator notifies terminal operator about completion
  - plan (Terminal Operator -> Crane Operator)
  - loading report (Crane Operator -> Trucker)
  - completion report (Crane Operator -> Tucker, Terminal Operator)
- truck (post-haul) receives container and documents; terminal of destination sends completion notice to ModalNET and truck (post-haul) provides pick-up notice to ModalNET
  - completion notice (Terminal of Destination -> ModalNET)
  - pick-up notice (Truck (post-haul) -> ModalNET)
- [truck departure process] trucker leaves loading station, at exit gate OCR gate gets information from truck, truck gate provides information to terminal operator, trucker leaves gate
  - container information (Truck Gate -> Terminal Operator)
- truck (post-haul) transports container to delivery point and drops off container and documents, upon detected completion ModalNET sends a transport chain completion signal to log. planner and consignor, truck (post-haul) waits for empty container to be picked up, post-haul truck delivers empty container to container depot, container depot receives empty container
  - transport chain completion signal (ModalNET -> Log. Planner, Consignor)

Phase 5: Progress supervision

- consignor or log. planner request status report for shipment from ModalNET, ModalNET uses monitoring and traceability information to generate status report, ModalNET provides status report
  - status report request (Consignor, Log. Planner -> ModalNET)
  - status report (ModalNET -> Consignor, Log. Planner)

Phase 6: Shipment completion and invoicing

- terminals and port authorities issue invoice to SSS shipping company for handling and port fees, SSS shipping company, truck (pre-haul) and customs agent issue invoice to log. planner, log. planner processes invoice and informs consignor of shipment completion, log. planner issues invoice to consignor, all parties pay their respective invoices
  - invoice (Terminal of Origin, Port of Origin, Terminal of Destination, Port of Destination -> Shipping Company (SSS))
  - invoice (Shipping Company (SSS), Truck (pre-haul), Customs Agent) -> Log. Planner)

- shipment order completion notice (Log. Planner -> Consignor)
- invoice (Log. Planner -> Consignor)

ANNEX C

AUTOMATED WATERBORNE SEAPORT HINTERLAND TRANSPORT

Planning Layer

Phase 1: Planning initiation

- consignor sends shipment order, log. Planner feeds data to ModalNET, ModalNET responds with feasible transport options, log. Planner transmits multimodal transport plan to consigner for approval.
  - shipment order (consignor -> log. planner)
  - transport order (log. planner -> ModalNET)
  - feasible transport options (ModalNET -> log. planner)
  - multimodal transport plan (log. planner -> consignor)
  - approval (consignor -> log. planner)

Phase 2: Transport chain planning

- Log. Planner initiates booking through ModalNET, ModalNET creates and sends individual bookings to transport required transport companies
  - approved transport plan (Log. Planner -> ModalNET)
- Truck (pre-haul) receives the booking, completes the transport information and confirms the booking
  - booking (ModalNET -> Truck (pre-haul))
  - confirm booking (Truck (pre-haul) -> ModalNET)
- Shipping company (IWT) receives the booking, completes the transport information and confirms the booking, shipping company requests long-term port call planning through AVSPM at both ports, AVSPM performs berth pre-reservation and informs port authority, terminal operator and shipping company (IWT), port authority and terminal operator can submit change request to pre-reservation
  - booking (ModalNET -> Shipping Company (IWT))
  - confirm booking (Shipping Company (IWT) -> ModalNET)
  - long-term port call request (Shipping Company (IWT) -> AVSPM (Port Authority of Origin and Destination)
  - berth pre-reservation notice (AVSPM -> Port Authority, Terminal Operator, Shipping Company (IWT))
  - change notice (Port Authority, Terminal Operator -> AVSPM)
- ModalNET receives all booking confirmations and send confirmation notice to log. planner, ModalNET send booking information to VCOP of shipping company
  - booking confirmation notice (ModalNET -> Log. Planner
  - booking information (ModalNET -> VCOP)

Phase 3: Customs preparation

- If a customs agent is required the log. planner will request rates and select a customs agent, if a framework contract exists no rate needs to be requested, log. planner books a customs agent.
  - request(s) (Log. Planner -> Customs Agent)

  - rate information (Customs Agent -> Log. Planner)
  - booking (Log. Planner -> Customs Agent)
  - confirmation (Customs Agent -> Log. Planner)

Phase 4: Planning completion

- log. planner completes the planning process, prepares transport documents and informs consignor about the completion of the planning phase.
  - shipment information (Log. Planner -> Consignor)

Execution Layer

Phase 1: Shipment preparation

- log. planner will provide customs details to customs agent if required, customs agent will start export customs procedure, customs office of export will provide export clearance and documents, customs agent forwards the information and documents to the log. planner
  - customs information (Log. Planner -> Customs Agent)
  - export summary declaration (Customs Agent -> Customs Office of Export)
  - export clearance and documents (Customs Office of Export -> Customs Agent)
  - export clearance and documents (Customs Agent -> Log. Planner)
- log. planner will transmit all required transport details to respective transport companies, transport companies confirm reception of transport details and wait for the start of their transport leg
  - transport details (Log. Planner -> Shipping Company (IWT), Truck (pre-haul))
  - confirmation (Shipping Company (IWT), Truck (pre-haul) -> Log. Planner)

Phase 2: Pre-haul transport leg

- the truck (pre-haul) provides monitoring updates to ModalNET during the transport, the truck starts his transport, picks up the container at the empty depot and delivers the container to the consignor for stuffing, the truck picks up the loaded container and transports them to the terminal of origin
  - monitoring updates (Truck (pre-haul) -> ModalNET)
- [truck arrival process] upon arrival truck passes OCR gate and weighbridge when entering the terminal, truck checks into terminal of origin and transports container to the unloading station at the terminal
  - container information (Truck Gate -> Terminal Operator)
  - VGM information (Truck Gate -> Terminal Operator)
- [unload container(s)] The terminal operator provides pre-planning information to the crane operator, the trucker unlocks the container and crane operator unloads the container, crane operator notifies trucker and terminal operator about completion
  - plan (Terminal Operator -> Crane Operator)
  - completion notice (Crane Operator -> Tucker, Terminal Operator)
- the trucker hands over the documents and terminal operator acknowledges the receipt to ModalNET, terminal operator saves documents and stores container
  - acknowledgement of receipt (Terminal Operator -> ModalNET)

    - transport documents (Truck (pre-haul) -> Terminal Operator)

Phase 3: IWT leg

- the IWT shipping company provides monitoring updates to ModalNET, inland vessel sends a loading and discharge request to the terminal, terminal of origin prepares terminal operations and transfers documents
    - monitoring updates (Shipping Company (IWT) -> ModalNET)
    - loading / discharge request (Shipping Company (IWT) -> Terminal of Origin
    - transport documents (Terminal Operator -> Shipping Company (IWT))
- [IWT arrival processes 1/2] ROC initiates port call planning with AVSPM, AVSPM performs short term port call planning request final berth position, terminal operator confirms berth, AVSPM transmits berth data to ROC, ROC returns ETA and vessel data, AVSPM relays ETA and vessel data to port authority and terminal operator, inland vessel send arrival notice and AVSPM provides traffic and environmental data, after arrival vessel transmits continuous status updates to AVSPM, terminal has to provide readiness signal for vessel arrival through AVSPM, otherwise vessel requests waiting position from port authority, once at berth the vessel starts the autonomous mooring sequence
    - initialization (ROC -> AVPSM)
    - berth request (AVSPM -> Terminal Operator)
    - confirmation (Terminal Operator -> AVSPM)
    - berth data (AVSPM -> ROC)
    - ETA and vessel data (ROC -> AVSPM; AVSPM -> Port Authority, Terminal Operator)
    - arrival notice (Auton. Vessel -> AVSPM)
    - traffic and environmental data (AVSPM -> Auton. Vessel)
    - status update (Auton. Vessel -> AVSPM)
    - readiness signal for arrival (Terminal Operator -> AVSPM)
    - readiness signal from TOS (AVSPM -> Auton. Vessel)
    - waiting position request (Auton. Vessel -> Port Authority)
    - waiting position information (Port Authority -> Auton. Vessel)
    - start mooring sequence signal (Auton. Vessel -> AMS)
- [execute mooring sequence] vessel signals AMS to start, AMS initiates and detects surroundings, AMS performs mooring process, AMS returns to parked position, AMS signals completion to vessel
    - Start signal mooring sequence (Auton. Vessel -> AMS)
    - mooring complete signal (AMS -> Auton. Vessel)
- [IWT arrival processes 2/2] AMS signals mooring completion, vessel notifies AVSPM of status all fast
    - mooring complete signal (AMS -> Auton. Vessel)
    - berth all fast (Auton. Vessel -> AVSPM)
- vessel registers with port authority
    - arrival notice (Shipping Company (IWT) -> Port Authority)
- [load containers 1/2] terminal operator provides final container IDs and details to VCOP, VCOP finalizes stowage plan and transmits to ROC for approval, ROC rejects (causing a replanning) or confirms the stowage plan, ROC signals vessel ready for cargo operation to

VCOP, VCOP relays the signal to terminal operator, terminal operator signals terminal ready for work to VCOP (relays to ROC), ROC starts cargo operations, VCOP send (un-)loading plan to terminal operator and ACHS, for loading terminal provides cargo at quay side and informs VCOP
    - final container IDs and details (Terminal Operator -> VCOP)
    - stowage plan (VCOP -> ROC)
    - stowage plan rejection (ROC -> VCOP)
    - stowage plan confirmation (ROC -> VCOP)
    - vessel ready for cargo operation signal (ROC -> VCOP; VCOP -> Terminal Operator)
    - terminal ready to work signal (Terminal Operator -> VCOP; VCOP -> ROC)
    - cargo operations signal (ROC -> VCOP)
    - (un-)loading plan (VCOP -> ACHS, Terminal Operator)
    - container at quay signal (Terminal Operator -> VCOP; VCOP -> ACHS)
- [(un-)load cargo] ACHS receives (un-)loading sequence, ACHS moves containers to planned positions at quay or on board, ACHS sends a report for each movement to VCOP, ACHS return cargo crane to parked position, ACHS sends completion signal
    - (un-)loading sequence (VCOP -> ACHS)
    - container ID and slot report (ACHS -> VCOP)
    - cargo operation completion (ACHS -> VCOP, ROC)
- [load containers 2/2] VCOP receives container and slot report, VCOP updates ROC and terminal operator, ACHS signals cargo operations complete, VCOP relays signal to ROC and terminal operator, VCOP send transshipment notice to ModalNET
    - container ID and slot report (ACHS -> VCOP)
    - status update (VCOP -> ROC, Terminal Operator)
    - cargo operations complete signal (ACHS -> VCOP; VCOP -> ROC, Terminal Operator)
    - transshipment notice (VCOP -> ModalNET)
- shipping company (IWT) sends pick-up notice to ModalNET
    - pick-up notice (Shipping Company (IWT) -> ModalNET)
- [IWT departure processes 1/2] the inland vessel checks for sufficient fuel or enough battery power, if insufficient the ROC requests bunkering or a battery swap, the bunkering or battery provider confirms the request before the refuelling process is executed, for bunkering a comparison of the bunker quantity is required, once the vessel is ready for departure the departure intention is signalled by the ROC to the AVSPM which replies with a confirmation of the departure time for the vessel, once the terminal has signalled ready for departure through the AVSPM the vessel starts the unmooring sequence
    - bunkering request (ROC -> Bunkering Provider)
    - bunkering confirmation (Bunkering Provider -> ROC)
    - bunker quantity notice (ROC -> Bunkering Provider)
    - battery swap request (ROC -> Battery Provider)
    - battery swap confirmation (Battery Provider -> ROC)
    - departure intention (ROC -> AVSPM)
    - departure time confirmation (AVSPM -> ROC)

  - readiness signal for departure (Terminal Operator -> AVSPM; AVSPM -> Auton. Vessel)
  - Start unmooring sequence signal (Auton. Vessel -> AMS)
- [unmooring at terminal] vessel signals AMS to start, AMS removes all mooring lines, AMS moves robot arm to parking position, AMS signals unmooring compete
  - start signal unmooring sequence (Auton. Vessel -> AMS)
  - signal unmooring complete (AMS -> Auton. Vessel)
- [IWT departure processes 2/2] AMS signals mooring complete, vessel updates status unmoored with AVSPM, Vessel departs from port and sends departure notice to AVSPM, bunkering or battery provider create and issue invoice for their services
  - unmooring complete signal (AMS -> Auton. Vessel)
  - vessel unmoored signal (Auton. Vessel -> AVSPM)
  - departure notice (Auton. Vessel -> AVSPM)
  - invoice (Bunkering Provider, Battery Provider -> Auton. Vessel)
- vessel deregisters with port authority, vessel informs next terminal about voyage
  - departure notice (Shipping Company (IWT) -> Port Authority of Origin)
  - voyage information (Shipping Company (IWT) -> Terminal of Destination)
- [IWT transport containers] vessel requires lock passage and switches to high-attention mode, ROC notifies lock operator, lock operator provides occupancy information, ROC adjusts vessel course, vessel arrives at lock and enters once entry is possible, vessel moors inside lock, lock operator performs lockage and provides leave advise, vessel unmoors and exits lock, vessel switches to low-attention mode and continues journey
  - service request (with ETA) (ROC -> Lock Operator)
  - occupancy information (Lock Operator -> ROC)
  - mooring notice (ROC -> Lock Operator)
  - leave advise (Lock Operator -> ROC; ROC -> Auton. Vessel)
- Shipping company sends loading / discharge request to terminal of destination, if required shipping company submits export customs declaration, customs office of exit processes export declaration and sends export confirmation to customs office of export, customs office of export transmits an export notice to customs agent, customs agent informs log. planner
  - loading / discharge request (Shipping Company (IWT) -> Terminal of Destination)
  - export customs declaration (Shipping Company (IWT) -> Customs Office of Exit)
  - export confirmation (Customs Office of Exit -> Customs Office of Export)
  - export notice (Customs Office of Export -> Customs Agent; Customs Agent -> Log. Planner)
- [IWT arrival processes 1/2] identical to description above
- [execute mooring sequence] identical to description above
- [IWT arrival processes 2/2] identical to description above
- vessel registers with port authority
  - arrival notice (Shipping Company (IWT) -> Port Authority)
- [unload containers 1/2] identical to load containers described previously
- [(un-)load cargo] identical to description above
- [load containers 2/2] identical to load containers described previously

- shipping company (IWT) sends drop-off notice to ModalNET, terminal operator acknowledges receipt, shipping company provides transport documents to terminal operator, transport leg is complete, IWT vessel departs from port and deregisters from port of destination, terminal operators and port authorities determine fees
    - drop-off notice (Shipping Company (IWT) -> ModalNET)
    - acknowledgement of receipt (Terminal Operator -> ModalNET)
    - transport document (Shipping Company (IWT) -> Terminal Operator)
    - departure notice (Shipping Company (IWT) -> Port Authority of Destination

Phase 4: Progress supervision

- consignor or log. planner request status report for shipment from ModalNET, ModalNET uses monitoring and traceability information to generate status report, ModalNET provides status report
    - status report request (Consignor, Log. Planner -> ModalNET)
    - status report (ModalNET -> Consignor, Log. Planner)

Phase 5: Shipment completion and invoicing

- terminals and port authorities issue invoice to IWT shipping company for handling and port fees, IWT shipping company, truck (pre-haul) and customs agent issue invoice to log. planner, log. planner processes invoice and informs consignor of shipment completion, log. planner issues invoice to consignor, all parties pay their respective invoices
    - invoice (Terminal of Origin, Port of Origin, Terminal of Destination, Port of Destination -> Shipping Company (IWT))
    - invoice (Shipping Company (IWT), Truck (pre-haul), Customs Agent) -> Log. Planner)
    - shipment order completion notice (Log. Planner -> Consignor)
    - invoice (Log. Planner -> Consignor)