Public recommendations for inland transport in Northern Europe

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Advanced, Efficient and Green Intermodal Systems

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Executive Summary

"Public Recommendations for Inland Transport in Northern Europe" serves as a comprehensive guide, providing practical insights for policymakers and industry stakeholders striving for a sustainable and efficient inland waterway transport (IWT) system. Specifically focusing on the objectives of the AEGIS project's Use Case B, led by DFDS, supported by Aalborg University (AAU) and the Technical University of Denmark (DTU), the report underscores the crucial need to optimize transportation activities within the European waterborne transport sector.

By advocating for the adoption of zero-emission propulsion systems and innovative vessel designs, the report aims to facilitate the seamless integration of eco-friendly practices within the IWT framework. It highlights the importance of customized shuttle sizes and efficient cargo transshipment processes to ensure the smooth movement of goods between ports and terminals. The recommendations stress the significance of cultivating collaborative partnerships and standardized protocols to enable streamlined coordination and data exchange across various transport modes, fostering a cohesive and sustainable logistics network.

With a strong focus on sustainable freight corridors and public awareness campaigns, the report emphasizes the advantages of IWT, including reduced carbon emissions, cost-effectiveness, and employment opportunities. It underscores the critical role of regulatory enhancements and the allocation of dedicated funds for infrastructure development, climate resilience, and the advancement of green technologies. Aligned with the goals of the European Green Deal and the broader sustainability objectives of the European Union, these recommendations aim to nurture a resilient and environmentally conscious inland waterway transport system, paving the way for a more sustainable future in European maritime logistics.

Definitions and abbreviations

AG: Advisory Group

AEGIS: Advanced, Efficient and Green Intermodal Systems

BEP: Breakeven Point

CAPEX: Capital Expenditures

CBA: Cost-Benefit Analysis

CEF: Connecting Europe Facility

CESNI: European Committee For Drawing Up Standards In The Field Of Inland Navigation

DFDS: Det Forenede Dampskibs- Selskab

DTU: Technical University of Denmark

EU: European Union

ETS: Emissions Trading System

GHG: Greenhouse Gases

IWW: Inland Waterways

IWT: Inland Waterways Transportation

ISE: Institut für Strukturleichtbau und Energieeffizienz

KPI: Key Performance Indicator

LoLo: Lift-on Lift-off

OPEX: Operating Expense

RoRo: Roll-on, Roll-off

TEN-T : Trans-European Transport Network

TTW: Tank to Wake or Tank to Wheel

UC: Use Case

WP: Work Package

WTT: Well to Tank

WTW: Well to Wake or Well to Wheel

1 Introduction

This deliverable presents the public recommendations to support the development of an inland autonomous RoRo barge service in the Rotterdam-Ghent area (AEGIS Use Case B, or UCB), as part of a new waterborne transport system for Europe. This document is an abridged compilation of the results of various deliverables of the AEGIS project focused on the navigable waterway segment, to which the reader shall be redirected for further information. The implementation of the proposed system would require changes to the status quo in the region, affecting various stakeholders in different ways. The objective of this document is to advise the public on what must be done to achieve such change and to fulfil the objectives of the project, namely the transfer of cargo from road to water. It is not the remit of this document to generalize such recommendations to other European regions or modes of transport, for circumstances may differ. Rather, this document serves to inform readers on what must be done, in the context of this case, to overcome those challenges and bottlenecks identified in the course of the project.

This section will define and explain the objectives for this deliverable. The objectives of UCB and WP 9 itself are presented in the first subsection, followed by the objectives of this deliverable in particular. The organization of the rest of this report is presented in the third subsection.

1.1 Objectives of WP9: UCB

Work package 9 (WP9) pertains to the analysis necessary for the Use Case B (UCB) specifically, as mentioned.

UCB examines the Belgium and Netherlands's short sea and inland interface. The two countries are significant hubs for cargo transportation from and to Europe. Rotterdam, located in the Netherlands, is the largest port in Europe and one of the largest ports in the world, with shipping lines established to all corners of the globe. Everything from dry bulk to liquid bulk, containers, and breakbulk, in which category one finds RoRo cargo, is passing through the port, constituting a total of 436,800,000 tonnes of cargo in 2020. The second busiest European port is Antwerp, in Belgium. Furthermore, the port of Ghent is part of the so-called North Sea Port – a conglomeration of Vlissingen, Terneuzen, and Ghent. Consequently, the port extends over 60 kilometers, 9.100 hectares (ha), across two countries: Belgium and the Netherlands. It is ranked number 9 of all European seaports measured in the volume of goods and number 6 of seaports in the Hamburg – Le Havre range also measured in the volume of goods. Freight transportation through the inland waterways is already well developed, but there is still space for more cargo to be distributed via waterways. This region is ideal for the purposes of AEGIS, and this is why it was chosen for this Use Case B.

In summary, the objectives of UCB are to:

- Apply and validate the results from WPs 2-7 into use-case B, which examines the short sea and inland interface in Belgium and Netherlands, with partner DFDS being involved as a WP leader. The area under examination involves the ports of Rotterdam, Antwerp, Ghent, and Zeebrugge.
- Use the above results to bring cargo as close to the end destination as possible with small vessels with zero emission propulsion (battery, fuel cells, etc.).
- Address possible administrative and regulatory challenges and bottlenecks that should be tackled for efficient and environment-friendly solutions.

The main intention of UCB and the work carried in WP9 pertains to the idea of picking up and dropping of cargo as close as realistically possible to its origin and destination, using small vessels with zero emission propulsion as a first step and green, autonomous vessels as an end goal. In order to address this, WP9 has investigated existing DFDS-related activities in the interface between Rotterdam, Ghent and Zeebrugge, which includes but is not necessarily limited to barge shipping, short sea shipping, truck logistics, rail logistics, warehousing, freight forwarding etc. These parameters have been used as building blocks for investigating alternative vessel concepts and design to simplify such business activities with the aim of bringing a larger part of the door-to-door transport (i.e. from origin to destination) unto a waterborne transport modality.

The main emphasis of UCB and the work carried in WP9 have thus been on the commercial and operational logistics of the AEGIS network. Consequently, WP9 has the following tasks:

Task 9.1	**Analysis of transport needs – led by DFDS:** A task that will perform an analysis of transport needs for partner DFDS and for the geographical are of interest, mapping the status quo. Data will be collected on flows, origins, destinations, and transhipment points. This data will feed into the technical work packages (WP 2-7).
Task 9.2	**Specification of transport system – led by ISE:** A task that will design a new transport system with suitably sized shuttles and automated transhipment, while also looking at the availability of underutilised terminal infrastructures and present services on the inland waterways in the chosen region.
Task 9.3	**Identification of bottlenecks and other obstacles – led by DTU:** A task that will identify barriers and delays caused by administrative, regulatory and/or physical bottlenecks and other obstacles that need to be alleviated or removed for the AEGIS transport system to be successful in the context of UCB.
Task 9.4	**Detailing and validation of the AEGIS solution – led by DFDS:** A task that will develop and validate the AEGIS solution for this use case as to achieve maximum utility of the services as per the KPIs developed in the AEGIS project (WP7), focusing predominantly on the commercial feasibility of the use of the inland waterways as an alternative to trucking.
Task 9.5	**Public recommendations – led by DTU:** A task that will provide a set of recommendations specific to this use case. The task will function as an encapsulating conclusion to the work carried in WP9, providing recommendations with regards to the transport system, the bottlenecks/obstacles and the commercial feasibility.

1.2 Objective of Task 9.5: public recommendations for UCB

The objective of Task 9.5 (and therefore of this deliverable) has been set as follows:

Based on Task 9.3, Task 9.5 will provide a set of recommendations that are specific to this use case. These will also feed into the general conclusions of WP6 and WP7.

It is to be clarified that the target receivers of these recommendations include, among others, transport carriers, shippers, ports/terminals, and policy makers. They also include technology providers in sectors such as ship design, ship propulsion, cargo handling, and information and communication technologies (ICT).

It is also to be clarified that the above stated objective is to be interpreted broadly, meaning that Task 9.3 will not be the only prior task of WP9 (or of other WPs) that will provide input to the recommendations of Task 9.5. Additional input is based on the prior results of other WPs, and specifically of WP2, WP6 and WP7, as those pertain to UCB (WP9). These prior results are presented in Section 2 of this report. Results of other technical WPs, such as WP3, WP4 and WP5, are not explicitly presented in this deliverable, however these WPs have been critical in the analyses and results of WP2, WP6 and WP7, and also of prior tasks of WP9 (and especially of Task 9.3), and, as such, have very much influenced the outcome of WP9 and of this deliverable.

1.3 Organization of the rest of this report

The rest of this document is organized as follows: Section 2 presents the findings of this project that are relevant to UCB, focusing on WP2, WP6, WP7 and WP9 (prior to Task 9.5). Section 3 presents the recommendations for industrial stakeholders, and Section 5 those for policy makers. Finally, Section 4 presents this report's conclusions.

2 Summary of findings relevant to UCB

In the upcoming section, we will endeavor to summarize all pertinent activities conducted within the AEGIS project, particularly those related to the UCB. These activities have encompassed WP9 as well as other WPs and Tasks that were not originally part of WP9. Other relevant WPs are WP2, WP6 and WP7. This section will be divided into subsections corresponding to these WPs, with subsections 2.1, 2.2, 2.3 and 2.4 corresponding to WP2, WP6, WP7 and WP9 respectively. Again, WPs such as WP3, WP4 and WP5, are not explicitly presented in this section, however these WPs have been critical in the analyses and results of WP2, WP6 and WP7, and also of prior tasks of WP9 (and especially Task 9.3), and, as such, have implicitly but clearly impacted the outcome of WP9 and of this deliverable.

2.1 Summary of findings in WP2

WP2 has covered the development of methods for logistic system redesign. This includes simulator development, effects of standardized cargo-units, ISPS and resilience. All these aspects of the new logistic system are analyzed in deliverables through the WP. These deliverables, with input from other WPs, made the basis for the roadmap in D2.6 that addresses how these solutions can be deployed to realize the logistic system redesign.

D2.2 investigated the effects of standardized cargo units. The main finding is a set of possible suitable cargo units for the requirements of the new logistic transport system that is used as a basis for ship design in WP4 [1].

D2.3 looked at ISPS and its function as a barrier to reduce possibility of security-related events during port calls. It describes the ISPS processes and addresses how these must be built into the autonomous system technologies proposed in the project [2].

D2.4 covered the implementation of a simulator for assessing the effects of adopting the new technologies and ship designs developed in the other work packages. It documents the functionality of the simulator and how it is developed to be able to evaluate the transport system under the KPIs defined in WP7 [3].

D2.5 presents a methodology for assessing resilience of the logistic system redesign using the bowtie method. It addresses resilience both at a use case level and an overall autonomy level. It shows how autonomy introduces new threats related to human to machine interactions, setting a precedence for the need for new, preventative barriers [4].

2.2 Summary of findings in WP6

AEGIS WP6 work focused on policy support associated with the whole of the project's transport concept, of which inland waterway transport is a fraction. The work of WP6 identified legal and regulatory challenges and resulted in an analysis of how AEGIS may be implemented. The course of work resulted in three separate deliverables based on desk-based research and semi-structured interviews with key stakeholders and informants. These three deliverables analysed the status quo of public policy applicable to waterborne transport systems [5], the legal and regulatory challenges that hinder on the introduction of innovative technical solutions [6], and a roadmap to design adequate implementation measures to overcome such challenges [7], all of which apply partly to the inland waterway segment. In a nutshell, the findings of this work may be summarised as follows:

- **Policy Support Integration and Regulatory Reforms**

Integrating the AEGIS project within the European waterborne transport system necessitates meticulous policy alignment and regulatory adjustments. For instance, the implementation of green propulsion technology in vessels faces hurdles such as complex emission standards and international maritime regulations, demanding comprehensive policy adaptations to accommodate these advancements. Additionally, ensuring the harmonization of cross-border policies to facilitate seamless cargo movement requires strategic negotiations and legal frameworks that balance the interests of multiple nations and stakeholders. One key institution to include in future policy support efforts at the national level is CESNI (European Committee for drawing up Standards in the field of Inland Navigation), who is responsible for creating technical regulations and standards for inland navigation in Europe. The CESNI recommendations primarily focus on enhancing safety, improving technical aspects, and promoting harmonization in the field of inland navigation within Europe. CESNI's recommendations are not legally binding on their own but serve as a reference for European countries to develop and align their national regulations regarding inland navigation. These recommendations aim to facilitate consistency and safety across European inland waterways, promoting efficient navigation and trade.

- **Comprehensive Governance Framework**

Establishing a comprehensive governance framework demands addressing intricate challenges related to stakeholder collaboration and regulatory adaptability. An example includes the coordination of policy frameworks among various governmental bodies, port authorities, and industry associations, requiring effective intergovernmental agreements and collaborative initiatives. Additionally, ensuring regulatory adaptability to accommodate technological advancements in autonomous vessels involves proactive legal frameworks that ensure safety and operational standards without stifling innovation.

- **Learning from Implementation Failures**

Reflecting on past implementation challenges reveals significant hurdles in bridging the gap between policy objectives and tangible outcomes. For example, historical challenges in integrating sustainable transport solutions into existing infrastructure highlight the necessity for targeted investment in port infrastructure, including the development of specialized terminals and transhipment facilities. Moreover, addressing historical inefficiencies in intermodal connectivity demands a comprehensive policy approach that fosters seamless integration between inland waterways and land-based transportation systems, necessitating legal reforms and standardized protocols.

- **Optimizing Inland Waterway Policy**

Optimizing inland waterway transport systems necessitates overcoming multifaceted challenges related to infrastructure development and environmental sustainability. For instance, ensuring the optimization of underutilized terminal infrastructures requires strategic policies that incentivize private sector investments and public-private partnerships to revitalize and modernize existing port facilities. Furthermore, addressing environmental concerns and mitigating ecological impacts involves the implementation of stringent emission regulations and eco-friendly practices, demanding comprehensive legal frameworks and environmental accords at the regional and international levels.

- **Sustainability and Efficiency Integration**

Successfully integrating sustainability practices and efficiency enhancement initiatives demands a strategic blend of innovative technologies and comprehensive regulatory measures. For example, fostering environmental consciousness in the shipping industry necessitates the introduction of carbon pricing mechanisms and eco-friendly incentives that encourage the adoption of greener technologies and fuels. Furthermore, optimizing resource management in the context of waterborne transport involves establishing waste management protocols and circular economy initiatives that minimize resource depletion and environmental pollution, requiring robust legal frameworks and industry-wide agreements.

These findings all converge to the general conclusion that a new European waterborne transport system can only be implemented with policy support and some level of legal reform. These would apply necessarily to various dimensions of the proposed system: digital system development and maintenance; registration, classification and certification of vessels; insurance and risk management; autonomous navigation (offshore & inland); remote operation; ship-to-ship loading; cargo handling; SME port development; data exchange. Many initiatives to tackle these issues – of relevance to UCB, begun during the course of the AEGIS project at the EU level (e.g. CESNI and CCNR). Yet many more are to come as new concepts are proposed to industrial actors, and thus the findings of AEGIS point to a direction rather than to an end point of policy development. Thus, the relatively abstract nature of recommendations for policy makers (see below Section 4).

2.3 Summary of findings in WP7

WP7 entailed a cost benefit analysis (CBA) broken down in three dimensions, economic, environmental and social. The corresponding deliverables are D7.6, D7.7, D7.8, and D7.9 [8-11], respectively. In all three use cases, and with few exceptions, the AEGIS system was found to exhibit significant advantages over the non-AEGIS, baseline solution.

More specifically for UCB, the following results are summarized below:

2.3.1 Economic analysis

In Table 1, the green and red cells show the advantages of the AEGIS and non-AEGIS (baseline) scenarios on the set of economic KPIs. Green cells indicate a superiority of the AEGIS solution, and red cells indicate a superiority of the baseline solution.

Table 1 – Comparing the superiority of the base scenario and AEGIS in UCB.

KPI Name	AEGIS	Baseline-Truck
CAPEX		🟥
OPEX	🟩	
Maintenance Cost	🟩	
Port Charges or THC		🟥
Fuel Cost	🟩	
Wages	🟩	
Transport Cost Per Unit	🟩	
Cost Per Unit Cargo	🟩	
Loading Time		🟥
Sailing or Drive Time		🟥
Unloading Time		🟥
Energy consumption	🟩	
Cargo Carried	🟩	

Frequency of service	🟩	
Energy efficiency	🟩	

As can be seen, the AEGIS solution, in terms of OPEX, fuel cost, and energy consumption, is better than the road-based system. For example, we can observe that when comparing the electricity (or energy) cost with the fuel cost of road-based transportation, AEGIS results in a lower-cost solution per tonne-km.

Furthermore, although the CAPEX cost of the baseline system is lower than the marine mode, considering the total (cumulative) CAPEX and OPEX costs at the same time, the results indicate that after about four years, AEGIS is better than road transportation in terms of total expense. This breakeven time (BEP) is seen from Figure 1 to be equal to 197 weeks, or 47 months.

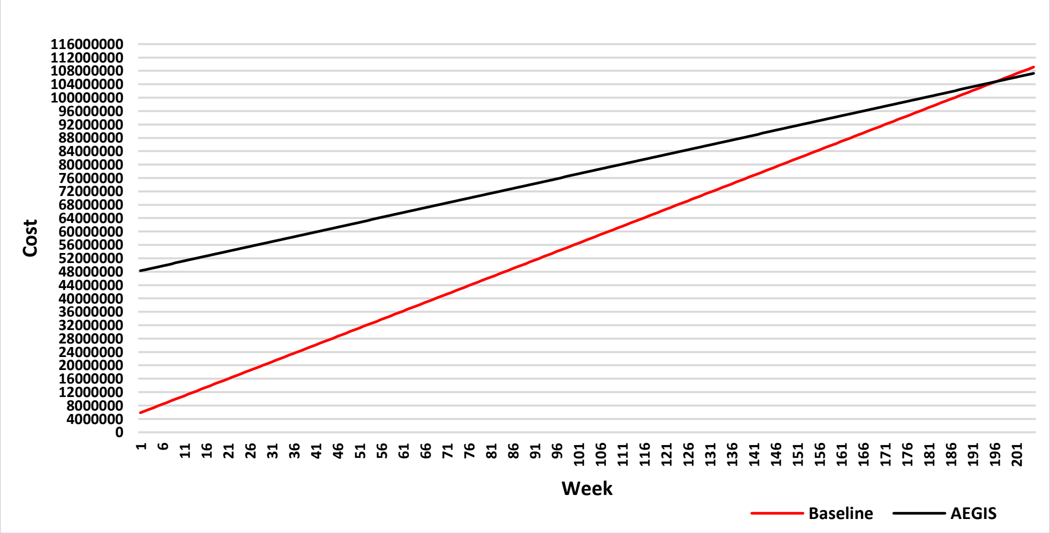

Figure 1: Cumulative costs for UCB.

2.3.2 Environmental analysis

In Table 2, the green and red cells show the advantages of the AEGIS and baseline scenarios (respectively) as regards the environmental KPIs (note: it can be seen that there are no red cells). It should be noted that there are two types of air emissions, named Tank to Wake (TTW) (or Tank to Wheel for road or rail vehicles) and Well to Tank (WTT). TTW concerns the operational emissions of the vessel or vehicle. WTT concerns upstream emissions, those associated with the production of the fuel to the vessel or vehicle. If the fuels are produced using renewable energy sources their WTT emissions are also zero, however if the energy sources to produce these fuels are non-renewable (for instance, use of a coal plant to produce electricity), then the WTT emissions are nonzero and need to be accounted for. The same is the case with batteries. There is also the term WTW (Well to Wake or Well to Wheel) which is the sum of WTT+TTW. Even though in the AEGIS Grant Agreement no delineation between these two types of emissions was made and the main focus of the emissions calculation was by default assumed to be TTW, due to the increased emphasis of policy makers, particularly in the EU, but also in the IMO, on WTW emissions, in D7.7 we have also selectively calculated WTT (and WTW) emissions for the CO_2 related KPIs.

Table 2 – Comparing the superiority of the base scenario and AEGIS in UCB.

KPI Name	AEGIS	Baseline
CO_2-WTW	🟩	
NO_x-TTW	🟩	
SO_x-TTW	🟩	
PM_{10}-TTW	🟩	
Acoustic Emissions- Noise	🟩	

As can be seen in Table 2, it is expected that after the implementation of AEGIS, we will have a significant improvement in the reduction of emissions in the UCB. The main reason for this is due to the use of batteries for the AEGIS ships in this use case.

In the rest of this part, we look to find out how much emissions will be reduced over the years with the implementation of AEGIS.

For this purpose, we have represented all four emissions under consideration in Figures 2 to 5 and equations 1 to 4. As one can see in these figures, if we consider the year 2030, the AEGIS solution will have prevented significant emissions of the examined gases. Again, to compare the GHG emissions (CO_2) for both scenarios, we have used the WTW (=WTT+TTW) approach in order to have a more precise assessment.

$$CO_2 - WTW\ :(124{,}695) - (46{,}340) =\ 78{,}355\ tonnes\ of\ CO_2 \tag{1}$$
$$NO_x - TTW:(36) - (0) =\ 36\ tonnes\ of\ NO_x \tag{2}$$
$$SO_x - TTW:(0.40) - (0) =\ 0.40\ tonnes\ of\ SO_x \tag{3}$$
$$PM_{10} - TTW:(0.40) - (0) = 0.40\ tonnes\ of\ PM_{10} \tag{4}$$

Figure 2: WTW CO_2 emissions for UCB.

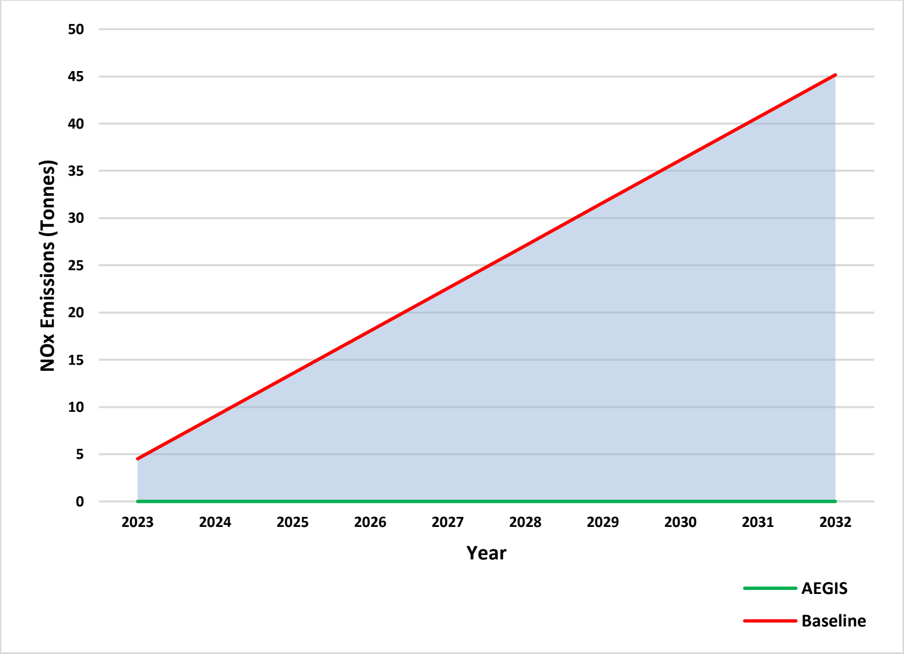

Figure 3: TTW NO_x emissions for UCB.

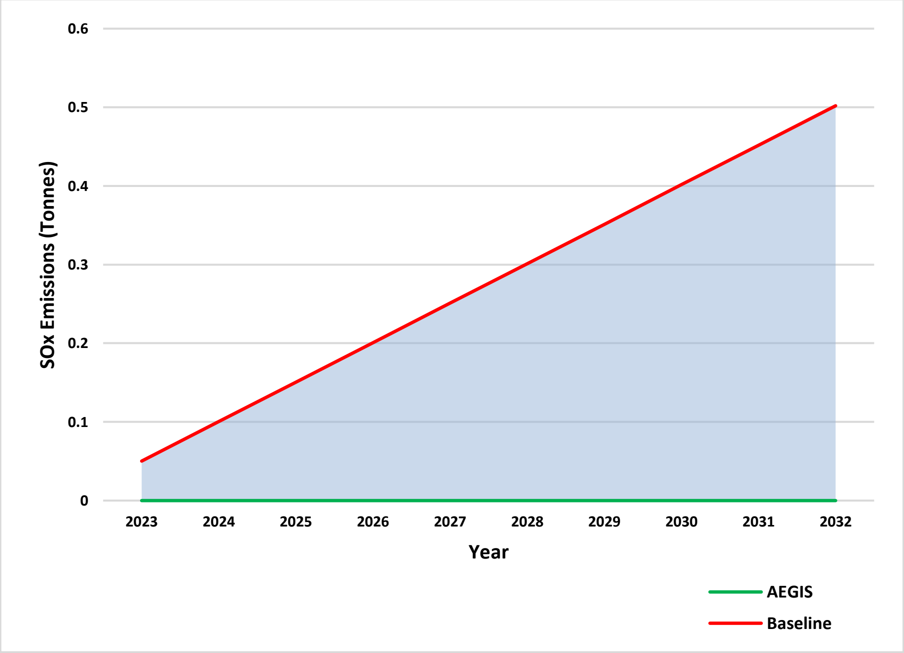

Figure 4: TTW SO_x emissions for UCB.

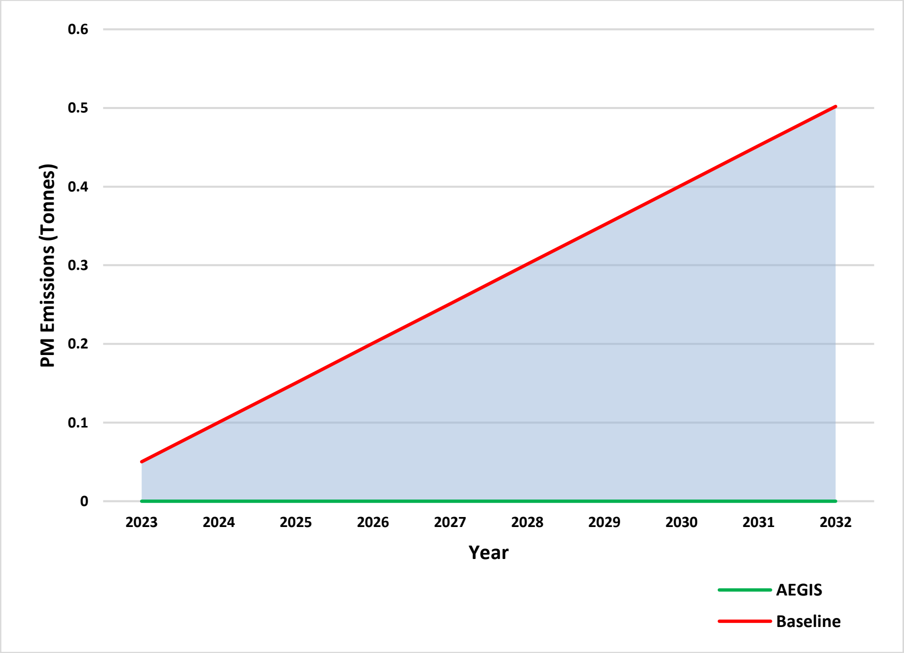

Figure 5: TTW PM_{10} emissions for UCB.

Therefore, as can be seen in the results, it is evident that these four KPIs will be much lower with the AEGIS solution compared to the use of trucks (even if these are EURO 6).

Finally, it must be noted that as road transportation is also gradually moving to electro-mobility, a similar environmental benefit will be enjoyed if electric trucks are to be used in the future. The analysis of such a scenario is subject to many uncertain parameters and is beyond the scope of the AEGIS project.

2.3.3 Social analysis

In the social analysis, a main social benefit of the AEGIS solution was found to be the anticipated reduction of road accidents and fatalities due to moving traffic from road to the AEGIS solution.

Based on the statistics of EU Transport in figures- statistical pocketbook in 2022, the number of accidents on the Netherlands and Belgium roads in 2020 were 17,040 and 30,230, respectively. These include fatalities, injuries, and damage to vehicles or other property. Also, the fatality rate in 2020 was 4 and 17 for heavy goods vehicles (HGVs) in the Netherlands and Belgium, respectively. In addition, based on that report, the annual transportation volume from the road in Netherlands and Belgium in 2020 was around 67.2 and 34.4 billion tonne-km, respectively. Hence, the share of heavy vehicles in these two countries' road accidents and fatalities (on an annual basis) is estimated in equations 5 - 7.

Netherlands:

$$\boldsymbol{Accidents}: 17040 * \frac{3.82\ billion}{67.2\ billion} = 968.45 \tag{5}$$

$$\boldsymbol{Fatalities}: 4 * \frac{3.82\ billion}{67.2\ billion} = 0.23 \tag{6}$$

Belgium:

$$\boldsymbol{Accidents}: 30230 * \frac{3.82\ billion}{34.4\ billion} = 3356.27 \tag{6}$$

$$\boldsymbol{Fatalities}: 17 * \frac{3.82\ billion}{34.4\ billion} = 1.89 \tag{7}$$

It should be noted that the fraction equations represent the share of transportation volume that UCB is involved in both countries. These equations are the normalized rates of accidents and fatalities, which are calculated by dividing the annual volume transported in tonne-km in UCB by the annual volume transported in tonne-km in both countries. The distance for UCB is 320 km for a round trip.

In addition, operation of the AEGIS system would require the construction of a control room for the overall supervision of the shipping operations in these inland waterways and during mooring. The control centre can be located somewhere other than the Netherlands or Belgium, if it can effectively interact with the ships and exchange data and guidance during operations. This is expected to create some higher paying jobs, for personnel tasked to be employed in the remote operation centre and in other positions.

2.3.4 Win-win solutions

Looking at the previous deliverables of WP7, the results of the economic, environmental and social analyses, it should be clear that most of the AEGIS solutions for UCB are already win-win, in the sense that significant benefits of the AEGIS solution vs. the non-AEGIS (baseline) solution have been identified in all three analyses. Some exceptions, however, exist, mainly in terms of the CAPEX and time KPIs, in which the AEGIS solution performs worse than the non-AEGIS solution. This result is obviously to be expected, and as far as CAPEX goes the fact that CAPEX is higher for AEGIS is perhaps of lesser importance as it was shown that the overall cumulative (CAPEX+OPEX) cost of the AEGIS solution is less than the equivalent total cost of the non-AEGIS solution after some years of operation. The result of the time KPIs (i.e. ,that the AEGIS solution is generally slower than the non-AEGIS solution) is also to be expected, and it remains to be seen what (if anything) can be done to improve this KPI, and how significant that result really is, in a holistic way.

Another issue that is open is how the economic KPIs are expected to change due to significant developments in EU legislation in the context of the “fit-for-55” package, and specifically as regards the impending inclusion of shipping and road transport into the EU Emissions Trading System (ETS). This will impact some of the economic KPIs for both the AEGIS and non-AEGIS solutions and was not examined in the economic CBA. The win-win report we take this opportunity to investigate how this development will impact our results.

With respect to time KPIs, our analysis has shown that some improvements can be realized by a vessel speed increase (in all use cases) and by other adjustments. Obviously, however, with the increase in the ship's speed, OPEX are expected to increase as well due to increased energy consumption.

Furthermore, it has been observed that with the application of the EU ETS, the competitive advantage of the AEGIS solution is expected to increase in UCB, versus the case of no application of EU ETS.

2.4 Summary of findings in WP9

This section will attempt to encapsulate all relevant work carried in the AEGIS project pertaining to the UCB specifically, which has been developed explicitly within the WP9 itself. The section is separated into subsections based on the work tasks of WP9 [12-15], as mentioned in previous section.

2.4.1 Analysis of transport needs

This task sets out to analyse the transport needs of the AEGIS partner DFDS in a predefined geographical area of interest and their further inland connectivity via waterways, using data collected on flows, origins, destinations, and transshipment points.

First, a reflection was made on the dichotomies of unit types, transport modalities and integrated logistics networks. These reflections resulted in three so-called mental frames that proved to be the foundation of the work throughout the WP9 tasks and deliverables:

1. The purpose of the AEGIS Use Case B autonomous transport system and its focus on RoRo transportation by the inland waterways is not to directly compete with existing LoLo services in the region, but instead to convert existing trucking services unto the inland waterways in the area.
2. When looking at transport systems in general and on multimodal transportation in particular one must differentiate between the so-called direct runs (A-B), or milk runs (A-B-C…). The two types of routes each offer different advantages and challenges. A direct run offers high cargo volumes to be transported between two given points as fast as possible, but in turn requires that a sufficiently high cargo volume exist between the two points. A milk run instead offers connectivity to terminals with smaller cargo volumes that in themselves could not substantiate a direct run, but at the cost of longer transportation time between the end points due to the multiple stops.
3. It is worth noting the difference between entire autonomous transport systems as opposed to an individual autonomous transport mode. Said differently, making individual autonomous transport modes, or legs or the supply chain, instead of an entire autonomous transport system will likely create significant issues further down the transportation chain. An autonomous ship will create a multitude of problems in the port, if the port is not synced to accommodate such ships. An autonomous port may further create problem for a rail or truck transportation if these in turn are not synced to the port. So in essence, it is thinking in the door-to-door transportation of a cargo unit as a fully autonomous transport chain and not merely thinking of a single component within this transport chain in isolation. This is where the project sees RoRo transportation as advantageous for UCB as it allows for more seamless last mile transportation than does LoLo transportation by e.g., offering better opportunities to call smaller terminal with no to limited infrastructural investments than LoLo transportation, which requires a higher level of infrastructural investments (cranes etc.). This also creates an opportunity for RoRo vessels to visit infrastructures which would not traditionally be considered a port or a terminal.

Second, looking at the region generally and the DFDS activities in the region specifically, it was found that Port of Rotterdam provided high cargo volumes destined for multiple places throughout the Benelux region and as such offered an ample opportunity for creating a hinterland distribution hub here with autonomous barges to distribute the cargo further. Regarding the DFDS barging activities at that time, it was found that these were primarily centered around the DFDS terminal in Ghent with services going to primarily Antwerp and Rotterdam as well as Moerdijk, Terneuzen and Vlissingen. Consequently, with the outset in this operation, the UCB mother concept was established: a direct inland waterways route between the ports of Rotterdam and Ghent. This area also proved to be of particular interest due to the high congestion and accident numbers on roads at present which are expected to increase even further in the near future.

2.4.2 Specification of transport system

This task sets out to specify in detail the transport system(s) in the area of interest, including suitable sized shuttles or barges and an automated transhipment at the ports. With this goal in mind, the task applied the following methodology:

1. study of advanced RoRo approaches already existing, mainly in Europe;
2. describing autonomous RoRo operation in general on a high level;
3. introducing advanced vessel concepts developed in WP4, feasible for UCB;
4. investigating ports of interest along the routes under consideration; and,
5. combining the above findings and information into two specific flows, building the sound basis for further detailing and verification of the transport system

The following will address each of these points, highlighting the main findings within each.

Point 1: Only a few RoRo approaches existed, with most studies focusing on LoLo approaches instead. Suitable vessels sizes range from small to medium in size (max. CEMT IV) in order to connect smaller IWW routes to the core TEN-T network and by doing so reaching far into the European hinterland. Furthermore, little autonomation or autonomy was found in IWT although studies indicate that autonomy could lever a competitive opportunity of IWT through the use of smaller barges – an opportunity which proves of high potential in the region of Benelux due to the high density of IWW near strategic ports such as Rotterdam, Antwerp and Ghent.

Point 2: Autonomous RoRo operation was divided into three descriptive components: 1. vessel operation, 2. transshipment, and 3. port operation. It showed that both benefits and obstacles exist with automation/autonomy. As benefits were found increased safety, efficiency and flexibility – especially with regards to cost savings that could make an inland RoRo service viable. As obstacles were found communication issues and regulatory barriers. From a technical perspective, automated/autonomous equipment is needed during sailing and port operations, with everything from navigation to berthing to cargo operations etc. necessitating some level of automation. This further includes requirements to terminal space utilization and restricted areas for autonomous vehicles in clear human-machine collaboration designs.

Point 3: Advanced vessel concepts were developed in a separate deliverable in WP4. For UCB, close studying of the ports, routes and flows in the region (undertaken in parallel with point 4 in the methodology), IWW vessel concepts were made ranging from CEMT IV+ to CEMT II. The former of these were found feasible due to its high capacity combined with the innovative idea of loading/unloading through the side of the vessel, which allowed for transversal storage and an onboard lifting device to store in two layers. This was especially interesting for milk run routes where individual cargo units may want to be reachable, while at the same time enabling the vessel to moor on quays with no port-side ramps and as such the possibility of accessing smaller ports (or operating in bigger ports with minimal disturbances).

Point 4: An extensive study of ports, their possibilities and their adjacent points of interest was conducted, including possible logistics centres, warehouses, factories, rail connections, expansion potentials etc. as well as cargo inflows and outflows, where available. High potentials were found for the main route between Rotterdam-Ghent and Rotterdam-Antwerp, but also for the further connections into the hinterland along the Albert Canal and the Scheldt and the many smaller and underutilized terminals along these water mouths. As such, the transport systems would be constituted of a combination of a direct route connecting the main ports with a milk route connecting this with the hinterland.

Point 5: Two overall transport flows were found from Rotterdam southbound: a south-eastern flow passing through Antwerp into the Albert Canal and a south-western flow passing through Ghent into the southern Scheldt. Although both of these flows were examined and elaborated upon in Task 9.2, it was later decided as part of a scoping exercise to focus only on the south-western flow as this proved to be an especially underutilized IWT opportunity. The flow was divided into a direct route from Rotterdam to Ghent and a milk route from Ghent to Lille with multiple stops on the way, potentially extending down to Paris as part of the Seine-Scheldt project developments. The direct route has no intermediate stops and, hence, offers fast transportation with a maximum capacity. The milk route has several stops en-route, either on a scheduled basis or partially as on-demand tramp trade. For this kind of transportation, a highly flexibly loading and unloading is needed for trailers to “jump on/jump off” at the different ports. This may however prove difficult with the transversal stowage given its need for CEMT IV+ while the waterways south of Kortrijk only offers CEMT IV and thus being too narrow for transversal stowage of trailers in its current setup. However, the waterways from Ghent to Paris are expected to be extended to CEMT V (a + b) as part of the Seine-Scheldt developments, which indeed would enable the transversal stowage as per CEMT IV+.

2.4.3 Identification of bottlenecks and other obstacles

This task sets out to identify the barriers – bottlenecks and obstacles – of the UCB and subsequently determine the priority and importance of each of these, respectively for the two scenarios:

The baseline scenario: Cargo is moved from Ghent to Rotterdam (and vice versa) by truck.

The AEGIS scenario: Cargo is moved from Ghent to Rotterdam (and vice versa) onboard an AEGIS vessel.

To do so, the task attempted three overall objectives to succeed with such goal:

1. Identifying, clustering, and exploring bottlenecks.
2. Establishing the priority and importance of bottlenecks.

Point 1: The barriers were separated into six overall themes, namely operational barriers; transport technology barriers; ICT barriers; infrastructure and geographical barriers; regulatory barriers; and, other barriers not pertaining to the aforementioned categories. The list of barriers discovered is as follows:

A. **Operational barriers:**

1. Administrative processes when entering the terminal
2. Ship/truck interoperability
3. Poor terminal organization
4. Speed limits in canals (ship design aspect)
5. Travel time
6. Waiting time for loading and unloading
7. Uncertain planning and finding priorities in different types of ships and cargo
8. Cargo consolidation
9. Lack of captains for the vessel and truck drivers in the near future
10. Lack of operational standards across supply chains
11. Transshipment to truck for last-mile
12. Lack of appropriate planning for customers service offering (unified or individual)
13. Rest hour requirements for crews
14. Lack of contractual relationship between barge operator and terminal operator

B. Transport technology barriers:

15. Ship capacity
16. Truck capacity
17. Ship speed
18. Port handling requirements
19. Hinterland transportation of LoLo units
20. Container transhipment to trailer

C. **ICT barriers:**

21. Lack of standardized interfaces between systems (e.g., between ROC and ship, etc.)
22. No agreed-upon standard for secure and trusted data transfer
23. Protocols and standards not currently suitable for JIT (Just-in-Time)
24. Standardization of RoRo vs EDIFACT
25. Compliance Flow (e.g., Digitalization of Customs Interaction)
26. Standardization of yard planning across terminals
27. Overall standardized system integration
28. Transition period Manual Handling vs Autonomy
29. Handling of unforeseen events
30. Trust between parties
31. Scalability

D. Infrastructure and geography barriers:

32. Storage capacity
33. Gate capacity
34. Traffic jams in the terminal
35. Traffic jams along the route
36. Canal locks
37. Lack of infrastructure for berthing and mooring
38. Lack of available automatic facilities services (AFS)
39. Shallow water sections
40. Limited geographical scope
41. Accessibility
42. Bridges

43. Port security requirements (infrastructure aspect)
44. Multimodal access
45. Lack of standards infrastructures and equipment in terminals
46. Capital investment for infrastructures
47. Lack of transportation network

E. **Regulatory barriers:**
    48. Crew requirements (qualification and manning)
    49. Vessel technical requirements
    50. Navigation police rules / traffic rules
    51. Transport of dangerous goods by water

F. **Other barriers:**
    52. Long dry spells
    53. Noise restrictions on canals
    54. Inertia of past experience (transforming and adapting to the new system)
    55. Changing the cargo transportation structure according to customers' requests
    56. Lack of knowledge of crew to use the new transportation system

Point 2: The subsequent data analyzed of the priority and importance of the barriers listed above revealed the following:

- The major causes for delays in the current transportation system are relevant to operational bottlenecks, Infrastructure and geography bottlenecks (such as traffic jams along the route and rest hour requirements for crews).
- Since AEGIS is based on automated transportation and also a new system, the ICT, infrastructure and geography, and regulatory bottlenecks are the most critical upcoming hindrances for this scenario (such as lack of standardized interfaces between systems, lack of available automatic facilities services (AFS) and lack of infrastructure for berthing and mooring).
- By comparing the two scenarios, we can find that there will be more and more important barriers to the AEGIS transportation system. This is because the land-based system has been operating for many years, and its challenges have been identified and resolved over time. However, AEGIS is a new system based on the automation of equipment and RoRo ships. Indeed, many aspects of transportation will be faced with issues that did not exist before.

2.4.4 Detailing and validation on the AEGIS solution

This task sets out to develop concrete examples that validate the technical and economic proposals as presented in the previous tasks with the aim of finding applicable scenarios in which one can reasonably argue for a potential of converting road-based freight transportation to waterborne freight transportation, herein particularly that of IWT.

A time-economic model was used to validate the scenarios; a model which incorporates threshold economics that determines the parameters and thresholds after which an inland waterway transport (IWT) solution becomes cost-competitive with road transportation. The model is supported by a comprehensive EUROSTAT dataset on European trucking activities to estimate potential cargo volumes available for the specific scenarios as well as deep operational data provided by operational personnel from logistics partner DFDS. As such, this task is closely connected to the methodological developments of WP10, Task 10.1 [16] and the associated deliverable thereto. The analysis revealed promising opportunities for converting cargo between the regions of Rotterdam-Ghent and of Ghent-Paris, incl. adjacent regions in both cases, leading to further support of the methodology developed in Task 10.1 and the economic feasibility of transitioning from road-based to waterborne transportation.

Concretely, the analysis proved that waterborne solutions can effectively compete with direct linehauls, particularly because of the lower costs anticipated to come with new barge solutions. Calculations were conducted for both RoRo and LoLo scenarios, adjusting the number of units feasible for transportation in each of the cases. Two overall setups were considered: a 50-trailers vessel configuration identical to that proposed as part of the WP4 & WP9 collaboration, and an 83-trailers configuration representing the equivalence of a 220 TEU container unit already operating in the area and a concept already investigated by DFDS in terms of costing and pricing. Furthermore, sensitivity analyses were undertaken in extension of the conversion analyses, revealing that especially the Rotterdam-Ghent direct route was highly sensitive to fluctuations in €/km prices for linehauls, potentially yielding adverse results for the use case. Oppositely, the Ghent-Paris milk route showed much lower sensitivity due to the longer distance and the cost-effectiveness of the barge solutions.

In conclusion, both scenarios – Rotterdam-Ghent direct route and Ghent-Paris milk route – demonstrate promising cargo flow volumes combined with economic feasibility when it comes to converting road-based traffic to waterborne traffic in the area and as such validates the conceptual network established in AEGIS UCB from a viewpoint of commercial feasibility.

3 Recommendations for industry stakeholders

The integration of autonomous solutions into the maritime transport industry presents a multifaceted challenge that defies a singular approach. In light of this complexity, the following categories of recommendations are offered for consideration. For UCB, the focus is inland waterway navigation, however some of the recommendations in this section may have a broader applicability.

3.1 Acknowledge the Complexity

Recognize that autonomous solutions bring both benefits and challenges to the maritime sector. These innovations enable vessels to operate continuously, bolstering operational efficiency and reducing external dependency. Moreover, they hold the potential to mitigate risks associated with human-operated RoRo operations, enhancing safety. At the same time, however, autonomous ships are not just an advanced development of conventional ships, but an entirely new innovation in itself that challenges the boundaries of what is “within the innovation itself” and what is “external to the innovation”. An example of such is the need for remote control centers as integrated parts of autonomous ship operation – but as of now it is not entirely clear where such centers lie in a legal and perhaps more abstract sense: is it within or outside the innovation? The same applies for the enormous complexity of autonomous control systems and submodules onboard the ship itself, which may not necessarily come from the same technology provider. Complexity therefore also lies in the onboard technology and its intimate interwovenness with other systems onboard. Consequently, it is recommended to finely evaluate the complexity of the onboard technology architecture as well as the ship-shore architecture.

3.2 Embrace Sustainability Opportunities

Beyond operational advantages, autonomous solutions offer substantial sustainability potential. They create avenues for commercial opportunities while promoting energy-efficient vessel utilization, aligning with global sustainability objectives. As such, autonomy will both be an enabler for more efficient vessel operation as well as an enabler for new concepts and designs. Waterborne modalities are seen as a catalyst in the sustainable development of the EU and are thus a fundamental part of the European Green Deal. Ambitions herein include shifting a significant amount of cargo from road-based to waterborne transportation modes as well as to increase freight transported by waterborne modes in general. It was however found through the work of AEGIS that the trend is currently moving in the opposite direction, with high operational costs, low speed and uncertain reliability as the main variables working against the waterborne modalities. Autonomous systems are expected to potentially address all of these, especially the first and the last of these, as operational costs and reliability can be expected to be better for autonomous ships. Furthermore, autonomous control systems may themselves offer better operational attributes of onboard systems such as propulsion and route planning etc. through their utilization of big data pools to continuously reevaluate the operation of the vessel itself – both for its onboard systems and its operation in a broader business environment. Consequently, it is recommended to push the development of autonomous ship technologies as a core enabler for sustainable transport opportunities.

3.3 Address Legacy Challenges

Confront the industry's challenges stemming from entrenched legacy thinking and conflicting business models. Overcoming these obstacles is critical to facilitate the alignment and adoption of new business processes. As seen in many industries, incumbent firms are increasingly being challenged by innovative technologies and companies capable of setting up advantageous business models based on such technologies. Whereas incumbent ship operators traditionally rely on offering a range of established services relying heavily on the use of own ships together with long-term and clearly established partnerships with customers and third parties (e.g. ports), innovative firms rely instead on digital technologies such as online freight forwarding platforms and the use of third-party assets to undertake the transportation itself. It is not entirely certain how autonomous ships will be owned and operated, although it is expectable that it will fall within the latter category. Although not explicitly a part of AEGIS, technologies such as 3D printing and blockchain have shown that disruptive technologies in themselves will not change the maritime industry, but instead will innovative business models that can utilize such innovation to its full potential. Consequently, it is recommended that innovative business models are explored and further enabled to fully utilize the capabilities of autonomous ships.

3.4 Cultivate a Collaborative Ecosystem

Create a business ecosystem that is essential for the maritime industry to function seamlessly as a logistics chain. Encourage collaboration among stakeholders through data and information exchange. This endeavor demands alignment of strategic stakeholders and partnership formation. Businesses are today increasingly interdependent on other businesses for reasons such as complementary products, markets and integration of additional capabilities within a broader operational context. For maritime, this includes in finely interwovenness between ship owners, ship operators (both technical and commercial), technology providers (both hardware and software), classification societies, ports and terminals, cargo owners, freight forwarders etc. The multitude of actors presently involved in shipping ecosystems are only expected to increase as the assets herein become more complex. This is expected not only to create new relational trade-offs, but potentially also the relational trade-offs between primary and secondary partners as well as partners to which the focal company has no direct relationship. A simple example is company A that delivers rubber to company B that delivers wheel to company C that delivers cars to a customer. An example in the context of autonomous ships could instead be company A that delivers optical sensors to company B that delivers object identification capabilities to company C that offers holistic collision avoidance intelligence to a ship owned by company D that delivers transport to company E that needs cargo transported. Autonomous ships may potentially see this linear trade-off shift to another linear trade-off or a more circular collaboration between the parties that inhabit this smaller (sub)ecosystem. Consequently, it is recommended that consideration is given beyond the question of value creation of autonomous ships in themselves to the question of value distribution across the broader ecosystem that the autonomous ships inhabit and how this further may create or shift entirely new ecosystems.

The two subsequent subsections can be considered as pertaining to this overall theme of collaborative ecosystems.

3.5 Recognize Complementary Capabilities

Success hinges on recognizing the complementary capabilities of stakeholders and aligning activities accordingly. Collaboration should harness the strengths of each participant to realize the full potential of autonomous solutions. Already today, ships are equipped with increasingly advanced technology to which the ship owners and operators themselves do not necessarily have a sufficient level of expertise personnel in-house. Consequently, shipping companies are increasingly relying on third parties such as classification societies and technology providers to support them in their due diligence, inspection and maintenance of such systems. With the advent of increasingly self-diagnosticating and smart algorithms across various subsystems, components and modules, ship operators must increasingly look at complementary support outside of their own organization. Consequently, a clear need develops in which business interdependencies as mentioned in above paragraph on collaborative ecosystems become a necessity as well as the acknowledgement that the ships and their systems themselves – whether they are onboard or outboard – are increasingly relying on other technologies and systems in order to perform their assigned capabilities. In a concrete example from today's vessels, the autopilot in most bridge systems require input from other technologies such as the gyro compass and the main engine (and potentially other systems such as the weather sensors, nautical chart etc.) to successfully maintain its full capabilities as an autopilot. The control system needs an array of sensory input in order to compute such input and act "intelligently". With autonomous systems, such are dependent on an increasingly larger array of sensory input data stemming from a multitude of different sensory systems both onboard and ashore in the remote-control center, the ship operator's office, the ports and other infrastructures, and a multitude of other sources. Consequently, it is recommended that the complementary capabilities are recognized and intimately considered in the design, operation and inspection of autonomous shipping.

3.6 Acknowledge Supply Chain Interdependencies

Any given shipping route depends just as much on the ship operator as it is on the cargo available in the area as well as the capabilities of the port(s) and infrastructure(s) that must accommodate the ship and the cargo. An example of this can be seen in the initial introduction of the container as a unit of transportation, which both required and allowed vessels to be designed in new ways and consequently saw ships becoming increasingly large to carry an increasingly high volume of cargo. This is what is often referred to as "economy of scale" that has been the prevailing paradigm in shipping over the recent multiple years. An indirect consequence from this has been that ports and terminals have found it necessary to make increasingly large investments in infrastructure and equipment in order to accommodate such ships, with the few that are able to make such investments now facing significant congestion issues from the so-called "megaships" and the many that are not able to make such investments being left behind with less and less cargo moving through these ports. As mentioned, autonomous ships may enable novel and smaller vessel designs, which in turn may have a democratizing effect that allows the ports left behind by economy of scale to once again become commercially and operationally interesting for ship operators and cargo owners. However, at the very same time, some investment is required from ports, terminals and other infrastructures to enable the use and accommodation of autonomous ships in their vicinity. WP10 of the AEGIS project has focused extensively on the use of autonomous ships seen from the viewpoint of ports, and reference is given to their deliverables on the matter when it comes to the specific requirements to ports. Nevertheless, this is a crucial aspect in the simplified triangulation of ship operators, ports and cargo owners as the essential constellation in maritime freight transportation. Consequently, it is recommended that autonomous ships are not considered in the isolation, but in their broader application in supply chains, including the necessary investments to be made by ports and associated infrastructure(s) to accommodate such ships both from a safety, security, environmental and commercial perspective.

3.7 Define Clear Standards for Autonomy Levels

The integration of autonomous technologies in waterborne logistics necessitates clear standards, particularly regarding autonomy levels and the delineation of tasks between humans and autonomous systems. Standardization bodies play a pivotal role in establishing consistent definitions and autonomy levels applicable across industries.

In conclusion, the integration of autonomous solutions into the maritime industry and short sea shipping is a complex endeavor that requires a nuanced and adaptable approach. These recommendations underscore the importance of sustainable, safe, and efficient maritime operations, positioning the European Union at the forefront of autonomous shipping development.

4 Recommendations for policymakers

This section is tailored to policymakers at the EU level, but it may well serve to those at the national and local governance levels. It addresses the challenges and obstacles identified in this use-case, drawing from the comprehensive findings of the AEGIS project, which consider the interconnected nature of inland waterway transportation (IWT), short-sea shipping, and port development. A certain level of abstraction is necessary to accommodate contextual factors during the introduction of the AEGIS concept beyond the specific context of Use-Case B (Belgium and Netherlands). Several categories of recommendations are considered pertinent, and within each category, specific recommendations have been formulated:

4.1 Green and Sustainable Vessels and Innovation

Financial Incentives for Zero-Emission Propulsion Systems: Develop a comprehensive range of financial incentives to encourage investments in zero-emission propulsion systems for small vessels. These incentives could include grants, tax benefits, and subsidies. Additionally, consider providing rebates on vessel registration fees and reduced taxes on green technologies. The goal is to stimulate the adoption of environmentally friendly propulsion systems while aligning these incentives with recommendations from the European Committee for drawing up Standards in the field of Inland Navigation (CESNI).

Dedicated Funding for R&D: Allocate dedicated funding under the CEF funding programme for long-term research and development initiatives. Collaborate closely with industry experts and research institutions to identify and nurture promising green and autonomous vessel technologies. Ensure that these innovations meet European safety and navigation standards.

Research and Innovation Initiatives: Dedicate substantial resources within the TEN-T corridors (namely the Motorways of the Sea priority) to research and innovation initiatives aimed at enhancing vessel design, propulsion systems, and cargo handling technologies. Foster partnerships among public institutions, academic organizations, and industry players to drive innovation in the IWT sector.

Customized Eco-Friendly Vessels: Encourage vessel operators to invest in fleets of shuttles customized for various cargo types and volumes. Offer appealing financial incentives for the acquisition of vessels that meet predefined eco-friendly and efficiency criteria. These criteria should encompass zero-emission propulsion systems and energy-efficient designs.

Pilot Projects and Feasibility Studies: Fund pilot projects and feasibility studies under TEN-T and CEF to test new concepts and technologies within the corridor. This includes innovations related to vessel propulsion, cargo handling, and sustainability. CESNI's expertise should be incorporated into these projects to ensure navigational safety is not compromised.

4.2 Intermodal Connectivity and Standardization

Promoting Transport Partnerships: Actively promote partnerships between diverse transportation modes, such as inland waterway transport, barge shipping, short sea shipping, truck logistics, rail logistics, warehousing, and freight forwarding. Create attractive incentives to encourage companies to participate in these partnerships, thereby enhancing a seamlessly integrated logistics network.

Standardized Interfaces and Protocols: Advocate for the establishment of standardized interfaces and protocols within the TEN-T framework to ensure efficient cargo transfer between various transportation methods. Additionally, support the development of digital platforms that enable real-time tracking and coordination of cargo movement across modes.

Comprehensive Collaboration: Encourage comprehensive collaboration among various stakeholders in line with TEN-T and CEF policies. This collaboration should aim to prevent conflicting initiatives and ensure a unified approach to issues such as labelling systems, technology standards, and environmental regulations. CESNI should also be involved to harmonize navigational standards and ensure navigational safety.

4.3 Shuttle Sizes and Efficiency

Resource Allocation for Efficient Shuttles: Allocate resources within TEN-T for a thorough analysis, conducted in collaboration with industry experts, to ascertain the most efficient shuttle sizes for cargo transfer between larger RoRo ships and smaller ports. Key factors such as cargo volume, vessel capacity, and infrastructure capabilities should be considered when establishing guidelines for shuttle sizes.

Customized Shuttle Fleet for Efficient Cargo Transfer: Promote tailored shuttle fleets within the Roll-on/Roll-off (RoRo) transport system by encouraging vessel operators to invest in vessels optimized for diverse non-standardized cargo types. Offer incentives and policy support for the acquisition of customized shuttle fleets, enhancing the RoRo model's versatility beyond wheeled cargo. Collaborate with industry experts to design shuttle fleets specifically tailored for bulk goods, fragile items, and perishable goods, complementing the efficient handling of standardized cargo within the RoRo system. This approach ensures a more comprehensive inland waterway transport network, optimizing cargo transfer efficiency for both standardized and non-standardized cargo types within the RoRo framework.

4.4 Sustainable Freight Corridors and Public Awareness

Sustainable Freight Corridors: Spearhead the creation of sustainable freight corridors that prioritize inland waterway transport as the preferred mode of cargo transportation within the corridor. These corridors should be meticulously designed with significant input from key stakeholders, including port authorities, shipping companies, and logistics providers. Navigational standards recommended by CESNI should be incorporated into the corridor planning to ensure safety.

Stakeholder Collaboration: Collaborate closely with stakeholders to ensure the sustainability and efficacy of these corridors. Address challenges related to navigation infrastructure, water depth, and environmental impact to optimize the use of inland waterway transport. Ensuring alignment with CESNI's standards is crucial to maintain navigational safety.

Public Awareness Campaign: Initiate a focused public awareness campaign to educate businesses, industries, and the public about the advantages of IWT within the framework of TEN-T objectives. Emphasize the benefits, including reduced emissions, congestion relief, cost-effectiveness, and job creation. Actively engage with local communities and environmental organizations to address concerns transparently, conducting comprehensive environmental impact assessments.

4.5 Regulatory Support and Funding

Regulatory Framework Enhancements: Undertake a comprehensive review and update of existing regulations to accommodate the expansion of IWT within the corridor. Collaborate closely with relevant authorities to ensure the harmonization of safety, environmental, and navigational standards.

This includes broadening the definition of 'Combined Transport' to encompass diverse transport modalities, extending beyond road haulage.

Streamlined Permit and Licensing Processes: Streamline permit and licensing processes to expedite the deployment of green and autonomous vessels within the inland waterway transport sector. Establish transparent criteria and timelines for permit approvals while maintaining rigorous safety checks. Ensure that permit processes are in line with CESNI recommendations for navigational safety.

Funding for Infrastructure and Climate Resilience: Allocate sufficient funding and support through programs like Horizon Europe and CEF for innovative infrastructure projects within inland waterway transport. This funding should be targeted at enhancing sustainability, resilience, and navigational safety. Encourage research and development efforts that specifically address climate resilience issues in IWT (e.g., draught impacts on the Rhine River).

Internalization of externalities: incorporate external costs like environmental impact and infrastructure maintenance into pricing strategies for IWT. This approach fosters fair competition among transport modes, incentivizes cleaner vessel technologies, and encourages longer IWT voyages. By internalizing externalities, policymakers promote sustainable practices and a level playing field while optimizing environmental and economic benefits in the transportation sector. It is noted here that deliverable D7.9 [11] examines such an internalization, by considering the economic impact of the inclusion of shipping and road transport into the EU Emissions Trading System (ETS) and generally finds that such an inclusion would favor the AEGIS system in all three use cases.

Overall, the key message for public policy makers is that the implementation of the AEGIS concept to the broader EU context requires policy support and a coordinated approach to the regulation of transportation systems. The existence of legacy principles that support road transport cannot be circumvented without steering and incentives, and the introduction of new technologies needs to be governed and supervised to ensure a harmonized standard across the European logistics chain.

4. Conclusions

The comprehensive analyses and recommendations within Work Package 9 (WP9) of the AEGIS project have significantly illuminated the intricate landscape of Use Case B (UCB), specifically centered on the optimization of inland waterway transport (IWT) operations. Leveraging the invaluable commercial insights from DFDS and the collaborative expertise of the involved research institutions, the meticulous evaluations undertaken in WP9 have paved the way for a comprehensive blueprint aimed at enhancing the efficiency, sustainability, and commercial feasibility of IWT within the European maritime sector.

Emphasizing the need to address the challenges and bottlenecks pertinent to the specific domain of IWT, the recommendations put forth for industry stakeholders and policy makers underscore the critical importance of embracing sustainable vessel designs, fostering intermodal connectivity, and streamlining regulatory frameworks tailored to the unique requirements of inland waterway operations. By advocating for the integration of zero-emission propulsion systems and the development of customized eco-friendly vessels, the proposed measures seek to accelerate the adoption of sustainable transport solutions, thereby aligning with the European Green Deal objectives and fostering a more environmentally conscious approach to maritime logistics.

Furthermore, the significance of fostering collaborative ecosystems, standardizing interfaces, and promoting comprehensive collaboration among stakeholders remains central to the successful implementation of IWT initiatives. By encouraging seamless coordination and data exchange between various stakeholders, the recommendations seek to bolster the efficiency and effectiveness of inland waterway operations, promoting a cohesive and integrated approach to cargo transportation along key European waterways.

The overarching focus on addressing logistical complexities, identifying operational bottlenecks, and developing a robust and efficient transport system underscores the commitment of WP9 towards enhancing the commercial viability and operational efficacy of IWT. By providing tailored recommendations specific to the UCB, the conclusive insights offered by WP9 not only reflect a deep understanding of the unique challenges inherent to inland waterway logistics but also reinforce the pivotal role played by sustainable, technology-driven solutions in fostering a more resilient and efficient maritime sector within the European Union.

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