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D2.1 - STATE-OF-THE-ART AND BASELINE FOR THE SEAMLESS USE CASES

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Responsible Author(s)	Hendrik Jungen, Patrick Specht, Jakob Ovens, Thorsten Friedrich (ISL)		
Contributor(s)	Anita Abođi (FTTE), Cyril Alias (DST), Pablo Gil Ara (VPF), Anastasiya Azarko (PNO), Igor Bačkalov (DST), Lea Corbeck (DST), Miguel Llop Chabrera (VPF), Marion Degache (VNF), Fionn Halleman (VNF), Ole Hartwig (PoB), Morten Ingebretsen (KMNO), Jorge Miguel Lara López (VPF), Jan Karsten (KMFI), Vladislav Maras (FTTE), Aida Mora (VPF), Odd Erik Mørkrid (SO), Håvard Nordahl (SO), Ann-Sofie Pauwelyn (Zulu Associates), Danijela Pjevčević (FTTE), Vassilis Podimatas (NTUA), Aleksandar Radonjić (FTTE), Bob Spanoghe (POAB), Antoon Van Coillie (ZULU Associates)		
Reviewer(s)	Vladislav Maraš (FTTE), Cyril Alias (DST)		
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EXECUTIVE SUMMARY

Expectations towards automation in maritime and inland shipping are manifold and range from a solution for labour shortages, the outlook of higher logistical performance to a stronger uptake of sustainable propulsion technologies. An important prerequisite for market acceptance and exploitation is to ensure an economically viable integration of autonomous waterborne concepts into multimodal transport and logistics chains. The SEAMLESS project addresses this challenge by embedding the development of technical Building Blocks within a landscape of curated use cases that represent relevant scenarios for automated and autonomous waterborne operations in shortsea shipping and inland waterway transport.

This deliverable represents the work carried out in SEAMLESS task 2.1 from January 2023 to September 2023 and provides a detailed description of the different envisioned SEAMLESS concepts and respective logistics environments and establishes the current status quo for each use case. First, a set of demonstration use cases that are dedicated to testing the SEAMLESS Building Blocks under real-world conditions and featuring physical as well as digital assets were analysed. Within Northern Europe, the project places its developments within a concept for an autonomous and emission-free waterborne transport service network in the vicinity of Bergen. Another demonstration use case covers autonomous inland waterway transportation within the Lower Rhine and French-Belgian canal network which represents some of Europe’s most important inland waterways. On a conceptual level, the development of the project is reflected in the light of six transferability use cases which aim at evaluating the transferability and replicability of the project’s building blocks in other contexts. The report provides an initial outline of these cases which includes different kinds of cargoes and are geographically spread along important MoS or TEN-T corridors.

Along with a description of the baseline for each scenario, the results of this preliminary study highlight existing areas of action and weaknesses of the current state of proposed concepts for autonomous operations. The list of identified gaps and requirements towards the SEAMLESS building blocks may be further elaborated on within the conceptual and technical work packages and may thereby serve as a repository or backlog for further prioritization and coordination of the respective activities. Lastly, the document allows for a consolidated reflection of motivational factors and barriers for the use cases in light of the domain of autonomous shipping as a whole, which may ultimately help to derive a clearer research agenda for the next phases within the project.

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REFERENCES TO THIS DOCUMENT – ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

Abbreviation	Description
AdSP MAS	Autorità di Sistema Portuale del Mare Adriatico Settentrionale (North Adriatic Sea Port Authority)
AIS	Automatic Identification System
APICS	Antwerp Port Community Information System
BB	Building Block
BTS	Barge Traffic System (Antwerp)
CEMT	Conférence Européenne des Ministres des Transports
DC	Distribution Centre
DDTM	Direction départementale des territoires et de la mer
DEASP	Environmental Energy Planning Document
DG	Dangerous Goods
DGITM	Direction générale des infrastructures, des transports et des mobilité (French ministry of transport)
DUC	Demonstration Use Case
EMS	Environmental Management System
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
EU	European Union
FCL	Full container load
GHG	Greenhouse Gas
IWT	Inland Waterway Transport
LEZ	Low emission zone
LOA	Length over all
LoLo	Lift-on Lift-off
LCL	Less than container load
LSP	Logistics Service Providers
NOK	Norwegian Krone (currency)
PMIS	Port Management Information System
RIS	River Information Service
RCC	Remote Control Centre
ROC	Remote Operations Centre
ROI	Return on investment
RoRo	Roll-On Roll-Off

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RTS	Rail Traffic System (Antwerp)
SSS	Short-Sea-Shipping
TEU	Twenty-Foot Equivalent Unit
TRL	Technology Readiness Level
TOS	Terminal Operating System
TUC	Transferability Use Case
UKC	Under Keel Clearance
ULCV	Ultra Large Container Vessel
UPS	Uninterruptable Power Supply
VHF	Very High Frequency Radio
VNF	Voies navigables de France
VTS	Vessel Traffic Service
Zedis	Zeebrugge Electronic Data Interchange Service

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DEFINITIONS

Autonomous Ship System

In accordance to previous projects, the term acknowledges that an autonomous ship is usually integrated into a broader system "including land and ship based sensors and control systems" (Rødseth, p. 34).

Remote Control Centre (RCC)

A Remote Control Centre relates to a facility external to the craft that allows to monitor or take control over some or all navigational ship processes. Within this report, the term will be used only in the context of inland navigation.

Remote Operations Centre (ROC)

A Remote Operations Centre is a facility outside an autonomous vessel that allows to operate some or all aspects of its functions. It may consist of one or more Remote Operations Workstations, mission planning and administrative systems and services as well as associated infrastructure.

Shortsea Shipping (SSS)

Shortsea Shipping is considered as the transport of goods over short and continental distances. As such, it also includes "feeder services" which are used to consolidate or redistribute freight flows originating from intercontinental services.

Inland Waterway Transport / Inland Navigation (IWT/IN)

Inland Waterway Transportation is considered as the transport of goods by means of ships or barges on waterways on inland waterways, i.e., free-flowing or canalized rivers or canals, as classified by the UNECE Bluebook. In addition, the term "inland navigation" may be used to emphasize the act and tasks related to sailing on inland waterways.

1 INTRODUCTION

1.1 PROBLEM STATEMENT

The concept of highly automated and autonomous waterborne transport is receiving more and more attention Negenborn et al. (2023). Expectations are manifold and range from solving labour shortages by reducing personnel requirements and improving working conditions, the outlook of higher logistical performance in terms of availability and flexibility over to fostering the uptake of more sustainable propulsion technologies. With respect to shortsea shipping (SSS) and inland waterway transport (IWT), automation in shipping ultimately carries the hopes of stimulating modal shift and thus enabling more sustainable transport which is needed to reduce global carbon emissions.

From a research perspective, a lot of effort is currently underway to realize the technological and organisational building blocks for highly automated and autonomous waterborne transportation. As major challenges have been and are still to be overcome, the main focus has predominantly been on the development, testing and evaluation of the autonomous waterborne transport concepts itself. However, maintaining this focus poses a significant risk to the adoption of these technologies in real transport contexts as it involves the risk of missing out transport customers' expectations and a lacking integration of waterborne transport into the broader transport system. By the end of the day, a waterborne transport focus may lead to situations in which engineering achievements do not obtain the required level of user acceptance.

What is required is a seamless and economically viable integration of autonomous waterborne concepts into multimodal transport and logistics chains. As such, the SEAMLESS project takes in a holistic perspective and aims at redesigning logistics systems "to support seamless, safe, synchromodal, resilient cargo transport" (SEAMLESS Consortium, 2022, p. 13). A set of carefully selected use cases that represent relevant scenarios for automated and autonomous waterborne operations in shortsea shipping and inland waterway transport will have a significant role in this task. Based on the respective SEAMLESS use case landscape, a logistics system design (WP2) will guide the developments of physical and digital building blocks that enable autonomous port operations (WP3), autonomous fleet operations (WP4) as well as digitalized logistics operations (WP5). The different solutions will then individually and jointly be evaluated within Demonstration and Transferability Use Cases (WP6/7).

This deliverable represents the work carried out in SEAMLESS Task 2.1 from January 2023 to September 2023 and will provide a detailed description of the different use cases that will be further elaborated on during the course of the project. The report includes an initial outline of the various envisioned SEAMLESS concepts, will map the existing logistics environment, and will establish the current state-of-the-art for each of the use cases. As such, the deliverable will ensure a common terminology and understanding of the inside and outside the consortium of the SEAMLESS use case landscape. By describing existing transport solutions, it also introduces the reference cases to which the SEAMLESS evaluation results will be mapped against in the later course of the project.

1.2 SEAMLESS USE CASE LANDSCAPE

As introduced in the previous section, the SEAMLESS use case landscape is considered as the central environment for the validation and verification of the SEAMLESS building blocks in terms of technical, economic, environmental and social aspects. It can be divided into two types of use cases, Demonstration Use Cases (DUC) and Transferability Use Cases (TUC):

DUCs are designed to inspire and test the SEAMLESS building blocks under real-world conditions and thus to verify the targeted technology readiness level (TRL) (SEAMLESS Consortium, 2022, p. 16). Demonstrations will cover physical assets (e.g., vessels and vehicles, cargo flows, transshipment facilities) as well as digital assets (e.g., software systems and information flows) and may be expanded by means of virtualization (e.g., simulated vessels and equipment, or environmental conditions). For economic reasons, it will not be possible to realize and simultaneously put all the elements into a fully functional supply chain. In that sense, the services will be examined in different scenarios that are intended to simulate realistic waterborne transport outlines.

Table 1: Overview SEAMLESS Demonstration Use Cases

	Northern Europe	**Central Europe**
Means	SSS	IWT
Cargo	Containerized	Containerized
Route / network	Bergen and hinterland ports	Dourges – Antwerp – Duisburg
MoS or TEN-T corridor	Northern Maritime Corridor	Rhine-Alpine / North-Sea-Baltic / North-Sea Mediterranean
Extra-EU corridor	Norway	-

TUCs shall reflect commercially viable scenarios which will be examined and evaluated at a conceptual level (SEAMLESS Consortium, 2022, p. 18). The analyses will aim at evaluating the transferability and replicability of the Building Blocks (BB) and will thus have a guiding role for the development stages in order to avoid results that are too specifically adapted to the demonstration use cases and thus lack generalisability. Also, they will help creating sustainable business models in the upcoming tasks within the project (e.g., T6.4), outline marketing and deployment opportunities as well as adoption barriers and constraints on the transport routes across Europe and between EU member states and associated countries within the European TEN-T network.

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Table 2: Overview SEAMLESS Transferability Use Cases

	Western Europe	**Central Europe-UK**	**Adriatic Sea**	**Black-Sea**	**Danube**	**West Med**
Means	IWT	SSS	SSS/IWT	SSS	IWT	SSS
Cargo	Liquid Bulk	Container	RoRo	Container	Container and RoRo	Container RoRo
Route/ network	Hinterland of Dunkirk	Antwerp – Hull (UK)	Venice – Piraeus	Piraeus – Constantza	Constantza – Novi Sad	Valencia – Castellón/Alicante/Teruel/Zaragoza/Albacete/Murcia/Almería
MoS or TEN-T corridor	North Sea – Med	Western Europe	South-East Europe	South-East Europe	Rhine-Danube	South-West Europe
Extra-EU corridor	-	UK	China PR	Turkey	Serbia	-

As can be derived from Table 1 and Table 2, the different use cases can be described and compared in terms of specific characteristics:

From the perspective of waterborne transport concepts, it becomes apparent that SEAMLESS does not only consider maritime **shortsea shipping** but also **inland navigation**. This distinction allows to assess a broader spectrum of autonomous operations in terms of nautical requirements, vessel operational concepts and conditions, or legislative frameworks but also allows to foster synergies between maritime and inland shipping. Also, the use cases focus on very **different types of cargos** ranging from containerized goods to RoRo applications and to the transport of liquid bulk. This requires the consideration of different vessel concepts, cargo handling infra- and superstructures but also takes into account different market settings. The same is also valid for the variety of **routes and networks** (shown in Figure 1) within the use case landscape that involve domestic as well as cross-border transports. Implications also arise with respect to nautical conditions and respective legislative regimes.

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Figure 1: Geographical scope of SEAMLESS Use Case Landscape

Source: PNO

In conclusion, the SEAMLESS Use Case landscape represents a diverse set of cases that reflect the heterogeneous conditions of the European waterborne transport network. This is considered a strong foundation for the upcoming analyses and developments to obtain a high degree of transferability and informative value.

1.3 SEAMLESS LOGISTICS MODEL TAXONOMY

This deliverable proposes and makes use of an initial logistics model which is intended to help contextualize and map the physical and information processes and interdependencies within the cases. Due to its generic nature the logistics model is intended to be adapted depending on the specific purpose and scope of the investigation. It adopts a multi-dimensional approach as it is introduced in the Industry Blueprint by the Digital Container Shipping Association (DSCA) which was founded by the largest container shipping companies (DSCA, 2022).

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The first dimension is established to set the logistical scope of investigation and introduces a set of generic milestones. In its most comprehensive form, this reaches from the moment a transport demand is generated up to the point that it is fully satisfied and all accompanying tasks completed. Within the DSCA taxonomy, this is referred to as the "end-to-end" (E2E) process. For example, it may be decided to only investigate the waterborne transport from leaving the port to arriving a port. Against the background that SEAMLESS considers waterborne transport chains, it is assumed that each logistics flow comprises at least three transport legs (pre-carriage, main haul, on-carriage). However, it is also possible to extend this representation to more complex designs.

The second dimension sets the scope on specific objects that are part of spatial-temporal transformation activities and thus are subject of a logistics "flow". Mostly, flows comprise a physical as well as an informational sphere and may relate to "shipments" (i.e., act of shipping specific goods), "equipment" (e.g., containers or trailers) or "vehicles" (e.g., trucks, vessels, trains). The latter represents a deviation from the DSCA taxonomy, as we include the possibility to represent other transport vehicles that are used for pre- and on-carriage or movements within ports.

The most specific level of investigation is the process dimension which is used to describe a series of related activities, messages or artifacts related to a flow object (dimension 2) within a set frame of investigation (dimension 1). The process level also maps different parties involved into the activity frame. The representation used for the scope of this deliverable is the Business Process Modelling Notation 2.0 (BPMN 2.0). Figure 2 visualizes the different dimensions and perspectives that may be considered in the analysis.

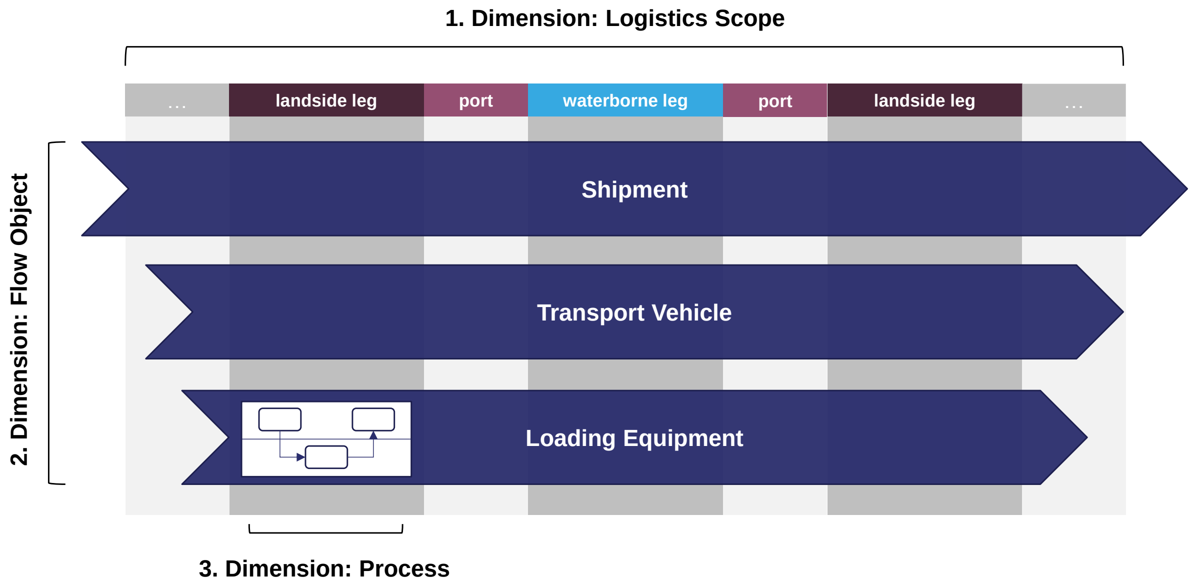

Figure 2: Modelling Taxonomy used within this deliverable

Source: ISL based on DSCA (2022)

1.4 COURSE OF ACTION

An important requirement towards the methodological approach is to provide a common framework that allows for comparison between the different use cases, while allowing enough flexibility to capture and reflect the specifics of each individual scenario. Figure 3 describes the 5-stage research framework that has been followed and that will be adopted to structure this report.

- First initial ideas and concepts of the proposed SEAMLESS Use Case are to be gathered during the first stage for both DUCs. This includes the analysis of motivators and drivers behind the use case as well as gathering a preliminary outline of the waterborne transport specifics.
- Next, characteristics of the existing logistics environment are mapped for all use cases in stage 2. This includes political, economic, social, technological, environmental, and legal aspects that influence logistics operations within the use case.
- A more detailed analysis of nautical conditions, existing processes and information flows is conducted for the DUCs and mapped using the BPMN2.0 language in stage 3. Similarly, existing transportation concepts are described for the TUCs with a reduced level of detail.
- Summarizing the results of the preceding stages, gaps between what is to be established for the DUCs and the current situation are initially defined. In the case of the TUCs, potential autonomous or highly automated use cases are outlined as the **fourth stage**.
- Finally, in **stage 5** a consolidated look will help shaping a research agenda for the remainder of the project. This includes common hypotheses and initial motivations to be proofed, existing barriers, transferability options as well as common implementation recommendations.

Data collection and ideation have been conducted based on secondary data, use case specific workshops as well as stakeholder surveys. After that, results were compiled using digital whiteboarding tools.

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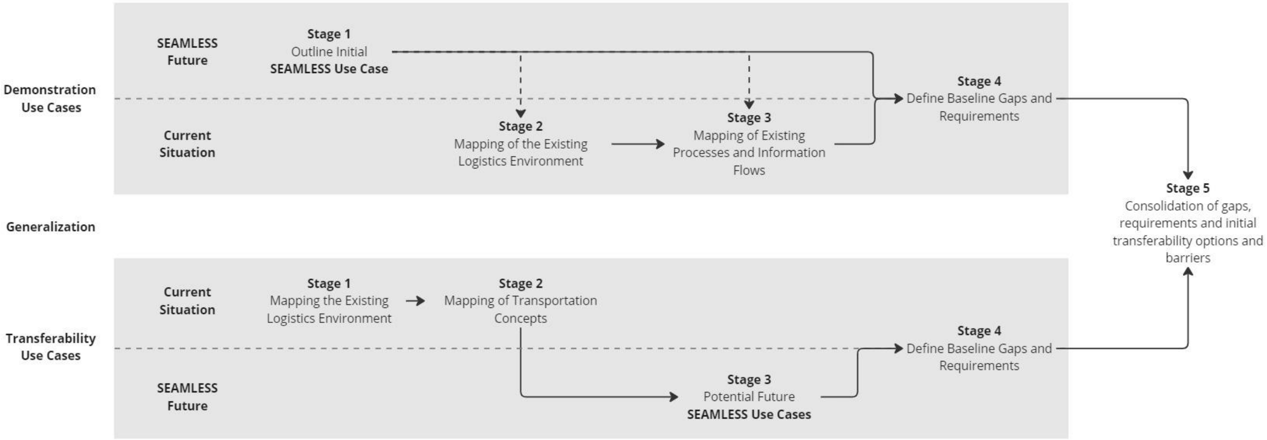

Figure 3: Illustration of Task 2.1 Research Framework

Source: ISL

Chapter 2 focuses on the two DUCs "Northern Europe" (2.1) and "Central Europe" (2.2). The preliminary state of the six SEAMLESS Transferability Use Cases is presented within chapter 3. The succeeding Chapter 4 outlines a derived research agenda by summarizing the overall findings in terms of common opportunities and motivational factors (4.1), threats and barriers (4.2) for autonomous shipping as well as identified research directions (4.3). Lastly, chapter 5 provides an outlook on how the results are expected to be used within the ongoing course of the project.

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2 SEAMLESS DEMONSTRATION USE CASES

2.1 NORTHERN EUROPEAN DEMONSTRATION USE CASE

2.1.1 SEAMLESS Use Case Outline

2.1.1.1 Problem Statement and Motivation

With the aim of improving the quality of urban life and health of its population, the city council of Bergen (Norway), has expressed the goal to phase out fossil fuels by 2030 and to reduce the emissions of greenhouse gases (GHG) by 50 per cent until 2023 as compared to the levels of 1991 (Bergen Kommune, 2019, p. 8). This goal has been operationalized by various emission requirements for different industrial sectors, low-emission zones with additional toll on days with high emission levels and the expectation that zero emissions are to be strived for, whenever technology allows. As a result of this political agenda, the Bergen Port Authority faces the challenge of reducing the environmental footprint of its activities which currently take place in the city centre. Today, Bergen represents the main hub for maritime cargo within the region and as such accounted for around 59 million tonnes of cargo in the year 2022. Against this background, decisions have been made to relocate major parts of port operations to Ågotnes, which is located on the island of Sotra, 11 nautical miles west of the City of Bergen (see Figure 4).

Experts believe that this shift will significantly increase future road transports in the region. For example, in order to substitute the current flows into the port of Bergen, around 40.000 additional truck runs are expected to be required between Sotra and Bergen each year (Flowchange, 2019, p. 3). According to estimations of the Bergen Port Authority, this not only comes with an increase of transportation costs between NOK 600-800[1] per round trip which would strongly weaken the competitive position of the region for maritime transport (Flowchange, 2019, p. 11) but would ultimately increase the emission of greenhouse gases and pollutants in relation to the current situation. This outcome would foil the original ambition and result in an externalization of environmental effects caused by industrial and urban activities.

To prevent this scenario, the Port Authority of Bergen follows the strategy of establishing a zero-emissions logistics network within the area which makes use of autonomous and emission-free feeder loops and zero-emission terminal operations as well as last and first mile transports. This bigger vision creates the framework for the SEAMLESS DUC1 which aims at investigating and

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[1] ~71 € (NOK 1 = 0,089 € on the 3rd of August 2023)

demonstrating a containerized **Ågotnes-Bergen feeder service** by means of a highly automated and autonomous waterborne transport concept.

2.1.1.2 Waterborne Transport Concept

This section outlines the current state of knowledge on the future waterborne transport concept for the Northern European Demonstration Case, for which it was decided to focus on containerized cargo. While it is used to set the frame for the analysis of the current situation and should serve as guidance for the later work packages, the details of this concept may be subject to changes during the course of the project.

Service Network Design

The proposed service network connects the ports of Bergen and Ågotnes with a number of smaller satellite ports within the area. In this concept, Ågotnes is designed to represent the major consolidation hub for international maritime transport, especially containerized cargo.

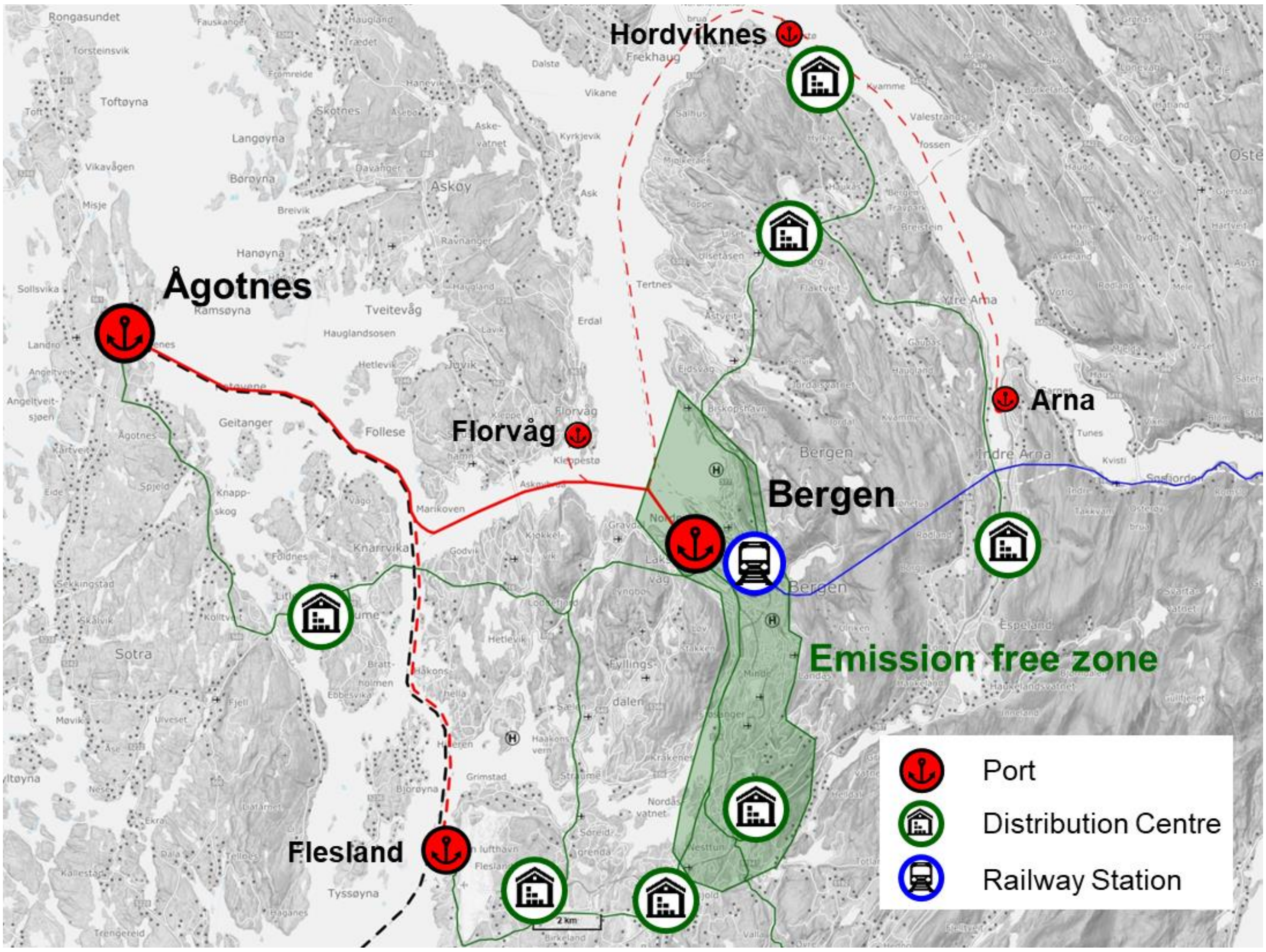

Figure 4: Envisioned network and routes

Source: ISL based on Flowchange (2019) and Norwegian Mapping Authority (2023)

Besides Ågotnes and the port in the city centre of Bergen (Bergenhus city district), four other network nodes are currently under investigation, covering Flesland (Ytrebygda city district), Hordviknes (Åsane city district), Arna (Arna city district) and Florvåg (Askøy municipality) as illustrated in Figure 4. While the full set of suitable services needs to be defined based on demand patterns within the region, a scheduled service between the terminals in Ågotnes and Bergen is considered as the initial base scenario.

Based on an investigation of current flows and volume distributions per weekday and hour, the Port of Bergen envisions a scheduled feeder loop that covers 1-2 roundtrips per working day and 2 trips per day on the weekends when a lot of cargo is expected. The travel time for this 11 nm distance is expected to be around 90 minutes while port stay time will amount to 3 hours in Ågotnes and 1.5 hours in Bergen (Flowchange, 2019).

On- and pre-haulage between the respective ports and consignees or distributions centres (DC) is expected to take place with electric trucks[2] via emission free corridors (see Figure 4). A similar transport chain is currently deployed within the ports of Horten and Moss located at the Oslofjord and distribution centres of the Norwegian wholesale company ASKO (ASKO, 2023).

Vessel Operations

The use case envisions the operation of self-propelled vessels that allow for highly automated and autonomous operations. The vessels are planned to operate unmanned and in a “Low Attention Mode” via a Remote Operations Centre (ROC). In this context, low attention means that the respective operator takes in a monitoring role for more than one simultaneously sailing vessels (1:n relationship). In order to realize this, the vessel must be able to carry out most tasks within the port and during transit without human support (Rødseth, pp. 42–43). Given the above-mentioned schedules, these functionalities must be guaranteed day and night and under moderate to tough weather conditions.

To this date, the expected degree of automation with regards to the planning of vessel operations as well as maintenance are still to be defined. However, given the need of providing a competitive service, reducing manual efforts within these activities seems to be strongly encouraged, with an ultimate goal of full autonomy within the next and on dependence of regulating authorities.

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[2] It is worth mentioning that Norway posseses the highest share of renewable sources in electricity production in Europe Norwegian Ministry of Petroleum and Energy (2015).

A type of vessel that meets these requirements and thus has been selected for the use case deployment is the DNV GL classified **AutoBarge** vessel concept developed by Naval Dynamics in partnership with Kongsberg. It covers two designs, a RoRo and a container version. While there exists no containerized AutoBarge yet, two RoRo units (Therese: IMO 9921788; Marit: IMO 9921776) have been brought into service in 2022 and are currently operating for ASKO Maritime between Horten and Moss.

Figure 5: RoRo AutoBarge "Therese" at berth in Horten, Norway

Source: ISL

The AutoBarge comes with dimensions of a length over all (LOA) of 67.50 metres, a beam of 15.00 metres and a maximum draft of 1.80 metres while displacing around 640 dwt. The propulsion is realized as a battery electric system with a capacity of around 1,800 kWh. It covers a stern azimuth thruster with 500 kW as well as an azimuth thruster with 200 kW. At an average speed of 8 knots, it is able to travel a distance of 24 nm per charge. The recharging process is currently being automated and takes around 1 hour for one charge cycle.

In the containerized version, these vessels may carry up to 64 TEU which are stored in 4 rows and in up to 2 tiers. If required, it is possible to equip the cargo hold with metal rails to prevent lateral displacement in case of harsh weather conditions. However, the need for this needs to be validated depending on the nautical conditions (see 2.1.2.3).

The RoRo version has a capacity of up to 16 trailers that can be loaded and unloaded using an automated ramp at the stern of the vessel. For the event of rough weather conditions, trailers can be secured at lashing points that are installed on the cargo deck. Unloading of 1 trailer takes around 2 minutes each, allowing for complete discharge within less than one hour with one terminal tractor.

Remote Operations is realized by Kongsberg and operated by Massterly and considers different stages towards autonomy, ranging from monitoring & support operations to direct control and finally monitoring of autonomous operation by single or multiple vessels. A first operational phase with reduced manning (Master + Deck Officer + Engineer) has been completed in May 2023. In the current phase, the system is being tested with constrained autonomous operations, in which the remote operator has the role of monitoring, supervising, and interacting with an autonomous vessel, while a crew is still on board.

Port Operations

One central objective for port operations within the proposed logistics system is to significantly improve the overall efficiency. Vessels approaching at berth are supposed to moor and charge automatically, with the help of land or ship-based systems. Commercial, shore-based solutions for automated mooring are already available on the market and meet the functional requirements of unmanned ship operation. However, these solutions entail high investment cost, which would lower the profitability or even inhibit the adoption of autonomous shipping, especially in the case of smaller terminals as is the case for some of the mentioned above. This hurdle could be overcome by ship-based mooring systems, which, still have a lower technological readiness level. These advantages and disadvantages of both approaches will be subject for analysis within the use case analysis.

In order to guarantee the proposed schedules, servicing of vessels and trucks is expected to take place 24/7. Besides these general requirements, both ports within the feeder loop will fulfil different roles and thus pose different requirements. The following description only includes containerized operations, as it is the purpose of the demo study.

The terminal of Ågotnes is expected to become the main hub for international and domestic trade and will thus replace respective operations in the centre of Bergen. As such, it requires to not just accommodate facilities for loading and unloading of geared and non-geared vessels, but should also provide space for storage of full and empty containers, repacking facilities as well as customs handling. Moreover, the Port Authority aims at increasing container annual throughputs in the region to around 60,000-70,000 TEU within the next decade. This needs to be taken into account with respect to required space and equipment. Figure 6 shows the designated location of the terminal.

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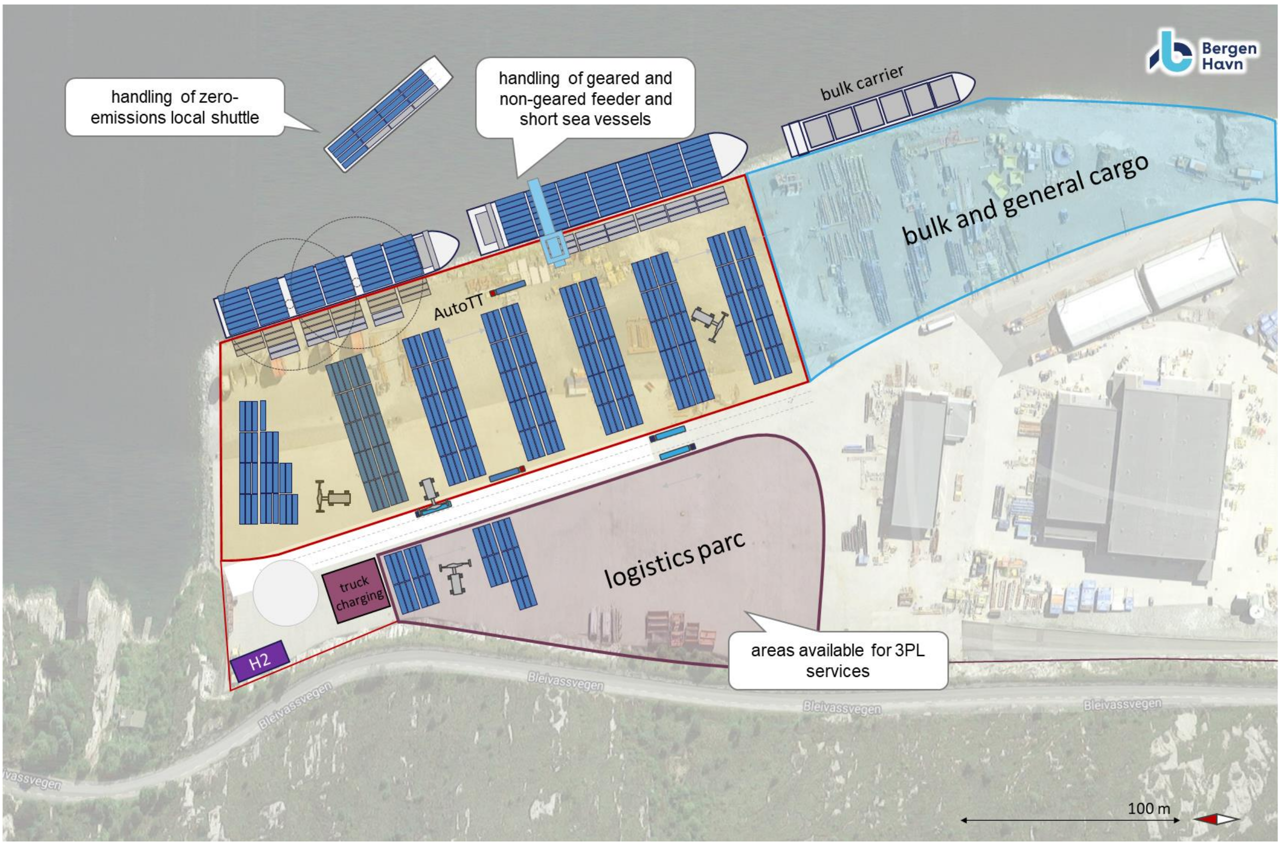

Figure 6: Preliminary location and layout of the terminal in Ågotnes

Source: Flowchange (2019) - translated

For the Bergen terminal, the aim is to minimize the footprint of port operations in terms of required space and pollution as much as possible. Therefore, it is expected to serve solely as a transhipment and short-term buffering area and will not cover further logistics services in the long run. The envisioned design covers a quay of 60 metres which is connected to a terminal area of 50 x 60 metres (3,000 m^2). As such, the storage capacity amounts to around 128 TEU. Loading and unloading of vessels, movements within the yard and transhipment from and to trucks is expected to be carried out by means of one manned or autonomous reach stacker. Given the above-mentioned schedule, the servicing of one vessel needs to be carried out within 3 hours, while at the landside, 10 trucks may be served per hour. Given capacity and space restrictions, pre-announcement of trucks is a prerequisite to allow for efficient yard management and landside handling. The designated area of the terminal is located north of the Puddefjord Bridge and is shown in Figure 7.

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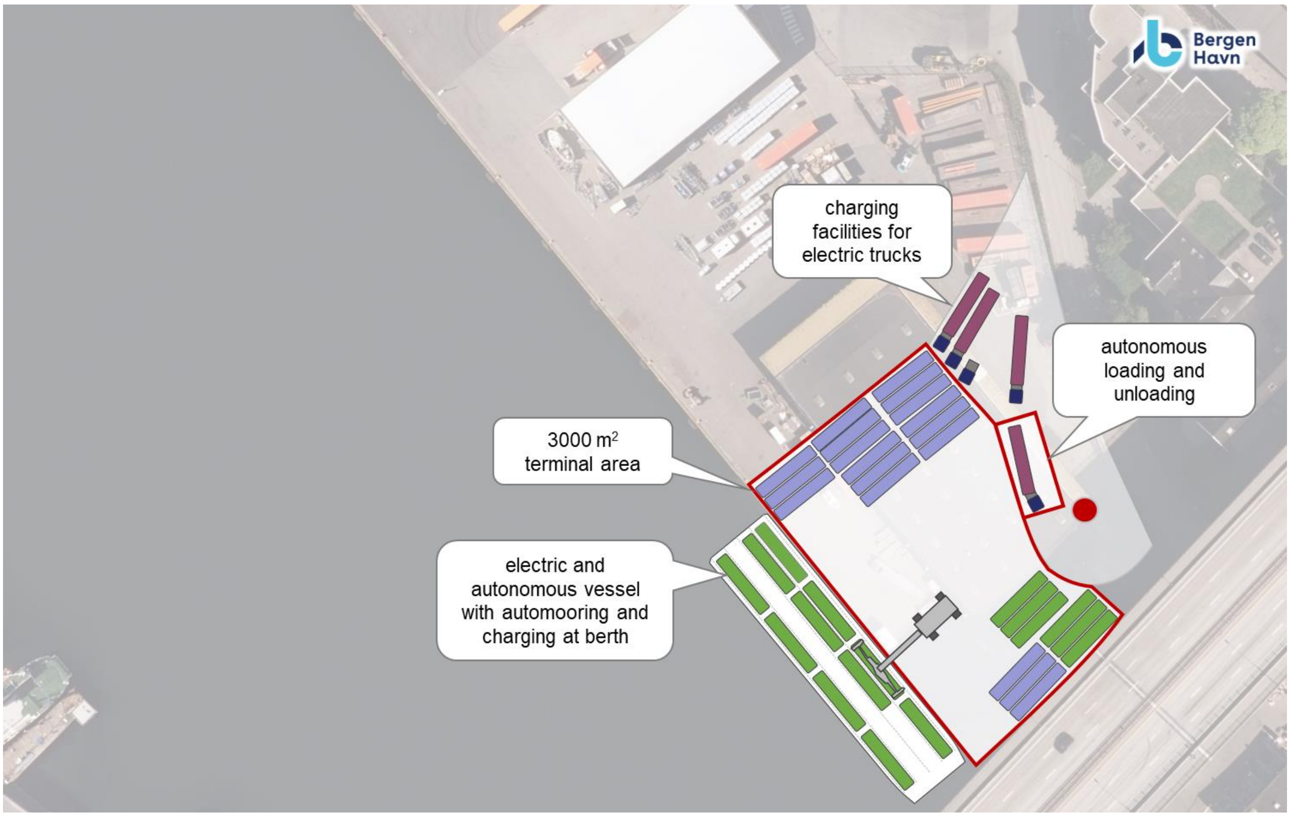

Figure 7: Preliminary location and layout of the terminal in Bergen

Source: Flowchange (2019) - translated

2.1.2 Logistics Environment

2.1.2.1 Transport & Market

Bergen is located in the county (nor: "fylke") of Vestland. In the year 2022, the county was home to 641,292 inhabitants of which 289,330 lived in the city of Bergen, which serves as its administrative centre.[3] Bergen constitutes the economic focal point of Vestland as it is base to several offices and accounts for 53.7 per cent of Vestland's employees (328,064 in 2022). It is worth noting that the proportion of employees engaged in industrial activities in Bergen (17.8 per cent) is comparably lower than the average share of Vestland which is at 22.0 per cent.[4] This indicates that in the city itself other economic branches, especially services, are relatively more prevalent. Industrial activities

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[3] Figures for 2022, based on Statistics Norway (nor: Statistisk sentralbyrå).

[4] Figures for 2022 based on Statistics Norway. Industrial activities include group levels B to F as per Standard Industrial Classification (SIC2007).

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settling in the periphery of urban agglomeration is a well-observed phenomena that will be addressed more detailed at a later point.

Transport Accessibility

The motorway E39 crosses the city of Bergen north to south. Northbound it is possible to follow the road along the coast up to Ålesund/Trondheim or turn eastbound onto E16 and head to the inlands, ultimately reaching Oslo. Southbound, the E39 leads towards Stavanger and Kristiansand. Again, it is possible to turn eastbound, where the E134 provides connection to Drammen/Oslo. Right in the centre of Bergen an interchange gives the possibility to turn further westbound. Motorway 555 connects Bergen with Straume and the island of Sotra, where Ågotnes is also located.

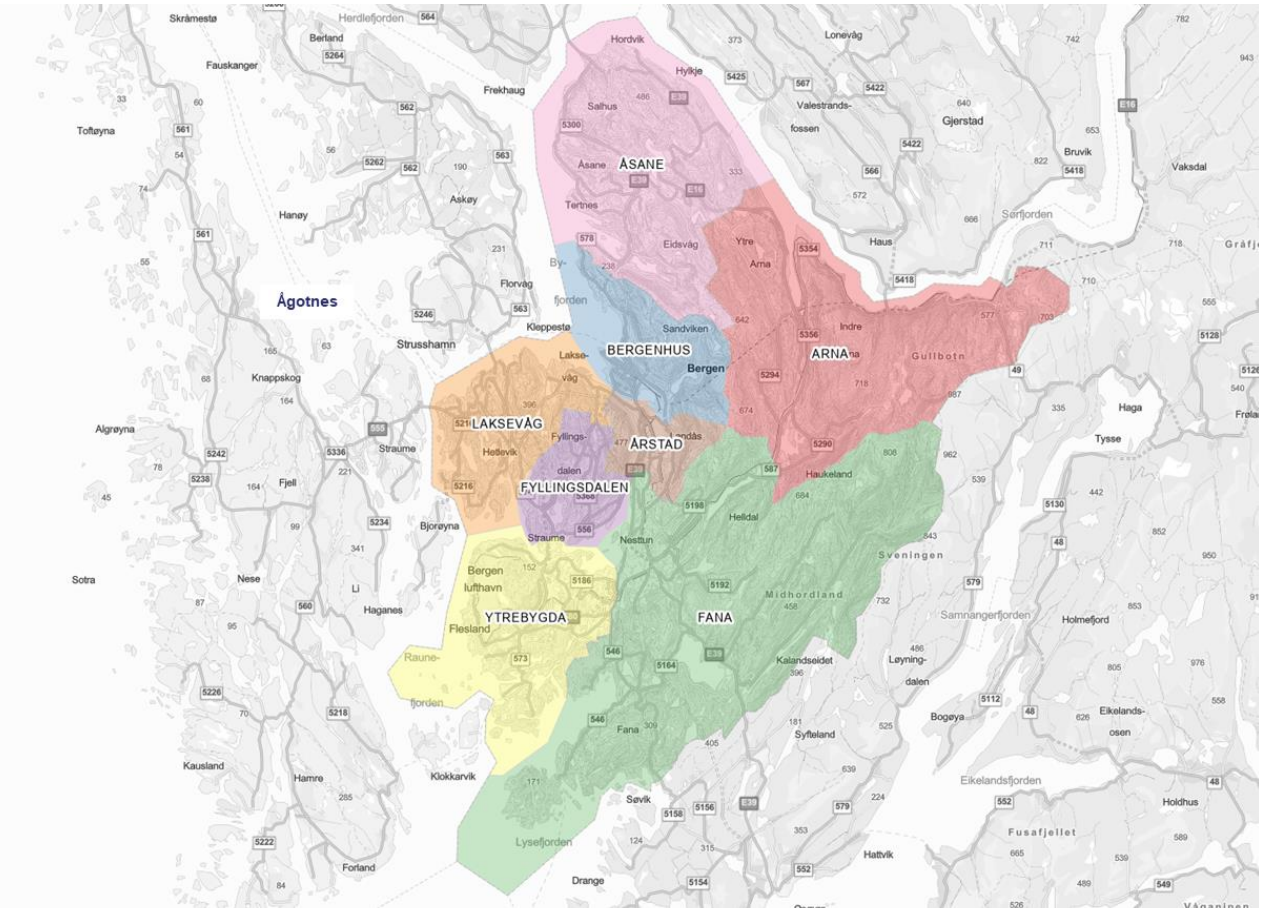

Figure 8: Map of Bergen District and Location of Ågotnes

Source: Bergen Kommune (2021)

Bergen's railway station is located in the centre of the city. Passenger and cargo handling take place in proximity. The international airport of Bergen is based in the south and is Norway's second-busiest airport.

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Current Role of Port Activities

The city's harbour plays a central role. The port serves as an important passenger transport hub. In 2022 travel activities resumed with 381,931 cruise passengers but remained below former heights when 600,000 cruise passengers passed Bergen.[5] The port marks one end of the famous Hurtigruten line which conveys post, passengers, and cargo northbound along the Norwegian coastline. The port provides many additional ferry lines. Bergen's economy has been shaped by its maritime connection. While traditional waterborne industries such as ship building or fishery are less present in central Bergen nowadays, these ties remain. The city is still considered the "*seafood capital"* of Norway. Aquaculture is well settled in the region and the city supports the industry in terms of innovation, research, and education.[6] Bergen also has strong links with the oil & gas industry. Due to the region's proximity to large oil fields supply for offshore rigs, maintenance and complementary services are provided in the area. In fact, Bergen and its surroundings (nor: Bergen and Omland; statistical entity) had a maritime throughput of 59 million metric tons of which 55 million metric tons are oil, oil products or liquified gas.[7]

According to the statistics of Bergen Port Authority of the total throughput only 0.5 million metric tons are associated with handling at public docks (nor: "offentlige kaier"). This refers to the terminals located in the centre of Bergen. Jekteviksterminalen hosts a wide range of operations. Cruise and ferry services provide many connections and possibilities to convey passengers, cars and freight (in trailers). Frieleneskaien and Dokkeskjærskaien have facilities for the handling of break bulk cargo and containers.

Local & Regional logistics structure

The port is a key piece in the city's logistic structure which is subject of the following analysis. Bulk cargo will not be considered because its transport chains are highly specific and subject to individual shippers often with own handling operations. This examination aims at depicting the flows that are relevant for the demonstration use case which is containerized cargo. To review this, the port cannot be assessed as a stand-alone system but rather as a piece of the general logistic network for the segment of containerized freight.

Therefore, the section regarding the logistics environment relies heavily on the Varestrømsanalyse for Bergensregionen 2013 (commodity flow analysis for the region of Bergen 2013) by Asplan Viak AS (2014) (NHO Logistikk og Transport, region Vestlandet being the client). While the base year of

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[5] Figures for 2022 based on Statistics Norway.
[6] https://www.investinbergen.com/business-opportunities/key-industries/seafood-and-aquaculture/
[7] Figures for 2022 based on Statistics Norway

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2012 is not representative in terms of transport volumes, this piece of work has been found to be the most precise source for the logistics structure of Bergen. The methodical assessment covers a detailed urban scope and has been carried out with the contribution of local logistics companies. The insights obtained from a sample of real transport data on such a detailed level cannot be matched with official statistical publications on transport. Since the survey is based on logistics companies, the unit of reference is shipments and not necessarily full truck or container loads.[8] However, this does not limit the implications in any way.

As of 2012, approximately 20 per cent of the considered long-haul freight was allocated to waterborne transport. The remaining portion is evenly split among the modes train and road (40 per cent each) (Asplan Viak AS, 2014; Flowchange, 2019, p. 8) Within Bergenhus, the central district of Bergen, logistics services providers (LSP) are located at the port and goods station. According to the Varestrømsanalyse, additional logistics service providers as well as shippers and consignees with a relevant volume are located in districts around Bergenhus, especially south(west)bound. A shift of more goods being moved to the outlying districts Åsane (north), Arna (east) or Ytrebygda (south, nearby the airport) was observed compared to the preceding examination with the base year of 2008. There is no indication that the trend of cargo's origin/destination moving to the urban periphery has stopped or turned around in the last decade. In fact, continuation seems more likely.

With 28,000 to 23,000 metric tons, the districts of Laksevåg, Ytrebygda, Bergenhus and Åsane account for similar shares of waterborne import cargo. Export activities are concentrated in Ytrebygda where nearly fifty thousand tons of freight designated for export via the port originate from. Ågotnes and Bergenhus rank second and third with 15,300 and 13,900 metric tons respectively. The port serves as an important gateway for the logistic environment of Bergen's districts, in the centre and the periphery. In contrast, municipalities outside of Bergen only account for marginal volumes of sea freight with the exemption of the municipality of Straume to some extent.

The number of TEU handled in the port picked up since the examination of 2012 where 31,529 TEU were handled (Asplan Viak AS, 2014, p. 18). After a minor decline in 2021, the container handling rose again reaching 41,234 TEU in 2022. Activities in the port focus on the weekend (+ Mondays)

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[8] As the study is survey-based transports that are conducted without logistic service providers are not represented. This is even more common for Bergen's sea shipments compared to the other modes. The survey data covers approximately 65 per cent of the port's throughput. Possible explanations include direct pick-up in the port by the consignee, shipping company providing road transport services (carrier's haulage), trailers of forwarders not included in the survey (foreign or non-Bergen-based). As this implies mostly full truck or container loads it reflects a minor shortfall and does not affect the analysis for the local logistic environment heavily.

when 72 per cent of the containers have been loaded or unloaded (Flowchange, 2019, p. 7). Container handling in the port initiates 20,000 truck trips into and out of the port per year.

Developments in the logistics environment

In the last ten years, the number of handled trailers fluctuated periodically but follows an upward trend. While in 2012 a total of 8,416 trailers were handled in the Port of Bergen, the year 2022 was closed with a total trailer throughput of 13,199 trailers. Although *container-like* cargo such as trailers and swap bodies could potentially be relevant for the demonstration use case if cargo is transported in containers instead, it will not be considered here. The transport chains are strongly incorporated to the ferries and their routes and the trailers will often travel longer distances into the hinterland after pick-up than most of the containers. In addition to that, handling of the trailers has to happen at the place where ferries are handled. This will most likely not fit with the proposed sites of the new cargo operation facilities.

The concentration of logistic activities is subject to action and needs of the exporters and importers and their design of transport chains. Different developments affected the logistical map of Bergen since the recent Varestrømsanalyse. The districts of Åsane and Arna did not experienced much change. The presence of wholesaler “ASKO VEST” continues to determine transport volumes for Arna, while the facilities of “Ikea” and “Rema” (food and convenience distribution) are the important players in Åsane. The southern districts of Bergen recorded more movement. Takeovers of companies or facilities changed the pattern here. Most recently decisions concerning the freight station played a role. The LSPs “Schenker” and “Posten Norge” will look to move operations, most likely to the southern district of Ytrebygda.

As of today, many LSPs are located and well-integrated into the range of services provided in the port. Shrinking the port area to what is needed to serve as sole loading/unloading area will require a relocation of activities. This will not mean to move the existing facilities elsewhere as the new feeder transport leg will reshape existing supply chains. Services that are now carried out in the port might need to be shifted to Ågotnes or even other locations based on the supplier’s or importer’s capabilities and needs. Recent shifting experiences of the LSPs formerly integrated to the freight station could be a blueprint for port-based LSPs (Bring) and lead to a further concentration of logistic activities in Ytrebygda. The Varestrømsanalyse reveals that in 2012 approximately one fourth of the cargo handled in the port area has no maritime transport leg but is linked to rail transport or road transhipment (Asplan Viak AS, 2014, p. 22). These logistics network effects must be considered in the development of a new waterborne transport system with reduced landside operations.

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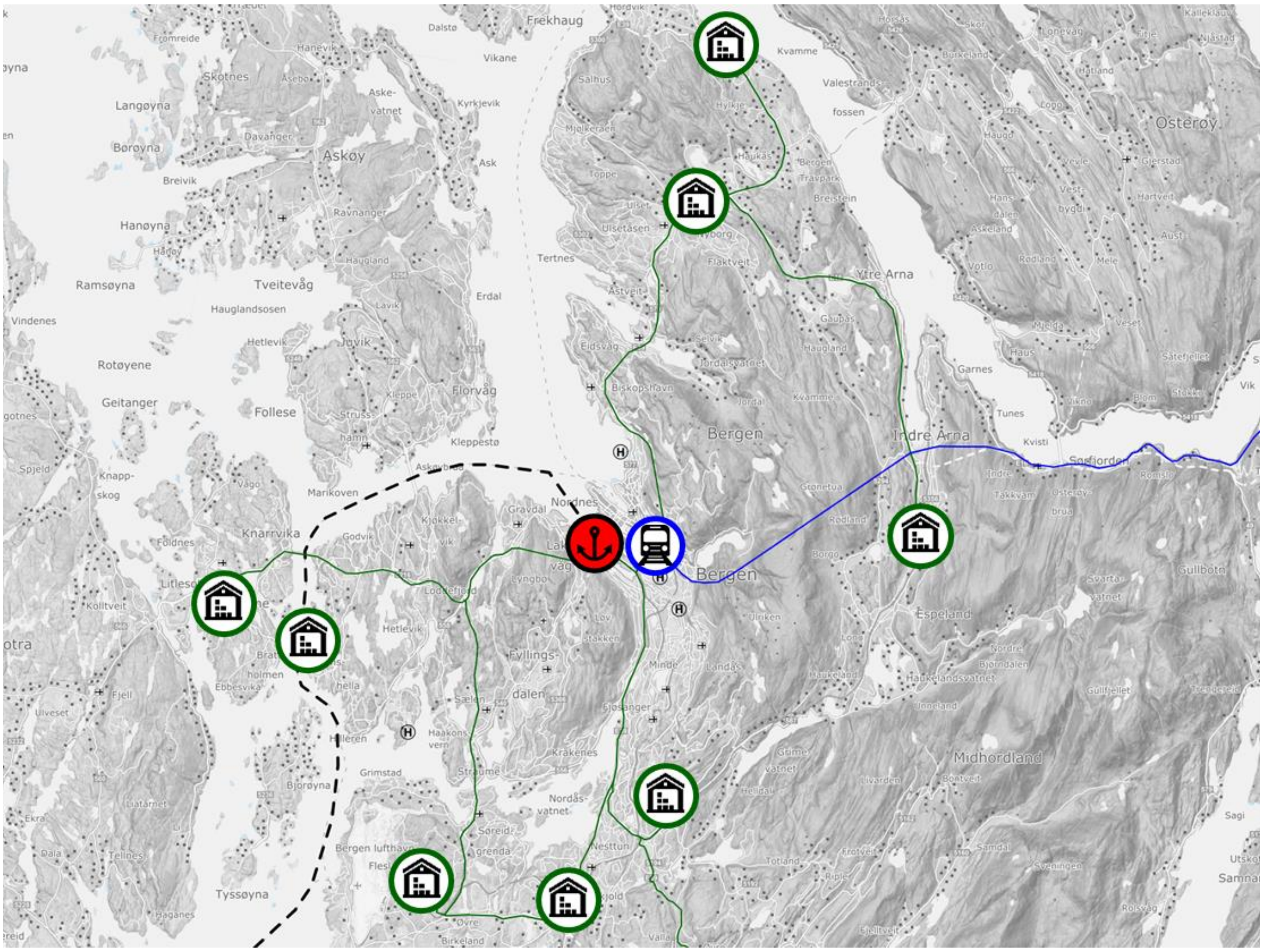

Figure 9: Existing logistics environment with single port (red), railway station (blue) and major road network (green)

Source: ISL based on Flowchange (2019) and Norwegian Mapping Authority (2023)

2.1.2.2 Existing Transport Concept

Maritime Accessibility of Bergen Port

The port of Bergen is served in the container sector by various liner shipping companies in shortsea feeder services and has direct connections to a large number of European ports. From the 1st of October 2022 to the 1st of May 2023 an overall of 151 container ships called the Port of Bergen. With 128 port calls, most of the container ships calling Bergen berthed at the Dokkeskjærskaien, 21 at Frieleneskaien and only two at Jekteviksterminalen 1 & 5 (see Figure 10 and Figure 11). It is important to mention that Frieleneskaien and Dokkeskjærskaien together represent the berths of the container terminals operated by Westport and Greenport Services AG respectively.

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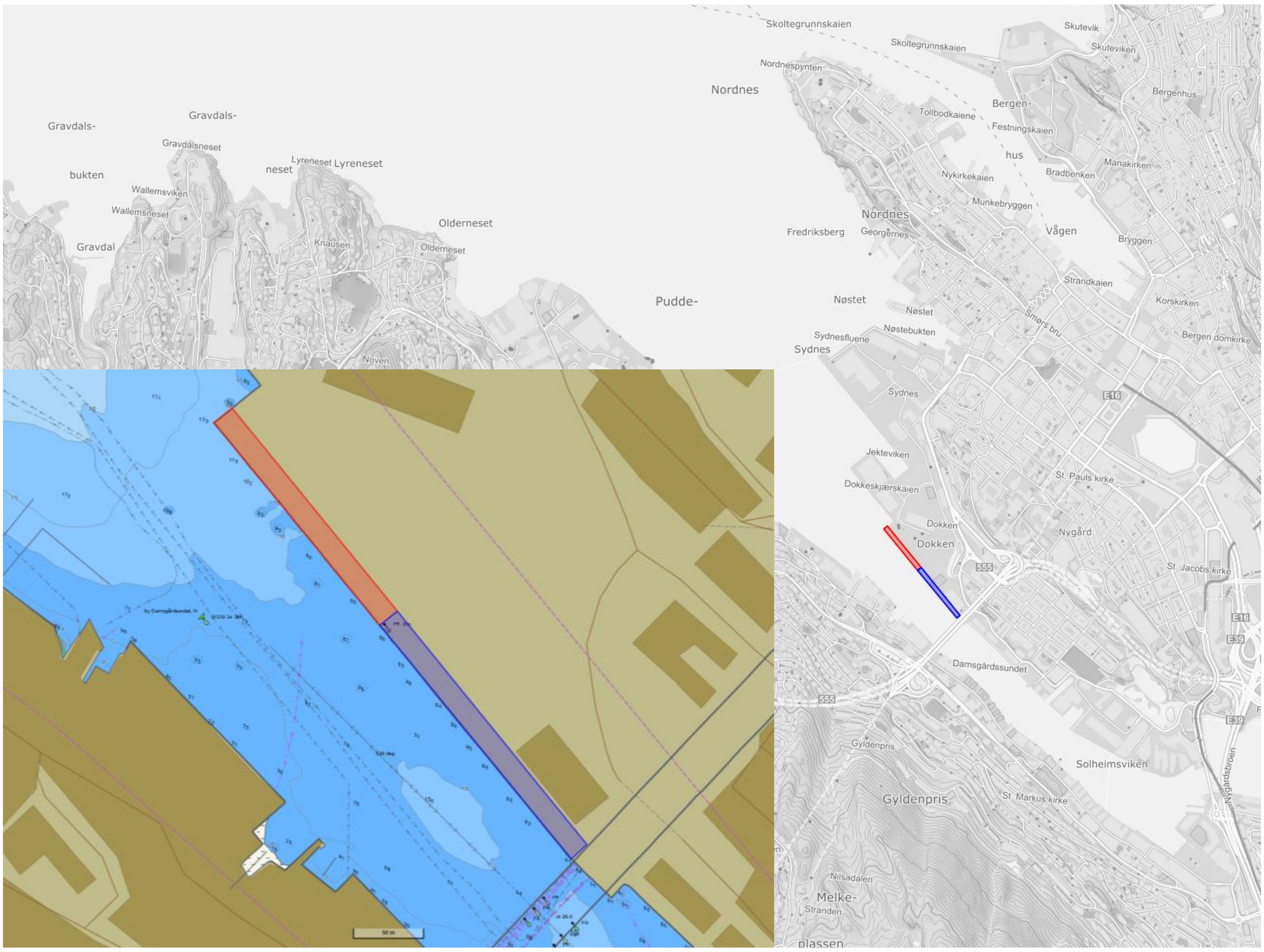

Figure 10: Location of Dokkeskjærskaien Vest 4 (red) and Frieleneskaien 1-2 (blue) in the City of Bergen

Source: ISL based on Norwegian Mapping Authority (2023)

Active container lines are offered by a total of five liner operators, namely North Sea Container Line (NCL), Arctic Container Line (ACL), Mediterranean Shipping Company (MSC), Maersk and Samskip (see Table 3), which call at Bergen weekly with one or two ships. The ship arrival statistics of the Bergen Port Authority show that the container ships calling Bergen are usually full container feeder vessels with own loading gear and a capacity of 600 to 1,100 TEU. Samskip is currently the only operator using a vessel without cargo gear and with a capacity of only 340 TEU.

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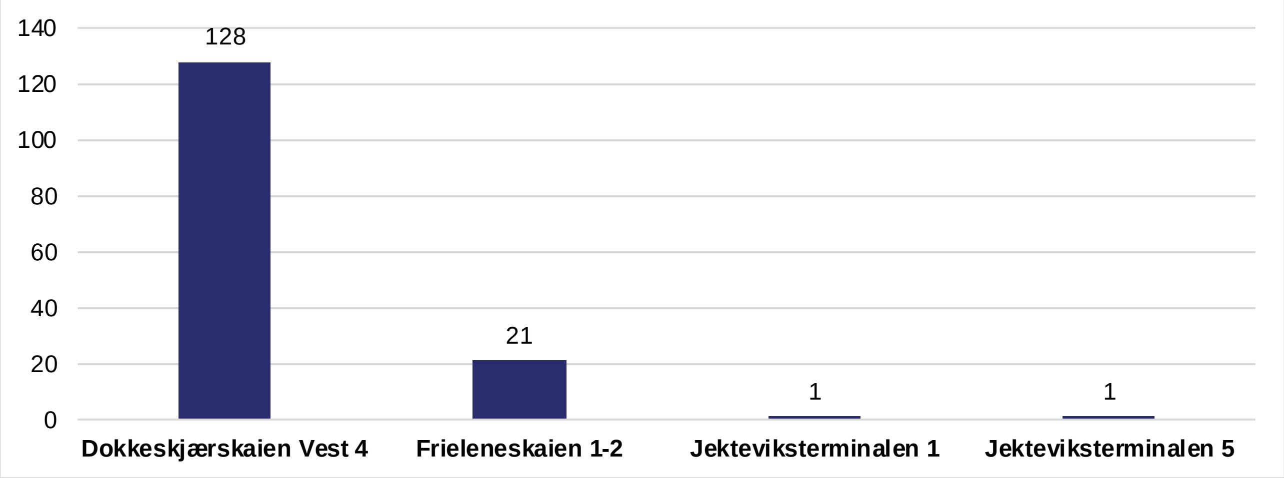

Figure 11: Number of container ship calls with terminal

Source: Bergen Havn (2023b)

Table 3: Active container shipping lines calling Bergen

Operator	Service	Frequency	Ship size	Source
NCL	Bremerhaven – Rotterdam – Egersund – Tananger – Haugsund – Bergen – Bremerhaven	Weekly	660 TEU	(Bergen Havn, 2023b; North Sea Container Line, 2023)
NCL	Hamburg – Bremerhaven – Tananger – Haugesund – Bergen – Florø – Måløy – Ålesund – Ikornnes – Hamburg	Weekly	957 TEU	(Bergen Havn, 2023b; North Sea Container Line, 2023)
Maersk	Bremerhaven – Egersund – Stavanger – Fusa – Bergen – Måløy – Ålesund - Bremerhaven	Weekly	957 TEU	(Bergen Havn, 2023b; Maersk, 2023)
MSC	Bremerhaven – Stavanger – Bergen – Måløy – Ålesund – Bremerhaven	Weekly	1118 TEU	(Bergen Havn, 2023b; MSC, 2023)
Samskip	Rotterdam – Tananger – Haugesund – Bergen – Tananger – Rotterdam	Weekly	340 TEU (gearless)	(Bergen Havn, 2023b; Samskip, 2023)
ACL	Bremerhaven – Hamburg – Tananger – Haugesund – Bergen – Måløy – Orkanger – Gjemnes – Ålesund – Florø – Bremerhaven	Weekly	657 TEU	(Arctic Container Line, 2023; Bergen Havn, 2023b)
ACL	Rotterdam – Tananger – Haugesund – Bergen – Florø – Ålesund - Orkanger – Måløy – Rotterdam	Weekly	712 TEU	(Arctic Container Line, 2023; Bergen Havn, 2023b)

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Container Terminals

While there is basically only one container terminal in Bergen with the berths at Dokkeskjærskaien and Frieleneskaien, the terminal is operated by two terminal operators, namely Greenport Services and Westport. According to the Bergen Port Authority, roughly 25 per cent of the container operations are currently handled by Westport and 75 per cent by Greenport (Workshop Bergen, 2023).

The continuous pier used by the terminals has a length of approximately 390 m, which is divided into the berths Dokkeskjærskaien Vest 4 and Frieleneskaien 1-2. This separation by name is due to historical reasons, as the two quays have only existed together since 2017 after intensive construction work and were previously completely separated from each other. However, the two quays still have a different superstructure with different fender systems. The newly built Dokkeskjærskaien Vest 4 has a length of approximately 180 m and is equipped with a combination of V fenders and dumper tire. The length of Frieleneskaien 1-2 is approximately 210 m long and equipped with cylindrical bar and chain fenders with 1.1 m in diameter and 2.3 m in length (see Figure 12).

Mooring of the container ships is done without tug assistance. The linesmen for the mooring operations are third party service providers that are neither employed by the terminal operators nor by the port.

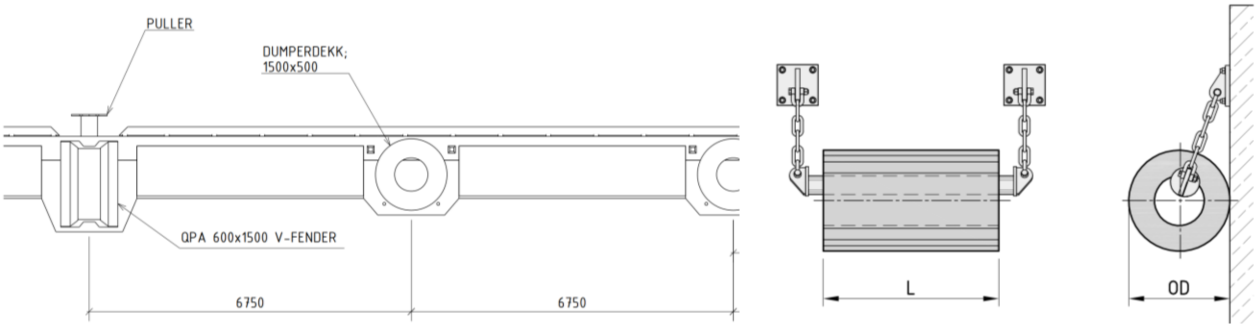

Figure 12: Fender setup Dokkeskjærskaien Vest 4 (left) and Frieleneskaien 1-2 (right)

Source: Skanska Norge AS (2016)

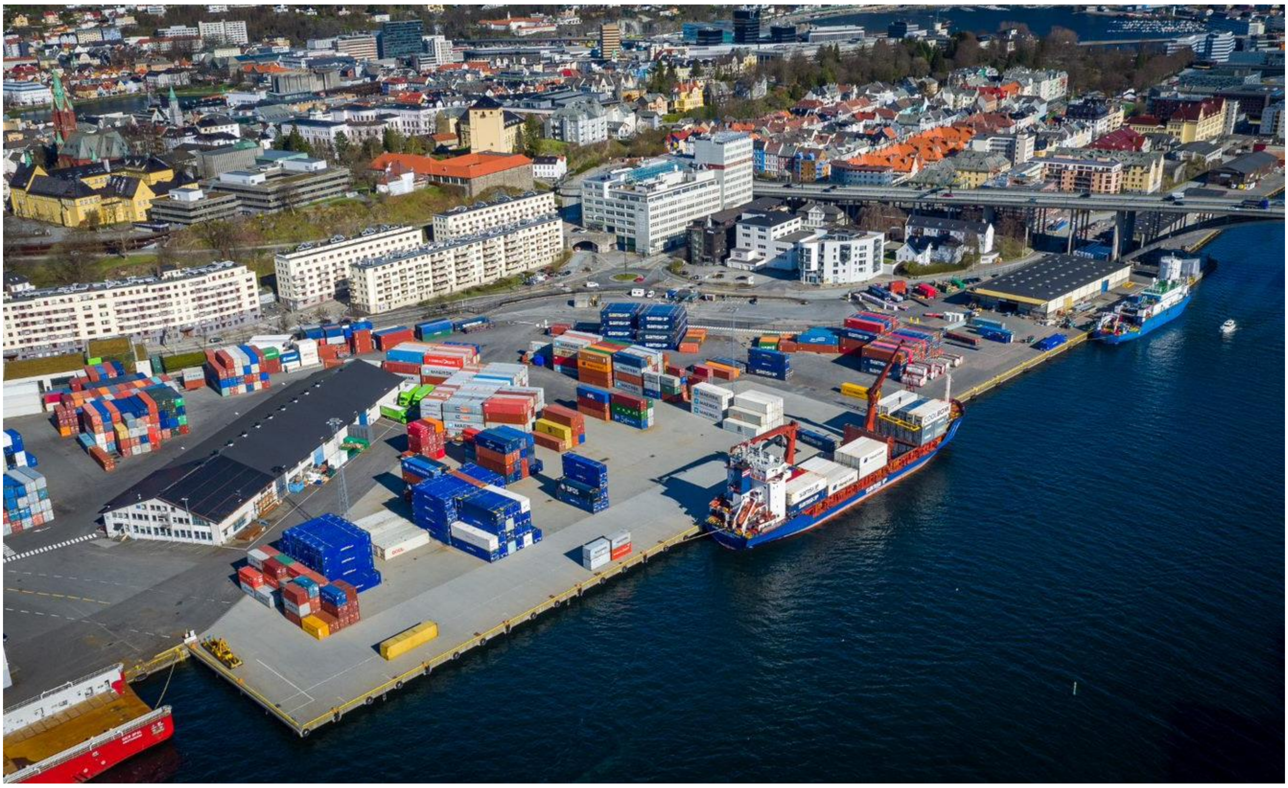

Figure 13: Container terminal Bergen

Source: Port of Bergen

Both terminal operators operate their own equipment, whereas Westport has one and Greenport two reach stackers. The port-based mobile crane is property of the port and is solely operated by personnel directly employed by the port and not by the terminal operators. In general, loading and discharging is done by ship's gear, except for Samskip vessels who call Bergen with a small gearless container ship as shown in Figure 13 and is currently the only container liner service customer of Westport.

Hinterland Access

For incoming road traffic, there currently exists a central gate to the terminal areas which is operated manually, i.e., without any integration to any terminal operating system. Furthermore, the terminals can nowadays be visited without prior announcement. In order to streamline access to port facilities, the Port of Bergen has recently initiated a "SmartGate" digitalization project, which includes passage fees and a digital application for temporary access (Bergen Havn, 2023a).

The landside logistics process for a container transport differs whether the container contains cargo in full container load (FCL) or in less than container load (LCL). In case of an import FCL transport the container is moved directly (in the case of the Bergen region using the road network) to the consignee after unloading at the port. An LCL container is processed by an LSP who could be located either in the port as well as outside. At the facility of the LSP, the container is opened (or

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"stripped") and the shipments are forwarded to the respective final consignees. An export transport where a LSP collects cargo from multiple shippers would proceed accordingly in reverse direction. LCL and FCL import processes are depicted in the following figures[9]:

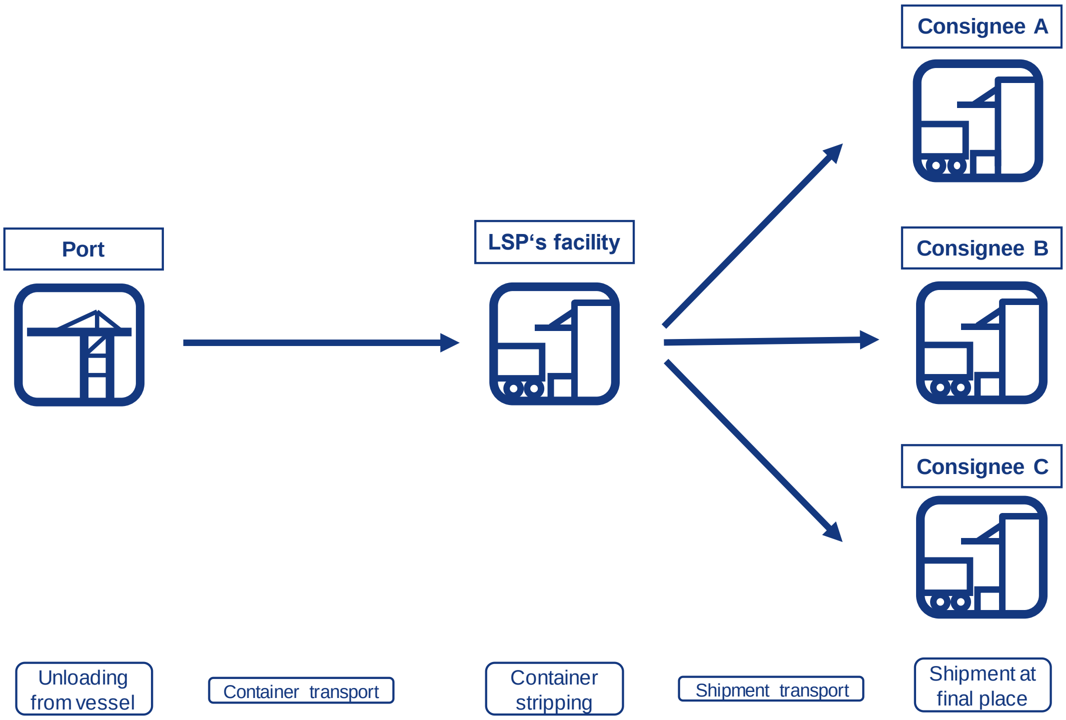

Figure 14: Depiction of LCL import process

Source: ISL

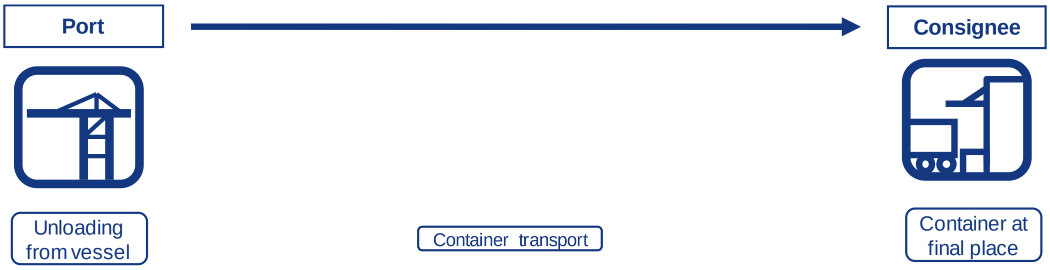

Figure 15: Depiction of FCL import process

Source: ISL

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[9] The export processes are designed analogously but with reversal of direction, while shippers replace consignees.

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2.1.2.3 Existing Nautical Conditions

The following section provides a detailed overview of the nautical conditions in the DUC's area of observation. In addition to the route between Ågotnes and Bergen, which is directly relevant for the DUC, the routes of the container feeder ships currently calling at Bergen are also shown. The aim of this section is to provide an overview of the DUC's area about to any nautical hazards, but also with regard to organisational aspects, such as reporting obligations or pilot boarding areas.

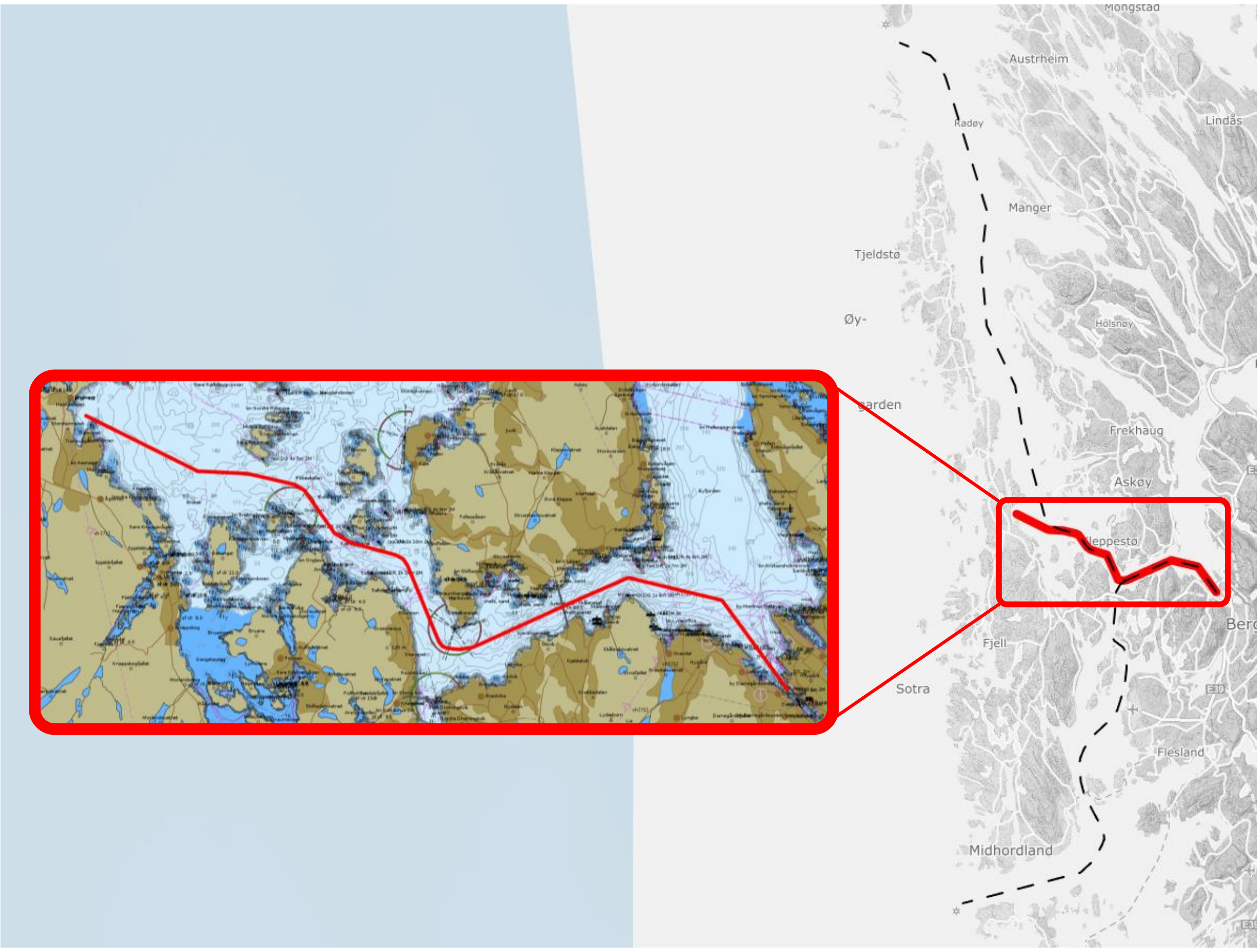

Figure 16: Observation area with shortsea feeder system (black dashed line) and 24/7 autonomous feeder loop service (red line)

Source: ISL based on Flowchange (2019) and Norwegian Mapping Authority (2023)

Approach to and departure from Bergen for container feeder vessels

The container vessels of the identified liner shipping companies (see Table 3) usually approach the Port of Bergen from the south through the Korsfjorden, coming from Haugesund or Stavanger. The principal channel for large vessels from the Korsfjorden towards Bergen is Lerøyosen (60°14’N, 005°10’E) before entering Raunefjorden (60°16’N., 005°10’E.). According to the schedule of Maersk, the ships of their liner service take a slightly different route with a stop in Fusa, meaning that these

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ships first turn south in Lerøyosen entering Bjørnafjorden to Fusa (Maersk, 2023). After calling Fusa, these ships take the same route back to Lerøyosen to follow the route to Bergen.

The preferred passage for larger ships from the north end of Raunefjorden to the north of Bjorøy is through Vatlestraumen (60°19’N., 005°12’E.) which fairway is deep and free from dangers. Passing the Sotra Bridge (60°22’N., 005°10’E.) that crosses Knarreviksundet the ships then enter the south-west arm of Byfjorden which is crossed by the Askoy Bridge (60°23.7’N., 5°12.9’E.) with a vertical clearance of 63 m. From Byfjorden the ships then enter Puddefjorden to approach the southwest berth of Dokken terminal in Bergen (60°23’N., 005°19’E.). The overall length of the passage from the pilot boarding ground in the Korsfjorden to the berth is roughly 23 nm.

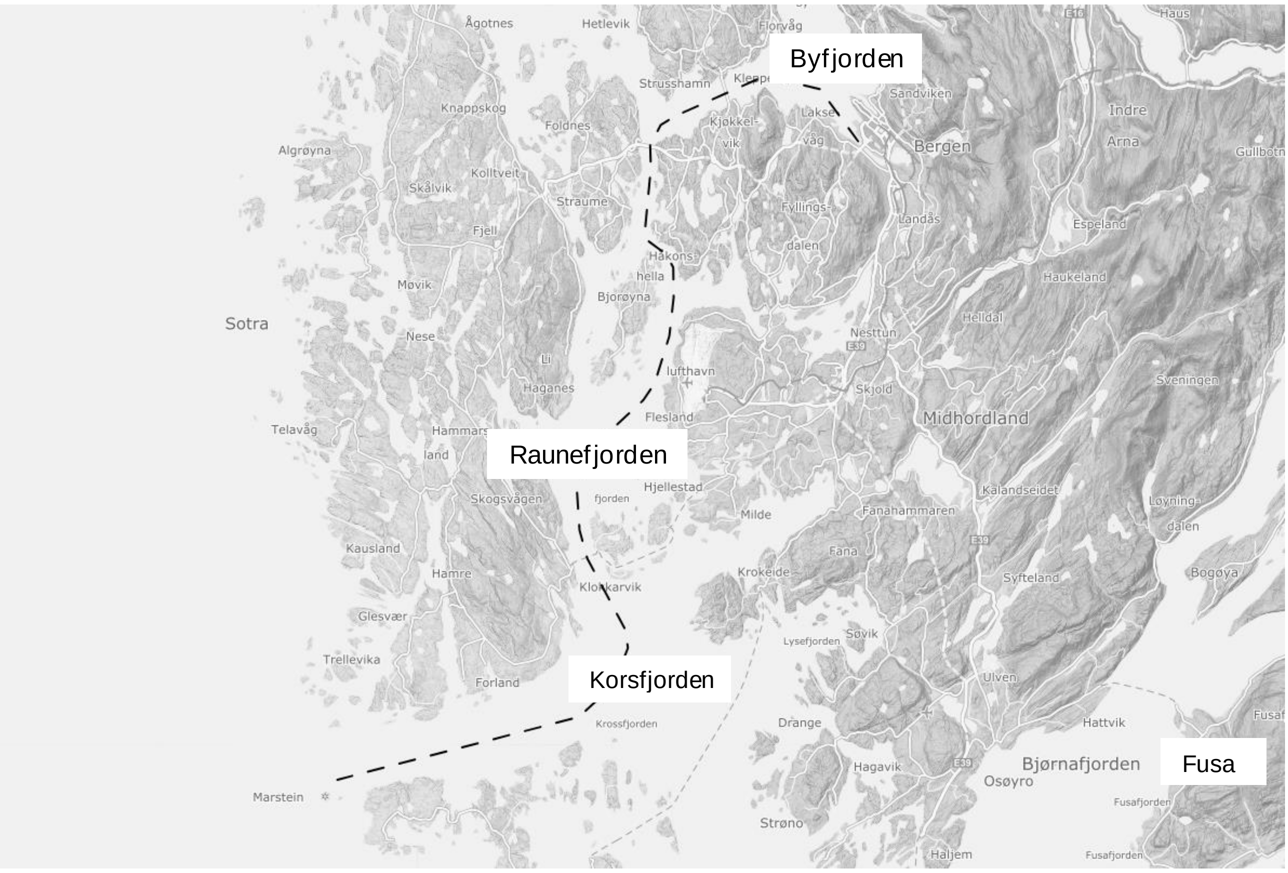

Figure 17: Passage for container feeder vessel calling Bergen

Source: ISL based on Norwegian Mapping Authority (2023)

Within some liner services Bergen represents the northernmost port with Tananger or Bremerhaven as next ports of call (see Table 3). Here, the southbound route is accordingly the same. But, for most services the main direction outbound is to the north with next ports of call in Norway being Florø, Måløy, Ålesund, Orkanger, Gjemnes or Ikornnes.

The main shipping route from Bergen is again through the south-west reach of Byfjorden and then north into Hjeltefjorden. Ships pass northbound through the entire length of Hjeltefjorden which is exited through Fedjeosen (60°44'N., 004°44'E.) into the sea. The distance is roughly 32 nm from berth to the pilot boarding ground in Fedjeosen. It is noteworthy, that Ågotnes is on the way of this route.

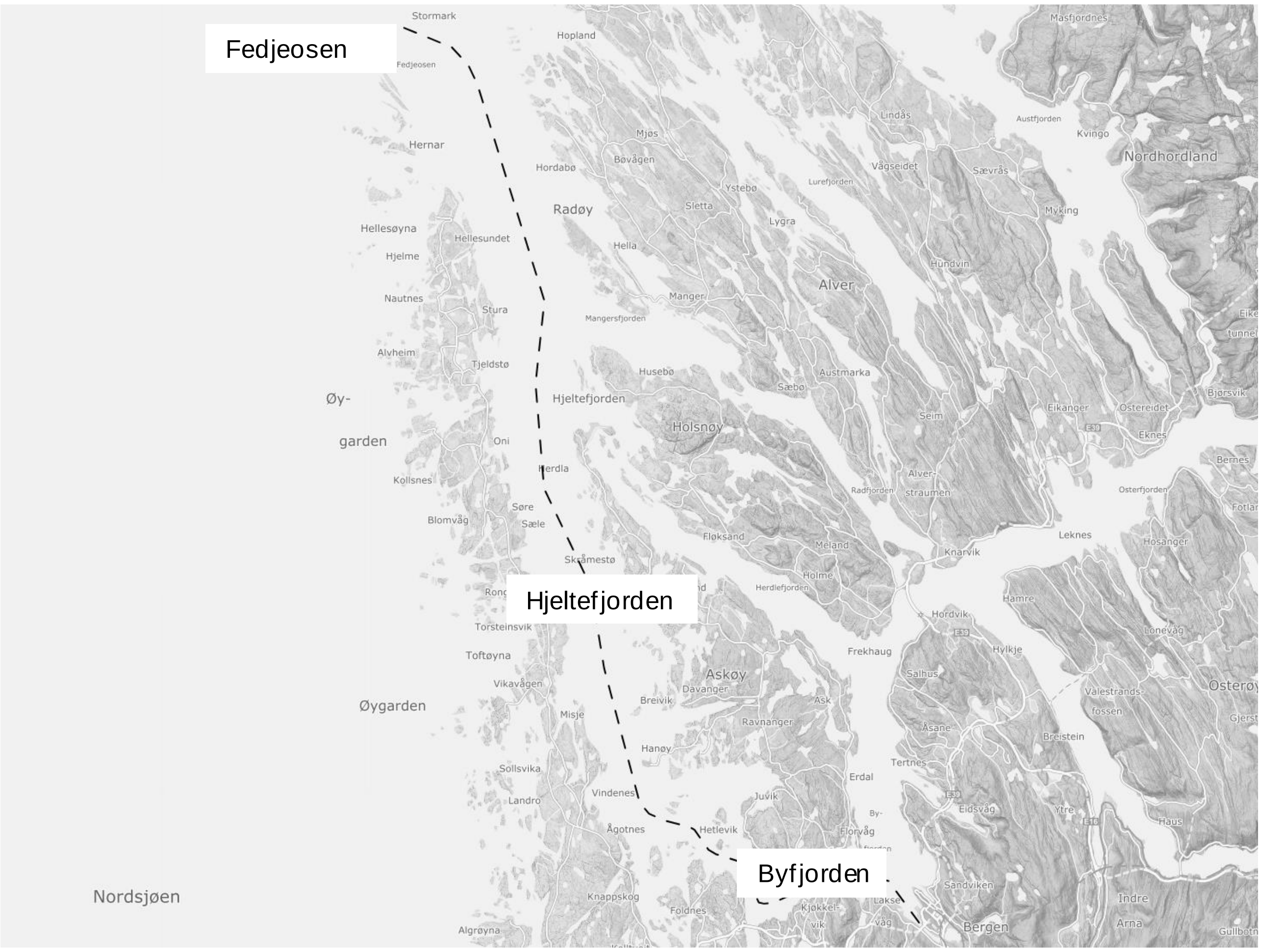

Figure 18: Passage for container feeder vessels departing Bergen to the North

Source: ISL based on Norwegian Mapping Authority (2023)

24/7 feeder loop service Ågotnes – Bergenhus

The core element of the DUC described in 2.1.1 is the 24/7 emission free autonomous feeder loop service between Ågotnes and Bergen. The route between the two ports is approx. 11 nm, which the intended system can cover in approx. 1 to 1.5 hours. The route has no significant hazards for a vessel of the intended size with a draft of just 1.8 m and there is sufficient water depth with high under keel clearance throughout. Due to the importance of the port of Bergen and the good maritime connections, the traffic density in Byfjorden and Hjeltefjorden can be considered as relatively high.

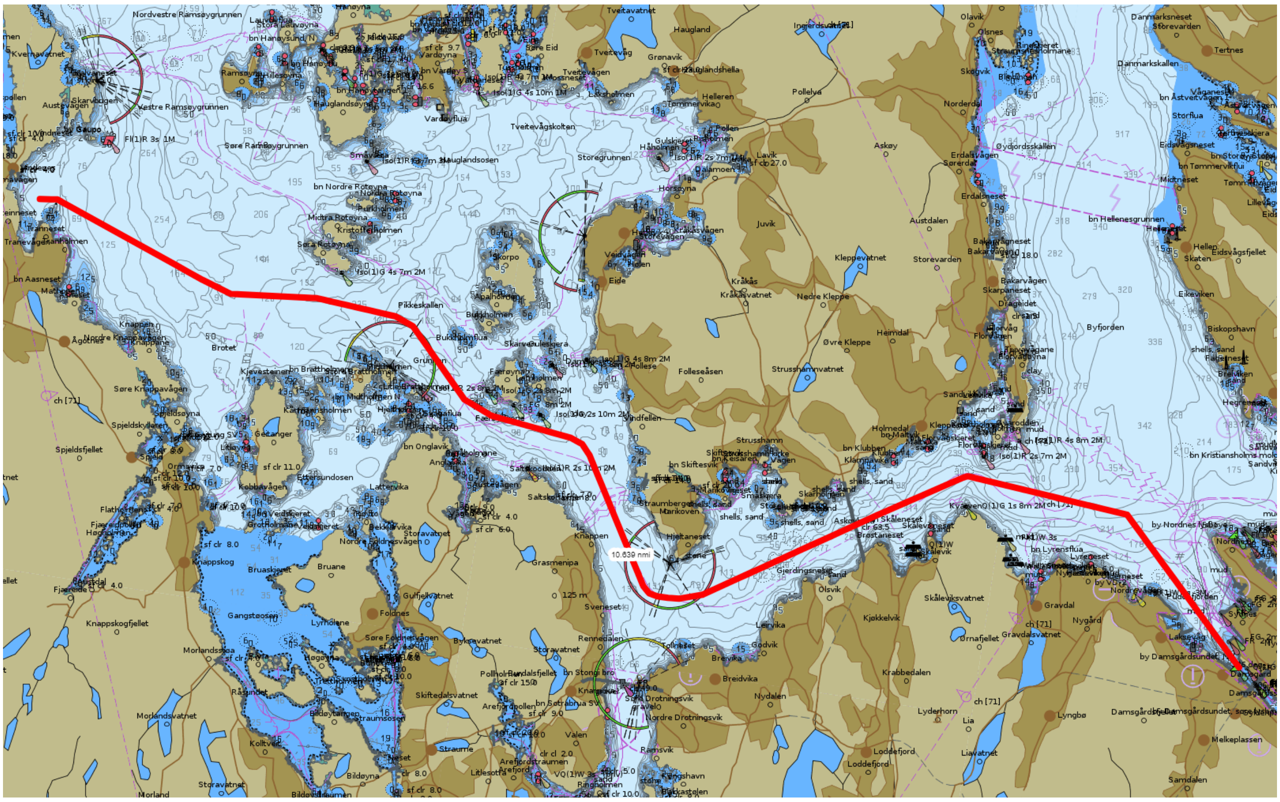

Figure 19: Route for autonomous feeder loop service between Ågotnes and Bergen

Source: ISL based on Norwegian Mapping Authority (2023)

Weather and water depths

The general wind direction in Bergen during winter is from south to south-east and from north to north-east during summer. The climate in Bergen is relatively mild, humid, and rainy with ice only during very severe winters that usually offers no hindrance to navigation. Especially during summer, Bergen experiences both sea and land fog with a maximum (16 per cent) occurring in July (NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY, 2022, p. 85), that usually, according to the Bergen Port Authority, offers no hindrance to navigation as well. The highest tidal range that can usually be expected during spring tides is about 1.2 m (*Bergen Tide Times*, 2023) with high water intervals of about 10 hours 17 minutes and negligible tidal currents (NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY, 2022, p. 85).

Pilotage

In general, pilotage is compulsory and can be ordered either via the SafeSeaNet portal or through Kvitsoy Pilot Booking Center at an additional cost. The pilot boarding ground when approaching Bergen is northbound in position 60°08,6'N., 005°00,9'E and southbound in several positions at the entrance of Fensfjorden. Pilots shall be ordered a minimum of 24 hours before arrival and confirming at least 5 hours in advance. The Kvitsoy Pilot Booking Center can be contacted by phone, email or

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VHF channel 13 (NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY, 2020, 144–147). Under certain circumstances there might be exemptions from pilotage. According to the Port of Bergen most masters of container vessels calling Bergen have such an exemption. Details on compulsory pilotage (e.g., what conditions must be met for a pilot exemption) are regulated in the "Regulations on compulsory pilotage and the use of pilot exemption certificates" (Compulsory Pilotage Regulations, 2014/2019).

Vessel Traffic Services (VTS)

The vessels traffic from and to Bergen is organized and managed by the Fedje Vessel Traffic Service. All vessels wishing to navigate within the VTS area must request sailing clearance from the Fedje VTS at least 1 hour before their arrival at the limit of the VTS area. Apart from the last 2 nm before and after the berth, the previously described approach- and departure-routes to and from Bergen lie in its entirety within the area of Fedje VTS.

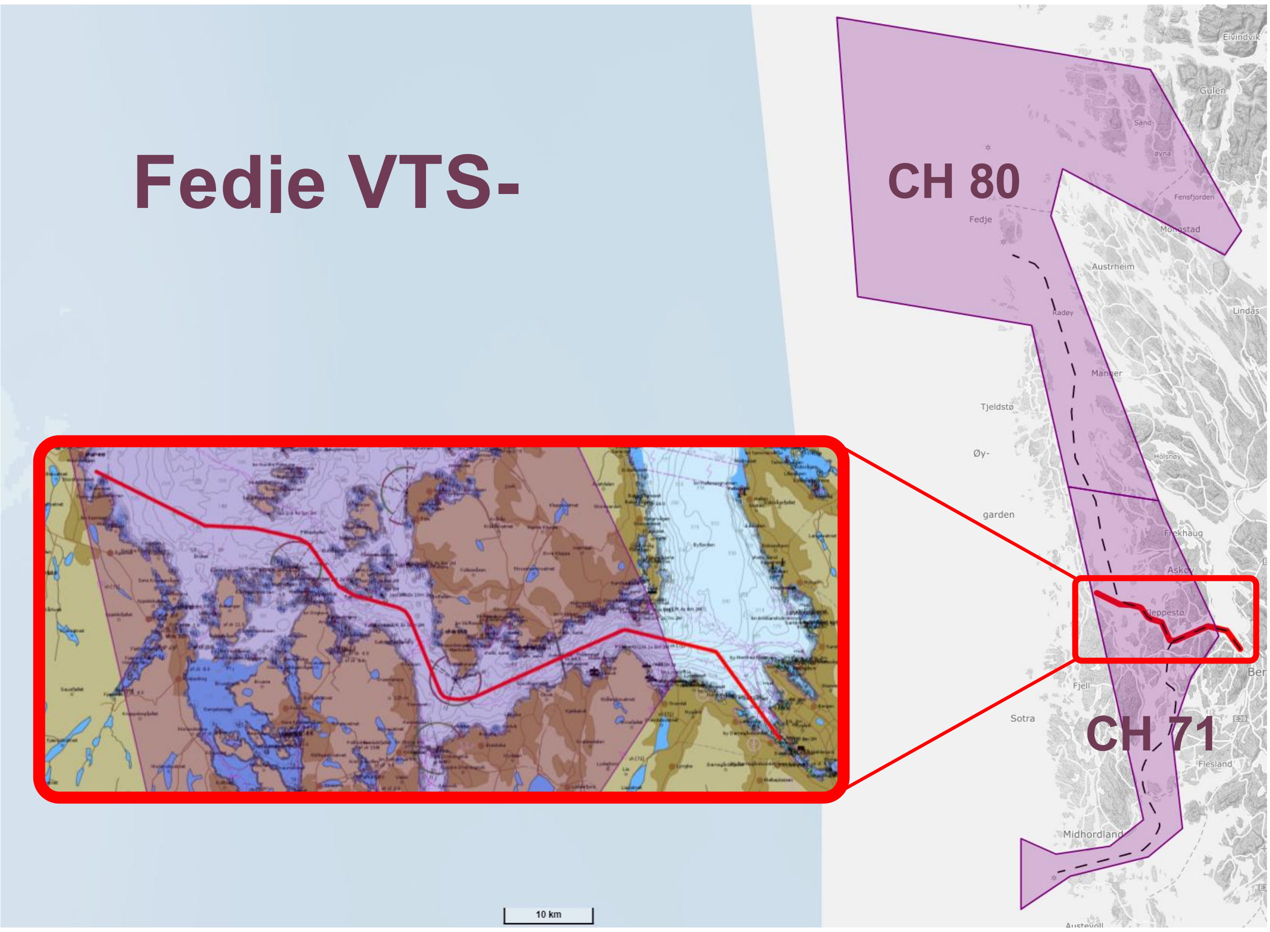

Figure 20: Boundaries of Fedje VTS-Area with radio channels

Source: ISL based on NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY (2022) and Norwegian Mapping Authority (2023)

When requesting sailing clearance, the message should include the following information and can be done by E-mail (fedje.vts@kystverket.no), VHF (CH 71) or telephone.

> “*1. Vessel name and call sign.*
>
> *2. Sailing Plan and destination.*
>
> *3. ETA at the outer limit of the VTS area and the ETA at the port, mooring, or anchorage—for vessels located outside the operational area of the VTS.*
>
> *4. ETD from the VTS area—for vessels inside the area.*
>
> *5. Any other information requested by the VTS, such as vessel type, nationality, and port of registration.*
>
> *Vessels should send position reports to Fedje VTS, as follows:*
>
> *1. When passing the limits of the VTS area when heading into the VTS area.*
>
> *2. When passing between VHF channel sectors.*
>
> *3. Before moving within the VTS area (leaving the wharf, berth, or mooring facility).*
>
> *4. When being towed.*
>
> *5. When at anchor.*
>
> *6. When involved in an accident.*
>
> *7. Immediately if the vessel is in difficulty and likely to result in a change of voyage plan*
>
> *All communication with the VTS shall be in a Scandinavian language or, if not using a pilot, in English.”* (NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY, 2022, p. 98)

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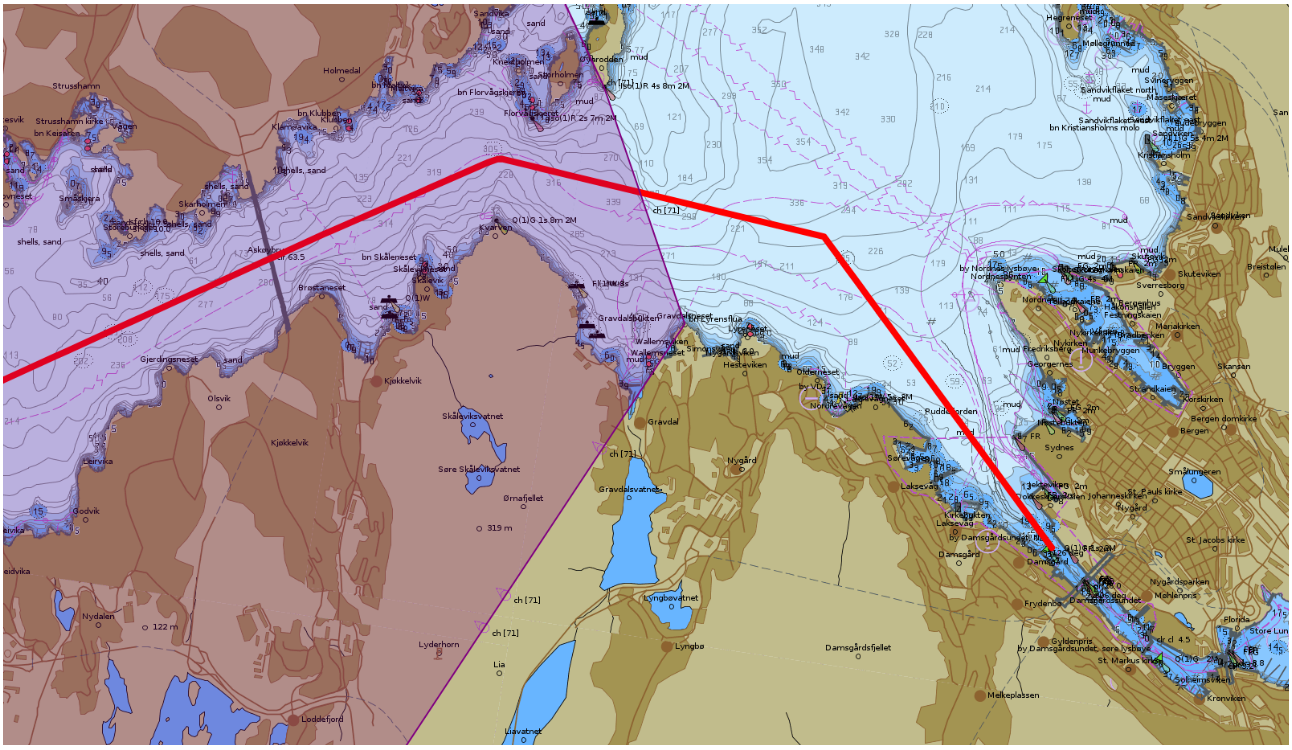

Figure 21: Eastern boundary of Fedje VTS-area in Byfjorden near Bergen

Source: ISL based on NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY (2022) and Norwegian Mapping Authority (2023)

Port Control

After a vessel has left the VTS area on its way to Bergen, the port is responsible for further coordination. Here, certain notification and reporting requirements apply, as is the case with VTS regulated areas. Within the port, a port control centre serves as a central hub for managing and coordinating various activities related to maritime operations within the port waters. Its primary function is to ensure safe, efficient, and organized movement of vessels and cargo in and out of the port.

"Vessels shall send their ETA to Port Control at least 1 hour prior to arrival. The ETA message should include the following information:

1. *Vessel name and call sign.*
2. *Length overall, beam, and draft.*
3. *Flag.*
4. *Purpose of port call.*
5. *Name of agent.*
6. *Last port-of-call and next port-of-call" (NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY, 2022)*

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2.1.3 Processes and Information Flows

2.1.3.1 Context

Given the scope of the SEAMLESS Use Case, an initial investigation of current process and information flows has considered international containerised maritime transport chain as the baseline scenario. In a first step, current logistics flows have been used to identify different phases that may become subject to investigation.

As described above, the Port of Bergen is mainly integrated into container service networks that connect major North Range Ports such as Rotterdam (Netherlands), Bremerhaven (Germany) and Hamburg (Germany) with the Norwegian Westcoast. It is therefore possible to use these container services for shipments from and to Central Europe. In this context, logistics processes will take place within the Central European and the Bergen Hinterland, while waterborne transport will connect the Port of Bergen with one of the North Range Ports. As of the above-mentioned North Range Ports provide trimodal accessibility, hinterland transport may be carried out within the European road, rail or inland waterway network. As Bergen mainly serves a regional hinterland (see 2.1.2.1), road transport will be the dominant mode. The different phases that would be required to pass through in the import as well as export direction are illustrated in Figure 22.

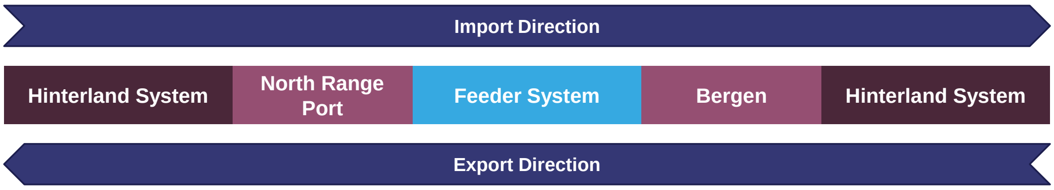

Figure 22: Generic Phases for Containerized Maritime Transport between Central Europe and Bergen

Source: ISL based on DSCA (2022)

Based on the evaluation of container flows, most containerized shipments going from and to the Port of Bergen are part of intercontinental trade. In these cases, an additional maritime leg is introduced (see Figure 23) so that the North Range Ports become transhipment hubs only.

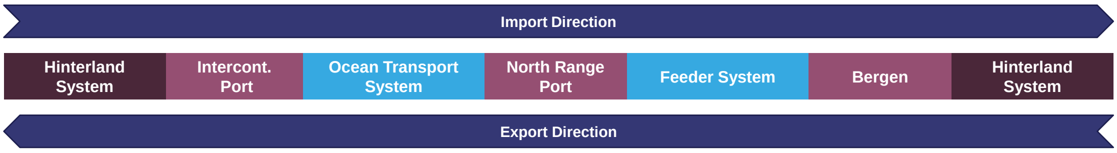

Figure 23: Generic Phases for Intercontinental Containerized Maritime Transport Chains to and from Bergen

Source: ISL based on DSCA (2022)

2.1.3.2 Shipment and Container Equipment Flows

While all of these phases have the potential to impact later development of the SEAMLESS Building Blocks (e.g., providing end-to-end visibility by means of the WP5 BBs), we will furthermore outline the characteristics of a selected part of related flows, to highlight important aspects and specifics. First, we will consider the flows of FCL and LCL shipments as well as the flows of container equipment in the import case while setting the scope to the time both objects arrive at the port till the arrival of the shipment as well as container at its final destination (see Figure 24).

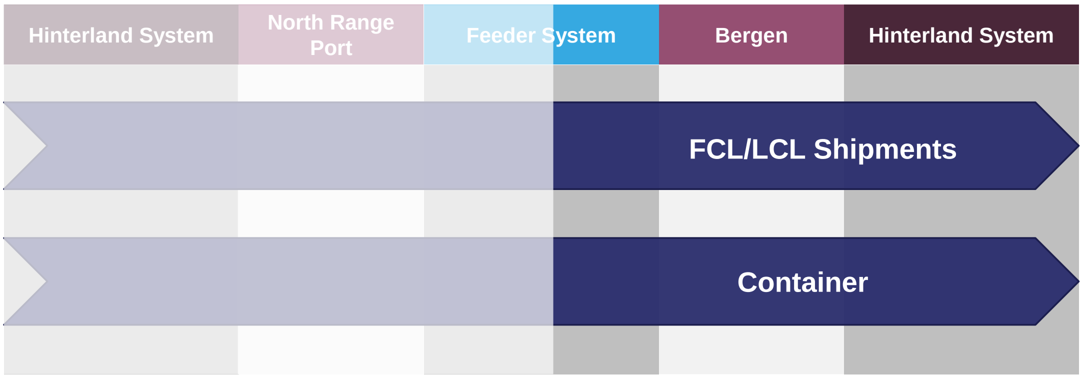

Figure 24: Shipment and Container Flows - Import direction

Source: ISL based on DSCA (2022)

The subject of investigation is one single container which may contain one (FCL) or several shipments (LCL). On the highest process level, the flows of interest follow a set of consecutive conditional events that are mainly driven by changes of the physical (e.g., “Container discharged”) or informational (e.g., “Container available for pickup”) status of the container. As the initial mapping assumes ideal conditions, the aspect of disruption management (e.g., “customs clearance cannot be obtained) that may cause deviations is not considered yet.

The high-level process map is depicted in Figure 25.[10] The middle lane represents activities that involve the full container, while the top lane considers empty container activities and the bottom lane shipment only activities.

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[10] A high-resolution image can be found in the Annex.

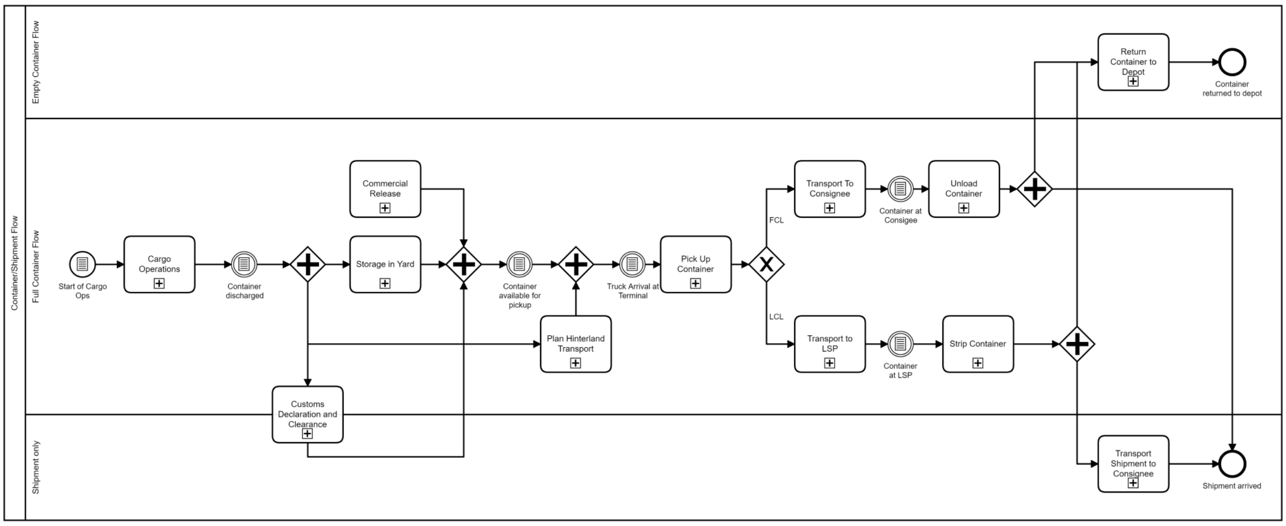

Figure 25: High-Level Process of FCL/LCL Imports

Source: ISL

The flows are triggered by the start of cargo operations, which relates to the vessels or terminals (in the case of gearless vessels) unloading and loading activities of relevant containers. Once a container has been discharged, it needs to be moved to and stored at a suitable place within the terminal yard. However, in order to pick up the container by truck, administrative requiremets must be met. First, a customs declaration that has to be made by a responsible party (e.g., a customs or forwarding agent or the consignee) must be processed up to final clearance by the customs authority. This may also involve physical or document inspection.

Once the container is available for pickup, a truck may arrive at a terminal to pick it up. From this point on, the process depends on whether one FCL or several LCL shipments are of interest. In the latter, the truck will transport the container to a LSP facility (the case that the LSP facility is located within the port is not considered here), where the container gets stripped. This marks the decoupling of the container equipment and shipment flow. Whereas the shipment needs further transportation by truck to the respective consignee, the empty container will usually be returned to a depot, which is likely to be in the port. FCLs will usually be trucked directly to the consignee to be unloaded. Once this has been finished, the empty container can be returned to the depot as well.

The processes within the high-level process map represent subprocesses which can be modelled in more detail. As an example, Figure 26 shows the physical exchange of the container between the terminal and the truck which covers the high-level processes “Plan Hinterland Transport” and “Pick Up Container”. While this exchange currently does not involve a lot of coordination, it represents a supposable candidate for logistical redesign given the limited terminal yard constraints.

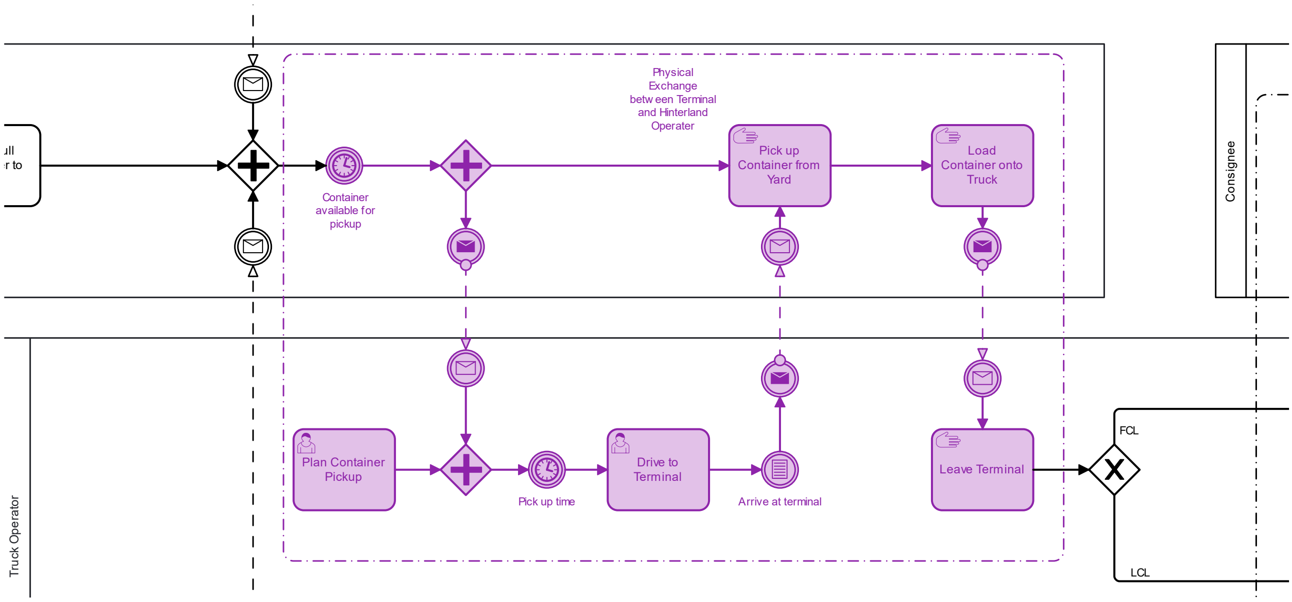

Figure 26: Operational Terminal-Hinterland-Interface

Source ISL

The initial high-level and selected processes that were mapped in more detail within T2.1 shall serve as a baseline and are to be extended by the following T2.3 and T2.4 within SEAMLESS.

2.1.3.3 Vessel Journey From and To Bergen

Besides the flows of the goods and objects to move, the investigation aimed at gathering insights on the specific processes connected to a vessel journey from and to Bergen. In the context of the modelling taxonomy, the following elaboration is located as shown in Figure 27.

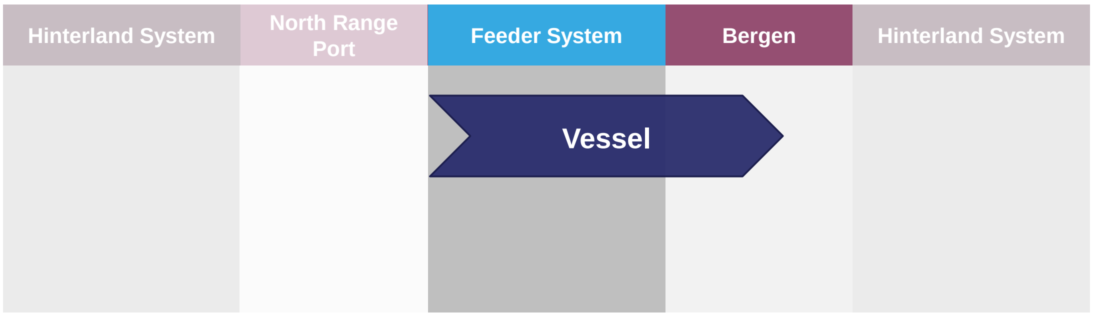

Figure 27: Vessel Journey From and to Bergen

Source: ISL based on DSCA (2022)

The subject of analysis is a container vessel which is about to visit the Port of Bergen. On the highest process level, the flow of interest follows a set of consecutive time-conditional events driven by changes of the location/time-distance (e.g., “24 h prior to arrival”) or status-conditional (e.g., “Arrival at Berth”). The flow of investigation is triggered by the event “Departure at previous port”, which in the generic case, is located outside the Norwegian VTS domain, and ends with the departure in Bergen (see Figure 28)[11]. For simplicity, navigational or traffic related aspects related to the departure in the leaving port are subsumed by the process “Sail to Bergen”. However, during the journey, the ocean carrier deploying the vessel may continue detailed planning of respective cargo operations in Bergen by providing the current stowage plan and load/unloading instructions to the terminal. Also, the carrier or an agent will take care of ordering linesmen for the port visit.

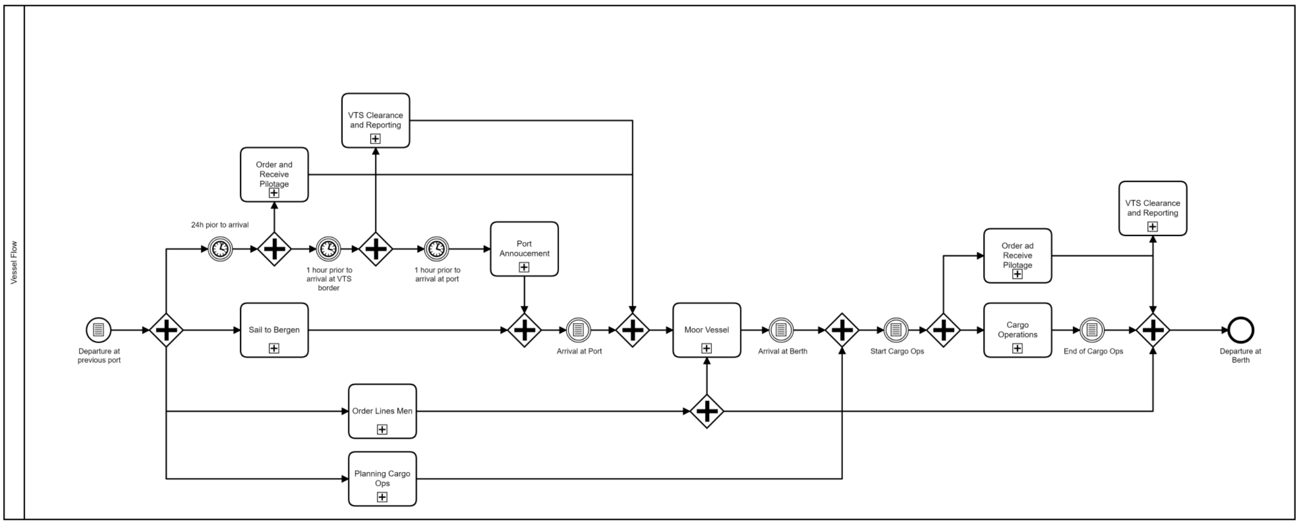

Figure 28: High-Level Process of Container Vessel Visit

Source: ISL

Besides all navigational aspects, the sailing process involves a number of vessel-to-authority communications and procedures: Latest 24 hours before arrival, pilotage needs to be ordered and confirmed 5 hours before entering the pilotage area. Also, clearance to enter the coastal VTS area needs to be obtained and regular position reports to be made (see Figure 29). Lastly, port control needs to be informed about the arrival in advance and the allocation of the respective berth to be made.

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[11] A high-resolution image can be found in the Annex.

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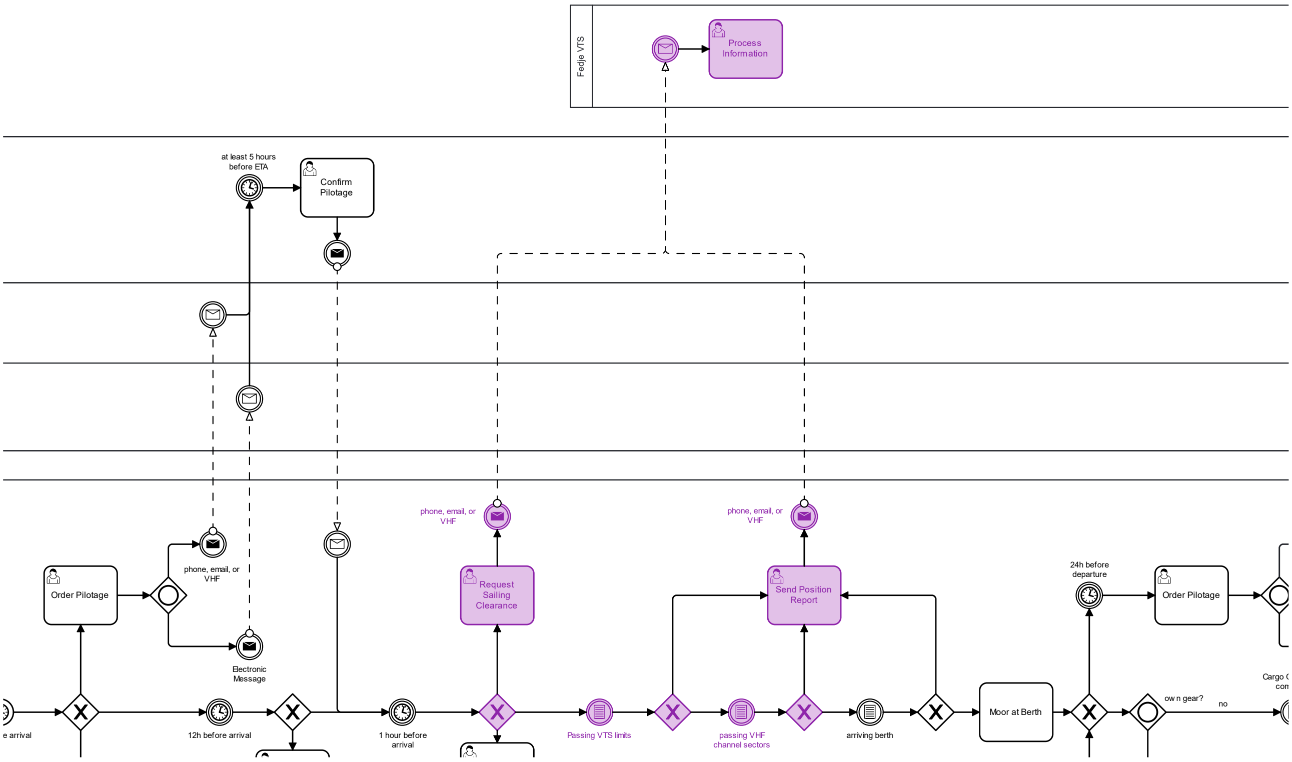

Figure 29: Carry out Vessel-to-Authority Reporting obligations

Source: ISL

Once the vessel arrives at the port, mooring needs to be performed aided by land-side linesmen support. Once all cargo operational planning has been completed, unloading and loading procedures are carried out. Depending on whether the vessel is equipped with own gear or not, this process is to be conducted by the crew. In any case, this process needs to be monitored by a responsible crew member. Also, preparational activities for the departure such as the ordering of pilotage is carried out. Once cargo operations are completed and VTS sailing clearance obtained, the vessel may depart to its next destination.

The initial high-level and selected processes that were mapped in more detail within T2.1 shall serve as a baseline and are to be extended by the following T2.3 and T2.4 within SEAMLESS.

2.1.4 Recommendations, Gaps and Requirements

2.1.4.1 Identified Implications for Building Block Development

One of the main objectives of this deliverable is to derive initial implications that need to be taken into account during the development of the SEAMLESS building blocks. The comparison between the proposed SEAMLESS Use Case and the current state has revealed a set of requirements and aspects to be investigated further, which can be mapped to specific fields of research:

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Logistics Concept (WP2)

- The current analysis has closed with a high-level overview on activities and processes relevant within the DUC. Based on that, the investigation should be followed more in-depth and consolidated with the results of the other use cases within T2.3 and T2.4 in order to provide reference models which will be further operationalized within the concept of future operations in T2.5.

Port Operations (WP3)

- Currently, the stowage planning process is not centralized, but is largely handled on the ship side. That means that during the journey, the ocean carrier deploying the vessel may continue detailed planning of respective cargo operations in Bergen. 24 to three hours prior to arrival a stowage and sequence plan is sent to the terminal by the ship. This procedure induces that stowage and sequence planning vary very individually from ship to ship. This must be taken into account in the development of an autonomous stowage planning system, and the processes on the terminal side as well as on the ship and shipping company side would have to be changed significantly.

- The mooring and the ordering of lines men is currently a completely manual process. While the installation of an autonomous mooring system in the baseline scenario with Bergen, Agotnes and maybe also Flesland seems possible, especially from a cost point of view, such an investment is currently seen as unrealistic at the smaller nodes described in section 2.1.1. Same is true for an investment in reach stackers big enough for loading and unloading of the vessels. In case an extended network scenario with smaller nodes is envisioned, the vessels would probably need ship-based loading gear. Further elaboration is needed to prove these claims.

- The specifications of the reach stackers from Westport and Greenport are not known. Regarding the DUC, however, it is important to note that the reach stackers used must meet certain minimum requirements to be able to load and unload the vessel. Here, the plan is to load the AutoBarge design ship with up to four rows with a reach stacker directly from the pier. Considering the design of the AutoBarge, a fender system that gives a berth clearance of roughly 1.1 m because of the fenders and a safe distance of the reach stacker tires from the edge of the pier of about 0.5 m, the possible outreach of the reach stacker must be higher than 13.6 m (see Figure 30). The biggest reach stackers of KALMAR designed for container handling, the DRG450-92S5X has a maximum outreach of 8.9 m from the front of tires to the centre of the load (Kalmar, 2019). By using an optional extended boom nose for barge operation the outreach can be extended by another 2.0 m to 10.9 m (Kalmar, 2019), which is still below the required 13.6 m.

- The current design of the vessel system to be used provides a cell guide system to secure the cargo, which is one reason for the relatively wide beam of the vessel compared to an inland barge carrying the same number of rows of containers. Due to the resulting problem that such a vessel could only be used to carry containers and no RoRo cargo, and that it might be too wide to be loaded by a reach stacker, it was discussed whether the cell guides could be dispensed with altogether. Whether the cell guides could be dispensed with, and how the load could be secured instead, would require intensive evaluation in a later work package. Whatever cargo securing system is chosen, it must always be ensured that the requirements of the CSS Code are met. Alternatively, a detailed cargo securing manual would need to be calculated and prepared. Possible alternatives to a cell guide system could be stacking cones or twist locks. However, in such a case, twist locks would have to be used for the second layer of containers, which would probably mean that a human process of inserting or removing the twist locks is unavoidable. Another possibility would be to stow the containers in a tight fit and thus secure themselves. All that would then be required is a sufficiently high and enclosing hold wall. Partial loading of the ship would probably not be possible in such a case.

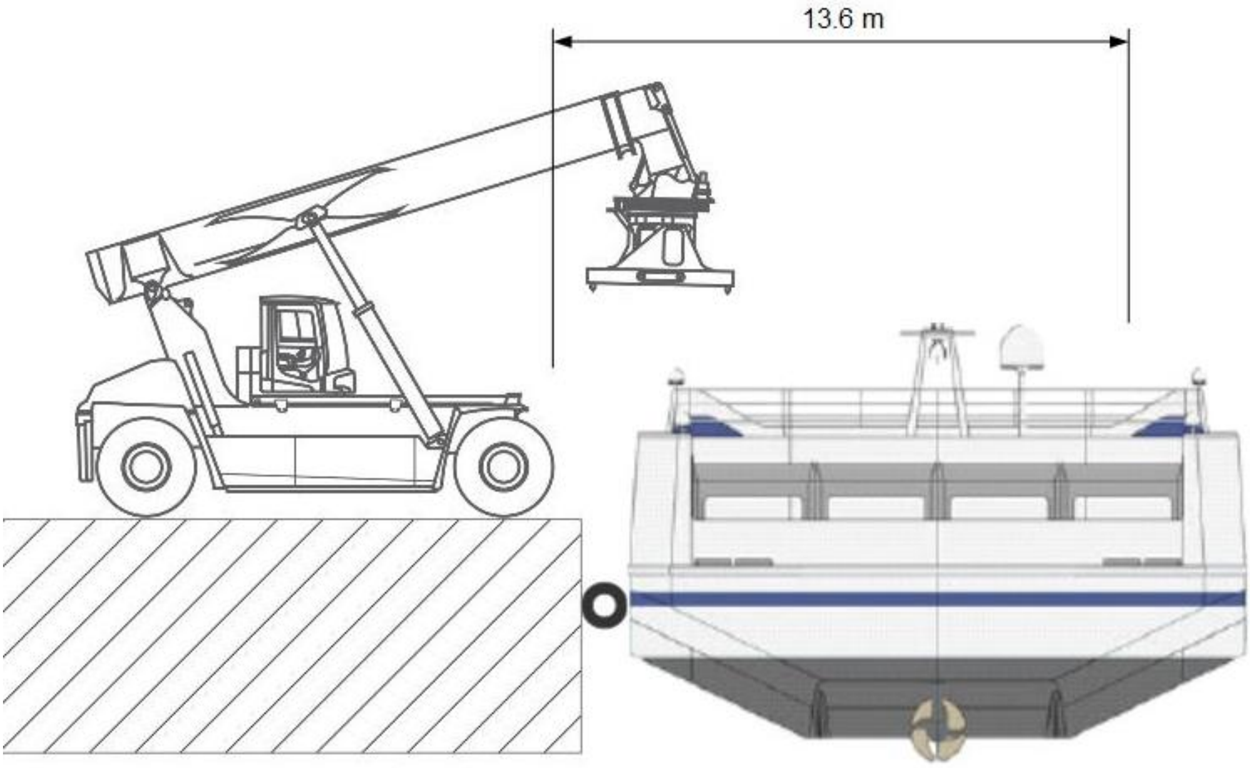

Figure 30: Distance of the outreach that must be bridged by the reach stacker in the intended system for loading and unloading (almost to scale)

Source: ISL based on Kalmar (2019) and Flowchange (2019)

- The terminal within Bergenhus will be designed to operate with low space requirements. This will result in a significant reduction in block storage capacity and probably high use of these limited capacities. From a terminal perspective, this dramatically increases yard management complexity and if done under uncertainty of incoming and outgoing flows increases the risk of inefficient operations (i.e., unproductive moves). In addition, truck parking areas can only be kept to a limited extent which further stresses the need to provide low truck turnaround times. Against this background, the requirements on landside coordination (e.g., the necessity of pre-announcements) should be considered when considering the final terminal design.

Vessel / Fleet Operations (WP4)

- Particularly in the area at the southern tip of Askøy Island, traffic situations that would require manoeuvres according to regulation 17 COLREG, which are not always clear and whose execution requires a quick intervention of a human operator could regularly arise. The reason here is that three shipping routes meet in this area, so that a variety of traffic situations could arise here and that the area measures only a radius of roughly 3.6 cables[12]. If several vessels were to meet simultaneously in this area with the involvement of the DUC system, course changes may be carried out simultaneously by several vessels (see Figure 31). In such a case, the courses and speed of all participants involved in the traffic situation will change continuously. For a sufficiently accurate interpretation of the situation, a human operator needs experience to anticipate the situation and the actions of the other vessels. An autonomous system may not be able to provide such a capability, or only with limitations.

- The water depths toward Bergen are very high generally exceeding 100 m by far with very steep shores. Anchoring, incl. emergency anchoring, is therefore only possible in certain areas.

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[12] Nautical measurement. 1 cable = 1/10 sm = 185.2 m

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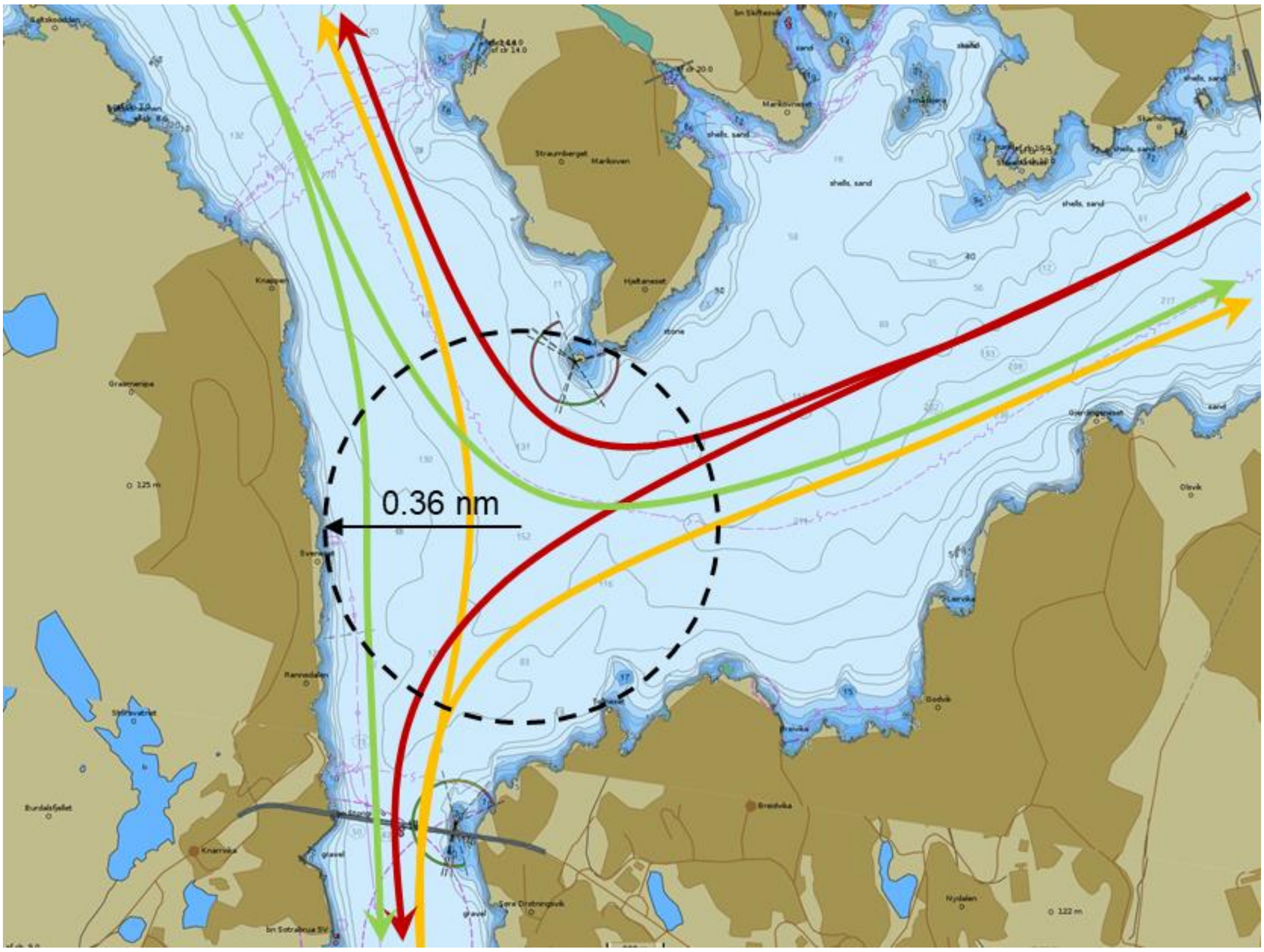

Figure 31: A hypothetical traffic situation with three or more involved vessels with several possible course changes in the Byfjorden at the entrance of Knarreviksundet

Source: ISL based on Norwegian Mapping Authority (2023)

- How can the intended system in the DUC comply with compulsory pilotage? According to “§1 Scope” of the Compulsory Pilotage Regulation, the regulations apply inter alia to the territorial water and the internal waters the regulations do not apply to military vessels and other vessels under military command. Since the vessel of the DUC1 is not a military vessel or under military command and the area of operation lies within the territorial waters of Norway (see

- Figure 32), the regulation would probably apply. In §3, the regulation states what vessels are subject to compulsory pilotage. According to §3 (1) (a) all vessels with a length of 70 metres or more or a width of 20 metres or more are subject to compulsory pilotage when operating in waters that are defined as subject to compulsory pilotage in §4 Compulsory Pilotage Regulation.

§3 (b) to (i) further extents compulsory pilotage to vessels with a length of less than 70 metres and a width of less than 20 metres when these vessels meet certain criteria. Accordingly, ships outside the limits of §3 (1) also have a pilotage obligation under the following conditions:

> *"b) Vessels that push or tow one or more objects, and the object or objects have a total length of 50 metres or more*
>
> *c) Vessels with a double hull with a length of 50 metres or more that are carrying hazardous or pollutive cargo in bulk as mentioned in MARPOL Annex I, or cargo in pollution categories X, Y or Z, which is regulated in MARPOL Annex II, cf. IBC Code, Chapters 17 and 18. Except offshore support vessels transporting limited amounts of hazardous and noxious liquid substances in bulk, as defined in Regulations of 1 July 2014 no 944 relating to dangerous cargo on board Norwegian ships, § 6.*
>
> *d) Vessels with a single hull with a length of 35 metres or more that are carrying hazardous or pollutive cargo in bulk as mentioned in MARPOL Annex I, or cargo in pollution categories X, Y or Z, which is regulated in MARPOL Annex II, cf. IBC Code, Chapters 17 and 18*
>
> *e) Vessels with a length of 50 metres or more that carry gas condensate in bulk, cf. IGC Code, Chapter 19*
>
> *f) Vessels with a length of 50 metres or more that are carrying 10 metric tonnes or more of hazardous or pollutive cargo in packaged form under hazard class 1, as regulated in MARPOL Annex III, cf. IMDG Code*
>
> *g) Vessels that are carrying substances regulated by the INF Code*
>
> *h) Nuclear-powered vessels*
>
> *i) Passenger vessels with a length of 50 metres or more when carrying passengers"* (Compulsory Pilotage Regulations, 2014/2019)

Firstly, it should be noted that the DUC's sailing area is likely to take place within waters for which pilotage is in principle mandatory, as the sailing area is within the Norwegian baseline (see Figure 32). The question remains whether the vessel is subject to compulsory pilotage. According to information from Port of Bergen, the vessel to be used will have a length of 67.5 metres and a beam of 15.0 metres, which is below the limits for compulsory pilotage according to §3 of the Compulsory Pilotage Regulation. While some of these rules of §3 should not play a role in DUC1, e.g., the transport of passengers, the rules on the transport of dangerous goods may lead to restrictions with regard to the cargo to be transported if a

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pilotage obligation is to be circumvented. Due to its dimensions, the ship would probably not initially be subject to compulsory pilotage, but could then possibly be subject to compulsory pilotage again if, for example, it carried more than 10 tonnes of hazardous class 1 cargo.

Should the vessel be subject to compulsory pilotage, it would have to be investigated whether a pilot exemption could also be issued to a remote operator in an ROC. Currently, the Compulsory Pilotage Regulations do not provide for such a case. §15 states that "[o]n vessels subject to compulsory pilotage that are navigating without a pilot in waters subject to compulsory pilotage, at least one deck officer with a valid pilot exemption certificate must be present on the bridge and in charge of the navigation and manoeuvring." (Compulsory Pilotage Regulations, 2014/2019) The main question here is whether an ROC equates as the bridge of a ship.

The Norwegian Department *of* Trade, Industry and Fisheries (Nærings- og fiskeridepartementet) issued the "Act relating to ports and navigable waters" (Lov om havner og farvann (havne- og farvannsloven) dealing specifically with compulsory pilotage for autonomous vessels and permission for autonomous coastal sailings (Act relating to ports and navigable waters, 2019). The specifics are to be worked out in another work package.

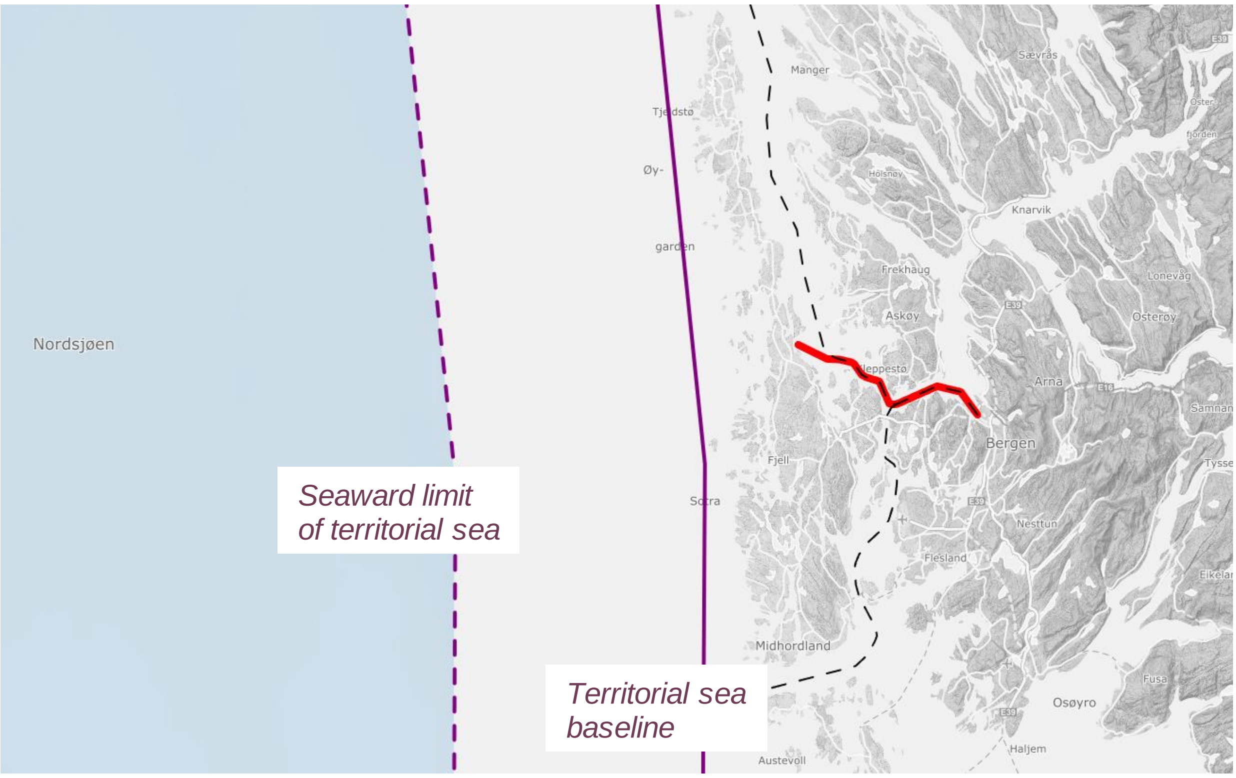

Figure 32: Limit of territorial sea and territorial sea baseline

Source: ISL based on NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY (2020) and Norwegian Mapping Authority (2023)

- For the DUC it is important that the reporting requirements to the VTS as mentioned in 2.1.2.3 are complied with. That means that sailing requests are to be sent to Fedje VTS in due time before leaving the berth in Ågotnes and before leaving the berth in Bergen. In addition, a position report is to be sent when passing the limits of the VTS area when heading into the VTS area and before moving within the VTS area (leaving the wharf, berth, or mooring facility). That means, that in addition to the sailing clearance request, probably a minimum three position reports need to be sent for the intended feeder loop service between Ågotnes and Bergen, namely when departing the berth in Ågotnes, when departing the berth in Bergen and when entering the VTS area en route to Ågotnes. Although a position report is not explicitly required when leaving the VTS area, such a report is common practice in maritime shipping and would possibly mean another reporting point on the way to Bergen.

- The development process and later demonstration should assess the requirements on securing containerized loads on the Auto Barge concept under varying weather conditions.

Digitalisation (WP5)

- The analysis has highlighted existing information flows, e.g., regarding vessel-to-authority and carrier-to-terminal communications and it is expected that the future transport concept enforces even stronger coordination requirements. Even though these requirements may be addressed by the digital SEAMLESS building blocks such as the AVSPM, ModalNET and VCOP, the actual integration (which involves roles, responsibilities and interfaces) of each system within the demonstration case needs to be further specified and operationalized.

- The initial stakeholder analysis has shown that a lot of actors are involved in the existing logistics chain. Apart from the technical and functional perspective, emphasis should also be placed on involving key end users (trucking companies, LSPs, terminals) and convince each party to contribute to end-to-end visibility.

2.1.4.2 Stakeholder Analysis and Management Requirements

The stakeholder analysis for the Northern European Demonstration Use Case was conducted as part of a face-to-face workshop with local stakeholders within the consortium. It was analysed which stakeholders play a vital role in the current situation and which stakeholders will have a significant stake in the proposed and future of the SEAMLESS Use Case. The stakeholder analysis does not claim to give a complete and extensive list of all involved stakeholders, but is intended to provide an overview of the involved stakeholder groups. The following ten groups of stakeholders were identified, that are also based on the subset of stakeholders that were identified in the AUTOSHIP project (Nordahl et al., 2021, p. 11):

- Cargo Interest
- Finance/Insurance
- Fleet Owners/Charterers/Operators

- Logistic Service Providers
- Nautical/Technical Service Providers
- Regions and Municipalities
- Regulators/Flag States/Port Authorities
- Sea-/Inland Port Operator
- Technology Provider and Research
- Other

Each stakeholder group was analysed individually. First, the role of the stakeholder within the current situation was elaborated and the status quo shortly depicted. In the next step, views on the anticipated role after deployment of the respective SEAMLESS Use Case were collected.

To clarify the “expectations and motivations” of each stakeholder, the “objectives and needs” were identified first. Objectives and needs were considered as static propositions that stay equally relevant in both the current situation as well as in the SEAMLESS use case. The objectives and needs can serve as a first indicator, whether there could arise conflicts between the interests of different stakeholders. An example would be a conflict between the objectives of a Maritime Authority and those of an operator of autonomous ships; while the ship operator would like to have their ship sail completely without a crew, the Maritime Authority may have a different understanding of risks due to its mandate and still require a crew. The stakeholder’s “expectations” towards the SEAMLESS use case that can both be positive or negative, were also covered under the topic of “expectations and motivations”. An example for such a motivation would be a wholesaler that expects reduced warehouse times as a result of seamless supply chains. The full “expectations and motivations” are represented in the Annex 6.1.3.

In the next step, the “influence” of each stakeholder was described qualitative and estimated on a scale ranging from 0-9. Influence describes the degree to which a stakeholder can facilitate or hinder progress towards the goal of a project. The influence of a stakeholder can be understood as the extent to which stakeholders are able to influence or coerce others into making decisions, and following certain courses of action. The influence can derive from the nature of a stakeholder’s organization, for example an authority whose powers are granted by law. But, more informal forms of influence are also possible, e.g. a large corporation may have strong personal connections or influence over ruling politicians (Kennon et al., 2009, p. 12). The qualitative descriptions of the “influence” are represented in the Annex 6.1.3.

After that, the “importance” of each stakeholder was estimated qualitatively. Importance is understood as the priority given to satisfying the respective stakeholders’ needs and interests from being involved in the design of the project and in the project itself in order for it to be successful. In other words, this is about how important or essential it is that certain stakeholders are involved. This involvement does not need be a direct project participation but could also be in a later stage long after

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the SEAMLESS project has finished, e.g. the drafting and introduction of suitable legislation for autonomous shipping for the respective SEAMLESS use case (Kennon et al., 2009, p. 12). The qualitative descriptions of the "importance" are represented in the Annex 6.1.3.

The initial research of the stakeholder analysis ends with study of the stakeholder relations. It was elaborated, what assumptions and risks can arise from the respective stakeholder to the use case and how the stakeholder is involved within the lifecycle of the SEAMLESS project, if they are involved.

The most important results from the stakeholder analysis are depicted in Table 4. The full results can be followed in the Annex 6.1.3.

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Table 4: Extract of Stakeholder Analysis for DUC1: Relevant stakeholders and role description

No	Stakeholder Group	Stakeholder Name	Role description within SEAMLESS use case	Influence [0-9]	Importance [0-9]
1	Cargo Interest	Manufacturers/Wholesalers/Distributors	Creating demand for autonomous transport and logistic services	4	5
2	Finance/Insurance	Norwegian Government - State funding (ENOVA, RCN, etc.)	Stimulate technological development and realisation of environmentally friendly and societal cost reducing initiatives	9	9
3	Fleet Owner/Charterer/Operator	ASKO Maritime	See the potential for establishing a dedicated shuttle service operating between Ågotnes and Bergen for the transport of their own cargo. Want to explore the viability of deploying the autonomous ship concept that they have launched in the Oslo fjord (Therese and Marit)	9	9
4	Fleet Owner/Charterer/Operator	SAMSKIP/NOR-LINES, NCL	Potential ship operator calling on Ågotnes	7	7
5	Fleet Owner/Charterer/Operator	SeaCargo	Potential ship operator calling on Ågotnes	5	3
6	Fleet Owner/Charterer/Operator	Wilhelmsen	Will establish a freight route in the region, including Bergen and Ågotnes. Received EU financing for a hydrogen powered cargo ship.	3	5
7	Logistics Service Providers	Bring Cargo International	Potential logistics service provider using Ågotnes	8	8
8	Nautical/Technical Service Providers	Massterly	ROC operator	6	8
9	Other	Næringsråd (organisation/cluster for the industry/businesses - there is one for each relevant municipality)	Ambassadors for the case	6	7
10	Regions and Municipalities	Bergen Kommune		9	5
11	Regions and Municipalities	Vestland Fylkeskommune	Evaluator of results - to be convinced that the solutions are needed and that they should provide subsidies	9	9
12	Regulators/Flag States/Port Authorities/Port State	Bergen Havn	Port authority. Infrastructure owner (quays, potentially charging and mooring)	9	9
13	Regulators/Flag States/Port Authorities/Port State	Classification Societies	Regular class renewals	9	2
14	Regulators/Flag States/Port Authorities/Port State	Kystverket (Coastal Administration)	Responsible for development/maintenance of fairways and VTS area and reporting in Byfjorden	9	9
15	Regulators/Flag States/Port Authorities/Port State	Sjøfartsdirektoratet (Norwegian Maritime Authority)	Create a guidance for the construction and implementation of automated vessels that can be operated fully autonomous or at least partially autonomous	9	3
16	Sea-/Inland Port Operator	Green Port Services	Potential terminal operator at Ågotnes	3	3
17	Sea-/Inland Port Operator	Westport	Potential terminal operator at Ågotnes	3	3
18	Technology Provider and Research	Cavotec	Providing the mooring solution	1	6

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19	Technology Provider and Research	Kongsberg	Development and technological implementation of operation concepts.	8	8
20	Technology Provider and Research	MacGregor	Further development and implementation of triple joint crane for cargo operations and autonomous stowage planning; Development of on-board mooring and charging crane.	7	7
21	Technology Provider and Research	Naval Dynamics	Conceptual development of autonomous vessel	1	2
22	Technology Provider and Research	SINTEF Ocean	Contribute in quantification and impact studies. Participate in policy recommendation and possibly input paper to municipality or Norwegian government	7	7

The quantified measures Importance and Influence are entered into a stakeholder matrix to get an understanding for necessary stakeholder management, which is a crucial aspect. Entering the stakeholders into the stakeholder matrix automatically assigns the stakeholder into one of four quadrants. Each of which indicates an individual mode of stakeholder management that needs to be applied for the respective group. Stakeholders of a low influence or a low importance need to be monitored during the progression of the project and should not be missed out. Stakeholders of low influence, but of a high importance are a critical group and need to be kept satisfied. While their influence on the project itself is comparably low, they still bring importance assets into the consortium and can pressure drastic changes or even failures of the use case. Stakeholders of high influence and low importance need to be kept informed. Even with little importance on the use case itself, these entities may have the ability to hinder further progress. An example for such a stakeholder is a classification society; while they have no stakes in the design of the use case, they have to classify the vessel before it gets a class approval to operate, which is why it is best to include the classification societies from the early stages of the project. Stakeholders of high influence and of high importance are considered as the key stakeholders that require a close management during the progress of the use case. They should be included in important decision and regularly give their inputs and advice (Browning, 2016; Kennon et al., 2009, p. 12; Larry W. Smith, 2000). The stakeholder matrix of the Northern European Use Case is depicted in Figure 33. The corresponding stakeholder for each marking can be obtained from Table 4. It is worth to note, that 12 out of 22 considered stakeholders are considered to be key stakeholders, with 5 of them being consortium members of the SEAMLESS project.

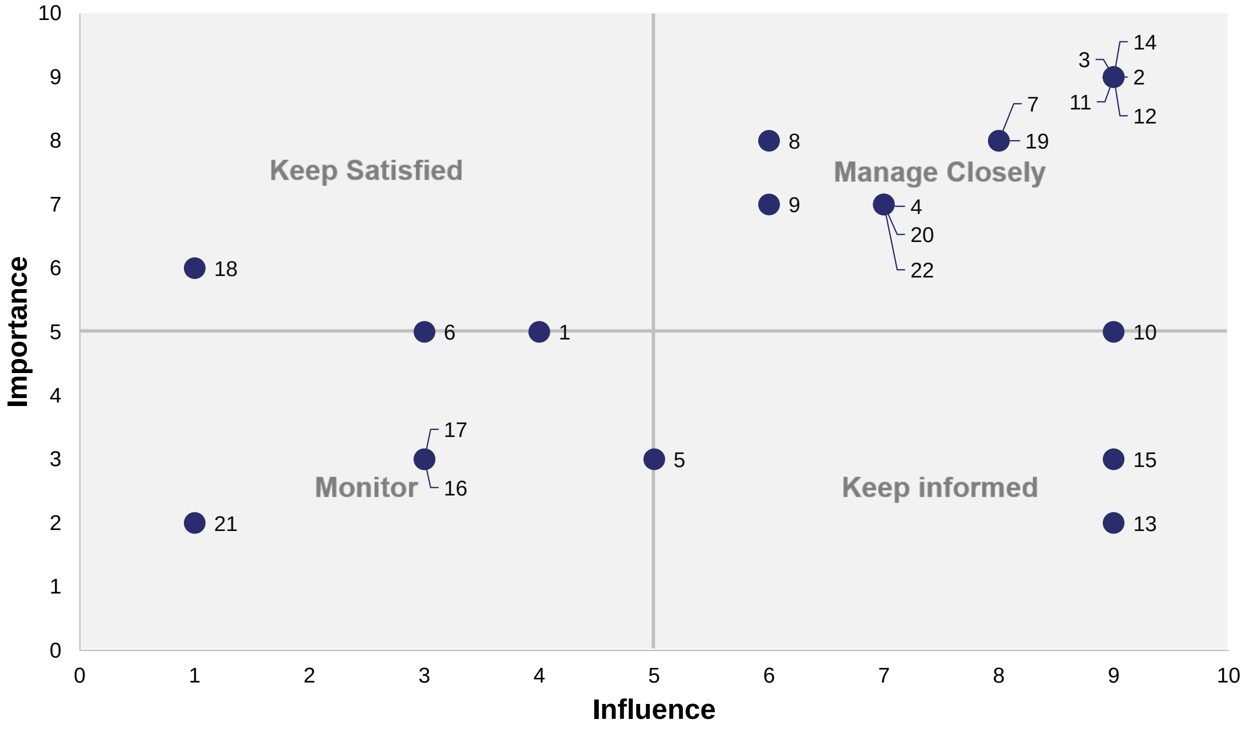

Figure 33: DUC1 Stakeholder Matrix

Source: ISL

Besides the identification of required stakeholder management regimes, several risks where identified, that could be emanated from the individual stakeholders and that could potentially become a hindrance to the project.

- The main risk that was identified in the group of "Cargo Interests" (1) is an opposition against autonomous solutions and a possible evocation of lobbyism for the alternatives such as road transport or the status quo. However, this risk is expectedly only applicable if autonomous solutions fail to offer an improved service, time and cost-wise. A comparable risk was identified for industrial clusters and organizations that fall under stakeholder group "Others" (9).
- Failing to fulfil the requirements of stakeholders in "Finance and Insurance" (2) might lead to cutting of funds or subsidies, which is why this stakeholder needs to be managed very closely.
- While there are strong promoters of autonomous shipping among the group of "Fleet Owners, Charterers and Operators" (3, 4, 5, 6), close management is crucial to bear the requirements of the group in mind. Failing to do so might result in a negative impact on the perception of the SEAMLESS concepts and negatively influence the market for autonomous shipping solutions.

- “Logistic Service Providers” (7) need close stakeholder management as well. They are depending on highly efficient last mile logistics. Failing to demonstrate the efficiency and reliability of the SEAMLESS concept opens the risk of this group to route their logistics network through other ports and with alternatives to waterborne transport systems.
- “Nautical Service Provider” (8) Massterly needs to be integrated closely in the project, because without the ROC the use case fails in a market environment, where ROCs are merely operating as pilots for a small fleet of automated vessels.
- The group of “Regions and Municipalities” (10, 11) have a high focus on the plans and strategies, that were decided to be implemented. Need to be informed and managed closely, as they might tend to stick with plans that can be brought to life within the current situation rather than discussing theoretic future concepts. As organizers of subsidies, relevant decision makers on potential municipal investments, need to be convinced of the SEAMLESS solutions for them to leave the pilot stages.
- The largest risk with stakeholders of “Regulators, Flag States, Port Authorities and Port States” (12, 13, 14, 15) is that regulations are not decided in favour of autonomous shipping or that exception permits are withdrawn in case of any serious incident. While the stakeholders of this group are having different importance, the influence of them is, partly to their legal power, very high, which is why close management and close communication is crucial. In any case, the SEAMLESS Use Case needs to prove positive effect on operational and societal costs, to build on the further support of this stakeholder group.
- “Sea-/Inland Port Operators” (16, 17) need to be monitored closely and should not be missed out. While their importance and influence on the project is low, they are at risk of losing volume to other ports or to other modes of transport, if the efficiency of SEAMLESS solutions is not sufficient to maintain or improve the current level of attractiveness of the Port of Bergen.
- Main risk in the stakeholder group of “Technology Providers and Research” (18, 19, 20, 21, 22) is, that the concepts, which are developed and tested within the Use Case are getting too expensive and fail to achieve economic viability in the long run. Another risk is, that the developed concepts prove to only be applicable within the Northern European Use Case and cannot be applied to other use cases.

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2.2 CENTRAL EUROPEAN DEMONSTRATION USE CASE

2.2.1 SEAMLESS Use Case Outline

2.2.1.1 Problem Statement and Motivation

Increasing exploitation of inland waterways is seen as an important prerequisite for improving the sustainability of the (continental) transportation sector. Within its Sustainable and Smart Mobility Strategy, the European Commission has announced the objective of increasing transport volumes of IWT by 25 per cent till 2030 and 50 % by 2050 (European Commission, 2020, p. 11) to reach the objective to reduce GHG emissions by 90 per cent till 2050 (European Commission, 2020, p. 2). Besides the need for modal shift in freight transportation, it further states the core objective to set IWT on “an irreversible path to zero-emissions” (European Commission, 2021, p. 2) by means of the NAIDES III action programme. At the same time, the IWT sector is facing significant challenges which severely put those growth objectives at risk.

Like other transport sectors, IWT is increasingly confronted with a shortage of labour. Even though comparative data is limited, it is assumed that employment in IWT has followed a stagnating or negative trend (depending on data source) in central and eastern Europe throughout the last ten years (CCNR, 2021a, p. 6). Especially self-employed barge owner-operators, which is still a common business scheme in Western Europe, report difficulties to find successors (CCNR, 2021a, p. 9). Over the last years, shortage of personnel in Western Europe had been somewhat mitigated by working migration from East to West (CCNR, 2021a). Experts claim that the jobs in inland navigation lack attractiveness due to unregular and not family friendly working conditions (van Leeuw Weenen et al., 2013, p. 39). Furthermore, IWT is carried out in a tense market environment which is expected to change significantly in the upcoming years: As most European countries transition their energy sectors, dry and liquid bulk markets which have traditionally been dominated by IWT, e.g. the transport of coal or oil-products, are expected to shrink (CCNR, 2021a, p. 22). A rather positive outlook and potential is given for the demand for transportation of smaller or containerized commodities (CCNR, 2021a, p. 23). Economically, IWT has also suffered from low-water conditions, which diminish capacity and thus profitability of IWT or even cause completely halted operations. It is projected that this situation will rather become worse than better given increasingly warm winters and dry summers in Europe as a result of climate change. Not only in the public perception, but also within the transport industry, inland navigation must therefore evolve to convince new customers of its quality as a reliable transport alternative. All of the above-mentioned trends will likely force the IWT sector to foster adaptation and change, requiring the redesign of business models but also the introduction of alternative waterborne transport concepts. As part of this discussion, the automation of inland navigation is increasingly seen as an enabler and catalyst to allow for more ecological, social and economic sustainability.

Even though IWT generally allows for transports with a low energy input per ton kilometre, comparatively high air pollutant (esp. NOx and particle matter) emissions cloud the environmental footprint

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of fossil-fuelled inland waterway vessels (CCNR, 2017, pp. 130–131; van Essen et al., 2019, p. 164). As fossil-fuelled vessels make up the majority of the existing and aged fleet. Given the technological requirements that automation poses towards the adaptations and renewal of the fleet, it may provide additional reasoning to make the shift from fossil to alternative and zero-emission propulsion, such as battery-electric systems. Likewise, the required fleet renewal opens possibilities to adapt vessel designs to the effects of low water conditions which ultimately improves the resilience of inland waterway transport chains. This hope is in line with the economic intention to maximize total productive sailing time by reduced personnel requirements on board. The reduction of personnel, which currently makes up a significant amount of operating expenditures (Al Enezy et al., 2017, p. 15) is furthermore expected to further reduce costs (Verberght & van Hassel, 2019, p. 5). In this way, alternative markets which are currently considered unprofitable with existing service patterns could be developed in the future. However, these expected benefits must outweigh the significant investment costs of automation. Social sustainability is expected to be improved by more attractive working conditions that among others are safer and more family friendly compared to the current situation. While automation in IWT may build upon or add to the development of automation in the maritime domain, it comes with a set of specific requirements. This ranges from environmental aspects such as the characteristics of inland waterways compared to open waters such as the limited and narrow fairways, over to technical characteristics of inland vessels or legislative aspects. Even though first remote-controlled and highly automated solutions have proved to provide satisfying performance, the automation technology market is far from being mature yet, leading to high investment needs. From a business standpoint, the challenge is to reconcile the technological and organizational challenges in such a way that competitive and profitable transport services can be offered and thus the promises made to automation come true.

The Central European Demonstration Use Case seeks to demonstrate ways towards successful market entrance and scaling up of flexible automated business models in the IWT domain. The geographic and market setting will be set by the Lower Rhine and the French-Belgian canal network, which represent some of Europe’s most important corridors in terms of transport market volume and can thus be considered as challenging from a competitive point of view.

2.2.1.2 Waterborne Transport Concept

This section outlines the current state of knowledge on the future waterborne transport concept for the Central European Demonstration Case, for which it was decided to primarily focus on containerized cargo. While it is used to set the frame for the analysis of the current situation and should serve as guidance for the later work packages, the details of this concept may be subject to changes during the course of the project.

Service Networks

In the current configuration, the proposed network considers three legs:

- The first leg covers the route from Duisburg (DE) to Antwerp (BE) via the Lower Rhine and Rhine Delta region over to the Schelde Estuary. Along this stretch, possible ports to be visited are Moerdijk (NL), Nijmegen (NL), Emmerich (DE), or Emmelsum/Wesel (DE).
- The second leg connects Ghent (BE) and Antwerp (BE)
- The third leg connects Ghent (BE) and the city of Dourges (FR) via the Belgium and French Canal Network. Possible stops along this stretch are Wielsbeke (BE), and Lille (FR).

All of these ports accommodate are container terminal and are represented in Figure 34.

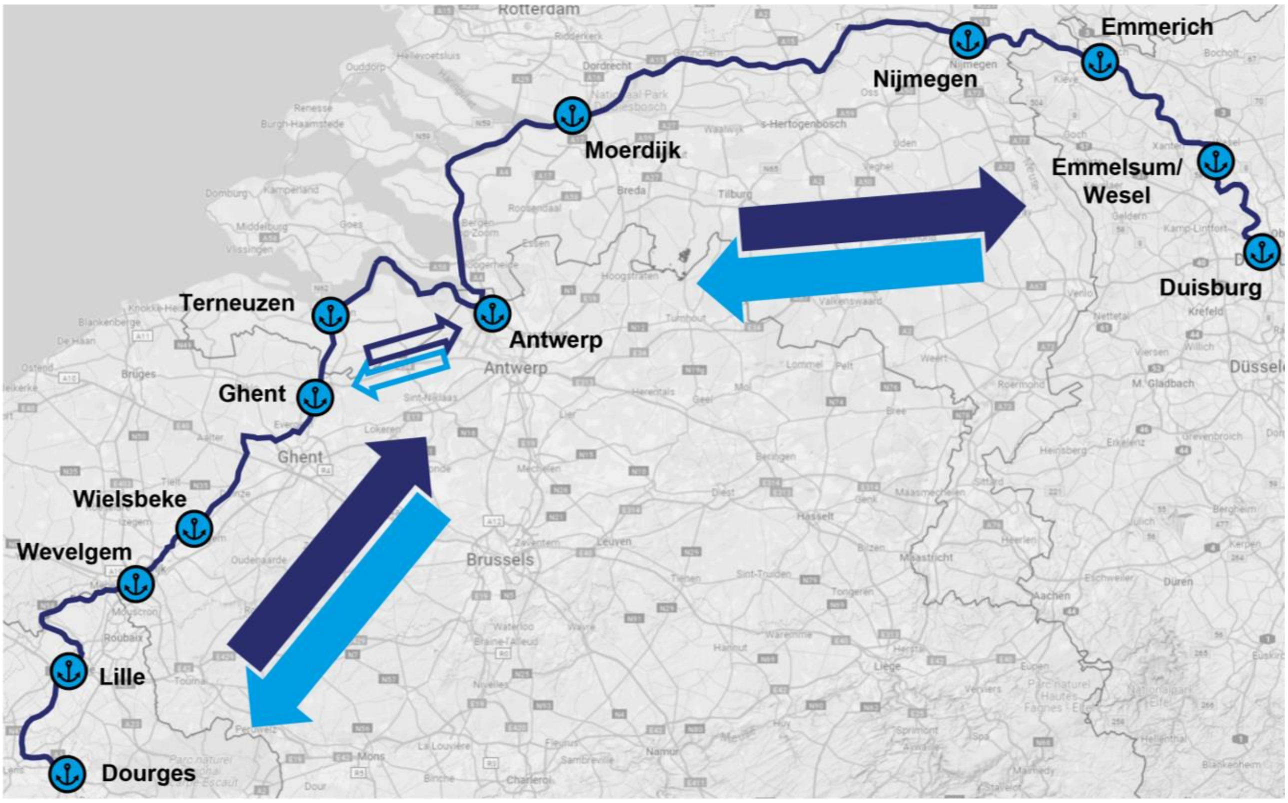

Figure 34: Envisioned DUC 2 routes and ports

Source: Google LLC

Given this picture, the port of Antwerp represents a central hub for maritime cargo flows. Pre- and on-carriage of containerized cargo to and from the inland ports is usually carried out by truck. In view of the large number of transhipment locations along the envisaged corridor, the potential of continental transports also remains of interest. Against this background, a further extension of the scope over to the West German canal network up to the port of Minden located at the Mittelland Canal would be conceivable.

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The service to be realized is expected to eventually operate 24/7, even if it will not be feasible at the beginning. This represents an extension of sailing times compared to most existing services, which are following the Rhine operating modes A1 or A2.

A significant share of cargo transport within the corridor is international / cross-border. This comes with implications with respect to the legislation on the specific waterway stretches. While the canal network is subject to either French or Belgian legislation, the Rhine is considered international waters governed by CCNR (Commission Centrale pour la Navigation du Rhin).

Vessel Operations

The use case envisions the operation of a self-propelled inland vessel that allows for remote controlled and highly autonomous operations. While this requires a manned transition phase, the vessels are planned to ultimately sail unmanned and supervised via a Remote Control and Operations Centre. Given the aforementioned service conditions, “flexibility” which refers to the ability of the vessel to be deployed under different nautical and market conditions, as well as a high availability which refers to the ability to maximize sailing time (i.e., making it independent from personnel restrictions, minimize time to recharge energy storage, limited range restrictions) are key conceptual requirements towards vessel operations.

The type of vessel that has been selected for the use case deployment is the **X-Barge** concept designed by Naval Dynamics AS and developed by ZULU Associates and matches the technical requirements of the ES-TRIN standard for inland vessels. Construction of this vessel is expected to be finished by the end of 2024. Dimension-wise, the X-Barge can be classified as a CEMT class IV vessel, which comes at a length of 85 meters, a beam of 9.6 meters, a maximum/scantling draft of 2.95 meters and an air draft of 5.0 meters when loaded to 2.5-meter water draft. The 1,500-dwt vessel may be used for transportation of dry bulk, break bulk or containerized cargo, the latter with a cargo capacity of 90 TEU.

Propulsion will be realized using an electric drive that is supplied by a swappable container-based energy system, which can be loaded to a special on-deck compartment at the aft of the vessel (3x 20’-Containers). This storage may come in the form of batteries, hydrogen or other power units. Today, only a limited and not standardized number of respective solutions are available. One of which is a battery-system developed by Wärtsilä. The lithium-battery comes with a weight of 27 tonnes, and a capacity 2,000 kWh. Connection between the vessel and the battery can be established using a multipole quick-power connector which allows for moderate positioning deviations and does not require manual handling. The containers are equipped with a ventilation and cooling, a fire protection system as well as a data connection and energy management system.

Two stern azimuth thrusters with 330 kW each will provide forward propulsion up to 10 knots (8 knots expected cruising speed), while a 200-kW tunnel bow thruster may be used for transversal propulsion. Given this setup, the barge comes with automated positioning capabilities, which may be used for non-moored lockages. Equipped with 3 battery-containers with a capacity of 1.5 MWh each, the vessel is expected to have a range of 500 km. In addition, the vessel is equipped with an uninterruptable power supply (UPS) of 114 kWh.

Figure 35: Rendering of ZULU X-Barge

Source: ZULU Associates

Furthermore, the X-Barge will be equipped with the sensor and communications technology that allows for remote controlled operations. However, the exact specifications are currently still under development and have not been available when this report went to press.

Port Operations

In its basic configuration, the X-Barge is designed to operate with automatic mooring systems that are installed at berth. However, since these infrastructures are not yet available at a lot of inland ports, manual mooring by landside personnel may be required as a preliminary step. Furthermore, to increase the vessel autonomy, the possibility to install and operate onboard-systems will be evaluated during the project as well (WP3).

Another central aspect of port operations is to ensure reliable supply of the vessel with swappable energy containers. Given a 20’ container design, the exchange of those containers can be integrated into normal cargo operations. Today, only a limited number of respective solutions are available. The above-mentioned system developed by Wärtsilä is brought to market by the company “Zero Emission Services” (ZES) which is a company owned by Wärtsilä, Ebusco, ING and the Port of Rotterdam (Zero Emission Services, 2022). The ZES business model includes an open access and pay-per-use system, i.e., not contractually binding, which makes use of a network of loading facilities within inland port terminals. However, in order to allow not be dependent on and restricted to the network

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of a single company, the SEAMLESS use case envisions a standardized solution that allows the use of multiple energy container providers. Another potential supplier is the company ZENOBE. This company is developing a battery system for inland ships based on their experience and know-how of bus electrification and battery parks. Possible charging locations are currently under negotiation.

Lock Operations

In order to pass through the defined corridors, the highly automated and autonomous use of locks must be guaranteed. Areas of tension include communication between lock personnel and ships as well as technical challenges such as positioning and mooring.

The current concept stage foresees communications in remote control mode to be realized as is via VHF. With regard to mooring, the possibilities of using the ship's dynamic positioning capabilities will be investigated so that no mooring lines need to be used.

An organisational challenge concerns the extension of vessel operating times, which would also require an extension of the lock opening hours. As an example, on the large gauge canal network in France, there exists a special lock service, allowing, on request and for a fee, passage through the locks in the evening from 8:30 p.m. to midnight, Monday to Saturday. These requests must be made the same day, before 5 p.m. By 2025, there will be remote control on the whole of this route with probably longer navigation times than those currently in place.

2.2.2 Logistics Environment

2.2.2.1 Transport & Market

The considered corridor of Dourges – Antwerp – Duisburg is a centrepiece of the most densely populated European axis, sometimes referred to as the “Blue Banana”. This corridor, which ranges from Liverpool to Milan, represents a focal point in terms of European economic and urban concentration (Brunet, 2002).

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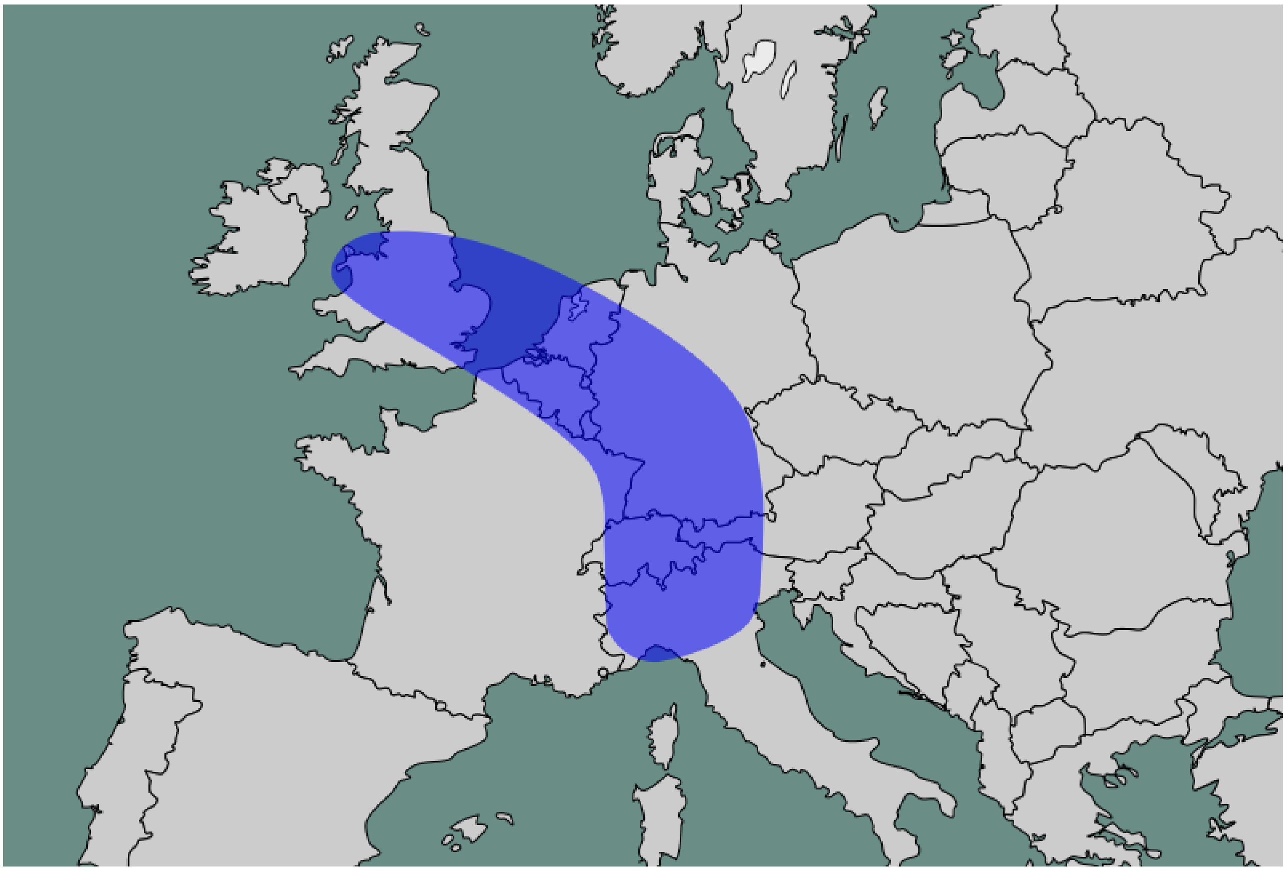

Figure 36: Illustration of the Blue Banana

Source: ArnoldPlaton[13]

It is no coincidence that the Rhine Delta region is fully incorporated in this spatial framework. Being one of the busiest inland waterways of the world, it has affected its contiguous territories. The river attracted settlements and fostered their urbanization and development by providing a substantial transport system. Railway tracks flank the river; additionally, the area is streaked by a cohesive motorway network. Given its interregional integration, it is not feasible to define and isolate a demographic or economic zone around the DUC corridor. Dourges is located just south of the European Metropolis of Lille, while Duisburg at the other end is part of the Rhine-Ruhr Metropolitan Region. Antwerp is the centrepiece of the eponymous metropolitan area.

Central European IWT is of high importance for various commodities of bulk cargo. The transport mode also offers great options for break bulk as it is possible to handle cargo beyond road and rail

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[13] Illustration *Blue Banana.svg* by Wikimedia user ArnoldPlaton, uploaded on 21st of February 2012 under CC BY-SA 3.0 (please see https://creativecommons.org/licenses/by-sa/3.0/deed.en).

transportation's limits for dimensions and weight. Inland waterways are also used to haul containerized goods. However, their role is strongly limited to the pre- and on-carriage of containers to seaports. IWT data of Germany shows that only 0.1 percent of all full containers were neither discharged nor loaded at a seaport.[14] Many of these non-seaport related transports can be traced to specific and often nonrecurring projects. Nonetheless, IWT is quite frequently used to balance empty container stocks between terminals, as it reflects an inexpensive transport option.

There are no rail transports reported between Dourges/Lille and Duisburg.[15] With a road distance of approximately 350 kilometres, transportation by truck is a feasible option here. Therefore, containerized continental transportation in the corridor seems to be predominantly served by road. Transportation data of this specific level of detail is not on hand. This section will therefore approximate the DUC's pattern in terms of transport market and logistics.

Firstly, it is suitable to consider the corridor as two legs with Antwerp as the focal point. Being Europe's second-largest seaport, Antwerp has emerged to a leader in the petrochemical sector and harbours miscellaneous industries. The nautical conditions on the two legs Dourges – Antwerp and Antwerp – Duisburg are very unlike (See chapter 2.2.2.3) and so is the IWT-related logistic network. The Rhine-Waal haul is served by large barge units with a continuous schedule up the numerous terminals to Switzerland. The Dourges – Antwerp leg does not obtain similar levels of traffic.

According to ISL's European Container Traffic Model (ECTM) a grand total of 236,106 hinterland containers (in TEU) were transported between Antwerp and the five terminals in the corridor in 2021. Only terminals accessible directly, i.e., no need to pass locks or side canals, along the haul were considered as relevant. The majority of the corridor's volume was handled in Duisburg. The number of export containers that were transported to Antwerp exceeded the import figures in each terminal except for Emmerich.

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[14] Special inquiry to the Federal Statistical Office of Germany, data for 2021.
[15] Special inquiry to the Federal Statistical Office of Germany, data for 2021.

Table 5: Barge container transportation (full and empties) in the Antwerp – Duisburg leg estimates for 2021

Inland terminal	To Antwerp	From Antwerp	Total
Duisburg (DE)	88,546 TEU	48,287 TEU	136,834 TEU
Emmelsum / Wesel (DE)	13,147 TEU	9,960 TEU	23,107 TEU
Emmerich (DE)	6,502 TEU	11,654 TEU	18,156 TEU
Nijmegen (NL)	30,843 TEU	9,987 TEU	40,830 TEU
Moerdijk (NL)	9,837 TEU	7,342 TEU	17,179 TEU

Source: ISL European Container Traffic Model (ECTM)

On the Dourges – Antwerp leg six terminals were considered relevant. Terneuzen and Ghent are the busiest of them and account for 70 % of the 107,054 hinterland containers (in TEU) that were transported to and from Antwerp in 2021 by barge according to the data from the European Container Traffic Model (ECTM). Of the listed terminals Wevelgem represents a special case as it is part of the eponymous industrial zone. Much of the traffic is dedicated for the food processing company Alpro, whose plant is contiguous to the terminal.

Table 6: Barge container transportation (full and empties) in the Dourges – Antwerp leg, estimates for 2021

Inland terminal	To Antwerp	From Antwerp	Total
Terneuzen (NL)	18,456 TEU	15,096 TEU	33,552 TEU
Ghent (BE)	23,436 TEU	17,891 TEU	41,327 TEU
Wielsbeke (BE)	3,370 TEU	4,156 TEU	7,526 TEU
Wevelgem (BE)	2,527 TEU	3,117 TEU	5,644 TEU
Lille (FR)	1,540 TEU	1,298 TEU	2,838 TEU
Dourges (FR)	8,771 TEU	7,395 TEU	16,166 TEU

Source: ISL European Container Traffic Model (ECTM)

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2.2.2.2 Existing Transport Concept

The following table provides an idea of the regular barge connections in the DUC2 corridor. It represents only an indication. The information is gathered from schedules and statements provided by the operating companies and additional desk research. Sources are often inconsistent and uncertainties regarding the current status of schedules remain.

Table 7: Barge connections in the corridor

Operator	Ports calling (in corridor)	Frequency	Additional information
neska Container Line B.V.	Duisburg – Antwerp	2x/week (downstream 4x/w)	
Hutchison Ports Europe Intermodal	Duisburg – Antwerp	2x/week	
Contargo together with Haeger & Schmidt Logistics	Duisburg – Emmelsum/Wesel – Antwerp	3x/week	
Danser	Nijmegen – Moerdijk – Antwerp	3x/week	
Combined Cargo Terminals	Moerdijk – Nijmegen – Antwerp	6x/week	
unknown	Emmerich – Antwerp	3x/week	
Danser	Dourges – Lille – Halluin – Wevelgem – Terneuzen – Antwerp	5x/week	
Stukwerkers	Ghent – Antwerp	5x/week	
Contargo	Dourges – Antwerp	2x/week	2x push barge with 78 TEU capacity
Contargo	Terneuzen – Antwerp	on request	
Contargo	Ghent – Antwerp	on request	
Contargo	Wevelgem – Wielsbeke – Antwerp	6x/week	3x push barge with 54 TEU capacity

Source: ISL

In the area of Lille standardized units are commonly used for the transport of waste via inland waterways and account for a large share of this transport segment. In 2021 the terminal of Halluin solely had respective shuttle traffic with Sequedin. For this reason, Halluin is not included as a relevant terminal in the preceding enumeration, despite being listed in Danser's schedule. A similar shuttle

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system exists between Santes and Bethune, also in standardized, container-like, units (Voies navigables de France, 2021, p. 34).

It is worth noting, that there are no barge services which connect ports of the two legs directly nor services without calling Antwerp. This further supports the notion that containerised IWT in the DUC2 corridor is predominately (one exception being the above-mentioned waste shuttles) embedded in the pre- and on-carriage of deep-sea container transports via Antwerp. In addition to the IWT options, rail services connect Antwerp to the hinterland and provide transport capacities.

2.2.2.3 Existing Waterway Conditions

Demonstration Use Case 2 is about containerised inland waterway transport on the Dourges – Antwerp and Antwerp – Duisburg routes and vice versa. The total distance between Dourges and Duisburg is approximately 495 km, with the Dourges – Antwerp leg being approximately 213 km and the Antwerp – Duisburg leg approximately 282 km (EuRIS, 2023b). On the planned route from Dourges to Duisburg there are a total of 12 locks with different specifications and dimensions. Ten of the eleven locks are located on the first leg Dourges – Antwerp and only two locks on the other section. Especially on the section between Dourges and Antwerp, the density of bridges is very high and there are well over 100 bridges to pass on this stretch. Between Antwerp and Duisburg, the number of bridges is considerably lower, at around 20 (EuRIS, 2023b).

Table 8: Relevant locks in DUC 2

No.	Lock name	Location name	Operated by
1	Don	Don	VNF
2	Grand Care	Lille	VNF
3	Quesnoy	Quesnoy-sur-Deule	VNF
4	Comines	Lys	SPW
5	Nieuwe stuwsluis te Menen	Menen	DVW
6	Stuwsluis te Harelbeke	Harelbeke	DVW
7	Sluis te Sint-Baafs-Vijve	Wielsbeke	DVW
8	Sluizen te Evergem	Evergem	DVW
9	Terneuzen	Terneuzen	RWS
10	Zandvliet - Berendrecht Complex	Antwerp	Port of Antwerp-Bruges
11	Kreekraksluis	Rilland	RWS
12	Volkeraksluizen	Willemstad	RWS

Source: EuRIS (2023a)

Also due to the battery capacities, a direct transit from Dourges to Antwerp or Antwerp to Duisburg, or vice versa, is not possible. In DUC2, therefore, several en-route ports are planned as transhipment and battery exchange points. The first leg is currently planned with possible stops in Lille, Wevelgem, Wielsbeke, Ghent and Terneuzen (see also Figure 37). The port of Ghent plays a special role here, as in addition to the two legs already described, a further leg directly between Antwerp and Ghent would also be conceivable. For example, cargo consolidation could also take place in Ghent.

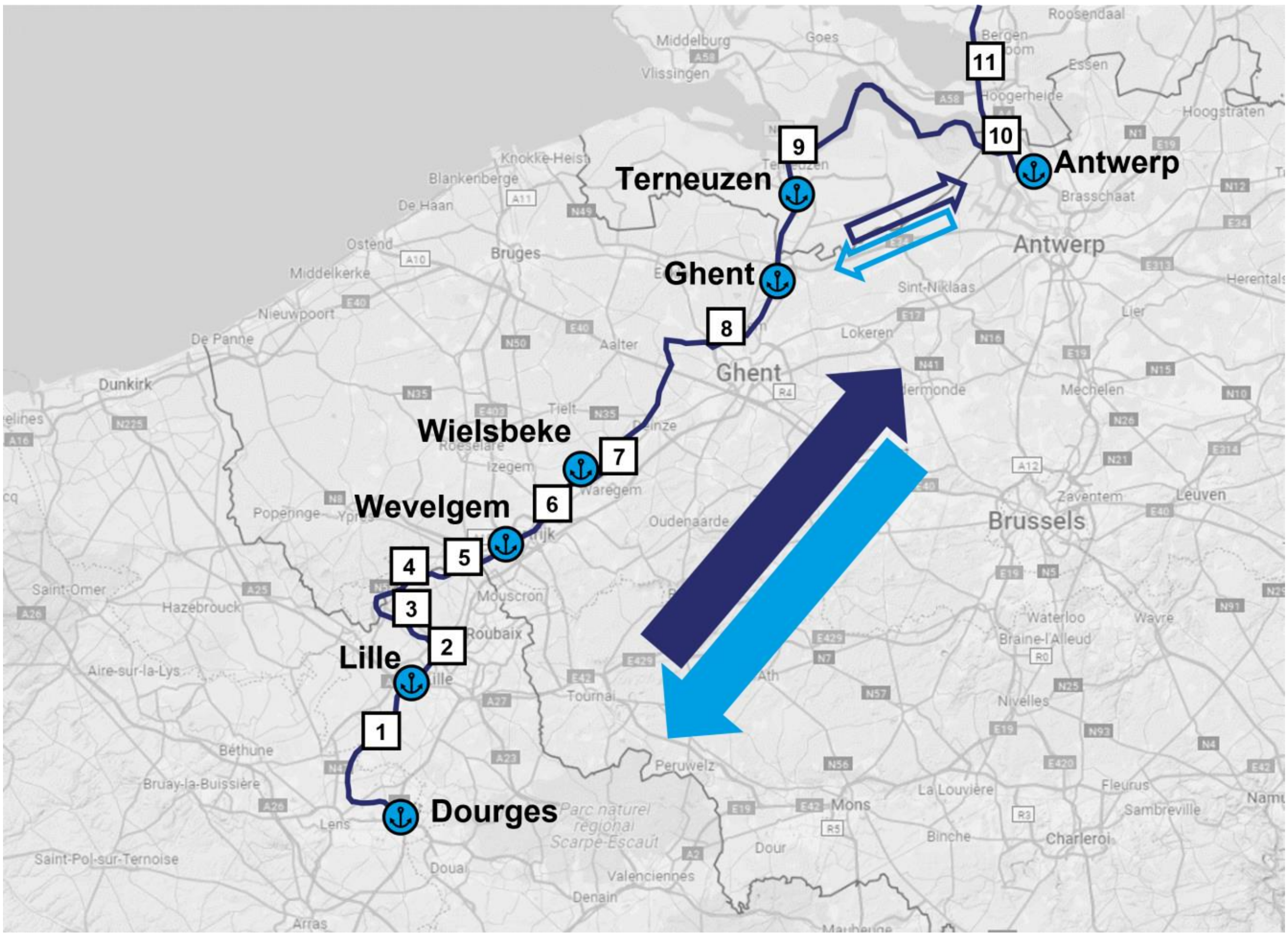

Figure 37: DUC2 leg Antwerp- Dourges with lock numbers in white boxes

Source: ISL based on Google LLC

For the Antwerp-Duisburg leg planned en-route ports are Moerdijk, Nijmegen, Emmerich and Wesel (see also Figure 38).

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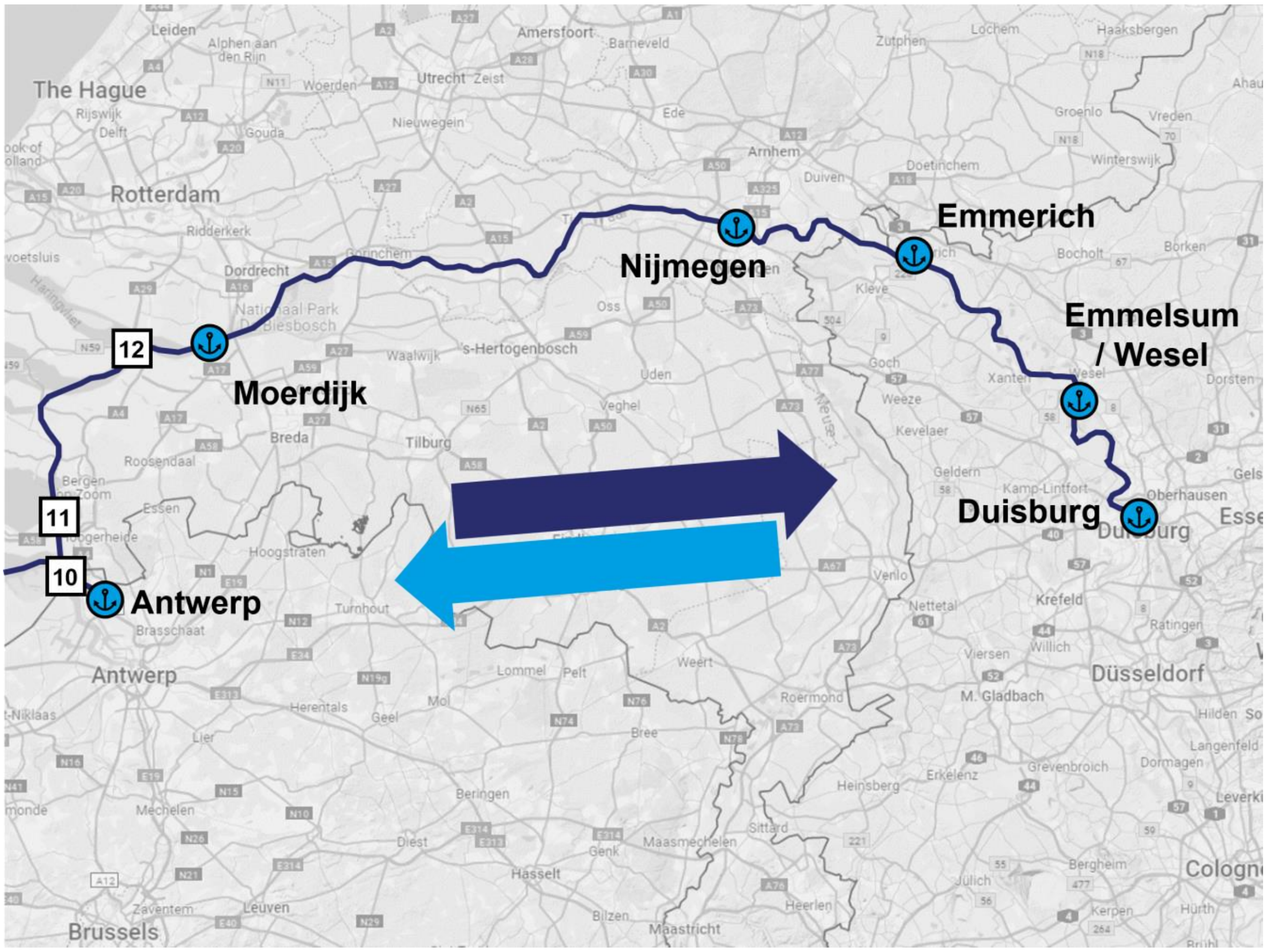

Figure 38: DUC2 leg Antwerp- Duisburg with lock numbers in white boxes

Source: ISL based on Google LLC

Locks

The French part of the DUC stretches from Dourges to Halluin north of Roubaix, with the last 15 km or so between Deûlémont and Halluin running directly on the border between France and Belgium. Here, international agreements have been reached regarding the maintenance of these sections. There are three locks in the French part. One near Don and the other in Lille.

- Don (50.54620778 N; 2.917811188 E)

The "Don" lock (Écluse de Don) is the first lock on the section from Dourges to Antwerp and is located near the town of the same name about 20 km southwest of Lille on the "Canal de la Deûle". The lock chamber dimensions are 146,25 m x 12.0 m and the permissible dimensions for ships entering this lock are 144.60 m long, 12.0 m wide and 4.5 m high with a maximum draft of 3.5 m. According to EURIS, the lock is locally operated. According to information from VNF, the lock is scheduled to be operated remotely from 2025 onwards. The lock does not operate 24/7 and can be reached on radio channel 22 during operating hours The responsible authority for the lock is VNF (EuRIS, 2023a).

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Operating Hours

Mon – Sat 06:30 - 20:30 (special service 20:30 – 23:59)
Sun 09:00 - 17:00

Figure 39: Lock near Don (France)

Source: ISL based on Google LLC and EuRIS (2023a)

- Grand Carre (50.647863420 N; 3.045310870 E)

The Grand Carre lock is located in the Canal de la Deûle right in the centre of Lille. The lock chamber dimensions are 147.6 m x 12.0 m and the permissible dimensions for ships entering this lock are 144.60 m long, 12.0 m wide and 3.74 m high with a maximum draft of 3.5 m. According to EURIS, the lock is locally operated and according to information from VNF is scheduled to be operated remotely from 2025 onwards. The lock does not operate 24/7 and can be reached on radio channel 18 during operating hours The responsible authority for the lock is VNF (EuRIS, 2023a).

Figure 40: Grand Carre in Lille (France)

Source: ISL based on Google LLC and EuRIS (2023a)

- Quesnoy (50.704402869 N; 3.013167105 E)

The Quesnoy lock is located in the Canal de la Deûle just 1 km southeast of the municipality of Quesnoy-sur-Deûle. The lock chamber dimensions are 111.3 m x 12.0 m and the permissible dimensions for ships entering this lock are 110.0 m long, 12.0 m wide and 3.74 m high with a maximum draft of 3.5 m. According to EuRIS, the lock is locally operated and according to information from VNF, is scheduled to be operated remotely from 2025 onwards. The lock does not operate 24/7 and can be reached on radio channel 22 during operating hours The responsible authority for the lock is VNF (EuRIS, 2023a).

It is planned to expand and enlarge the lock between 2023 and 2025 (see Figure 42). The goal of this operation is to give the lock a length that is consistent with the other locks on the wide gauge line, all of which measure 144.6 meters compared to Quesnoy-sur-Deule's 110 meters. Additionally, this project will enable the ability to absorb higher river traffic (VNF, 2023).

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Figure 41: Lock near Quesnoy-sur-Deûle (France)

Source: ISL based on Google LLC and EuRIS (2023a)

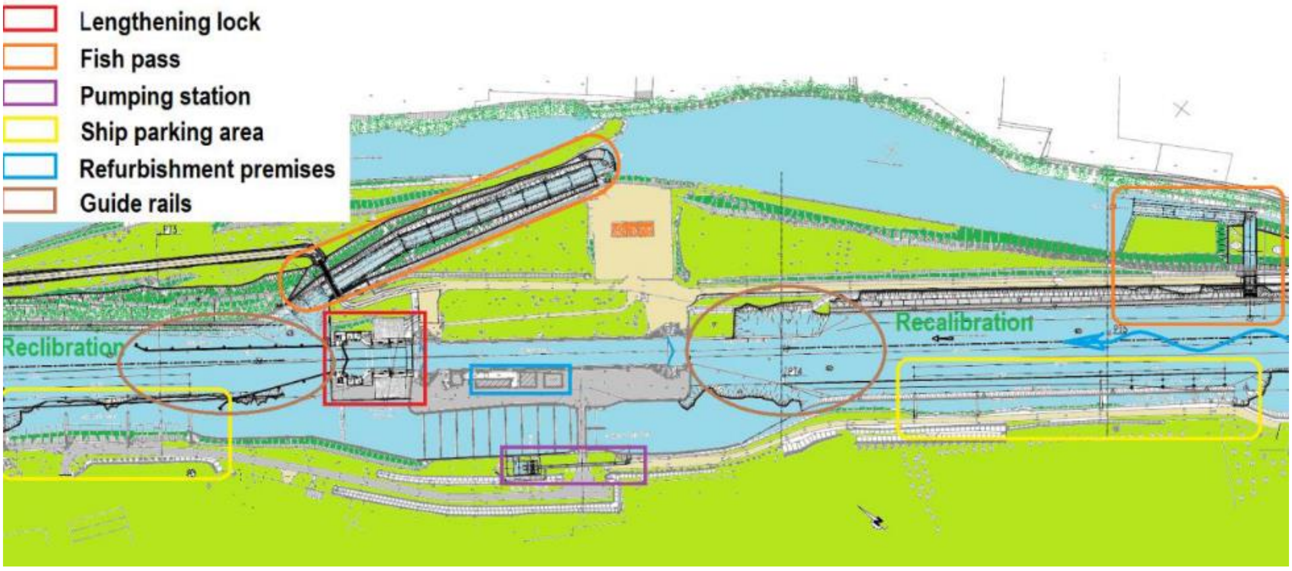

Figure 42: Planned expansion measures

Source: Schalkwijk et al. (2018)

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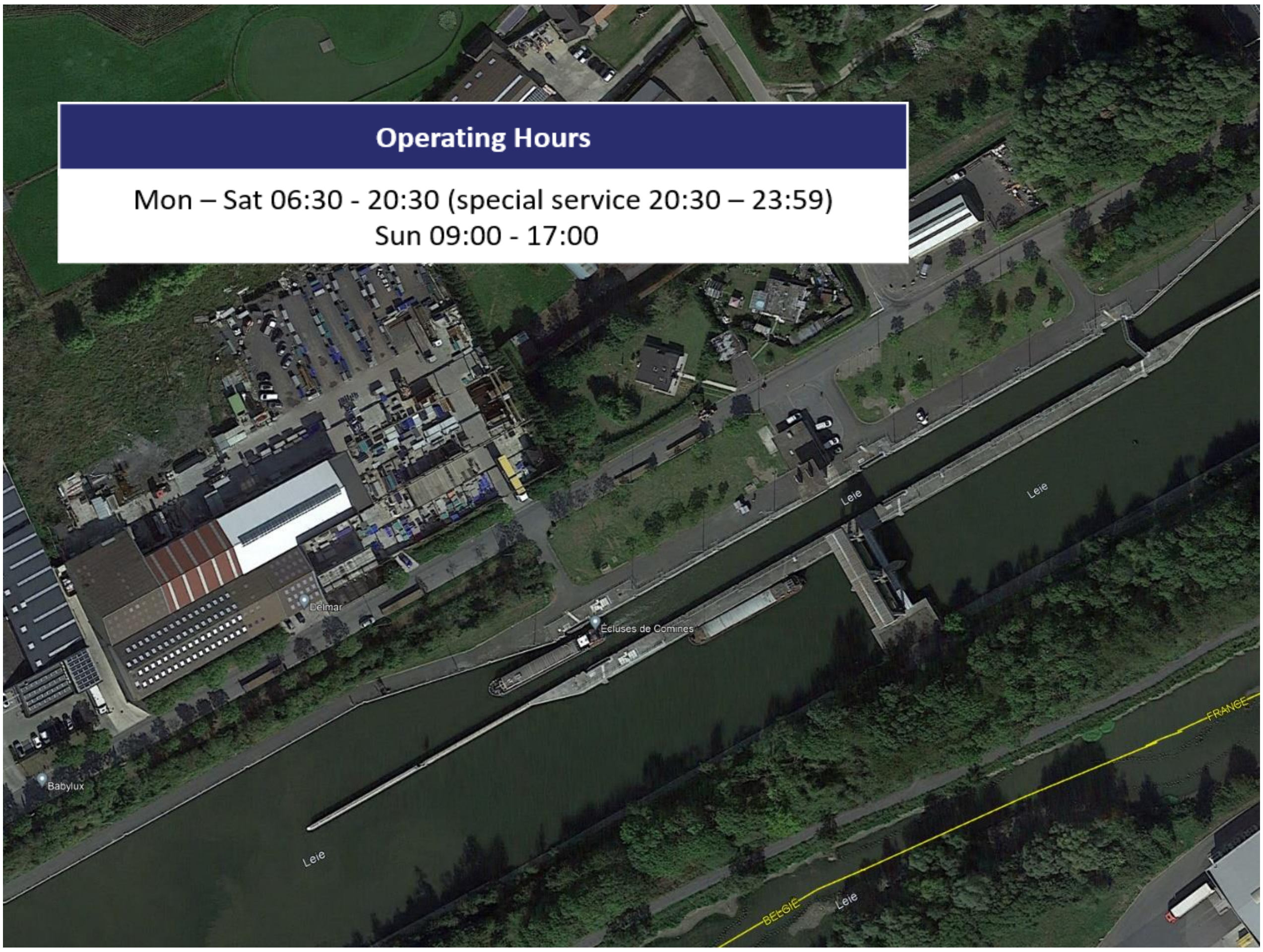
- Comines (50.760291427 N; 2.990372375 E)

The Comines lock is located in the Leie near the town Comines. This specific stretch of the Leie is called Grensleie because here the river is the border between Belgium and France. According to EuRIS the lock chamber dimensions are 110.0 m x 12.0 m and the permissible dimensions for ships entering this lock are 109.4 m long, 11.4 m wide and 4.34 m high with a maximum draft of 3.5 m. EuRIS does not state any information about the opening hours or whether the lock is locally or remotely operated. Operation is carried out by the Service public de Wallonie. Currently, neither the French ENC nor in the Belgian ENC have updated information regarding the lock (EuRIS, 2023a).



Operating Hours

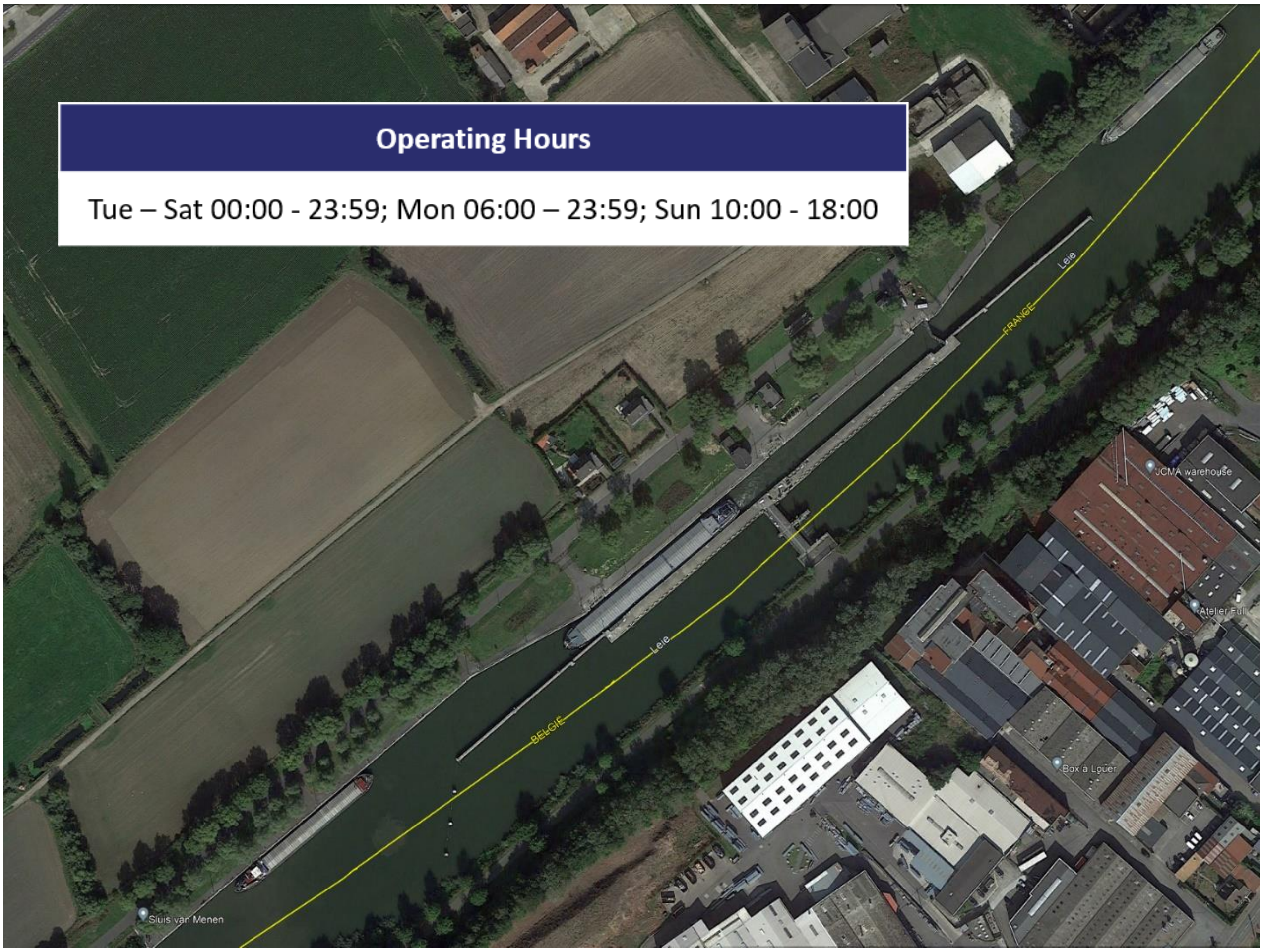
Mon – Sat 06:30 - 20:30 (special service 20:30 – 23:59)
Sun 09:00 - 17:00

Figure 43: Lock near Comines (Belgium)

Source: ISL based on Google LLC and EuRIS (2023a)

- Nieuwe Stuwsluis te Menen (50.780669473 N; 3.100836858 E)

The *Nieuwe Stuwsluis* (new weir lock) is located in the Grensleie near the town Menen. According to EURIS the lock chamber dimensions are 195.0 m x 12.5 m and the permissible dimensions for single ships entering this lock are 110.0 m long, 10.3 m wide and 9.7 m high with a maximum draft of 2.4 m. Combined transport are allowed 195.0 m in length and 12.5 m beam. According to EURIS, the lock is locally operated. The lock does not operate 24/7 and can be reached on radio channel 20 during operating hours The responsible authority for the lock is De Vlaamse Waterweg (EuRIS, 2023a).



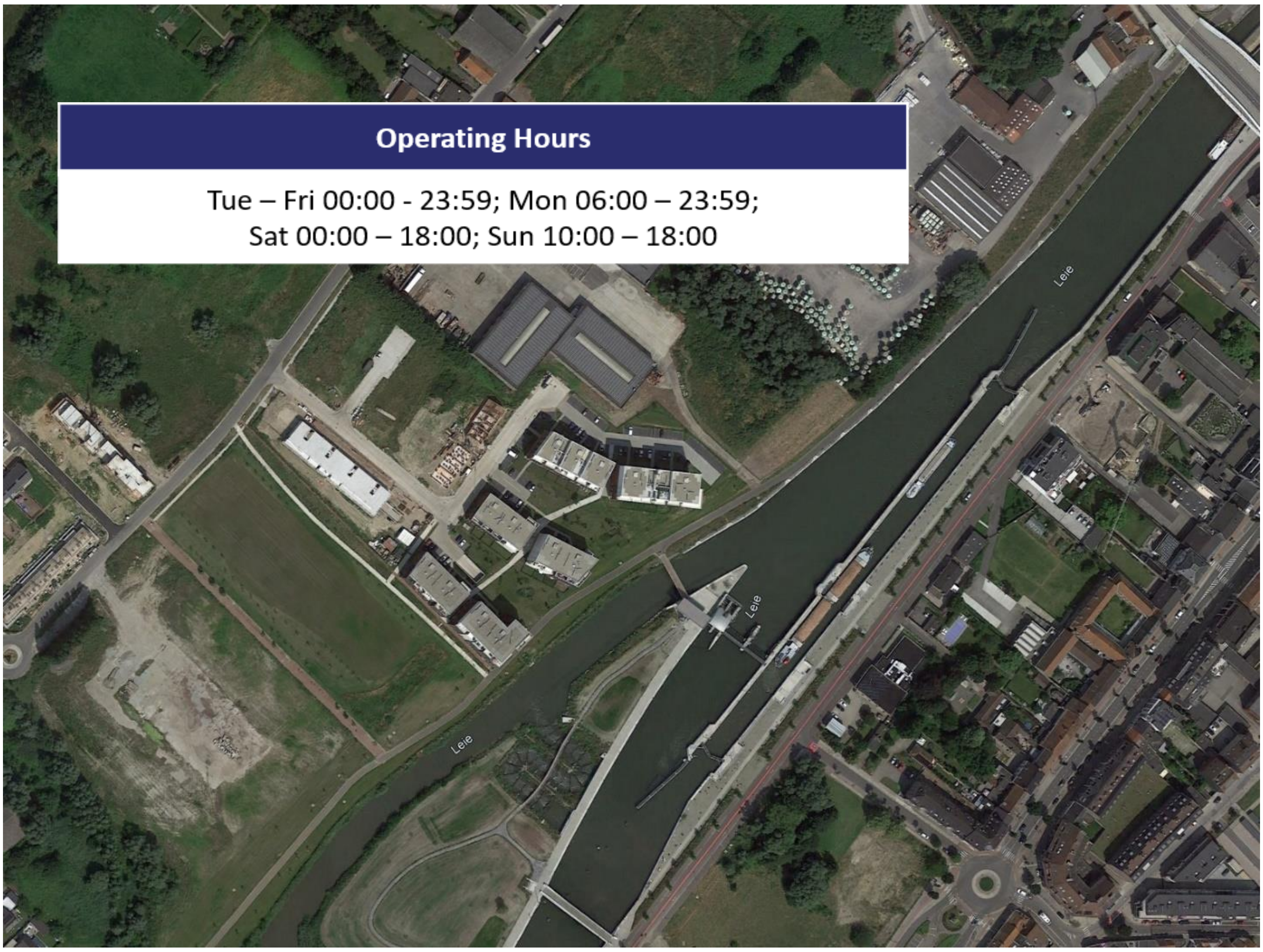
Operating Hours
Tue – Sat 00:00 - 23:59; Mon 06:00 – 23:59; Sun 10:00 - 18:00

Figure 44: Lock near Menen (Belgium)

Source: ISL based on Google LLC and EuRIS (2023a)

- Stuwsluis te Harelbeke (50.855344097 N; 3.306164577 E)

The Stuwsluis (weir lock) is located in the Leie near the town of Harelbecke. According to EURIS the lock chamber dimensions are 235.0 m x 12.5 m and the permissible dimensions for single ships entering this lock are 185.0 m long, 11.4 m wide with a maximum draft of 3.5 m. Combined transport are allowed 195.0 m in length and 12.5 m beam. According to EURIS, the lock is locally operated and can be reached on radio channel 20 during operating hours The responsible authority for the lock is De Vlaamse Waterweg (EuRIS, 2023a).


Operating Hours

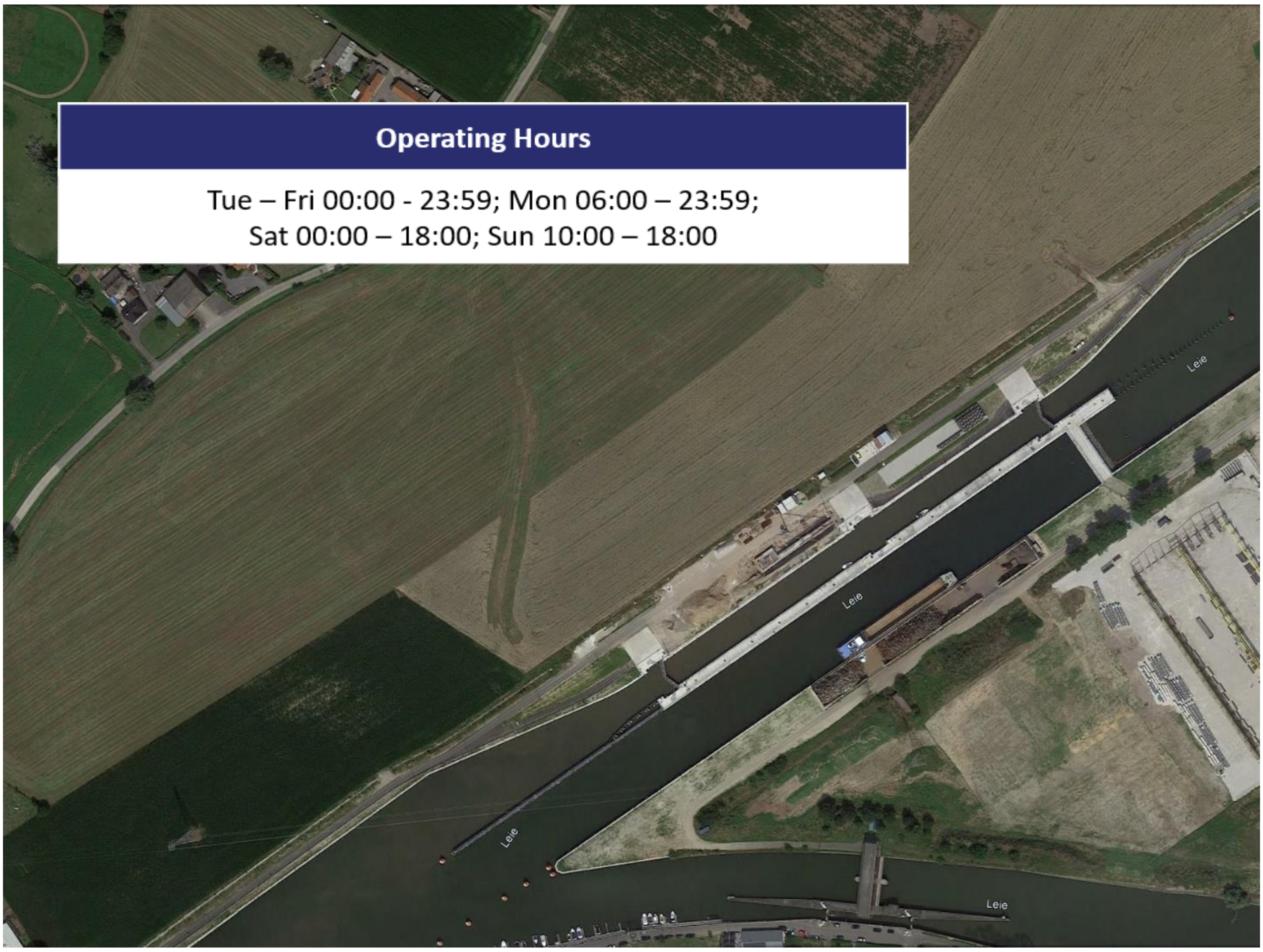
Tue – Fri 00:00 - 23:59; Mon 06:00 – 23:59;
Sat 00:00 – 18:00; Sun 10:00 – 18:00

Figure 45: Lock near Harelbeke (Belgium)

Source: ISL based on Google LLC and EuRIS (2023a)

- Sluis te Sint-Baafs-Vijve (50.913143387 N; 3.412560601 E)

The lock is located in the Leie near the municipality of Wielsbeke. According to EURIS the lock chamber dimensions are 240.0 m x 16.0 m and the permissible dimensions for single ships entering this lock are 110.0.0 m long, 11.5 m wide with a maximum draft of 2.8 m and an air draft of 6.78 m. According to EURIS, the lock is locally operated and can be reached on radio channel 22 during operating hours. The responsible authority for the lock is De Vlaamse Waterweg (EuRIS, 2023a).



Operating Hours

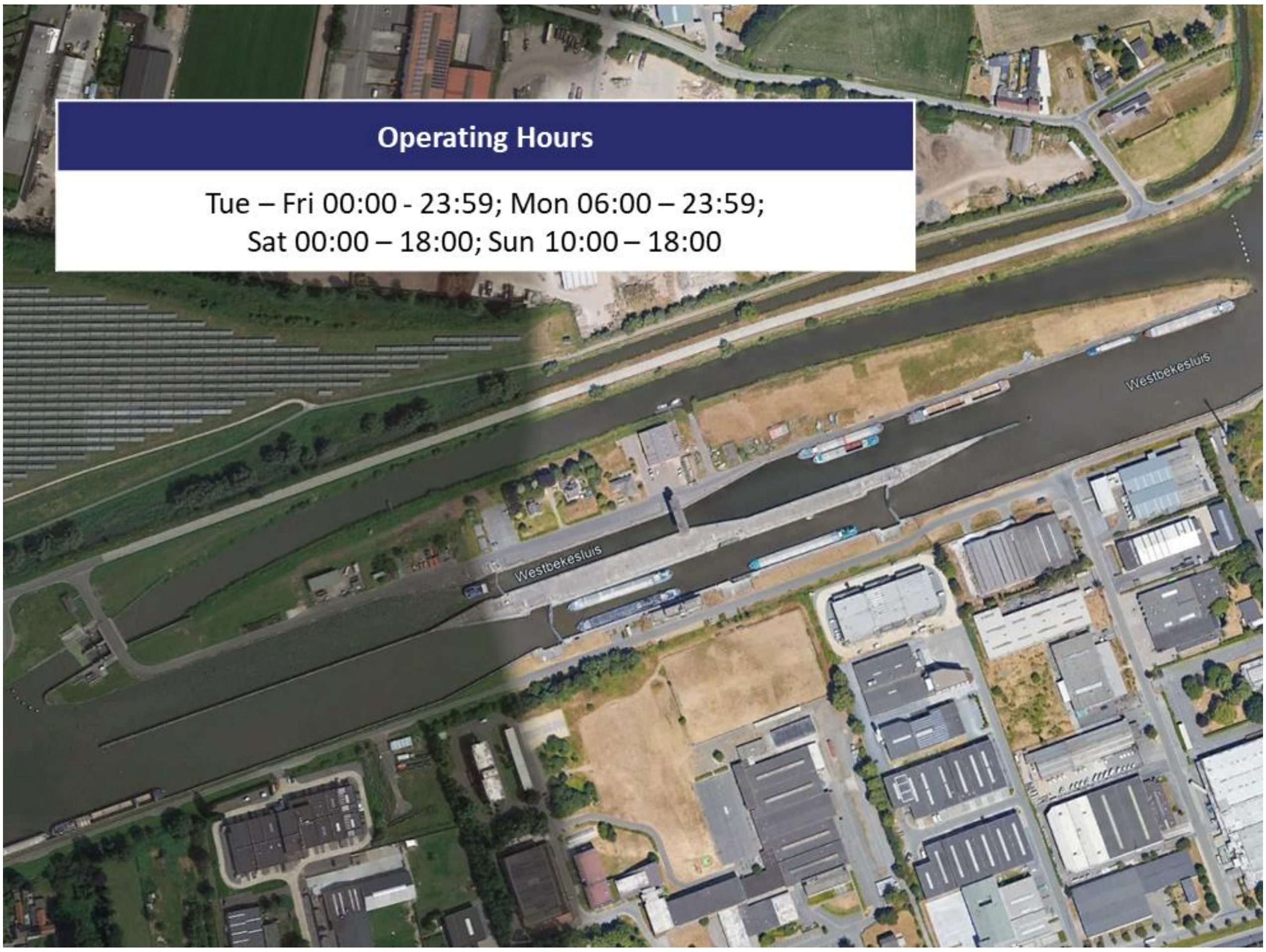
Tue – Fri 00:00 - 23:59; Mon 06:00 – 23:59;
Sat 00:00 – 18:00; Sun 10:00 – 18:00

Figure 46: Lock near Wielsbeke (Belgium)

Source: ISL based on Google LLC and EuRIS (2023a)

- Sluizen te Evergem (51.089654 N, 3.668936 E)

The lock near the town of Evergem just north of Ghent. The lock has two chambers, the k*leine sluis* and the g*rote sluis.* According to EURIS the lock chamber dimensions are 136 m x 16.0 m (*kleine Sluis*) and 230 m x 25 m (*grote sluis)*. The permissible dimensions for single ships entering this lock are 110.0.0 m long, 11.5 m wide with a maximum draft of 3.0 m (*kleine sluis*) and 3.80 m (*grote sluis*) and an air draft of 6.46 m. According to EURIS, the lock is locally operated. The lock does not operate 24/7 and can be reached on radio channel 80 during operating hours The responsible authority for the lock is De Vlaamse Waterweg (EuRIS, 2023a).



Operating Hours

Tue – Fri 00:00 - 23:59; Mon 06:00 – 23:59;
Sat 00:00 – 18:00; Sun 10:00 – 18:00

Figure 47: Sluizen te Evergem in the north of Ghent

Source: ISL based on Google LLC and EuRIS (2023a)

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- Terneuzen Complex (51.330242 N, 3.823597 E)

The lock complex in Terneuzen consists of three locks, the *Westsluis*, the *Middensluis* and the *Oostsluis*, whereas the *Middensluis* is currently being dismantled to make way for a new lock which is planned to be ready in 2024. The Oostsluis is 280 m long by 24 m wide and can accommodate ocean-going vessels of 260 m x 24 m. The lock can be reached by VHF channel 18. The Westsluis is a bit larger and can receive ocean-going vessels with 290 m x 38 m and can be reached on VHF channels 69 & 6. The new built lock, the *Nieuwe Sluis* is considerably larger with a lock chamber of 427 m x 55 m and can accommodate vessels up to 366 m in length, 49 m width and a draft of 14.5 m (Vlaams-Nederlandse Scheldecommissie, 2023).

According to EURIS, the locks are operated locally. The locks operate 24/7. The responsible authority for the lock is Rijkswaterstaat (EuRIS, 2023a).

Figure 48: Terneuzen lock complex

Source: ISL based on Google LLC and EuRIS (2023a)

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- Zandvliet - Berendrecht Complex (51.345873 N, 4.286108 E)

The lock complex consists of two locks, the *Zandvlietsluis* and the *Berendrechtsluis*, leading into the inner port of Antwerp. The locks are located at the north part of the port and can receive the biggest ocean-going vessels in the world with permissible ship dimensions of 490 m x 55 m (*Zandvlietssluis*) and 500 m x 66 m (*Berendrechtsluis*). Information about the operating hours are not available on EuRis but a 24/7 operation is expected. The lock is under the responsibility of the Port of Antwerp-Bruges (EuRIS, 2023a).

Figure 49: Zandvliet - Berendrecht Complex

Source: ISL based on Google LLC and EuRIS (2023a)

- Kreekraksluis (51.448229610 N; 4.230654829 E)

The Kreekrak lock is a lock cmplex with two lock chambers located in the Scheldt-Rhine Canal in the municipality of Reimerswaal, in the Dutch province of Zeeland. According to EURIS the lock chamber dimensions are 320.0 m x 24.0 m and the permissible dimensions for single ships entering this lock are 318.0 m long, 24.0 m wide with a maximum air draft of 9.2 m. The lock is locally operated, operates 24/7 and can be reached on radio channel 20. The responsible authority for the lock is Rijkswaterstaat (EuRIS, 2023a).

Figure 50**: Kreekraksluis near Reimerswaal (Netherlands)**

Source: ISL based on Google LLC and EuRIS (2023a)

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- Volkeraksluizen (51.690788742 N; 4.409236029 E)

The Volkeraksluizen is a lock complex with three large chambers located near Willemstad. According to EURIS the lock chamber dimensions are as follows:

- East chamber. 331.5 m x 24.1 m (permissible ship dimensions 331.5 m x 24.1 m).
- Middle chamber: 329.0 m x 24.1 m (permissible ship dimensions 308.9 m x 24.1 m)
- West chamber: 350.0 m x 24.0 m ((permissible ship dimensions 308.9 m x 24.1 m)

The lock is locally operated, operates 24/7 and can be reached on radio channels 7,78 & 64. The responsible authority for the lock is Rijkswaterstaat (EuRIS, 2023a).

Figure 51: Volkeraksluizen near Willemstad (Netherlands)

Source: ISL based on Google LLC and EuRIS (2023a)

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Terminals/Ports

- Dourges
- Port de Lille
- Port of Antwerp – Bruges
- Dordrecht
- Nijmegen – BCTN
- North Sea Ports
- Port of Duisburg

Except for BCTN in Nijmegen, the terminals in DUC2 are not yet specified in more detail. At present, it is only the intention to call at certain ports, without there already being a concrete selection of terminals or berths for the DUC 2 in named ports. A description or even analysis of port or handling facilities is therefore not yet possible and must take place in subsequent WPs.

2.2.3 Processes and Information Flows

Given the scope of the Central European SEAMLESS Use Case, an initial investigation of current process and information flows has considered IWT as part of an intercontinental containerised transport chain as the baseline scenario. In a first step, current logistics flows have been used to identify different phases that may become subject to investigation.

The port of Antwerp represents the focal point of the investigations as it connects the ocean transport system with the central European inland waterway system. In this context, IWT is used to as the main leg within the hinterland system while short range transports, i.e., by truck is used for short range distribution in the vicinity of an inland port. The respective phases that would be required to pass through in the import as well as export direction are illustrated in Figure 52.

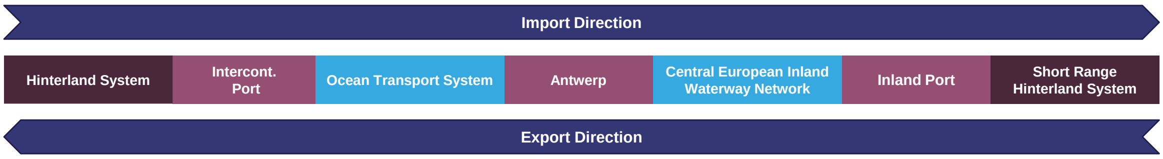

Figure 52: Generic Phases for Containerized Intercontinental Transport involving Central European IWT

Source: ISL based on DSCA (2022)

As described within the transport market analysis, containerized transportation within the corridor is mainly done within an intercontinental setting. However, continental transportation which is used to connect two European locations may represent a potential case for containerized IWT as well as indicated in Figure 53.

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Figure 53: Generic Phases for Containerized Continental Transport involving Central European IWT

Source: ISL based on DSCA (2022)

An generic high-level process view of the vessel-journey from Duisburg, Germany to the Antwerp Container Terminal (ACT) in Belgium which was designed at an early stage is given in Figure 54. As can be depicted from the process map, the journey may consist of various stops in inland ports along the Lower Rhine stretch and continues with two consecutive lock passages located at the Volkerak and Rhine-Schelde Canal. It closes with the port call in Antwerp, which requires earlier and more elaborate VTS activities and vessel planning procedures as it is the case for inland ports. While V2A communications within Antwerp is supported by means of the digital platform APICS, communication with locks and traffic coordination centres is carried out via VHF.

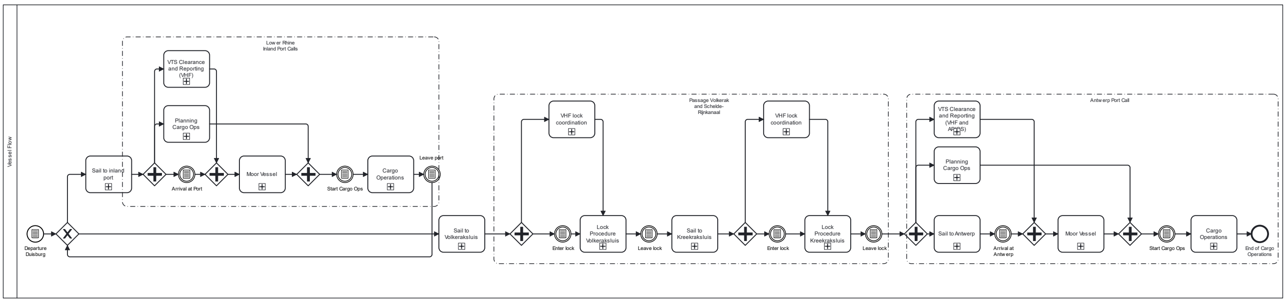

Figure 54: High-Level Process Mapping of Vessel Journey from Duisburg to Antwerp

Source: ISL

2.2.4 Recommendations, Gaps and Requirements

2.2.4.1 Identified Implications for Building Block Development

Logistics Concept (WP2)

- Balancing range, availability of energy container supply and network flexibility
- The logistics concept of DUC2 still seems to be relatively unspecific. There is a residual risk that the DUC could still change significantly, which would have a major impact on the subsequent WP. A consistent exchange with the ambassadors of this use case is therefore of utmost importance.

Port Operations (WP3)

- Functional and business evaluation of on-board vs shore-side mooring systems

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- Analysis of existing port and handling facilities can only be done once terminals and berths in ports have been concretised. Currently there is only a rough idea about the ports that the X-Barge shall call but not the specific terminals.

Vessel/Fleet Operations (WP4)

- Range evaluation: The range of 500 km specified for the X-Barge with 3 x 1.5 MWh is considered very critical and overoptimistic by experts. With significantly larger battery packs with a nominal capacity of 2.6 MWh per pack, ZES indicates a range of 60 to 90 km per pack or 180 - 270 km with three packs for a ship with LOA 90 m and a capacity of 104 TEU (Zero Emission Services, 2023). Even though the X-Barge is somewhat smaller, the design is energy optimized and the autonomous navigation probably makes the ship more energy efficient overall, the stated range does not seem plausible. The presentation of the range should be much more detailed and transparent for the use case.

- The available dimensions, especially the specified air draft of the X-Barge does not seem to be correct. At a draft of 2.5 m the max. air draft is stated with 5.0 m. According to ZULU, the air draft of the final design will probably be in the range of 5.90 m. Here, the other WP need to be informed about a final design as soon as it is available.

- An obstacle for the feeder loop traffic on the Dourges-Antwerp route are lock opening hours, especially on weekends, that do not currently allow a 24/7 service at the moment. Whether 24/7 service is possible in the future is therefore entirely in the hands of the authorities operating the locks.

- The current concept foresees the use of the vessel’s dynamic positioning capabilities within the dock so that no mooring is required. This procedure needs further investigation as well as clearance by authorities.

Digitalization (WP5)

- The initial stakeholder analysis has shown that a lot of actors are involved in the existing logistics chain. Further analysis needs to be done with respect to the digital integration of these stakeholders. This includes the technical perspective, e.g., ensuring data flow and connectivity along the systems (TOS, LSP systems, ROC) as well as the stakeholder management perspective, i.e., convincing respective stakeholders to contribute to end-to-end visibility.

2.2.4.2 Stakeholder Analysis and Management Requirements

The stakeholder analysis for the Central European Demonstration Use Case was carried out using a two-step approach. First, an initial analysis was provided by the use case lead which was further discussed during a face-to-face workshop with stakeholders of the consortium. In specific, the stakeholders who are essential to the status quo and those who will potentially have a significant stake in the development of the SEAMLESS Use Case were examined. The purpose of the stakeholder analysis is to draw stakeholder management recommendations without claiming to provide a comprehensive list and analysis of all involved stakeholders. Based on the subset of stakeholders identified for the AUTOSHIP project, the eight stakeholder groups listed below were determined for the Central European Use Case (Nordahl et al., 2021, p. 11):

- Cargo Interest
- Fleet Owners/Charterers/Operators
- Infrastructure Service Provider
- Logistics Service Providers
- Regulators/Flag States/Port Authorities
- Sea-/Inland Port Operator
- Seafarers/Unions
- Technology Provider and Research

Each stakeholder group underwent a separate analysis. First, the status quo was briefly described along with the stakeholder's position in the current situation. Second, the comments on the anticipated role upon deployment of the relevant SEAMLESS Use Case were gathered.

The "objectives and needs" were first determined in order to better understand the "expectations and motivations" of each stakeholder. In both, the present and the future SEAMLESS use case, objectives and needs are viewed as static concepts that remain equally applicable. The objectives and needs can be used as a preliminary signal of potential conflicts between the interests of various parties. An example would be a conflict between an inland waterway authority's and an operator of an autonomous ship's goals; while the barge operator wants his vessel to sail entirely without a crew, the IW authority may have a different understanding of risks because of its mandate and still require a crew. The subject of "expectations and motivations" also included the stakeholder's "expectations" toward the SEAMLESS use case, which may be both positive and negative. An example for an expectation is a wholesaler that expects an improved and more secure and resilient supply chain from the Use Case to improve his business. The annex contains a complete representation of the "expectations and motivations" of the Use Case.

The "influence" of each stakeholder was then qualitatively described and rated on a scale of 0-9. The rating was based on the Use Case Ambassadors individual ruling in his role as expert on the respective Use Case. Influence refers to how much a stakeholder may support or hinder a project's development toward its objective. The degree to which a stakeholder can persuade or force others to make decisions or take specific actions can be viewed as the extent of their influence. It can originate from the structure of the organization of the stakeholder, such as a legal authority. However, less formal kinds of influence are also conceivable; for instance, a big company may have significant personal ties to or influence over the government's leaders (Kennon et al., 2009, p. 12). The qualitative descriptions of the “influence” are represented in the annex.

Subsequently the "importance" of each stakeholder was qualitatively determined. In order for a project to be successful, it is important to prioritize meeting the requirements and interests of every stakeholder who will be engaged in its design as well as its execution. In other words, this is about the significance or need of specific stakeholders' participation. It is possible that this involvement may occur at a later time, long after the SEAMLESS project has ended. An example would be the development and introduction of appropriate laws for autonomous shipping for the specific SEAMLESS use case (Kennon et al., 2009, p. 12). The annex contains the qualitative descriptions of the "importance".

Studying stakeholder relations has been the last step of the analysis. It was explained what assumptions and risks the relevant stakeholder may have with regard to the use case and how, if at all, the stakeholder would be involved throughout the SEAMLESS project's lifespan.

Table 9 presents the most significant findings from the stakeholder study. The Annex contains all of the results.

Table 9: Extract of Stakeholder Analysis for DUC2: Relevant stakeholders and role description

No	Stakeholder Group	Stakeholder Name	Role description within SEAMLESS use case	Influence [0-9]	Importance [0-9]
1	Cargo Interest	TBD	Derivative stakeholder	6	6
2	Fleet Owner/Charterer/Operator	Danser	Provide the economic flows	8	8
3	Infrastructure Service Provider	ZENOBE	Provide energy in usable form	8	8
4	Infrastructure Service Provider	ZES	Provide energy in usable form	8	8
5	Logistics Service Providers	TBD	Derivative stakeholder	6	6
6	Regulators/Flag States/Port Authorities/Port State	CCNR	Determining approval critera	9	9
7	Regulators/Flag States/Port Authorities/Port State	CESNI	Determining approval critera	9	9
8	Regulators/Flag States/Port Authorities/Port State	De Vlaamse Waterweg (DVW)	Determining approval critera	9	9
9	Regulators/Flag States/Port Authorities/Port State	GDWS/WSV	Determining approval critera	9	9
10	Regulators/Flag States/Port Authorities/Port State	Lloyds Register	Certification of vessel and ROC and related ystems	9	9
11	Regulators/Flag States/Port Authorities/Port State	Local Police of relevant waterway	Upholding regulations & laws	6	7
12	Regulators/Flag States/Port Authorities/Port State	Rijkswaterstaat (RWS)	Determining approval critera	9	9
13	Regulators/Flag States/Port Authorities/Port State	Voies Navigables de France (VNF)	Determining approval critera	9	9

14	Sea-/Inland Port Operator	Nijmegen terminal - BCTN	Determining approval critera	8	8
15	Sea-/Inland Port Operator	North Sea Ports	Determining approval critera	8	8
16	Sea-/Inland Port Operator	Port de Lille	Determining approval critera	8	8
17	Sea-/Inland Port Operator	Port of Antwerp - Bruges	Determining approval critera	8	8
18	Sea-/Inland Port Operator	Port of Duisburg	Determining approval critera	8	8
19	Seafarers/Unions	Unions (e.g., EBU/ESO)	Define jobs	7	7
20	Technology Provider and Research	Macgregor	Develop mooring system	8	8
21	Technology Provider and Research	Undisclosed	Develop autonomous container barge	6	6
22	Technology Provider and Research	TBD	Develop platform	9	9
23	Technology Provider and Research	TBD	Develop Remote Control centre	9	9
24	Technology Provider and Research	TBD	Develop data communication platform	8	9
25	Technology Provider and Research	ZULU	Provide barge & manage LL	9	9

In order to grasp the key feature of stakeholder management, importance and influence are incorporated into a stakeholder matrix. When stakeholders are entered into the stakeholder matrix, they are automatically placed into one of four quadrants. Each of these identified quadrants requires a specific method of managing stakeholders that is advised to be used for the relevant group. Low influence or low importance stakeholders must be kept track of and should not be overlooked as the project moves forward. Stakeholders with little influence but great importance are a crucial group that must be kept content. Although they have little influence on the project itself, they nonetheless contribute valuable resources to the consortium and have the power to force a use case failure or radical adjustments. Information needs to be shared with both high influence and low importance stakeholders. They could be able to obstruct future development, even if they have little bearing on the use case itself. A classification society is an illustration of such a stakeholder; while they have no stake in the use case's design, they must classify the vessel before it receives a class approval to operate, therefore it is better to involve them from the project's inception as early as needed. The key stakeholders who need attentive control as the use case progresses are those who have significant influence and importance. Important decisions should always involve them, and they should often offer their views and counsel (Browning, 2016; Kennon et al., 2009, p. 12; Larry W. Smith, 2000).

Figure 55 shows the stakeholder matrix for the Central European Use Case, while the appropriate stakeholder for each marking can be derived from Table 9. It is important to highlight that all 25 stakeholders are considered key stakeholders, with 5 of them belonging to the consortium for the SEAMLESS project.

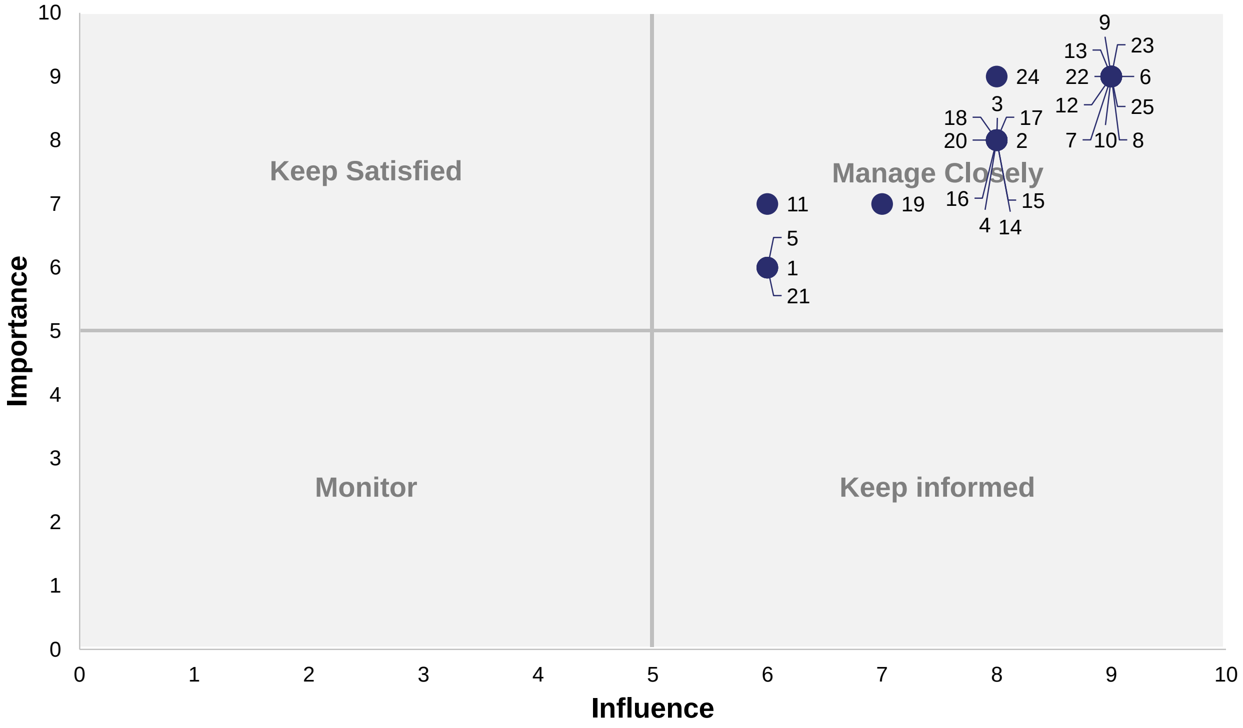

Figure 55: DUC1 Stakeholder Matrix

Source: ISL

Along with identifying the necessary stakeholder management frameworks, a number of risks that may originate from the various stakeholders and perhaps impair the project were identified by the Use Case Ambassador in their role as experts of the respective business environment. As only key stakeholders are involved in the Central European Use Case, a close stakeholder management is the best method to mitigate any potential risks.

- The main risk identified within the groups of “Cargo interests” (1), “Fleet Owners, Charterers and Operators” (2) and “Logistic Service Providers” (5) is, that expected cargo volumes cannot be met, is best prevented by close discussions with the stakeholders through the duration of the project.
- In the group of “Infrastructure Service Providers” (3, 4) the main risk is, that the project or the use case experiences delays due to environmental restrictions and required permits.
- Agreeing on requirements on and test protocols for autonomous systems with representatives of the stakeholders in the group “Regulators, Flag States, Port Authorities and Port States” (6-13) is important for the success of the Use Case. Not agreeing on this by failing to conduct a close stakeholder management with this group could lead to severe changes or even failure of the project.

- Associated risk with the stakeholder group “Sea-/Inland Port Operators” (14-18) is, that many operational details and regulations need to be clarified, before the Use Case can take off. These discussions, if started to late, have the potential to delay the process of the project.
- Risks in the stakeholder group “Technology Providers and Research” (20-25) are mainly the development risk, that the technological solutions that are developed do not reach a sufficient level of economic sustainability or can only be applied within the specified definition of the Use Case.

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3 SEAMLESS TRANSFERABILITY USE CASES

Within the project, the Transferability Use Cases aim to examine commercially viable scenarios on a conceptual level and thus reflect on the requirements and transferability of the SEAMLESS building blocks. Thus, they help to broaden the spectrum of operating conditions and types of cargo.

3.1 TRANSFERABILITY USE CASE "WESTERN EUROPE"

The TUC "Western Europe" has been designed to exemplify a full class of opportunities to deploy the SEAMLESS building blocks (such as DockNLoad, Modular Vessel and Operations Concepts and ModalNET) on short and regular feeder services, using smaller vessels that can navigate the narrow-gauge canal networks which are still prevalent in EU countries such as France.

The TUC "Western Europe" is based on an existing long-standing domestic logistics operation in the region of Dunkerque, France. It describes a flow of liquid bulk food stock (crude vegetable oil) from port to local industry, more specifically from a liquid bulk terminal within the port of Dunkerque to a bottling and shipment facility operated by Lesieur (Groupe Avril) in the nearby town of Coudekerque-Branche.

3.1.1 Existing Logistics Environment

The port of Dunkerque (also known by its English-language exonym Dunkirk) is, based on yearly cargo volumes in tonnes, the third largest port after Le Havre and Marseille. Its strength lies in bulk traffic to and from the industrial sites in its hinterland, which is principally domestic, comprising the French "Hauts-de-France" region. The port is also active in other segments such as cross-Channel RoRo lines to Great Britain and is the second important French port for trade with Great Britain. The port handled 49 million tonnes of freight in 2022 (+1,5 %), including 745,000 TEU of container traffic. Overall, the port of Dunkirk ranks 7th port of the Northern European Range (from Le Havre to Hamburg), it is also the first French port for the import of minerals and coal (inforMARE, 2023; Port of Dunkirk, 2023).

In terms of inland navigation, Dunkirk is the largest river port in the Hauts-de-France region, with 19 per cent of the overall tonnage handled in the region in 2021. It is thus ahead of Lille, which handled 14,6 per cent and Valenciennes with a share of 10 per cent (Guy Arzul et al., 2022).

Dunkirk has the status of a "grand port maritime". This status, defined by the law of July 4, 2008, makes the port a State-owned body, with its own governing board and statutory responsibility for:

- the construction, operation and maintenance of maritime accesses to the port
- enforcement, safety and security
- the management of its public lands
- the management and preservation of the natural areas it owns or manages

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- construction and maintenance of port infrastructure
- the promotion of the offer of rail and river services
- the development and management of industrial or logistics zones linked to the activity of the port (République française, 2008).

Since the law of 2008, logistics activities and terminal construction and management are the purview of third-party operators, such as Rubis Terminal (see below).

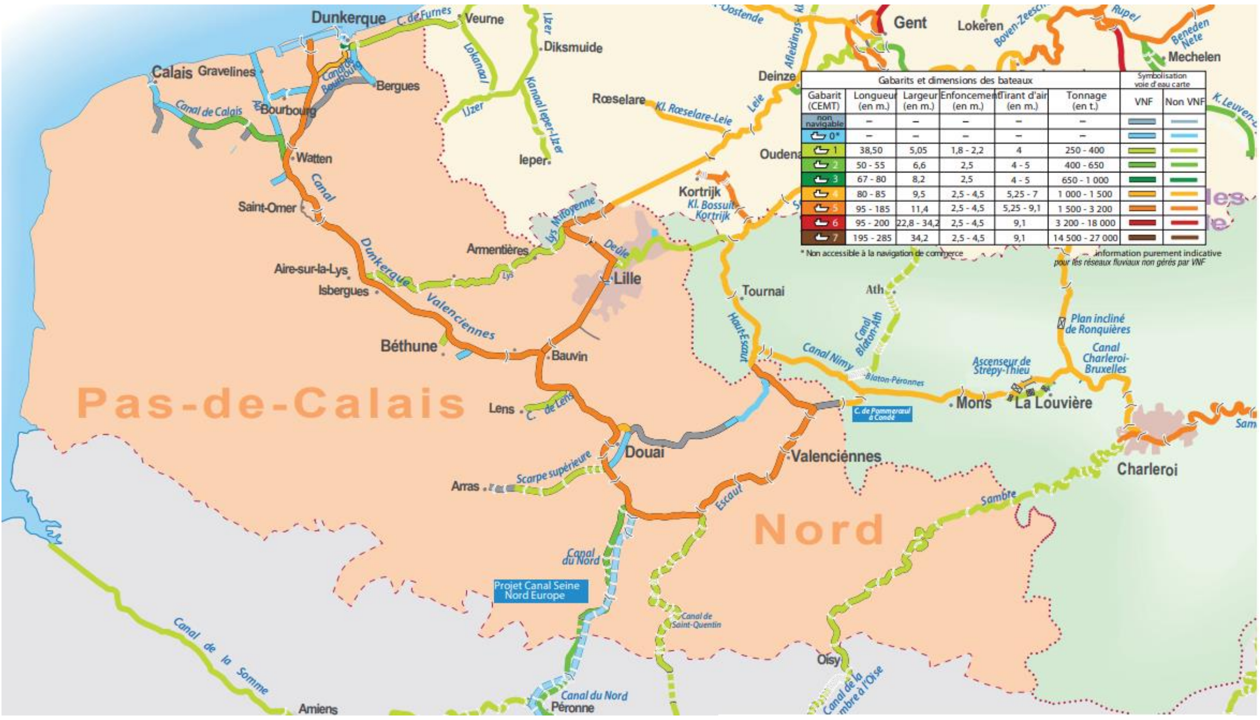

Figure 56: Inland navigation routes in northern France

Source: Voies navigables de France (2021)

	Opportunities	Threats
Political	• Dunkirk, having a per capita income 11 % lower than the national average, is eligible for tax incentives. In particular, part of the route is an urban regeneration area, with a favourable tax regime • The route serves an industrial facility. Maintaining industrial activity is a stated priority of the government • The potential for decarbonized as well as automated operations can chime in	• The route crosses a mix of industrial and urban area. The sentiment of the local population and its perception of the danger can thus be a factor, even though the town of Dunkirk is already dense in Seveso sites • The route might not be in favour of politics due to its short length and it therefore being mainly of local concern

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	with France's political strategy to achieve its climate targets by leveraging nuclear electrical power. As it happens, Dunkirk is located next to a major nuclear plant, in the municipality of Gravelines	
Economical	• The line has a long-term single customer and a regular flow of work, which can help support the business case for the upfront investment in autonomous operation • Beyond the expected financial ROI (Return on investment), the industrial client might be able to benefit from an improved reliability and resilience of his supply chain and stock management, as an autonomous operation would be less dependent on human barge operators • The short route could allow for decarbonized electrical propulsion as well as automation • The current vessels used on the route have a low fuel efficiency	• It is uncertain whether it is possible to retrofit the current vessels for automation. If investing in new boats is required, the break-even point may well be set too far in the future to make sense • On such routes, trucks can provide a flexible and possibly cost-effective alternative, provided the congestion of the port allows for smooth road operations • The application of SEAMLESS building blocks will have an impact not only on navigation but also on port operations. This may well require further investments to make the docks compatible with automated operations • The very specific types of cargo handled (liquid bulk + food) may mean it is hard to achieve economies of scale or hope for widespread replicability
Societal	• The advancing age of the current owner-operators of barges, and the current difficulty in recruiting boat captains means that there could be unfilled vacancies after their retirement • In addition, the boats under consideration are small and therefore unappealing to potential new entrants, as they cannot offer the same opportunities and comfort as larger vessels	• The current owner-operators are unlikely to find a ready role in a new automated process. This means that they, and their boats, might need to be "bought out" as a transition measure • In addition, automation could be a sensitive topic for port dockers and their unions • The social climate in Dunkirk is markedly better than in other French ports, without a single strike in the first 30 years since the founding of the current reformist dockers' union • In spite of this, automated barge navigation may still be seen as a disruptive

		innovation not worth the management picking a fight with the unions over
Technological	• The route is short and straightforward • The infrastructure is in an above average condition, with no fundamental flaws • Two existing locks on the route, one in the port, one along the canal segment, are already equipped for remote operation	• Any proposed SEAMLESS deployment would need to be compatible both with inland and with port traffic rules • The canal is shared with leisure traffic • While the infrastructure isn't in any imminent peril, there is infrequent dredging, as often in these types of waterways. The build-up of silt in the canal and pools makes turn manoeuvres difficult • Locks are automated for remote operation, but have yet to be ascertained to what extent the current lock operation technologies need to be adapted to autonomous traffic or even be significantly updated • Specific equipment and procedures is needed for the autonomous handling of liquid bulk • In addition, foodstuff tanks require specific traceability and hygiene procedures. These need to be documented for future controls
Ecological	• The planned route goes through residential areas, so a reduction of noise and local pollutant emissions is seen as desirable • The crude vegetable oil carried by the boats does not fall under the the inland transportation of dangerous goods by inland waterways (ADN) regulations	• A potential major hurdle is that port of Dunkirk hosts a number of Seveso type-II sites, including some within the Rubis terminal wharf, where the vessels in the Use Case will load the cargo • An autonomous solution might therefore have to demonstrate an even higher level of safety compliance than in less demanding environments
Legislative	• The route is entirely domestic and within the jurisdiction of the French authorities	• In spite of the short distance covered by the oil-carrying boats, there are two different legal regimes to be considered (ports and inland waterways) • This could mean more complexity in the authorization process

		• This could extend to the process of applying for and obtaining a new navigation certificate, if the SEAMLESS building blocks require the commissioning of a new class of boats rather than the reuse of the existing vessels

3.1.2 Existing Transportation Concepts

3.1.2.1 Outline

Prior to the storage in the port of Dunkirk, the crude vegetable oil is delivered by tankers from overseas producing countries, for instance Ukraine for sunflower oil or Spain for olive oil.

The oil is moved from the sea port terminals to the Lesieur factory in a shuttle service based on a small fleet of manned CEMT class I barges, the former “Freycinet” class. These barges are traditional designs that have been adapted with tanks and pumps for the transport of crude vegetable oil. They have no other uses outside supplying their single customer, the Lesieur factory. The barges are operated in a short loop to transport the crude vegetable oil between the Rubis Terminal in the port of Dunkirk and the Lesieur factory over a distance of about 5.5 km. The yearly tonnage transported in the loop is about 60,000 tonnes.

The complete rotation departs from the Quai de l’île Jeanty overnight berthing spot to the port terminal, onwards to the factory, with a return to the place of departure for a second rotation or, more generally, back to the berth in the case of a single rotation.

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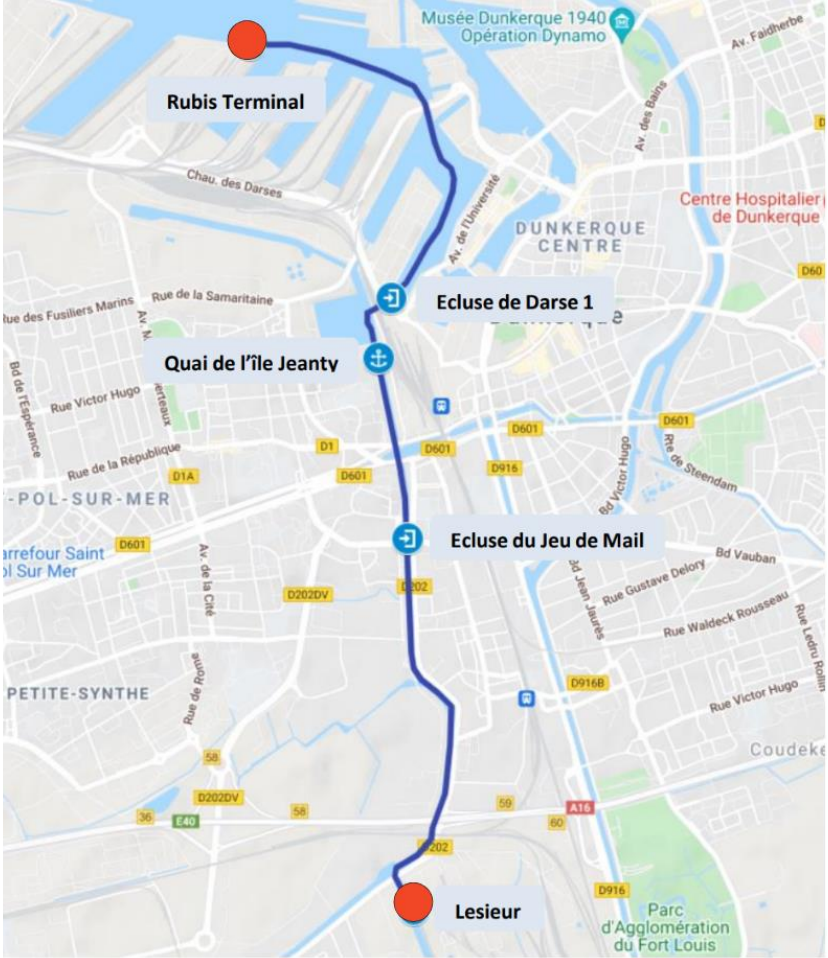

Figure 57: Route of the existing operation

Source: Google LLC , overlay by VNF

For each rotation, the boat travels a total of 10.5 km and passes 2 locks, which means, that 4 lock passages are required for a round trip. Although mainly one rotation is done per day, the frequency of service can be raised up to 2 rotations per day. The rotations are carried out at the request of Lesieur. In general, the boat owner works 5 days a week. The daily schedule breaks down as follows:

Table 10: schedule and cargo status of the existing operation

	Outward journey	Return journey
Schedule	• 7:30 am. to 1 p.m./1:30 pm.	3 pm./3:30 pm. to 4 pm
Cargo status	• Empty tanks from the Quai de l'île Jeanty to Rubis Terminal (pier 5) • Filling up of tanks with crude sunflower oil at Rubis Terminal • Full tanks from Rubis Terminal towards Lesieur factory • Unloading at Lesieur factory	• Empty cargo tanks from Lesieur to the Quai de l'île Jeanty are compensated by 15 to 20 t of ballast

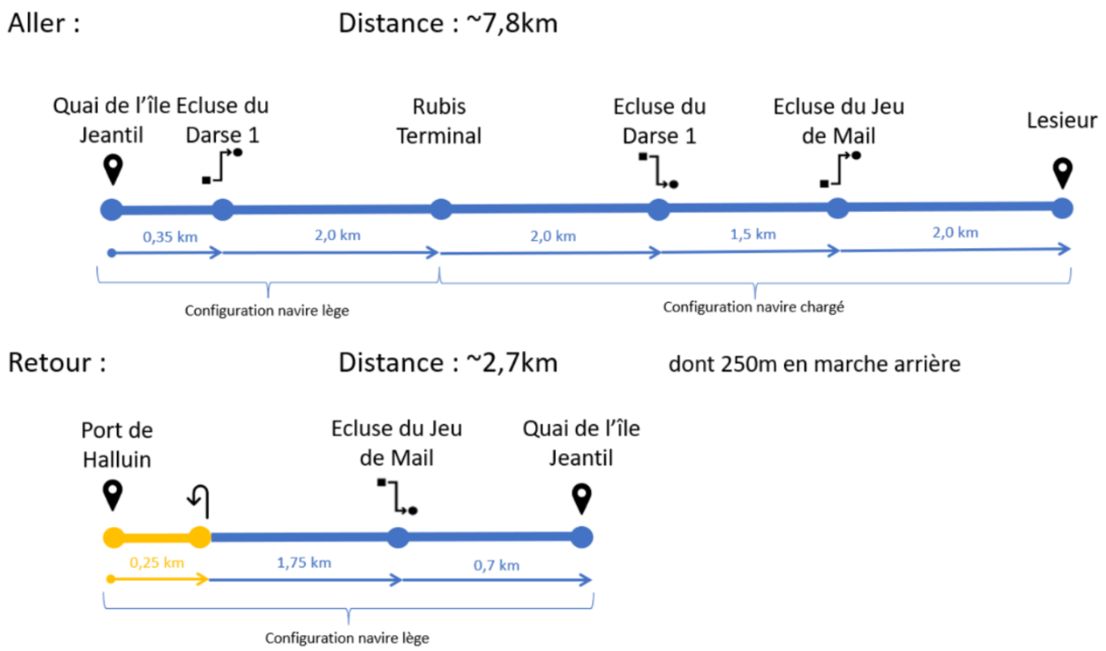

Figure 58: Descriptive graph of the existing route

Source: VNF

Due to silting and low water depth in the basin adjoining the factory, the boat reverses for about 250 m and does a U-turn to exit the unloading area. It uses its bow thruster for this manoeuvre.

Table 11: breakdown of the typical daily operations

	Days with a single rotation	Days with two rotations
Average duration of service	8h12	15h30
Average time sailed	3h18	~6h30
Loading/unloading time	4h54	~8h
Average time off-duty at berth	15h48	9h30

Fuelling of the barges is done by trucks at the Quai de l'île Jeanty. A quayside power supply (32 A) provides power for the onboard lodgings during the unloading operations.

3.1.2.2 Existing Waterborne Transport Concepts

3.1.2.2.1 Analysis of Vessel Fleet

The two boats currently operating on the run are the "Lavera" and the "Vulcain":

Figure 59: Bow view of the Lavera liquid bulk carrier

Source: VNF

Figure 60: Stern view of the Lavera liquid bulk carrier

Source: VNF

Table 12: Technical characteristics of the existing operators

	Lavera	Vulcain
Type	CEMT class I barge "Freycinet-class", adapted as a liquid bulk carrier	CEMT class I barge "Freycinet-class", adapted as a liquid bulk carrier
Date of construction	1950, Arsenal de Cherbourg	1960
Length	38.73 m	38.5 m
Beam	5.04 m	5.05 m

Max draft	2.5 m	2.2 m
Max load	362.4 tonnes	369.0 tonnes
Cruising speed	6-8 km/h	6 km/h (empty), 4-5 km/h (loaded)
Crew quarters	Yes (unused)	Yes (unused)
Carrying capacity	Not recorded	6 integrated tanks for a total load of 399.4 m^3: • 2 small tanks (63.0 m^3 and 63.8 m^3) • 2 medium tanks (65.0 m^3 and 65.4 m^3) • 3 large tanks (70.8 m^3 and 71.4 m^3)
Equipment	Generators: • 1 x 17 kVA HIMOINSA generator – Yanmar engine • 1 x 18 kVA LEROY SOMER generator – Super Star engine • 1 x 6 kVA LOMBARDINI generator – Lombardini engine Offloading pump and engine Bow thruster Anchor winches Navigation equipment: • AIS • GPS – AdvanSea • 2 x VHF radios • rudder indicator	Not fully described. Engine: 330 cv diesel Baudoin Bow thruster
Crew	1 regular crewmember. Occasionally up to 3	1 regular crewmember. Occasionally up to 3

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3.1.2.2.2 Analysis of Ports and Infrastructure

Cargo Origin: Rubis Terminal

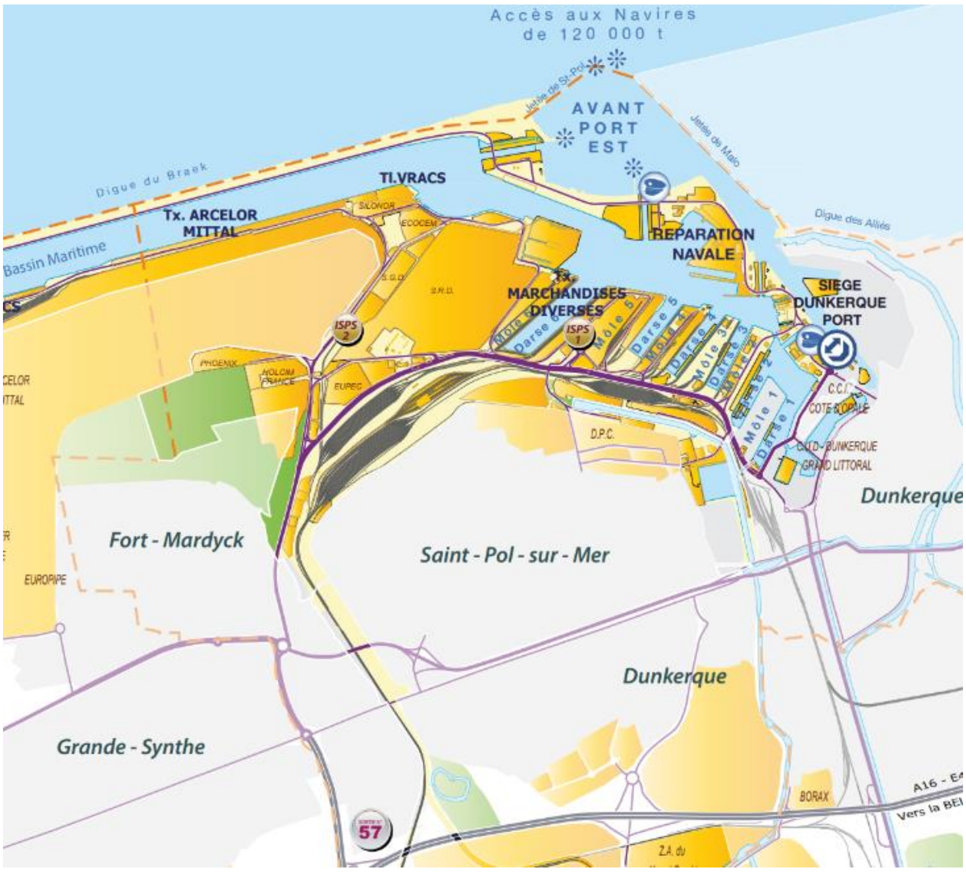

Figure 61: Overall view of the eastern port of Dunkirk

Source: Dunkirk Port

The terminal where the vegetable oil is stored is run by Rubis Terminal Infra, headquartered in Paris, an independent company operating in the storage of industrial liquid bulk products and gases including as chemicals, fertilizers, biofuels, and fuels. The company operates 15 terminals (which encompass 27 Seveso sites) in France, Spain and within the Amsterdam-Rotterdam-Antwerp-Range (ARA).

Since 2020, the ownership of Rubis Terminal Infra is split between by Rubis SCA (55 %), an independent energy firm and I-Squared Capital (45 %), an infrastructure investment fund. Products stored onsite of the terminal range from foodstuffs to chemicals but, by volume, comprise mainly fuels and biofuels.

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Figure 62: Rubis Terminal installations on wharf n°5, port of Dunkirk

Source: Rubis Terminal

Some of the sites on within the port area are classified as Seveso upper tier sites of type II. A site is declared as a Seveso Site if hazardous substances, such as flammable substances or products are handled or stored on the site. Being a type II-Seveso site means, that the amount of the substances equals or exceeds the high qualifying threshold. European Directive 2012/18/EU applies to these sites and requires them to create safety reports, emergency plans, and policies for the purpose of preventing significant incidents. In the event of an accident, the public and relevant authorities must be informed.

On the Rubis terminal, 4 jetties are available, as are 475,000 m^3 of storage in 124 tanks that range in size from 260 to 23,000 m^3. Connections from the terminal to the Hinterland or other ports include barge, pipeline, rail, road and sea links.

Figure 63: Rubis Terminal installations on wharf n°5, port of Dunkirk

Source: Rubis Terminal

Cargo Destination: Lesieur factory

Figure 64: View of the Lesieur factory and unloading quay, Coudekerque-Branche

Source: VNF

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Founded in 1908, Lesieur is a subsidiary of the Avril group, an industrial and financial group active in the vegetable oil and protein sector. Lesieur is the leading commercial brand on the vegetable oil market in France. The Coudekerque-Branche industrial site is Lesieur's historic factory.

It houses a refining unit that transforms vegetable crude oil into refined cooking oil. Its conditioning centre manufactures the bottles, bottles the oil and palletizes it. The site has a logistics department for shipping and hosts a Research, Development and Innovation centre. Overall, Lesieur employs around 250 staff on their Coudekerque-Branche site.

Waterways Network Between Origin and Destination

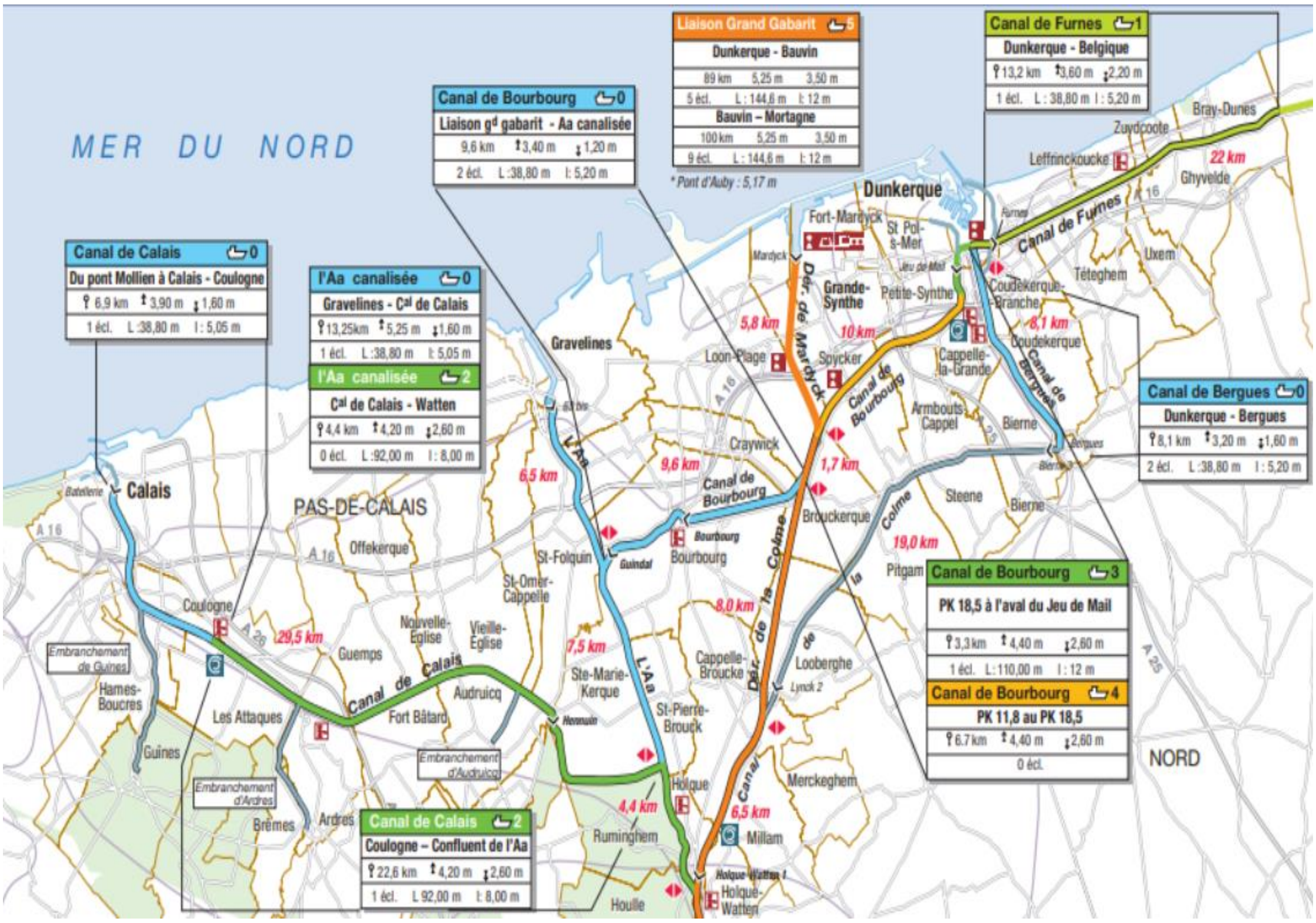

Figure 65: Overview of the canal network around Dunkirk

Source: VNF

The route begins in an area managed by the Dunkerque port authority, continues into a stretch of waterway managed by VNF and crosses two locks along the way.

Darse n°1 Lock

The first lock to be crossed is a narrow-gauge lock connecting the East port of Dunkirk to the regional river and canal network, crossing from the port into a parking basin (known as the Île Jeanty basin) and onwards either to the French waterways network or to the Belgian network via the Furnes/Veurne canal.

The single lock was inaugurated in 1880. Heavily damaged by bombing during the German occupation during the Second World War, it was last rebuilt in 1957.The lock is 43 m long and 6 m wide, with a 2.75 m draft. The lock operates on a 24/7 basis and is remotely operated by the Dunkerque Port Authority.

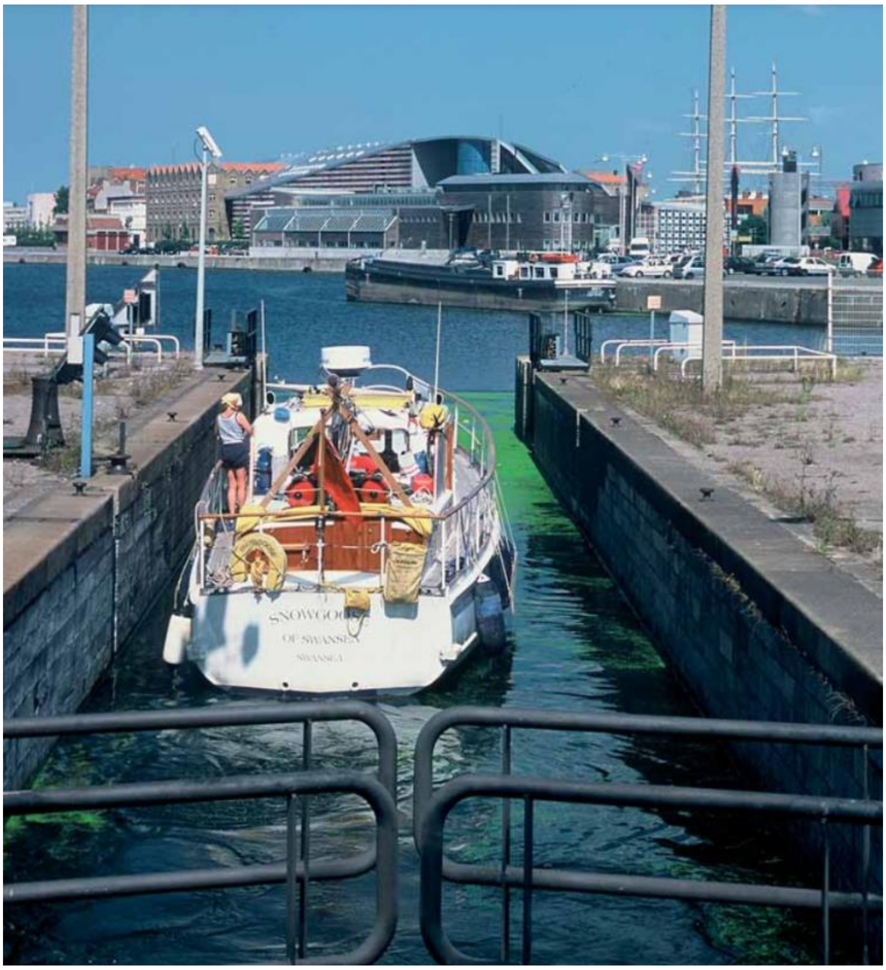

Figure 66: The Darse n°1 lock, view towards the port

Source: Port of Dunkerque

Jeanty Basin and Canal

This parking basin and short stretch of canal, both operated by the port, caters to CEMT class I compliant barges.

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Figure 67: The Île Jeanty basin, view towards the port

Source: VNF

Figure 68: The Île Jeanty basin, entrance from the port

Source: VNF

The Île Jeanty parking basin is used both for stationary houseboats and for waiting barges, including the bulk oil carriers used by Lesieur.

Canal de Bourbourg

This canal, operated by VNF, can accommodate ships up to class III up to the Jeu de Mail lock, class IV beyond.

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Figure 69: The Bourbourg canal

Source: VNF

The Bourbourg canal is one of the two inland waterways linking the port of Dunkirk to the French hinterland. However, most of the traffic takes the shorter, broad-gauge, Mardyck canal. The traffic along the canal is a mix of leisure vessels and occasional freight barges (including those for Lesieur).

Jeu de Mail Lock

This single-chamber lock is managed by VNF. A physical remote control gives boats self-service access, and a remote-control centre supervises the lock. The dimensions of the lock are 110 m x 12 m x 2.6 m.

Figure 70: The Jeu de Mail lock

Source: VNF

The lock, managed by VNF, has limited operating hours:

- 07.00 to 12.30 in the mornings (09.00 on Sundays)
- 13.30 to 19.00 in the afternoons.

The lock is also closed to traffic on certain public holidays; New Year, Easter Sunday, May Day, Bastille Day (14th July), Armistice Day (11th November) and Christmas day.

Darse de Coudekerque

This basin, under VNF management, allows access to the quay that runs alongside the processing facilities within the Lesieur factory. It is partly silted up.

Figure 71: The Coudekerque-Branche basin, delivery point of the crude vegetable oil cargo

Source: VNF

3.1.3 Potential SEAMLESS Transportation Scenarios

3.1.3.1 Outline

SEAMLESS building blocks enabling technologies are envisioned to be used for this short haul circular feeder service, which has been explained in detail in section 0.

Given the nature of the service small, unmanned, remotely supervised autonomous shuttles are operated in an emission-free feeder loop, which is operated on a semi-continuous basis between origin and destination of the cargo.

The wider relevance of such a scenario would be to change the economic equation of this as well as many other waterborne services, for instance:

- by moving goods over just a short distance, but out of areas affected by more acute storage, pollution or congestion issues (such as can be found for trucks leaving larger seaports).

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- by spreading the goods flow over a greater number of hours to improve its regularity and possibly reduce the storage requirements at one or both ends, allowing just-in-time operations. This assumes the infrastructure also operates around the clock.
- by making port calls with small boats both time- and cost-efficient.
- by increasing the overall reliability of the river-borne part of a supply chain by reducing the dependency on single owner-operators.
- by expanding inland navigation's capacity to offer a viable alternative to short-haul trucking for new and different types of water-edge businesses.
- by making reduced ship weights and loading drafts more cost-effective, meaning lower demands on the infrastructure managers,
- finally, this particular use case can include electrification to offer an attractive solution for decarbonized and transport. This appeals to support those companies aiming for a shift to low-carbon logistics. Groupe Avril, the mother company of Lesieur, is one such company, being committed to developing solutions to optimize the carbon footprint of its transport activities.

The reduction in other pollutants or nuisances, such as noise, is another benefit in urbanised port areas. It must however be noted that Dunkirk is the lowest-priority group of urban areas when it comes to implementing a mandatory low-emission zones (LEZs) (Ministère de la Transition écologique et de la Cohésion des territoires, 2023).

3.1.3.2 Stakeholders

The principal stakeholder for this SEAMLESS Transferability Use Case “Western Europe”, is the Lesieur factory and its owners, the AVRIL group, who are the sole customer of this particular shuttle feeder service. The most direct benefit to Lesieur would be financial, as SEAMLESS aims to substantially reduce the overall cost of the existing feeder service by introducing an autonomous solution. Lesieur might also be expected to derive other benefits, such as smoother operations and a reduced ecological impact.

SEAMLESS provides some of its value by facilitating the information flows between multiple parties. However, in the case of TUC “Western Europe”, the number of parties is fairly small. It will therefore remain to be investigated whether the deployment of SEAMLESS services on a small scale is possible outside the case of a single procuring party such as Lesieur or, at a minimum, a very tightly coordinated group of customers.

Other stakeholders have been identified for the use case, each of which can contribute to its success or ensure its failure if not dealt with properly:

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Regulatory Authorities

SEAMLESS aims to substantially streamline the current approval process. Within the transferability Use Case “Western Europe”, the primary regulatory contact point is the regional branch of the French ministry of transport for the Hauts-de-France region (Direction départementale des territoires et de la mer, or DDTM). New areas in inland navigation policy, of which autonomous navigation is assuredly part, will be reviewed by the national policymaking department within the central administration of the transport ministry (Direction générale des infrastructures, des transport et des mobilités or DGITM), based in Paris.

The transferability use case examines a purely domestic operation, with no provisions for crossing borders or for navigating on international waterways. However, this does not mean that cross-border or international approval processes can be disregarded: the Hauts-de-France region is closely integrated with the neighbouring Walloon region in Belgium, so it is only a matter of time before even a short feeder service operating with small vessels requires cross-border or international approval.

Infrastructure managers

During the short voyage under consideration, responsibility for the infrastructure is shared between the port of Dunkerque and Voies navigables de France (VNF), the French inland waterways authority. Each operates one of the locks along the route.

Within VNF, the area under consideration is managed by the Nord-Pas de Calais territorial unit.

Rubis Terminal, which is located within the port of Dunkirk, represents the provider of the upstream storage, the loading quay and the filling service and will be key in the exchange of information with the feeder service.

The quay at the Lesieur factory is owned and operated by the company.

Technology and service providers

The application of the SEAMLESS building blocks to this transferability use case will require a number of technology providers both for the vessels (yards for construction and retrofitting) and the autonomous equipment (both onboard and onshore).

A remote supervisory system, as envisioned by SEAMLESS, will be needed as well. Furthermore, a local service provider for onsite interventions, both of a scheduled and unscheduled nature will be required.

Enablers

Political support for this use case is considered helpful to facilitate the alignment of the multiple public operators. As such, support could be sought from the regional government, the Région Hauts-de-France. Dunkirk is a poorer-than-average part of the region, and therefore a candidate for investment schemes that can maintain or boost local economic activity.

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Financing facilities will have to be put into place through banks or dedicated lenders to fund the transformation. Insurance firms are needed to provide the appropriate coverage for the automated feeder service.

Both these classes of firms need to have a full understanding of the economic, regulatory and technical risks involved, which various parts of the SEAMLESS project will investigate.

Community stakeholders

Finally, several professionals and communities will be affected by an automated logistics operation:

- the owners and operators of the existing barges that serve the route, as well as their crews.
- the staff currently working at the logistics facilities at either end of the route, whose tasks, skill requirements or work schedules would be impacted to varying degrees.
- the port authority and VNF staff tasked with supervising the locks, who will need to be trained in new communication protocols and operating procedures when handling automated boats.
- the other users of the waterway, which include both other freight operators and assorted leisure navigators.
- the residential populations living along the route, for whom noise and pollution levels may be improved by a change in the operation concept.

It is therefore highly relevant for TUC “Western Europe” that the SEAMLESS project plans to conduct work on the social acceptability of automated feeder services.

3.1.3.3 SEAMLESS Waterborne Transport Concept

3.1.3.3.1 Potential Vessel Fleet Concepts

Within the transferability use case, the overriding factor when considering the potential vessel fleets will be the limitations to the possible geometries of each individual vessel comprising the fleet. These are dictated mainly by the lock restrictions along the route. In TUC “Western Europe”, the vessels to be envisaged can only ever have, at best, the hull dimensions (size and draft) of the existing CEMT class-I boats currently operating the route today. The case does not, as such, dictate a hull type (single- or multi-hull) or shape, but the need to fit tanks for the transport of the crude vegetable oil points towards a traditional flat-bottomed design which can maximise the carrying capacity for a given draft.

The vessel design constraints identified above for the TUC are likely to produce designs that stay close to those of the existing vessels, which opens the question of whether the existing vessels are apt to accommodate the SEAMLESS building blocks by a retrofit. These existing vessels have been identified as being respectively over 60 and 70 years old and come equipped with elements such as crew quarters that take up space and would become obsolete in an autonomous service concept. Already, the current vessels are no longer used as housing and the crew quarters are currently not used. They remain in place as the cost of stripping them out would far exceed any value derived from additional hold space. Other important adaptations would be required to implement an autonomous service. The need to install new and additional sensors, control and actuation systems may complicate the reuse of existing vessels due to the complexity and costs associated with retrofitting. While not strictly part of the SEAMLESS concept, the conversion to an electric propulsion system, with its associated energy storage and resupply equipment, would also make a retrofit scenario more difficult.

However, the appeal of a new design will need to be balanced with economic realism, given the fact that many CEMT class-I barges have non-null residual values and have lifespans that can still, barring any drastic regulatory change, be stretched out for decades. Currently there over 200 CEMT class-I vessels are operated in French waterways: the cost of scrapping these and transitioning to a new design remains an important consideration.

If a new build were required for the application of the SEAMLESS building blocks, then it would become possible to consider smaller concepts that diverge from the dated CEMT class-I design, for instance lighter, lower-draft vessels. These might be able to ensure the same daily or weekly tonnage, spread over a greater number of voyages. Such boats might be able to demonstrate to lower investment costs and be better suited to small feeder routes such as that in TUC “Western Europe”. From the perspective of the port and waterway managers, they might make lower demands on the navigation infrastructure and other resources. This, however, remains hypothetical: on balance, it seems more likely that optimal economic efficiency will be best achieved with the biggest possible vessel that the infrastructure will allow.

Depending on the vessel concept and the infrastructure restrictions (in particular the lock opening times), the fleet needed to service the route may be anything between 1 and 4 vessels. It is unlikely that any “vessel train“ concept, be it physical coupling or software platooning, would be of any use on this very short route.

3.1.3.3.2 Potential Ports and Infrastructure Concept

Whatever the optimal size of the vessel, the deployment of SEAMLESS building blocks for the Transferability Use Case “Western Europe” would call for several adaptations of the existing infrastructure, in the Rubis terminal in particular. While the existing quays would be expected to remain unchanged, the need to autonomously moor the vessel process might call for adaptations to the on-quay apparatuses to render them fit for the technologies of the SEAMLESS “DockNLoad” toolbox. This could mean anything from very minor changes upwards to complete rebuilds of the port installations. Small changes might comprise adapting certain landmarks to facilitate their identification by computer vision or improving the lighting conditions for longer and safer automated operating hours. The application of SEAMLESS building blocks could also require dedicated quayside devices to allow mechanical or magnetic auto-docking. This has the potential to seriously impair the commercial viability of the use of the SEAMLESS building blocks in TUC "Western Europe". The use of boardside mooring equipment could provide a means to solve this issue.

If the SEAMLESS autonomous scenario is combined with the electrification of the propulsion, then, in addition, the charging of the fixed batteries or the swapping batteries also requires consideration. This charging phase, which would also be automated, would have to be either combined with other phases of the journey, such as the loading/unloading, or kept separate, adding extra steps to the logistical cycle described previously.

The locks on the route are already equipped for a form of remote operation. Nevertheless, adaptation will probably have to be made to the processes and the hardware, they are used to control access of the vessels to the locks. Currently the preferred device for VNF locks is a physical remote control. A virtual remote control would need to be derived from the current design without weakening the robustness or cybersecurity of the system. Legacy users of the port and canal locks would, in all likelihood, continue to use the current system, meaning any such evolution would also have to be backward-compatible. A notable difficulty for the autonomous crossing of locks is protecting both the vessel and the lock doors from unwanted contact or collision. Maintaining the position of the vessel within the lock is normally done by mooring it to a minimum of two points. Moving to an autonomous concept would either require the boat to auto-moor, or to demonstrate its ability to maintain its precise position without moors. The choices will depend on the outcomes of the SEAMLESS DockNLoad concept.

Finally, the loading and unloading process also needs to be automated, with the aim to reduce berthing times and cargo handling costs. SEAMLESS aims for a substantial reduction in both. For this particular use case, this will mean equipment capable of autonomously handling liquid bulk cargo. This is beyond the scope of what is developed within SEAMLESS DockNLoad toolkit, but other research projects, such as CoboTank, supported by SEAMLESS partner DST, are looking into this aspect of automation, for liquid bulk including fuels.

3.1.4 Requirements and Technology Gaps

The main challenge for SEAMLESS in regards to Transferability Use Case "Western Europe" will be the capacity of the project to scale down the project innovations and building blocks to render them compatible with the small size of the vessels under consideration for this Use Case. This scaling down covers two main aspects:

The barges envisioned within the TUC, being small due to the previously mentioned lock limitations, will have limited space to install equipment. Although space is limited, the installation of the required sensory equipment will not be a show stopper, as even tiny vessels already are able to carry a full complement of automation-enabling equipment.

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However, this will not be the case for the cranes, loading arms, and charging or auto-docking mechanisms. These will thus need to be designed small enough to be fitted on a CEMT class-I-sized hull, without reducing hold capacity unduly. The expense of installing automation paraphernalia on a smaller vessel could prove to be a substantial obstacle to making SEAMLESS building blocks work on smaller inland navigation vessels, such as those envisioned for the case.

SEAMLESS innovations should therefore either have a very low construction cost or they must show the prospect of achieving low unit costs through addressing high volume markets and thus profit from fixed cost degression. A final route could be to develop within SEAMLESS a lighter set of minimum specifications aimed towards smaller vessels or for vessels operating less demanding and well- charted routes, such as is the case for the bulk vegetable oil deliveries to Lesieur.

As identified previously, there will also be a need for specific developments for handling liquid bulk, which are beyond the stated scope of SEAMLESS, but which need to adhere to the same “light and frugal” design philosophy.

On balance, Transferability Use Case “Western Europe” can be seen as mostly a financial and economic challenge, in addition to a technical challenge. While the vessels and logistic flows under consideration are individually marginal, success in applying the SEAMLESS building blocks to the TUC will vastly expand the applicability of SEAMLESS to new routes, territories and services, allowing it to reach places other waterborne and maritime services cannot reach.

3.2 TRANSFERABILITY USE CASE “CENTRAL EUROPE-UK”

The Transferability Use Case "Central Europe - UK" aims at setting up a emission free service with small highly autonomous vessels on existing trades between the port of Antwerp/Bruges and the east coast of the United Kingdom. The Use Case depends on the successful deployment of all SEAMLESS building blocks.

3.2.1 Existing Logistics Environment

The objective of the "Central Europe - UK" Transferability Use Case is the deployment of autonomous, zero-emission LoLo (Lift-on Lift-off) vessels to transport commodities from the Port of Antwerp/Bruges to the UK, namely to the Thames and the East Coast areas. The use case investigates the possibilities of this new mode of transportation by adapting the traditional port call process for autonomous port call procedures, and it does so from different perspectives.

Political Environment

Like many other sectors, the inland shipping sector faces a major challenge in realizing the sustainability transition. Objectives for inland shipping have recently been set at European, national and regional level. This includes objectives to reduce emissions, objectives for sustainable mobility and for the modal shift. The end goal is a zero-emission logistics sector and therefore also zero-emission inland shipping by 2050. The Flemish Green Deal Inland Shipping aims to green up Flemish inland

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shipping. More specifically, an emission reduction that benefits both the climate (CO_2 reduction) and local air quality by reducing emissions such as nitrogen oxides and particulate matter.

The ultimate goal of the Flemish Green Deal, of which the Port of Antwerp-Bruges is one of the initiators, is a shared ambition that is in line with the European objectives for this theme and that is further refined into a set of strategic objectives. All parties involved endorse this ultimate goal and are committed to achieving it together. The actions are clustered within four thematic work areas:

- Technological solutions for green inland shipping
- Financial solutions for green inland shipping
- Policy to support green inland shipping
- Implementation of green inland shipping

With regards to maritime and shortsea shipping, the cooperation between the UK and Belgium has been strengthened significantly. On Friday October 27th 2023, Belgian North Sea Minister Paul Van Tigchelt signed a cooperation agreement with UK Maritime Minister Charlotte Vere. The agreement mainly concerns Green Shipping Corridors with a focus on environmentally-friendly transport routes between British and Belgian ports. The aim is to increase the number of ships and number of routes by 2030 (The Brussels Times, 2023). The Green Shipping Corridors originates from the Clydebank Declaration that was signed at the COP26 climate summit in Glasgow in the year 2021. As part of it, 24 countries have committed themselves to create 'Green Shipping Corridors': shipping routes between two or more ports, on which at least one zero-carbon-emission ship travels. A minimum of six routes should be operational worldwide by 2025 (UK government, 2021).

Economic Environment

The Port of Antwerp-Bruges is the second largest port in Europe. With more than 300 scheduled services and connections to more than 800 destinations, it connects the European continent with the rest of the world. The Port of Antwerp-Bruges provides 72,600 direct jobs and no less than 20 billion euros of added value. The port handles around 290 million tonnes of international maritime cargo annually and hosts the largest integrated chemical cluster in Europe. The port is the 13th biggest container port in the world (Port of Antwerp-Bruges, 2023b).

The freight market potential of the area is huge as the United Kingdom is an island state and goods need to be transported over the water with vessels. Apart from the channel tunnel connecting Folkestone (UK) with Coquelles (FR) and in certain cases air transport, there is no commercially viable alternative to waterborne transport.

The present current logistics environment is mainly based on RoRo vessels that are large, fully crewed and use mainly fossil fuels. A typical up to date vessel is the MS Céline with a Dwt of 27,687 t, a length of 234 m, a breadth of 35 m, a draft of 8 m and which is equipped with a combustion engine of 21,060 kW. These vessels are not built to be optimal in sustainability as their freight includes also additional weight for trailers and tractors, they need accommodation for passengers and are dimensioned for large cargo volumes, which means that they are assumed to often sail with excess capacity. Making these vessels sustainable will be difficult because of the energy need per ton-mile and in absolute amounts.

Because of their size, these vessels need large port facilities and therefore have access to a limited number of ports, which also increases congestion and emissions issues on the land side as well as additional road flows to final destinations. There is also a looming shortage of qualified crew.

There is also an existing green corridor between the UK & Belgium that stimulates this kind of shortsea sailing (VIL, 2021).

Social Environment

The Port of Antwerp-Bruges provides a total of 164,000 direct and indirect jobs. The advancing age of the current owner-operators of barges, and the current difficulty in recruiting boat captains means that there could be unfilled vacancies after their retirement. This case works under the assumption that the shift to remote operations of ships will lead to a better work-life balance for skippers which might attract new and younger people to the shipping sector.

Technological Environment

Reporting entry and exit from the port, consulting moorings and booking locks for inland waterways are done digitally in Antwerp through the Antwerp Port Community Information System (APICS) Barge application. The Zeebrugge Electronic Data Interchange Services (Zedis) does the same job for Zeebrugge. Through various applications linked to APICS, the following is possible:

- Inland skippers can reserve a lock, consult the available berths in real time and register their (de)mooring movements in APICS
- Terminals can enter and modify the planning for seagoing vessels in APICS

Besides APICS, the Barge Traffic System (BTS), and Rail Traffic System (RTS) platforms aim to simplify communication between the various players in the logistics chain.

The Port of Antwerp Bruges stimulates actively smart shipping innovation projects by opening the port as an open innovation platform. The existing technological developments make it possible to sail autonomously and zero-emission. Several existing experimentations in smart shipping are already tested inside the port environment of Port of Antwerp-Bruges.

Ecological Environment

There is a strong focus in most ports on a need for sustainability and acceleration of the “greening” of the existing inland/shortsea fleet in Europe. The existing fleet is outdated and relies heavily on internal combustion engines. One of the underlying assumptions is that smaller autonomous vessels might better face the unstable weather due to climate change.

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Furthermore, Port of Antwerp-Bruges is working on becoming a climate neutral port. The port is investing to become a multi fuel port with a focus on green fuels.

Legislative Environment

Testing of autonomous sailing in Belgium is possible due to a royal decree that regulates an experimental legal framework. Possible threat however is that the legal framework will stay in an experimental phase for the next 4 years before it will evolve to operation legislation. Furthermore, there are ongoing negotiations concerning creating a legal framework for autonomous shipping between Belgium and the UK. Any proposed SEAMLESS deployment would need to be compatible both with inland and with port traffic rules.

3.2.2 Existing Transportation Concepts

3.2.2.1 Outline

The goal of the Transferability Use Case "Central Europe – UK" is the use of autonomous zero emission LoLo vessels for moving goods from the Port of Antwerp/Bruges (i.e., Zeebrugge) to the UK in particular to the Thames (Tilbury, Medway, London Gateway) and the East Coast (Hull, Immingham, Goole, Teesside). The use case explores the potential of this new way of transport from the perspective of adaptation of the standard port call process for autonomous port call processes and this from the logistic, infrastructural, nautical port governance, safety and security and legal perspective.

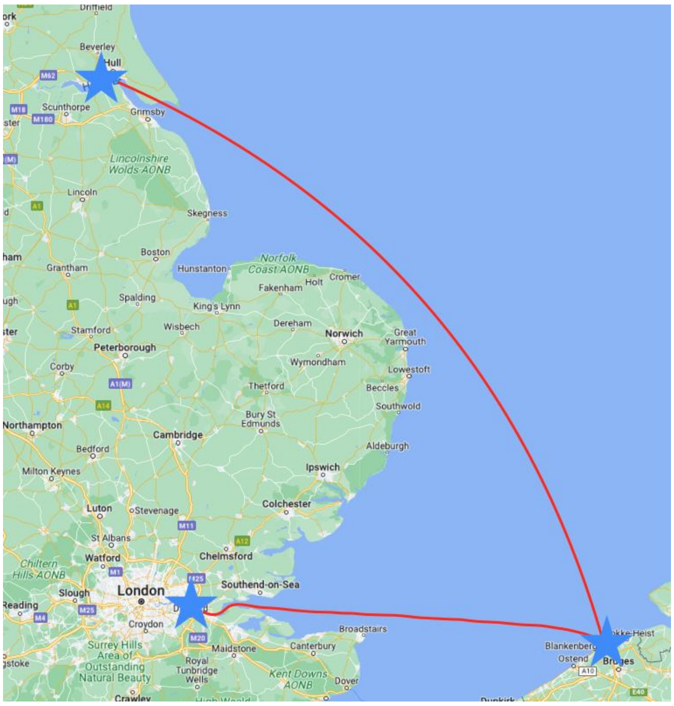

Figure 72: Route of the TUC "Central Europe - UK"

Source: Google LLC

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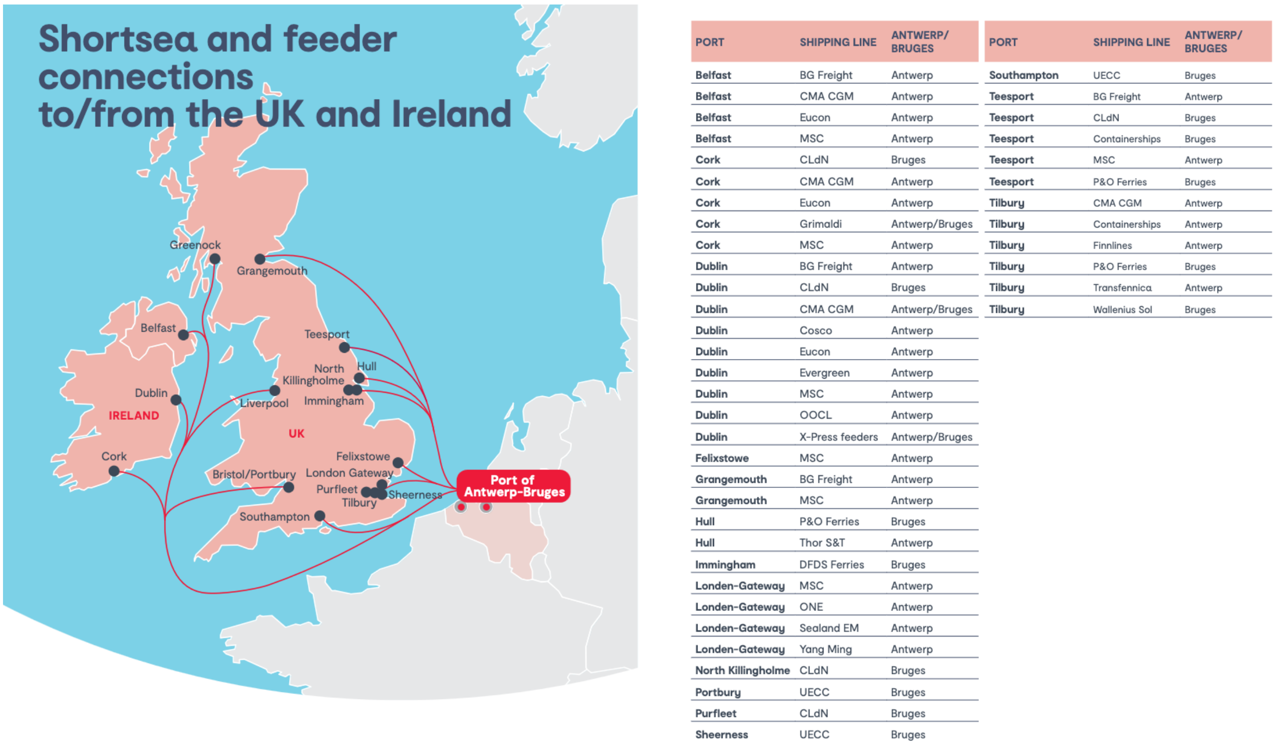
3.2.2.2 Existing Waterborne Transport Concepts

3.2.2.2.1 Analysis of Vessel Fleet

The Port of Antwerp-Bruges, and Zeebrugge in particular, is a hub for freight traffic to and from the United Kingdom. More than seventy scheduled services connect Antwerp and Zeebrugge with various regions in the United Kingdom and Ireland every week.

RORO in particular is an important market: RoRo transport via Zeebrugge ships 2.2 million new cars every year, of which 580,000 leave annually to and from the United Kingdom. Usage of RORO vessels also induces congestion and emissions to & from the ports involved.



PORT	SHIPPING LINE	ANTWERP/ BRUGES
Belfast	BG Freight	Antwerp
Belfast	CMA CGM	Antwerp
Belfast	Eucon	Antwerp
Belfast	MSC	Antwerp
Cork	CLdN	Bruges
Cork	CMA CGM	Antwerp
Cork	Eucon	Antwerp
Cork	Grimaldi	Antwerp/Bruges
Cork	MSC	Antwerp
Dublin	BG Freight	Antwerp
Dublin	CLdN	Bruges
Dublin	CMA CGM	Antwerp/Bruges
Dublin	Cosco	Antwerp
Dublin	Eucon	Antwerp
Dublin	Evergreen	Antwerp
Dublin	MSC	Antwerp
Dublin	OOCL	Antwerp
Dublin	X-Press feeders	Antwerp/Bruges
Felixstowe	MSC	Antwerp
Grangemouth	BG Freight	Antwerp
Grangemouth	MSC	Antwerp
Hull	P&O Ferries	Bruges
Hull	Thor S&T	Antwerp
Immingham	DFDS Ferries	Bruges
Londen-Gateway	MSC	Antwerp
Londen-Gateway	ONE	Antwerp
Londen-Gateway	Sealand EM	Antwerp
Londen-Gateway	Yang Ming	Antwerp
North Killingholme	CLdN	Bruges
Portbury	UECC	Bruges
Purfleet	CLdN	Bruges
Sheerness	UECC	Bruges
Southampton	UECC	Bruges
Teesport	BG Freight	Antwerp
Teesport	CLdN	Bruges
Teesport	Containerships	Bruges
Teesport	MSC	Antwerp
Teesport	P&O Ferries	Bruges
Tilbury	CMA CGM	Antwerp
Tilbury	Containerships	Antwerp
Tilbury	Finnlines	Antwerp
Tilbury	P&O Ferries	Bruges
Tilbury	Transfennica	Antwerp
Tilbury	Wallenius Sol	Bruges

Figure 73: Shortsea and feeder connections to/from the UK and Ireland

Source: Port of Antwerp-Bruges (2023a)

3.2.2.2.2 Analysis of Ports and Infrastructure

The current port superstructure within midsized and larger ports such as Hull, London and Antwerp consist either of RoRo equipment (e.g., ramps) or large container cranes. Mooring is done with mooring ropes. Locks are operated in situ and need crews for mooring, etc. Guidance into the port is done with VTS and pilots. Standard port call procedures are mostly digitally administrated and VHF oriented in relation to the main communications between all operational parties.

The VTS is responsible for the shipping guidance of seagoing and inland vessels behind the locks. To ensure a smooth, safe and efficient traffic flow, VTS provides information and advice, for example

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relating to routes, weather conditions and potential risks, to all water-related traffic participants behind the locks. In addition to the shipping guidance, the Port of Antwerp-Bruges is committed to transparency and the optimisation of shipping planning. For example, the team of port planners ensures the safe, efficient planning and processing of moorings. They take into account the various actors, such as the port, the port facilities and the port users, as effectively as possible. Radar infrastructure plays an important role in the guidance of shipping traffic. In Antwerp, the radar network will be fully digitised and further expanded. Because of its location in the hinterland and the associated complex calls, the nautical chain operation is of crucial importance for smooth traffic in Antwerp. In recent years, significant investments have been made in the digital interconnection of the chain partners, including more and better data exchange**.** The analogue radars were replaced by digital ones and, in addition, new radar towers were built.

3.2.3 Potential SEAMLESS Transportation Scenarios

3.2.3.1 Outline

The Transferability Use Case will make use of the same routes as in the current situation. The main difference is the introduction of autonomous vessels to set up an autonomous and emission-free feeder loop. The potential alternative through autonomous vessels is a scenario whereby relatively small container vessels are used instead of the large-scale RoRo vessels. This allows for a competitive alternative that is sustainable, redundant and green. The dominant strategy of ocean carriers to realize economies of scale leads to ever growing vessel sizes. However, due to their sizes the access to some ports may be restricted (Jungen et al., 2021, p. 256). In order to reduce externalization effects and thus avoid operational restrictions by existing port infrastructure, this TUC proposes a switch back to smaller vessels. This would potentially make transports more flexible and more ports available again.

Automation is part of greening a fleet. If there is no crew on board, a ship can be designed differently: there is no need for crew accommodation and there is no energy used to heat or ventilate the accommodation. Furthermore, the ship can be designed in a way that it does not need that much energy to sail. Following this reasoning, switching to smaller autonomous vessels is expected to create economic leverage to use more expensive zero emission propulsion.

The automated ship for the use case will be electrified, as the emissions of current diesel motors of regular ships are considered to be too high, if conventional fuels are used. Therefore, the ship will sail with batteries. As the shortsea stretch from Zeebrugge, BE to Tilbury, UK has a comparably small distance of 120nm, it is possible to sail with 3 batteries on board, while at each shore 3 more batteries, fully loaded with green electrical energy, wait for the ship to arrive. During unloading and loading, which is expected to last around 12-14 hours, the batteries will be switched. The used batteries will be charged ashore and will be ready for usage when the ship returns.

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The ship which may carry up to 200 TEU and will be able to sail one way per day, which makes it slightly slower than a conventional RoRo vessel. However, switching from RoRo to LoLo entails new operational steps to be included:

- Separate terminal equipped with container handling equipment, mooring systems, energy provision (battery switches/hydrogen).
- Adding new procedures to the overall port call process, digital communication protocols, data driven vessel-port call system interaction
- Automatization of nautical manoeuvres such as mooring, lock passage and loading of cargo.
- Establishment of ROCs.
- Approval by flag states (UK & Belgium) and other relevant authorities.
- Additional/alternative smaller ports as destinations.

3.2.3.2 Stakeholders

As autonomous shipping is an innovation that does not yet have broad market presence and availability, an important stakeholder group are the regulatory bodies and flagstates. For this specific use case the following regulatory bodies need to be involved in order to create a framework that allows ships to sail autonomously:

- Ports: Port of Antwerp/Bruges – Zeebrugge – Port of Tilbury – Port of Hull Port Authority/Port Operators
- Belgian authorities: Federal Department for Mobility (FOD Mobility), Flemish Department for Maritime and Coastal Services (MDK), Belgian Flag State
- UK authorities: MCA, UK Flag State

From an operational point of view the following stakeholders are important:

- Port of Antwerp/Bruges and Port of Tilbury, Port of Hull: all port authorities will need to make sure that on an operational level, the new type of ship can access, moor, load and unload in the port in a safe way
- Communication providers: as communication between ship and shore will be without a human in the loop, the ship and the shore-based infrastructure and remote-control centre rely heavily on a safe way of communication
- The ship owner has to make sure that all operational aspects from his side are arranged in order to sail efficient and safe

From a technological point of view the following stakeholders are important:

- Alternative energy providers: the use case needs to have a green fuel. Several companies that produce batteries have already shown interest to take part in the realisation of this
- Maritime Autonomous Surface Ship systems providers: an autonomous ship needs more than the regular technology that can be found on a ship. All technology should be able to interact in a safe and reliable way. It is important to include these system providers as soon as possible in the process of designing an autonomous ship.

From a commercial point of view, there needs to be an interest. From cargo owners, shipping lines and investors to make the use case viable. Identified potential users are:

- Logistical companies: ECS, Cobelfret, DFDS, Samskip, NCL, Carisbrooke, A2BOnline
- Shippers: Nike, AMAZON, K&N, DHL, Aurubis, Saint Gobain, Wienerberger

3.2.3.3 SEAMLESS Waterborne Transport Concept

3.2.3.3.1 Potential Vessel Fleet Concepts

The vessel intended to be operated in the Transferability Use Case is the ZULU MASS. This ship is specifically designed for shortsea shipping. Preliminary specifications set it at a length of 105 m, a beam of 17 m, a draft of 5 m, while having 210 TEU cargo capacity.

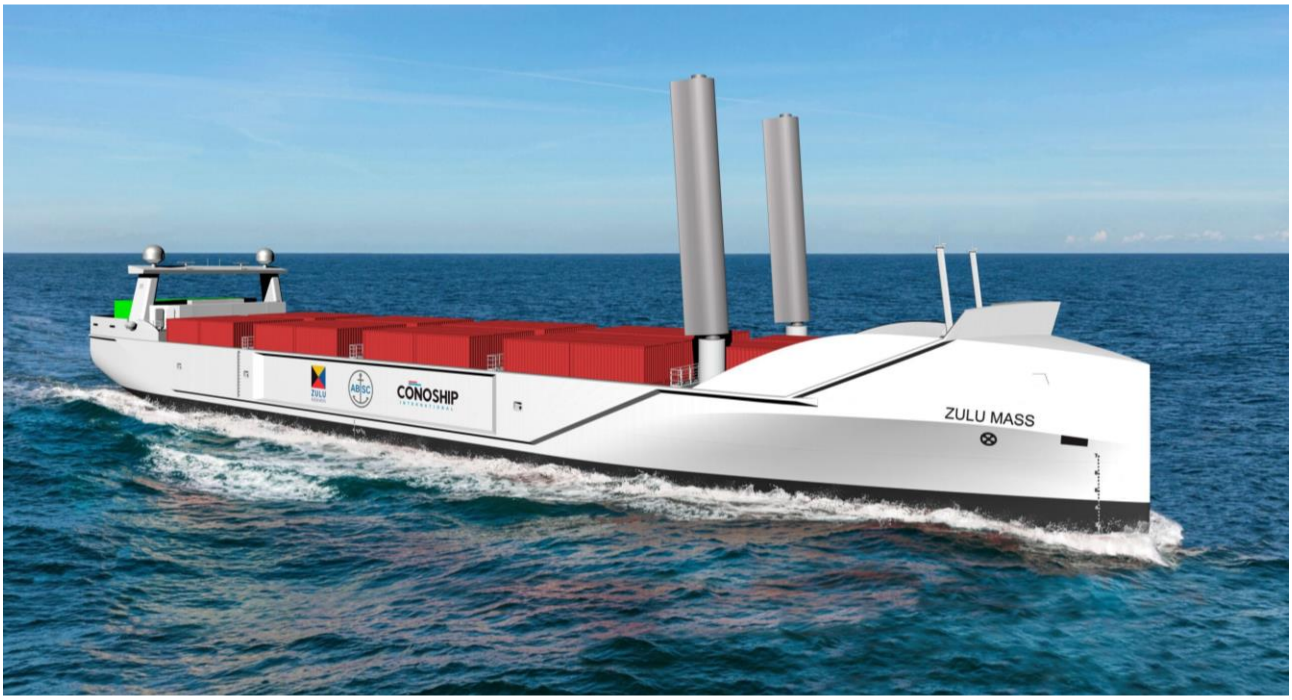

Figure 74: Visualisation draft of ZULU MASS

Source: Zulu Associates

The ship is expected to be able to sail autonomously but there will always be a human in the loop through the remote-control centre. During the voyage, the ship can make its own decision, but in places that are more challenging to sail, like port areas or pilot passages, a human operator in an ROC can take over. The vessel will accommodate a modular propulsion concept using power packs, while batteries will be used in first instance. Furthermore, the vessel is equipped with auxiliary wind propulsion.

For the mooring of the vessel in the port, it is possible, that humans ashore do the mooring together with the remote-control centre. In the future it is possible that mooring happens fully autonomously with the help of infrastructure ashore. Cargo will be transferred through containers in a LoLo way. Automated cranes will load and unload the vessel.

On specific shipping routes, it is expected that a fleet of ZULU MASS vessels are deployed. This enables a more or less constant transport of containers.

3.2.3.3.2 Potential Ports and Infrastructure Concept

As there is a switch from RoRo to LoLo, there is a need for designated terminals with adapted cargo handling systems, mooring systems and energy provision. The concept follows the notion that everything happens as automated as possible, but the infrastructure is not made for automation in combination with LoLo. Designated terminals may be used to make sure there is space for this new type of shipping and at the same time other vessels can still make use of the other terminals.

Furthermore, it is expected that an autonomous ship will need additional and other port services than regular ships. Examples for these services are not limit to but include a “loadmaster” responsible for the cargo, technical assistance and energy provision.

There is a need for extensive data exchange and use, with planning of cargo and with existing Port Call systems. In addition to the Demonstration Use Case 2 there will also be build an sandbox application for autonomous port calls in WP3 of seamless that will be tested during the demonstrator use-cases to test the machine (vessel) to machine (port call system) data exchange during the different demonstrator voyages.

3.2.4 Requirements and Technology Gaps

For this Use Case to happen, several challenges need to be tackled. First there need to be agreements made with terminals to create dedicated terminals that can be used by this new concept. Those terminals will need infrastructure that is capable of automated mooring, automated cargo operations and infrastructure for energy, so that the power packs can be charged with electricity from renewable sources. Dedicated terminals will lead to the necessity to adapt terminal planning and to combine terminal planning with stowage planning. For this to happen, the port call system needs to be adapted so that the port can communicate with autonomous ships. This includes the availability of an autonomous port call system that provides an alternative to VHF communication for port interactions. Furthermore, it would be beneficial to have an ROC in all ports involved in the shortsea route.

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All automation will lead to a lot of data and data exchange. There is a need to establish a platform that has enough capacity to contain all the data and accepted database protocols are needed. The data will be used to give the autonomous ships information to sail, moor, load and unload safely. It is also very important to take cybersecurity into account.

3.3 TRANSFERABILITY USE CASE "ADRIATIC SEA"

The Transferability Use Case "Adriatic Sea" aims to enhance the connection between the Port of Venice in Italy and the Port of Piraeus in Greece by introducing an innovative and seamless connection through an autonomous Roll-on/Roll-off (RoRo) vessel, contributing to improved trade and connectivity in the region. Currently, the connection between these two cities involves a combination of road transport (Athens/Port of Piraeus – port of Patras/Igoumenitsa) and conventional shipping (see Figure 75). However, the proposed concept seeks to optimize this route using an autonomous vessel, rendering the need for road transport redundant. This integration of various modes of transport into a single waterborne mode promises greater efficiency, and lower environmental impact, all while striving to make a concrete contribution towards shifting freight from the road to water. Overall, this proposal seeks to create an uninterrupted, efficient, and environmentally friendly transportation corridor between these two European cities. The successful establishment of the TUC is influenced by various factors, which collectively contribute to its viability and success.

3.3.1 Existing Logistics Environment

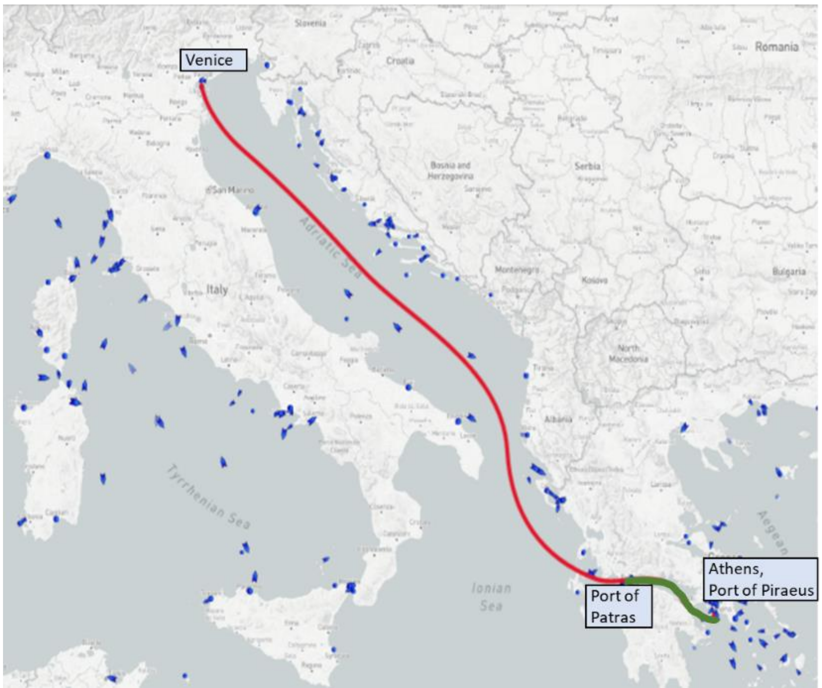

Figure 75: Transferability Use Case "Adriatic Sea" Existing connection: in green – road route, in red – conventional ship route

Source: Illustration by PNO & NTUA

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Over the span of 2022 to 2024, the Port of Venice is poised for a series of strategic developments within the area (Autorità di Sistema Portuale del Mare Adriatico Settentrionale, 2022). Key initiatives include the construction of a new railway bridge in the west channel (Porto di Venezia, 2023b), a revision and modernization of the video surveillance system and enhancements to the “Smart Control Room” in Marghera (Metropolitano.it, 2020). Additional plans aim at significant railway and road upgrades. These transformative years also foresee the establishment of a new container terminal, accompanied by the development of crucial rail links including culminating in the realization of an advanced intermodal platform.

Since 2011, the North Adriatic Sea Port Authority (AdSP MAS) has steadfastly pursued an Environmental Management System (EMS) which is integrated with the Quality Management System (Porto di Venezia, 2023a). In 2019, the Port Authority crafted an Environmental Energy Planning Document (DEASP). The DEASP, rooted in energy consumption data, outlines a carbon footprint and CO2 reduction targets, harmonizing with North Adriatic Sea Port Authority planning documents.

The Port of Piraeus, being one of the largest and busiest ports in the Mediterranean, includes RoRo terminals that cater to the transport of vehicles and other wheeled cargo. These terminals are essential for trade and logistics operations, as they allow for the efficient transportation of goods that are not containerized but still require maritime transport. Given Piraeus’ strategic location and its role as a major port in the Mediterranean, it is likely that RoRo terminals and vessels are present to facilitate the movement of wheeled cargo to and from Greece and other international destinations.

Piraeus has been involved in various initiatives and developments related to maritime technology and innovation, although specific initiatives directly aimed at the adoption of autonomous vessels are absent. The potential adoption of autonomous vessels involves several factors, including regulatory frameworks, technological advancements, safety considerations, and infrastructure adaptations. While the Port of Piraeus may not have had specific initiatives dedicated solely to autonomous vessels, broader efforts to enhance port infrastructure, digitalization, and innovation, which can indirectly support the integration of autonomous vessels in the future have been made. Efforts related to the broader digital transformation and modernization of ports, including Piraeus, could contribute to creating an environment conducive to autonomous vessel operations. These efforts include digital infrastructure, collaborative research, safety and navigation systems, regulatory engagement, and stakeholder engagement.

3.3.2 Existing Transportation Concepts

3.3.2.1 Outline

The Port of Piraeus represents the largest and busiest port in Greece and plays a pivotal role in the Mediterranean region's maritime trade. Situated approximately 10 km southwest of Athens, the Port of Piraeus is equipped with modern and well-equipped container terminals, efficiently handling a substantial portion of Greece's container throughput. Moreover, the port is specialised in RoRo operations, facilitating the seamless roll-on/roll-off movement of vehicles and cargo between Greece and other countries. On the other end, the Port of Venice, strategically lies at the apex of the Adriatic Sea, serving as a crucial terminal for two European transport corridors – the Mediterranean and the Baltic-Adriatic. It is a vital link in the Motorways of the Sea of the Eastern Mediterranean, connecting Central Europe to Africa and the Middle East, while also supporting river-sea intramodality and balanced goods transportation via barge through the Po Valley.

By harnessing the potential of autonomous ships, this Transferability Use Case seeks to optimise RoRo transport between these two key port systems, offering numerous compelling benefits. First, shifting these transports to sea holds the promise of increased efficiency and streamlining cargo movements, and lowering operational costs. Additionally, this transformation would alleviate road congestion and contribute to the sustainability of transport by reducing GHG emissions associated with road-based transport. The integration of autonomous ships in this maritime route would enable reliable and precise navigation, ensuring enhanced safety and security during the voyage. Furthermore, the utilization of advanced autonomous technologies paves the way for increased operational flexibility, enabling vessels to adapt to dynamic market demands and respond effectively to changing logistical requirements. Ultimately, this approach to RoRo transport promises to foster stronger economic ties between Greece and Italy, promote international trade, and contribute to the growth and prosperity of the Mediterranean region's maritime industry.

3.3.2.2 Existing Waterborne Transport Concepts

The North Adriatic Sea Port System, made up of the ports of Venice and Chioggia, is strategically located at the apex of the Adriatic Sea at the crossroads of two European transport corridors, the Mediterranean and the Baltic-Adriatic; it is the terminal of the Motorways of the Sea of the Eastern Mediterranean that connect Central Europe to Africa and the Middle East, and the terminal of the river rod that crosses the Po Valley, allowing river-sea intramodality and the balanced transport of goods by barge.

The Veneto Port System has a specific multipurpose vocation, an aspect that is particularly present in the port of Venice and of extreme relevance since, in a multifunctional port, no sector prevails in a preponderant manner, but the different sectors and supply chains are equally balanced.

3.3.2.2.1 Analysis of Vessel Fleet

The Port of Venice receives a diverse and bustling fleet of vessels that cater to the various types of cargo transported through its waters. According to the Throughput Statistics (Giulio Cesare Stella, 2023) of the first quarter of 2023 of the Port of Venice, the transported cargo consists of three primary categories that encompass a wide range of commodities that play a vital role in the economic activities of the region: liquid bulk, dry bulk, and general cargo (containerized, RoRo, other). General

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cargo is a broad category that encompasses goods transported in a variety of ways, including containers, RoRo vessels, and other specialized carriers.

The fleet in the Port of Venice displays a wide range of characteristics based on the type of cargo they transport. Vessel dimensions, carrying capacities, and operational profiles vary to accommodate the specific needs of different cargoes.

The Port of Piraeus is one of the busiest and largest ports in the Mediterranean region, handling a wide variety of vessels due to its strategic location and importance in global maritime trade. The types of vessels that pass by or call at the Port of Piraeus most commonly include container ships (44 %), Passenger ships (10 %), RoRo/Passenger ships (6 %), Vehicle carriers (6 %), Oil/Chemical Tankers (5 %), and other types of vessels, e.g., support vessels, fishing vessels, and pleasure crafts (29%) (MarineTraffic.com, 2023b). The types of vessels calling at the Port of Piraeus varies based on market conditions, global trade patterns, seasonal factors, and regional events. The local traffic refers to the vehicles that enter the port area but do not engage to any RoRo-related transport, whereas transit traffic refers to vehicles that enter the port area and engage in RoRo-related operations. A typical vessel that currently transports RoRo freight from Patras/Igoumenitsa to Venice by crossing the Adriatic is approximately 200m long and 26m wide, gross tonnage of around 32,000 GT. Examples of such vessels are ANEK's OLYMPIC CHAMPION (IMO 9216028), and ASTERION II (IMO 8922163).

3.3.2.2.2 Analysis of Ports and Infrastructure

Port of Venice

The Port of Venice works and relates with different supply chains (agro-food, steel, chemical, energy), as well as commercial and tourist ones, not only in the Veneto region but also in northern Italy. Analysing the entire port system, and therefore including the Port of Chioggia, the fishing supply chain is also involved. With respect to the sphere of influence in terms of flows and relations activated, these support the regional entrepreneurial fabric and, more generally, the entire North-East.

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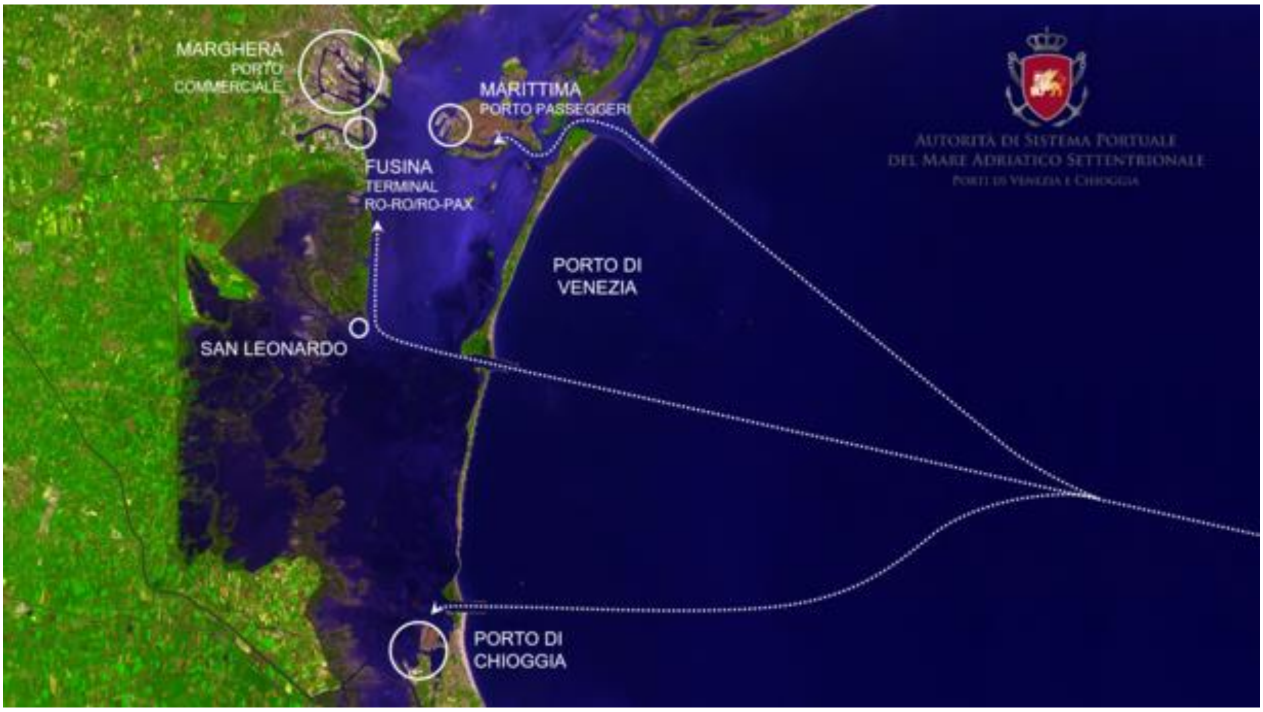

Figure 76: Port of Venice maritime area

Source: Porto di Venezia (2023d)

The Port of Venice covers a total area (Porto di Venezia, 2023f) of over 2,045 hectares, equal to 5 % of the entire Venetian municipality and 11 % of the urbanised municipal territory. It has over 30 kilometres of quays, on which 163 berths are operational, organised through its 27 terminals, divided into commercial, industrial and passenger terminals. The port consists of two main areas: the Porto Marghera area, where logistics, commercial and industrial activities take place, and the Venice area, developed mainly in the Marittima area and in smaller berths, where passenger activities for cruise ships, hydrofoils and yachts are carried out. The Port of Venice, located within the Venetian lagoon, is accessible every day of the year and at all hours. The two port sections of Marghera and Marittima offer 12 km of quays for the berthing of ships. The ports of Venice and Chioggia are the only ones in Italy that are also river ports and allow the forwarding of goods through the inland navigation network that runs along the Po Valley. This is a great opportunity that is also recognised by the European Union (which considers the Lombardo-Veneto River route a component of the Mediterranean corridor of the Ten-T networks) (Porto di Venezia, 2023g).

Figure 77: River connection from port of Venice to Milan

Source: Porto di Venezia (2023c)

Equipped with a 45 km railway network, the Port of Venice connects directly to the national rail and motorway networks and to the TEN-T corridors. It has its own freight terminal, and connects with the rest of Europe through internationally important railway corridors. The Port Authority wants to strengthen the railway network to support intermodality and sustainable transport. The main goods handled in the district are steel products (in 2018, the reference year in these considerations because it does not include the exceptional events of 2019 and the first half of 2020, about 55% by weight of total traffic), energy (18%), agro-food (15%), chemicals (6%) and semi-trailers and containers (5%).

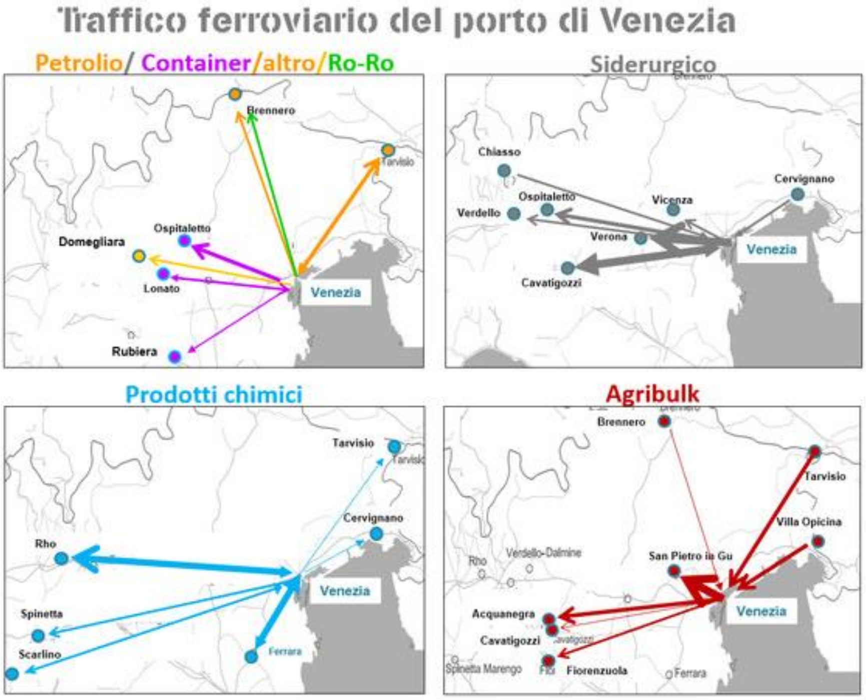

Figure 78: Railway traffic of Port of Venice

Source: Porto di Venezia (2023e)

Due to its strategic geographic position with respect to North-Eastern Italy and Central-Eastern Europe, especially as a key focal point of the eastward shift of European manufacturing in the last decade, companies operating within the port of Venice, along with their customers, are increasingly opting for railway transportation to access diverse destinations across the heart of Europe.

Figure 79: Road network of Port of Venice

Source: Porto di Venezia (2023h)

The Port of Venice is directly connected to the state and European road network (Baltic - Adriatic and Mediterranean corridors). The Port Authority is working to improve road accessibility to the commercial and passenger terminals by relieving the city roads of heavy traffic and making them safer. Freight traffic in/out of the Marghera port section, where the commercial and industrial terminals and companies operating within the port are located, travels along Via dell'Elettricità, which is connected to the Romea State Road, the Padana Superiore Regional Road, and the motorways. Car access to the Marittima section is via Ponte della Libertà, which is also connected to the Romea State Road, the Padana Superiore Regional Road, and the motorways as well as the Triestina State Road.

Port of Piraeus

The port of Piraeus, located in the southeast of Greece, is home to one of Europe's busiest maritime ports embarking and disembarking passenger (eurostat, 2022). The Greek capital city of Athens is 12 kilometres (7 miles) from Piraeus Port. Piraeus is currently the largest port in Greece and one of the leading ports in the Mediterranean, an important centre of the merchant marine, industry, and transport (www.piraeus.org, 2023). Piraeus port is the main exit point from the city by sea for destinations amongst the Aegean Islands and elsewhere in the east Mediterranean. Domestic destinations include all the Aegean islands. The port of Piraeus is also used by several European cruise companies.

The Port of Piraeus has:

- three container terminals (Terminal 1 with a total capacity of 1.1 million TEU, Terminal 2 with a total capacity of 3 million TEU and Terminal 3, completed in 2016, with a total capacity of roughly 2.7 million TEU). The above statistics refer to the terminals’ maximum container capacity, and not the annual throughput.
- a cargo terminal with a storage area of 180,000 m^2 and an annual traffic capacity of 25 million tonnes
- an automobile terminal with two car terminals of approximately 190,000 m^2, a storage capacity of 12,000 cars and a transhipment capacity of 670,000 units per year
- a passenger terminal
- transportation links: Piraeus metro station is located next to the port and is the southern terminus of Athens Metro Line 1

The RoRo Terminals at the Port of Piraeus serve as significant transit hubs for automobiles in the Eastern Mediterranean, Black Sea, and North African regions. Beyond facilitating the loading, unloading, and secure storage of new vehicles, these terminals efficiently manage a diverse range of wheeled cargo. This encompasses heavy machinery, trucks, low roll trailers, trailers, and various types of general cargo. Among the Port of Piraeus’ clients are major automakers, whose vehicle transfer needs are met through the port’s RoRo Terminals, contributing to an annual throughput of over 260,000 vehicles. Following most of the Port of Piraeus’ shares being acquired by COSCO

SHIPPING Co. in mid-2016, the RoRo Terminals have experienced rapid and substantial development. This progress has been achieved while maintaining a high level of customer service and significantly reducing the rate of cargo damage. With a total handling capacity of 600,000 movements annually in both terminals, the RoRo Terminals can handle significant cargoes. The spatial characteristics of the two terminals are presented in the following table.

Table 13: G1 & G2 car terminals' characteristics

Characteristic	G1 Terminal	G2 Terminal
Surface area (m^2)	45,890	145,000
Quay length (m)	373	1,167
Draft (m)	11	11
Berthing slots	1	5
Vehicle storage capacity	2,300	6,700

Source: Piraeus Port Authority (olp.gr, 2021)

Since RoRo vessels do not require any special quay side infrastructure (like e.g., cargo handling equipment for containers), these terminals do not have any specialised infrastructure related to RoRo operations. The port's versatile infrastructure and strategic location make it a hub for a diverse range of maritime activities.

Piraeus has a series of terminals that serve a wide variety of needs. Arguably the most important one (in terms of annual TEU throughput) is the Piraeus Container Terminal (PCT). The most important RoRo terminals are the G and G2 car terminals (MarineTraffic.com, 2023c, 2023d). The total traffic of cars from 2011 to 2018, as well as the traffic of local and transit cars separately is presented in the following from the website of Piraeus Port Authority (olp.gr, 2021).

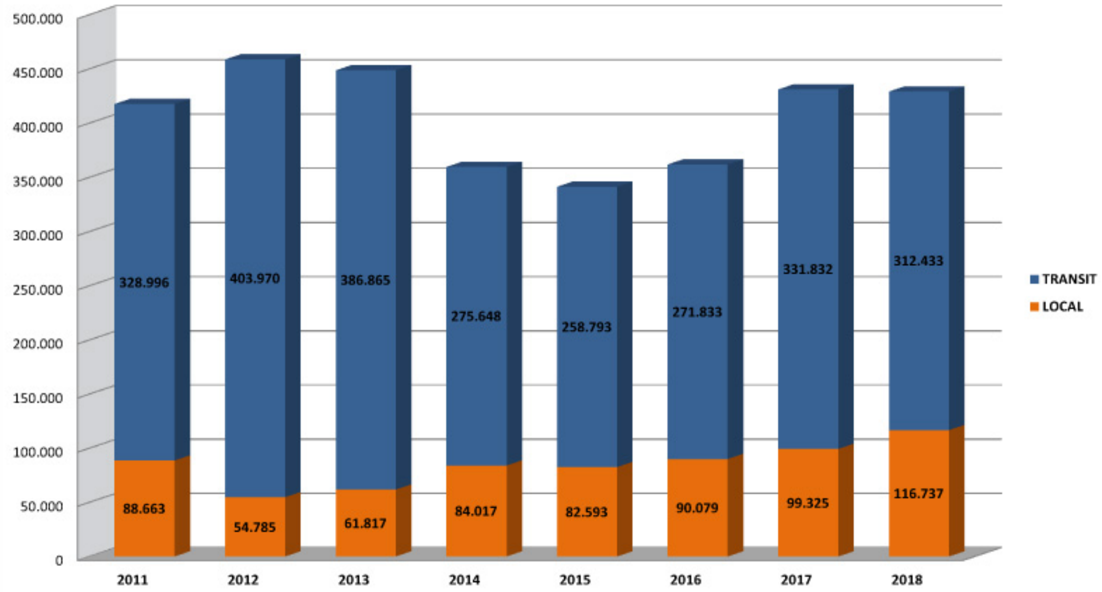

Figure 80: Local and transit car traffic in Piraeus Port RoRo terminals

Source: Piraeus Port Authority (olp.gr, 2021)

3.3.3 Potential SEAMLESS Transportation Scenarios

3.3.3.1 Outline

The proposed transferability use case seeks to optimize the route from Piraeus, extending it with an inland waterway leg, directly connecting Venice to Milan for conducting RoRo operations (i.e., carrying trucks and cars). By implementing this concept, the entire route from Port of Piraeus towards the Port of Patras (via the Corinth Canal), then proceeding to Venice by sea, and finally utilizing the inland waterway to reach Piacenza (gate to Milan), can be seamlessly covered by a combination of autonomous SSS and IWT vessels. The intended route is pictured in Figure 81.

Figure 81: TUC "Adriatic Sea" potential connection

Source: Illustration by NTUA

It should be noted that the reason why a combination of vessels was selected was due to a set of intricacies related to this voyage. The first leg, i.e., Piraeus-Patras, includes navigation in relatively protected waters through the Corinth canal which (as also mentioned above) sets a geometrical constraint to the main particulars of the ships that can pass through it. This part of the journey can be covered by a series of inland waterway RoRo shuttles that will be capable of offering a resilient ad dependable, just-in-time service. The third leg of the voyage, i.e., Venice-Milan, entails navigation through an inland waterway, which can also be covered by an inland vessel like the one handling the Piraeus-Patras route. The second leg however, i.e., Patras Venice, includes navigation through the Adriatic Sea, which poses a unique set of threats to a ship's safety, that are not to be underestimated. For example, the prevailing winds of "bora", "jugo", and "maestral" can cause severe sea conditions (Zec et al., 2016) that oftentimes lead to loss of navigational control of ships, especially the ones that are relatively small (i.e., less than 90m), and do not have the necessary installed horsepower to properly respond to bad weather (Malnar et al., 2022). To that end, it was deemed imperative to utilise a closed-type SSS RoRo ship for covering this part of the voyage.

The Port of Venice holds a strategic geographical advantage as it is the sole port in Italy with an inland waterway port, offering a direct pathway for cargoes sailing up the Po Valley. Leveraging this unique feature, an extension of the route to Milan via inland waterways is envisioned within the use case. Furthermore, the Port of Venice is located at the convergence point of major European high-speed and high-capacity corridors. This positioning allows for rapid connections to an extensive hinterland, spanning from North-Eastern Italy to Central-Eastern Europe. As a result, the TUC will have the potential to serve a vast and economically significant region, strengthening its role as a critical logistics hub for the transfer of trucks and cars through RoRo operations.

Numerous studies (Marco Molica Colella et al., 2023; Munim, 2019) have provided substantial evidence highlighting the primary business drivers favouring the adoption of autonomous seamless shipping over a combination of road transport and conventional sea ships. These findings underscore key advantages, including significant cost savings, optimized routes leading to faster transit times, reduced human error risks, the potential for non-stop 24/7 operations, and substantial environmental sustainability benefits. As autonomous shipping relies on waterborne transportation, it reduces the dependence on congested road networks and potentially overloaded road infrastructures. This can lead to a more reliable and predictable shipping process. All these drivers collectively offer compelling reasons for businesses to consider and invest in autonomous shipping solutions.

3.3.3.2 Stakeholders

Ship owners and ship operators

Since the connection between the port of Patras and port of Venice (which is also part of the proposed Piraeus-Venice TUC) has been declared as a Motorway of the Sea (Circle, 2015), it is expected that all the currently implicated shipping companies would be interested in participating towards the development of relevant technologies and solutions that would facilitate the realisation of this TUC. Some of these companies include ANEK Lines, Grimaldi Lines, Neptune Lines, and SUPERFAST Ferries.

Port and Terminal operators

In Piraeus, the car terminal is operated by Piraeus Port Authority, whereas in Venice the Ro-Port is developed and operated by Venice Ro-Port MoS Scpa, who were also responsible for the design and construction of the intermodal hub.

Administrative and Strategic Stakeholders

This group comprises entities that indirectly shape the course of the autonomous shipping corridor through their administrative and strategic influence. The Port of Venice and the Port of Piraeus are pivotal, as both ports serve as crucial nodes within the corridor. Additionally, container terminals (in Venice and in Piraeus) in these ports play a significant role in ensuring efficient cargo handling. The Italian Ministry of Infrastructure and Transport holds the power to provide regulatory frameworks that can facilitate the corridor's operations seamlessly. Regulatory bodies such as the European Maritime

Safety Agency (EMSA) and the Italian Maritime Administration (RINA) further ensure that safety and compliance standards are met.

Commercial stakeholders

There is currently a wide variety of operational stakeholders that utilise the already existing transport chain connecting Piraeus with Venice through RoRo services, shipping products like precious metals and ores, various household appliances, computers, medicine, and food (e.g., fish, olive oil, wheat, fruit) (United Nations, 2023) It can therefore be assumed that the same stakeholders will be interested in the realisation of this TUC through autonomous technologies. To that end, these operational stakeholders include UNILEVER, FAGE, FIAT, MYTILINEOS Aluminium, Hellenic Fish Farming SA.

Technological Stakeholders

Technological stakeholders include universities and research centres, as well as companies of various kinds, which are involved in research aimed at developing autonomous ships on inland waterways. These include the National Technical University of Athens (School of Naval Architecture and Marine Engineering – Laboratory for Maritime Transport), the Institute of Communication and Computer Systems (ICCS – iSENSE department), CORE Group, the Hellenic Shipowners Association of tugs, salvage, antipollution, and OSVS, the National Centre For Scientific Research Demokritos, and a plethora of Greek shipping companies (e.g., DANAOS) that already have R&D departments studying autonomous technologies for use in the maritime domain

3.3.3.3 SEAMLESS Waterborne Transport Concept

3.3.3.3.1 Potential Vessel Fleet Concepts

This section will provide an in-depth exploration of the anticipated vessel fleet concepts crucial to the autonomous shipping corridor between the Port of Piraeus and the Port of Venice. While comprehensive details are currently in development, the ongoing collaboration with the Port of Venice authorities ensures that precise and innovative vessel fleet compositions will be elaborated in subsequent updates.

As it is outlined above, the state of the art in transporting RoRo freight from Piraeus to Italy through the Adriatic, is by using a combination of road and maritime transport. This TUC proposes to exploit the convenience of the Corinth Canal (Corinth Canal S.A, 2023) and the Po valley to perform RoRo operations in a safe, resilient, and green manner through a 24/7 service incorporating the SEAMLESS specific Building Block modules. The realisation of TUC3 will require the use of both SSS and IWW autonomous vessels.

The SEAMLESS waterborne transport concepts that pertain to IWT are comparable to the ones outlined in other TUCs (e.g., TUC1). However, the rather unconventional aspect here is that this IWT ship must be capable of carrying vehicles as well as provide accommodation for limited number of passengers (e.g., truck drivers). An ideal IWW RoRo vessel would have to be capable of passing through the Corinth canal, as well as navigating the inland waterways from Venice to Milan, while simultaneously carrying as much cargo as possible. To that end, such a vessel should have adequate main particulars that could accommodate the transport of at least 50 trucks per trip, while simultaneously being able to navigate through the Corinth canal where the maximum depth and width are 8m and 21m respectively (Corinth Canal S.A, 2024). Utilising a shuttle service of a small fleet of vessels with these characteristics would be sufficient for serving the first and third legs of this TUC. Considering that the proposed route has been performed through a combination of road and waterborne transport for multiple decades, literature research has indicated that there is currently no commercial vessel available that could fulfil the specifications mentioned above.

As far as the SSS part of the journey is concerned, a characteristic example of a vessel concept that would be capable of covering this route is the MIRAMAR EXPRESS (IMO 9183790). With a length overall of 153 m, a beam of 23 m, a draught of 7 m, and a carrying capacity that can reach 120 truck trailers, this `type of vessel would be capable of seamlessly cooperating with the fleet of autonomous RoRo IWW vessels towards offering an integrated service for efficiently and safely carrying commercial vehicles from Piraeus to Venice and Milan. As mentioned above, the use of only IWW vessels in this case would not be capable of providing an adequate safety operational level to all the implicated stakeholders. The suggested concept may contradict the whole "escaping the economy of scale" rationale of SEAMLESS, that can be relatively easily adopted in European IWWs and SSS use cases that include protected waters (e.g., the Norwegian Fjords). However, when it comes to crossing waters that present with rough seas all year long (e.g., the Adriatic and the Aegean Sea), autonomy alone is not enough to counteract the forces of nature. In fact, operational experience has shown that in these cases, vessels that are of a particular size (e.g., more that 150m in length), and have sufficient installed propulsion power, can withstand the severe weather conditions encountered in these areas. As a result, even though the SSS concept of TUC3 does not reflect the core of the SEAMLESS concept due to its large size, its selection was deemed imperative due to safety reasons.

3.3.3.3.2 Potential Ports and Infrastructure Concept

The forthcoming analysis in this chapter will reveal the intricate potential ports and infrastructure concepts integral to the autonomous shipping corridor's realization. The relevant stakeholders will actively engage with the Port of Venice authorities to formalise the strategic design and configuration for these essential components and lay the groundwork for the application of the SEAMLESS building blocks in this corridor.

To sustain and support this use case, all the entailed ports will need to be equipped with state-of-the-art equipment and operate according to regulations that will allow autonomous ships to dock at them. This will require the following:

- Highly automated mooring solution that could interface with legacy infrastructure (e.g., bollards), thus rendering the need for investing in additional port-side equipment, redundant.

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- Port call software solution that will be capable of making the required negotiations between the autonomous vessels and the port.

- In case the vessels utilise alternative fuels (e.g., hydrogen, ammonia) or are fully electrified, then the ports will need to provide the necessary infrastructure for the respective bunkering operations.

- By far the biggest challenge to the proposed TUC will be the RoRo transhipment operations. The suggested route will entail two transhipments, both of which will require the relocation of vehicles which can prove to be a cumbersome and tedious procedure that could act as a serious bottleneck to the whole process. It should be noted however that SEAMLESS' scope primarily entails streamlining the transport of containerised cargo through European SSS and IWT via the development of an autonomous shuttle service. Therefore, the analysis of RoRo operations related to transhipments of vehicles, albeit quite interesting, falls outside the research scope of the project. Nevertheless, an interesting concept that could be suggested and perhaps aid with the delays of RoRo transhipment is the use of autonomous vehicles (apart from autonomous ships) that would relocate from one RoRo carrier to another, without the need for human intervention, thus rendering this process more efficient. Albeit, for the reasons outlined above, this will not be something examined in the context of SEAMLESS.

3.3.4 Requirements and Technology Gaps

The TUC “Adriatic Sea” expects to investigate different building blocks such as an automated port interface, modular vessel and operation, as well as integrated supply chain support e.g., by means of the ModalNET platform. The implementation of these building blocks within the proposed TUC requires a significant redesign of the logistics supply chain since it will completely circumvent the use of the road transport network. Therefore, the capabilities of the ModalNET platform will be fully utilised.

The SEAMLESS DockNLoad system will also be required, but not to its full extend. While an autonomous mooring system is to be made available, cargo operations will not require autonomous handling systems. The automated stowage planner by MacGregor is focused on containers, therefore, its applicability will require further development for the application within this TUC. The building block of autonomous operations that will allow for transcending from 1-1 vessel operation to 1-many, is also applicable since it is part of the SEAMLESS service. The same applies for the various vessel concepts, since this use case will eventually utilise both SSS transport, as well as IWT.

One of the primary factors in favour of a future deployment of SEAMLESS building blocks within the scope of the proposed TUC is the collaborative approach of port policies that support and encourage the integration of autonomous scenarios within the port. However, it is essential to be aware that the political process for implementing these policies might be time-consuming, and careful planning and coordination are required.

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3.4 TRANSFERABILITY USE CASE "BLACK SEA"

This section is pertinent to the East Med – Black Sea Transferability Use Case of project SEAMLESS. Its ambitious goal is to concretely contribute towards the development of TEN-T corridor Rhine – Danube that will seamlessly connect port of Piraeus with port of Duisburg through a combination of SSS via the Aegean Sea, Sea of Marmara, and the Black Sea, and IWT via Danube. This endeavour is quite challenging, especially considering that:

- It requires SSS autonomous vessels (carrying containerised cargo) that are capable of withstanding the rough seas of the Aegean Sea, which -even to this day- are responsible for a plethora of accidents that lead to casualties (Euronews, 2023).
- It needs the vessels to perform a passage through the Dardanelles strait and Bosporus, which (for an autonomous ship) is extremely challenging not only from a technical, but from a regulatory, and administrational standpoint as well.
- There must be an integrated system that is capable of handling the interface process with the port-side for mooring and for cargo transfer.
- It requires IWT autonomous vessels that are capable of transferring containerised cargo, while simultaneously circumventing Danube's bottlenecks (e.g., low draft, under-bridge clearance).

Considering all the above, it is noted that some of these requirements, fall outside the scope of the ambition of SEAMLESS (e.g., MASS passing though straits). Nevertheless, as it will also be highlighted in the following paragraphs, through its innovative outcomes, the project can significantly contribute towards the realisation of this TUC.

3.4.1 Existing Logistics Environment

The Black Sea Leg is complimentary (albeit not identical) to the South-East Europe Motorway of the Sea and represents a waterborne alternative to the Orient-East Med TEN-T corridor (Figure 82)

). Its goal is to connect the port of Piraeus, Greece, with port of Constantza, Romania, through an autonomous freighter feeder loop service, carrying containerised cargo. It should be noted however that as far as the mapping of the logistics environment is concerned, the focus will be placed on political, economic, social, technological, ecological and legal factors related to Greece and Romania.

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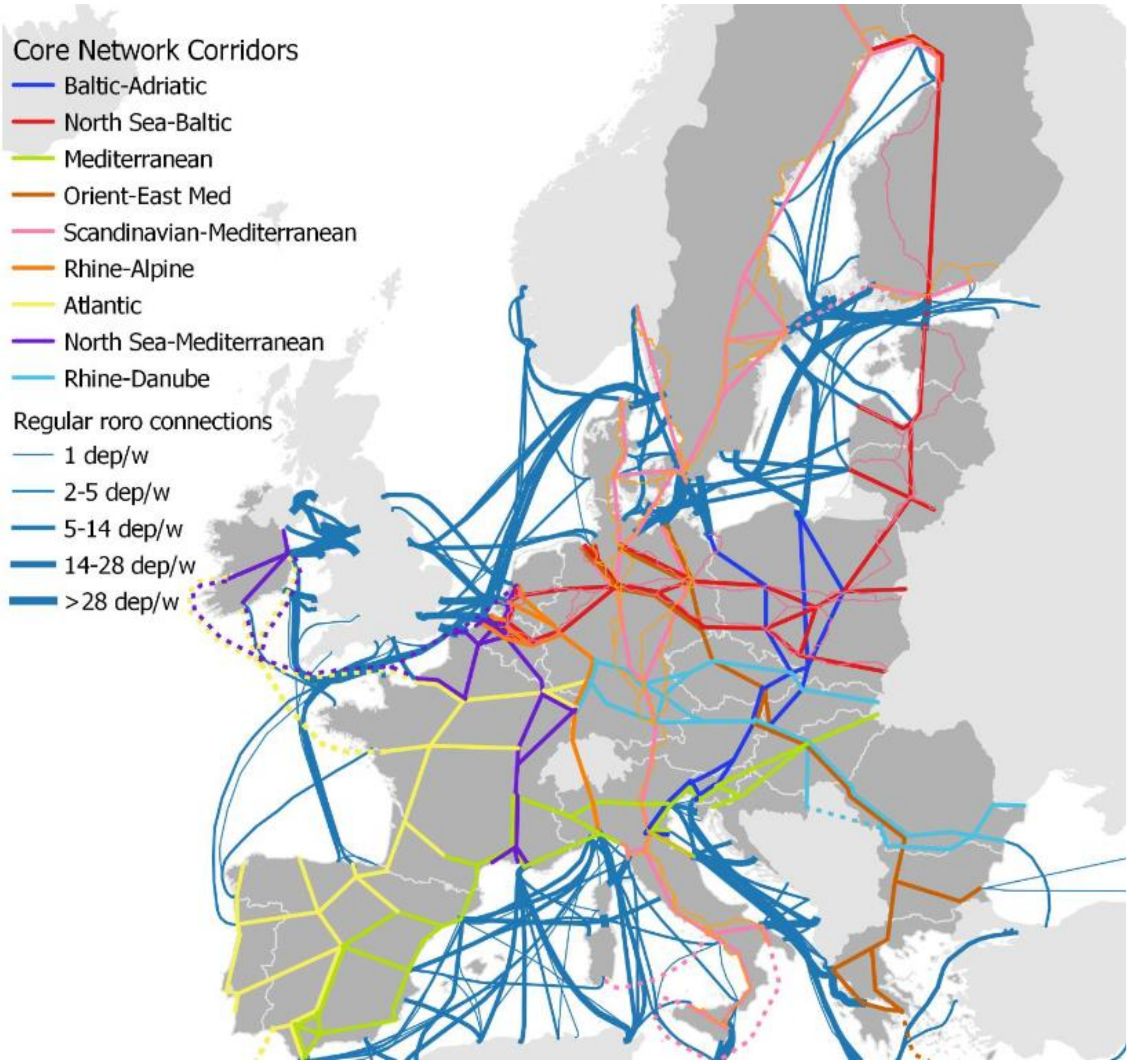

Figure 82: Core network corridors preliminary; Ro-Ro shipping routes exclude regular car carriers

Source: ISL

Political Factors

Considering that Greece and Romania collaborate closely on a European level, as well as within the framework of various regional organisations and initiatives (e.g., OSCE, SEECP, SECI, BSEC), the political relation between the two countries are at an excellent level (Embassy of Greece in Bucharest, 2023). As a result, there is a track record of regional cooperation and trade facilitation that could concretely foster a potential implementation of advanced technological solutions such as the ones

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proposed by SEAMLESS. On the other hand, as with all automated/autonomous technologies, aspects that may threat this implementation are related to national security concerns, as well as the public perception and acceptability of the SEAMLESS disruptive solutions.

Economic Factors

As far as the Black Sea Leg is concerned, SEAMLESS presents with an untapped potential to incur significant cost saving through streamlining the cargo transfer while boosting the efficiency of the various interconnections and interfaces. This effect will also be amplified by an improved supply chain management system, which constitutes an offering of the integrated solutions of SEAMLESS. On the contrary, inhibiting agents relevant to economic aspects of Piraeus and Constantza include the potential high cost of the initial investment for autonomous technologies that, especially in Eastern-European countries, could have a detrimental effect to the realisation of the SEAMLESS solutions, and one cannot disregard the competition with other modes of transport (e.g., trucks, rail) that may appear as more attractive to the relevant stakeholders. Nevertheless, it should be noted that following the global trend in automatization of transport that includes self-driving cars, trains, remote piloted drones, self-piloted for sea going ships, shipping companies (e.g., Trading Line) are looking to make transportation more predictable, lean and achieve sustainable cost savings for the entire value chain, by becoming an early adopter of autonomous technologies.

Social Factors

With respect to the social factors, the adoption of the SEAMLESS solutions is expected to promote and generate jobs that have the potential to be higher in pay while offering better working conditions as in the current state due to the automated processes. This of course in turn will create the need for the development of new skills, and training regimes relevant to the redesigned logistics chain. On the downside, the implementation of automated/autonomous systems bears the possibility of totally reducing the required size and composition of crew, albeit this remains to be proven in practice (Kooij & Hekkenberg, 2021). Furthermore, another threat is whether there will be adequate market acceptance and cargo owner preference towards automated systems and technologies.

Technological/Infrastructure Factors

One of the major benefits of automating operations from a technological standpoint, lies in the standardisation and streamlining of port operations. This will in turn contribute towards achieving lower shipping costs, which will eventually reverberate throughout the supply chain. This endeavour is further supported by the substantial technological advancements in maritime automation, artificial intelligence, and communication systems (Munim & Haralambides, 2022). However, there are certain limitations as well that include the limited infrastructure readiness (especially in Eastern-European countries), and the seemingly untapped potential for cybersecurity vulnerabilities (Yoo & Jo, 2023).

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Ecological Factors

Concerning the ecological factors that can offer opportunities for integration of the SEAMLESS innovations, the most prominent one is the fact that the main motivation behind every technological development and desktop study lies with the highlight of the environmental benefits in a sustainable manner. On the other hand, what remains to be determined is the impact these autonomous technologies may have on the marine and aquatic ecosystems, e.g., from the standpoint of disrupting the migratory routes of marine life.

Legal Factors

Opportunities related to legal factors in Greece and Romania include the ever-growing autonomous vessel certification and compliance framework, since both countries are member-states of IMO (SEAMLESS will concretely contribute to this item through the development of a standardised Risk-Based Approval process), the standardisation and harmonisation with already existing rules and regulations, and the development of a framework for liability sharing and insurance. On the opposite, legal factors that may hinder the incorporation of the SEAMLESS solutions, include specific verses of the International Maritime Law (Ringbom et al., 2021), crewing and employment regulations, and in some cases certain geopolitical considerations (e.g., does the liability for the MASS, shifts country when it crosses boarders?).

3.4.2 Existing Transportation Concepts

3.4.2.1 Outline

Currently, the transport of containerised cargo between Piraeus and Constantza is accommodated through a combination of trucks, trains, and inland waterway transport through the Danube via the European network of trade corridors (see Figure 83).

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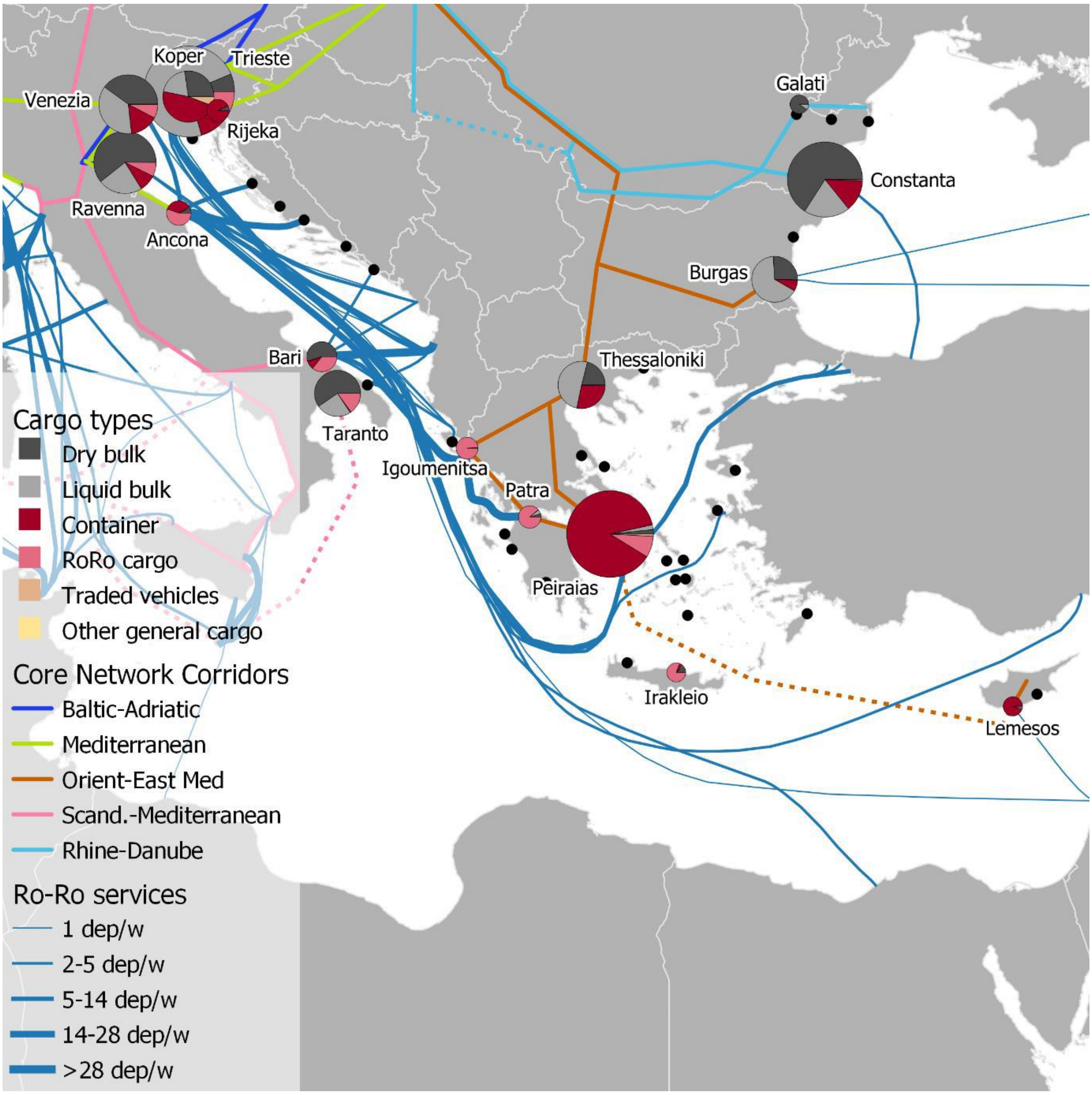

Figure 83**: Core network corridor ports in the East Med and Black Sea**

Source: ISL, 2021

The main objective of this Transferability Use Case is to propose an alternative cargo flow route from Piraeus to Constantza, that will i) motivate the shift of cargo from road to the sea, and ii) be applicable to other ports of the Black Sea (e.g., Burgas, Varna, Batumi). The proposed waterborne route is presented in Figure 84.

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Figure 84: High-level TUC4 proposed route

Source: Illustration by NTUA

In general, cargo is shipped from the Port of Piraeus to the Black Sea, with potential transhipment at intermediary ports like Constantza, Romania or Varna, Bulgaria. This part of the journey is typically achieved through container ships, bulk carriers, and Ro/Ro ships. After reaching a suitable Black Sea port (e.g., Constantza), cargo can be transported along the Danube River to reach e.g., the Port of Galati in Romania. In the Black Sea, there are containership services linking Burgas (Orient-East Med corridor) with Georgia and Constantza (Rhine-Danube corridor) and with Turkey and Thessaloniki. Finally, the Rhine-Danube corridor links the Romanian ports of Constantza and Galati with Central and Western Europe. The Danube is already intensively used for bulk transport while container transport only plays a minor role.

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3.4.2.2 Existing Waterborne Transport Concepts

3.4.2.2.1 Analysis of Vessel Fleet

The fleet of vessels that will be outlined below will be pertinent to SSS vessels that are capable of transporting cargo from Piraeus to the various Black Sea ports via the Aegean Sea, the Dardanelles strait and Bosporus.

Port of Constantza

The capacity of Eastern Danube was recently heavily increased with river vessels that were relocated from river Rhine area. According to Inland Shipping, about 300 more units (self-propelled, pushers and barges) were moved from Rhine (from March 2022 till today) with a cumulative capacity of 500,000 tones. The actual average rotation of barges is 1,25 per month, whereas, Inland Shipping, has successfully made four (4) rotations per month when they used STS operations and discharge barges up-on arrival to transfer cargo to/from another larger SSS vessel, with no additional delays.

Port of Constantza serves both IWW and SSS vessels. The main types of cargo accommodated are bulk and containers. In 2022, the annual throughput of the port reached 776,590 TEUs (Port of Constanta, 2020c). Typical SSS containership vessels that call at Constantza include the AKADIMOS (L= 300m, B= 48.5m, T= 15m), and MSC HOGGAR (L= 137m, B= 20m, T= 10m).

Port of Piraeus

As one of the prominent ports in Europe, Piraeus is where a plethora of vessels call daily. These include RoRo, RoPax, passenger ships, tankers, tugs, and standby vessels. However, the most common type of vessels calling at Piraeus are containerships. PCT can accommodate a wide array of containerships. From feeders like the 2,700 TEU CELSIUS LIVERPOOL (L=195.3m, B=20.3, T=12.5), to ULCVs (Ultra Large Container Vessels) like the 20,000 TEU COSCO SHIPPING ARIES (L=382m, B=58.6m, T=16m).

The piers operated by PCT are exclusively designed for serving vessels carrying containerised cargo. All the containers present at PCT can be classified into the three following types of traffics: export, import or transhipment containers. The export flow within PCT starts when the container (full loaded or empty) enters the terminal by means of a truck or a train. This container is generally stored at the yard terminal and after few hours or days is finally moved to the berth for its loading on a vessel. The import flows follow the inverse process and comprise the phases of container unloading and its horizontal transport to the yard where it is stored until its delivery to a land transport operator (road or rail transport companies). The transhipment is described as the process by which a container is unloaded from a vessel and stored at the yard terminal until a new vessel arrives. Then the container is again transported to the berth and loaded on the vessel. Some interesting operational steps that could be taken into consideration for the autonomy aspects of this leg of TUC4 are related to berthing/unberthing, and loading/unloading of containerships operating at the Piraeus Container

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Terminal. These processes are presented in box diagram form in the following Figure 85, Figure 86, Figure 87, and Figure 88 (All were sourced from PCT).

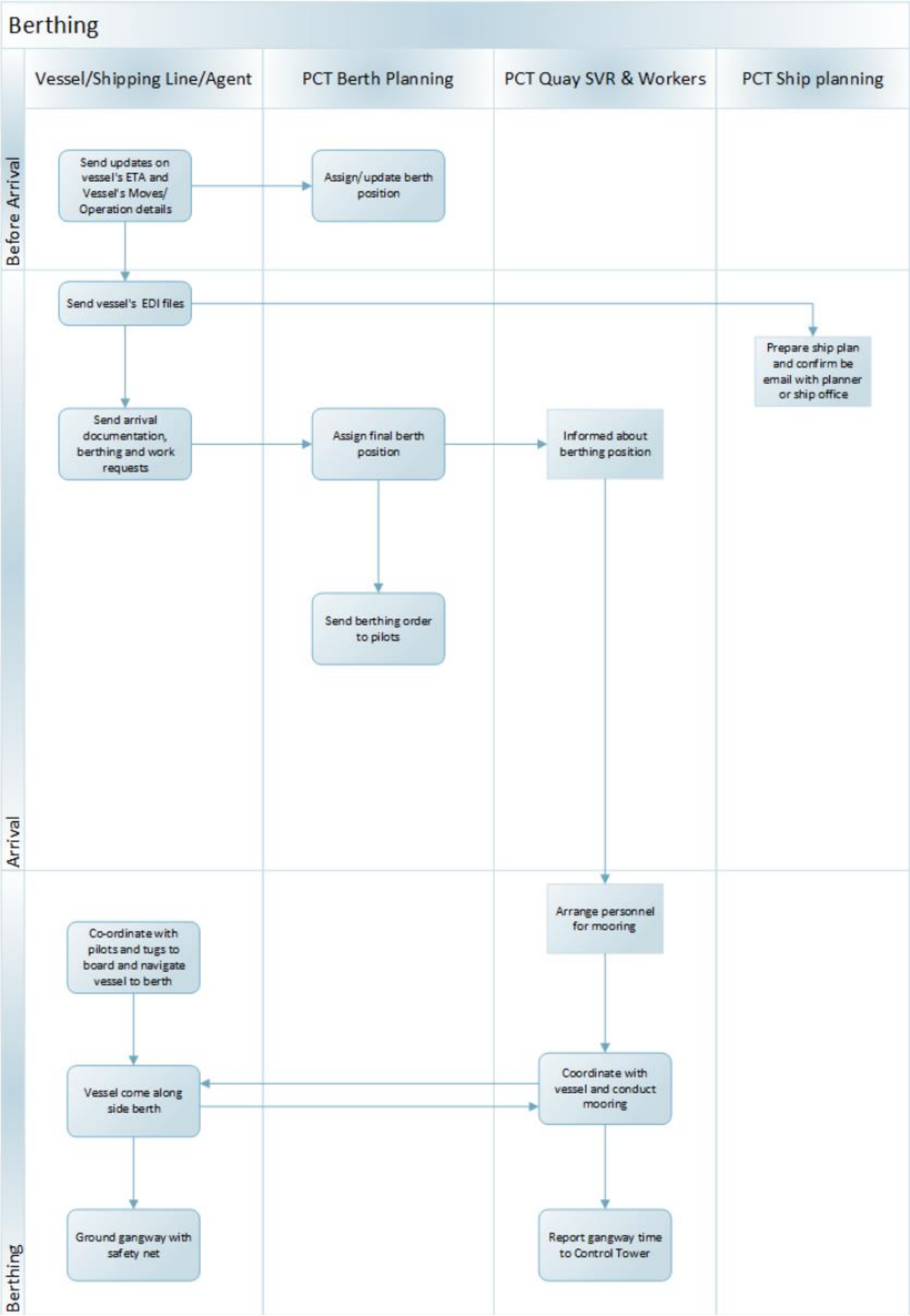

Figure 85: Berthing Process in PCT

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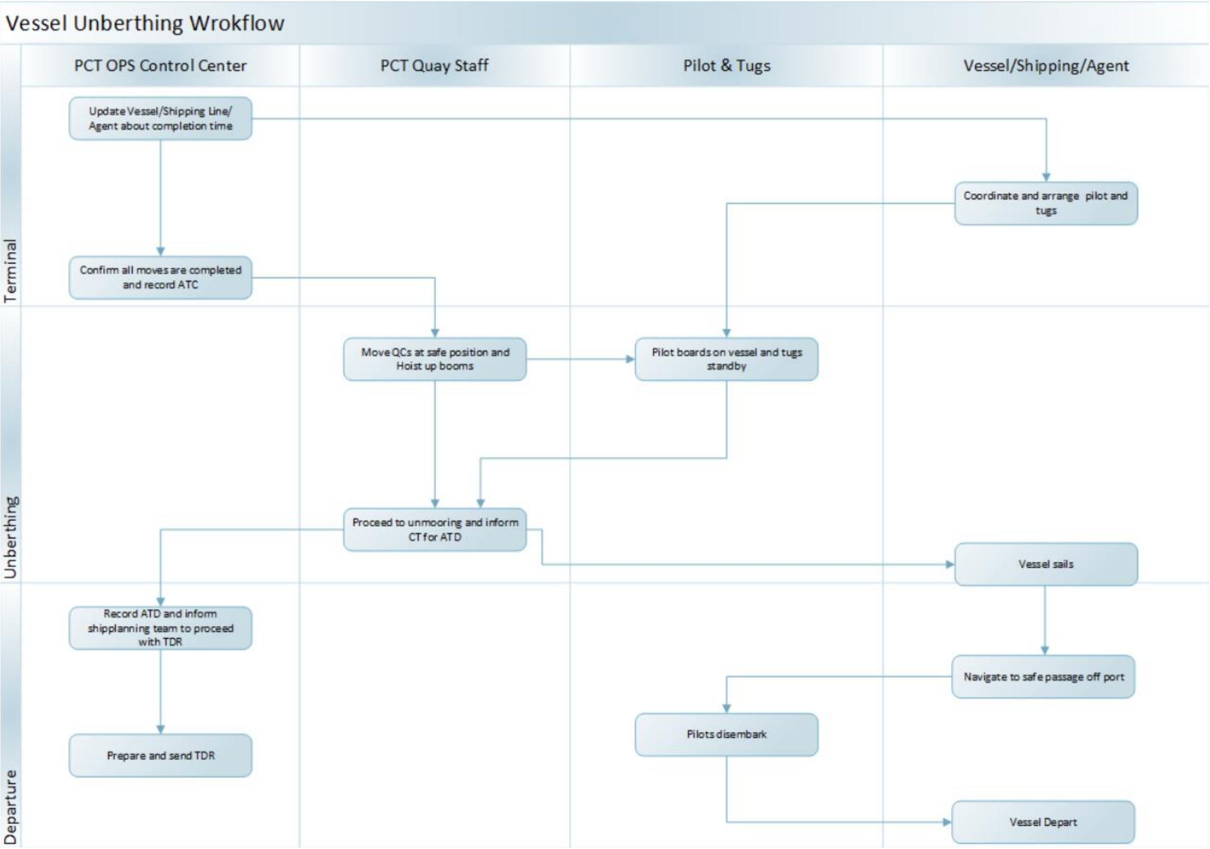

Figure 86: Unberthing Process in PCT

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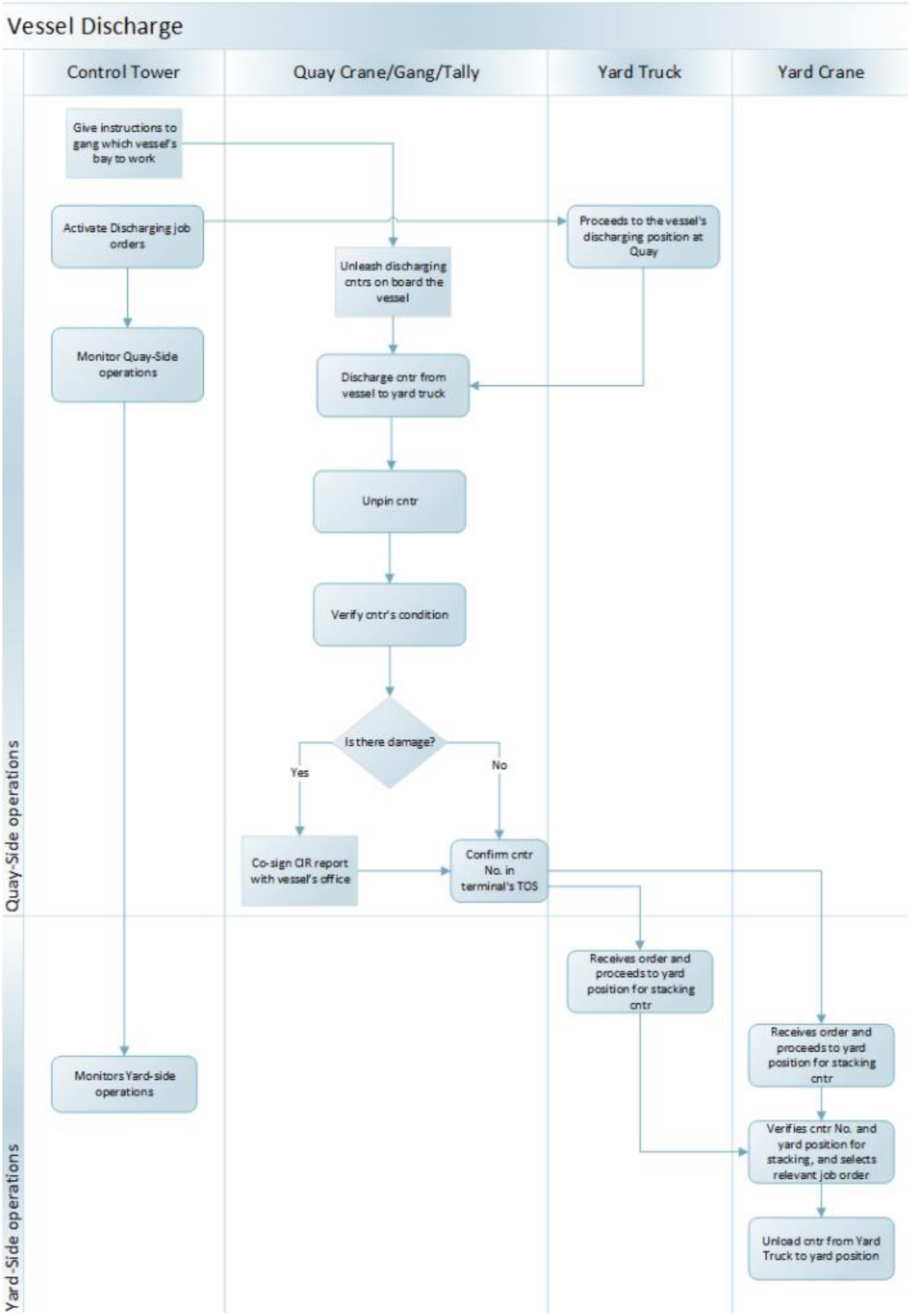

Figure 87: Unloading Process in PCT

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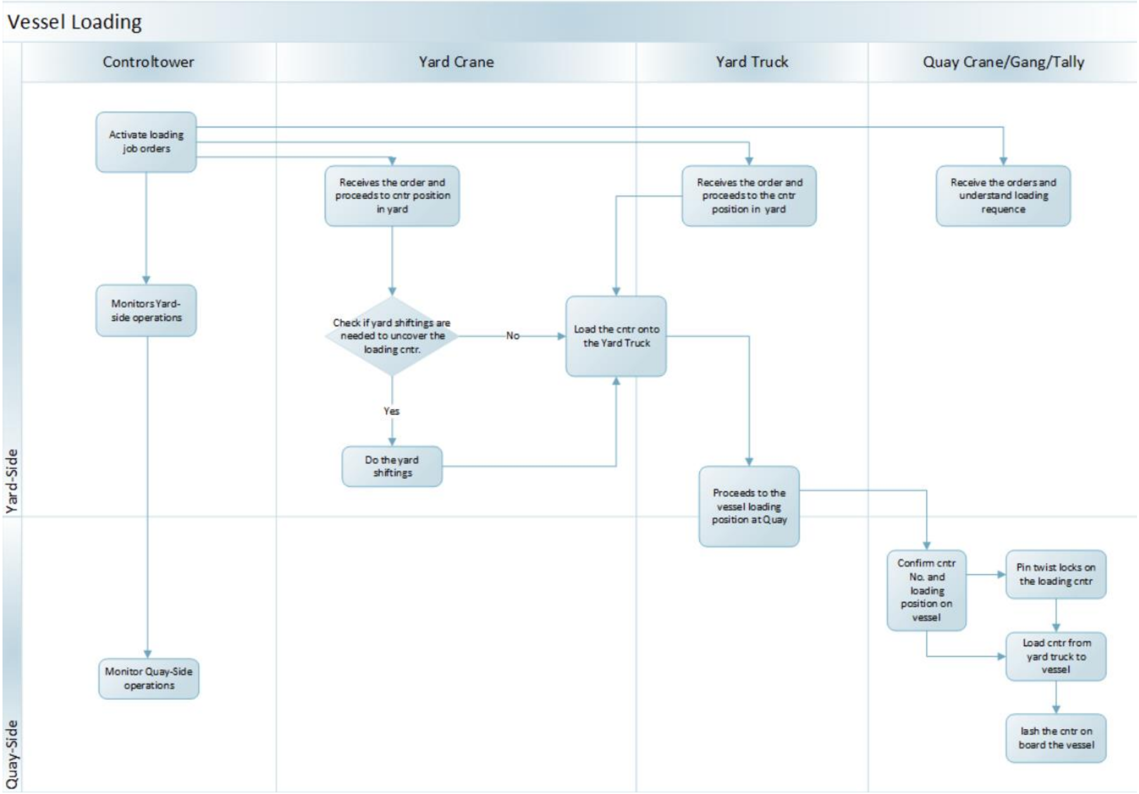

Figure 88: Loading Process in PCT

3.4.2.2.2 Analysis of Ports and Infrastructure

Port of Constantza

The strategic geographical placement of Constantza Port has proven advantageous, since it is situated along the vital Rhine-Danube transport corridor which spans across Europe. Serving as a pivotal node in the European intermodal transport network, Constantza Port holds a significant position where trade routes converge. This nexus links the markets of landlocked nations in Central and Eastern Europe with the Trans Caucasus region, Central Asia, and the Far East.

The port stands as a key distribution hub for Central and Eastern Europe, boasting numerous advantages, including:

- A versatile port equipped with state-of-the-art facilities and ample water depths in its basins, capable of accommodating the largest vessels transiting the Suez Canal.
- Unrestricted access to Central and Eastern European countries via the Pan-European Rhine-Danube Corridor.
- A central hub for Black Sea container traffic.
- Ro-Ro terminals ensuring swift connections with the Black Sea and Mediterranean ports.

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- Seamless connectivity across all modes of transport: railway, road, river, airway, and pipelines.
- Customs facilitations streamlining commercial operations at the Port of Constantza.
- Contemporary facilities catering to passenger vessels.
- Available land for future expansion.
- Holding Free Zone status, through which the Port of Constantza establishes a conducive framework for facilitating foreign trade and the transit of goods to/from Central and Eastern Europe.

Constantza offers two main modern container terminals (See Figure **89**) capable of accommodating state-of-the-art containerships (Port of Constanta, 2020a). In recent years, the incorporation of direct service lines connecting it with the Far East has transformed the port into a pivotal distribution centre for the Black Sea region as well as the Central and Eastern Europe. This role extends to serving neighbouring ports through efficient feeder ship connections. In 2003, Constantza possessed the largest specialised container terminal in the Black Sea. Boasting quay depths of at least 14.5 meters, the terminal is equipped to handle post-Panamax container vessels, while its advanced operational facilities guarantee an efficient vessel handling rate, enhancing the port's capabilities. The terminal's main berth length is 636 meters, the feeders' berth length is 411 meters, whereas the containers' storage area is 5,000 square meters. They are equipped with five post-Panamax cranes, and three mobile harbour cranes. Also, the terminal offers trans-shipment capabilities through the integration of rail services. Three railway lines, each 616 meters long, are capable of simultaneously handling three trains, each with thirty wagons. Container service lines have commenced in the Danube region since 2005, connecting Constantza port with river destinations such as Giurgiu, Belgrade, and Budapest.

Figure 89**: Top view of Constantza port**

Source: Port of Constanta (2020b)

Digital infrastructure within the port of Constantza which has relevance for the scope of this use case includes digital truck appointment systems which are required to access the port area through the Complete management solution and automation truck access in Constantza port app, an automatic weighing system (probably out of scope). The port of Constantza is also part of the E-COLD project which is financed by the European Union through the Connecting Europe Facility framework. The project's goal is to prepare the groundwork for installing onshore power supply modules at ten (10) berthing spots within the Port of Constantza. This will alleviate the need for the moored vessels to consume fossil fuel to cover their hotel needs and thus, contribute to the decrease of emissions in the port as well as the broader region.

Port of Piraeus

The Port of Piraeus is one of the busiest and largest ports in the Mediterranean region, handling a wide variety of vessels due to its strategic location and importance in global maritime trade. The types of vessels that pass by or call at the Port of Piraeus most commonly include container ships (44%), Passenger ships (10%), RoRo/Passenger ships (6%), Vehicle carriers (6%), Oil/Chemical Tankers (5%), and other various types of vessels (e.g., support vessels, tugs, leisure crafts; 29%)

(MarineTraffic.com, 2023a). The types of vessels calling at the Port of Piraeus can vary based on market conditions, global trade patterns, seasonal factors, and regional events. The port's versatile infrastructure and strategic location make it a hub for a diverse range of maritime activities.

Piraeus has a series of terminals that serve a wide variety of needs. However, arguably the most important one (in terms of capabilities, and commercial use) is the Piraeus Container Terminal (PCT). The container terminal facilities and operations at the port of Piraeus are developed, maintained, and managed so that they can accommodate all types of containers and essentially provide a gateway and transhipment hub in Greece, Mediterranean, and Europe. In 2022, port of Piraeus was the second port in the Mediterranean, and the fourth port in Europe in terms of container throughput (approx. 5.0MTEUs/yr.) (PortEconomics, 2023). PCT's main activities include the provision of loading / unloading and storage services for import and export containers handled via the Port of Piraeus, including cargoes which use Piraeus only as an intermediary station of transport (transhipment cargo). The strategic location of Piraeus makes it an ideal port to be used as a hub for destinations in the Central and Eastern Mediterranean, as well as the Black Sea. In addition, PCT is linked with the European Rail Network with its owned Rail Ramp. Based on its facilities - able to handle up to 10 trains per day - can offer reliable rail transportation solutions from Piraeus Port to Central Europe & Balkans. An overview of the feeder network accommodated by PCT is presented in Figure 90.

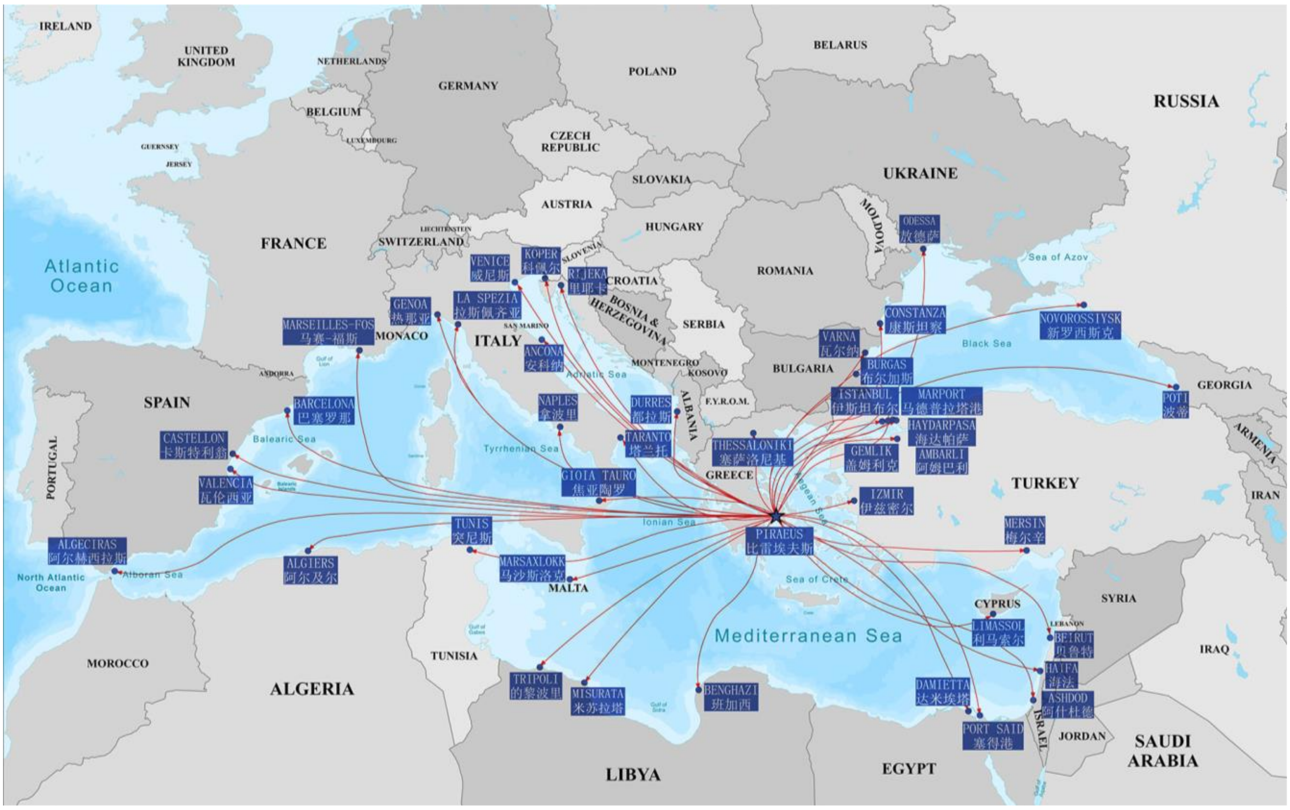

Figure 90: Feeder Network Layout of Piraeus

Source: PCT (2023)

With respect to port infrastructure, the berthing, loading, and unloading operations of large containerships (e.g., New Panamax class), all take place in Piers II and III, whereas Pier I is for handling smaller feeder vessels. A top view of the container terminal piers is presented in Figure 91. In the next few years, the terminal capacity is expected to reach 3.2M TEUs in Pier II, and 3M TEUs in Pier II, adding up to a total capacity of 6.2M TEUs. Additional details about the particulars and equipment utilised in port of Piraeus is provided in Table 14 and Table 15.

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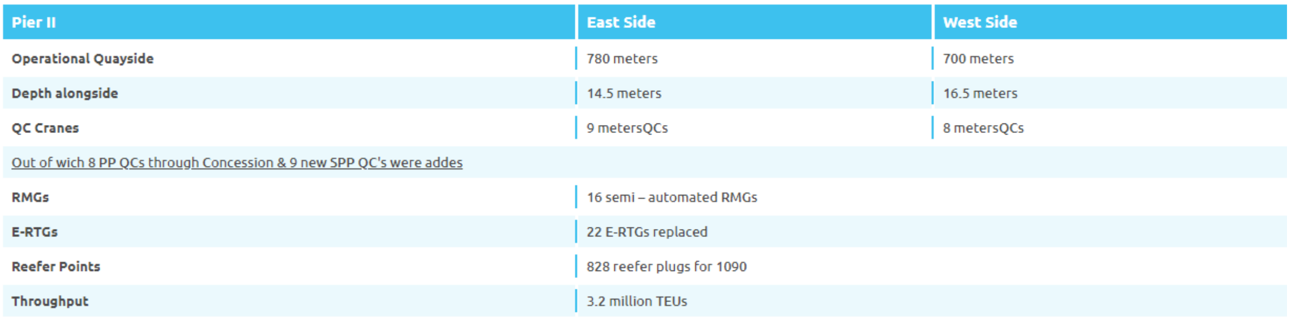
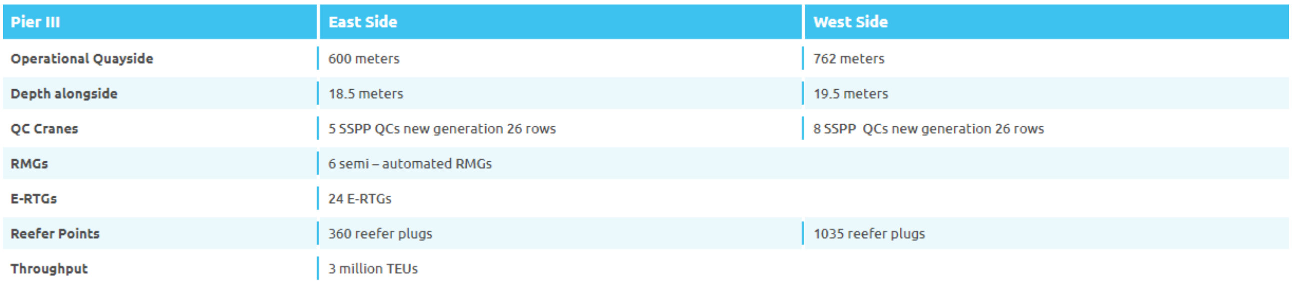
Table 14: PCT Pier II particulars



Pier II	East Side	West Side
Operational Quayside	780 meters	700 meters
Depth alongside	14.5 meters	16.5 meters
QC Cranes	9 metersQCs	8 metersQCs
Out of wich 8 PP QCs through Concession & 9 new SPP QC's were addes		
RMGs	16 semi – automated RMGs	
E-RTGs	22 E-RTGs replaced	
Reefer Points	828 reefer plugs for 1090	
Throughput	3.2 million TEUs	

Source: PCT

Table 15: PCT Pier III Particulars



Pier III	East Side	West Side
Operational Quayside	600 meters	762 meters
Depth alongside	18.5 meters	19.5 meters
QC Cranes	5 SSPP QCs new generation 26 rows	8 SSPP QCs new generation 26 rows
RMGs	6 semi – automated RMGs	
E-RTGs	24 E-RTGs	
Reefer Points	360 reefer plugs	1035 reefer plugs
Throughput	3 million TEUs	

Source: PCT

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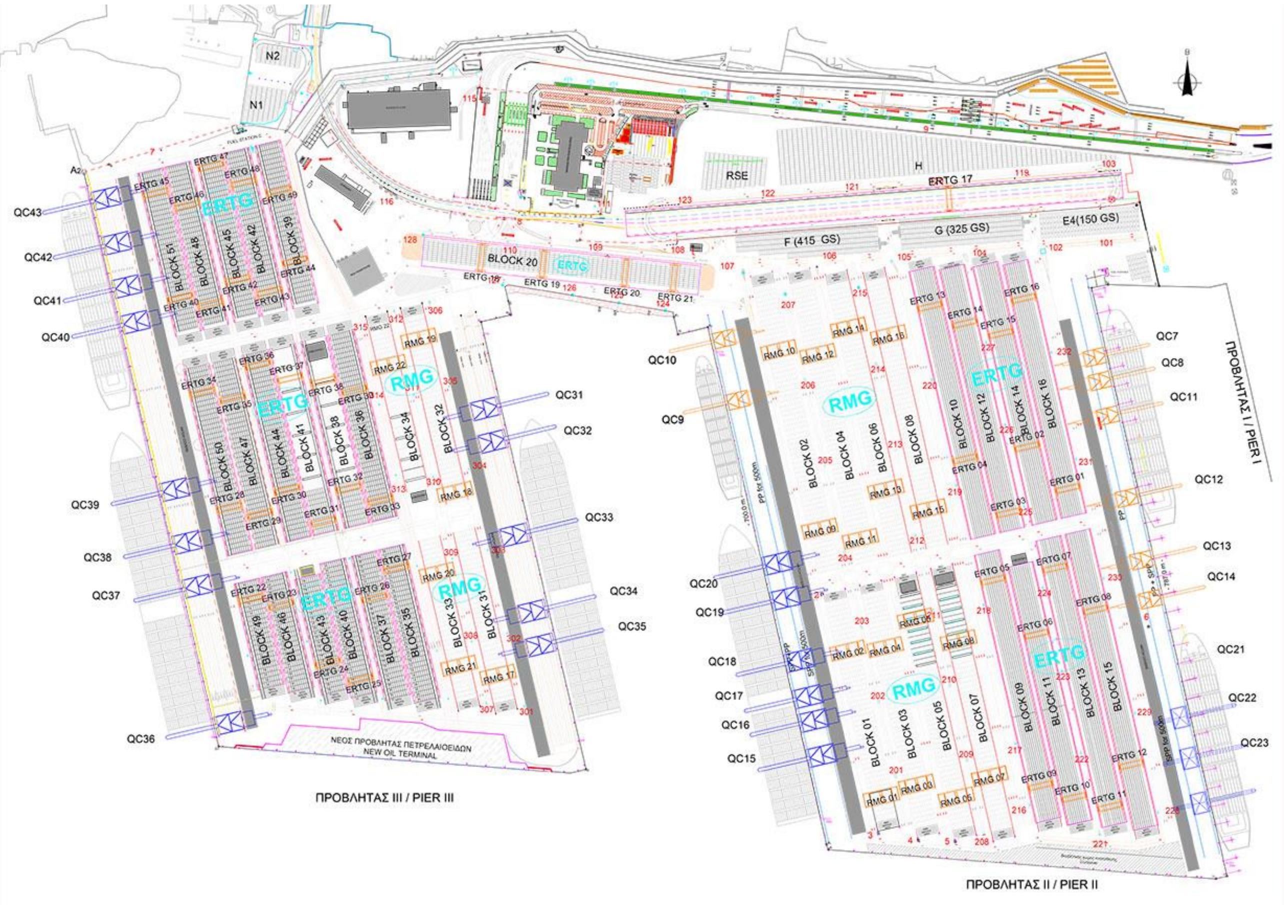

Figure 91**: Top view of PCT's Piers II & III**

Source: PCT[16]

Furthermore, it should be noted that, Piraeus also possesses a 7,500 sqm multiple operating facility that is capable of handling, sorting, and loading containers to trains and trucks, providing connections to other modes of transport, and intermodal services (see Figure 92).

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[16] https://www.pct.com.gr/specifications-layout

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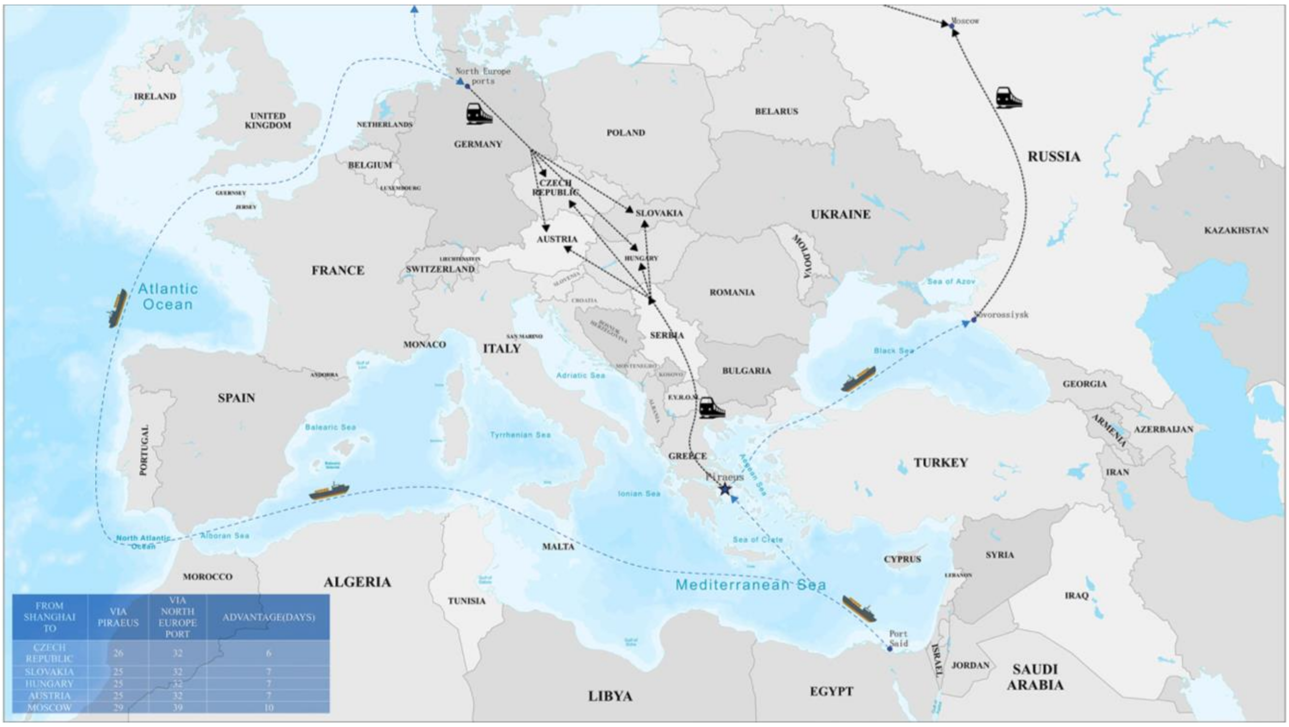

FROM SHANGHAI TO	VIA PIRAEUS	VIA NORTH EUROPE PORT	ADVANTAGE(DAYS)
CZECH REPUBLIC	26	32	6
SLOVAKIA	25	32	7
HUNGARY	25	32	7
AUSTRIA	25	32	7
MOSCOW	29	39	10

Figure 92: Port of Piraeus intermodal services

Source: PCT

3.4.3 Potential SEAMLESS Transportation Scenarios

3.4.3.1 Outline

The Black Sea leg of TUC4 proposed a waterborne route that will shift cargo from road and rail to the sea. The proposed route is presented in Figure 93. As also mentioned above, the cargo that gets transported from Piraeus to Constantza, does so through a multimodal combination where the containerised cargo gets transhipped from containerships to trains in Piraeus port. It then reaches Thessaloniki through rail (orange line), where once again it gets transhipped to trucks (purple line) that essentially cover the last part of the route through the road network[17]. The route enclosed within the green frame (emission-free feeder loop service) highlights the proposed SEAMLESS loop. The proposed loop is also applicable to other ports of the Black Sea like Constanza, Varna, Batumi, etc.

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[17] The current transport route was verbally confirmed by PCT. Due to confidentiality issues, however, the associated documentation could not be provided.

Figure 93: Envisioned SEAMLESS Transport Scenario

Source: NTUA/PCT

3.4.3.2 Stakeholders

This subsection will present the most important stakeholders that are required for the realisation of this leg of TUC4. The identification of the stakeholders was attained through literature review, and meetings with PCT, and Inland Shipping, the former being a port operator, and the latter being an inland vessel operator.

Operational Stakeholders

Ship owners and ship operators include Inland Shipping (SEAMLESS Partner), Trading Line Romania, Damen SA, DANAOS, COSCO, ARKAS Maritime, NAVROM PORT SERVICE SA, CNFR NAVROM GALATI, and ROMNAV SA.

Port and terminal operators include PCT (SEAMLESS Partner), DP World Constantza, Socep, APM Terminals Romania, Schenker Logistics Romania, UMEX, Sea Container Services, Alfa Terminal Constantza.

Administrative and Strategic Stakeholders

Administrative and strategic stakeholders include Piraeus Port Authority, and National Company Maritime Ports Administration JS Co. Constanța (Romania).

Technology Developers

Technology developers interested in this leg of TUC4 include ZULU Associates (SEAMLESS partner), DANSER, Kongsberg Maritime (related to SSS; SEAMLESS partner), MacGregor, Trelleborg, National Technical University of Athens, CORE, and CAVOTEC

3.4.3.3 SEAMLESS Waterborne Transport Concept

3.4.3.3.1 Potential Vessel Fleet Concepts

The Black Sea Leg of the East Med-Black Sea TUC requires the utilisation of SSS vessels. The route entails the transport of containerised cargo from port of Piraeus via the Aegean Sea, through the Çanakkale and Bosporus straits, all the way to Constantza. Research has shown that small feeder vessels (e.g., approx. 1,000 TEUs), are more often involved in accidents during rough seas/bad weather conditions in the Aegean Sea, compared to their larger counterparts (e.g., containerships with a capacity of 4,000+TEUs) (Ventikos et al., 2021). This can be heavily attributed to the fact that feeder vessels do not have adequate characteristics (i.e., length, beam, draught, and installed horsepower) to withstand the weather conditions that manifest in the Aegean Sea. Notwithstanding the above, the concept of SEAMLESS discusses about the disruptive idea of shifting from the economy of scale rationale to a business model that in its core will be comprised of a fleet of small (e.g., L=80m), agile, resilient, and safe vessels capable for SSS and IWT navigation. Taking into consideration all the above, especially the aspect of navigational safety during rough weather (which is a commonality in the Aegean Sea), the suggested size of the containership that could efficiently and safely cover the route from Piraeus all the way to the estuaries of Danube in the Black Sea, is that of the Panamax. A typical Panamax containership has a length of around 280m, a beam of 32m, and a capacity of approx. 5,000 TEUs. Examples of state-of-the-art Panamax vessels include the sister vessels COSCO SHIPPING RHINE, and COSCO SHIPPING DANUBE (L=283m, B=48.2m, T=13m, 9,000TEUs). An illustration of them is presented in Figure 94.

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Figure 94**: Illustration of concept hull for COSCO SHIPPING RHINE & DANUBE**

Source: COSCO SHIPPING Lines (2023)

3.4.3.3.2 Potential Ports and Infrastructure Concept

To sustain and support this use case, both port of Piraeus and port of Constantza will need to be equipped with state-of-the-art equipment and operate according to regulations that will allow autonomous ships to dock at them. This will require the following:

- Containerised cargo handling solution capable of interfacing with ports' TOS and autonomous vessels. It would be advantageous if the solution was also operating autonomously, so that it could be part of the port's integrated offering towards autonomous vessels calling.
- Highly automated mooring solution that could interface with legacy infrastructure (e.g., bollards), thus rendering the need for investing in additional port-side equipment, redundant.
- Port call software solution that will be capable of making the required negotiations between the autonomous vessels and the port.
- In case the vessels of the Black Sea Leg utilise alternative fuels (e.g., hydrogen, ammonia) or are fully electrified, then the ports will need to provide the necessary infrastructure for the respective bunkering operations.
- By far the biggest challenge for an autonomous vessel in this Leg of TUC4, will be the passage through the Çanakkale and Bosporus straits. Not only from a technical point (e.g., having the right equipment and sensors), but from an administrative and regulatory as well. This issue however (i.e., autonomous navigation through straits), is outside the scope of this subsection and SEAMLESS in general.

3.4.4 Requirements and Technology Gaps

The main modules of the SEAMLESS building block that are applicable here are the following:

DockNLoad

All the modules of DockNLoad are applicable in this leg of TUC4. The autonomous cargo handling for containers by MCG will seamlessly cooperate with VCOP will be capable of interacting with autonomous vessels to conduct (un)loading operations without the need for human intervention. The highly automated mooring solution by MCG will utilise legacy infrastructure, like bollards, for use with

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autonomous vessels, reducing investment costs the ports while simultaneously developing a resilient service that does not get hindered by the port mooring system. In addition, AWAKE.AI's port call manager for autonomous vessels will be capable of handling all the required negotiations between the vessel and the port, ensuring the minimisation of docking delays.

Modular Vessel & Operations Concepts

The technological module that is applicable in this Leg is KMNO's Remote Operation Centre concept that will be capable of offering "low attention" operation of a "fleet" of vessels, i.e., a single operator will be able to monitor and (if necessary) control more than one vessel at the same time.

ModalNET

ModalNET and its integrated offering that will allow for the development of a collaborative framework of information, the digital administration capabilities, and the voyage planning and control, while providing operational support and resilience, is also applicable here.

It is noted that all SEAMLESS building blocks are generally applicable.

Logistics Chain Redesign

The integration of an autonomous service will incur significant changes in the logistics processes of the chain, since currently containerised cargo from Piraeus to Constantza requires the use of trains and trucks, while the Black Sea Leg of this TUC, requires the utilisation of autonomous vessels for use in short sea shipping.

Gaps

Gaps that are outside of the scope of SEAMLESS include the autonomous vessel passage through straits, the transhipment of containerised cargo in estuaries with no STS cargo handling infrastructure, and a series of administrative/regulatory issues related to navigation of autonomous vessels in international waters (e.g., liability sharing in case of an accident).

3.5 TRANSFERABILITY USE CASE "DANUBE"

3.5.1 Existing Logistics Environment

Transferability Use Case "Danube" covers the TEN-T corridor Rhine – Danube, i. e., its section from the Duisburg Port to Galati Port, and as such takes operations on the river Danube into special consideration. As such, it sheds light on an EU-extra corridor which relates to the inclusion of operations within Serbia.

The team of the TUC – consisting of the Faculty of Transport and Traffic Engineering of the University of Belgrade, DST – Development Centre for Ship Technology and Transport Systems, and Trading

Line Group – has investigated ways to define this TUC so as to include all listed geographical characteristics. Transportation of cargo between the Port of Novi Sad (Serbia) and the Port of Constantza (Romania) meets all the requirements. However, there is no liner container service from the Middle Danube (which Port of Novi Sad belong to) and Black Sea (where Port of Constantza is located). For this purpose, an extensive desk research has been conducted on various topics and consolidated the findings in a digital collaboration board. In the following, the results have been discussed in a dedicated workshop and the displayed content enhanced, changed, and corrected, respectively.

As the Task 2.1 of the SEAMLESS project requires mapping of the landscape of the current logistic chain, the transport concept of TUC "Danube" is based on existing services between these two ports. In the vast majority of cases, these services include transportation of bulk cargoes, because 70 to 80 % of transhipped cargo in the Port of Novi Sad is bulk cargo. Therefore, the existing processes, involved stakeholders, information flows, vessel operational characteristics, involved IT systems related to bulk cargo transportation on the route Port of Novi Sad – Port of Constantza are described (see Figure 95).

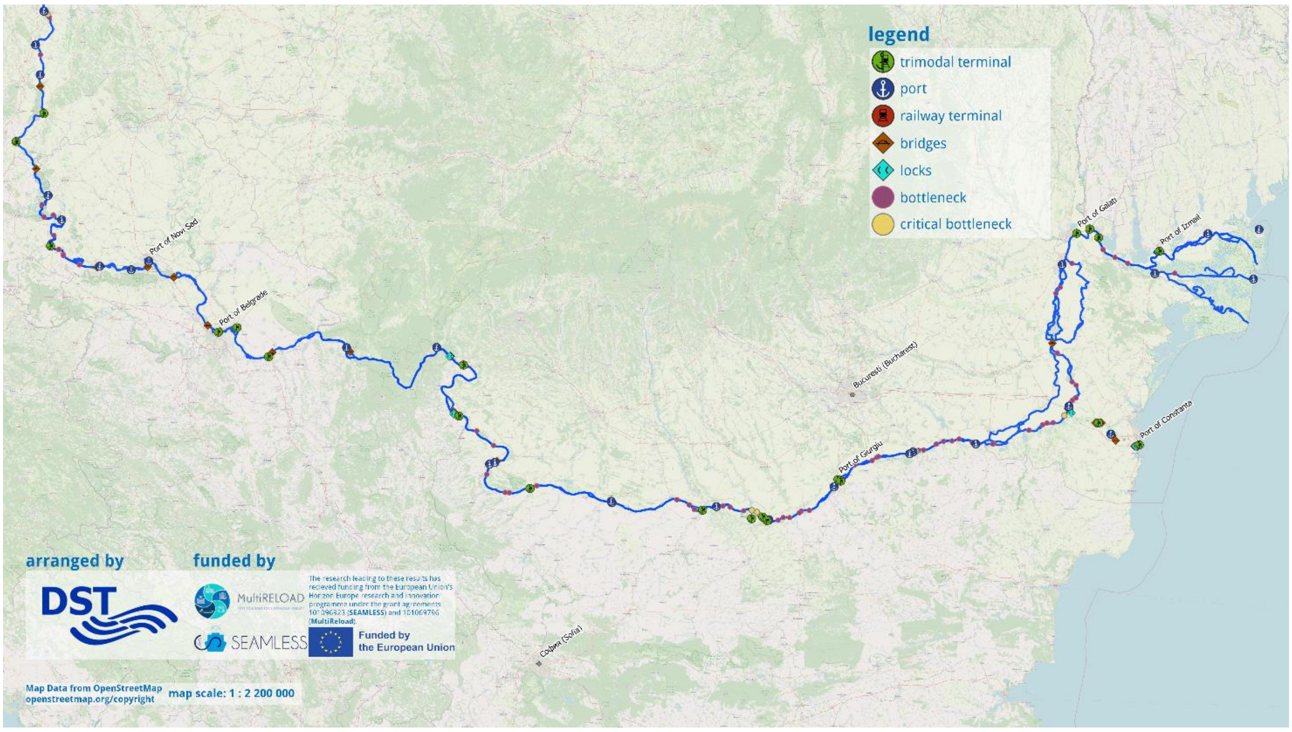

Figure 95: Envisioned inland waterway route of TUC5 between Port of Novi Sad to Port of Constantza

Source: DST

3.5.2 Existing Transportation Concepts

3.5.2.1 Outline

The transferability use case is based on the use of motor cargo vessels for bulk cargo transportation on the route between Port of Novi Sad (rkm 1255, Serbia) and Port of Constantza (Romania). In this way, both legs, i. e., Danube and Black Sea leg of the Transferability Use Case "Black Sea" are covered. The TUC "Danube" analysis includes all possible aspects of cargo transportation on a given route. Therefore, a detailed look has been taken into the following activities:

- unloading and loading of cargo in the port of Novi Sad,
- lock-through processes,
- sailing through the Danube – Black Sea canal,
- unloading and loading in the Port of Constantza.

As required in the Task 2.1 of the SEAMLESS project, for each of these activities, the technological process, stakeholders involved, cargo types and flows, information flows, involved IT systems, vessel operational characteristics, the available interconnections between waterborne transport and the hinterland, and the regional degree of exploitation of inland waterways (if available) are mapped and described.

3.5.2.2 Existing Waterborne Transport Concepts

3.5.2.2.1 Analysis of Waterway and Vessel Fleet

There are principally two different means of transportation on inland waterways: self-propelled ships and barges pushed by a self-propelled unit. Basically, inland cargo vessels operating on the river Danube and its navigable tributaries can be divided into three types according to the combination of their propulsion systems and cargo holds:

- Motor cargo vessels are self-propelled vessels which have an own motor drive and a cargo hold. Depending on the cargo type transported, motor cargo vessels are subdivided into dry cargo vessels, motor tankers, container vessels, and RoRo vessels.
- A pushed convoy usually consists of a motorized push boat and one or several non-motorized push barges (a non-motorised vessel built to be towed) or push lighters (a non-motorised vessel built to be pushed). They are permanently attached to the pusher convoy so that at least one unit is in front of the push boat.
- Coupled convoys involve a motorized cargo vessel which is used to push a convoy (instead of a push boat). Typically, a coupled convoy consists of a motor cargo vessel with one to two lighters or barges coupled alongside.
- Likewise, pushed coupled convoys involve a motorized cargo vessel and one to two lighters or barges coupled to the side of the motor cargo vessel and additional lighters or barges located forward of the motor cargo vessel.

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- Towed convoys consist of a tug (or tug boat) which is used to tow non-motorized vessel units, so-called barges (i. e., vessels for carriage of goods with a helm for steering). Due to their inferior cost effectiveness in comparison with pushed convoys, towed convoys are rarely used on the Danube anymore.

Waterborne freight traffic on the Middle and Lower Danube is dominated by the various types of (pushed, coupled and pushed-coupled) convoys, so that the overwhelming share of all transports is carried out by convoys with only a small share being transported by individual motorized cargo vessels. On the Upper Danube, on the other hand, the ratio between self-propelled vessels and ship convoys is more balanced. For the sake of comparison, it should be noted here that self-propelled vessels dominate on the Rhine (viadonau, 2019, 2021, 2023).

Radojčić et al state that approximately 80 % of cargo is transported by pushed convoys and merely 20% by self-propelled vessels, referring to statistical data for IWT on the Danube. With respect to fleet structure, 75 % are vessels for dry cargo, 6 % inland tank vessels, and 19% are push boats and tugs. The average age of inland vessels on the Danube amounts to 74 years as the majority of these vessels were built between 1960 and 1990. The share of self-propelled vessels, however, is slowly increasing due to decommissioning of even older barges and push boats and the steady acquisition of pre-owned self-propelled vessels from the Rhine Corridor (Radojčić et al., 2021).

In Europe, waterways are divided into the so-called CEMT classes according to which the maximum size of a vessel that is suited for a certain waterway is defined. Figure 96 shows the waterway classes on the Danube and maximum possible vessel sizes on the different stretches between Bavaria and the Black Sea.

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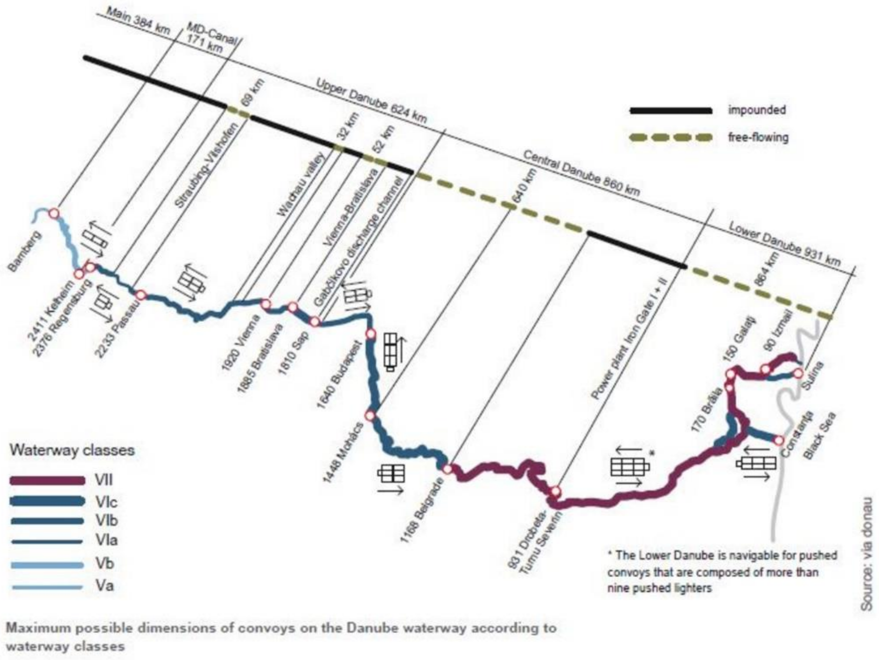

* The Lower Danube is navigable for pushed convoys that are composed of more than nine pushed lighters

Source: via donau

Maximum possible dimensions of convoys on the Danube waterway according to waterway classes

Figure 96: Waterway classes on the Danube and maximum possible vessel sizes

Source: viadonau (2019)

On the Danube river, i. e., from Bavaria via Austria and Hungary to Belgrade, Serbia, the waterway is categorized as class VI a, VI b, and VI c, respectively. Waterways of the class VI a can be navigated by pushed convoys with two barges coupled side by side whereas those of class VI b can even be used by pushed convoys with four barges, i. e., two side by side and two coupled in front. On waterways of class VI c, the pushed convoy may consist of six barges, i. e., three side by side in two rows or two side by side coupled in three rows. Thus, a pushed convoy may have a length of 110 m (class VI a), 195 m (class VI b or class VI c), or even 280 m (class VI c), a beam of 22.80 m (class VI a/b/c) or 34.20 m (class VI c), and a draft between 2.50 m and 4.50 m (class VI a/b/c).

From Belgrade to the Black Sea, the Danube is categorized as a class VII waterway, enabling operation of pushed convoys with nine barges, i. e., three barges coupled side by side in three rows. The dimensions of the convoys operating on this stretch include 285 m length, 34.20 m beam, and a draft between 2.50 m and 4.50 m. This holds true for a part of the Danube Delta via Galati, Romania, to Izmail, Ukraine, whereas another tributary in the Delta to Sulina, Romania, is categorized as class VI b and the Danube-Black Sea Canal to Constantza, Romania, as class VI c.

Apart from the fairway and lock restrictions of the Main river and the Rhine-Main-Danube Canal, the seaports of Rotterdam, the Netherlands, and Antwerp, Belgium, could link to the Romanian ports of Galati and Constantza and the Ukrainian port of Izmail, all at the Black Sea, via waterway connection of class VI a at least. From the perspective of the waterway classification, the prevalence of large pushed convoys is evident and understandable. In the following, the main vessel types on the Danube are presented regarding their sizes.

To add to the complexity, the formation of pushed convoys may differ depending on travelling direction. A convoy of six barges may be arranged in two rows with three barges coupled next to each other in upstream travel and in three rows with two barges coupled side by side in downstream journey (see Figure 97). Moreover, an overview of potential formations of is (pushed, coupled and pushed-coupled) convoys given in Figure 98. The multitude of formations in both upstream and downstream travel results from the decisions whether a motor cargo vessel or a push boat is used as propelling unit and which formations of lighters next to or in front of the propelling unit is to be adopted.

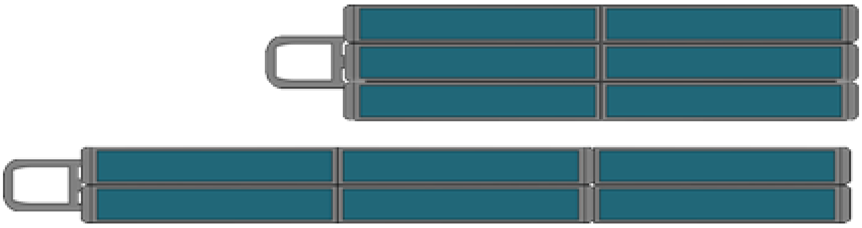

Figure 97: Convoy with six barges in upstream (above) and downstream (below) formation

Source: DST

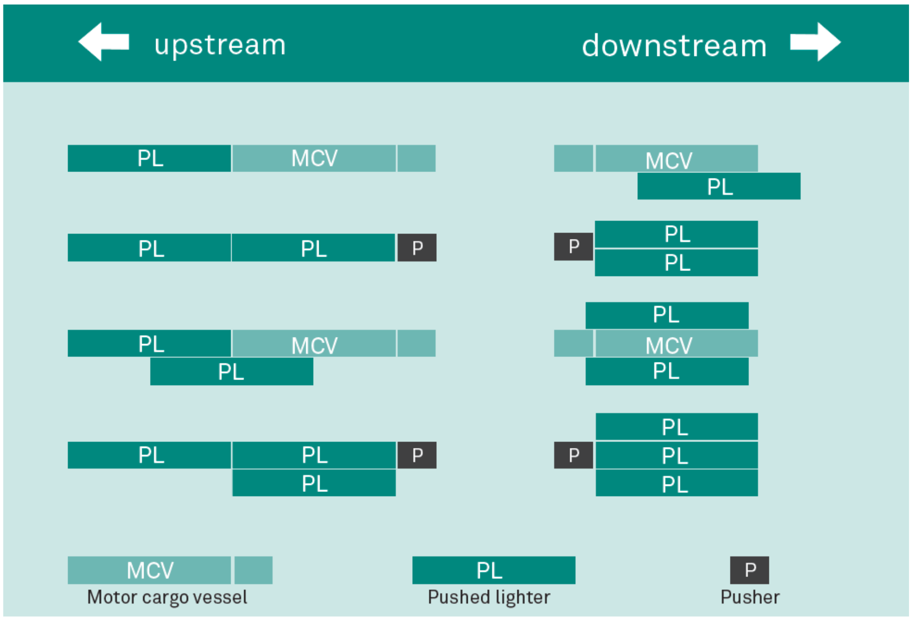

Figure 98: Vessel formations on the Danube

Source: viadonau (2019)

The findings in this section presented are based on the data given in the "Annual statistics of the Danube Commission" reports which cover the period of 60 years, from 1962 to 2021. Despite the vast amount of data available, the reports do not present the same type of information for each year and do not comprise the data for all the Danube riparian countries for all years. Moreover, individual reports exhibit inconsistencies in the underlying data. Considering the consistency issues and taking into account that the goal of the analysis is to establish the main trends in the Danube cargo fleet development, the data for the last four years (2018–2021) and, in some cases, the first five years (1962–1966) were omitted (Danube Commission, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023).

The Danube region was impacted by the series of massive political and economic shifts which affected both the fleet and the consistency of the reporting. The unification of Germany, the dissolution of the Soviet Union, the split of Czechoslovakia, the collapse of the Socialist Federative Republic of Yugoslavia, the subsequent Yugoslav wars (and economic sanctions imposed on Yugoslavia), and the NATO bombing of Yugoslavia all took place within a single decade, from 1989 to 1999. From the available data, it becomes apparent that these events had a considerable negative effect on the fleet. The quality of reporting was affected as well; it became less frequent and less regular, while the inconsistency of data increased.

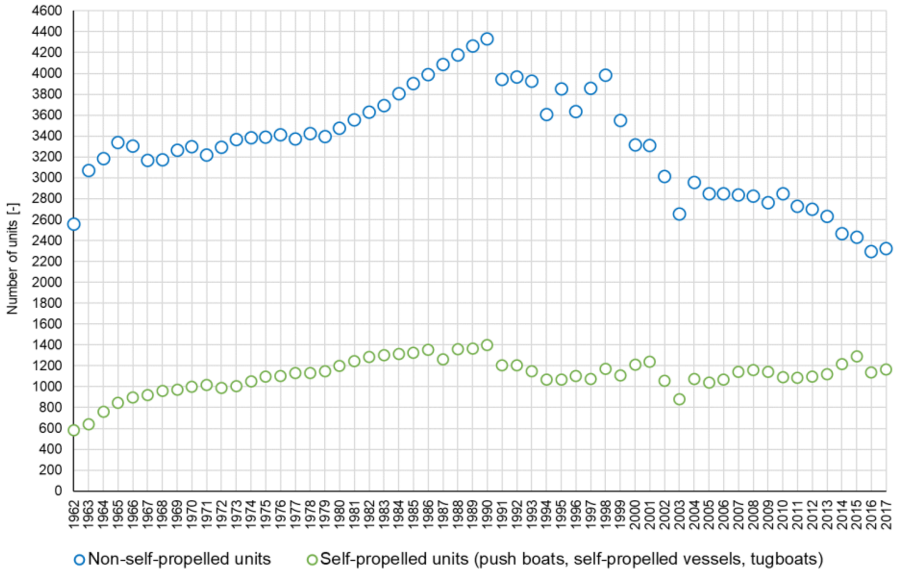

Figure 99: Evolution of the Danube fleet

Source: Own illustration based on “Annual statistics of the Danube Commission” reports

Thus, two distinct periods in evolution of the overall Danube fleet may be observed (see Figure 98). The first period (1962–1990) is characterized by the steady growth of the fleet, see also Figure 99. The consistency of the data given in the Danube Commission reports for this period allows for straightforward conclusions. The number of self-propelled units (push boats, tugboats, and self-propelled vessels) increased from a little less than 600 in 1962 to almost 1,400 in 1990. The number of non-self-propelled units increased from some 2,500 in 1962 to over 4,300 in 1990. The total cargo-carrying capacity of self-propelled vessels increased more than 12 times, while the total cargo-carrying capacity of non-self-propelled units increased from 1.7 million t to 4.6 million tons. In the second period (1991–2017) the Danube fleet declined both in terms of number of units and in terms of cargo-carrying capacity. For example, at least one quarter of the Yugoslav fleet of self-propelled units disappeared between 1990 and 2000. Nevertheless, the overall decline did not affect all the fleet segments, as may be seen in Figure 99.

Table 16: Some features of the Danube fleet in the most prominent years of the analysed period[18]

		1962	**1990**	**2017**
Number of self-propelled units[19]*	[–]	586	1,399	1,163
Number of self-propelled vessels	[–]	82	421	521
Number of non-self-propelled units	[–]	2,556	4,333	2,323
Cargo capacity of self-propelled vessels	[t]	39,827	499,973	608,766
Cargo capacity of non-self-propelled units	[t]	1,767,692	4,653,609	2,733,886

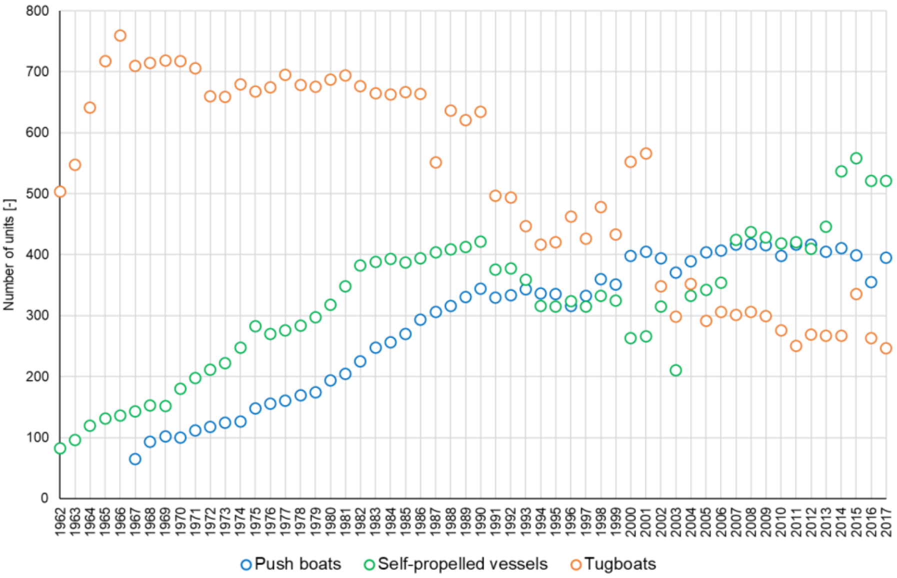

Figure 100: Number of push boats, self-propelled vessels, and tugboats on the Danube

Source: Own illustration based on "Annual statistics of the Danube Commission" reports

In the evolution of the fleet of self-propelled vessels (self-propelled dry cargo ships and tankers), several periods may be distinguished which can be seen in Figure 101. The first period (1962–1990) is characterized by a steady increase of the number of units, as shown in Table 16. In this period,

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[18] The first Annual statistics report of the Danube commission was published in 1962. The fleet reached its maximum in 1990. The 2017 report is the most recent report containing reliable figures.

[19] Self-propelled units: push boats, tugboats, and self-propelled vessels

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not only did the number of self-propelled vessels increase fivefold, but the average cargo capacity increased as well, reaching 1,200 t in 1990, as compared to less than 500 t in 1962. The vessels were both more numerous and larger. In period 1991–2002 the fleet of the self-propelled vessels declined; by 2001, the number of units fell well below 300. As of the early 2000s, this particular segment of the fleet recovered, and attained a new maximum in terms of number of units (over 400 vessels) in 2008. This was followed by a four-year period of stagnation and decline. As of 2013, the fleet of self-propelled vessels was on the rebound again. At the end of the examined period, the Danube fleet of the self-propelled vessels was at its peak as far as the number of units and the total cargo-carrying capacity are concerned. The data recorded in the years after 1990 exhibit large year-to-year variations. This is partly due to the changes in the number of participating countries, and partly due to the deteriorating quality of reporting.

Similar to self-propelled vessels, the push boat fleet on the Danube recorded a steady growth in period 1967–1990, reaching nearly 350 units of the total power over 375,000 kW, see Figure 102. The fleet saw a decline and stagnation during the last decade of the 20th century. The fleet recovered in the beginning of the 2000s. Since then, the fleet stagnates: the number of vessels remained at the level of 400 units. As of 1978, the average power of the Danube push boats has little changed, remaining around 1,200 kW.

Figure 101: Evolution of the self-propelled vessels fleet on the Danube

Source: Own illustration based on “Annual statistics of the Danube Commission” reports

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Figure 102: Evolution of the push boat fleet on the Danube

Source: Own illustration based on “Annual statistics of the Danube Commission” reports

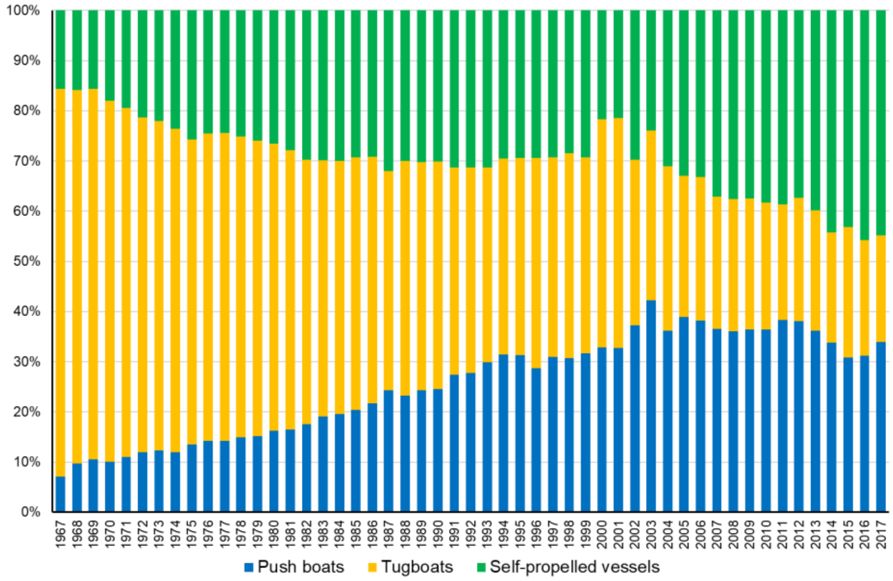

Figure 103: Composition of the Danube fleet[;20]

Source: Own illustration based on “Annual statistics of the Danube Commission” reports

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[20] until 1967, push boats were merged with tugboats and were not reported as a separate category

It is often stated that inland waterway transport on the Danube is dominated by pushed convoys. Nevertheless, this does not mean that the fleet itself is dominated by push boats. The evolution of the composition of the Danube fleet over the examined period is reported in Figure 103. As expected, the share of the tugboats has significantly decreased, from nearly 80 % in 1967 to around 20 % in 2017. The share of push boats in the fleet peaked in the early 2000s, but since then stagnated at around 35 %. The self-propelled vessels formed 30 % of the fleet over a very long period, from the 1980s until the early 2000s. Since then, the self-propelled vessels are the only segment of the fleet which kept on increasing its share, reaching around 45 % in 2017. Thus, it seems that the Danube fleet is changing; the traditional concepts which imply large convoys pushed by powerful push boats appear to be giving way to self-propelled vessels, which are also capable of forming convoys but of a smaller size.

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3.5.2.2.2 Analysis of Ports and Infrastructure

Port of Novi Sad[21]

According to the Indicative extension of TEN-T Comprehensive and Core network in the Western Balkans, Port of Novi Sad belongs to the Core network of inland waterway ports. Basic facts about the port are given in the Table 17. More information about the Port is presented in the Annex 6.3.7.

Table 17: Port of Novi Sad - basic characteristics and indicators

Characteristics	Indicator	Novi Sad
Port operator(s)		DP World AD Novi Sad (www.lukanovisad.rs) NIS (www.nis.eu)
River		Danube
Location	River km	1,254[22]
Bank	Left / right	Left
Type of port		Canal type
Total port surface	ha	24.19
Water area	ha	6
Depth	m	4-10
Total quay length	m	800[23]
Vertical quay	m	170
Berthing places (simultaneous)		5
Connection to national railway network	yes/no	Yes
Railway tracks length	m	6000
Open storage area	m^2	100,000
Closed storage area	m^2	44,000
Container storage area	m^2	/
Anchorage capacity	No. of vessels	/
Oil products storehouse capacity	m^3	270,000

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[21] This subchapter represents an update of the description of the Port of Novi Sad provided in the Konrad Adenauer Stiftung (2022). Blue Connectivity: Maritime and Inland Waterways in the Balkans Peninsula, Chapter: Serbia (author: Maraš, V.), Tirana, Albania.

[22] at the entrance of the Danube-Tisza-Danube Canal (DTD Canal)

[23] of multipurpose trimodal terminal.

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maximum designed cargo handling capacity	tonnes/ year	2,000,000
Container storage capacity	TEU/ annually	/
Bunkering		Available at the Oil terminal
Waste collection		Not available
Shore-side power supply for vessels		Available at certain berths
Supply of alternative clean fuels		Not available
Open to public	yes/no	yes

Source: Transport Community (2021) Gazette Republic of Serbia (2014) Konrad Adenauer Stiftung (2022)

Annual volumes of cargo handled in the Port of Novi Sad is given in the Table 18. The main cargoes handled are grains, fertilizer components, scrap iron, ferrous metal products, etc.

At the end of 2018, the Government of Serbia initiated the process of privatization of the Port of Novi Sad. The procedure was completed in May 2019, and the consortium P&O Ports FZE managed by DP World from the United Arab Emirates became the owners of the Port of Novi Sad. P&O Ports FZE is a specialist company which manages small, multi-purpose ports including container terminals, bulk cargo and general cargo (DP World, 2023a).

Table 18: Total throughput in the Novi Sad port area

Port area – Novi Sad						
	2017	**2018**	**2019**	**2020**	**2021**	**2022**
Bulk	718,885.91	680,972.17	1,038,876.41	1,223,680.08	1,004,534.58	484,597.75
General cargo	26,487.59	12,845.00	1,288.00	34,834.47	25,772.00	11,419.00
Liquid	317,315.22	354,857.00	373,065.00	373,410.75	405,573.00	483,117.00
Total	1,062,688.72	1,048,674.17	1,413,229.41	1,631,925.30	1,435,879.58	979,133.75

Source: Data obtained from the Port Governance Agency – Republic of Serbia

Locks

On the route from Port of Novi Sad to Port of Constantza, there are four locks. Two on the Danube (Iron gate I and II) and one at the entrance to and another to the exit from the Danube - Black Sea canal. The locks on the canal are described in following chapter, so the characteristics of locks Iron gate I and II locks are given in Table 19. More information about the locks is presented in Annex 6.3.8.

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Table 19: Iron Gate I and II - basic characteristics and indicators

Characteristics	Indicator	Iron Gate I		Iron Gate II	
Bank		Left	Right	Left	Right
Location	River km	942+950[24]	942+950	863+700	863+000
Dimensions of lock chambers					
Length	m	310	310	310	310
Width	m	34	34	34	34
Min sill depth	m	4.5	5.0	5.0	4.5
Maximum allowed dimensions of barge convoy					
Length	m	300	300	300	300
Width	m	33	33	33	33
Average duration of lock-through process	h/ship or convoy	1,5	1,5	1,5	1,5

Danube – Black Sea canal

The Danube-Black Sea Canal is an artificial waterway in Romania and represents a navigable link between the Danube and the Black Sea. Overview of technical characteristics of the Danube – Black Sea canal are given in the Table 20. Annex 6.3.9 contains more information about the Canal and locks located at the entrance and exit of the Canal.

Table 20: Technical characteristics of the Danube – Black Sea canal

Length	64,4 km
Width	70-90 m
Depth	7 m
Max draft	5,5 m
Bridge vertical clearance	16,5 m
Min curve radius	3000 m

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[24] Distance from Sulina in rkm.

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There are two locks on the Danube – Black Sea canal – Cernavoda

Figure 104) and Agigea (Figure 105 and Figure 106). Their characteristics are given in Table 21.

Table 21: Characteristics of locks at the Danube – Black Sea canal

Lock	Cernavoda	Agigea
Position (km of the canal)	km 60+300	km 1+900
Length	300 m	310 m
Useful width	25 m	25 m
Max depth	7.5 m	7.5 m
Length of access channel for waiting	1,020 m	620 m
Width of access channel for waiting	150 m	150 m

Figure 104: Cernavoda Lock

Source: National company of navigable canals S.H. (www.acn.ro)

Figure 105. Agigea lock

Figure 106. Exits from the Agigea lock

Port of Constantza

The Port of Constantza is located in Constantza, Romania, on the Western coast of the Black Sea, at 179 nautical miles from the Bosporus Strait. Basic information about the port is given in Table 22 (Compania Nationala Administratia Porturilor Maritime SA, 2022; DAPhNE, 2017; DIONYSUS, 2021). Annex 6.3.10 contains more detailed information about the Port of Constantza.

Table 22: Port of Constantza - basic characteristics and indicators

Characteristics	Indicator	Constantza
Port land owner		State, Ministry of Transport and Infrastructure
Port authority name		National Company Maritime Ports Administration JS Co. Constantza
geographic coordinates		
Latitude		44° 7' 51" N
Longitude		28° 39' 43" E
Total port surface	ha	3,926
Land area	ha	1,313
North Port	ha	495
South Port	ha	818
Water area	ha	2,613
North Port	ha	322
South Port	ha	2,291
Max depth	m	19
Min depth	m	7
Total quay length	km	32
Number of terminals		22
Number of berths		156
North Port		82
South Port		74
Breakwater	m	13,904

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North Port	m	8,344
South Port	m	5,560
Connection to national railway network	yes/no	yes
Number of rail gates		6
Number of rail tracks		9
Railway tracks length		
along quay walls	km	19.87
within port area	km	300
Connection to national road network	yes/no	yes
Connection to European road network	yes/no	yes
Number of road entrances		10
Length of road infrastructure	km	100
Number of road lanes		25
Storage capacity	m^2	3,898,325
Storage capacity (CEU - car equivalent unit, for RoRo terminals)	CEU	6,600
Oil products storage capacity	m^3	1,700,000
maximum designed cargo handling capacity	tonnes/ year	120,000,000
Container throughput capacity	TEU/ year	1,500,000
Container storage capacity	TEU	16,000
Bunkering facility within the port area	yes/no	yes
Waste collection		Available
Shore-side power supply for vessels		Available
Facilities for dangerous cargo vessels	yes/no	yes
Open to public	yes/no	yes

The river-maritime area in the Port of Constantza has recently implemented a waiting area for barges, either self-propelled or not. The facilities have the main purpose of providing temporary mooring quays for incoming and outgoing barges and pushers without interfering in transit coming from the Danube-Black Sea channel and other cargo handling operations.

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Figure 107: Port of Constantza - map of the Barge terminal

Source: Compania Nationala Administratia Porturilor Maritime SA (2022)

Considering a mooring scheme with 1 to 2 barges perpendicular to the quay, a barge width of 11.40 m and a safety distance of some 1 to 2 m between the barges the existing terminal allow for safe mooring of some 150 to 200 barges. Characteristics of the barge terminal (Figure 107 are the following:

- water depth is 7 m,
- the total quay length is some 1,200 m
- available water area is some 350,000 m^2

The majority of cargoes handled in the Port of Constantza belong to the following types: cereals (37.3 %), crude oil (9.9 %), miscellaneous cargoes (9.1 %), oil products (8 %), iron ores and scrap (7 %), natural and chemical fertilizers (6 %), solid mineral fuels (5 %), non-ferrous ores (4,6 %), etc.

3.5.2.2.3 Analysis of Process Flows

3.5.2.2.3.1 Loading and unloading of cargo – Port of Novi Sad

Unloading of cargo

Included stakeholders are:

1. Shipowner
2. Shipper
3. Ship agent

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4. Border police
5. Custom
6. Port operator (DP World in the Port of Novi Sad)
7. Forwarder (nominated by the shipper)
8. Inspection company
9. Crew (of the ship to be unloaded or loaded in the port)
10. Crew (of the port tug)

Mapping of technological processes and information flow

Technological processes included in the unloading of cargo in this case are given in the Figure 108, while information flow is presented in the Figure 109. Details of these processes and flows are described in the Annex 6.3.1.

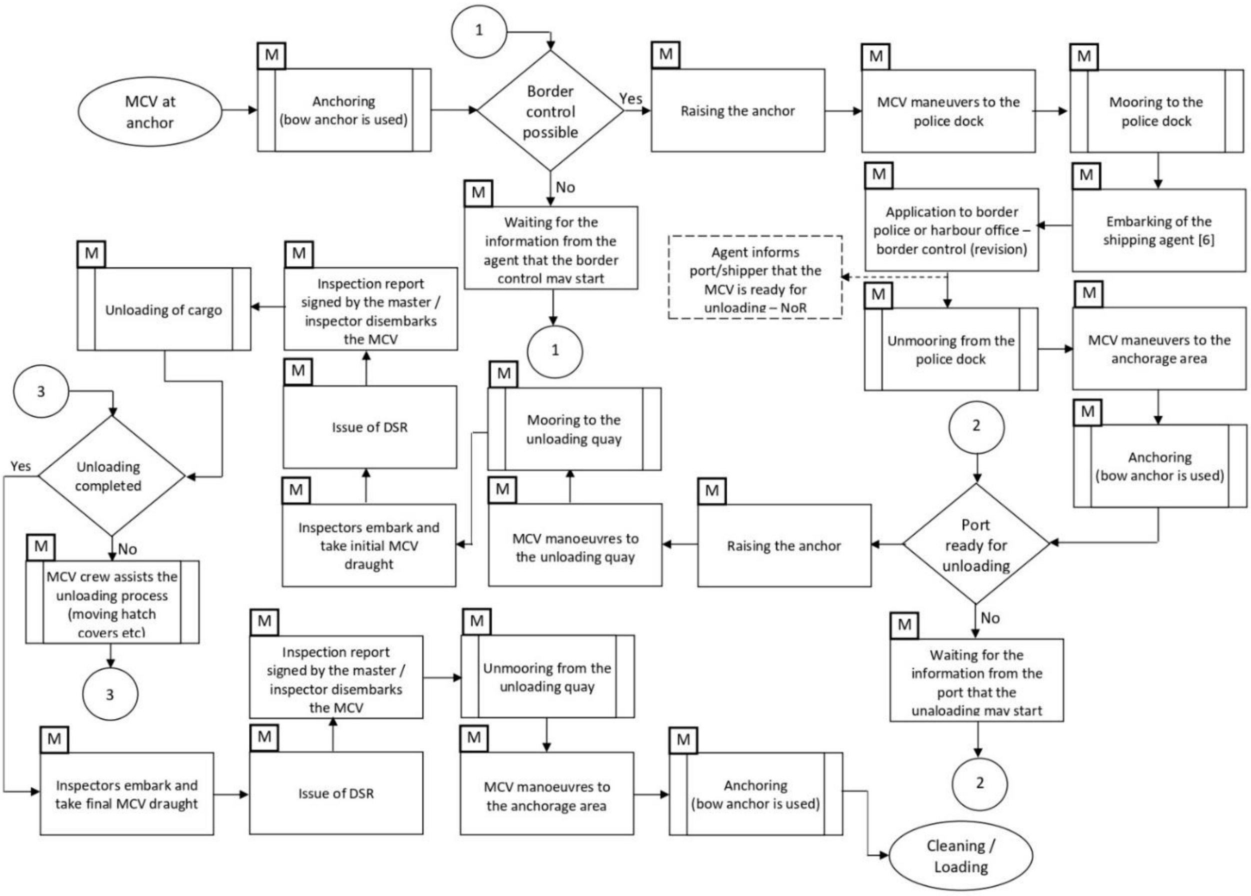

Figure 108: Unloading of cargo at the Port of Novi Sad – technological view

Source: FTTE

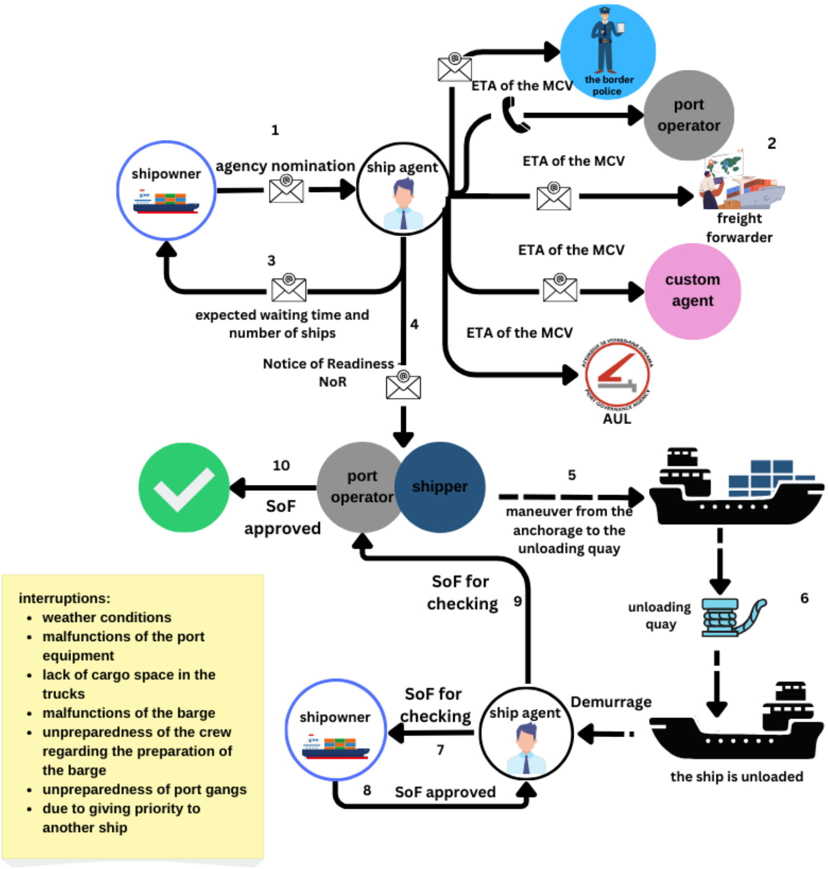

Figure 109: Unloading of cargo at the Port of Novi Sad – information flow[25]

Source: FTTE

Loading of cargo

Included stakeholders are:

1. Shipowner
2. Shipper
3. Ship agent
4. Custom
5. Port operator (DP World in the Port of Novi Sad)
6. Forwarder (nominated by the shipper)
7. Inspection company (nominated by the shipper)
8. Crew (of the ship to be loaded in the port)
9. Crew (of the port tug)
10. Pilot (for manoeuvres within the Port area)

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[25] The numbers in the Figure indicate the order in which the activities are performed.

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Mapping of technological processes and information flow

All technological process related to loading of cargo at the Port of Novi Sad are given in the Figure 110 while information and documentation flows are depicted in Figure 111. Annex 6.3.2 contains detailed descriptions of these processes and flows.

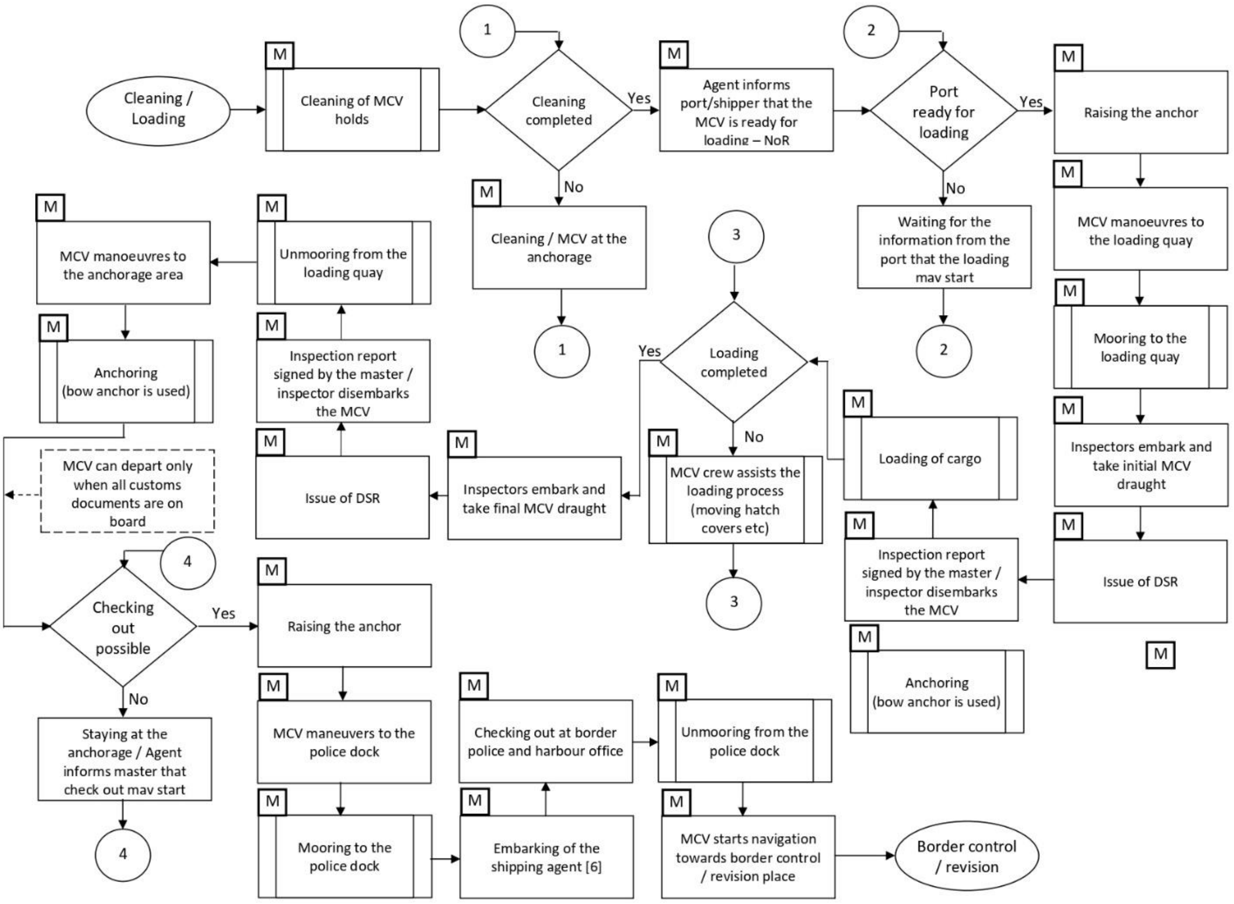

Figure 110: Loading of cargo at the port of Novi Sad – technological processes

Source: FTTE

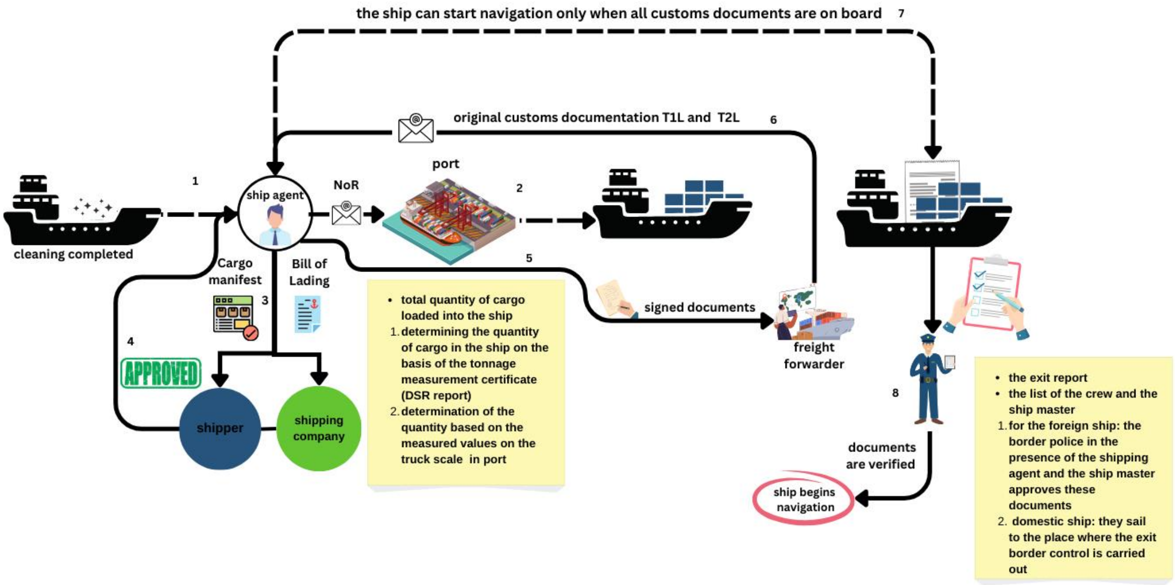

Figure 111: Loading of cargo at the Port of Novi Sad – information flow

Source: FTTE

3.5.2.2.3.2 Lock-through processes

Included stakeholders are:

1. Crew (of the MCV to be locked)
2. Lock operator

Mapping of technological processes and information flow

Lock-through processes, which are related to both locks (Iron Gate I and II) on Danube, are depicted in the Figure 112. Respective information flows are presented in the Figure 113. Annex 6.3.3 provides detailed description of both lock-through technological processes and information flows.

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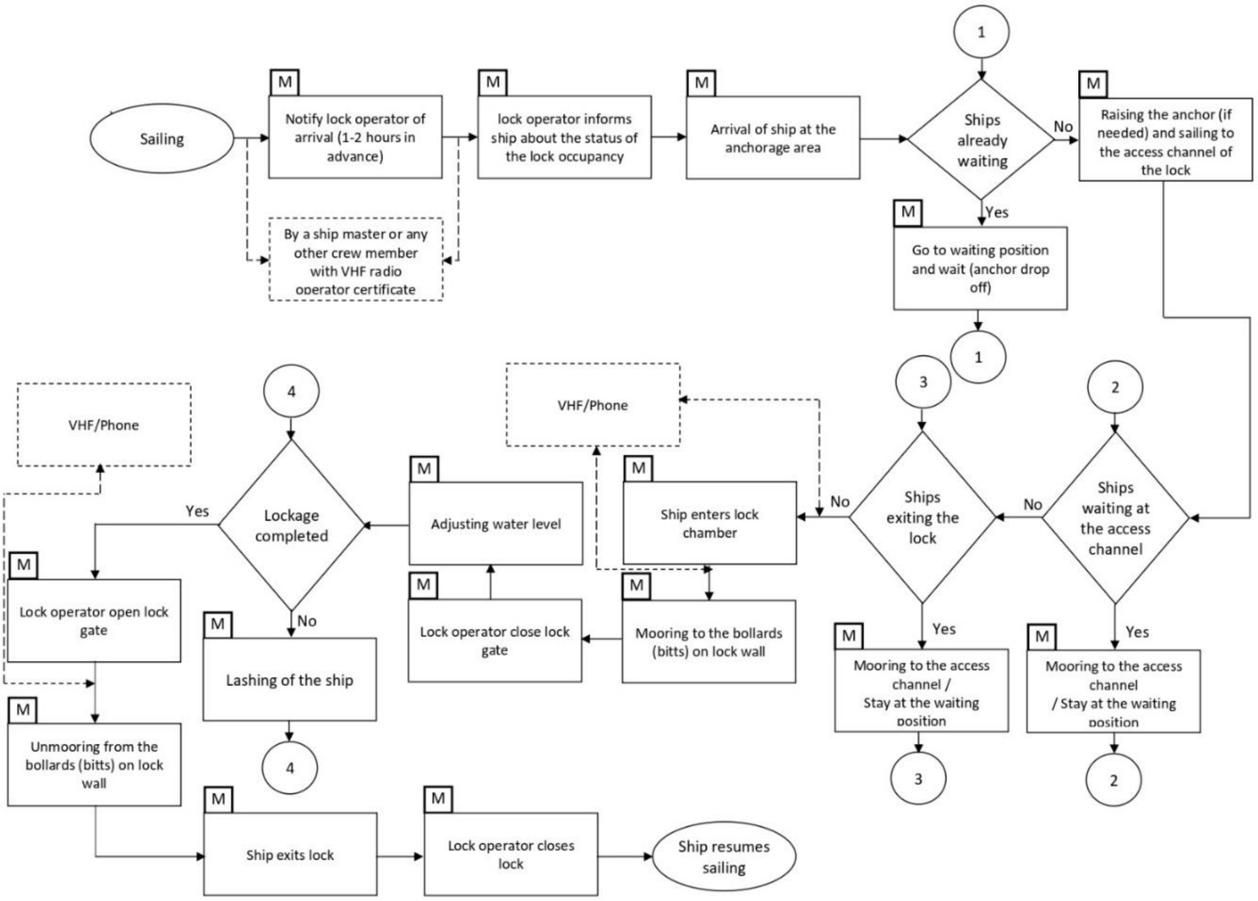

Figure 112: Lock-through process at Danube locks Iron Gate I and Iron Gate II – technological processes

Source: FTTE

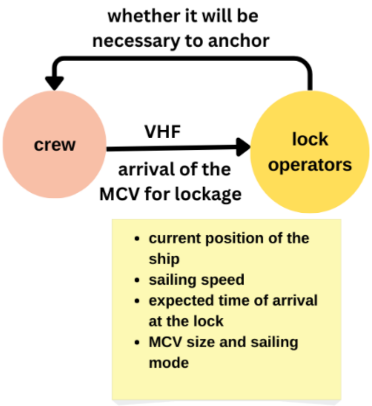

Figure 113: Lock-through process at Danube locks Iron Gate I and Iron Gate II – information flow

Source: FTTE

3.5.2.2.3.3 Passing through Danube – Black Sea canal

Included stakeholders are:

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1. Shipping company
2. Crew (of the MCV transiting the canal)
3. Shipping agent (nominated by the shipping company)
4. Canal pilot
5. Customs
6. Border police
7. Harbour office
8. Lock operator
9. Port operator (nominated by the shipper)

Mapping of technological processes and information flow

Technological process related to passing through the Danube – Black Sea canal are mapped on the Figure 114, while matching information flow is presented in the Figure 115. Annex 6.3.4 gives detailed description of these processes and flows.

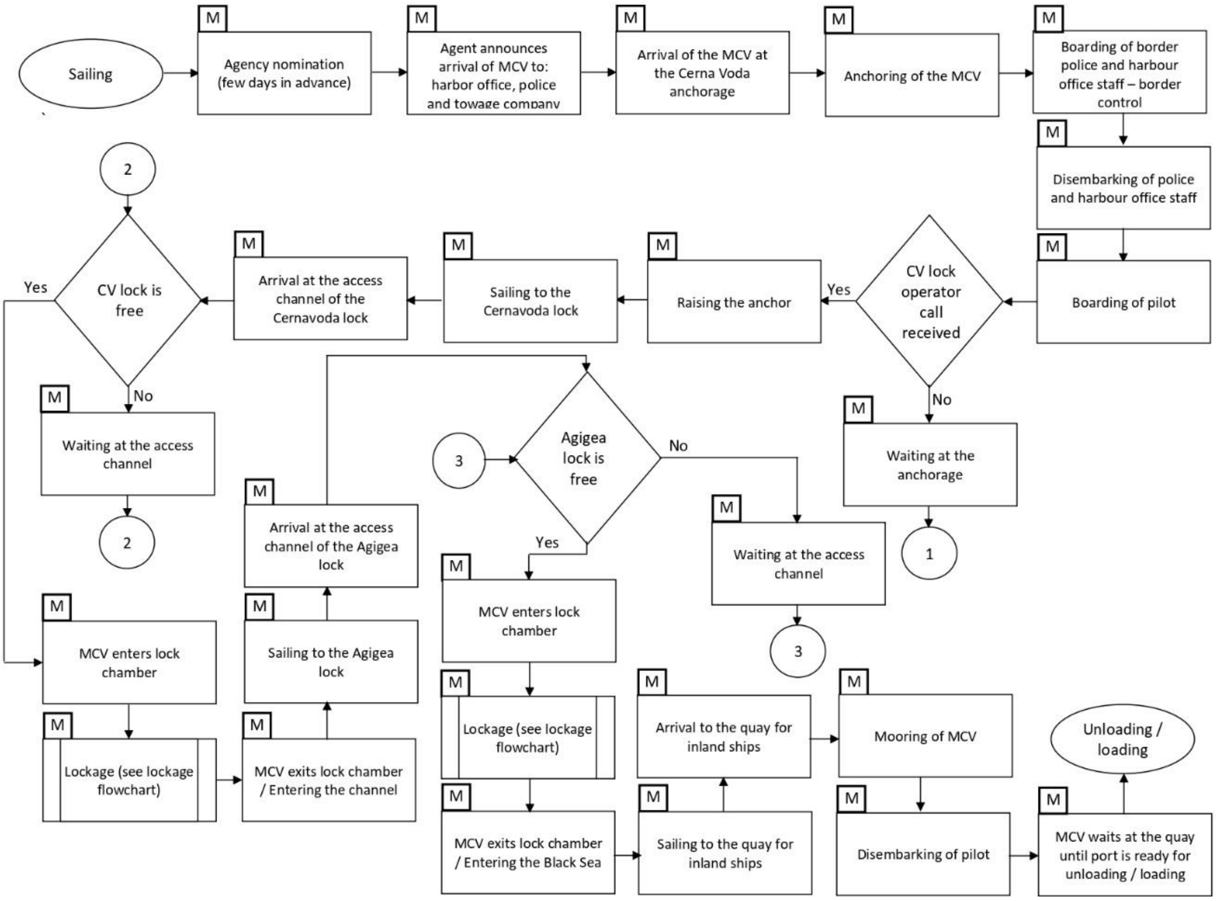

Figure 114: Passing through Danube – Black Sea canal : technological processes

Source: FTTE

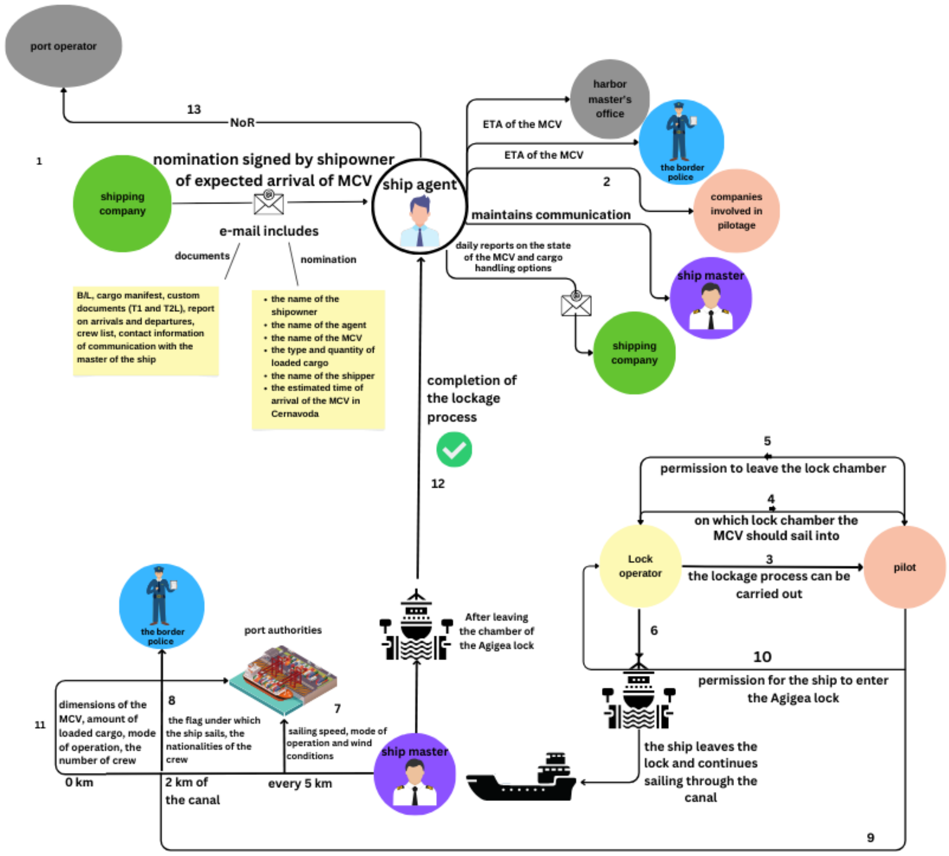

Figure 115. Passing through Danube – Black Sea canal – information flow

Source: FTTE

3.5.2.2.3.4 Unloading and loading at the Port of Constantza

Unloading at the Port of Constantza

Included stakeholders are:

1. Shipowner
2. Shipper
3. Ship agent
4. Custom
5. Port operator (nominated by the shipper)
6. Forwarder (nominated by the shipper)
7. Inspection company (nominated by the shipper)
8. Crew (of the ship to be unloaded in the port)
9. Crew (of the port tug)
10. Pilot (for manoeuvres within the Port area).

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Mapping of technological processes and information flow

Technological processes of unloading cargoes at the Port of Constantza are presented in the Figure 116. In addition, process of MCV departing the Port of Constantza is given on the Figure 117. Information flow encompassing both technological processes related to the unloading the cargo and departing Port of Constantza are depicted at the Figure 118.

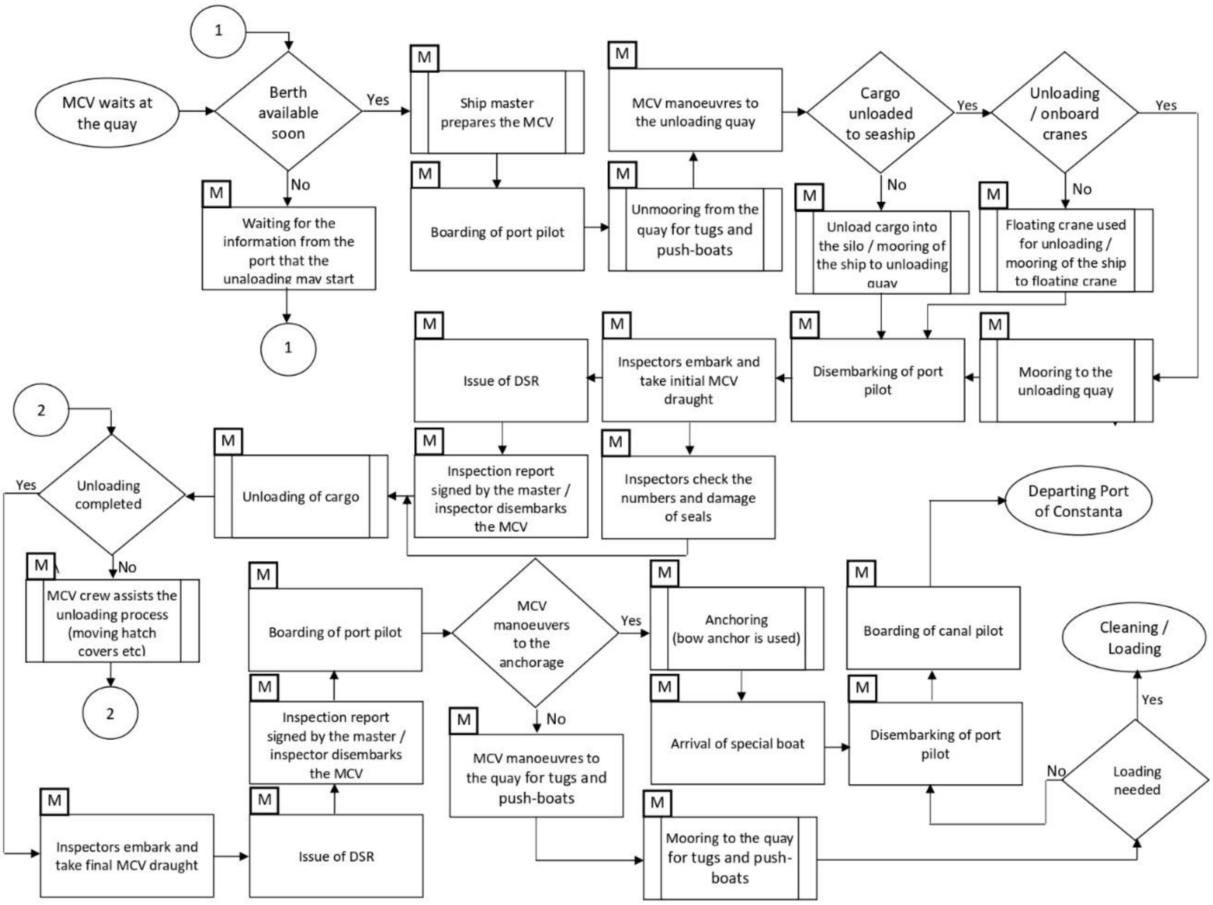

Figure 116: Unloading of cargo at the Port of Constantza – technological processes

Source: FTTE

Funded by the European Union

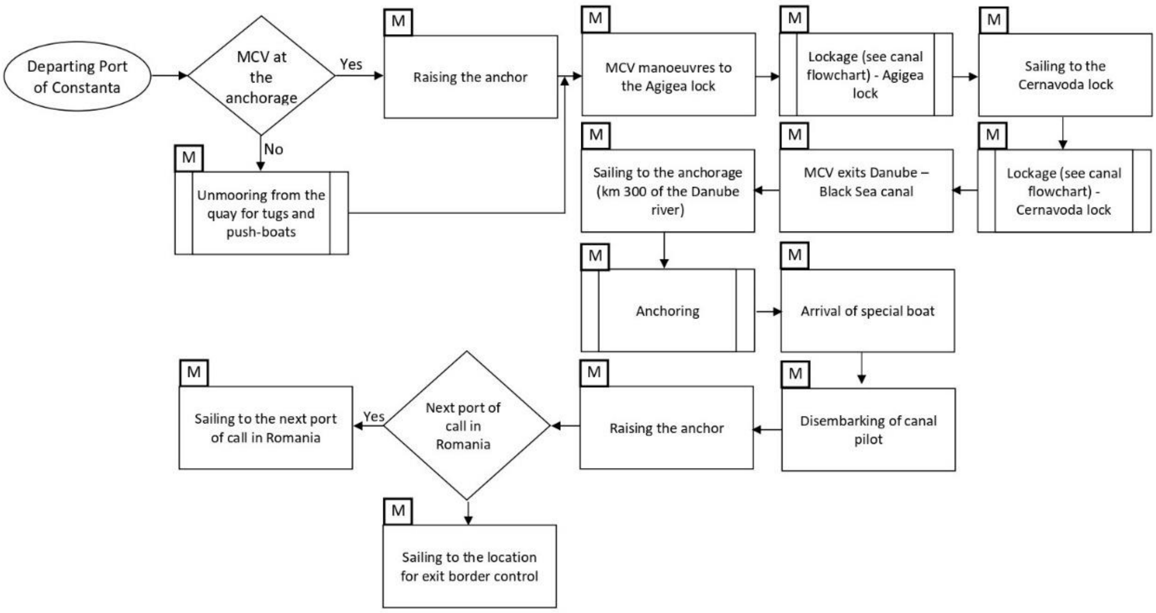

Figure 117: Departing Port of Constanta – technological processes

Source: FTTE

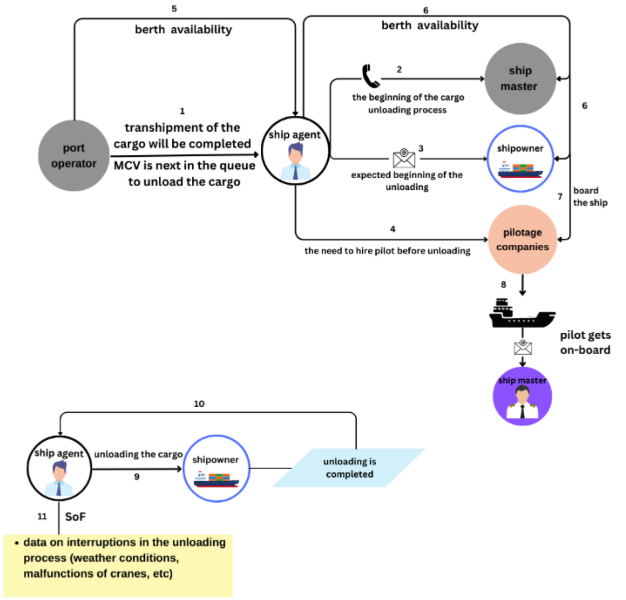

Figure 118 Unloading of cargo and departing the Port of Constantza – information flow

Source: FTTE

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Loading at the Port of Constantza

Included stakeholders are:

1. Shipowner
2. Shipper
3. Ship agent
4. Custom
5. Port operator (nominated by the shipper)
6. Forwarder (nominated by the shipper)
7. Inspection company (nominated by the shipper)
8. Crew (of the ship to be loaded in the port)
9. Crew (of the port tug)
10. Pilot (for manoeuvres within the Port area)

Mapping of technological processes and information flow

Technological processes of loading cargoes at the Port of Constantza are presented in the Figure 119, while Figure 120 gives relatable information flows. Annex 6.3.6 provides detailed description of these processes and flows.

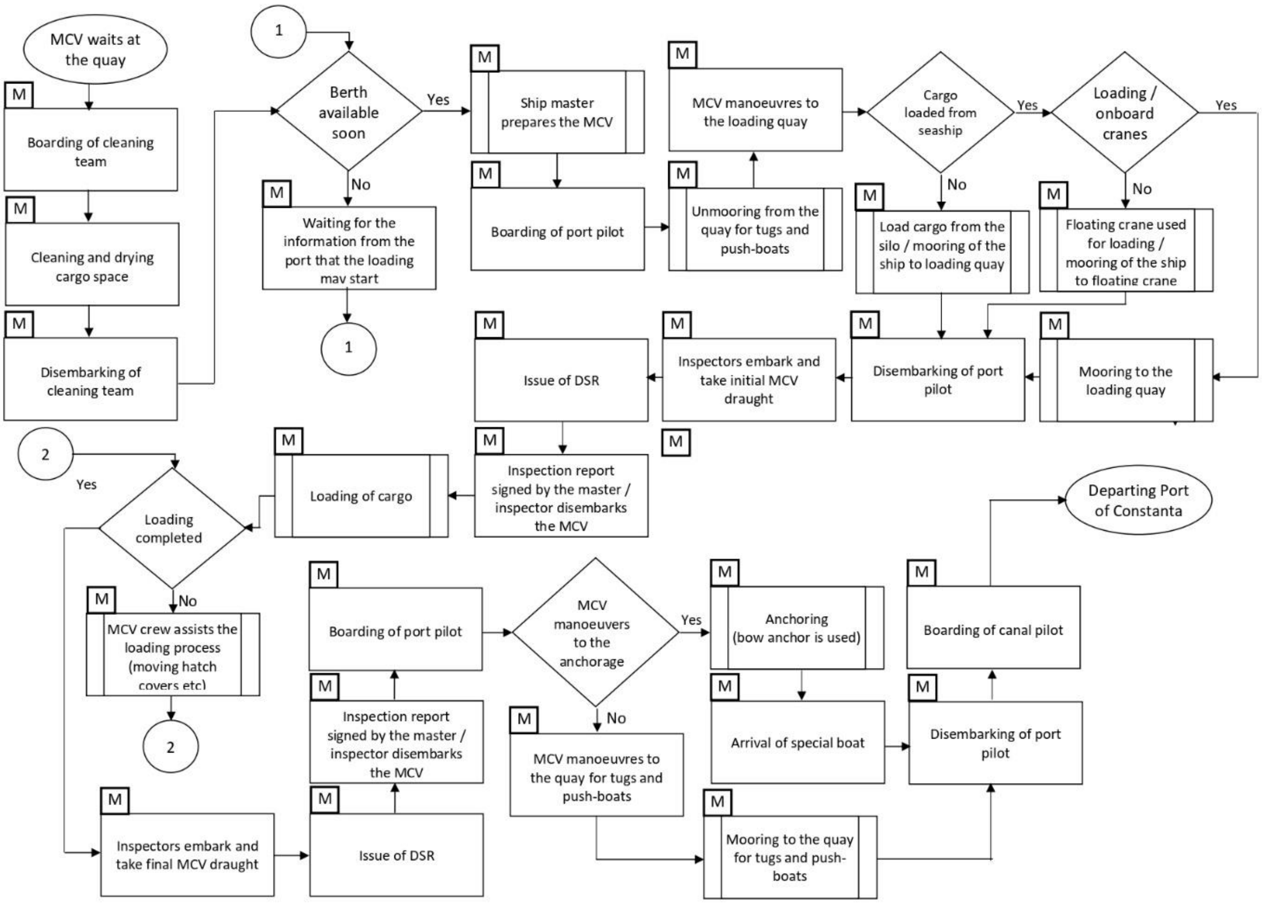
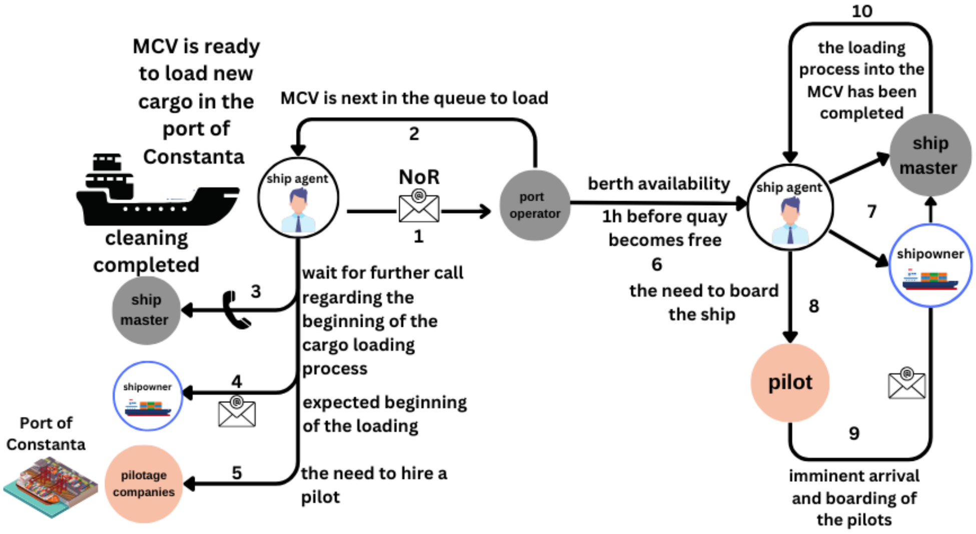


Figure 119: Loading of cargo at the Port of Constantza – technological processes

Source: FTTE



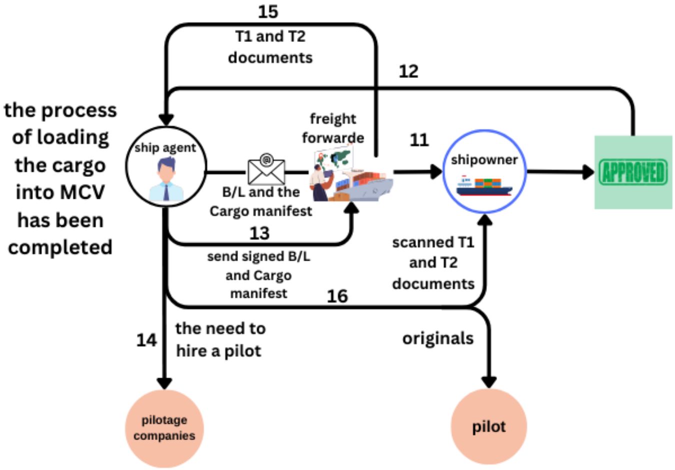


Figure 120 Loading of cargo at the Port of Constantza – information flows

Source: FTTE

3.5.3 Potential SEAMLESS Transportation Scenarios

3.5.3.1 Outline

There have been several attempts to establish container liner services running through the Middle Danube, especially in the period from 2005 to 2017. Some of them are:

- Joint service of BRP, JUGOAGENT, ZIM and Nord Marine between Port of Belgrade and Port of Constantza - this service was active in the period from 2005-2010;

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- HELO1, a weekly container service between Budapest-Belgrade-Constantza introduced in August 2010. It was a new and innovative container service on the Danube. Calling at Port of Smederevo was added in July 2011, while there were also occasional calling at Bulgarian ports. The service was organized by Helogistics Holding Gmbh and included river shipping companies such as EDDSG Gmbh and MAHART Duna Cargo Kft. Service was halted following the end of EC "Marco Polo" assistance in March 2012.

- DP World Novi Sad established a container service between the Port of Constantza and the Port of Novi Sad during spring 2022. In March, 2022, first 50 containers were delivered to the Port of Novi Sad, reloaded on trucks and shipped to end customers. However, this service ceased operation shortly after the first trips.

All these services have proven to be economically unprofitable. By taking into account such a situation, the main goal of the TUC "Danube" is to describe and analyse possibilities of establishment liner services on Danube based on utilization of autonomous vessels for container transportation between ports of Novi Sad and Constantza. Starting from the existing practice in the organization of cargo transportation on a given route, TUC "Danube" describes how the logistics processes and information flows would look like, as well as which stakeholders would be involved in the transportation of containers using autonomous ships. Also, through the TUC "Danube", the possibilities of applying SEAMLESS building blocks in a defined transport concept would be investigated, i. e., to what level they can contribute to the success of establishing a liner service on the route between the ports of Novi Sad and Constantza. In addition, the service would be in line with the goals of all relevant EU strategies such as European Green Deal, Fit to 55, Sustainable and Smart Mobility Strategy as it would contribute to the reduction of emissions from transport, increase of safety, cargo shift from road to more sustainable modes such as IWT, as well as to overcoming an issue of labour shortage.

3.5.3.2 Stakeholders

Existing stakeholders are described for each of the analysed technological processes. No detailed data are presented given that the existing situation refers to the transport of bulk cargoes. Since the potential transportation scenario relates to container barge transport, groups of the most relevant stakeholders, that would be involved in a Transferability Use Case, are presented.

Operational Stakeholders

Ship owners and ship operators

It is expected that all important Danube shipping companies, particularly from the Middle and Lower Danube, would be interested in taking part in the development of autonomous container barge shipping between the Middle Danube and the Port of Constantza. Some of these companies are the following: JRB (Yugoslav River Shipping), Agent Plus, DTL (Danube Transport and Logistics), Trading Line, Rhenus Danube Shipping GmbH, TTS (Transport Trade Services) S.A., Inland Shipping SRL, First DDSG Logistics Holding GmbH, etc.

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Port and terminal operators

In case of the Port of Novi Sad, as indicated in Table 17, DP World AD Novi Sad is the port operator which would play a significant role in the development of autonomous systems for ship service in this port. Main operators of container terminal in the Port of Constantza are the following: DP World Constantza, Socep, APM Terminals Romania, Schenker Logistics Romania, UMEX, Sea Container Services, Alfa Terminal Constantza.

Administrative and Strategic Stakeholders

Autonomous shipping will affect planning, improving, operating and maintaining of the waterway and port infrastructure. Therefore, the most important stakeholders are the following: Danube Commission, Ministry of Construction, Transport and Infrastructure – Department for Waterborne Transport and Safety of Navigation (Serbia), Port Governance Agency (Serbia), Authority for Determination of the seaworthiness (Serbia), Directorate for inland waterways (Serbia, RIS operator), Ministry of Transport and Infrastructure (Romania), National Company Maritime Ports Administration JS Co. Constanța (Romania), National Company River Danube Ports Administration – APDF (Romania), Romanian Naval Authority (operates the RoRIS system), Administration of Navigable Canals (Romania).

Commercial Stakeholders

Since container barge transport between the middle Danube and the Black Sea currently does not exist, no potential shippers are identified at the moment. However, autonomous shipping could be interesting for some companies who would like to achieve a delivery of their products on time, at a certain cost and low (zero) emission level, as well as an improved quality of service and handling of their goods.

Technology Developers

Technology providers include universities and research centres, as well as companies of various kinds, which are involved in research aimed at developing autonomous ships on inland waterways. Some of the potential technology developers from the Middle and Lower Danube regions are the following: University of Belgrade (Faculty of Transport and Traffic Engineering, Faculty of Mechanical Engineering - Serbia), University of Novi Sad – Faculty of Technical Sciences (Serbia), Agent Plus (Serbia), The "Lower Danube" University in Galati (Romania), National Company Maritime Ports Administration JS Co. Constanța (Romania), TTS S.A. (Romania), Inland Shipping SRL (Romania), NAVROM Shipyard SRL (Romania), European Integrated Project (Romania), Romanian River Transport Cluster (Romania), Budapest University of Technology and Economics (Hungary), The Hungarian National Association of Radio Distress-Signalling and Infocommunications (Hungary).

3.5.3.3 SEAMLESS Waterborne Transport Concept

3.5.3.3.1 Potential Vessel Fleet Concepts

Three facts are essential for the assessment of the possibilities for a successful transfer of a container ship design to the Danube:

- There are no self-propelled container vessels specifically designed for the Danube. Due to a range of economic and political reasons, inland waterway transport of containers never had a prominent role in the Danube basin. Hence, there was no strong requirement for the Danube container vessel. Thus, the design cannot be based on similar ships used as prototypes (as is common in ship design) but rather on first principles. Furthermore, this means that the Danube ports may not be equipped for container handling.
- The operational conditions on the Danube are specific, marked by shallow-water sectors where the navigation may be severely affected by extended and recurring low water periods. This means that the proper selection of design draft is the key point of the successful ship design for the Danube.
- Another important consideration, specifically related to the transport of containers, is the air draft, dictated by the height of the bridges along the Danube. Shallower the draft, greater is the air draft required to transport the same number of container tiers.
- The length of the navigable part of the Danube is over 2;400 km. Therefore, as the voyages on the Danube (both international and domestic) are typically long there is a requirement for considerable autonomy (in terms of the range covered using the energy provided by the systems available onboard).

On the other hand, multiple research projects and studies addressed the design of inland cargo vessels intended for the Danube, see (Radojcic, 2009), Guesnet et al. (2013), NEWS (2014), Bačkalov et al. (2016) or the vessels which may be used in low water-level conditions, see Bačkalov et al. (2022). In addition, a concept design of a container vessel (the X-Barge) is developed within the SEAMLESS project. These designs may be evaluated taking into account the aforementioned constraints of the Danube waterway. The main features of the designs are summarized in Table 23.

Table 23. Main features of inland container vessel designs (incl. X-Barge) intended for the Danube

Concept	**Radojčić (2009)**	**IDV (2014)**	**NEWS (2014)**	**X-Type (2016)**	**NOVIMAR (2022)**	**X-Barge (2023)**
Source	Radojcic (2009)	Guesnet et al. (2013)	NEWS (2014)	Bačkalov et al. (2016)	Bačkalov et al. (2022)	n/a
L [m]	104.00	105.00	110.00	103.80	104.00	85.00
B [m]	11.65	11.40	11.44	13.90	11.45	9.60
d [m]	2.50	2.80	2.97	2.30	2.00	2.50

D [m]	3.10	3.10	4.50	2.50	3.00	n/a
m_{LIG} [t]	695.7	688.2	989.9	670.8	780	n/a
m_{DWT} [t]	1,969.9	2,261.2	2,298.8	2,248.4	1,317	1,200
η_{DWT} [-]	0.739	0.767	0.699	0.770	0.628	n/a
TEU	192	192	156	240	104	90
m_{con} [t]	9.23	10.6	13.26	8.43	11.3	n/a

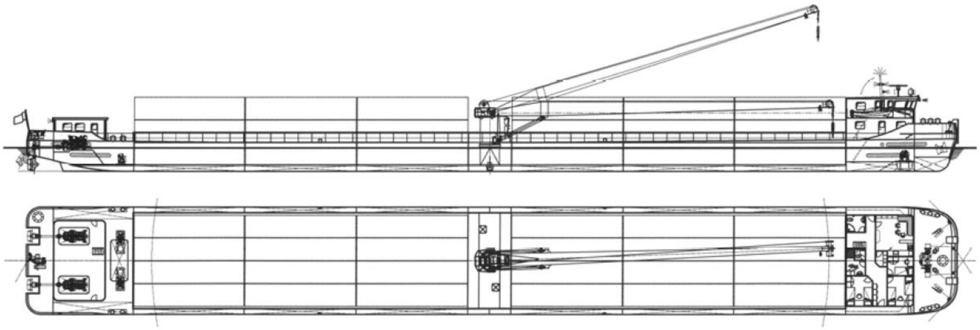

Figure 121: Container ship concept – a variant with the onboard crane

Source: Radojcic (2009)

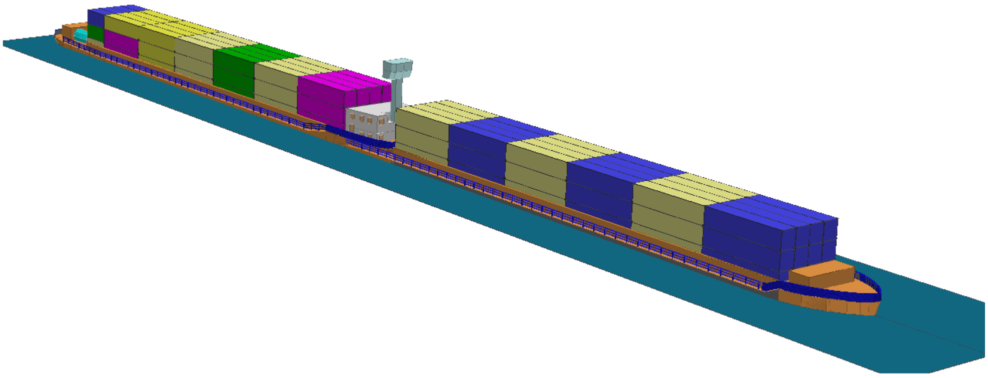

Figure 122: Container vessel for the Danube, shown in the coupled convoy with a barge

Source: Guesnet et al. (2013)

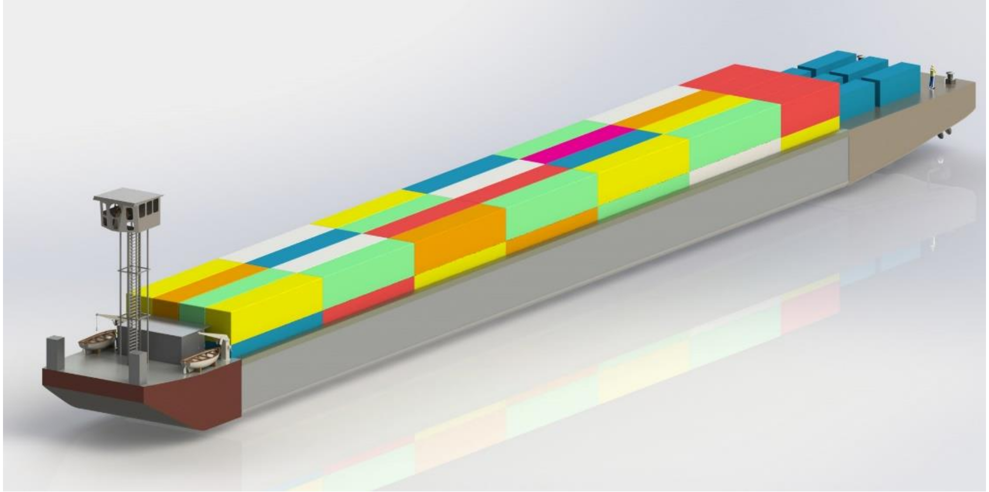

Figure 123: Project NEWS inland container vessel

Source: NEWS (2014)

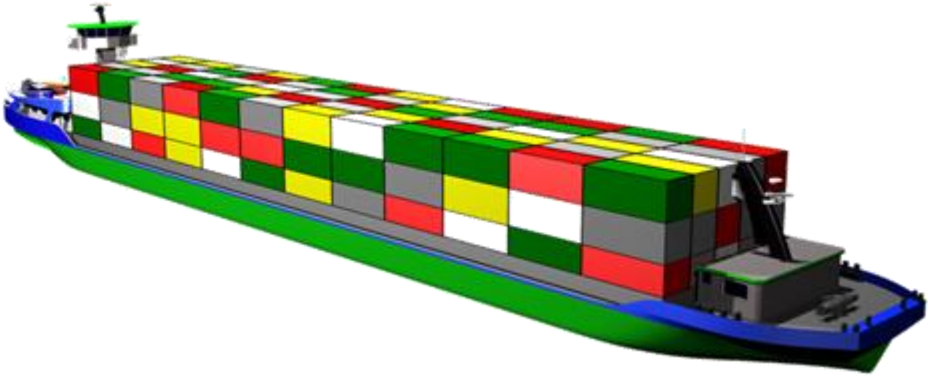

Figure 124: X-Type container vessel for the Danube

Source: Bačkalov et al. (2016)

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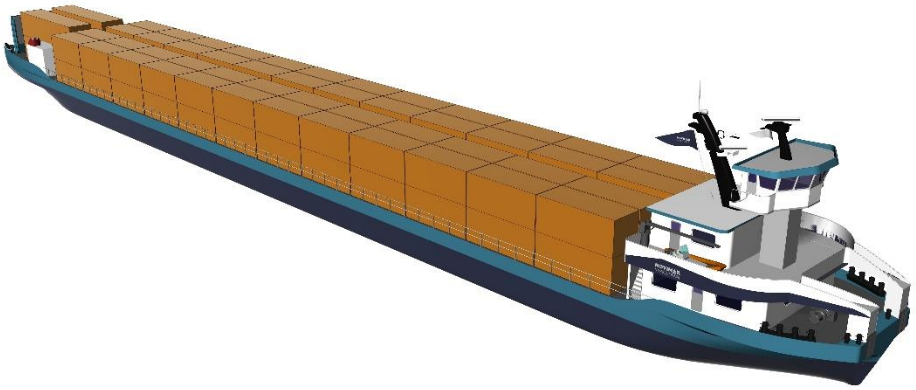

Figure 125: Stern access container RoRo vessel for the Vessel Train

Source: Bačkalov et al. (2022)

Apart from the X-Barge, all designs given in Table 23 are CEMT class Va vessels. The length of the vessels corresponds to the limitations of the Danube lock chambers: a vessel longer than 110 meters could not enter the 190-meter-long Regensburg lock chamber in a coupling formation with a standard, 77-meter-long Danube barge. The same applies to the beam of the vessels; the X-Type, however, is an exception in this respect as its beam does not allow sailing upstream of Regensburg, where the lock chamber cannot accommodate ships with B > 11.65 m. The year-round operability of the vessels may be evaluated considering the possible drafts of the vessels on the Danube, in period 2018–2022, as given in the Danube Commission's "Market observation for Danube navigation" reports, see Figure 126 and Figure 127. It may be observed that the vessels could be loaded to drafts greater than 2.40 meter only occasionally, over several months in a couple of years in the observed period. This gives a clear competitive advantage to X-Type and NOVIMAR designs with d = 2.3 m and d = 2 m, respectively. Except for the X-Barge to be demonstrated in the SEAMLESS project, all examined vessels are capable of forming a pushed convoy with a barge, which is a feature of exceptional importance for the Danube, allowing for expansion of the cargo-carrying capacity in low-water conditions. Finally, regarding the cargo handling capabilities of the examined ships, all the vessels feature vertical LoLo handling of containers, except for the NOVIMAR ship which utilizes the horizontal RoRo container handling. However, it was pointed out that not all of the Danube ports may adequately be equipped for container handling. Thus, this issue should be tackled from the ship design perspective. In case of the design featured in study (Radojcic, 2009), this is achieved by an onboard crane; in case of the NOVIMAR vessel (see Bačkalov et al. (2022)) a greater flexibility in the Danube ports is achieved by RoRo loading/unloading of containers with a dedicated vehicle over the stern ramp.

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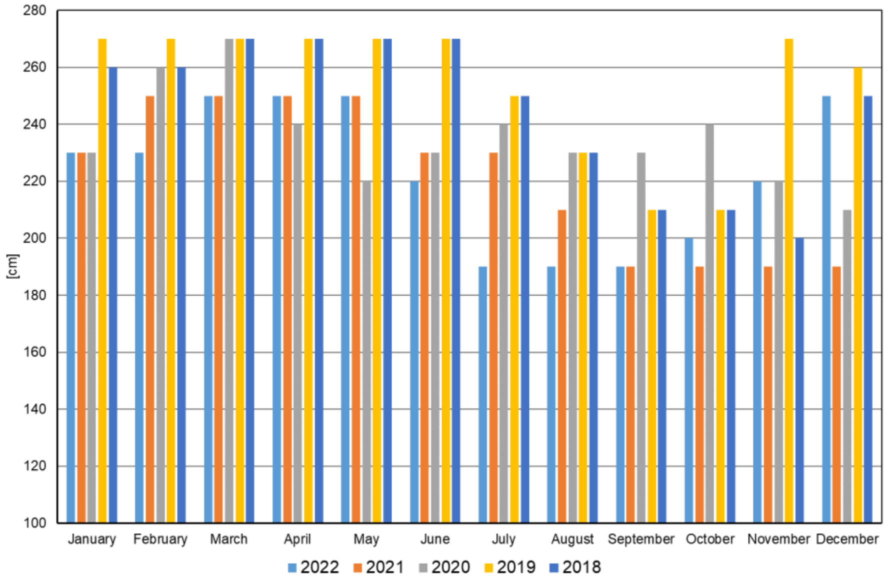

Figure 126: "Working" drafts of Danube vessels in upstream voyages (2018–2022)

Source: Own illustration based on "Market observation for Danube navigation" reports

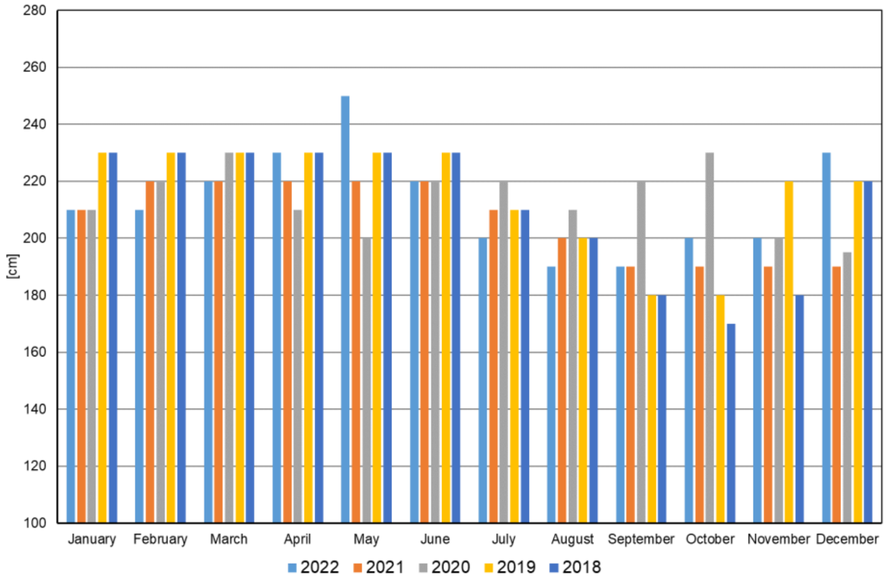

Figure 127: "Working" drafts of Danube vessels in downstream voyages

Source: Own illustration based on "Market observation for Danube navigation" reports

Thus, the following recommendations should be considered when designing a container vessel for the Danube:

- The vessel should have a low design draft.
- The vessel should have an onboard technical solution for container handling.

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- The vessel should be capable of forming a coupled convoy with a barge.
- The vessel should have a sufficient level of autonomy to cover long-range voyages typical of the Danube navigation.

3.5.3.3.2 Potential Ports and Infrastructure Concept

Technical solutions, existing as well as those that are being developed, which are intended to contribute to the establishment of the concept of autonomous navigation on inland waterways, will lead to changes in the ways of performing certain tasks onboard ships as well as related to the ship operations. Their application on ships that would be used for the transport of containers on the Danube, i. e., from the Port of Novi Sad to the Port of Constantza, would cause a change in many common procedures related to the servicing ships in ports and their lockage at the locks located on the corridor between the mentioned ports. (A. Eijk et al., 2018) provides an overview of the changes in tasks on board inland navigation vessels that can be expected due to the development of autonomous technologies for ships. In this report, the processes related to ports and locks, as infrastructural elements on the given section of the Danube, are considered. Therefore, we will present the changes in the tasks onboard ships related to the following activities:

- Mooring and unmooring of ships,
- Loading and unloading of cargoes,
- Lock-through process.

Mooring and unmooring of ships

Mooring and unmooring operations are done at the following technological processes:

- Unloading of cargo at the Port of Novi Sad (see Figure 108)
  - ➢ Mooring to the police dock;
  - ➢ Unmooring from the police dock;
  - ➢ Mooring to the unloading quay;
  - ➢ Unmooring from the unloading quay;
- Loading of cargo at the port of Novi Sad (see Figure 110)
  - ➢ Mooring to the loading quay;
  - ➢ Unmooring from the loading quay;
  - ➢ Mooring to the police dock;

  - Unmooring from the police dock;
- Passing through Danube – Black Sea canal (see Figure 114)
  - Mooring of MCV to the quay for inland ships (Port of Constantza);
- Unloading of cargo at the Port of Constantza (see Figure 116)
  - Unmooring of MCV from the quay for inland ships;
  - Mooring to the unloading quay;
  - Unmooring from the unloading quay;
  - Mooring of MCV to the quay for inland ships (tugs and push boats);
- Departing Port of Constantza (see Figure 117)
  - Unmooring of MCV from the quay for inland ships;
- Loading of cargo at the Port of Constantza (see Figure 119)
  - Unmooring of MCV from the quay for inland ships;
  - Mooring to the loading quay;
  - Unmooring from the loading quay;
  - Mooring of MCV to the quay for inland ships.

Mooring of MCV in the Port of Novi Sad implies that the port workers receive mooring lines from the ship crew, and secure them. All of these processes are done manually. In case of unmooring, the crew onboard ship has to deploy and remove the mooring lines. After that, the ship is separated from the quay. Average duration of mooring and unmooring processes, either at police or loading/unloading quay, based on experiences of shipping companies, is around 10 to 15 minutes. It does not include mooring manoeuvres of MCV.

Before mooring in the Port of Constantza, the MCV performs a mooring manoeuvre or a manoeuvre alongside a quay. After that, it is moored to the location where the unloading will take place. After unmooring from this location, i. e., the unloading quay, MCV executes a manoeuvre to the quay for inland ships. Mooring and unmooring to or from the quays is also done in case of cargo loading in the Port of Constantza. The processes are the same as in the case of the Port of Novi Sad. In addition, these processes (mooring and unmooring) in the Port of Constantza are realized on the quay for inland ships (tugs and push boats). Average duration is also around 10 to 15 minutes per

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activity excluding mooring manoeuvres (manoeuvre alongside a quay that usually last about 10 to 15 minutes).

Quay for inland ships, within the Port of Constantza, provides a temporary mooring quay for incoming and outgoing barges and pushers. It allows for safe mooring of some 150 to 200 barges.

On the other side, Eijk et al. (2018) indicates some of the characteristics of the automated mooring systems. They are:

- Automation levels 4 and 5 in inland navigation require automated mooring systems based on vacuum or magnetism either on board of the ship or at the shore side (port quays, waiting areas or in locks); as a more recent solution for automated mooring, we can consider development of robotic arms – Yara Birkeland has two robotic arms installed in the bow and in the stern of this ship;
- Significant progress has been made in the development of the automated mooring system, but their use entails high investment costs;
- There are different systems, but not standards in their production;
- For the ship operating on a spot market, for which it is unsure whether mooring systems are available, automated mooring systems should be installed on board of the vessel.

Loading and unloading of cargoes

Loading and unloading operations, in the given use case, take place at the Port of Novi Sad and Port of Constantza. By analysing the corresponding figures (see Figure 108, Figure 110, Figure 116 and Figure 119) it can be determined that these processes include the following activities:

- Unloading of cargoes;
- Loading of cargoes;
- MCV crew assistance to the unloading/loading process (moving hatch covers, providing instructions to the crane operator on how to carry out loading etc).

Descriptions of technological processes provide a detailed overview of all activities and information flows before and after unloading or loading of cargos in the ports. The unloading and loading processes themselves are not considered in detail, since they are carried out in the usual way. Also, the descriptions of the existing situation are associated with the transportation of bulk cargoes (cereals, in most cases), while the analysis of potential transportation scenarios relates to the transport of containers in a liner service.

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Eijk et al. (2018) gives an overview of technical solutions that are being developed for handling autonomous ships in ports for various types of cargoes. The most important aspects related to containerized cargoes are the following:

- a stowage and loading and unloading plan need to be generated;
- stowage plan needs to be communicated with the terminal operator;
- stowage plan needs to be to be monitored;
- it is recommended that an automated program could generate an optimal stowage plan and check it against the statutory stability requirements;
- generation of stowage plan could be outsourced to a shore control centre or an administrative back office;
- Monitoring of the loading and unloading plan could be outsourced to automated camera and sensor systems, to shore personnel in a shore control centre or to terminal personnel;
- the terminal process should be automated so that information would be transferred directly from the automated ship/ control room to the terminal.

Lock-through processes

Description of the locks located on the river stretch between Port of Novi Sad and Port of Constantza is given in the section 3.5.2.2.2, while details about the usual lockage process are presented in the section 3.5.2.2.3.2. However, the use of autonomous ships also requires the development of technical solutions related to the lockage process. Solutions for waiting/mooring at the access channel and mooring to or unmooring from the bollards (bitts) in the lock are required onboard inland navigation ships with at least automation level 4.

3.5.4 Requirements and Technology Gaps

Bearing in mind the existing practice in mooring and unmooring ships in ports on the Danube, as well as development plans of these ports, it is not realistic to expect investments to be made in automated mooring systems on the shore side. Therefore, ships with an automation level of at least 4, would require onboard automated mooring systems. Such ships have the opportunity to carry out the mooring and unmooring processes in a greater number of ports. This would increase the possibility of using automated ships on the Danube, especially in terms of establishing container liner services.

The mooring of the ship, as explained, is a process that involves the engagement of a certain number of crew members. According to Eijk et al. (2018) at least three crew members (out of 5 onboard, required for the B operating mode of an inland navigation ship) participate in these activities. The mooring manoeuvre is considered to be relatively hazardous operation. Therefore, the development of an onboard automated mooring system would contribute to the reduction or elimination of crew from these activities, which would also be reflected in increasing the level of safety in inland waterway transport.

The current practice in servicing ships in Danube ports clearly indicates that the application of all appropriate SEAMLESS building blocks is necessary in order to enable the handling of autonomous ships in these ports. This is primarily related to:

- Autonomous Cargo Handling module or an innovative crane system, specifically designed for fully autonomous operation (incl. accurate position fixing) while maintaining humans-in-the-loop through remote monitoring and control capabilities;
- Automated stowage planning providing the SEAMLESS autonomous cargo handling system with the (un)loading sequence in advance of the port call; automated stowage planning system should re-configure the sequence whenever updated information from the supply chain is available; cargo information will be provided to the automated stowage planning by the SEAMLESS ModalNET and existing logistics platforms;
- Autonomous Vessels' Smart Port Manager (AVSPM) – a software prototype for automated port calls for autonomous vessels including: 1) port calls management and negotiations, 2) route planning optimisation within the port, 3) VTS services, 4) emergency situations' management, and 5) real-time safety and security monitoring.

Based on the description of technological processes, it can be concluded that all communication and exchange of information is realized manually. Therefore, it is necessary to develop and implement systems that will enable the improvement and digitization of procedures and communication among involved stakeholders. Development and implementation of the ModalNET platform would enable exchange of real-time information from different sources (i. e., logistics platforms, autonomous vessels, automated port infrastructure, ROCs, and logistics service providers). This would also contribute to overcoming administrative barriers, which, in many ways, affect the competitiveness of inland waterway transport in this region.

3.6 TRANSFERABILITY USE CASE "WEST MED"

3.6.1 Existing Logistics Environment and PESTEL Analysis

The Transferability Use Case "West Med" is centred in the Port of Valencia, the 4th most important port in Europe and located in Spain. For that reason, this logistics environment will be addressed from the point of view of the country. Some of the statements included in this section will be the same that those included in other transferability cases.

The mapping of the existing logistics environment is divided into six factors that are of political, economic, social, technological/infrastructure, ecological and legislative nature. In this section the most important opportunities and threats related to those factors are pointed out.

Table 24: PESTEL Analysis for TUC "West Med"

	Opportunities	Threats
Political	• Political will exists and autonomous ships will be included in the future Law that amends the Consolidated Text of the State Ports and Merchant Marine Law and the Maritime Navigation Law, while still adhering to the general rules of Spanish navigation • This article 258 outlines the regulations for autonomous ships, including their level of automation, navigation requirements, remote control, and necessary authorizations to operate in Spanish waters • The General Directorate of Merchant Marine established the explicit authorization of the entry of autonomous ships in Spanish waters with the Royal Decree 186/2023	• The absence of clear and specific legislation for autonomous ship operations can lead to uncertainty and delays in their adoption • Establishing appropriate regulatory frameworks and safety standards presents a significant political challenge
Economical	• The General Directorate of Merchant Marine in Spain leads the National Working Group on Autonomous Ships is composed of institutions and companies engaged in the development of these vessels • The group was created in 2020 as part of the Safe, Sustainable, and Connected Mobility Strategy 2030 framework and serves as an information exchange forum and a platform for contemplating advancements and their alignment with the maritime transportation sector's evolving landscape	• The current port and maritime infrastructure may not be ready for autonomous ship operations • Substantial investments in technology and infrastructure upgrades are necessary to fully accommodate and support autonomous ships

Societal	• Spain introduces the use of technology from an early age, which prepares students for a bright digital future • The ICT sector is one of the fastest-growing sectors in Spain over the past decade, and digitalization is a strategic focal point for the transformation of the productive model	• The operation of autonomous ships will necessitate a workforce with technical skills and updated knowledge in technology and automation • The absence of an adequate skills base in autonomous navigation could impede the implementation and adoption of this technology in the Spanish market
Technological	• With the creation of the National Working Group on Autonomous Ships in 2020, various companies, associations, institutions, and organizations have exchanged opinions and information with the aim of creating a national network in this field	• The lack of clear regulations and technological standards in the field of autonomous ships could generate uncertainty and difficulties regarding the certification, compliance, and security of the technological systems used in these vessels
Ecological	• New autonomous ship designs require green technologies in combination with new cargo management concepts	• Autonomous vessels must comply with environmental regulations, such as those related to waste management and the protection of endangered species • Ensuring proper compliance with these regulations can be challenging
Legislative	• The General Directorate of Merchant Marine in Spain is working on the deployment of regulations regarding autonomous ships, particularly in the area of safety measures and connectivity of test areas with maritime traffic, with the aim of adapting their specificities to the conventions of the International Maritime Organization (IMO)	• The operation of autonomous vessels presents challenges in legal responsibility • Determining liability in accidents, damages, or infringements can be complex, particularly when autonomous systems and algorithmic decisions are involved • The lack of clarity in laws and regulations can hinder the proper allocation of responsibilities and the protection of rights for all parties involved

3.6.2 Existing Transportation Concepts

3.6.2.1 Outline

The port of Valencia is the leading port in the Mediterranean in terms of container movements, but with a special relevance in RoRo traffic to its hinterland. The Port Authority of Valencia is responsible for the management of the ports of Valencia, Sagunto and Gandia following the model implemented in the Spanish state-owned port system in which the Port Authority provides the spaces and part of the infrastructures that support port activity, while private initiative is responsible for the development of operations and the provision of services in the ports, using the same infrastructure.

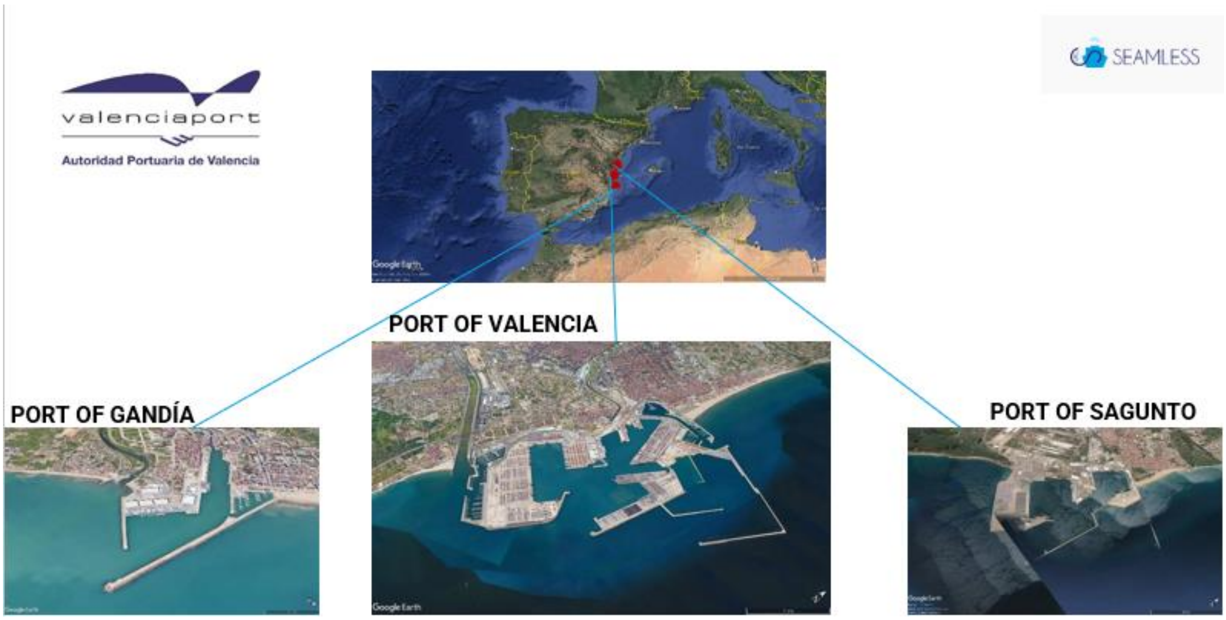

Figure 128: Main ports managed by Port Authority of Valencia

Source: Own elaboration by VPF

Within this framework, and in accordance with the applicable regulations, the Port Authority also becomes the regulator of the private activities conducted in the ports and the regulator of the private activities carried out within its sphere of competence.

In the case of the Autoridad Portuaria de Valencia (APV), it could be considered that this model has already evolved towards what has been called "advanced landlord", in which the Port Authority assumes the role of leadership of the Port Community beyond its own jurisdiction to contribute to its structuring and improve the services offered to the logistics chains that use the ports managed by the Port Authority.

The main objective of the TUC “West Med” is to evaluate, analyse and define potential alternatives for the shift of goods from road to shipping to be delivered or received by the shippers in the hinterland. This modal shift pursues several objectives in itself that are:

- This scheme promotes alternatives that can help to decarbonise the port for the point of view of emissions, congestions and noise providing a solution more sustainable in the way of moving cargo nowadays and in the near future
- In view of the continuous growth of traffic in the port of Valencia and the expected new container facilities planned to be activated in the future according with the Strategic Plan, the aim is to be able to offer intermodal alternatives for this cargo moved not only from the point of

view of the port and the terminal operators but also and mainly the final customers that choose the port of Valencia to move the cargo

- One of the objectives in short-term is to alleviate the increasing road transport traffic peaks by offering a stable shuttle service diverting traffic to other less congested ports in the Mediterranean Coast
- As a result of this solution, the TUC provides an advantage for the rest of ports analysed in order to extend the connectivity of the port of Valencia to increase the traffic carried by other ports, increasing competitiveness, a larger market and a more environmentally sustainable service for shippers. It represents an alternative to the current logistics for this cargo
- Additionally, the TUC provides a solution to the possible future needs of goods from a fully digitalised approach
- The TUC offers an opportunity to analyse the future of autonomous shipping in coexistence with traditional shipping in a big port from a holistic perspective
- Finally, the current situation deriving to a future scenario with more traffic leads to a scenario in which there will be different highly investment alternative infrastructure as solutions for these constraints. For that reason, the TUC serves as an aid to determine the pros and contras of a SEAMLESS solution as compared to other land-based solutions using roads or train

3.6.2.2 Existing Waterborne Transport Concepts

3.6.2.2.1 Analysis of Vessel Fleet

The vessel traffic in the ports managed by the Port Authority of Valencia is divided into domestic and foreign traffic and the statistics are expressed in number of vessels and total GT (Gross tonnage) per year. The following statistics correspond to 2022 in comparison with 2021:

Table 25: Vessel traffic statistics of Valenciaport

		2021	2022	Difference	%
Domestic	No.	755	666	-89	-11,79
	G.T.	18,237,727	18,289,691	51,964	0,28
Foreign	No.	6,540	6,855	315	4,82
	G.T.	237,394,415	272,964,765	35,570,350	14,98
Total	No.	7,295	7,521	226	3,10
	G.T.	255,632,142	291,254,456	35,622,314	13,93

Source: Autoridad Portuaria de Valencia (2022)

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The total number of ships reached in 2022 is 7,521 port calls mainly concentrated in foreign vessels (6,855 units in total). The total is 291.3 Mio GT in 2022. The main ships are containerships and passenger ships (Ro-Pax and freight) followed by general cargo and RoRo goods (new vehicles and trucks). Valenciaport is well ranked in terms of connectivity according to the UNCTAD (LCSI) reaching the 21st position in the world.

Over 100 regular lines run by some of the world´s largest shipping companies connect i to over 1,000 ports on all five continents. Its main customers are MSC, MAERSK, CMA-CGM, HAPAG-LLOYPD, HAMBURG SÜD, HANJIN, UASC, COSCO, EMES, EVERGREEN, BOLUDA, NYK, HOEGH, GRIMALDI, ACCIONA and BALEARIA.

Valenciaport is located in the centre of the western Mediterranean coastline, in line with the east-west maritime corridor crossing the Suez Canal and the Straits of Gibraltar. This privileged geostrategic position makes it the first and last port of call for the regular shipping lines operating between America, the Mediterranean Basin and the Far East. Valenciaport serves a hinterland which covers 51 % of Spanish GDP and half of Spain’s working population, in a radius of just 350 km. Its proximity to the Spanish capital, combined with its excellent road and rail connections (toll-free motorway to Madrid) and the latest port and shipping infrastructure, make it the natural port for Madrid and central Spain. It is also one of the key hubs for other economic regions in the country such as Castile-La Mancha, Aragón, Murcia and Eastern Andalusia.

As a hub for the Western Mediterranean, Valenciaport efficiently distributes goods over a radius of 2,000 km, both in southern EU countries and in North Africa (Morocco, Algeria, Tunisia and Libya), representing a huge market of 270 million consumers.

It also has an extensive network of feeder services connecting it to Eastern Mediterranean countries and the Black Sea, which are largely the driving force behind its container transhipments to these destinations.

3.6.2.2.2 Analysis of Ports and Infrastructure

The structure of the port of Valencia is divided into different specialized terminals that concentrates the movement of cargo. It comprises:

- 3 main container terminals operated by the three main shipping companies in the world
- 2 RoRo terminals, serving Balearic Islands, cabotage and short-sea shipping traffic connections with Italy mainly
- 2 cruise terminals
- 2 liquid bulk terminals providing petrol, oils, gases and chemicals in general
- 1 solid bulk terminal moving grain and chemicals products.

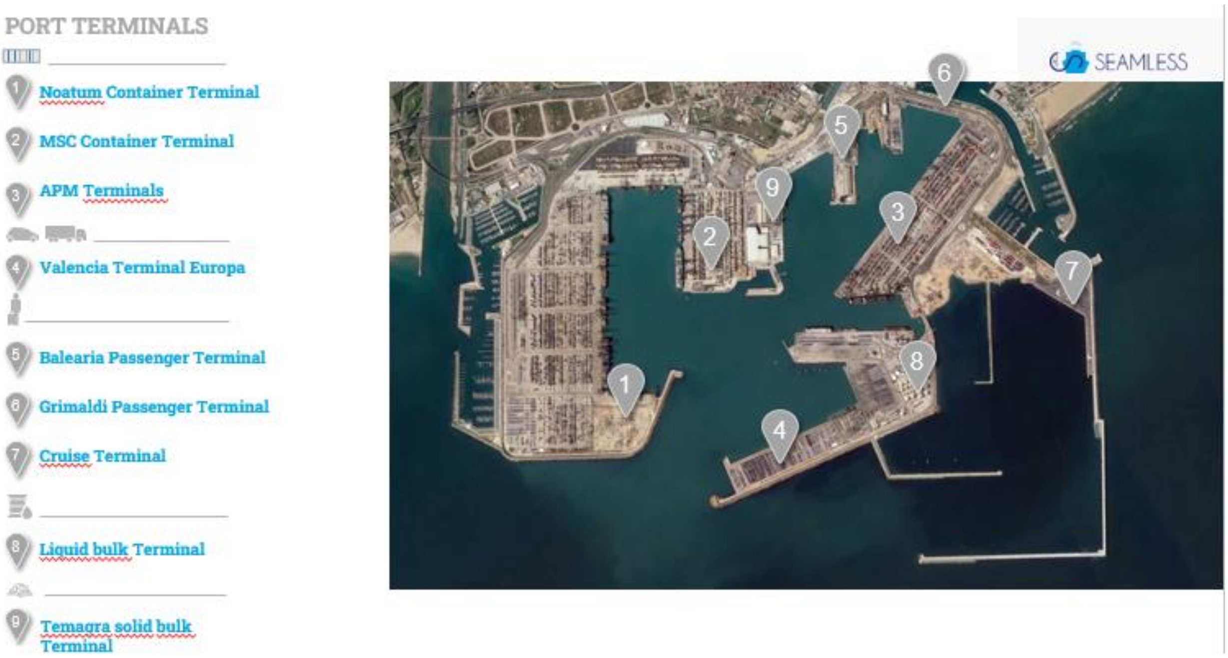
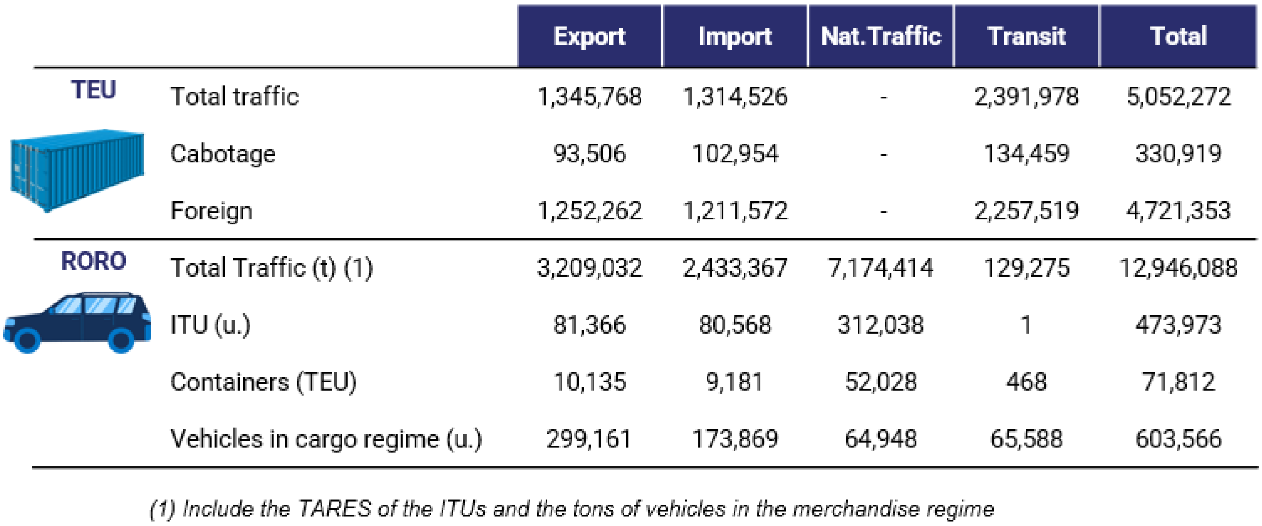


Figure 129: Main configuration of the terminals in the Port of Valencia

Source: Own elaboration by VPF

The main traffics are presented in the following table:



		Export	Import	Nat.Traffic	Transit	Total
TEU	Total traffic	1,345,768	1,314,526	-	2,391,978	5,052,272
	Cabotage	93,506	102,954	-	134,459	330,919
	Foreign	1,252,262	1,211,572	-	2,257,519	4,721,353
RORO	Total Traffic (t) (1)	3,209,032	2,433,367	7,174,414	129,275	12,946,088
	ITU (u.)	81,366	80,568	312,038	1	473,973
	Containers (TEU)	10,135	9,181	52,028	468	71,812
	Vehicles in cargo regime (u.)	299,161	173,869	64,948	65,588	603,566

(1) Include the TARES of the ITUs and the tons of vehicles in the merchandise regime

Figure 130: Statistics of the main traffics for the year 2022 in Valenciaport

Source: Autoridad Portuaria de Valencia (2022)

It is highlighted that container traffic is the most important one with 5.05 Mio TEU moved in 2022, with a 52.66 % (2.66 Mio TEU) of the traffic concentrated for export/import while the rest is cargo in transit. Regarding RoRo traffic, a total amount of 12.95 Mio tonnes are moved in the port. In the disaggregated data, 473,973 ITU´s are moved and 71,812 additional containers coming from Cont-

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Ro ships are managed. One of the main important traffics is the new vehicles that represents 603,000 units per year.

When considering traffic by land transportation mode (does not include maritime transit, fishing or provisioning) the current traffic in the port could be observed in 2022:

- The transport mode to deliver the container traffic to the hinterland in the port is using road and railway. From the total of 2.66 Mio TEU in export and import, 2.43 Mio TEU (93.1 %) are moved by truck, while 233,711 TEU (6.9 %) is transported by rail.
- A number of 810,634 TEU (30.47 %) of hinterland flows has been empty containers, while 1.85 Mio full containers (69.53 %) could be observed. In total, 48.62 Mio tonnes were moved.
- The delivery of the cargo is concentrated from Mondays to Fridays and some traffic in weekends. Approximately 4,900 trucks are in/out of the port per working day (260 days). The type of truck is mainly Euro VI or older. The estimated fuel consumption of this type of truck is 30 litres/100 km. In absolute figures, 1.3 Mio trucks are needed to move 2.4 Mio of containers.

A deep study on the distribution of the trucks at the port of Valencia in 2022 has been done, calculating the number of vehicles per hour (working days) in a year stating that the peak hour is 7 a.m. with a mean of 700 vehicles. The time slot with the highest activity is between 7 am.to 17 p.m.

The distribution of trucks on weekends provides a result of 182 vehicles mainly concentrated at 19 p.m. The same exercise was done with the peak month for working days at 2022 on may, with a mean of 9,346 vehicles and peak day of the week in 2022 is on Wednesday with a mean of 8,000 vehicles. These statistics are relevant to understand the congestions and the traffic within the port of Valencia of trucks during a year. It can be translated into a possible shuttle to shift cargo from road to MASS, motivation of this TUC.

Finally, the distribution of trucks regarding peak time consumed within the port has been calculated. This information will help to understand the total turnaround time that a driver takes in the port of Valencia according to the hour when they are entering the port. The hour of the day in 2022 that involves the longest time the truck spends inside the port is at 7am with an average of 220 minutes. When calculating the same comparing months in a year, April is the month when the port is more congested with an average turnaround time of 205 minutes.

With all, the aim of the TUC is to analyse all these figures and try to identify what traffics can be shifted to shipping and the feasibility of a shuttle service connecting other ports.

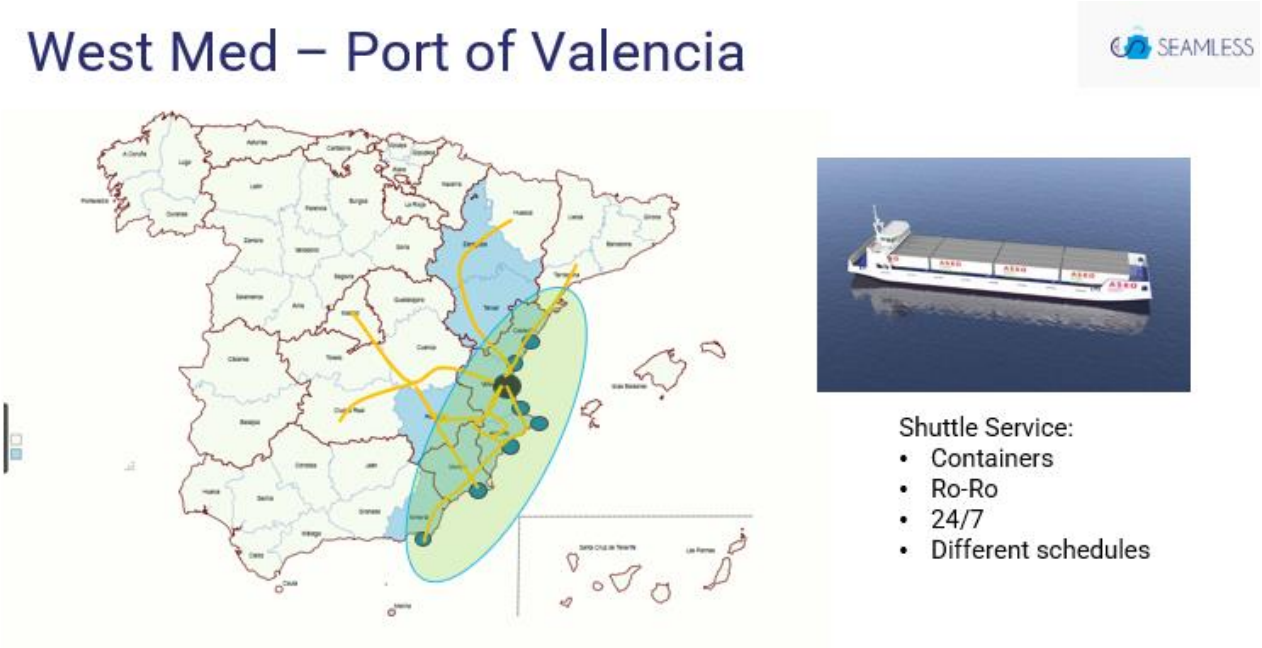
3.6.3 Potential SEAMLESS Transportation Scenarios

3.6.3.1 Outline

The TUC “West Med” takes into account the main traffic moved in the port of Valencia, taking advantage of the connectivity and the profile and needs of their customers/shippers located in different areas of Spain. The increasing road transport traffic moving mainly containers in the port of Valencia and the forecasted increasing number of operations in the near future obliges to provide a solution in terms of alternatives to move this cargo.

For that reason, this TUC focuses on the current statistics of cargo moved by shipping through the port of Valencia and delivered to different provinces. It is important to highlight that not all the cargo can be shifted to waterborne transport The analysis started with the definition of the possible ports for a shuttle route capable to move cargo to the final customer avoiding entering/leaving the port of Valencia by truck.

The Spanish Customs statistics were the keystone to elaborate a further detailed analysis of the possible provinces candidates to be further investigated. The main road infrastructures were also analysed in order to understand the current routes that the trucks are considering in their cargo deliveries in the hinterland.



West Med – Port of Valencia

Shuttle Service:
- Containers
- Ro-Ro
- 24/7
- Different schedules

Figure 131: Area of influence of the hinterland to be analysed in the TUC “West Med”

Source: Own elaboration by VPF

As it is shown in Figure 131, eight main provinces are firstly selected to be studied that are Valencia, Castellón and Alicante in Comunidad Valenciana, Teruel and Zaragoza in Aragon, Albacete in Castilla la Mancha, Murcia and Almería in Andalusia. In parallel a set of ports candidates are selected

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in order to comprehensively define future possible autonomous ship shuttle services to move containers, RoRo in a day basis with different schedules. The ports selected are: Castellón, Sagunto at the north of the Port of Valencia and Gandía, Denia, Alicante, Cartagena and Almeria in the south.

The next step is to analyse, according to the Customs statistics the shipments (origin and destination) of the export/import of the goods using the port of Valencia. In that sense, the statistics were selected from the total Autonomous regions in Spain.

Table 26: Customs statistics of the cargo moved with origin/destination the port of Valencia with its hinterland

Regions	Exportation or Shipment	Importation or Introduction
ANDALUSIA	3.78 %	3.66 %
ARAGON	3.74 %	1.70 %
ASTURIAS	0.29 %	0.13 %
BALEARIC ISLANDS	0.15 %	0.11 %
CANARY ISLANDS	0.08 %	0.03 %
CANTABRIA	0.20 %	0.28 %
CASTILE-LA MANCHA	4.28 %	4.08 %
CASTILE LEON	2.31 %	2.50 %
CATALONIA	4.62 %	5.03 %
COMMUNITY OF VALENCIA	65.81 %	56.73 %
EXTREMADURA	0.13 %	0.31 %
GALICIA	0.84 %	0.62 %
LA RIOJA	0.35 %	0.35 %
MADRID	6.09 %	17.39 %
MURCIA	4.93 %	4.42 %
NAVARRE	0.83 %	0.69 %
BASQUE COUNTRY	1.59 %	1.67 %
UNKNOWN	0.01 %	0.31 %
TOTAL	**100 %**	**100 %**

Source: VPF with data from Spanish Customs

Once selected the provinces, a detailed analysis has been made identifying the typology of the cargo moved per province. Moreover, with an average of 35 tonnes per truck, the calculation of the potential number of trucks has been calculated partially per province and per potential selected port of call.

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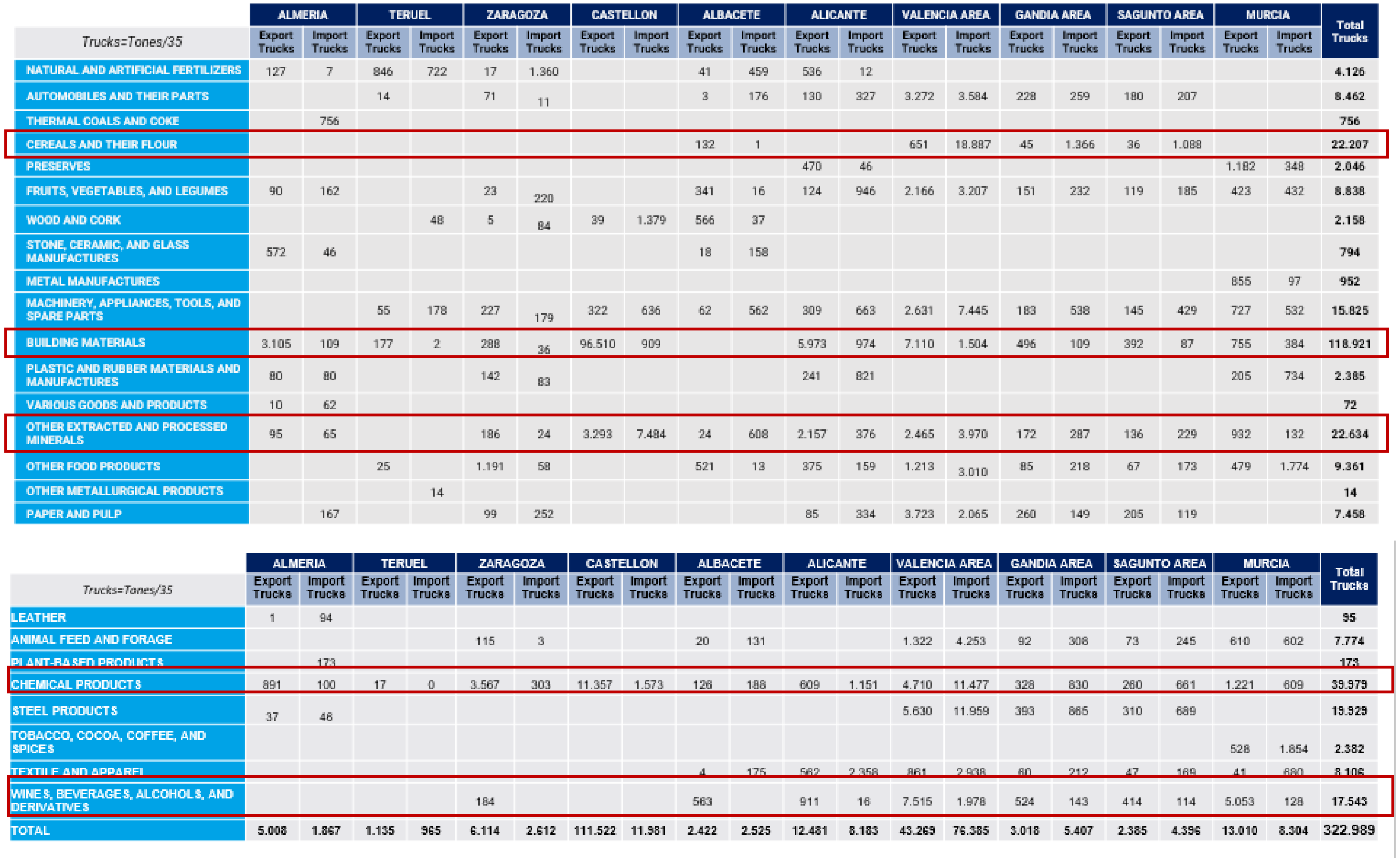

Trucks=Tones/35	ALMERIA		TERUEL		ZARAGOZA		CASTELLON		ALBACETE		ALICANTE		VALENCIA AREA		GANDIA AREA		SAGUNTO AREA		MURCIA		Total Trucks
	Export Trucks	Import Trucks	Export Trucks	Import Trucks	Export Trucks	Import Trucks	Export Trucks	Import Trucks	Export Trucks	Import Trucks	Export Trucks	Import Trucks	Export Trucks	Import Trucks	Export Trucks	Import Trucks	Export Trucks	Import Trucks	Export Trucks	Import Trucks	
NATURAL AND ARTIFICIAL FERTILIZERS	127	7	846	722	17	1.360			41	459	536	12									**4.126**
AUTOMOBILES AND THEIR PARTS			14		71	11			3	176	130	327	3.272	3.584	228	259	180	207			**8.462**
THERMAL COALS AND COKE		756																			**756**
CEREALS AND THEIR FLOUR									132	1			651	18.887	45	1.366	36	1.088			**22.207**
PRESERVES											470	46							1.182	348	**2.046**
FRUITS, VEGETABLES, AND LEGUMES	90	162			23	220			341	16	124	946	2.166	3.207	151	232	119	185	423	432	**8.838**
WOOD AND CORK				48	5	84	39	1.379	566	37											**2.158**
STONE, CERAMIC, AND GLASS MANUFACTURES	572	46							18	158											**794**
METAL MANUFACTURES																			855	97	**952**
MACHINERY, APPLIANCES, TOOLS, AND SPARE PARTS			55	178	227	179	322	636	62	562	309	663	2.631	7.445	183	538	145	429	727	532	**15.825**
BUILDING MATERIALS	3.105	109	177	2	288	36	96.510	909			5.973	974	7.110	1.504	496	109	392	87	755	384	**118.921**
PLASTIC AND RUBBER MATERIALS AND MANUFACTURES	80	80			142	83					241	821							205	734	**2.385**
VARIOUS GOODS AND PRODUCTS	10	62																			**72**
OTHER EXTRACTED AND PROCESSED MINERALS	95	65			186	24	3.293	7.484	24	608	2.157	376	2.465	3.970	172	287	136	229	932	132	**22.634**
OTHER FOOD PRODUCTS			25		1.191	58			521	13	375	159	1.213	3.010	85	218	67	173	479	1.774	**9.361**
OTHER METALLURGICAL PRODUCTS				14																	**14**
PAPER AND PULP		167			99	252					85	334	3.723	2.065	260	149	205	119			**7.458**
LEATHER	1	94																			**95**
ANIMAL FEED AND FORAGE					115	3			20	131			1.322	4.253	92	308	73	245	610	602	**7.774**
PLANT-BASED PRODUCTS		173																			**173**
CHEMICAL PRODUCTS	891	100	17	0	3.567	303	11.357	1.573	126	188	609	1.151	4.710	11.477	328	830	260	661	1.221	609	**39.979**
STEEL PRODUCTS	37	46											5.630	11.959	393	865	310	689			**19.929**
TOBACCO, COCOA, COFFEE, AND SPICES																			528	1.854	**2.382**
TEXTILE AND APPAREL									4	175	562	2.358	861	2.938	60	212	47	169	41	680	**8.106**
WINES, BEVERAGES, ALCOHOLS, AND DERIVATIVES					184				563		911	16	7.515	1.978	524	143	414	114	5.053	128	**17.543**
TOTAL	**5.008**	**1.867**	**1.135**	**965**	**6.114**	**2.612**	**111.522**	**11.981**	**2.422**	**2.525**	**12.481**	**8.183**	**43.269**	**76.385**	**3.018**	**5.407**	**2.385**	**4.396**	**13.010**	**8.304**	**322.989**

Figure 132: Calculation of trucks per type of cargo for export/import shipments and province of origin/destination channelled through the port of Valencia

Source: VPF with data from Spanish customs

As shown in the above table, a total of 322,989 trucks have been calculated that connects the port of Valencia customers located in the hinterland selected for this study. In that sense, a detailed list of types of cargo are shown. Cereals and their flours, Building materials, other extracted and processed minerals, chemical products and wines, beverages, etc. are the main cargoes identified summing up more than 68.55 % of the total amount. Finally, a comprehensive port capture analysis have been made to analyse the potential of each port in terms of cargo diverted from the port of Valencia through a possible shuttle instead of using road transport.

Table 27: Port capture analysis for the TUC "West Med"

Truck = Tones/35		**Export Trucks**	**Import Trucks**	**Total Trucks**
North Area	**Castellón**	118,771	15,557	134,328
	Sagunto	121,156	19,953	141,108
South Area	**Gandia**	17,921	16,115	34,037
	Denia	17,921	16,115	34,037
	Alicante	27,913	19,012	46,926
	Cartagena	32,921	20,879	53,801
	Almeria	18,018	10,171	28,189

Source: VPF

As it can be seen in Table 27, the ports of Sagunto, Castellón in the north and Alicante and Cartagena in the South are good candidates for establishing a shuttle schedule of an autonomous ship to move cargo.

3.6.3.2 Stakeholders

In this section, a draft list of potential and relevant stakeholders is presented. The complexity of a big port environment makes difficult the elaboration of a list of possible involved parties in such as exigent TUC. It should be noted that the Port of Valencia is one of the most important ports in the world where dozens of entities are interacting with each other. The element gathering the common interest of this TUC is the cargo that belongs to hundreds of shippers and are managed by a lot of intermediate and peripheral stakeholders. As the cargo that is expected to be analysed is the sum of the potential cargo shifted, it is impossible to summarise them. In any case, the potential stakeholders are the following:

Administrative and strategic stakeholders (indirect influence on the realization of TUC)

- High Importance
    - Port Authority of Valencia
    - Port Maritime Administration (Harbour master)

- Medium Importance
  - Puertos del Estado – Organisation that manages the Spanish port system
  - MITMA – Ministry of Transport and works
  - DGMM – Spanish Maritime Administration
  - Generalitat Valenciana – Regional Government
  - Customs
- Low Importance
  - Town Hall
  - Borders Inspections Organisms
  - MITECO – Ministry of Ecology Transition

Technological Stakeholders

- High importance
  - Fundación Valenciaport
  - Port Community System
  - TIC 4.0
- Medium importance
  - Infoport

Operational stakeholders that are those that are operationally engaged in the SEAMLESS TUC

- High importance
  - Mooring service
  - Towage service
  - Pilotage service
  - Port Authority of Valencia
  - Customs
  - Harbour Master
  - Stevedores
  - Port terminals
    - MSCTV
    - COSCO
    - APMT
    - Balearia
    - GNV
    - Grimaldi
- Medium importance

  - IPCSA
  - Valencian Shipowners association
  - Freight Forwarders
  - Ship´s Agents
  - Logistics operators

- Low importance
  - TIC 4.0

Other relevant stakeholders in the port

  - Commercial that generate demand for SEAMLESS TUC have not yet been analysed

3.6.3.3 SEAMLESS Waterborne Transport Concept

The SEAMLESS Waterborne Transport Concept including the concepts for vessel fleet as well as ports and infrastructure has not yet been developed and is under work with the most relevant stakeholders.

3.6.4 Requirements and Technology Gaps

The TUC “West Med” depends on all relevant SEAMLESS building blocks. However, as the waterborne transport concept is so far undisclosed, no further details for requirements and technology gaps are given at the moment, expect for the connections with the following building blocks:

- Logistics redesign – Redesigning the whole logistics chain of the TUC
  - Autonomous port operations
  - Mooring system
  - Handling equipment
  - Real time visibility and control
  - Very high-performance hinterland access
- Autonomous fleet operations
  - Remote operations centres (ROC)
  - Remote control/navigation
  - Stowage planning

- Digitalizing logistics operations
  - ModalNet
  - Collaborative framework
  - Digital Administration
  - Voyage Planning & Operational support

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4 CONSOLIDATION OF MOTIVATIONS, BARRIERS AND RESEARCH AGENDA

Picturing a technology adoption life cycle, automation in shipping is still in an early stage in which innovators and early adopters are challenging current implementation boundaries. Hence, a lot of research is currently underway to better understand the motivations, barriers and open questions that may be addressed by technological providers to accelerate market uptake. Among others, the AUTOSHIP project has investigated necessary steps towards a broad implementation of autonomous transportation solutions, e.g. within their *Roadmap for autonomous ship adoption and development (Nordahl et al.)*. The objective was to develop a generalised roadmap for the implementation of autonomous ships in four main shipping segments, i.e., Sheltered Water Shuttles, Inland Waterways, Short Sea Shipping and Deep Sea/Intercontinental Shipping and the identification of gaps, constraints and required policy actions. SEAMLESS task 2.1 starts here and tried to map comparable aspects for selected and very concrete demonstration and transferability use cases. The following chapter consolidates the results of the individual PESTEL analyses from chapters 2 and 3.

4.1 OPPORTUNITIES AND MOTIVATIONS FOR AUTONOMOUS SHIPPING

There are multiple motivations that encourage stakeholders to engage and invest into autonomous and highly automated shipping and grasp its opportunities. It is generally perceived that motivators arise from the need to deviate from the current status or be better prepared for future challenges and can thus be reactive responses as well as proactive measures.

Given this context, it is crucial to have a clear understanding of the motivation for autonomous shipping and an even clearer understanding of missing gaps and added uncertainties that exist for the respective use case. This is especially true for the economic perspective of autonomous shipping, because *“autonomous merchant ships are expected to serve one purpose above others—to haul cargoes between ports, bringing revenue to their owners and operators. Without an economic feasibility of the technology, its concept remains questionable from its very roots.”* (Ziajka-Poznańska & Montewka, 2021, p. 13)

The following section aggregates the results of PESTEL analyses within the Demonstration and Transferability Use Cases and combines it with literature findings in order to outline the most important opportunities and motivations for autonomous shipping.

4.1.1 Political Opportunities and Motivations

Political decisions have the potential to accelerate and foster progress in autonomous shipping. An example where autonomous shipping is brought up to the political agenda, is the Norwegian Government’s action plan for green shipping. It explicitly encourages the development and operation of more autonomous vessels to benefit from their energy efficient and more streamlined operation. In this context, the government is playing an active role in funding relevant projects and in providing aid to legislation on a national and on international level (Norwegian Ministry of Climate and Environment, 2019, pp. 24–25). Furthermore, the Norwegian maritime industry has established the so-called Green Shipping Programme as a public-private partnership to strengthen Norway's ambitions towards improved efficiency and environmental sustainability in shipping (Green Shipping Programme, 2023). Policy makers in Norway have already begun to amend relevant shipping regulations to enable automated shipping in the future and have opened three testing fields for autonomous ships in 2016 and 2017. Having taken a pioneering role in the domain of autonomous shipping, Norway shows a strong political will for further implementation and opens the opportunity for the success of the Northern European Demonstration Use Case.

Many port cities in Europe experience the global trend towards urbanization with ever increasing number of inhabitants that need to be supplied. This means, that the currently already strained supply chains need to prepare for even higher capacity in the future. Currently, last mile city logistics within urban areas is often carried out per truck. An increasing population inside the cities therefore results in an increase of road traffic and congestion which leads to a loss of logistics efficiency. Additional truck traffic also comes with an increase of emissions in greenhouse gases, pollutants and noise, effectively lowering the quality of life inside the city area. Port cities and cities with access to inland waterway networks may benefit from exploiting autonomous shipping for urban distribution with goods via smaller satellite terminals and drop-off facilities that are served by autonomous ships of smaller sizes. Further, existing terminals inside the city can be scaled down and be partly "moved" outside of city centres as a hub port with only smaller automated terminals designed as scaled down feeder ports remaining to sustain the supply chain for the city (*ABB Conversations. From Autonomous Cars to E-Mobility in Shipping: Electric, Digital, Connected*, 2023). The Northern European Demonstration Use Case serves as a good example. The municipality wants to reduce the impact of the port on the city and develop urban residential area. Therefore, it encourages a movement of the terminal from Bergen to Ågotnes and the establishment of an emission free feeder loop between the city of Bergen and Ågotnes.

4.1.2 Economic Opportunities and Motivations

A major economic motivator for autonomous operations is a reduction of operating costs, which is mainly reasoned with the possibility of having less or even no crew on board. Operating autonomous vessels with a reduced crew size while still matching safe manning requirements means that the costs for salaries, accommodation and supply of the crew can be reduced, which is a major contributor to the total operation costs of a vessel. However, there is a consensus, that cost savings for the crew can be diminished by the need for a shore based ROC to control the vessel and the maintenance concept of the vessel (Kretschmann et al., 2017, p. 81; Nguyen et al., 2022, p. 13). A cost model to estimate the yearly cost of a ROC was introduced within the scope of the AUTOSHIP project (Nordahl et al., 2021, pp. 42–44). The literature also mentions that having no crew on board at all times may require having a designated maintenance crew available for any maintenance tasks that can be done during waiting or berth times. However, a designated maintenance or boarding crew creates negative impact on the operating costs of a liner network (Kretschmann et al., 2017, p. 81). In a modelling approach of an autonomous liner network, with conventional so-called “mother ships” operating in international waters while the transhipment in Europe being made with autonomous “daughter ships” it was estimated, that operation costs could be reduced as much as 11 per cent on average, with the possibility of an additional reduction of 6 per cent if advanced transhipment routes would be utilized. In this study total savings in operational costs of up to 20 per cent compared to a conventional operation could be realized if “mother ship” and “daughter ships” were to be engaged autonomously in advanced route management (Akbar et al., 2021, p. 1762). The importance of the configuration of the liner shipping network, the autonomous vessels or the autonomous fleet is operated in, is also highlighted by other authors. A bad configuration or a dynamic schedule of the liner network is expected to have a negative impact on operating costs (Nguyen et al., 2022, p. 25). Nonetheless of all the potential savings associated with autonomous shipping it is assumed, that autonomous solutions will first take off in high-cost countries such as Norway (Akbar et al., 2021, p. 1762).

Besides influencing the operational costs, it is expected, that autonomous ships may also have a reducing effect on the voyage costs. It is assumed that autonomous vessels have an improved fuel efficiency compared to common vessels. Fuel savings in a conservative estimation could be as high as 6 per cent (Nguyen et al., 2022, p. 13). Not having a crew on board allows new ship designs without deckhouse structures that are generally increasing air resistance. A reduced air resistance means lower fuel consumption and therewith additional fuel savings. Fuel consumption is further reduced by a lighter ship weight due to the removed deckhouse and reduced load for the hoteling system. It must be kept in mind, that a boarding crew might be needed for a pilotage or for berthing, which could diminish savings in voyage costs (Kretschmann et al., 2017, p. 82).

While the absence of a deckhouse in an autonomous vessel lowers production costs and therefore the capital costs of an autonomous vessel by an estimation of 5 per cent, it is also expected also, that the required systems and redundancies of an autonomous ship add up to an increase of 15 per cent of the building costs, resulting in increased capital costs for autonomous ships as compared to regular vessels (Kretschmann et al., 2017, pp. 82–83). During the discussion on the SEAMLESS Use Cases it was stated, that emission free propulsion systems may increase the newbuilding prices of future vessels. Some partners argued that this price increase alone may foster autonomous operations as reduced operating costs will support deploying sustainable technologies while still staying competitive. However, these arguments still lack empirical backing.

Besides autonomous vessels potential cost advantages as compared to conventionally operated vessels, other economic factors can be seen as opportunities for autonomous shipping from a broader logistics perspective. It is believed that governmental intervention with regard to economic regulations may support inland waterway transport. As an example, taxes and tolls on the use of roads and bridges apply to means of road transport and effectively raising the cost of road transport, which can be an opportunity for shipping. That autonomous shipping can be more cost efficient than road transport even in shortsea shipping is expected to hold true for the Northern European Use Case. According to estimations for the Bergen Port Authority, using autonomous vessels instead of road transport in the Demonstration Use Case would result in savings of NOK 800[26] per round trip (Flowchange, 2019, p. 11).

Funding and new markets have been identified to be other opportunities for autonomous shipping. Ship owners can receive significant funding or subsidies when deciding to build autonomous vessels or for using alternative propulsion systems such as electric drive trains. Autonomous vessels can also be used as a tool for ship owners to tap smaller, regional markets or use these vessels for direct transport from manufacturers.

4.1.3 Social Opportunities and Motivations

Social opportunities are among the most often raised motivators in discussions on autonomous shipping. An issue that was repeatedly expressed during the discussion on many SEAMLESS Use Cases was that shortsea shipping and inland waterway shipping both lack skilled personnel to ensure safe manning of vessels in the near future. The average age within the respective workforce is often quite high in the two sectors. Although new personnel is in training at all times, it is foreseeable, that it will not fill the gap, that arises when the large share of the current personnel pool will leave due to retirement in the coming years. Autonomous shipping is seen instrumental to close this gap, because it opens up the possibility to operate ships with a smaller crew or with no crew at all (Ghaderi, 2019, p. 168).

Possibilities to create new jobs or changing the scope of existing ones is another social motivator. Even though the role of humans in shipping might decrease, unmanned ships will always rely on monitoring the operations and the possibility to intervene from inside an ROC, where skilled personnel is interacting with the vessel or a fleet of vessels from a control room. Currently, the number of such sites in Europe is quite small, but the demand is expected to increase with an uptake of autonomous vessels being underway (Bogusławski et al., 2022, p. 328). Besides the operators in an ROC, the design and building of autonomous vessels further requires a wide range of skills due to the added complexity of the units as compared to conventional ships. This does not only include engineers and naval architects, but data analysts and specialists in cyber security due to added systems on these types of vessels (Ghaderi, 2019, pp. 167–168). Several universities, for example in Norway, have begun offering specialized courses in the research of autonomous systems. In combination with a general high acceptance of new technologies by the Norwegian population, this is seen as a

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[26] ~71 € (NOK 1 = 0,089 € on the 3rd of August 2023)

good foundation for approaches such as the Northern European Demonstration Use Case and ensures that suitable specialists will also be found for further future applications of autonomous shipping.

During the discussions on the Demonstration Use Cases it was mentioned that jobs onboard of inland vessels and on shortsea ships are generally not seen as attractive in terms of work-life-balance, career prospects and the overall working conditions. Deployment of autonomous systems may potentially improve the attractiveness of these jobs by automating low-stress tasks such as navigating the vessels during long passages and continuously monitoring the surroundings and assisting the seafarers in decision by analysing real-time data measured from various sensors. This relieves seafaring personnel from monotonous works, which was seen as an improvement of the jobs. Literature sources on the other hand claim that reducing the job of a seafarer or of an operator in a ROC to more complex and stressful tasks might achieve the exact opposite and indeed does increase the stress levels of mariners (Tam et al., 2021, p. 52). Also, studies on the long-term effects of ROC are still missing. It is expected that increasingly autonomous vessels become less prone to incidents or accidents that can be traced back to human error, fatigue or substance abuse (Komianos, 2018, p. 336). Also, regarding SEAMLESS Transferability Use Case “West Med” it was highlighted, that autonomous ships can be employed and operated 24/7 as well as on holidays. Working time restrictions that are applicable to an onboard crew are not to be applied to fully autonomous vessels. This trait can be used to improve the logistical service (Akbar et al., 2021, p. 1763). However, it still needs to be examined, which working time restrictions might apply to work-shift organized operators in an ROC.

As such, society may benefit from autonomous shipping by a reduction of external costs, which describe indirect costs that occur to society as a whole and are not being borne by the causer. One of the most typical examples for external costs is air pollution, or the emission of greenhouse gases and noise, congestion or accidents. Shipping is generally considered as a transport means with low external costs as compared to road transport. An autonomous vessel may be managed and controlled more efficient than a regular vessel, which results in reduced total emissions. Although autonomous ships could be designed with a range of different propulsion systems, they are typically designed and fitted with electric propulsion system due of their lower required maintenance compared to diesel powered drive trains. These propulsion systems can be powered with batteries or fuel cells, with the latter now having a significantly lower technological readiness level than batteries. Combining autonomous vessels with a low emission propulsion system reduces external costs even more (Marco Molica Colella & Anastasiya Azarko, 2023).

4.1.4 Technological Opportunities and Motivations

Autonomous waterborne transport concepts require new digital systems, sensors and improved connectivity between the vessel and an ROC. As a result, lots of operational and real-time data is created and recorded. While at the baseline the collection and real-time evaluation of said data is a

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prerequisite to operate autonomous vessels, it is also an asset for technology providers. The collected data can be used by them to widen their understanding of the operation and the behaviour of ships. Improving the operating algorithms, processes and refining the systems that are required to operate the fleet creates new knowledge, which can be a motivating factor for autonomous shipping.

4.1.5 Ecological Opportunities and Motivations

Autonomous vessels share a strong connection with economically sustainable shipping. They are generally fitted with electric propulsion systems. Depending on the electricity mix that is used to charge the vessels, autonomous vessels can be operated with reduced emissions or even emissions free. Same holds true for the use of alternative fuels, if they are sourced in an environmentally sustainable fashion. The need to reduce the transport emissions to tackle climate change creates a big opportunity for autonomous shipping and acts as a large motivator that is already being embodied in legislation and regulation.

4.1.6 Legislative Opportunities and Motivations

A legislative opportunity identified for the Northern European Demonstration Use Case is that the government of Norway is already in the process of drafting regulations for the operation of autonomous shipping. The aim of the Norwegian Maritime Authority is to create a guidance for the construction and implementation of automated vessels that can be operated fully autonomous or at least partially autonomous. Further regulations, such as e.g., those concerning the compulsory pilotage of seagoing vessels, are part of the government's agenda as well. A government body actively supporting the development of autonomous vessels by embodying specific requirements into legislation was considered as a very strong opportunity during the discussions on the Northern European Use Case.

Besides national government, international regulatory bodies are incorporating autonomous shipping into their strategies. The Central Commission for the Navigation of the Rhine declared a detailed vision to improve the digitalization along the Rhine and to promote highly automated and autonomous solutions. It is recognized that automated solutions have the potential to fundamentally change all aspects of inland navigation. The CCNR is creating a landscape to conduct pilot projects in autonomous navigation to gather enough experience to adapt current regulations to a future where autonomous vessels have an increasing share in inland waterway transport (CCNR, 2021b).

Regulation concerning the emission of greenhouse gases, pollutants and noise is getting stronger in many countries. In this context, autonomous vessel fleets possess an advantage towards conventionally operated vessels due to alternative propulsion systems and their more energy efficient operation.

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4.2 THREATS AND BARRIERS FOR AUTONOMOUS SHIPPING

Part of the scope of the PESTEL analyses for each Demonstration Use Case and for each Transferability Use Case was the identification of threats and barriers for autonomous shipping.

4.2.1 Political Threats and Barriers

A big threat to autonomous shipping is an insufficient backing within the political landscape. Lacking political will to support change can result in slowed infrastructural development, which is prerequisite for autonomous shipping. Likewise, political instability especially on a regional level is a significant threat towards autonomous shipping because it poses uncertainty on previous political agendas, visions or strategies and thus will create a unfavourable investment condition.

Also, autonomous inland and shortsea shipping is in competition with other means of transport (i.e., road or rail transport), that are also developing and have their own strategies. This may create the risk that political decision will fall in favour of other means of transport and e.g., new infrastructure or adverse regulations such as tax exemptions.

4.2.2 Economic Threats and Barriers

High initial investment costs are stated as a significant economic barrier in the Transferability Use Case “Black Sea”. This claim is also backed in the literature, although it is stated as well, that high initial investment costs are expected to be diminished by reduced operational costs (Kretschmann et al., 2017, p. 84; Nguyen et al., 2022, p. 13). High investment costs also arise for ports, if new equipment is needed to accommodate autonomous vessels. Section 4.2.40 elaborates further on this topic from a technical side; especially autonomous mooring systems can either be installed on board and make use of existing port infrastructure or they could be entirely located ashore. Ports therefore face the risk of increased investment costs, if autonomous mooring systems are required to be built ashore.

An aspect that needs to be considered in the operation of autonomous vessels in shortsea shipping as introduced within the SEAMLESS use cases, is the productivity of a single autonomous vessel or an autonomous fleet. Due to the vessels being designed for and operated at lower speeds than conventional vessels and possessing smaller cargo capacity, less cargo will be transported over a longer period of time. This renders autonomous vessels less productive and less profitable, whereas more vessels need to be employed in a service. Therefore, goods that are not critical in terms of travel durations and where profit margins are depending on low transport costs, are a suitable cargo choice in autonomous shipping. This is especially applicable, if cargo owner, operator and owner of the vessel are the same legal person. This concept is true for example in the case of the Yara Birkeland (O'dwyer, 2020) and for the Transferability Use Case “Western Europe”.

Competition with other transport means is less of a barrier by itself but rather a risk that is closely tied to economic barriers. This was implied in the Transferability Use Cases “Western Europe” and

“Black Sea”. The associated higher costs of autonomous shipping at least in the beginning could lead to other transport means being a preferable option of shippers and cargo owners from a solely economic perspective. Such a choice could severely hinder further uptake of autonomous shipping technologies before it could profit from economies of scale and technological progress.

A barrier, which was mentioned in the Transferability Use Case “Danube” is the economic activity in the respective corridors. A low level of activity in the hinterland might result in only small cargo volumes that might not be sufficient to justify the establishment of container liner services. While in the context of the use case this threat or barrier is more targeted towards the current situation and the creation of container liner services with conventional vessels, it also holds true for autonomous vessels. Autonomous vessels tend to be of a lower cargo capacity but still require a sufficient level of economic activity to generate a transport demand.

4.2.3 Social Threats and Barriers

Potential social barriers were discussed among the Central European Use Case and in Transferability Use Cases “Black Sea” and “Western Europe”, of which potential repercussions cannot be estimated until a later stage, when autonomous ships start to gain traction. Although autonomous vessels are interpreted as a potential solution towards an insufficient supply of skilled labour, protests against autonomous shipping by unions and lobbyists in fear of jobs losses cannot be ruled out. If and to what extent such protests could develop is not generally foreseeable. The risk of such protests is higher in areas with traditionally strong unions and a strong maritime sector.

Furthermore, a missing acceptance by the public and potential cargo owners could become a threat by creating further opposition or negating the business case of autonomous shipping itself. It is expected that this may especially be the case for high value goods. In this case, high insurance fees may further diminish the competitive of autonomous transports.

4.2.4 Technological Threats and Barriers

Transferability Use Case “Central Europe – UK” mentioned a barrier of technological nature, which is related to the availability to alternative energy sources. The vessels within the SEAMLESS Demonstration Use Cases rely on exchangeable battery-based propulsion systems. However, these batteries are not yet mass produced. Other alternative energy carriers such as hydrogen, ammonia or methanol are as well only available at a small scale yet, although it is expected, that the production for such energy carriers is to be ramped up in the future.

In the same Transferability Use Case it was mentioned, that currently there is no unified solution concerning data transfer and data protocols across several platforms, which is deemed necessary for autonomous shipping, especially with regards to locking and port operations.

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Furthermore, cybersecurity is regarded as a threat that even affects the whole current transport sector. Autonomous vessel operations rely on an increased number of systems and digital interconnection of vessels and the ROC. With increasing levels of autonomy, the reliance on technological systems increases as well. This growing dependence creates additional attack vectors from a cybersecurity perspective, which can lead to more severe threats.

Operational Threats and Barriers

Bureaucracy is an operational barrier, which was mentioned in the Transferability Use Case “Danube”. It was explained that the customs clearance procedure between Serbia and Hungary currently can take up to three days, resulting in delays and sequentially increased transport costs. While this observation is inclined towards the current situation with conventional shipping, it is crucial, that bureaucratic barriers are reduced as much as possible to sustain smooth operations in autonomous shipping. In the Transferability Use Case ”Western Europe” it was discussed that an advantage of the respective use case is the omission of border crossings and hence the prevention of anticipated bureaucracy issues.

Another barrier brought up in the Transferability Use Case “Central Europe – UK” is the lack of unified terminal planning solutions with an integrated stowage planning that respects autonomous vessels.

Compatibility Between Ports and Autonomous Ships

A large cluster of barriers relates to the technological compatibility with existing infra- and superstructures. Two large barriers are the compatibility with existing mooring facilities and existing cargo transfer systems. Vessels usually get moored with mooring lines on bollards, which are mounted on the landside. With autonomous vessels, this becomes an issue, because this kind of mooring is depending on manual labour; at least a crew on board, or on bigger vessels employed in shortsea shipping, an additional mooring crew ashore as well. In autonomous vessels these two crews can be replaced by either landside or boardside solutions. While most ports are still relying on a traditional mooring setup this compatibility barrier could be overcome by the robotic mooring arm setup proposed within SEAMLESS which is under development by SEAMLESS partner MacGregor.

Cargo operations could become less of a barrier, but still was discussed as a potential barrier among the SEAMLESS Use Cases. It is generally agreed, that a traditional shore-based setup of equipment for cargo transfer is a good solution, because it does not rely on having a crew onboard or commanding a ships crane from a ROC, potentially creating safety hazards in the port.

Transferability Use Case “Central Europe – UK” mentioned that bunkering or the energy transfer from shore to an autonomous vessel is an important compatibility barrier that needs to be lowered. Currently most bunkering and energy transfer solutions in ports rely on some form of human interaction to ensure a safe connection between ship and shore, before an energy transfer is conducted. Another compatibility barrier that was mentioned in both Transferability Use Cases “Western Europe” and “Central Europe - UK” is the communication from an autonomous vessel with the port or with other vessels. While VHF communication could be relayed from an ROC, a fully autonomous use case would require safe communication between other autonomous as well as non-autonomous traffic and port participants.

Depending on the route, autonomous vessels might also make use of locks. In this context, the same communication and mooring issues are applicable. However, in the Central European Use Case an idea was discussed, where dynamic positioning could be used to keep the autonomous vessels in position during a locking.

4.2.5 Ecological Threats and Barriers

Unstable weather conditions or non-favourable hydro-meteorological conditions were identified in both Transferability Use Cases "Central Europe – UK" and "Danube". Another considered risk is climate change that adds uncertainty regarding weather stability and could lead to stronger durations of drought periods with low water levels in river and canal networks. These low water levels are a threat towards autonomous vessels that was mentioned during the PESTEL analysis of the Transferability Use Case "Danube". Lower water levels result in vessels that cannot be loaded to their full capacity and raise the need to operate additional ships to operate a service.

In some areas or use cases, the topographies of the seabed can be a challenge for autonomous shipping. Also, when creating routes for autonomous shipping, migratory routes of marine life need to be kept in mind that should not be interrupted.

In some port areas such as in Dunkirk multiple industrial sites exist, to which the Seveso-III-Directive (Directive 2012/18/EU) applies, which refers to establishments within the European Union that handle hazardous substances. These establishments need to produce safety reports and emergency plans and issue policies to prevent major accidents. Relevant authorities and the public need to be informed in case of an accident. Having autonomous vessels operating in such a setting means incorporating them into any relevant plan.

4.2.6 Legislative Threats and Barriers

Several legislative barriers, being currently in place, need to be amended or extended to enclose the operation of partially autonomous vessels controlled from an ROC and the operation of fully autonomous vessels. An example represents article 94 of the United Nations Convention on the Law of the Sea which defines the duties of a flag state and mandates a master and the officers with their appropriate qualifications to be in charge of each ship (United Nations Convention on the Law of the Sea). Other examples are the IMO requiring within the International Safety Management Code, that each ship is to be manned with medically fit seafarers holding valid national or international certificates (Maritime Safety Commitee, 2013) or regulation 14 of Chapter V of the International Convention for the Safety of Life at Sea states that "*all ships shall be sufficiently and efficiently manned*" (International Convention for the Safety of Life at Sea).

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Generally current legislation can more often than not be interpreted in such a way that a crew has to be on board under all circumstances. However, the IMO has embarked into a so called regulatory scoping exercise to address the operation of autonomous vessels (Maritime Safety Commitee, 2021).

A barrier for autonomous shipping is the crossing of borders, because this involves legal systems legislations and authorities of several countries, that all need to be respected. If for example the requirements of one authority in the Central European Use Case are not met, this sets the whole use case at risk to be shut down. This lack of international unified standards and legislation also means, that the ROC currently needs to be in the country of operation.

4.3 IDENTIFIED RESEARCH DIRECTIONS

This document represents an initial analysis of the SEAMLESS use cases and has already revealed a number of topics that are to be considered and potentially addressed in the further course of the project:

Research Topic	Elaboration	Potential KPIs
Maintenance concept	How is (regular/condition based) maintenance done, when there is no crew on board? How is the need for condition-based maintenance detected?	
Repair concept	How are condition-based repairs done? How are condition-based repairs detected?	
Cargo transfer	How can safe cargo transfer be ensured without being dependant on systems that are not widespread available?	
Mooring systems	How can safe mooring be ensured without being dependant on systems that are not widespread available?	
Lock procedure	How are lockings done without damage to the locks or other vessels in the lock?	
Working restrictions in ROC	What working restrictions apply in a ROC? Work on holidays? 24/7 operation possible?	Operation hours per ROC [h/y]
Profitable liner network	How does an economic sustainable business model for an autonomous liner network look like?	Share of Empty Containers [%] Cost of Insurance [$] Cost of Cybersecurity [$]
Bunker concept	How can energy supply from shore to ship be done without direct human interaction? What fuels/energy carriers can be transferred without direct human interaction?	
Communication concept	How is communication with ports/vessels/etc established from a vessel coordinated by an ROC? How is communication with conventional ports/vessels/etc established from a fully autonomous vessel?	

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	How is communication with fully autonomous ports/vessels/etc established from a fully autonomous vessel?	
Cybersecurity attack vectors	What cybersecurity attack vectors apply to remote operated vessels? What cybersecurity attack vectors apply to fully autonomous vessels?	Number of attack vectors [#] Cost of Cybersecurity [$]
Integration with different autonomous means of transport and cargo handling equipment	How does the handshake between remotely operated vessels and other autonomous means of transport (such as trucks) and CHE work? How does the handshake between fully autonomous vessels and other autonomous means of transport (such as trucks) and CHE work?	
Working environment in ROC	What are the working conditions in a ROC? What tasks are done in a ROC? How are the stress levels of the different tasks in ROC evaluated? How is stress handled in ROC?	Stress and pressure [?] Reactions to hazardous situations [#] Sick leave [d/y/employee] Number of vessels operated per remote operator [#]

As part of SEAMLESS WP2, some of the aspects will be acknowledged within the upcoming deliverables D2.2 (SEAMLESS reference logistics architecture, standards, and simplified administrational procedures), D2.3 (Concept of Operations and requirements for SEAMLESS Building Blocks) and D2.4.(Comparative law analysis of existing legal frameworks and roadmap of recommendations).

5 SUMMARY AND OUTLOOK

This report has outlined the conditions and current state of the art of the two demonstration and six transferability use cases. While illustrating the diversity and broad spectrum of potential cases for highly automated and autonomous waterborne transport, the results provide additional focus and support for further course of the project.

First of all, the structured analysis allows to form a common language and understanding of the cases within consortium. Also, it makes visible potential weaknesses and lacking maturity of the current state of work regarding the proposed concepts for autonomous operations. Therefore, the report provides a number of gaps and requirements towards the SEAMLESS building blocks which should be further elaborated on within other work packages of the project for each use case. The document may serve as a repository to further prioritize and coordinate the respective activities.

With respect to WP2, the use case outline may serve as a starting point for an in-depth investigation of the legal framework for autonomous shipping. Furthermore, initial process mappings will be elaborated on to provide reference logistics and administrational procedures, which will ultimately be mapped to the use cases in terms of a concept of operations (ConOps).

Besides its value for shaping the development of technology building blocks and further specification and preparation of use case specific work, a consolidated look on identified opportunities and motivational factors as well as threats and barriers highlights possible levers, constraints and areas of attention. Thus, the results are expected to guide the project on the quest to provide research-based policy recommendations and ultimately foster autonomous operations in shortsea shipping and inland navigation.

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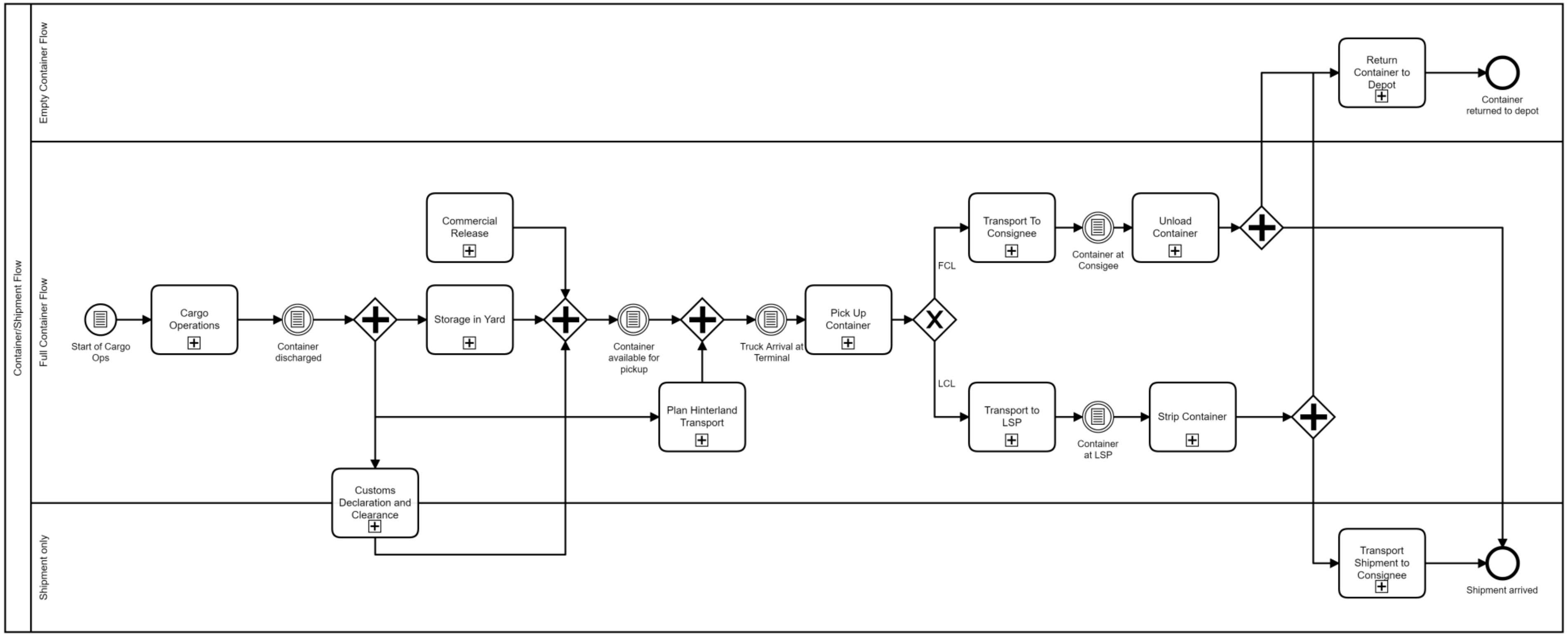
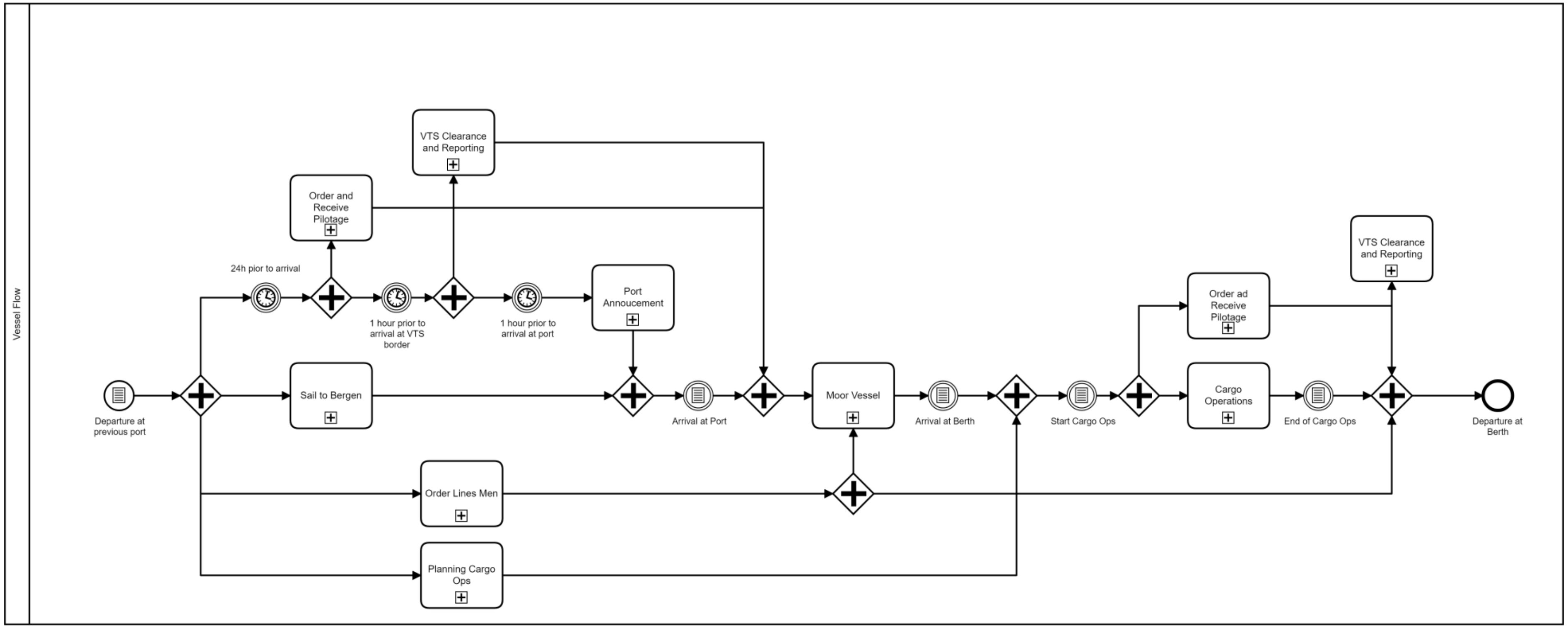
ANNEX

6.1 NORTHERN EUROPEAN DEMONSTRATION USE CASE

6.1.1 DUC1: Existing Import Process (Container/Shipment Flow)



6.1.2 DUC1: Existing Port Call Process (Vessel Flow)



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6.1.3 DUC1: Results of the Stakeholder Analysis

General Information		Role of the Stakeholder		Expectations and Motivation		Stakeholder Influence		Stakeholder Importance		Stakeholder Relations	
Stakeholder Group	**Stakeholder Name**	**Role description within current situation**	**Role description within SEAMLESS use case**	**Objectives and Needs**	**Positive/negative expectations towards use case**	**Describe Influence**	**Influence [0-9]**	**Describe Importance**	**Importance [0-9]**	**Assumptions and Risks**	**Involvement during Project**
Cargo Interest	Manufacturers/Wholesalers/Distributors	Creating demand for transport and logistic services	Creating demand for autonomous transport and logistic services	Efficient transport of cargo from A to B at a low price Reliability and visibility of supply chain	Positive: Supply chain visibility can improve. Reduced emissions in the long run. Negative: Current system is working well for this group. Might fear, that autonomous solution increase transport costs and decrease reliability	Could use trucks instead of autonomous vessels. Could influence decision makers	4	Could become important for the design of the supply chain	5	Opposition against SEAMLESS solutions may hinder the project and evoke lobbyism against it, or for the alternatives (only applicable, if road transport is cheaper)	
Finance/Insurance	Norwegian Government - State funding (ENOVA, RCN, etc.)	Stimulate techonological development and realisation of environmentally friendly and societal cost reducing initatives	Stimulate techonological development and realisation of environmentally friendly and societal cost reducing initatives	Ensure safe and efficient logistics for the public, with minimal societal and environmental costs	Positive: the SEAMLESS solutions provide transport with reduced societal and environmental	Makes the political decision to fund initatives for realisation of transport systems/infrastructure, etc.	9	Depending on SEAMLESS case economic viability, they may be key for realisation, need to focus on providing convicing "material"	9	Failing to match requirements may lead to cutting of fundings.	towards the end they should be approached to present the results and try to gain their support for promoting the seaborne alternative, and to provide subsidies for realisation
Fleet Owner/Charterer/Operator	ASKO Maritime	not specified	See the potential for establishing a dedicated shuttle service operating between Ågotnes and Bergen for the transport of their own cargo. Want to explore the viability of deploying the autonomous ship concept that they have launched in the Oslo fjord (Therese and Marit)	Reduced truck driving, emissions and societal costs from their logistical operations. Smooth, secure and resilient supply chain	Expect efficient zero-emission connection between Ågotnes and Bergen. Want to test their ferry on the route to establish viability	Potential investor in dedicated transport service Ågotnes-Bergen	9	As a potential investor in ships and terminal infrastructure, they are important for the use case. We should get their perspective, requirements, and motivations in more detail	9	Strong strategic interest, mostly interested in their own operations, but as seen in the Oslo fjord, potentially interested in carrying cargo for others to utilise capacity.	Partner, use case participant
Fleet Owner/Charterer/Operator	SAMSKIP/NORLINES, NCL	Calling Bergen with container liner services	Potential ship operator calling on Ågotnes	Competitive transport chain to keep or increase market share and cargo volume	Discussions with individual carriers show scepticism towards the re-location, but positive to creating a waterborne distribution system. Because of the varying depth of relationship with different carriers during and before analysis, these statements are not generally valid for all carriers. SAMSKIP/NORLINES: Positive to autonomous solutions NCL: sceptic to autono-	large network, potential for high influence on the market	7	Important as ship operators must see the business potential in operating based on using the SEAMLESS network/solutions - or else there will be no cargo to transport At least SAMSKIP/NORLINES and NCL are active in innovation projects and demonstrators, showing	7	Failing to convince them may have a negative impact on the market perception of the concept If they fail in their autonomy initatives, it may have a negative impact on the perception of the SEAMLESS concept.	towards the end they should be approached to present the results and try to gain their support for promoting the seaborne alternative

					mous shipping, somewhat less sceptic to autonomous ferries- SAMSKIP/NORLINES: Positive to autonomous solutions NCL: sceptic to autonomous shipping, somewhat less sceptic to autonomous ferries			willingness to invest in novel technology Are active in innovation projects and demonstrators, shown willingness to invest in novel technology			
Fleet Owner/Charterer/Operator	SeaCargo	Calls to the Bergen terminal Dokken for cargo loading/offloading - roro	Potential ship operator calling on Ågotnes	Competitive transport chain to keep or increase market share and cargo volume	SeaCargo (from NTNU Bachelor thesis): Fear negative impact as this means that the terminal is moved away from the market (cargo owner). The increased distance between terminal and cargo owner (last mile distance) might increase costs. Extra handling will also reduce efficiency and increase cost. Believes that much cargo will find another route and be "lost" for the port of Bergen. States that the move to Ågotnes is a financing of increased truck transport	Will need sufficient cargo volume to call to Ågotness - this may depend on the economic and logistical performance of the SEAMLESS solution. Will have market influence through their offered service	5	Important as ship operators must see the business potential in operating based on using the SEAMLESS network/solutions - or else there will be no cargo to transport	3	Could negatively influence market if they don't believe in the solution	
Fleet Owner/Charterer/Operator	Wilhelmsen	not specified	Will establish a freight route in the region, including Bergen and Ågotnes. Received EU financing for a hydrogen powered cargo ship.	Efficient terminal operations to enable their business case and to offer their ship transport service	Want to offer zero, or at least low, emission transport in the region	Invests in ships that may operate in the network, but currently no involvement in SEAMLESS. Could be a costumer of some of the results	3	Could be a driver and ambassador, and potential customer of some of the seamless building blocks such as auto-mooring, and autonomous technology	5		External, unknown if it is feasible with any involvement, but should be targeted for later dissemination activities
Logistics Service Providers	Bring Cargo International	Logistic providers using the terminal Dokken in Bergen	Potential logistics service provider using Ågotnes	(from NTNU Bachelor thesis): Need efficient last mile service, at least as good as status quo	(from NTNU Bachelor thesis): fears leakage of cargo to competitive ports/operators/providers, due to increased costs. Are moving their terminal to Kokstad, which implies truck to Ågotnes. [Unless a nearby shuttle service is established.] States that Ågotnes is too far from the customer, in terms of time and costs this reduces attractiveness.	Customer of the ship operators/owners (SeaCargo) Decides the transport solution that they use	8	Important as customers of the service and needs to be convinced of the competitiveness	8	Risk of losing volume to other ports, or even rail (ref NTNU study), if efficiency is not sufficient to maintain or improve the current level of attractiveness. Potential competitor to the waterborne transport alternative	External, unknown if it is feasible with any involvement, but should be targeted for later dissemination activities
Nautical/Technical Service Providers	Massterly	not specified	ROC operator	Expansion of the business	Positive: Implementation of Use Case grants operation by Massterly	Successful demonstration of business case.	6	Very low competition in the market with some kind of specialisation	8	Without an ROC the successful demonstration of the SEAMLESS Use Case is at risk	involvement via Kongsberg

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						Could influence decision makers inside the use case				
Other	Næringsråd (organisation/cluster for the industry/businesses - there is one for each relevant municipality)	lobbies for building new roads	ambassadors for the case	efficient transportation	efficient transportation alternative with minimal environmental and societal impacts	influences decision makers	6	Convincing them would help in convincing decision makers	7	If they are against the SEMLESS solutions, they may lobby against it, or for the alternatives	towards the end they should be approached to present the results and try to gain their support for promoting the seaborne alternative
Regions and Municipalities	Bergen Kommune	Local government making the political decision of moving the main terminal out of the Bergen city centre to Ågotnes				Makes the political decision of moving the terminal form the city to Ågotnes, approves area development and regulation plans	9	There is a theoretical potential in that the SEAMLESS results could influence their future decision making.	5	High focus on the real-life plans that they have decided to be implemented. Possibly hard to get involved in discussions on theoretical future concepts as they may restrict their thinking towards actual plans. This could be influenced by the project if we produce solid and convincing results that are presented to them	External, unknown if it is feasible with any involvement, but should be targeted for later dissemination activities
Regions and Municipalities	Vestland Fylkeskommune	not specified	Evaluator of results - to be convinced that the solutions are needed and that they should provide subsidies	Needs to provide infrastructure for efficient and environmentally friendly logistics. Needs to reduce societal costs of transport.	Want affordable, zero-emission, sustainable logistics	Could give the framework/requirements for what it would take for them to provide subsidies. If subsidies are needed for realisation, they are important	9	Could provide subsidies for realisation, if they believe in the SEAMLESS concepts and see the benefit	9	Risk: without subsidies, investment decision makers may decide to not invest Need to improve dialogue/relation and make them convinced of the need for the SEAMLESS solutions	towards the end they should be approached to present the results and try to gain their support for promoting the seaborne alternative, and to provide subsidies for realisation
Regulators/Flag States/Port Authorities/Port State	Bergen Havn	Port authority. Infrastructure owner (quays)	Port authority. Infrastructure owner (quays, potentially charging and mooring), terminal operator? Logistics service provider??	Move cargo from road to sea. Reduce noise, traffic, emission, congestion, etc. Facilitate regional transport.	Negative: cargo must be handled more times. Positive: reduced environmental effects - removal of trucks, increased predictability, expanded operational time (transport at night time - reduced traffic in Bergen sent rum in daytime/rush hours). Positive: Expect that the project produces input document to authorities (municipality) documenting economy, social costs, and need for subsides, compering to what they are already doing for personnel transportation.	Decision maker for investments, for what area development and regulation plans are prioritised for seeking approval, etc. Political influencer and facilitator for realisation. Publishes tender and can provide incentives (incl. economic) for stimulating realisation. Driver for acquiring subsidies if needed.	9	They are the "owner" of the Northern use case in that they are the port authority who are to make actual changes in the use case transportation network. They are key to give the project real life data. For the more academic studies which can be based on the Bergen case, they are important in understanding the area, the potential and the relevant stakeholders.	9	The market has low margins, showing that the SEAMLESS solutions results in significant cost reduction is critical for realisation. This can be difficult. Societal savings will be important to quantify such that it can be used to convince authorities that subsides should be provided. This will also be very different for the different "From-To" combinations. Often the cargo owner chooses truck due to the ability to track cargo. Similar solution is needed for ship transport. High likelihood of dependence on subsidies. This is provided for personnel transport, e.g., "Ratpack 2" Vestland Fylkeskommune (989MNOK 2024-2036). Similar subsidies are not currently provided for cargo transportation! Significant opportunity! The municipality	Partner, use case participant

										provides contract for operation of personnel transport which is significantly subsidised, should be possible to do the same for cargo.	
Regulators/Flag States/Port Authorities/Port State	Classification Societies	Classification of vessels and autonomous equipment	Regular class renewals	Maintain high level of safety and technical standards.		Vessel can probably not be operated without class	9	Comparable systems exist, society is only responsible for classification	2	Without a class the successful demonstration of the SEAMLESS Use Case is at risk. Probability of that happening is low -> comparable vessels with class exist	
Regulators/Flag States/Port Authorities/Port State	Kystverket (Coastal Administration)	Responsible for sea routes and ensuring safe and efficient traffic along the coast and into ports	Responsible for development/maintenance of fairways and VTS area and reporting in Byfjorden	Maintain high level of safety. Get to know requirements of autonomous vessels towards fairways, VTS, communication, etc.	Positive: Successful demonstration proves safe operation of autonomous vessels and conventional among each other	Decides, if/how autonomous vessels are obliged to report during operations in coastal waters and VTS	9	Strong involvement during the project to elaborate operating concepts. Permissions for autonomous sailing might be required	9	If they are against the SEAMLESS solutions for any reasons, they have the legal power, to withdraw permissions or shutdown operations	
Regulators/Flag States/Port Authorities/Port State	Sjøfartsdirektoratet (Norwegian Maritime Authority)	Supervisory authority related to safety, health, material assets and environment and shipping.	Create a guidance for the construction and implementation of automated vessels that can be operated fully autonomous or at least partially autonomous	High level of safety and cleaner environment.	Positive: Successful demonstration proves safe and environmentally sustainable operation of autonomous vessels and serves as a blue print for further legislations/regulations/etc	Decides, whether autonomous vessels are allowed to navigate territorial waters.	9	Involvement in the project and DUC design is not necessary. Permissions might be required.	3	If they are against the SEAMLESS solutions for any reasons, they have the legal power, to withdraw permissions or shutdown operations	
Sea-/Inland Port Operator	Green Port Services	Terminal operator for MEARSK, NCL, MSC, Arctic Container Line, at Bergen Port	Potential terminal operator at Ågotnes	(from NTNU Bachelor thesis): Need increased capacity, but would prefer that Dokken capacity was increased rather than moval to Ågotnes. Need efficient last mile service, at least as good as status quo	(From NTNU Bachelor thesis): fears leakage of cargo to competitive ports/operators/providers, due to increased costs. States that Ågotnes pricing must be low to compensate for increased distance to cargo owners/market. States that the cheapest option will always win, and fears that the moval will make Ågotnes-Bergen too expensive	Will want to position themselves as operator at Ågotnes - potential important ambassador	3	Important as terminal operators if they are chosen (9), but currently low	3	Risk of losing volume to other ports, or even rail (ref NTNU study), if efficiency is not sufficient to maintain or improve the current level of attractiveness.	minimal, unless Bergen Port signs contract for them to operate the terminal at Ågotnes. If they become terminal operator, they will be important and will be involved
Sea-/Inland Port Operator	Westport	Terminal operator for SAMSKIP and SeaCargo, at Bergen Port	Potential terminal operator at Ågotnes	(from NTNU Bachelor thesis): Ågotnes and the link to Bergen (end destination/source) needs to be efficient. The existing terminal is old and	New location could lead to increased cost due to extra transhipment, or need for road transport. Use case must overcome these challenges	Will want to position themselves as operator at Ågotnes - potential important ambassador	3	Important as terminal operators if they are chosen (9), but currently low	3	Risk of losing volume to other ports, or even rail (ref NTNU study), if efficiency is not sufficient to maintain or improve the current level of attractiveness.	minimal, unless Bergen Port signs contract for them to operate the terminal at Ågotnes. If they become terminal operator, they will be important and will be involved

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				not efficient. Terminal internal logistics is inefficient. Ågotnes could become the most modern terminal in Norway. Compering to similar changes (Stavanger) it is possible to increase activity and market share, if things are done correctly. New mini-terminal in Bergen must have high throughput. Need, or want, improved efficiency relative to status quo.							
Technology Provider and Research	Cavotec	not specified	Providing the mooring solution	Sell another mooring system	Positive: Selling mooring systems		1	Low competition in the market. Strong market position.	6	Risk: Concept getting too expensive. Might drop out, if technology is not economically viable in the long run	
Technology Provider and Research	Kongsberg	not specified	Development and technological implementation of operation concepts.	Development and marketing of new autonomous shipping technologies	Positive: Development and successful demonstration of operation concepts	large network, potential for high influence on the market	8	Low competition in the market. Strong market position.	8	Risk: Concept getting too expensive. Might drop out, if technology is not economically viable in the long run	Technology Provider for operating concept
Technology Provider and Research	MacGregor	not specified	Further development and implementation of triple joint crane for cargo operations and autonomous stowage planning	Development and marketing of new shipping technologies	Positive: Development and successful demonstration of operation concepts	large network, potential for high influence on the market	7	Autonomous stowage planning is a crucial part of a seamless logistic chain and currently low competition.	7	Risk: Incompatible data exchange between stakeholders involved in the cargo operation hinders autonomous stowage planning. No efficiency gains. Crane concept not applicable on the vessel.	Technology provider for stowage planning and cargo transfer
Technology Provider and Research	Naval Dynamics	not specified	Conceptual development of autonomous vessels	Selling ships and getting more experience in building autonomous vessels.	Positive: Successful implementation of the use case means, that the ship is built by ND. Successful implementation also great for marketing.	High competition in the markets with other ship designers. Designing the vessel to the requirements of the client.	1	High competition in the market. Experience with autonomous vessels available.	2		
Technology Provider and Research	SINTEF Ocean	not specified	Contribute in quantification and impact studies. Participate in policy recommendation and possibly input paper to municipality or Norwegian government	Sustainable, zero emission, efficient transportation with minimal societal impacts	Expect efficient zero-emission transport service that may have an application in several areas. Expect that extra terminal costs will be a significant obstacle that we must overcome. Hope	Research and knowledge provider, ambassador for the SEAMLESS case and solutions. Extensive industry, policy, standardisation body, and other	7	In autonomous ship research STF has a good reputation and have an influence on stakeholder opinions. Do not have any direct investment decision	7	View the additional handling of cargo as a high risk for the commercial viability. See the need to develop new and efficient solutions as additional handling may break the business case irrespective of how efficient the ship operates.	Partner, use case participant

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					to influence the decision-making processes related to establishing a waterborne transportation service in the Bergen region. Expect that project results can be used to promote SEAMLESS solutions and that if they do, that we can contribute to stimulating subsidy providers to invest in SEAMLESS solutions.	relevant stakeholders, network.		making role, though many actors trust STF opinion and may make decisions influenced by STF research. STF also have a role in the forming of policies by providing inputs based on research.			

6.2 CENTRAL EUROPEAN DEMONSTRATION USE CASE

6.2.1 DUC2: Results of the Stakeholder Analysis

General Information		**Role of the Stakeholder**		**Expectations and Motivation**		**Stakeholder Influence**		**Stakeholder Importance**		**Stakeholder Relations**	
Stakeholder Group	**Stakeholder Name**	**Role description within current situation**	**Role description within SEAMLESS use case**	**Objectives and Needs**	**Positive/negative expectations towards use case**	**Describe Influence**	**Influence [0-9]**	**Describe Importance**	**Importance [0-9]**	**Assumptions and Risks**	**Involvement during Project**
Cargo Interest	TBD	Cargo Owner	derivative stakeholder	na	Neutral	Useful	6	Could be replaced by alternative	6	Good flows do not realise	Non-Member
Fleet Owner/Charterer/Operator	Danser	Operate the barges	provide the economic flows	operate barges	Positive	Important	8	Alternatives can be found but preferably not	8	Good flows do not realise	Non - member
Infrastructure Service Provider	ZENOBE	Provide infrastructure & power packs	provide energy in usable form	energy needs fulfilled	Positive	Important	8	Alternatives can be found but preferably not	8	Delays due to environment permits	Non - member
Infrastructure Service Provider	ZES	Provide infrastructure & power packs	provide energy in usable form	energy needs fulfilled	Positive	Important	8	Alternatives can be found but preferably not	8	Delays due to environment permits	Non - member
Logistics Service Providers	TBD	Freight Forwarder	derivative stakeholder	na	Neutral	useful	6	Could be replaced by alternative	6	Good flows do not realise	Non-Member
Regulators/Flag States/Port Authorities/Port State	CCNR	Approval autonomous operation & alternative propulsion	determining approval critera	Approval & regulatory change	Positive	Essential	9	Essential	9	Can strongly influence result/Success	Non - member
Regulators/Flag States/Port	CESNI	Technical Approval	determining approval critera	Approval & regulatory change	Positive	Essential	9	Essential	9	Can strongly influence result/Success	Non-Member

Authorities/Port State											
Regulators/Flag States/Port Authorities/Port State	De Vlaamse Waterweg (DVW)	Approval autonomous operation & alternative propulsion	determining approval critera	Approval & regulatory change	Positive	Essential	9	Essential	9	Can strongly influence result/Success	Non - member
Regulators/Flag States/Port Authorities/Port State	Generaldirektion der Wasserstraßen und Schifffahrt/Wasserstraßen- und Schifffahrtsverwaltung des Bundes	Approval autonomous operation & alternative propulsion	determining approval critera	Approval & regulatory change	Positive	Essential	9	Essential	9	Can strongly influence result/Success	Non-Member
Regulators/Flag States/Port Authorities/Port State	Lloyds Register	Classification Society	certification of vessel and RCC and related ystems	Full certification	Positive	Essential	9	Essential	9	Can strongly influence result/Success	Non-Member
Regulators/Flag States/Port Authorities/Port State	Local Police of relevant waterway	Police	Upholding regulations & laws	Ability to uphold in new systems	Neutral	Essential	6		7		Non-Member
Regulators/Flag States/Port Authorities/Port State	Rijkswaterstaat (RWS)	Approval autonomous operation & alternative propulsion	determining approval critera	Approval & regulatory change	Positive	Essential	9	Essential	9	Can strongly influence result/Success	Non - member
Regulators/Flag States/Port Authorities/Port State	Voies Navigables de France (VNF)	Approval autonomous operation & alternative propulsion	determining approval critera	Approval & regulatory change	Positive	Essential	9	Essential	9	Can strongly influence result/Success	Member
Sea-/Inland Port Operator	Nijmegen terminal - BCTN	Approval to operate in the port	determining approval critera	Approval & regulatory change	Positive	Important	8	important for success	8	Potential delaying factor	Non - member
Sea-/Inland Port Operator	North Sea Ports	Approval to operate in the port	determining approval critera	Approval & regulatory change	Positive	Important	8	important for success	8	Potential delaying factor	Non - member
Sea-/Inland Port Operator	Port de Lille	Approval to operate in the port	determining approval critera	Approval & regulatory change	Positive	Important	8	important for success	8	Potential delaying factor	Non - member
Sea-/Inland Port Operator	Port of Antwerp - Bruges	Approval to operate in the port	determining approval critera	Approval & regulatory change	Positive	Important	8	important for success	8	Potential delaying factor	Member
Sea-/Inland Port Operator	Port of Duisburg	Approval to operate in the port	determining approval critera	Approval & regulatory change	Positive	Important	8	important for success	8	Potential delaying factor	Member

Seafarers/Unions	Unions (e.g., EBU/ESO)	Protect seafarers' rights	Define jobs	Define jobs	Positive	Important	7	important for success	7		Non-Member
Technology Provider and Research	Macgregor	Provide mooring system	develop mooring system	provides Mooring system	Positive	Important	8	Could be replaced by alternative	8	Development risk	Member
Technology Provider and Research	TBD	Autonomous container barge	develop autonomous container barge	Provide carrier	Neutral	useful	6	Could be replaced by alternative	6	Development risk	Non-Member
Technology Provider and Research	TBD	Cargo data platform	Develop platform	provide platform	Positive	Essential	9	important for success	9	Development risk	Non-Member
Technology Provider and Research	TBD	Remote Control Centre	develop Remote Control centre	Provide RCC	Positive	Essential	9	Essential	9	Development risk	Non-Member
Technology Provider and Research	TBD	Communication systems	Develop data communication platform	provide data communication platform	Positive	Essential	8	Alternatives can be found but preferably not	9	Development risk	Non-Member
Technology Provider and Research	ZULU	Provide and invest in barge	provide barge & manage LL	Provide barges	Positive	Essential	9	Essential	9	Building risk	Member

6.3 TRANSFERABILITY USE CASE "DANUBE"

6.3.1 Annex 1 – Unloading of cargo at the Port of Novi Sad

MAPPING OF TECHNOLOGICAL PROCESSES

It is assumed that the border control can be carried out at the port of loading[27]. Motor cargo vessel (MCV) arrives at the anchorage area. MCV is anchored, i. e., the bow anchor is dropped down. The MCV stays at the anchorage, until a call arrives from the agent, with a request to reach the police quay. After receiving the call, the anchors are raised and the MCV performs a separate navigation to the police quay. Upon arrival, the MCV is moored to the quay. The ship's agent boards the MCV. A report is made to the border police and the competent harbour office, i. e., the border control procedure is carried out.

Upon completion of this process, the ship agent notifies the port that the MCV is ready for unloading. The MCV unmoors from the police quay and manoeuvres back to the anchorage. At the anchorage, the bow anchor is dropped down again. MCV stays at the anchorage until a call arrives from the port representatives, i. e., notification that the port is ready to unload the cargo.

The ship agent hands over the required documentation to the freight forwarder of the cargo owner, who completes the customs formalities at the competent customs office, so that the cargo is formally ready for unloading. After the completion of customs clearance, the freight forwarder is obliged to submit a customs declaration to the port operator, so that the port operator can plan the unloading of cargo from MCV.

After receiving the call from the port dispatch service, the MCV raises the anchor and sails to the port's quay where unloading will be done. Upon arrival, the port workers receive ropes from the vessel, secure them and therefore assist the process of mooring MCV to the unloading quay.

Handing over and receiving of cargos is done in the presence of the representative of the shipowner, i. e., ship's crew and the port operators. The port is debited and re-debited with the cargoes based on the declared weight and number of parcels from the transport, i. e., customs documentation or the handing-over certificate. Upon request, and at the expense of the user of the port services, the Port is obliged to carry out official measurements or readings of the weights of individual parcels and make a record of any differences. The Port bears no responsibility for the resulting differences.

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[27] In accordance with the adopted Regulation on the regime of border controls of foreign and domestic vessels ("Official Gazette of the RS", no. 94/2019), the entry border control for vessels transporting goods subject to phytosanitary and veterinary control is carried out at the Bogojevo and Veliko Gradište border crossings, and for other vessels with goods that are not subject to phytosanitary and veterinary control, the entry border control can be carried out at the border crossing in the port of unloading.

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If the cargos are weighed on the port's truck scale during reception, the port is debited with the measured weight. Allowed deviations are within the tolerance limits of the electronic truck scale. The port is responsible for the difference outside the tolerance limits. If the cargoes are not weighed on the port's truck scale at the reception, and are weighed on the dispatch, the Port is not responsible for any difference between the weight measured during dispatch and the received declared weight.

The Port is not responsible for any defects-damages caused to the cargoes before unloading from the ship as well as any other transport mean, nor does it accept complaints. The port is responsible only for those damages which were caused by its labour and handling equipment, during unloading process. Observed defects-damages to the cargoes should be recorded immediately in the handing-over certificate.

Representatives of the inspection company, engaged by the shipowner or owner of the cargo, come on board and take the initial draft. Draft Survey Report (DSR) is issued, which is also signed by the ship master. After that, the cargo can be unloaded. Inspection company performs quantitative and qualitative control of the cargoes and prepare daily reports during unloading process. The time of cargo unloading depends on the unloading capacities at the unloading quay, i. e., the unloading rates for a specific appearance and type of cargoes. In Novi Sad, for bulk cargoes, it is about 1000-1500 mt/day.

When the unloading process is finished, the representatives of the inspection company come back to the ship and take the final draft. They issue again a DSR (Draft Survey Report), which, again, is signed by the master of the ship. The MCV executes unmooring from the unloading quay and performs a manoeuvre to the anchorage. It is anchored by lowering the bow anchor. In the event that loading of cargo is to be carried out in the same port, the ship's holds must be cleaned of the previous goods, that is, those that have been unloaded. Basic cleaning (with brooms) can also be done while the ship is moored at the unloading place. This kind of cleaning, which is usually done by the crew themselves, regularly takes up to one day. It is also possible to hire specialized companies, or third parties, that deal with these kinds of jobs.

INFORMATION FLOW

Before the arrival of the ship (MCV) in the port, the shipowner, via e-mail, makes an announcement of arrival to the ship's agent ("agency nomination"). After receiving the nomination, the ship agent has the task of informing all interested parties (stakeholders) about the expected time of arrival of the ship. The information is delivered either by e-mail or by phone. The interested parties are the border police (for a foreign flag ship) or the harbour office (if the case of arrival of a domestic ship), then the port operator, the forwarder (hired by the shipper or the buyer of the goods), as well as the buyer's customs agent. In order to give the ship agent enough time to deliver all the information to all the mentioned parties, in a timely manner, the nomination by the shipowner is made up to several days (at least one day) before the expected arrival of the ship in the port. However, inland shipping shipowner i. e., his agent is obliged to inform the port operator and the shipper, i. e., the recipient, about the time of the ship's arrival at the port of unloading or loading, within 72 hours before the expected arrival of the ship to the port, with the obligation to determine the actual time of arrival 24 hours earlier. If the ship is subject to paying port fees, the shipowner / his agent is obliged to inform the Port Governance Agency about the time of arrival of the ship at the port of unloading or loading.

After receiving the nomination and based on communication with the port operator, the agent informs the shipowner about the situation in the port in terms of the quay occupancy and existing schedule of serving ships at the quay. In this way, the shipowner receives information about the expected waiting time of the ship, as well as the number of ships that have already been nominated for handling at the quay. The agent delivers this information to the shipowner via e-mail. An example of such notification can be: "We have announced the ship arrival to the port operator. The ship is the fourth in waiting line to be served."

When the entry border control is completed, the ship agent issues a Notice of readiness - NoR. The agent, via e-mail, delivers the NoR to the port operator and the shipper, i. e., the buyer of the goods. The issuance of the NoR means that the ship is ready to unload the cargo, as well as that the ship is waiting for notification from the port that the quay is free. When such a notification arrives, the ship performs the manoeuvre from the anchorage to the unloading quay. Upon arrival, MCV is moored to the unloading quay. The NoR is also used as a valid document for calculating ship demurrage, should it occur. Demurrage is calculated after all unloading and loading activities at the port are completed. Those activities are considered completed at the moment when the inspection company completes the procedure of taking the final draft.

Upon completion of the cargo unloading process, the agent issues a Statement of Facts (SoF). It contains data related the cargo unloading process, i. e., the start and end times of these activities, as well as data on its interruptions, if any. The reasons for the interruption of unloading processes are also described in the SoF. Some of the possible reasons for interruptions are the following:

- weather conditions (rain, snow, fog, wind);
- malfunctions of the port equipment;
- lack of cargo space in the trucks into which the cargo is unloaded;
- malfunctions of the barge (most often on the hatch covers);
- unpreparedness of the crew regarding the preparation of the barge for unloading cargo;
- unpreparedness of port gangs;
- interruption due to giving priority to another ship at the unloading quay.

Before the agent issue the SoF, the shipowner checks and approves its content. The shipowner can request correction of the provided data, if the data does not correspond to the information at his

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disposal. After issuing the SoF, the agent also submits it to the port operator for review and signature. The port operator may also ask to change the provided data, in case they do not agree with the unloading process data available to the port operator. After the port operator signs the SoF, it is considered that all provided data has been officially confirmed. SoF can also be used to calculate ship demurrage, if it occurs.

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6.3.2 Annex 2 – Loading of cargo at the Port of Novi Sad

MAPPING OF TECHNOLOGICAL PROCESSES

Upon completion of the cleaning, i. e., washing and drying of the cargo holds, the shipping agent issues a Notice of Readiness (NoR) and sends it to the port. The MCV stays anchored until it receives a call from the port, i. e., an announcement that it is possible to load the cargo at the allocated quay. Upon receiving the call, the anchor is raised and the MCV sails to the loading quay in the port. After arrival, it is moored to the loading quay, i. e., port workers receive mooring lines and secure them. Representatives of the inspection company board the MCV and take, that is, read the initial draft of the ship. They prepare the Draft survey report and enter the draft values. Ship master signs the DSR. Once this process is completed, the loading of the cargo onto the ship begins. The usual loading rate for bulk cargoes in the Port of Novi Sad is around 1000-1500 mt/day. After the cargo loading process is completed, representatives of the inspection company come and board the MCV. The final draft is taken and provided in the Draft Survey Report. The master of the ship signs this report.

MCV executes the sailing manoeuvre to the anchorage. MCV is anchored by lowering the bow anchor. The ship stays at the anchorage, until the agent informs the master that it is possible to check out at the border police and the authorized harbour master office. When such an information (a call) from the agent arrives, the anchor is raised and the MCV executes a manoeuvre to the police quay. Upon arrival, the ship is moored to the quay. The ship's agent boards the MCV and checking out at the border police and the harbour master office is performed. The freight forwarder, on behalf of the shipper - owner of the goods, submits all documents obtained from the competent institutions (phytosanitary, veterinary inspection), as well as bill of lading and cargo manifest received from the agent of the ship, to the competent customs office for the purpose of carrying out customs formalities. Upon completion of customs formalities, the freight forwarder submits the documentation to the shipping agent. The shipping agent boards the MCV, submits the documentation to the ship's crew and check-out is made at the border police and harbour office.

INFORMATION FLOW

After cleaning and drying the MCV cargo space at the anchorage area, the shipping agent issues a Notice of Readiness (NoR) and delivers it to the port, via email.

Upon completion of the cargo loading process, the shipping agent issues a bill of lading and a cargo manifest. Before issuing the bill of lading and the cargo manifest, the agent must obtain the approval of the values entered in these documents by the shipping company and shipper. So, the agent delivers these two documents to the shipping company and the shipper via e-mail and asks for their approval. Once approved, the agent stamps and signs both documents. They are then sent to the forwarder, designated by the shipper, to be used for the preparation of customs documentation (T1L and T2L). The freight forwarder is in charge of preparing the customs documentation. The original

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documentation is delivered by mail directly to the shipping agent at the location where the exit border control (revision) is to be performed. Customs documents are therefore delivered to the ship at this location. The ship can depart and start navigation only when all customs documents are on board.

The shipping agent delivers a bill of lading and a cargo manifest to the freight forwarder, which was appointed by the shipper. Bill of lading (as well as, the cargo manifest) contains information about the total quantity of cargo loaded into the ship. This quantity is usually determined in two ways. The first way involves determining the quantity of cargo in the ship on the basis of the tonnage measurement certificate, and according to the draft of the ship, which is provided in the Draft survey report (DSR). The second way refers to the determination of the quantity based on the measured values on the weighbridge (truck scale) in port. Therefore, the mass of each truck is measured before and after unloading the cargo (which is then loaded onto the ship). The difference between these two quantities represents the net quantity of cargo loaded onto the ship. The shipping agent receives a list of all trucks and the net unloaded quantities for each one. The total amount of these quantities is entered in the Bill of lading.

In order to carry out an exit border control (revision), the ship master has to have the following documents on board: the exit report and the list of the crew with their passports. In the case of foreign ship, the border police, in the presence of the shipping agent and the ship master, approves (stamps) these documents. In the case of domestic ships, they just sail to the place where the exit border control is carried out. After the documents are verified and stamped, the representatives of the border police disembark from the ship, the ship is unmoored from the quay and begins downstream navigation (in case it is heading towards the Port of Constantza). The exit border control (revision) is carried out in Veliko Gradište.

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6.3.3 Annex 3 – Lock-through processes

MAPPING OF TECHNOLOGICAL PROCESSES

After the MCV arrives at the lock, in a situation where the lock is occupied, it is anchored at the anchorage area. It stays at anchor until the MCV receives an invitation to enter the lock. When such invitation is received, the anchor is raised and the ship sails to the access channel. If other ships or convoys, for which the lockage process has been completed, are leaving the lock, the MCV is moored to the wall of the access channel. MCV stays at that position waiting for the lock chamber to become free. When this happens, the ship enters it and begins the process of adjusting the water level in the lock chamber.

After entering the lock chamber, the MCV is moored to the bitts located on the lock wall. During the lockage, the ship's engines remains on, but it is forbidden to use them for manoeuvring in the lock. The crew is on the deck and carries out the lashing of the MCV during the water level adjusting process, depending on the type of bitts used in the lock. There are two types of bitts, stationary and self-levelling. With stationary ones, it is necessary to constantly transfer steel ropes to bitts at different levels by following the changes in the water level in the lock, while, with self-levelling ones, the height of bitts is automatically changed with the change of water level. After the completion of lockage and opening of the lock gates, the ship is unmoored from the bitts and continues sailing.

INFORMATION FLOW

While approaching the lock, the crew members, via VHF radio connection, notify the arrival of the MCV for lockage to the lock operators. This notification is made when the ship is about one to two hours away from the lock itself. The ship's arrival is notified by the master or another crew member who has permission to work with the VHF radio station (a special certificate is required for use). With this notification, lock operators (lock masters) are provided with information about the current position of the ship (river kilometre where the ship is located), sailing speed, expected time of arrival at the lock, MCV size and sailing mode. The lock master, based on the information received, informs the ship whether the lock chamber will be occupied at the time of the ship's arrival, i. e., whether it will be necessary to anchor the MCV and wait in the queue for lockage. This assessment is given by taking into account the number of ships already waiting to be locked, as well as the MCV sailing mode. For example, the MCV sails in A1 mode, and sailing is allowed until 20:00. The estimated time of arrival at the lock is at 19:30. In this case, the lock operator will give an order to anchor the MCV until the next morning at 6:00 a.m., when sailing in that mode will be possible again.

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6.3.4 Annex 4 – Passing through Danube – Black Sea canal

MAPPING OF TECHNOLOGICAL PROCESSES

The time of the border control (entry revision) and the boarding of the pilot on the ship depends on the its arrival time in Černavoda, as well as on its mode of operation (A1, A2, B). The mode of operation has the greatest influence on the start time of navigation through the channel. If the MCV arrived in the evening, the border control will be done upon its arrival. In this case, the arrival and boarding of the pilot on the ship is scheduled for 6:00 a.m. the next morning. If the MCV arrived in Černavoda during the day, the border control will also be done upon its arrival. However, the start of navigation through the canal, i. e., the embarkation of the pilot, depends on the chosen mode of operation. Considering the transit time through the canal (around 5-6 hours), as well as the time needed to pass through the two locks, the arrival of the ship in the afternoon, with the A1 mode of operation (daytime navigation for maximum 14 hours within a period of 24 hours), would probably also mean delaying the transit through the canal for tomorrow. In other words, the boarding of the pilot would take place the next day in the morning. Navigation in B mode of operation allows transit through the canal even during night. In order to increase the navigational safety of ships that transit the canal during the night (sailing in the B mode of operation), ships that sail in the A1 and A2 modes of operation usually do not spend the night in the canal.

After the MCV reaches Černavoda, it is anchored at the designated anchorage area. While the ship is at the anchorage, representatives of the competent port authorities and the border police board the ship, in order to carry out a border control (revision) for entry in Romania. Representatives of these authorities come to the ship in their own boat, in order to speed up the process of implementation of entry formalities, i. e., entry revision. This kind of practice is not common for Danube, but is specific only to Černavoda, because the border control of a large number of vessels is carried out there. If the MCV or any other ship leaves the canal in Černavoda, then the border control for exit the Romania is performed at the anchorage area.

The time of boarding the pilot on the ship depends on the estimated time of departure, i. e., transit of the MCV through the canal. However, if the transit is planned to be done on the same day as the border control, it may happen that the pilot arrives in the same boat as the representatives of the competent authorities. If this is not the case, the pilot comes in a special boat.

After the pilot boards the ship, the MCV stays at the anchorage area until it receives a call from the Černavoda lock operator. Regularly, no more than an hour passes from the moment the pilot boards the ship to the moment the call is received. After receiving the call, the anchor is raised and sailing to the lock (access channel) is performed. This is where the MCV enters the waiting queue for lockage. The lockage process is already described in a separate chapter.

After the lockage at the Černavoda lock is completed, the MCV begins navigation through the canal up to the Agigea lock, with a total length of about 64 km. During the navigation through the canal,

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the ship's master steer the ship, but also follows the advices, if necessary, regarding the safety of navigation, from the onboard pilot.

The width of the canal allows ships to pass each other safely, while overtaking is prohibited. Navigation through the canal goes up to the Agigea lock and takes about 5 to 6 hours. The maximum permitted speed of navigation in the canal is 10 km/h.

After arriving at the Agigea lock, the MCV is moored to the wall of the access channel. At this position, the ship joins the queue, if there is one, and wait for the lockage. However, there is usually no waiting line. After the lock chamber becomes free from the ships being locked in the opposite direction, the lockage of the MCV takes place. In other words, the ship sails into the chamber and is locked into the Black Sea. After the lockage process is completed and after receiving permission, the MCV leaves the Agigea lock and arrives at the Port of Constantza.

After lockage, the MCV, together with the onboard pilot, performs navigation manoeuvre to the berth (wall) for pushers and self-propelled motor vessels. In this way, the crew is given access to the shore. The pilot disembarks from the ship. The MCV remains in this position, i. e., moored to the berth, until it receives a call to unload or load cargo.

INFORMATION FLOW

Sailing of MCV through the Danube-Black Sea canal implies execution of a number of activities, granting of authorizations and the exchange of information between several participants. The shipping company, first of all, announces the expected arrival of MCV and intended passage through this canal to the ship agent. This announcement, or nomination, is most often realized via e-mail, a few days before the ship's arrival in Cernavodă. The nomination procedure involves submitting Agency nomination to the ship agent, which the ship owner has previously signed and certified. The following information is entered in the nomination itself: the name of the shipowner, the name of the agent, the name of the motor cargo vessel, the type and quantity of loaded cargo, the name of the shipper, as well as the estimated time of arrival of the MCV in Cernavodă. In the e-mail, through which the nomination of the agent is made, the following documents are also delivered to the agent: bill of lading, cargo manifest, customs documents (T1 or T2L), report on arrivals and departures (report 1 and 2), crew list, as well as contact information for communication with the master of the ship.

Upon nomination, the agent undertakes the following steps:

- informs the competent harbour master's office about the estimated arrival time of the MCV in Cernavodă;

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- informs the border police about the arrival of the MCV, in order to plan the border control before the entrance in Romania;
- informs the companies involved in pilotage about the arrival of the MCV, in order to ensure the presence of pilots on the ship during navigation through the Danube-Black Sea canal;
- maintains communication with the ship master in order to receive updated information about the time of arrival of the MCV in Černavoda;
- prepares and delivers to the shipping company, via e-mails, daily reports on the state of the MCV and the cargo handling options.

Černavoda lock operator notifies the pilot that the lock is free and that the lockage process can be carried out. The boarded pilot asks the lock operator, i. e., the control tower, for instructions on which lock chamber the MCV should sail into (left or right, see Figure 133).

While waiting at the access channel of the Černavoda lock, the boarded pilot is in constant communication with the lock operator. After the completion of the lockage, the MCV is waiting for permission to leave the lock chamber. The lock operator (from the control tower) is in charge of giving the permission. After receiving permission, the ship leaves the lock and continues sailing through the canal.

During the navigation through the canal, after every 5 km, the ship master is obliged to inform the competent port authorities about the sailing speed, mode of operation and wind conditions.

At km 2 of the canal, the ship master informs the border police of the Republic of Romania about the flag under which the ship sails and the nationalities of the crew members. Also, in the same position, the boarded pilot requests permission from the control tower, i. e., the lock operator, for the ship to enter the Agigea lock.

At km 0 of the canal, the master delivers the following information to the Port Authority of Constantza: dimensions of the MCV, amount of loaded cargo, mode of operation, as well as the number of crew members.

Before arriving at the Agigea lock, the boarded pilot, in communication with the lock operator, agrees all the details related to the lockage process itself.

Figure 133. Černavoda lock chambers

After leaving the chamber of the Agigiea lock, the pilot or the ship master informs the nominated agent about the completion of the lockage process. Based on that notification, the agent issues a Notice of Readiness (NoR), which contains the time of issuing this document. The agent sends the NoR to the terminal operator (specified by the shipper). In this way, the operator is informed that the MCV is in the Port of Constantza and that it is waiting for a call to unload or load cargo.

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6.3.5 Annex 5 – Unloading cargo at the Port of Constantza

MAPPING OF TECHNOLOGICAL PROCESSES

A motor cargo vessel has arrived in the Port of Constantza and is moored to the quay for tugs and push-boats. After ship master receives information from the agent that the quay will be available for unloading in about one hour, the ship master prepares the ship for manoeuvres. The port pilot boards the ship. According to the Port of Constantza rules, the pilot is necessary to be present on the MCV (flying foreign flags) in order to be able to perform any type of manoeuvre within the port area.

The MCV is unmoored from the quay for tugs and push-boats and executes the manoeuvre to the unloading quay. In certain cases, given the size of the Port of Constantza, this manoeuvre can be performed at a distance of 7-8 km. The manoeuvre can take up to one hour in the case when cargo unloading is planned at the farthest quays comparing to the location of the quay for tugs and push-boats.

Upon arrival at the unloading quay, the MCV performs a mooring manoeuvre. The ship is moored to the location where the unloading will take place. In this regard, the following cases can be distinguished:

- The cargo is unloaded into the silo – the ship is moored to the shore;
- The cargo is unloaded directly into the seagoing ship – the cranes of the seagoing ship are used for the transhipment of cargo from the MCV;
- The cargo is unloaded directly into the seagoing ship – a floating crane is used to tranship cargo from a MCV to a seagoing ship.

The port pilot disembarks from the ship. After positioning and mooring the MCV at quay, representatives of the inspection company get onboard and take the initial draft of the ship. A Draft Survey Report (DSR) is prepared and issued. The ship crew also take the draft. Both drafts measures should be matched. The draft, thus determined, is entered into the DSR, which is then signed by the ship master. The MCV, after taking the initial draft and issuing the DSR, is ready to unload the cargo.

Representatives of the inspection company also check the condition of the seals on the MCV. The process of checking seals includes the following activities:

- determining whether any of the seals are damaged;
- removing the seals and determining the compliance of the seal numbers with those recorded in the Sealing report, which was prepared and issued by the inspection company at the cargo loading port.

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If all the seals are there and undamaged, the engaged inspection company in the unloading port issues an Unsealing report. In this Report, the validity of the seals is confirmed, i. e., it is determined that the cargo holds have not been opened since the moment of completion of loading at the loading port.

Representatives of the inspection company also take a sample of the goods, i. e., the cargo, which needs to be unloaded and send it for phytosanitary analysis. In this way, the quality of the goods is determined. Samples for phytosanitary analysis can also be taken during the entry border control. In that case, the sample is taken in the presence of the customs representative. First, the seals on the cargo hold are removed and a sample of the goods is taken. After that, the hatch covers on cargo holds are closed and new seals are put on.

After all these formalities are completed, the unloading of the cargo from the ship begins. The crew of the MCV assists the unloading process by being in charge of moving the hatch covers on the ship's holds.

After cargo unloading is completed, representatives of the inspection company come onboard and take the final draft on the ship. The crew from the MCV also takes the ship's draft. Both drafts must be matched and, if so, it is entered in the DSR. The DSR is prepared and issued by the inspection company and it is also signed by the ship master. When the ship master signs the DSR, the unloading of the cargo from the ship is considered as completed. The port pilot boards the MCV.

Further steps in the process of servicing the ship in the Port of Constantza depend on whether it is planned to load the cargo or the ship leaves the port area after the unloading is completed.

Either on the anchorage or at the quay, the harbour pilot disembarks and the canal pilot gets onboard. If the ship is at anchor, the channel pilot comes to the ship on a special boat. The harbour pilot returns to shore in the same boat.

After boarding the canal pilot, the MCV departs the Port of Constantza. The anchor is raised in the case when the ship is at the anchorage, i. e., the ship is unmoored from the quay for tugs and pushboats, if it is located there. The ship performs manoeuvre towards the Agige lock. During the manoeuvre, the on-board pilot delivers information about the voyage to all interested parties, similarly as with sailing through the canal to the Port of Constantza.

The ship goes through the Agigea lock, navigates through the canal, reaches and come through the Černavoda lock. After the lockage process at the Černavoda lock, the ship leaves the canal and arrives at the anchorage, which is located at km 300 of the Danube River. The ship is anchored at this location. A boat comes to pick up the pilot and he disembarks from the ship. The anchor is raised and navigation continues towards the next port of call. In the case when the next port of call is located in Romania, the exit border control is not performed. However, if the next port of call is foreign comparing to the Port of Constantza, i. e., Romania, and the ship operates under the Serbian flag, exit border controls are carried out as follows:

- if the ship is heading towards Serbia, exit border control are carried out in Calafat or Turn Severin;
- if the ship is heading to Bulgaria, the exit border control is performed in Cernavoda or in another port in Romania, which is downstream from the port of call in Bulgaria;
- if the ship is heading to Moldova or Ukraine, the exit border control will be done in Galati.

In the second case, i. e., if it is also necessary to load the cargo, the MCV, after unmooring from the unloading facility, i. e., the unloading quay, executes a manoeuvre to the quay for tugs and push-boats. After mooring to this quay, the crew can access to the shore and the cleaning of the ship's holds may start. Cleaning the ship's holds is a prerequisite of the cargo loading process.

INFORMATION FLOW

A motor cargo vessel is moored to the quay for tugs and push-boats. The port operator at the quay where the cargo will be unloaded from the MCV, informs the nominated agent (announced by the shipper) that, during the day or night, transhipment of the cargo from the vessel (barge or self-propelled vessel) currently being serviced will be completed. The port operator also informs the agent that the MCV, represented by the agent, is next in the queue to unload the cargo. Therefore, the agent receives information about the expected start (within the next 24 hours) of cargo unloading from the ship. The agent, by telephone, informs the ship master about the received information and instructs him to wait for his further call regarding the beginning of the cargo unloading process. The agent's task is also to inform the shipowner, by e-mail, about the expected beginning of the unloading of its MCV. In addition, the agent submits a request to the pilotage companies, in the Port of Constantza, about the need to hire pilot in the period before unloading starts.

About an hour before the quay, where the cargo unloading is planned, becomes free, the port operator informs the nominated agent about the berth availability. After receiving this information, the agent let the ship master as well as the shipowner know about that. The agent gives also a call to the pilot, delivers the received notifications and informs him of the need to board the ship. The agent lets the ship master, as well as the shipowner, know about the imminent arrival and boarding of the pilots on the MCV. After port pilot gets on-board the ship, the ship master, by e-mail or otherwise, informs the shipowner of the moment of pilot boarding the ship.

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During the process of unloading the cargo from the MCV, the ship agent is obliged to inform the shipowner about all important moments related to this process itself. After the unloading is completed, the agent issues a SoF (Statement of Facts), i. e., a document specifying the start and end times of cargo unloading process. In addition, this document contains data on interruptions in the unloading process, if any. The reasons for these interruptions are also stated, such as weather conditions, malfunctions of cranes, i. e., unloading facilities, etc. The SoF is also used for the calculation of demurrage by the ship owner, if it is occurred due to one of the listed reasons.

6.3.6 Annex 6 – Loading of cargoes at the Port of Constantza

MAPPING OF TECHNOLOGICAL PROCESSES

Before loading the cargo into the MCV, it is necessary to clean the ship's holds i. e., cargo space. There is a difference between basic and detailed cleaning of the cargo space. Basic cleaning is applied when loading cargo that has the same or similar characteristics as cargo previously unloaded from the ship or cargo that cannot be damaged due to some of the characteristics of the unloaded cargo. This type of cleaning occurs when, for example:

- grain was unloaded, and also grain is to be loaded;
- grain was unloaded, and artificial fertilizer is to be loaded;
- grain was unloaded, and coal is to be loaded.

Basic cleaning involves usage of brooms and brushes to collect the remnants of previously unloaded cargo from the ship’s holds, the deck, the hatches, the hatch covers, etc. After the basic cleaning is completed, the MCV is ready to load new cargo.

Detailed cleaning of the cargo space is carried out in the case when the characteristics of the unloaded cargo may affect the quality or characteristics of the cargo that is to be loaded. Some examples of situations where detailed cleaning occurs are as follows:

- coal was unloaded, grain is to be loaded;
- artificial fertilizer was unloaded, grain is to be loaded.

In these cases, the cargo space is cleaned, i. e., washed with water and treated with chemical preparations before starting the cargo loading. After washing, it is necessary to dry the cargo area of the MCV. Drying is most often carried out naturally, that is, by airing.

Third parties, i. e., companies whose core activities include cleaning, most often perform these kinds of jobs in the Port of Constantza. In rare situations, the cleaning of the cargo space can also be carried out by the crew members of the MCV. In the case when these tasks are performed by third parties, the cleaning process begins after the ship is moored to the quay for tugs and push-boats. Teams with special equipment board the ship and the cleaning process begins. The removal of the remnants of the previously unloaded cargo depends on its amount, but usually takes several hours. Washing with water and chemicals, as well as drying the cargo space, usually lasts about one day.

The ship master prepares the ship for manoeuvres. The port pilot boards the ship. According to the Port of Constantza rules, the pilot is necessary to be present on the MCV (flying foreign flags) in order to be able to perform any type of manoeuvre within the port area.

The MCV is unmoored from the quay for tugs and push-boats and executes the manoeuvre to the loading quay. In certain cases, given the size of the Port of Constantza, this manoeuvre can be performed at a distance of 7-8 km. The manoeuvre can take up to one hour in the case when cargo loading is planned at the farthest quays comparing to the location of the quay for tugs and push-boats.

Upon arrival at the loading quay, the MCV performs a mooring manoeuvre. The ship is moored to the loading equipment. In this regard, the following cases can be distinguished:

- The cargo is loaded from the silo – the ship is moored to the shore;
- The cargo is loaded directly from the seagoing ship – the cranes of the seagoing ship are used for the transhipment of cargo to the MCV;
- The cargo is loaded directly from the seagoing ship – a floating crane is used to tranship cargo from a seagoing ship to a MCV.

After positioning and mooring the MCV at quay, representatives of the inspection company get on-board and take the initial draft of the ship. A Draft Survey Report (DSR) is prepared and issued. The ship crew also take i. e., measure the draft. Both drafts measures should be matched. The draft, thus determined, is entered into the DSR, which is then signed by the ship master. The MCV, after taking the initial draft and issuing the DSR, is officially ready to load the cargo. The port pilot disembarks from the ship.

Loading of the cargo into the ship begins. The crew of the MCV assists the loading process by being in charge of moving the hatch-covers on the ship's holds.

After cargo loading is completed, representatives of the inspection company come on-board and take the final draft on the ship. The crew from the MCV also takes the ship's final draft. Both drafts must be matched and, if so, it is entered in the DSR. The DSR is prepared and issued by the inspection company and it is also signed by the ship master. When the ship master signs the DSR, the loading of the cargo into the ship is considered as completed. The port pilot boards the MCV.

The MCV is unmoored from the loading quay (equipment) and performs the manoeuvre to the anchorage area. The ship is anchored at that location. In case of need, the manoeuvre can also be carried out to the quay for tugs and push-boats. Upon arrival at the quay, the MCV is moored. The pilot stays on board during execution of any of these manoeuvres.

Either on the anchorage or at the quay, the port pilot disembarks and the canal pilot gets onboard. If the ship is at anchor, the canal pilot comes to the ship on a special boat. The port pilot returns to shore in the same boat. The MCV is being prepared for departing, i. e., navigation through the Danube-Black Sea canal (Figure 137). The anchor is raised in the case when the ship is at the anchorage, i. e., the ship is unmoored from the quay for tugs and push-boats, if it is located there. The ship

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performs manoeuvre towards the Agige lock. During the manoeuvre, the on-board canal pilot sends information about the voyage to all interested parties, similarly as with sailing through the canal to the Port of Constantza.

The ship goes through the Agigea lock, navigates through the canal, reaches and come through the Černavoda lock. After the lockage process at the Černavoda lock is completed, the ship leaves the canal and arrives at the anchorage, which is located at km 300 of the Danube River. The ship is anchored at this location. A boat comes to pick up the canal pilot and he disembarks from the ship. The anchor is raised and navigation continues towards the next port of call. In the case when the next port of call is located in Romania, the exit border control is not performed. However, if the next port of call is foreign comparing to the Port of Constantza, i. e., Romania, and the ship operates e.g., under the Serbian flag, exit border controls are carried out as follows:

- if the ship is heading towards Serbia, exit border control are carried out in Calafat or Turn Severin;
- if the ship is heading to Bulgaria, the exit border control is performed in Černavoda or in another port in Romania, which is downstream from the port of call in Bulgaria;
- if the ship is heading to Moldova or Ukraine, the exit border control will be done in Galati.

INFORMATION FLOW

After the ship is moored to the quay for tugs and push-boats, the agent calls a representative of the company that will be hired for cleaning the ship's cargo space. The agent informs him about the position of the ship at the quay.

After the cleaning is done, the representative of the cleaning team informs the agent that the work is completed (the cargo space is washed and dried). It means that the MCV is ready to load new cargo.

In accordance with the received instructions from the shipper and upon completion of the cleaning, the agent issues a Notice of Readiness (NOR). It confirms that that the cargo loading process can begin. The agent delivers the NOR to the terminal operator, i. e., in this way informs the operator that the ship is ready and waiting for a call to load the cargo. Until such a call arrives, the MCV stays moored to the quay for tugs and push-boats in the Port of Constantza.

The port operator of the quay where the cargo will be loaded, informs the nominated agent (announced by the shipper) that, during the day or night, the cargo transhipment from the vessel (barge of self-propelled vessel) currently being serviced will be completed. The port operator also informs the agent that the MCV, represented by the agent, is next in the queue to load the cargo. Therefore, the agent receives information about the expected start (within the next 24 hours) of cargo loading. The agent, by telephone, informs the ship master about the received information and instructs him

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to wait for his further call regarding the beginning of the cargo loading process. The agent's task is also to inform the shipowner, by e-mail, about the expected beginning of the loading of its MCV. In addition, the agent submits a request to the pilotage companies, in the Port of Constantza, about the need to hire pilot in the period before loading starts.

About an hour before the quay, where the cargo is planned to be loaded, becomes free, the port operator informs the nominated agent about the berth availability. The agent delivers the obtained information both to the ship master and to the shipowner. The agent gives also a call to the pilot, conveys the received notifications and informs him of the need to board the ship. The agent lets the ship master, as well as the ship owner, know about the imminent arrival and boarding of the pilots on the MCV. The ship master, by e-mail or otherwise, informs the shipowner of the moment of pilot boarding the ship.

During the process of loading the cargo into the MCV, the ship agent is obliged to inform the ship-owner about all important moments related to the process itself.

The MCV stays at the anchor, i. e., moored to the quay, until cargo documentation is prepared and delivered to the ship master, as well as until the announcement of the ship's departure from the Port of Constantza is made. The ship agent, after receiving the information that the process of loading the cargo into the MCV has been completed, begins the preparation of this documentation and takes steps to announce the departure of the ship from the port of Constantza. Therefore, the ship's agent, based on the data received from the representative of the inspection company, prepares and issues the Bill of lading and the Cargo manifest for the ship. He sends, by e-mail, these documents to the forwarder, designated by the shipper, as well as to the ship owner and asks for their approval. Once approved, the agent notifies and signs both documents. They are then sent to the forwarder, designated by the shipper, to be used for the preparation of customs documentation (T1 and T2).

The agent announces to the company, which deals with pilotage in the Danube – Black Sea canal, about the need to hire a pilot for navigating the canal (canal pilot) in the next 24 hours. The agent also informs the canal administration about voyage planning and the passage of MCV through the canal.

The freight forwarder prepares the customs documents and sends them to the ship agent. After receiving, the agent scans and delivers them to the shipowner. The originals are delivered to the canal pilot, i. e., the pilot who will be on-board the ship during the passage through the Danube – Black canal.

The canal pilot hands over the custom documentation to the master, after boarding the ship.

During the departure from the Port of Constantza, the ship agent issues a SoF (Statement of Facts), i. e., a document specifying the start and end times of cargo loading process. Also, this document contains data on interruptions in the loading process, if any. The reasons for these interruptions are

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also stated, such as weather conditions, malfunctions of cranes, i. e., unloading facilities, etc. The SoF is also used for the calculation of demurrage by the ship owner if it is occurred due to one of the listed reasons.

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6.3.7 Annex 7 – Port of Novi Sad

The Port of Novi Sad (Figure 134) has one multipurpose trimodal terminal and one oil terminal. Port operations include cargo handling and storage of bulk cargo, general cargo, containers and liquid cargo. The handling equipment of Port of Novi Sad consists of (DP World, 2023b; Gazette Republic of Serbia, 2014; Transport Community, 2021):

- six portal cranes with a capacity 5 t to 27.5 t;
- 14 forklifts with a capacity varying from 3 t to 12.5 t;
- one forklift with a capacity of 28 t;
- 5 loaders;
- two weigh bridges – one for road and one for rail with a measuring range of 100 t;
- three telescopic funnels for bulk cargo handling with a capacity of up to 250 t/h;
- three packaging machines for 50 kg and 1,000 kg bags;
- a belt conveyor;
- pneumatic equipment;
- pumps for oil products, etc.

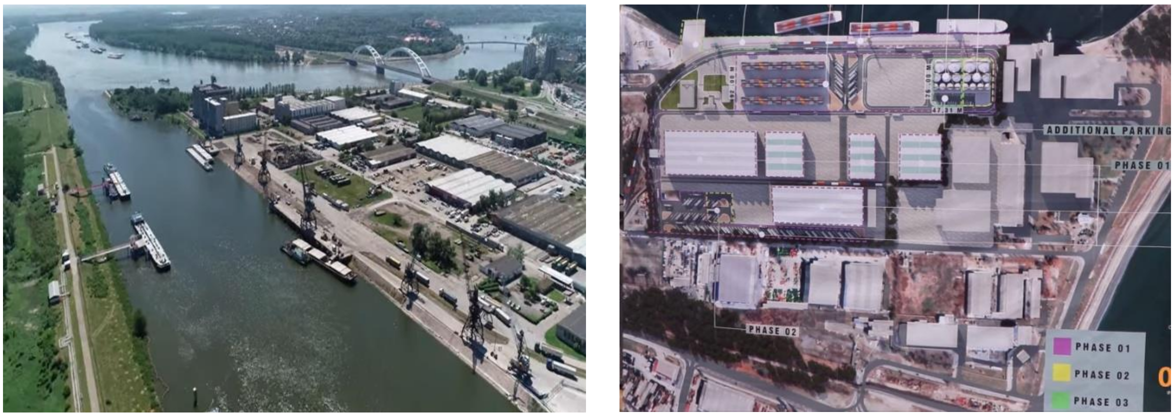

Figure 134. Port of Novi Sad and its development plans

Republic of Serbia is the owner of the land where the port lays and of most of the infrastructure. Within the port area, there are no free and available areas for further expansion. However, in the immediate vicinity, there is land that could be used for further development of the port.

According to the development phases of the Port of Novi Sad, the following facilities should be built, expanded or developed within the next five years:

- 20,000 t grain silo;
- container terminal;
- multimodal rail (Huckepack) terminal;
- RoRo terminal (in the later development phases)

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- storage facilities (expansion);
- logistic subsystems and additional services.

In addition, the port development plans in Novi Sad include:

- a larger capacity system for handling grains, fertilizer components and fertilizers;
- extension of the operating vertical quay;
- redesigning of the existing and acquisition of new higher capacity cranes and equipment;
- modernisation of the information system; and
- development of an automatic data processing system.

These plans are aimed at increasing the throughput capacity of the port, both in terms of bulk cargo and general cargo, including containers.

TEN-T Regulation 1315/2013 introduces the compliance indicators for Core inland ports. These are the following:

- CEMT connection (Class IV waterway connection);
- Connection to rail;
- Connection to road;
- Availability of clean fuels;
- Availability of at least one freight terminal open to all operators in a non- discriminatory way and application of transparent charges.

The report of the Transport Community (Transport Community, 2021) assesses the compliance of Core inland ports in Serbia as per each of these indicators. Based on the outcomes of that assessment, it is can be easily concluded that Port of Novi Sad, belonging to the extended TEN-T to the Western Balkans, is compliant with all requirements, i. e., requirements rail connection, road connection, CEMT connection and terminal availability, apart from clean fuels availability.

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6.3.8 Annex 8 – Locks

Iron Gate I (Figure 135) is composed of two locks, one on the Serbian and the other on the Romanian side of the dam on the Danube river. As parallel, single-row and double-chambered, the locks work in pairs, alternately changing lockage direction every seven days. It means that every Monday at 6:00 in the morning, one of them picks up ships/convoys from the downstream direction, and the other from the upstream direction. This rule is deviated from if one of the locks is undergoing major overhaul or is out of order due to failure of equipment, devices or due to repairs. In this case, the entire ship flow in the upstream and downstream direction is locked through one lock. The locks are two-staged, so that the upstream chamber is in the accumulation lake, and the downstream one is in the lower water.

Figure 135. Iron Gate I

Iron Gate II (Figure 136) is also made of the Serbian and Romanian locks. Both of them work as parallel, single-row, single-chamber locks, in pairs, alternating lockage direction every month. One of them receives ships/convoy from the downstream direction, and the other from the upstream direction.

Figure 136. Iron Gate II

Lockage of ships on the Danube (at both Iron Gates and on both sides - Serbian and Romanian) is free of charge, while both countries have an obligation to ensure continuous navigation, which implies proper maintenance of ship lock equipment.

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6.3.9 Annex 9 – Danube-Black Sea canal

The reason for the construction of the canal can be found in the geographical appearance of the Danube's turn to the north, whereby it moves away from the Black Sea, creating a large arch and a much longer waterway. Another reason for its construction is to bypass the Danube confluence, which is difficult for navigation. The canal shortened the route via the Danube confluence by approximately 400 km. This significantly shortens the waterway between the North and Black Seas via the Danube, Main and Rhine. This canal is inaugurated in 194 and is managed by Administration of Navigable Canals.

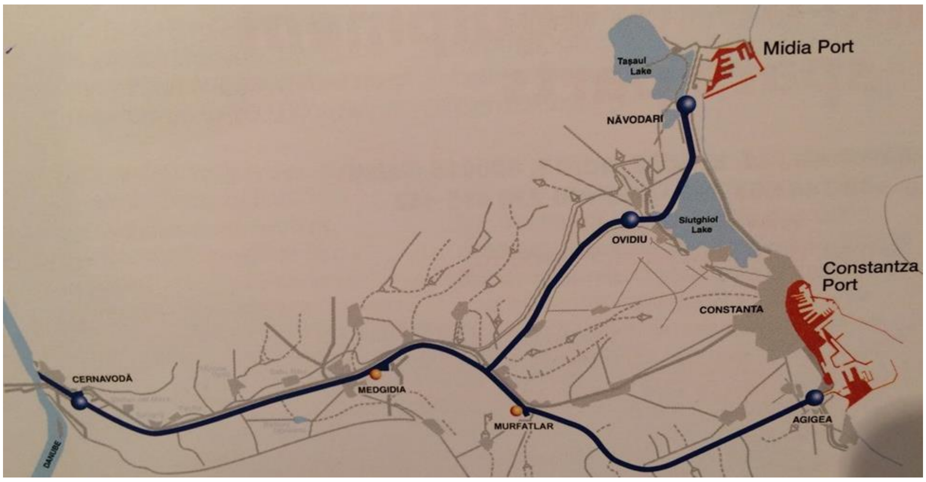

Figure 137. Overview of the Danube-Black Sea canal

Source: (Lukovic, 2019)

Positions of the ports, located on the Danube – Black Sea canal, are the following:

- Medgidia port – km 37+500, right bank;
- Murfatlar – km 25, right bank.

Special rules apply for navigation the Danube-Black Sea canal. Navigation or passing through the canal is allowed only if the canal pilot is onboard the ship. This pilot, based on the instructions from the dispatch concentred with the help of radio communication, is in charge to safely controls the ship during navigation through the channel. Ships that sail in opposite directions and meet during navigation are free to pass by each other by following the orders given by the canal pilot or dispatch centre. According to the CEMT classification, the size of the vessel/convoy transiting the waterway connection Danube – Black Sea canal is inland waterway class VIc.

The Danube – Black Sea canal and port of Constantza are under the jurisdiction of three port authorities, divided into the following sectors of the waterway:

- Černavoda Port Authority - from km 295 to km 48 of the Danube – Black Sea canal;

- Agigea Port Authority - from km 48 to km 0 of the Danube – Black Sea canal;
- Port Authority of Constantza - Port of Constantza

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6.3.10 Annex 10 – Port of Constantza

The connection of the port with the Danube river is made through the Danube-Black Sea Canal, ending the Rhine-Danube Corridor, which provides the main east-west link across Continental Europe. Its route along the Danube River connects Strasbourg and Southern Germany with the Central European cities of Vienna, Bratislava and Budapest, before passing through Serbian, Bulgarian and Romanian ports.

Based on the administration model – landlord port, the port infrastructure is leased to private operators. According to the Law 108/2010, the governing contract type concluded between NC "Maritime Ports Administration" SA Constantza and the operators for terminals and adjacent areas is the lease contracts. The port assets are leased out or sub-concessioned to private port operators.

The Port of Constantza is not an open shore port. Its infrastructure is basin type with three basins (including Midia). The main tuning basin for the North Port of Constantza is located in front of the oil terminal having enough area to enable the manoeuvring of the common vessels calling the North Port. The first is located at the port entrance, after passing the South breakwater, while the second is located at the exit from the port, in front of the basin between piers 1S and 2S.

The standard berthing manoeuvrings require tug assistance and present a significant challenge, especially for berthing container vessels at the Constantza South Port terminal in which the navigation is limited to one-way traffic.

Cargo handling capabilities of the Port of Constantza are the following:

- bulk cargoes
    - ten terminals;
    - iron and non-ferrous ore, grain, coal, coke, cement, construction materials, phosphate etc. are handled in specialized terminals located next to the river-maritime basin;
    - there are specialized terminals that operate iron ore, bauxite, coal and coke with 13 berths;
    - there is specialized terminal where fertilizers, phosphate, urea, apatite and other chemical products are operated;
    - there are many facilities for the operation and storage of dry cereals, which are served by several specialized berths;
- break-bulk (general) cargo
    - eight terminals;

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  - stevedoring companies provide all range of services for general cargoes;
  - food, beverages and tobacco, paper and cardboard, cellulose, rolled metals, machine parts, bagged cement and other break bulk cargo can be handled;
- oil/chemical/gas
  - four terminals
  - crude oil and oil products - main handled liquid bulk cargoes
  - there is specialised terminal for the import of crude oil and other oil products and for the export of refined oil products, oil derivatives and other liquid chemical products;
  - oil terminal is equipped with a modern and efficient fire and pollution fighting facilities;
- RoRo cargoes
  - two RoRo terminals - the car terminal and the RoRo Ferry terminal;
  - equipped with two ramps to handle any type of vehicle and RoRo cargo
  - main car operator splits its activity in two berths – there is no a fully dedicated terminal for cars;
  - the Ferry-Boat terminal offers exceptional facilities for the freight loaded in wagons, containers, and trucks and transported by ferry vessels and liner services on the Black Sea;
- tri-modal terminal;
  - five tri-modal terminals;
  - quick and safe access to port facilities from an inland transport system including inland water, railway system and road access;
  - limited number of containers moving inland by water freight;
  - there are a limited number of containers moving inland by water freight, railway system and road access;
- multipurpose terminals
  - eight multipurpose terminals.

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Private companies specialized in cargo transhipment are operating in the Port of Constantza. Using specialized equipment for intermodal transport they provide direct transhipment services for bulk and packed/unitized cargo: Sea vessels – barges, Barges – sea vessels, Wagons – barges and/or small sea vessels, Small sea vessels/barges – wagons.

Liquid bulk can also be transhipped into river vessels to various European destinations or carried through pipelines within the domestic hinterland. Pipelines network connects the port with the main refineries in the country thus securing fast transportation.

The quays in the port of Constantza are exclusively vertical. There is no sloped quay.

Waste management in the Port of Constantza represents an important component that comply with the national and international legislation on environment protection by creating an efficient working framework for collecting, treating, stocking and storing of port and marine wastes. There are four components: the incinerator, the ecological site, the collecting-ship, the wastewater treatment plant & leachate treatment station. To support the environmental pollution control of vessels the port offers facilities for the collection and reception of the used oil.

The Port of Constantza is located at the crossroads of the trade routes linking the markets of the landlocked European countries to Transcaucasus, Central Asia and the Far East. The port has connections with the Central and Eastern European countries through the Rhine – Danube Corridor.

The Port of Constantza is linked with the hinterland by the Danube – Black Sea canal. The entrance to the channel is on the South part of the Port and connects the Black Sea with the European inland waterway network. The canal offers an alternative route from the Black Sea ports to the Danube ports of Central Europe that is shorter by approximately 400 km.

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Figure 138**. Port of Constantza – link with the Danube – Black Sea canal**

Source: (Compania Nationala Administratia Porturilor Maritime SA, 2022)

The port is situated on the national railway line 800 (Bucharest North – Constantza – Mangalia). The total length is 268 km and the rail distance between Constantza and Bucharest is 220 km. The railway line has recently been improved and has a very good quality (120 km/h for cargo).

The Port of Constantza is very well connected with the national and European road network. The A2 motorway, nicknamed The Sun's Motorway, is linking Bucharest to city port Constantza and a length of 203 km. The port road infrastructure is in generally in a good condition. The port is directly connected to A2 highway, toward Bucharest (225 km) and other European or national roads:

- E 87 Antalya (Turkey) – Burgas (Bulgaria) – Constantza, Tulcea, Galati, Brăila (Romania) – Odessa (Ukraine)
- E 81 (E 81 begins in Constantza, Romania and ends in Mukachevo, Ukraine, is 956 km (594 mi) long.),
- E 60 (the second longest road in the International E-road network. It runs 8,200 km (5,100 mi), from Brest, France (on the Atlantic coast), to Irkeshtam, Kyrgyzstan (on the border with China),
- DN 39 (Constantza – Mangalia – Bulgarian border- Varna),

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- DN 2A Bucharest - Urziceni – Slobozia – țăndărei – Hârșova – Constantza (part of E60)
- DN 3 Bucharest – Fundulea – Lehliu Gară – Călărași – Ostrov – Basarabi – Constantza.

During the last decade, the Port of Constantza efficiently served the flows of goods that arrive or depart from/to the Central and Eastern Europe, including: Austria, Czech Republic, Slovakia, Hungary, Serbia, Bulgaria, Moldova and Ukraine. The Port of Constantza handled 67.483.435 million tonnes in 2021 and had 14.604 vessel movements of which 27% (3,985) were maritime-related and 73% on to the river network (10.619). This ratio between maritime and river calls (approximately 30%:70%) is typical for the Port of Constantza.

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