Lessons in Designing Green and Innovative Terminals (Multipurpose or Intermodal) in SME Ports

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Advanced, Efficient and Green Intermodal Systems

http://aegis.autonomous-ship.org/

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Summary

This report extracts the key lessons in designing green and innovative terminals in Small and Medium-sized Enterprise (SME) ports. It focuses on the primary findings and outcomes of AEGIS Work Package 10: "Case C - Revitalizing regional ports and city centre terminals." The aim of the study was to explore how green and innovative terminals could be designed in SME ports, with a particular emphasis on two Danish ports: the Port of Vordingborg and the Port of Aalborg.

The report outlines the key deliverables of the work package, highlighting the main findings from each one:

Deliverable 10.1 – “Potential transfer from road transport to shortsea-shipping in Denmark”: This deliverable analyzed the feasibility of shifting goods from road transport to short-sea shipping. It concluded that short-sea shipping should be competitive with or cheaper than road solutions, and identified that about 5 million tonnes of goods could be converted in Denmark under specific conditions.

Deliverable 10.2 – “SWOT analyses for Port of Vordingborg and Aalborg”: Separate SWOT analyses were conducted for both ports. The Port of Aalborg was positioned well due to its financial strength and intermodal capabilities. The Port of Vordingborg, though smaller, had invested in versatile infrastructure, setting the stage for potential growth.

Deliverable 10.3 – “Potential for calling the two Danish ports by DFDS”: This confidential report assessed the potential for port calls by the shipping company DFDS. It included detailed financial and time-based models, analyzing 22 different scenarios. The report found that potential port calls were economically viable.

Deliverable 10.4 – “Technology Gaps and Regulatory Challenges in Danish Case Studies”: This public report addressed technological gaps and regulatory challenges in implementing proposed concepts. Challenges included digitalization requirements, operational changes, and new vessel types. Infrastructure financing and regulatory hurdles were also highlighted.

Deliverable 10.5 – “Seminar on Multipurpose Terminals in Small Ports”: The seminar focused on the Port of Vordingborg and explored the development of a versatile RoRo terminal that can potentially be setup day-to-day. Design requirements were defined, and discussions revolved around capturing potential cargo through collaboration with local industries.

Deliverable 10.6 – “Seminar on Intermodal Green Terminals in Medium Ports”: This seminar centered on the Port of Aalborg and discussed purpose-built ships for autonomous, green transport solutions. Various vessel concepts were introduced, including RoRo and container vessels. A proposed layout for the container terminal was also presented.

Key lessons show that the collaborative effort has informed decision-making for both the Port of Vordingborg and the Port of Aalborg. It has contributed to the strategic outlook of these ports, guiding their investments and developments in terms of infrastructure, cargo conversion, and terminal operations. Through the utilization of economic models, technical analyses, and stakeholder engagement, AEGIS Work Package 10 has facilitated the transition towards environmentally sustainable and economically viable terminal solutions in these ports.

Definitions and abbreviations

CAPEX: Refers to the capital expenditure of companies. Encompasses the capital used by companies to acquire, and maintain physical assets, e.g., buildings, plants, equipment etc. CAPEX is often applied when making business cases for understanding investment decisions.

OPEX: Refers to operating expenses of companies. These relate to the costs companies incur to be operational. These would be any running costs related to conducting day-to-day business.

THC: Terminal Handling Costs. Is computed in the scenarios as the "price" a vessel operator would have to pay a terminal operator to load or unload 1 trailer to/from the vessel. Includes all handling costs portside per trailer.

Tug master: Vehicle that many terminal operators use. In the case of this report, it is referred to a smaller terminal vehicle that can "shunt" trailers around the port and to-from the vessel.

RoRo: Roll-on-Roll-off

SME: Small- and Medium Sized Enterprise

SWOT: Strengths, Weaknesses, Opportunities, Threats

WP: Work Package

1 Introduction

This report encapsulates the primary findings of AEGIS WP10 “Case C - Revitalizing regional ports and city centre terminals”. The report summarizes the primary findings of the work package, and moreover includes a further detailing of how green and innovative terminals can be designed in SME Ports.

The report includes a summarization, including an introduction to, the methodology of, and representation of the primary findings of the work package. This relates to assessments of goods flows that can be shifted from road to short sea shipping, the strategic positioning of the ports in the use case, calculations on potential Ro/Ro calls, legislative gaps and implications for port designs in small and medium sized ports. It furthermore combines the technical perspectives of developing green and innovative SME ports.

The report builds on base-line scenarios that have specifically been developed as part of AEGIS. These scenarios (e.g., for RO/RO operations) have been developed in collaboration with partner companies, such as DFDS. Concurrently, these should provide a neutral and objective stance in terms of timings, CO2 emissions as well as the economic aspects related to the use-case. This allows for analysis that can support decision making in the use-case, while still taking into account the business models and the ecosystem surrounding the port.

The purpose of the report is to consolidate the efforts of WP10, and give recommendations based on analysis of both the goods potential as well as the internal economics of the port. This is targeted towards the core players in the ecosystem, namely the port authorities, the vessel operators as well as the port operations. This is with the aim of providing both financially and environmentally sustainable recommendations that can be adapted by SME ports in a new terminal setup.

2 Lessons learned from Use-Case C

Use-case C has included four main deliverables as part of the work.

Deliverable 10.1, including an analysis of the gross-volume of goods that can be shifted from road to short sea-shipping. Deliverable 10.2, including separate and confidential SWOT-analyses for the Port of Aalborg and the Port of Vordingborg. Deliverable 10.3, including a confidential analysis of the potential for calling the two Danish ports by DFDS. Deliverable 10.4 included an analysis of the technology gaps and regulatory challenges in the Danish case studies. Finally, deliverable 10.5 and 10.6 included seminars with the emphasis of the development of SME ports with the cases of the Port of Vordingborg and the Port of Aalborg respectively.

The work carried out has given a series of concrete analyses and recommendations in the use case. In the following, a summarization of the lessons learned in the use-case will be given, with adherence to confidentiality in the reports. This is with the purpose of utilizing these for extracting the core points relevant for developing green and innovative terminals in SME ports.

2.1 Deliverable 10.1 - Potential transfer from road transport to shortsea-shipping in Denmark

The aim of the first deliverable in the work package was to obtain an overview of the potential goods that could be shifted from road to short-sea-shipping in Denmark. The WP included a comprehensive

study and analysis of all the movements of goods with trucks inside and to/from Denmark and the different European regions.

Under this deliverable, we obtained goods flow data for the year 2019 (Danish data) 2021 (international data), encompassing all relevant regions for the specified use-case. This dataset includes both national and international goods flow information involving all relevant European countries (accessed by EUROSTAT). The data contains intricate details such as loading and unloading destinations (NUTS2)[1], types of goods (NST2007)[2], tonnage, and the count of movements between the mentioned regions for each specific goods category.

This accumulation of data constitutes a comprehensive goods flow (trucking) dataset, comprising over 235,000 lines of information from the latest available records in 2021. To give an example of how the dataset was constructed, an example of goods transport is provided in the table below.

Table 1 - Exemplification of the data lines in the data set.

load_region	**unload_region**	**type_of_good**	**tonnes**	**movements**
DK030	BE230	04	5.784	484
↑	↑	↑	↑	↑
The NUTS2 load region, Southern Denmark, Denmark	The NUTS2 unload region, Ghent, Belgium	4: Food products, beverages and tobacco (NST2007)	Tonnes total	Trips total

The above allows for a detailed analysis of goods that are being transported between the regions in the use case. The above example can be visually shown in Figure 1 below.

[1] The NUTS implies the Nomenclature of Territorial Units of Statistics, used for regionalizing certain areas in the countries (in Europe). https://ec.europa.eu/eurostat/web/nuts/background
[2] The NST2007 is the standard goods classification for transport statistics, used to group different goods types. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Standard_goods_classification_for_transport_statistics_(NST)

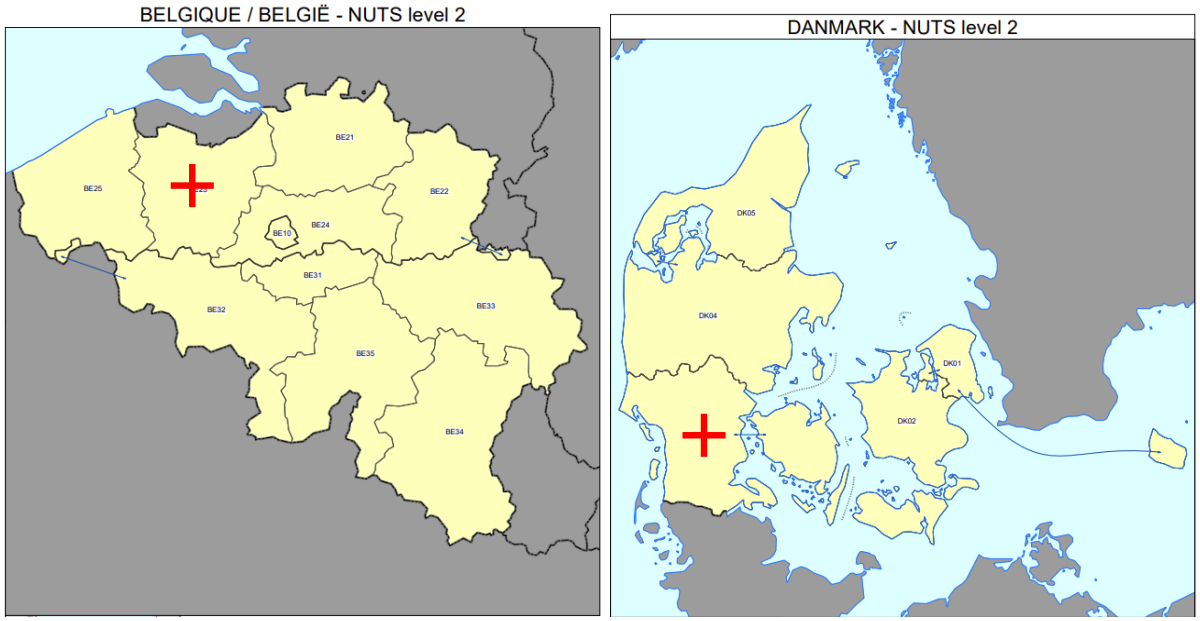

Figure 1 – NUTS 2 regions related to Ghent (Belgium) and Southern Denmark (Denmark). Source: Eurostat.com

The above example provided an entire overview of all goods movements between the regions in Denmark and relevant countries that had an entry in the EUROSTAT database. This was supplemented with an additional filtering layer.

In order to determine goods that was both relevant and probable to convert, we applied time-value of goods used by ASEK, the Swedish Traffic Authorities. The time-value of goods reflects the value of the cargo, and whether it is of importance goods are transported from A to B quickly. In essence, highly expensive goods such as expensive machinery, or e.g., fresh foods of high value, constitute such high value that the transport cost is negligible. Hence, in these instances, the fastest form of transportation is likely to be used.

The methodology made it possible to calculate, distinctly for truck transports, the relative switching costs between different types of goods and their conversion from truck to sea. The different goods types, and the scenarios for conversion are reflected in the two tables below.

Table 2 – Conversion from AMGODS to NST2007. [3] From: AEGIS, 2021 [1].

Code	Description	SAMGODS-commodity group
1	Products of agriculture, hunting, and forestry; fish and other fishing products	1,2,3,4
2	Coal and lignite; crude petroleum and natural gas	13,14, 21
3	Metal ores and other mining and quarrying products; peat; uranium and thorium	15,16, 18, 19,
4	Food products, beverages and tobacco	10, 11
5	Textiles and textile products; leather and leather products	9

[3] https://unece.org/DAM/trans/doc/2015/wp6/_Peter_Smeets__Report_TF_Prague_on_Classifications.pdf

6	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	5, 6, 7, 8, 24, 28, 31, 33
7	Coke and refined petroleum products	12
8	Chemicals, chemical products, and man-made fibers; rubber and plastic products; nuclear fuel	22, 23
9	Other non-metallic mineral products	27,
10	Basic metals; fabricated metal products, except machinery and equipment	17, 26
11	Machinery and equipment not elsewhere classified; office machinery and computers; electrical machinery and apparatus not elsewhere classified; radio, television and communication equipment and apparatus; medical, precision and optical instruments; watches and clocks	25, 32
12	Transport equipment	No
13	Furniture; other manufactured goods not elsewhere classified	Yes
14	Secondary raw materials; municipal wastes and other wastes	20,
15	Mail, parcels	No
16	Equipment and material utilized in the transport of goods	25
17	Goods moved in the course of household and office removals; baggage and articles accompanying travelers; motor vehicles being moved for repair; other non-market goods not elsewhere classified	N/A
18	Grouped goods: a mixture of types of goods which are transported together	29
19	Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.	No
20	Other goods not elsewhere classified	30

The analysis further included a range of scenarios in the potential conversion of goods, where only low- or medium time value goods were included.

Table 3 – NST2007 goods types overview. Estimation of potential conversion.[4] From: AEGIS, 2021 [1].

Code	Description	Potentially Convertible?	Why? And how to apply?
1	Products of agriculture, hunting, and forestry; fish and other fishing products	Yes	Low time-value (30% median scenario)
2	Coal and lignite; crude petroleum and natural gas	Yes	Low time-value (30% median scenario)
3	Metal ores and other mining and quarrying products; peat; uranium and thorium	Yes	Low time-value (30% median scenario)
4	Food products, beverages and tobacco	Yes	Low time-value (but some fresh) (30% median scenario)
5	Textiles and textile products; leather and leather products	Yes	Medium time-value (30% median scenario)
6	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	Yes	Undefined time-value (30% median scenario)
7	Coke and refined petroleum products	Yes	(30% median scenario)

[4] https://www.dst.dk/en/Statistik/dokumentation/nomenklaturer/standardgodsnomenklatur-til-transportstatistik--nst-2007-

8	Chemicals, chemical products, and man-made fibers; rubber and plastic products; nuclear fuel	Yes	Medium time-value (30% median scenario)
9	Other non-metallic mineral products	Yes	Low time-value (30% median scenario)
10	Basic metals; fabricated metal products, except machinery and equipment	Yes	Medium time-value (30% median scenario)
11	Machinery and equipment not elsewhere classified; office machinery and computers; electrical machinery and apparatus not elsewhere classified; radio, television and communication equipment and apparatus; medical, precision and optical instruments; watches and clocks	No	High time-value
12	Transport equipment	No	High time-value
13	Furniture; other manufactured goods not elsewhere classified.	Yes	Undefined time-value (30% median scenario)
14	Secondary raw materials; municipal wastes and other wastes	Yes	Low time-value (30% median scenario)
15	Mail, parcels	No	High time-value
16	Equipment and material utilized in the transport of goods	No	High time-value
17	Goods moved in the course of household and office removals; baggage and articles accompanying travelers; motor vehicles being moved for repair; other non-market goods not elsewhere classified.	No	Undefined time-value
18	Grouped goods: a mixture of types of goods which are transported together	Yes	Medium time-value (30% median scenario)
19	Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.	No	Unknown and undeterminable. Conservative estimation.
20	Other goods not elsewhere classified.	No	Unknown and undeterminable. Conservative estimation.
99	Grouped goods due to confidentiality and quality';	No	Unknown and undeterminable. Conservative estimation.

Based on the above, D10.1 included a comprehensive walkthrough of the different regions within and to/from Denmark and the possible conversion scenarios of the goods.

The primary countries contributing to international truck traffic to and from the Danish Regions were Germany, Sweden, Poland, Norway, The Netherlands, Belgium, France, and Spain. The combined traffic from these nations constituted 90% of the total incoming and outgoing truck movements involving Denmark.

The following table was generated through a synthesis of all analyses conducted on the movement of goods by trucks between each Danish region and all countries. It is important to underline that these scenarios are predicated on the assumption that short-sea shipping is either equivalent to or more cost-effective than alternative road freight solutions.

Upon considering all the analyses, even with conservative estimates for conversion probabilities, it was projected that under the median scenario, approximately 4,864,392 tonnes of goods could be transitioned from road transport to international truck transport in Denmark.

This is also portrayed in the excerpt below:

Table 4 – Total gross volume of goods that can be shifted from road to short-sea-shipping in Denmark. From: AEGIS, 2021 [1].

International/Denmark (yearly)	**Tonnes**	**Movements**
Total - International/Denmark (yearly)	26.471.732	1.576.052
Median Scenario of relevant goods	**4.864.392**	**274.755**
Jutland-Zealand National (yearly)	**Tonnes**	**Movements**
Total - International/Denmark (yearly)	1.003.000	57.000
Median Scenario of relevant goods	**177.540**	**9.899**
GRAND TOTAL	**5.041.932**	**284.654**
/day	13.814	780
% of relevant regions	18,4%	
% of all trucking goods (162,5+26,471732 mill.)	2,7%	

In summation, the potential overall volume of goods that could be transferred from road transport to short-sea shipping in Denmark was estimated to be around 5 million tonnes annually, accounting for roughly 18% of the relevant goods transported by trucks. This estimation hinges on the condition that any short-sea shipping solution matches or surpasses the cost-effectiveness of a competing direct road solution.

2.2 Deliverable 10.2 - SWOT analyses for Port of Vordingborg and Aalborg

The confidential report constituting the deliverable 10.2 included separate SWOT analyses for both the Port of Vordingborg and the Port of Aalborg.

Both reports included short-term and long-term implications for both ports in order to turn their position into concrete actions.

2.3 Deliverable 10.3 - Potential for calling the two Danish ports by DFDS

Deliverable 10.3 included a confidential report that conducted a deep analysis of the potential port calling of the two Danish ports by DFDS. Applying the economic model in principle from D10.1,

deliverable 10.3 furthermore detailed the operational costs (time, €) of creating a port call for each of the two ports.

2.4 Deliverable 10.4 – Technology Gaps and Regulatory Challenges in Danish Case Studies

This public report includes analyses on the technological gaps faced by both ports in implementing the concepts proposed in AEGIS. This includes the automation of ships and terminal operations, as well as communications. Moreover, the report covers potential regulatory challenges that may inhibit the development of new waterborne transport systems in Denmark.

The report identified that there were three primary technological gaps. The first gap was related to the digitalization requirements for autonomous shipping operations, including challenges of standardization and communication. Secondly, there was a gap identified related to how port operations were taking place today and autonomous cargo handling. Thirdly, new vessel types as a result for autonomitzation of the ports also includes new proposed propulsion systems and would thus require changes in the ports' existing infrastructure in order to service the new vessels.

Finally, the three gaps identified all have in common that additional financing will be necessary for the ports. Infrastructure has a high CAPEX and yield oftentimes only a surplus after several years (or decades) in operations. Concurrently, a guarantee for cargo/goods over a sustained period of time is often needed in order to justify new infrastructure investments to the stakeholders of the ports.

The report concludes that it is not the technology itself, but the implementation and utilization of the technology in the existing business system.

The report moreover identified concrete gaps in cargo handling and infrastructural support for both the Port of Aalborg and the Port of Vordingborg as part of introducing new, autonomous systems. These gaps are significant and will require investments for both ports.

The regulatory challenges identified in the cases relate to substantial public scrutiny and incorporate a licensing process, environmental impact assessments, zoning laws etc. Concurrently, any infrastructural changes to incorporate autonomous vessel calls, as well as green, autonomous terminal setups, will require significant administrative work.

A general conclusion from the report is that there are gaps and challenges that need to be elevated to regional and national levels, in order to fully implement new, green and innovative maritime solutions for each of the ports.

2.5 Deliverable 10.5 – Seminar on Multipurpose Terminals in Small Ports

This document provided a summarization of the seminar held on April 19th, 2023, in Vordingborg, Denmark. The seminar provided general findings related to the Port of Vordingborg use case as part of the work package.

The Port of Vordingborg has investigated the possibility of developing a "pop-up" RoRo terminal in a multi-pier setup, which could be used on a weekly basis. This would allow for other use of the terminal area at other times during the week. The Port of Vordingborg has set up design requirements for AEGIS multi-pier, including:

- Possibility for Ro/Ro

- Water depth of 10,4 meters
- Ready for autonomous ships
- Prepared for autonomous cargo handling.
- Capacity for 1 mio. tonnes of yearly cargo turnover

The financial calculations in previous deliverables (D10.1-D10.3) as well as the investigation of the technological and regulatory challenges in D10.4 have acted as catalyst for the ongoing development of the terminal at the Port of Vordingborg. The first design of the AEGIS multi pier setup thus allows for RoRo vessels with a capacity of 50 units (which was also used as a baseline scenario in the principal economic model used in the work package), as well as other ships with other commodities of a length of up to 200 meters.

Due to the relatively close proximity between the port and the city, the pier development has taken into account local zoning requirements, e.g., eventuating in no buildings being built on the pier, as well as westbound expansion of the harbor being limited.

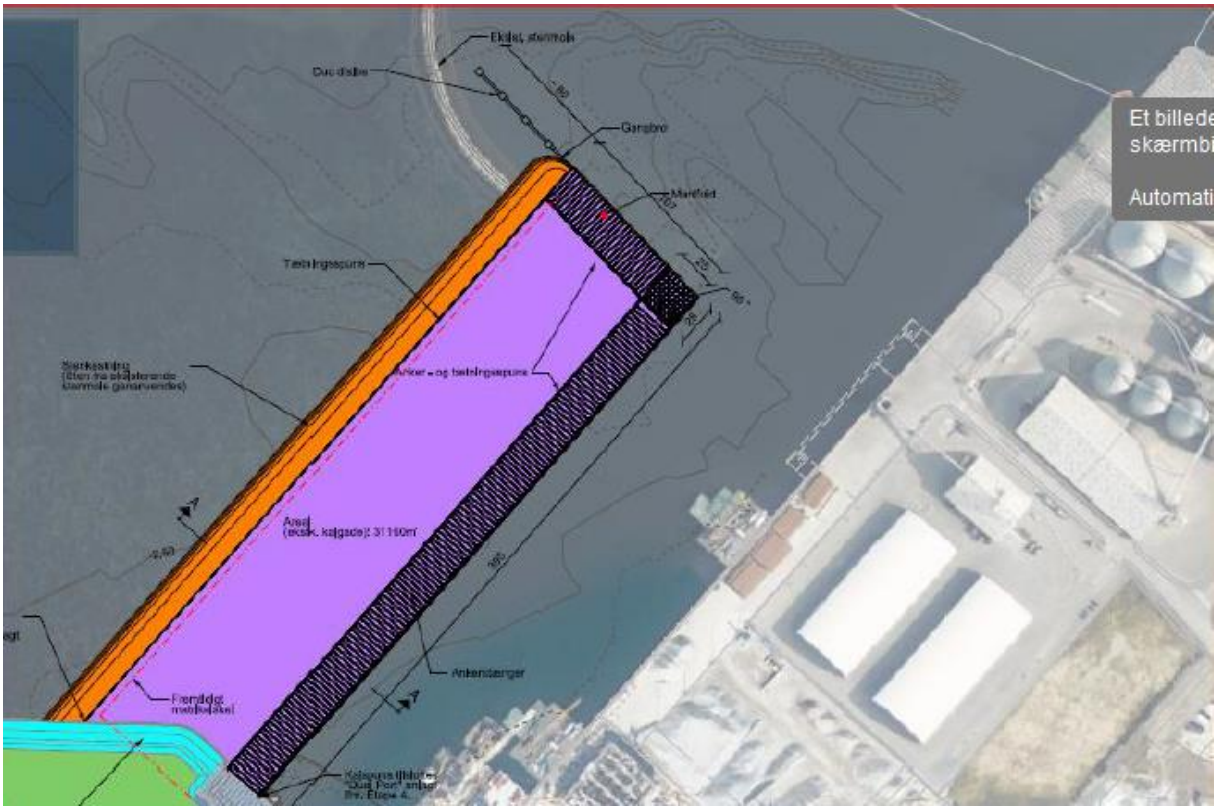

Figure 2 – Final Design of AEGIS Multi Pier. From: AEGIS, 2023a[13]

The pier development has taken into account the readiness for autonomous ships (in terms of basin requirements). The port of Vordingborg has, together with the partner ISE, moreover, considered purpose-built ships that can fit the requirements and potential goods flows to/from the port. This gave unique opportunities, in e.g., a call to the port of Elblag in Poland with shallow waters, through the Port of Vordingborg and then to address potentially the Ruhr area in Germany. This is illustrated in the figure below.

Figure 3 – Considered routes from Vordingborg to Northern Europe. From: AEGIS, 2023a[13]

This allows for ship concepts that can both include containerized cargo as well as bulk cargo. This provided for ship concepts in collaboration with ISE that could have a versatile, low-volume setup that would meet requirements for shallow water solutions.

The illustrations below show the concept illustration for a shallow water solution that can be applied on the aforementioned route.

Figure 4 – ISE concept for a low-emission autonomous shallow water coaster. From: AEGIS, 2023a[13]

Building on both the perspectives for the pier development as well as vessel concepts, the seminar furthermore involved a discussion of how the potential cargo (of up to 1. mio. tonnes per year) can be captured. This discussion captured a need for close dialogue with the local industries in order to support the conversion of goods to be captured by the port. A series of topics of potential activities were discussed, including fish exports, biomass, and more. This was paired with discussions of how the above vessel concept could be commercialized, including renumeration of the investments, partnerships and more. The discussions concluded that the concept had good potential for commercialization.

2.6 Deliverable 10.6 – Seminar on Intermodal Green Terminals in Medium Ports

This report documented the developments for the Port of Aalborg in the work package, as well as the discussions addressed on the seminar entitled "Intermodal Autonomous Green Terminals in Medium Ports". The seminar was held on April 18th, 2023, in Aalborg, Denmark.

Besides the core members of the AEGIS project, as well as management from the Port of Aalborg, several stakeholders from the transport and production industries from the region were represented at the seminar.

The seminar introduced and discussed the findings that had already been presented in the reports D10.1-D10.4.

This was followed by a presentation and discussion of how purpose-built ships could serve as a means for introducing autonomous, green transport solutions in relation to the port. The vessel concepts introduced different RoRo concepts that could be either introduced with a battery-propulsion or a methanol propulsion system.

These are shown in the illustrations below.

Figure 5 – RoRo vessel concept 1. From: AEGIS 2023b[14]

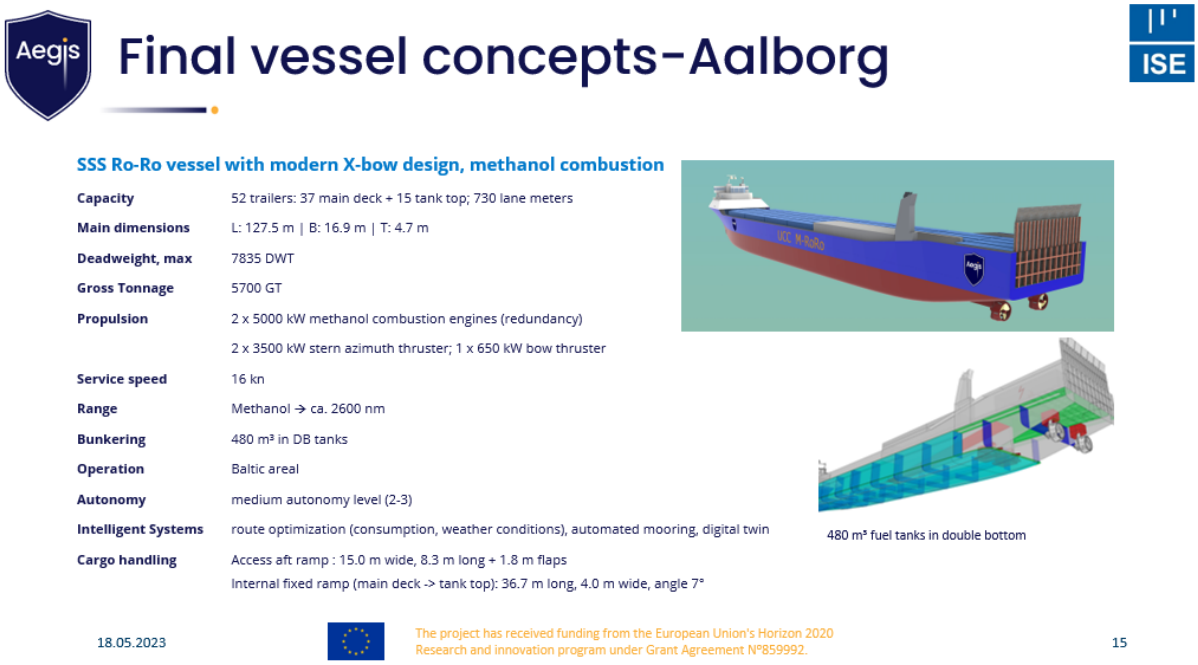

Figure 6 – RoRo vessel concept 2. From: AEGIS 2023b[14]

Besides these primary Ro-Ro vessel concepts, ISE has crafted a proposal for a container vessel (SSS) powered by methanol. This vessel boasts a capacity of 1,100 TEU, features on-board cargo handling machinery, and operates at an autonomy level of 2. This innovation holds promise for potential route deployment. Furthermore, ISE has explored the design of a completely electric, extensively autonomous, self-propelled shuttle. With a capacity of 100 TEU, this shuttle is intended to manage the final leg of cargo transportation, connecting terminals along the Limfjord (the local inland, sea-connected waterway near Aalborg).

The seminar moreover incorporated a full terminal setup, where the terminal could incorporate existing bulk- and project cargo operations, while revitalizing the container terminal setup for a potentially fully autonomous solution. This also included a rail yard for integrating the seaborne solution with another CO2 efficient land-solution.

In collaboration with the AEGIS partner Kalmar, a proposed layout for the container terminal was illustrated (including comprehensive simulations and calculations) as below:

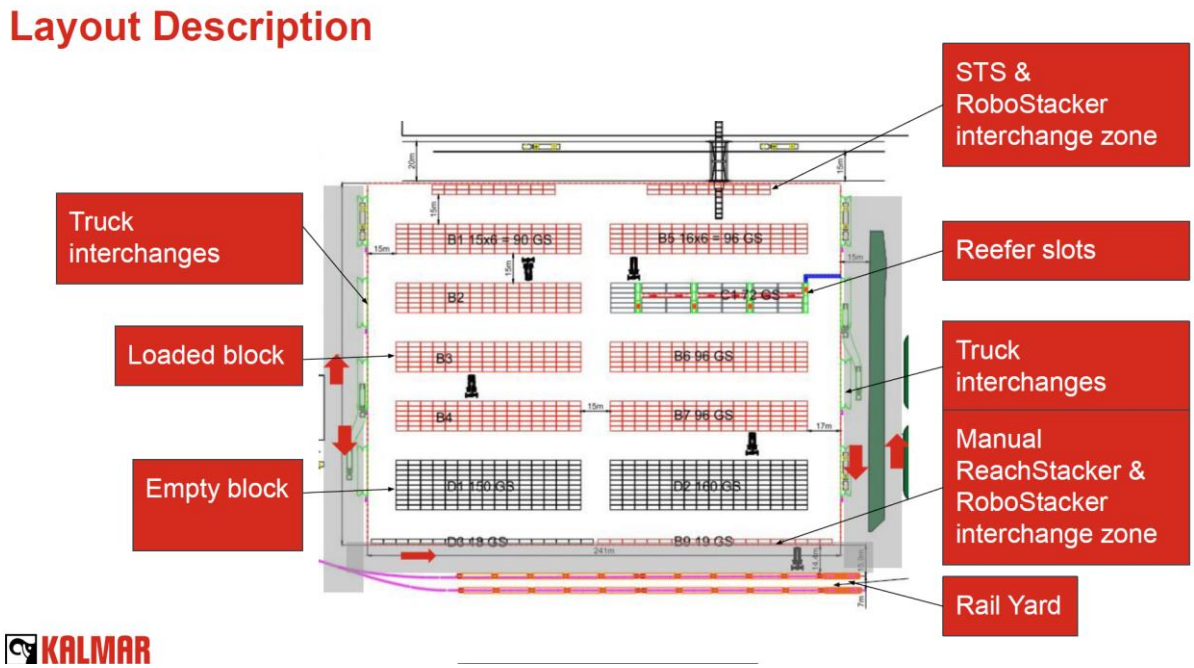

Figure 7 – Kalmar technical layout of Port of Aalborg Container Terminal. From: AEGIS 2023b [14]

In summation, the Port of Aalborg has had a comprehensive dialogue of how to innovate their port with all cargo areas in consideration. The terminal setup allowed for existing bulk- and project operations to continue and expand; where a clear possibility was related to RoRo and Container terminal renewal, allowing for integration with rail, and as necessary, with road. These are illustrated below.

Figure 8 – Visual overview of complete future terminal operations at Port of Aalborg. From: AEGIS 2023b [14]

Intermodal Automatic Green Terminal

- Transition from RAL terminal to a new era for Aalborg Containerterminal
- Currently "greenfield" state and in re-building phase
- Working on a 3 phase plan :
  - 25.000 TEU Renovating last half of terminal and investing in green equipment
  - 45.000 TEU Continued investment in green equipment and fenced yard with multiple drop off points
  - 75.000 TEU Prepare equipment for automation and potential for invest in a new gantry crane

17.05.2023

The project has received funding from the European Union's Horizon 2020 Research and innovation program under Grant Agreement N°859992.

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Figure 9 – Overview of Port of Aalborg core terminal layout and functional considerations. From: AEGIS 2023b [14]

As a result of participating in AEGIS, the Port of Aalborg has actively been working with, and remodifying their strategic outlook as a port authority. This is due to the contribution of the AEGIS project with both economic as well as technical analysis on goods potential, vessel concepts and terminal operations that allows for better grounds for making decisions on upcoming infrastructure investments.

2.7 Key lessons in the designing green and innovative terminals in SME ports

As has been shown in all the previous sections in this report, Work Package 10 has included a comprehensive and integrative work in understanding the economic- and technical feasibility of developing green and innovative terminals in SME ports. The key findings in relation to the deliverables are shown in the table below:

Table 5 – Key lessons from each of the deliverables in work package 10.

Deliverable	Key findings
D. 10.1 - Potential transfer from road transport to shortsea-shipping in Denmark	• Distance for short-sea-shipping viable with >150 km from end to end. • Short-sea-shipping solution should be on par, or cheaper, than competing road solution. • High time-value goods, such as e.g., machinery or valuable fresh foods are unlikely to be converted. • Approximately 5 mio. tonnes of goods can be converted in Denmark.
D. 10.2 - SWOT analyses for Port of Vordingborg and Aalborg	• Both ports were analyzed in separate SWOTs. • Both reports included short-term and long-term implications for both ports in order to turn their position into concrete actions • The content of the report is confidential.
D. 10.3 - Potential for calling the two Danish ports by DFDS	• Comprehensive financial- and time-based model analyzed. • Detailed analyses of potential calls for each port. • The content of the report is confidential.
D. 10.4 - Technology Gaps and Regulatory Challenges in Danish Case Studies	• Digitalization needs for autonomous shipping operations, involving standardization and communication challenges. • Gap in current port operations and autonomous cargo handling. • New vessel types due to port automation require changes in existing infrastructure. • Additional financing required for ports due to high infrastructure costs and the need for cargo guarantees.
D. 10.5 - Seminar on Multipurpose Terminals in Small Ports (PoV)	• Ro/Ro possibility • Water depth of 10.4 meters • Ready for autonomous ships • Prepared for autonomous cargo handling. • Capacity for 1 million tonnes of yearly cargo turnover • Initial AEGIS multi pier design accommodates RoRo vessels (50 units) and other ships (up to 200 meters). • Proximity to the city influenced pier development with no buildings on pier and limited westbound harbor expansion. • Readiness for autonomous ships considered in basin requirements. • Purpose-built ships for specific routes explored (e.g., Elblag, Poland to Ruhr area, Germany).
D. 10.6 - Seminar on Intermodal Green Terminals in Medium Ports (PoA)	• Presentation and discussion about purpose-built ships for autonomous, green transport solutions related to

	the port. Let to understanding that the routes in which these (often smaller) ships should take will impact the feasibility of the case (financially, practically). • Full terminal setup discussed, combining bulk, project cargo, and revitalized container operations for potential full autonomy. • Collaboration with Kalmar presents proposed layout for container terminal, also considering rail integration. • Remodification of port's strategic outlook due to AEGIS contributions: economic, technical analyses of goods potential, vessel concepts, and terminal operations. • AEGIS enables better-informed decisions for upcoming infrastructure investments.

Throughout the AEGIS Work Package 10 (and associated work packages), Use-Case C has achieved great insight for the development of innovative and green terminals in SME ports. The commercial insight delivered in D10.1-D10.3. has fueled the information grounds of making better decisions in terms of business focus areas and specific cases for investment in operations. This includes the potential cargo that can be converted, yet also more specifically how Ro/Ro terminal operations can take place from an economically and sustainable standpoint for both ports investigated in the use case. Moreover, working with AEGIS, insight in principle economic models for port development (with special focus on goods and new routes to be established) has enabled the ports to do scenario building based on an informed basis for future decisions.

The ports have ongoing discussions with AEGIS partners, as well as external stakeholders to use the knowledge, competences and network established through the AEGIS collaboration. Specifically for this Use-Case, the Port of Vordingborg is developing their multi-pier setup based on the knowledge acquired in AEGIS, and the Port of Aalborg has in collaboration with Kalmar begun specifically designing their new terminal setup; as well as begun planning activities for establishing a RoRo connection to the port.

3 Conclusion

Based on the comprehensive commercial and technical work from the AEGIS project, this report summarizes the key lessons achieved in AEGIS Work Package 10. Extracting the key findings from each of the deliverables, it is evident that AEGIS has contributed directly to both the planning of the development of the ports, as well as propelled direct development and now, ongoing partnerships, in making new investments in each of the ports. To summarize the core findings in the deliverables, it was established that the viability of short-sea shipping is recognized for distances exceeding 150 km end-to-end. This must be cheaper or on-par with existing road solutions. High-value, time-sensitive goods, e.g., fresh foods or machinery, are unlikely to be converted, and thus medium and low time value goods (as proposed by ASEK) should be in focus. Approximately 5 million tonnes of goods could be converted to short-sea shipping in Denmark. This analysis was supplemented by separate, confidential SWOT analyses for both The Port of Aalborg and The Port of Vordingborg.

For both ports, a financial- and time-based model was investigated for port calls, including potential implications for ports. The content of these analyses was confidential. Autonomous shipping requires digitalization, standardization, and overcoming communication challenges. Port operations and cargo handling need adaptation for autonomous vessels. New vessel types due to automation mandate changes in existing infrastructure.

ISE proposes methanol-powered container- and autonomous shuttle vessels for cargo transportation. Collaborations, like with Kalmar, present terminal layouts considering rail integration for full autonomy. AEGIS contributions, including economic, technical, and operational analyses, reshape port strategies, enabling well-informed infrastructure decisions.

In conclusion, the use case has demonstrated that there are both promising goods volumes as well as financial promise in developing innovative and green terminals in SME ports.

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